US Army Corps
of Engineers
Louisville District

Clean Water Act Section 404(b)(1) Evaluation

Barren River Lock and Dam No. 1 Removal

Prepared by:

U.S. Army Corps of Engineers, Louisville District

April 2022

Contents

List of Figures

Appendices

1 Project Description

1.1 Location

The proposed Action involves the removal of Barren River Lock and Dam 1 (BRLD1), located on the Barren River at River Mile (RM) 15 near the confluence with Taylor Branch. BRLD1 is located near the town of Greencastle, in Warren County, Kentucky (Figure 1).

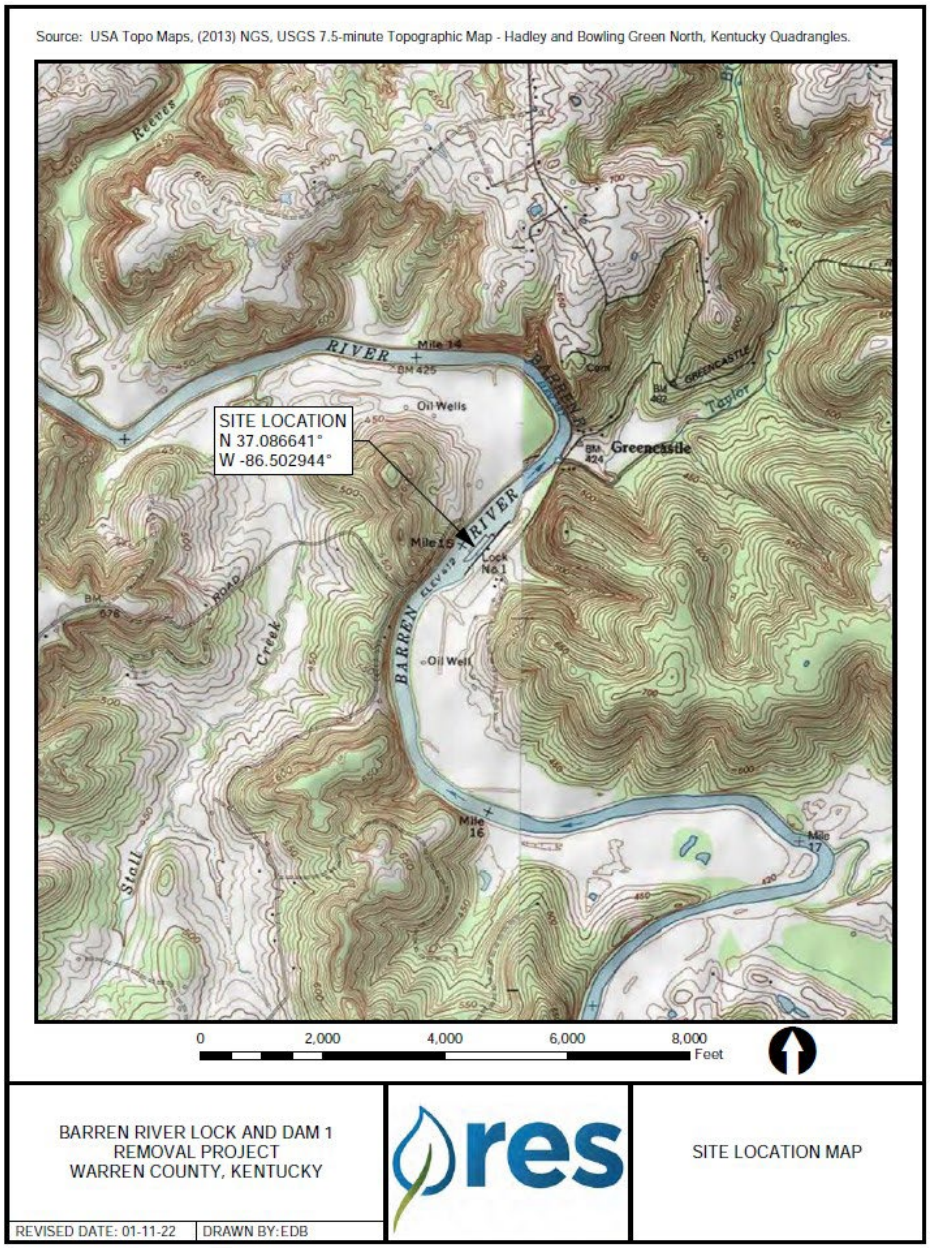


Figure 1. Site location map for the Barren River Lock and Dam #1 Removal Project, Warren County, Kentucky.

1.2 General Description

The purpose of Section 404(b)(1) Guidelines (40 CFR 230) is to restore and maintain the chemical, physical, and biological integrity of waters of the United States through the control of discharges of dredged or fill material. This document was completed to record the District's evaluation and findings regarding this project pursuant to Section 404 of the Clean Water Act. As described herein, the proposed Action involves the removal of BRLD1 and the surrounding infrastructure on the Barren River at RM 15. The goal of the proposed removal of BRLD1 is to improve passage for aquatic organisms and restore instream habitat above and below the dam for riverine fish and macroinvertebrates. The proposed Action will also alleviate safety concerns and eliminate costs associated with ownership and maintenance of the structure by the U.S. Army Corps of Engineers (USACE).

BRLD1 consists of a 276-foot-long dam and two locks along the right descending bank. The original lock (inner lock) is connected to the east end of the dam and consists of a 135-foot-long by 35-foot-wide chamber bounded by a river wall and a land wall, with guide walls extending approximately 150 feet upstream and 200 feet downstream from the land wall. A concrete plug is present at the upstream end of the inner lock chamber. The newer lock (outer lock) is located east of the inner lock towards the right descending bank. The inner and outer locks are separated by a 360-foot-long by 72-foot-wide area of earthen fill partially covered by a concrete esplanade. The outer lock consists of a 360-foot-long by 56-foot-wide chamber bounded by a river wall and a land wall, with guide walls extending approximately 310 feet upstream and downstream of the land wall. Miter gates are present at the upstream and downstream ends of the outer lock chamber. A second concrete esplanade is located along the right descending bank that spans the length of the outer lock chamber. A two-story concrete control tower is present on the outer lock esplanade.

The dam pool (Pool 1) extends approximately 23 miles upstream of BRLD1 to approximately RM 38, with a normal pool elevation of 412 feet above mean sea level (AMSL). The lock and dam structures are shown on Figure 2 and Sheet CD101 of the design plans (Appendix A).

The concrete lock walls are in good condition, with some minor weathering. The downstream side of the dam has some surficial damage, as indicated by zones of turbulent water flow. The lock walls do not show evidence of settlement or movement that would cause stability concerns. The miter gates are in good condition. The two-story control tower is missing windowpanes and has evidence of bullet holes, but there is no reinforcing exposed and the overall condition of the concrete is good. The lock and guide walls are in also good condition. The old lock chamber was removed from service by putting a concrete cutoff wall across the upstream sill and rock fill in the rest of the

chamber. This concrete cutoff wall appears to be in good condition. There is not much evidence of the rock fill in the chamber.

The downstream concrete apron of the dam has been undermined. Some sections of the apron have shifted and settled due to loss of the underlying fill. The void under the downstream apron of the dam has been there for quite some time. The dam is constructed from timber cribbing and rock fill with a concrete cap founded on timber piling.

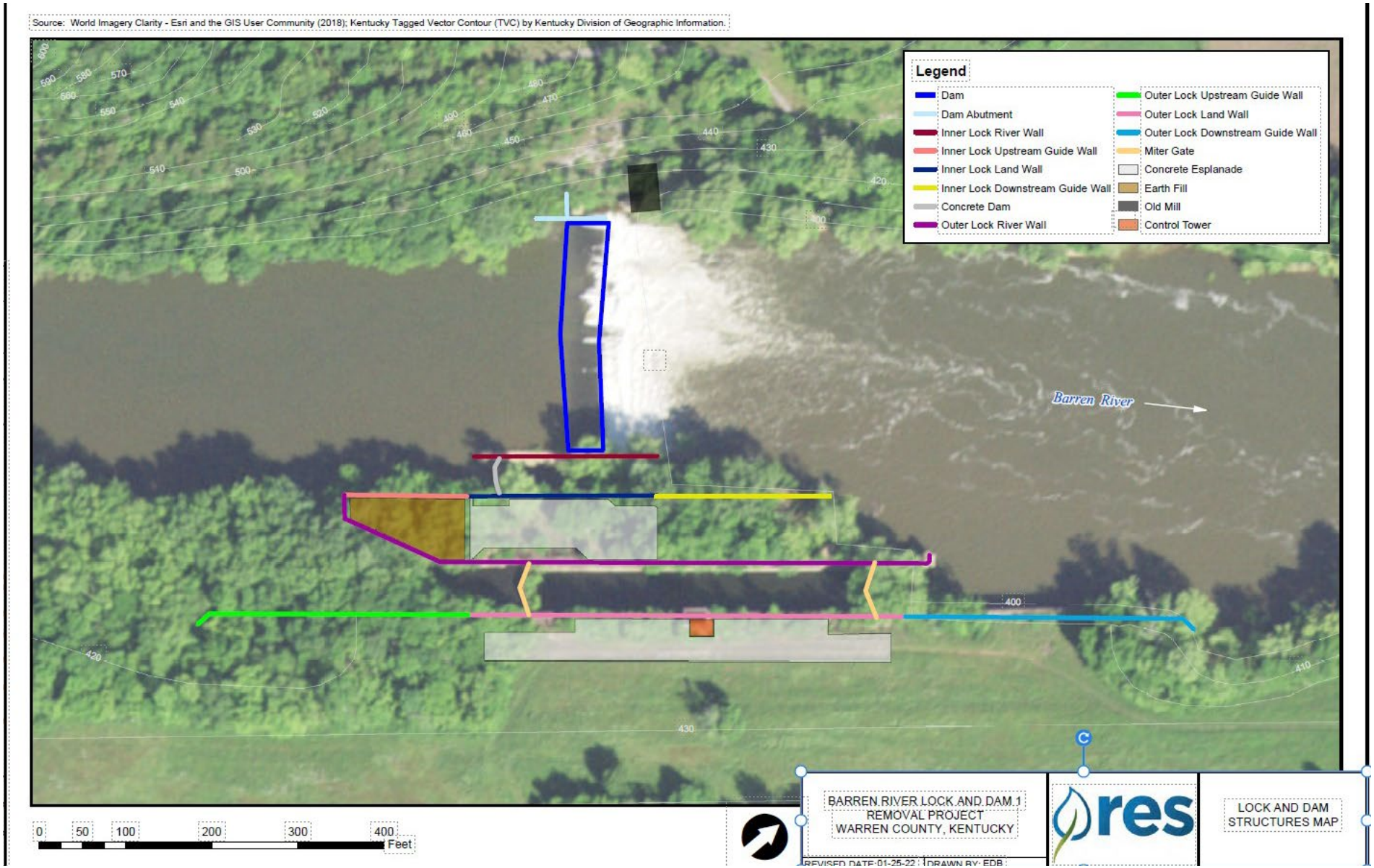


Figure 2. Project development map, Barren River Lock and Dam #1 Removal Project, Warren County, Kentucky.

1.3 Authority and Purpose

The purpose of the proposed Action is to improve passage for aquatic organisms and restore instream habitat above and below the dam for riverine fish and macroinvertebrates. The proposed Action will also alleviate safety concerns and eliminate costs associated with ownership and maintenance of the structure by the U.S. Army Corps of Engineers (USACE).

The Commonwealth of Kentucky built the original lock and dam in 1841 and was acquired by the Federal government in 1886. From 1933 to 1934, the USACE constructed a new lock east of the original lock along the right descending bank. Operation of the new lock began in 1934, and the original lock was taken out of service. A concrete plug was placed across the upstream end of the original lock chamber to prevent flow through the chamber. In 1965, the new lock was closed to traffic after failure of Green River Lock and Dam 4 which is located immediately downstream of the Barren and Green River confluence. This closure eliminated the possibility of commercial navigation into the Barren River. Since closure of BRLD1, the USACE has conducted multiple studies regarding the feasibility of deauthorization and disposal of the lock and dam. The most recent study, entitled Green River Locks and Dams 3, 4, 5 and 6 and Barren River Lock and Dam 1 Disposition Feasibility Study, Kentucky, was completed in 2014. The study reevaluated the current uses of the Green and Barren River locks and dams, assessed potential impacts based on loss of the dam pools, evaluated the condition and safety of the structures, and discussed potential future disposal of the facilities. The study recommended requesting Congressional deauthorization of commercial navigation for the locks and dams, as well as disposal of the facilities and associated properties through procedures established by the USACE and General Services Administration.

In Section 1315 of the 2016 Water Infrastructure Improvements for the Nation Act (WIIN 2016), BRLD1 was deauthorized for commercial navigation and was directed to be conveyed by USACE to the Commonwealth of Kentucky, a nonprofit, or non-governmental organization. This language also stated that the lock and dam should be removed at the earliest time feasible. The USACE implementation guidance for Section 1315 called for the completion of a disposal report and associated environmental documentation but did not address dam removal prior to transfer. In 2018, Section 1311 of the America's Water Infrastructure Act (AWIA) addressed the removal activities stating that the Secretary could proceed with removal if deemed necessary before conveyance of appropriated funds may be used and contribute of fund may be accepted for the removal action.

The removal of dams and restoration of natural river flow appear to have a positive impact on mussels. Mussels downstream of run-of-river dams have responded favorably to removals, and in some cases, have made dramatic increases (Haag 2012). The 2022 Biological Assessment (BA) was prepared to evaluate the environmental impacts associated with the removal of BRLD1 (USACE 2022). This document was supported by several bioassessment studies and the 2022 Biological Opinion by USFWS (USFWS 2022) which suggest that the removal of BRLD1 would result in long-term benefits to the Barren River watershed. Return of the upstream pool of the dam to free-flowing conditions would change the species composition by allowing lotic species to return to

this portion of the river, resembling a more natural community upstream. Habitat for mussels and other aquatic organisms would improve as accumulated sediment behind the dam moved downstream and exposed gravel bars and other favorable substrates and potential habitat. Lotic fish species could also move into the former pool, including host fish that would help mussel recolonization of this area.

Removal of BRLD1 will also eliminate USACE ownership and maintenance costs associated with the structure. After removal of BRLD1, ownership of the property will be conveyed to the Kentucky Department of Fish and Wildlife Resources (KDFWR) for management and maintenance.

The removal of BRLD1 will also address safety concerns associated with the lock and dam structures. The western portion of the dam apron has been undermined from shifting and settling due to loss of the underlying fill and continues to deteriorate, which increases the potential for structural failure and associated impacts. It poses a risk to boaters and other recreational users, who may inadvertently be carried over the dam and become trapped in the hydraulic effect at the dam base. Removal of the locks and associated structures would also reduce safety and risk concerns from unauthorized entry of these structures from the east side of the river.

1.4 General Description of Dredged or Fill Material

1.4.1 General Characteristics of Material

The proposed Action includes three separate activities: site preparation, lock and dam removal, and site stabilization. Demolition activities will be initiated on the right descending bank and will generally extend towards the river. The dam will be the first structure planned for demolition and will be scheduled when water levels and flow are expected to be low. To allow equipment to access the dam, a work pad will be constructed across the existing locks and associated structures. The first section of the work pad from the right descending bank to the concrete esplanade between the locks will be constructed by demolishing the control tower and upper portion of the outer lock land wall and placing the material into the outer lock chamber. After crossing the outer lock chamber, equipment will drive across the existing concrete esplanade to the inner lock. The section of the work pad across the inner lock chamber will be constructed by placing material generated from demolition of the upper portion of the inner lock land wall into the chamber immediately downstream of the concrete plug. The completed work pad will be used to access the eastern end of the dam. The locks and associated structures are made of concrete and will be demolished using hoe ram-equipped excavators or similar equipment.

After reaching the dam, a notch will be created to begin draining Pool 1. An in-stream work pad will then be constructed either on the downstream dam apron, immediately downstream of the dam, or along the upstream side of the dam to initiate dam demolition. Material from the dam will be used to continue the in-stream work pad across the river. Once the in-stream work pad is completed, additional material generated during dam demolition will be placed within or adjacent to the outer lock chamber.

The dam will be demolished in lifts, with the vertical extent of each lift determined by the water level to ensure that equipment is not working in more than two feet of water for

safety reasons. Depths of greater than two feet reduce the stability of the equipment and may submerge portions of the engine, resulting in potential release of engine fluids or damage to the equipment. The dam will be removed to approximately 392 feet AMSL, which is the average anticipated depth of the river bottom under the dam. Dam sills and timber pilings will also be removed to approximately 392 feet AMSL, and steel reinforcement rods, if present, will be broken at the proposed final elevation and bent downstream to avoid snags. The remaining portion of the dam will also be notched to an elevation below 392 feet AMSL in several locations to maintain flow and facilitate passage by aquatic organisms and recreational users during low river levels. The dam will be demolished to the dam abutment at the western end of the dam, which will be left in place. The remnants of the old mill downstream of the dam will also remain. After dam demolition is complete, the in-stream work pad material will be removed and placed within or adjacent to the outer lock chamber.

Demolition of the locks and associated structures will begin after initiation of dam demolition. The remainder of the inner lock river, land, and guide walls and lock floor will be removed to the same elevation as the remaining portion of the dam (approximately 392 feet AMSL). The concrete esplanade and earthen fill between the two locks will be removed, and the concrete from the esplanade will be placed within or adjacent to the outer lock chamber. The earthen fill will be placed adjacent to the outer lock chamber to help stabilize the bank. The outer lock river wall will be demolished to an elevation of approximately 399 to 404 feet AMSL, and the outer lock land wall and upstream and downstream guide walls will be removed to approximately 412 to 414 feet AMSL. Material from the walls will be placed within or adjacent to the outer lock chamber. The outer lock miter gates will also be removed and placed in the outer lock chamber. The outer lock chamber will be filled to the top of the lock land wall, then graded to create a constant 3:1 slope extending from the top of the land wall to the base of the former inner lock land wall. Any excess material generated will be placed in the scour area below the dam, as necessary. Any soil generated during demolition and removal will be used to cover the fill material on the slope. The remainder of the slope is expected to be covered naturally over time by sediments deposited during flood events.

Concrete will make up approximately 95 % of the demolition material. The majority of the timber piles and limestone rock fill will stay in the foundation; however, a small amount may be pulled up or broken off during demolition.

Demolition of the dam, lock walls, and guide walls is expected to generate material in excess of the volume of the lock chamber. The excess material will be used to stabilize the stream banks, create parking areas, dress the site access road, and for other activities.

Design plans for the proposed Action are provided in Appendix A.

1.4.2 Quantity of Material

Approximately 37,000 cubic yards (CY) of material will be generated from the demolition of the BRLD1 structures. Approximately 11,000 CY of material will be placed into the lock chamber, and the remaining 26,000 CY will be placed along the right-descending streambank, where the downstream guide wall currently stands.

1.4.3 Source of Material

Clean material from the demolition of the operations building, the lock land wall, the guide walls, and the dam will be used as fill for the lock chamber and the temporary work pad. Metal components of the demolished material, such as the steel sheet piling form the mooring cells, will be removed and disposed of off-site.

1.5 Description of the Proposed Discharge Sites

1.5.1 Location

The dam will be demolished in lifts, with the vertical extent of each lift determined by the water level to ensure that equipment is not working in more than two feet of water for safety reasons. Depths of greater than two feet reduce the stability of the equipment and may submerge portions of the engine, resulting in potential release of engine fluids or damage to the equipment. The dam will be removed to approximately 392 feet AMSL, which is the average anticipated depth of the river bottom under the dam. Dam sills and timber pilings will also be removed to approximately 392 feet AMSL, and steel reinforcement rods, if present, will be broken at the proposed final elevation and either cut or bent downstream to avoid snags. The remaining portion of the dam will also be notched to an elevation below 392 feet AMSL in several locations to maintain flow and facilitate passage by aquatic organisms and recreational users (e.g., boats, canoes, kayaks) during low river levels. The dam will be demolished to the dam abutment at the western end of the dam, which will be left in place. The remnants of the old mill downstream of the dam on the west side of the river will also remain. After dam demolition is complete, the in-stream work pad material will be removed and placed within or adjacent to the outer lock chamber.

Demolition of the locks and associated structures will begin after initiation of dam demolition. The remainder of the inner- and outer lock walls river wall, land wall, and guide walls and lock floor will be removed to the same elevation as the remaining portion of the dam (approximately 392 feet AMSL). The concrete esplanade and earthen fill between the two locks will be removed, and the concrete from the esplanade will be placed within or adjacent to the outer lock chamber. The earthen fill will be placed adjacent to the outer lock chamber to help stabilize the bank. The outer lock river wall will be demolished to an elevation of approximately 399 to 404 feet AMSL, and the outer lock land wall and upstream and downstream guide walls will be removed to approximately 412 to 414 feet AMSL. Material from the walls will be placed within or adjacent to the outer lock chamber. The outer lock miter gates will also be removed and placed in the outer lock chamber. The outer lock chamber will be filled to the top of the lock land wall, then graded to create a constant 3:1 slope extending from the top of the land wall to the base of the former inner lock land wall. Concrete material generated in excess of the volume of the outer lock chamber and not necessary for slope stabilization will be placed in the scour area below the dam (right descending bank), as necessary. Any soil generated during demolition and removal will be used to cover the fill material on the slope and will not be placed in the river or scour area. The remainder of the slope is expected to be covered naturally over time by sediment deposition during flood events.

1.5.2 Size

Approximately 1,050 linear feet of stream and 122,000 square feet of stream will be directly affected by demolition activities of BRLD1. Fill will be placed in area of approximately 34,000 square feet, including the lock chamber. Temporary work pads used to gain access to the dam for demolition activities may be constructed on either side of the dam. A 50-ft buffer on both sides of the dam was used to calculate an area of 22,000 square feet in which temporary fill may be placed for the work pads. This 50-ft buffer is included in the work area depicted in Figure 2.

1.5.3 Type(s) of Sites and Habitats

While the impoundment formed by BRLD1 has adversely affected the riverine habitat of the Barren River, it still provides suitable habitat for many aquatic organisms, including threatened and endangered mussel species. Lotic conditions downstream of BRLD1 provide ample flow for many riverine fish and mussel species. Upstream of the dam, habitat has been altered into more lentic conditions during periods of normal water levels due to the impoundment. As a result, the pool of BRLD1 has suffered from increased sedimentation, which has reduced habitat suitability for benthic organisms, and the fish species that rely on them as a source of food.

1.5.4 Time and Duration of Discharge

Assuming normal water level fluctuations, instream work associated with the proposed Action will begin in June of 2022. The demolition phase of the project is expected to take approximately 8 to 12 weeks to complete. Prolonged high-flow periods may increase construction time. The complete project, including site preparation, demolition, and site stabilization may continue through Fall 2023.

1.6 Description of Disposal Method

The disposal of material will be accomplished mostly with hydraulic excavators. The construction activities would utilize the following vehicles:

(2) Hydraulic Excavators 4.5 CY Bucket

(1) 200 HP Dozer

(1) Front End Loader 4 CY Bucket

(2) 25 Ton Off-Road Articulating Trucks

2 Factual Determinations

2.1 Physical Substrate Determinations

2.1.1 Substrate

The proposed demolition site is composed of various substrates, including sand, silt, gravel, cobble, and boulders. Substrate on the upstream side of the dam is generally more silt-laden than that immediately downstream of the dam. After removal of BRLD1, fine sediment from upstream of the dam will be transported and redistributed downstream, depositing in any scour areas downstream of the dam. In addition, the gravel, cobble, and boulders habitat substrates in Pool 1 will be exposed. Although large amounts of fine

sediment were not documented upstream of the dam, sediment transport is expected to occur downstream.

Substrate information recorded during the 2021 mussel survey indicates that large amounts of fine sediment have not accumulated behind the dam; however, clay and silt are present upstream of the dam and are expected to move downstream after dam removal. Impacts to listed mussels are not anticipated from sediment accumulation at the base of the dam due to the lack of suitable habitat currently in this area. However, sediment that travels beyond the scour area could increase sediment deposition in areas where mussels are known to occur downstream of the dam. Based on the incremental removal of the dam, accumulated sediment is anticipated to move downstream in small amounts over a period of time. Increased sediment deposition in the work area and immediately downstream is expected to be temporary as sediment is moved farther downstream. Sediment from Pool 1 will likely move into the work area with each high flow event until the accumulated sediment is redistributed throughout the river. Although a gradual drawdown of BRLD1 is anticipated, some bank sloughing from exposed banks is expected to occur before the site is stabilized which could result in additional sediment input within the work area. Although mussels may be able to tolerate minimal, temporary sediment deposition, the combination of sediment deposition from upstream of the dam and from areas farther upstream may be too substantial to allow all individuals to adjust. Sediment deposition that occurs during periods of low water temperature and decreased mussel activity will also reduce the ability of individuals to respond to deposition events (USFWS 2022).

2.1.2 Sediment Type

Soils mapped by the Natural Resources Conservation Service (NRCS) indicated soil units within the project area are mostly comprised of Nolin silt loam, frequently flooded.

2.1.3 Dredged/Fill Material Movement

Fill will be placed in a way to minimize movement after completion of the proposed Action. Large stones and concrete debris generated from the demolition will be used to cap fill areas to limit movement of material during high water events. Rock fill material used to build work pads will be removed simultaneously with the dam.

2.1.4 Physical Effects on Benthos

Potential stressors associated with removal of BRLD1 include sediment deposition, water quality degradation, changes to flow, crushing or striking of individuals, displacement of individuals, and exposure of individuals.

The proposed Action has the potential to expose benthic species to sediment disturbance and water quality degradation in the work area and the downstream of the work area and crushing or striking of individuals in the work area during lock and dam removal. The potential stressors are expected to have insignificant effects on the benthos throughout the remainder of the Action Area.

While these localized impacts to benthic organisms and their habitats would occur in the immediate areas of demolition activities, removal of BRLD1 is expected to have a positive effect on benthic community of organisms throughout the Action Area by

reestablishing the natural hydrologic regime and increasing interstitial spaces and abundance of periphyton in the river upstream of BRLD1. For these reasons, long-term, beneficial impacts to benthos are expected from the Proposed Action.

2.1.5 Other Effects

No other effects are known.

2.1.6 Actions Taken to Minimize Impacts

Best management practices during the initial site preparation phase of construction include the installation of erosion prevention and sediment control (EPSC) measures, improvement and construction of access roads, clearing and grubbing, and establishment of staging areas. These activities will require the use of heavy equipment (i.e., bulldozers, trackhoes, backhoes, trucks, etc.). While disturbances within the Barren River during the site preparation phase are not expected, EPSC measures will be installed to reduce erosion and minimize sediment deposition.

A site-specific Erosion Control Plan, including Best Management Practices (BMPs), will be developed by the project engineer, and appropriate measures will be installed prior to commencement of onsite activities and be managed and maintained throughout the construction period.

The following conservation measures are proposed to avoid and minimize impacts from the proposed Action to the physical environment and fish and wildlife habitat:

(1) Implement erosion control measures in the work area, including but not limited to:

a. Stabilization of disturbed areas as soon as practicable but no more than seven (7) days after construction activities have temporarily or permanently ceased in any portion of the work area. At a minimum, interim and permanent practices implemented to stabilize disturbed areas will include temporary and/or permanent seeding, erosion control matting, mulching, and/or sodding.

b. Structural measures will be implemented to divert flows from exposed soils, temporarily store flows, or otherwise limit runoff and the discharge of pollutants from exposed areas of the site. These measures shall be implemented in a timely manner during the construction process to minimize erosion and sediment runoff. Structures may include silt fence or coir rolls, stone silt check dams, temporary gravel construction entrances/exits, and/or riprap.

(2) Revegetate disturbed areas immediately following completion of ground disturbing activities.

(3) Perform instream activities during periods of low flow.

(4) Use of instream work pads during lock and dam removal to minimize impacts to the river from equipment. The work pads will be located in areas that do not provide suitable habitat for mussels.

(5) Implement best management practices (BMPs) when operating machinery on the instream work pad or within the riparian area to avoid and minimize the potential for

accidental spills and have a spill response plan in place should an accidental spill occur.

(6) Remove any remaining hydraulic fluid from the hydraulic piping system in the operations building and lock chamber and dispose of appropriately.

(7) Incremental removal of the dam to reduce the rate of water recession upstream of the dam.

(8) Monitoring in the upstream portion of the Action Area during dam removal to locate exposed mussels and return individuals to areas of suitable habitat.

These measures will be implemented throughout the work area during construction, as necessary and appropriate. The conservation measures are anticipated to help avoid and minimize adverse effects to substrates and fish and wildlife habitats. However, these measures are not expected to eliminate all adverse effects that may result from the proposed Action.

Immediately following the removal of BRLD1, site stabilization measures will be implemented including regrading, seeding, and mulching or covering disturbed areas, if needed. The main access road will remain in place to provide continued access to the BRLD1 property. The heavy equipment access road and crossing of Taylor Branch will be restored and stabilized, as necessary.

2.2 Water Circulation, Fluctuation, and Salinity Determinations

2.2.1 Water

Increases in turbidity would occur at the demolition areas and downstream of the areas during demolition. Temporary changes in turbidity have not been modeled; however, they are not expected to significantly impact water quality or to exceed levels experienced during typical high flow events on the river.

No significant negative impacts would be expected to water quality or sensitive organisms as a result of the Proposed Action.

Salinity

There are no impacts expected to salinity.

Water Chemistry

No significant impacts to water chemistry are expected.

Clarity

There may be a local and temporary increase in turbidity during construction activities. BMPs such as erosion control fencing and other measures would be implemented where appropriate at the upland or onshore locations to control and reduce turbidity during construction. Water clarity is expected to return to normal background levels shortly after operations are completed.

Color

Water immediately surrounding the construction area may become discolored temporarily due to disturbance of the sediment.

Odor

Negligible amounts of hydrogen sulfide may be expected when disturbing possible anoxic sediments at the construction sites. Otherwise, there are no long-term impacts to odor.

Taste

No impacts to taste are expected.

Dissolved Gas Levels

No impacts to dissolved gas levels would be expected.

Nutrients

There are no impacts expected to nutrients.

Eutrophication

Demolition activities would not lead to eutrophication of surrounding waters.

Others as Appropriate

None known.

2.2.2 Current Patterns and Circulation

Current Patterns and Flow

Removal of the dam will lower the water level of the Barren River throughout the upstream portion of the Action Area. Based on the Hydrologic and Hydraulic Analysis included in the Disposition Study, removal of BRLD1 will lower the water level seven miles upstream of BRLD1 by approximately 12 feet based on the 100% duration flow for August (base flow). The difference in water level will decrease with increasing distance from BRLD1 to the end of the Action Area just below RM 38. After the dam is notched, the water level in Pool 1 is expected to recede slowly due to the small size of the opening; however, as larger sections of the dam are removed and more water flows through, the rate of recession is anticipated to increase beyond the normal rate of recession during seasonal periods of low water. While completion of the proposed action activities would reduce surface water elevations upstream of the BRLD1, the Action is expected to reestablish the natural flow regime of the river within the action area.

Velocity

Removal of the dam would increase velocities within the former pool of BRLD1. Placement of material within the channel would not impact velocities.

Stratification

No change in this condition is expected**.**

Hydrologic Regime

Hydrologic regimes would be altered to the natural condition after removal of the dam. The former pool of BRLD1 would return to lotic conditions with increased water velocities at all water levels.

A detailed analysis of the changes to the hydraulic conditions in the Barren River after removal of BRLD1 were analyzed by the USACE based on available hydraulic modeling. A memorandum summarizing the findings was prepared by the USACE and is included in the 2022 Biological Opinion (USFWS 2022; Appendix C). According to the memorandum, BRLD1 is a run-of-river type dam and does not significantly impound flood water within Pool 1. The crest of the dam is located at an elevation of approximately 412 feet AMSL, and the elevation of the associated floodplain is approximately 420 to 430 feet AMSL. Due to the difference between these elevations, the hydraulic capacity over the dam is large enough to allow the inflow and outflow of Pool 1 to be effectively equal. Because flow downstream of the dam is not affected by the presence of the dam, the removal of the dam is not anticipated to change downstream flow from existing conditions. This lack of change is demonstrated in Figure 3.

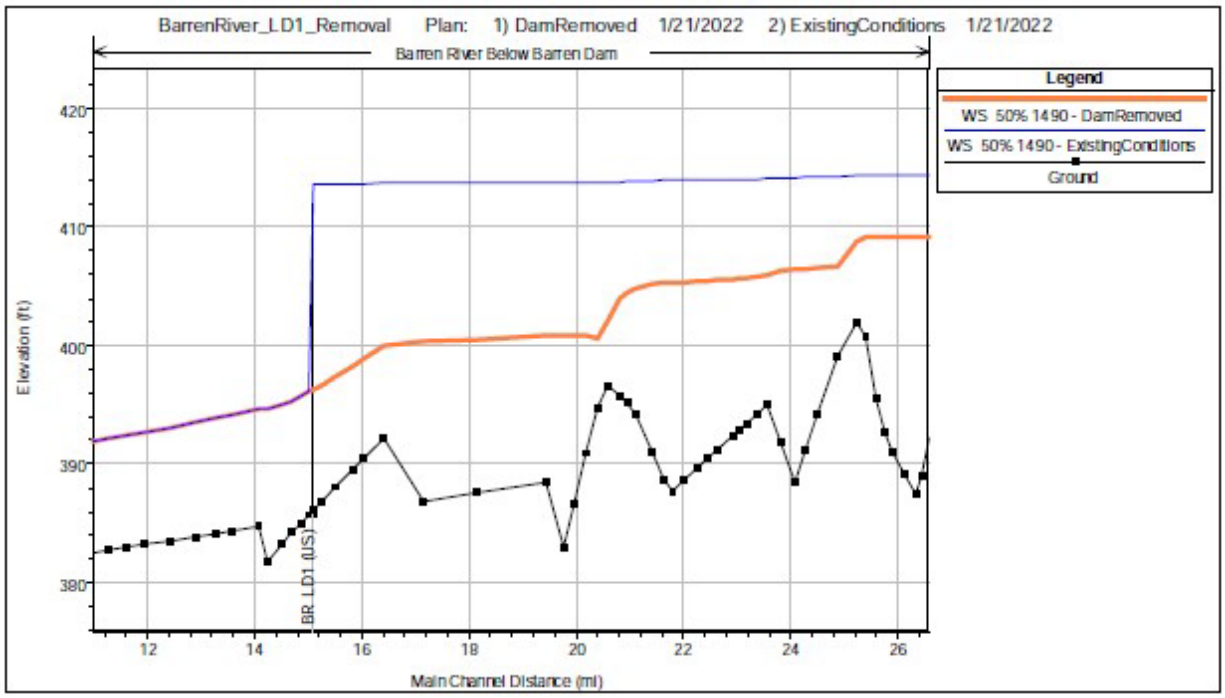


Figure 3. Model of water surface elevation changes from removal of Barren River Lock and Dam #1, Warren County, Kentucky.

2.2.3 Normal Water Level Fluctuations

Figure 3 shows the water surface profiles for the existing conditions with the dam in place (blue line) and conditions after dam removal (orange line). Both profiles are identical downstream of the dam, indicating that downstream flow is not affected by the dam. In addition, the depth and water surface slope downstream of the dam will remain the same after dam removal. While water levels downstream of the dam are not expected

to be affected by dam removal, the average water surface elevation within the existing pool of BRLD1 would be lowered significantly after removal of the dam (see Figure 3).

2.2.4 Salinity Gradients

There would be no change in salinity gradients.

2.2.5 Actions That Would Be Taken to Minimize Impacts

The footprint of the excess material would be minimized to the greatest extent practicable, such that impacts to water circulation and fluctuation would be negligible in the immediate work area.

2.3 Suspended Particulate/Turbidity Determination

2.3.1 Expected Changes in Suspended Particulates and Turbidity Levels in Vicinity of Disposal Site

Increased turbidity typically occurs during dam removals due to the disturbance and suspension of sediment that has accumulated behind the dam. The increased turbidity from dam removal is a temporary effect that will subside as sediment is flushed through the river system.

A temporary and localized increase in suspended particulates and turbidity levels is expected during placement of material into discharge sites. Upon completion of demolition activities, suspended particulates and turbidity levels are expected to return to existing levels.

2.3.2 Effects on Chemical and Physical Properties of the Water Column

Light Penetration

Turbidity levels would be temporarily increased during placement of material. Upon completion of demolition activities, light penetration is expected to return to current levels.

Dissolved Oxygen

Inputs of sediment or sediment disturbance in the Green River could result in increased turbidity and decreased dissolved oxygen (DO); a reduction in DO may occur at localized and temporary events during placement. Increases in DO above the dam may occur after removal from increased flow.

Toxic metals and organics

Substrate sampling conducted during mussel surveys above BRLD1 in 2019 indicated that large amounts of fine sediment had not accumulated behind the dam. This section of the river is classified as an Outstanding State Resource Water by Kentucky Division of Water (KDOW) and toxic metals or organics are not expected to be present. In addition, the suspension of sediment particles resulting from demolition of the structure is expected to be temporary. As such, the demolition and the placement of fill occurring during this

action would not result in detrimental effects to chemical and physical properties of the water column.

Pathogens

No pathogens have been found or are expected.

Aesthetics

Long-term positive impacts to aesthetics are expected from removal of BRLD1 and its associated structures. After removal, the site would revert to a more natural riverine setting as the former hydrology of the area is restored.

Others as Appropriate

None known.

2.3.3 Effects on Biota

Site preparation, lock and dam removal, and site stabilization could result in temporary water quality degradation through suspension of fine sediment in the water column. Sediment inputs in the Green River could result in increased turbidity and decreased DO. These conditions could result in harm or mortality of biota or cause individuals to move from an area if they persist for an extended period of time. High turbidity could affect the food supply of mussels by blocking sunlight needed by algae and phytoplankton and disrupt reproduction by reducing the visibility of mussel lures to fish hosts. Lower dissolved oxygen could affect the respiration of mussels and fish hosts.

Based on the gradual removal of the dam in stages, accumulated sediment is anticipated to move downstream in small amounts over an extended period of time. Increased turbidity in the work area and areas immediately downstream is expected to be temporary as sediment is moved farther downstream; however, sediment from Pool 5 will likely move into the work area with each high flow event until the accumulated sediment is redistributed throughout the river. Although mussels may be able to respond to minimal, temporary sediment deposition, the combination of sediment from directly upstream of the dam and areas farther upstream may result in deposition too substantial to allow all individuals to adjust. Sediment deposition that occurs during periods of low water temperatures and decreased mussel activity will also reduce the ability of individuals to respond to deposition events. While the initial reclamation stages of the river could increase turbidity and potentially harm biota, long-term impact of the Proposed Action is expected to result in significant benefits to the native biota.

2.3.4 Actions Taken to Minimize Impacts

The footprint of the material would be minimized to the greatest extent practicable, such that impacts from fill material to suspended particulates and turbidity levels would be negligible. Conservation measures listed in Section 2.1.6 will be implemented to minimize impacts to water quality from demolition activities.

2.4 Contaminant Determinations

Fill material used will be obtained onsite. Site investigations have revealed no reason to expect the fill material would be contaminated.

2.5 Aquatic Ecosystem and Organism Determinations

2.5.1 Effects on Plankton

Demolition activities and placement of fill are expected to have minor, temporary, local impacts on plankton from increased turbidity levels.

2.5.2 Effects on Benthos

The Proposed Action could expose benthic species to stressors that include sediment disturbance and water quality degradation in the work area and the Action Area downstream of the work area during lock and dam removal; and crushing or striking of individuals in the work area during lock and dam removal. The stressors are expected to have insignificant or discountable effects on the benthos throughout the remainder of the Action Area.

While these localized impacts to benthic organisms and their habitats would occur in the immediate areas of demolition activities, removal of BRLD1 is expected to have a positive effect on benthic community of organisms throughout the Action Area by reestablishing the natural hydrologic regime and increasing interstitial spaces and abundance of periphyton in the river upstream of BRLD1. For these reasons, long-term beneficial impacts to benthos are expected from the Proposed Action.

2.5.3 Effects on Nekton

No significant impacts to the nekton of the area from the Proposed Action.

2.5.4 Effects on Aquatic Food Web

Reductions in primary productivity from turbidity would be temporary and localized around the immediate area of the construction and would be limited to the duration of the plume at a given site. The removal of the dam is expected to result in long-term beneficial impacts to the aquatic food web.

2.5.5 Effects on Special Aquatic Sites

The Barren River beginning immediately downstream of BRLD1 is designated as an Outstanding State Resource Water (OSRW). The proposed Action would be expected to result in long-term beneficial impacts to the river and enhance its regional, state, and national significance.

2.5.6 Threatened and Endangered Species

In March 2022, the USACE submitted a final BA to the USFWS, Kentucky Field Office which analyzed the potential impacts to the seventeen Federally listed species. These species include the rough pigtoe (*Pleurobema plenum*), pyramid pigtoe (*Pleurobema rubrum*), spectaclecase (*Cumberlandia monodonta*), fanshell (*Cyprogenia stegaria*), purple cat's paw (*Epioblasma obliquata obliquata*), northern riffleshell (*Epioblasma torulosa rangiana*), snuffbox (*Epioblasma triquetra*), clubshell (*Pleurobema clava*), pink umcket (*Lampsilis abrupta*), rabbitsfoot (*Quadrula cylindrica cylindrica*), ring pink (*Obovaria retusa*), sheepnose (*Plethobasus cyphyus*), longsolid (*Fusconaia subrotunda*), Price's potato-bean (*Apios priceana*), Indiana bat (*Myotis sodalis*), gray bat (*Myotis grisescens*), and northern long-eared bat (*Myotis septentrionalis*).

The identification of species listed under the Endangered Species Act (ESA) for inclusion in the BA was based on a review of occurrence records maintained by the USFWS. The BA is included in the Appendix B of this evaluation. A final biological opinion (BO) from the USFWS was submitted in May 2022 (USFWS 2022; Appendix C).

Impacts to Listed Bat Species

Three listed bat species have potential to occur in the project area: gray bat, Indiana bat and northern long-eared bat. Based on the lack of impacts to gray bat hibernacula and roosting habitat and minimal impacts anticipated to foraging habitat, forage supply, and commuting habitat, effects to the gray bat as a result of the proposed Action are considered insignificant and a *may affect, but not likely to adversely affect* determination was included in the 2022 BA (USACE 2022). USFWS concurred with this determination during informal consultation process initiated in March of 2022 and in the 2022 BO (USFWS 2022; Appendix C).

The proposed Action will result in adverse effects to the Indiana bat and northern long-eared bat from habitat loss associated with tree clearing. As a result, an effects determination of "may affect, likely to adversely affect" for the Indiana and northern long-eared bats was made in the 2022 BA and informal consultation with the USFWS was initiated to address impacts to these two species. Adverse effects to both species will be mitigated through a payment to the Imperiled Bat Conservation Fund, utilizing the process set forth in the Revised Conservation Strategy for Forest-Dwelling Bats in the Commonwealth of Kentucky (June 2016).

Mussels

While potential impacts to these species have been minimized to the extent possible using conservation measures, adverse effects to the mussel species are expected as a result of the proposed Action. The 2022 BA determined that the proposed action "may affect and is likely to adversely affect" rough pigtoe and pyramid pigtoe. The USACE requested initiation of formal consultation on the Rough Pigtoe and formal conference on the Pyramid Pigtoe.

The USACE also determined that the proposed action "may affect, but is not likely to adversely affect" the spectaclecase, fanshell, purple cat's paw, northern riffleshell, snuffbox, clubshell, pink mucket, rabbitsfoot, ring pink, sheepnose, longsolid, and Price's potato-bean.

The final BO detailing the complete coordination process, the potential impacts to listed species, and the conservation and mitigation strategies to be implemented during the Action is included in Appendix C.

2.5.7 Other Wildlife

No significant detrimental impacts to other wildlife species are anticipated.

2.5.8 Actions to Minimize Impacts

The USACE and USFWS have committed to implement the following conservation measures (CM) specific to the affected freshwater mussels as part of the Action (USFWS 2022):

CM 1: Implementation of EPSC measures in the work area, including but not limited to:

(a) Stabilization of disturbed areas as soon as practicable, but no more than seven days after construction activities have temporarily or permanently ceased in any portion of the work area. At a minimum, interim and permanent practices implemented to stabilize disturbed areas will include temporary and/or permanent seeding, erosion control matting, mulching, and/or sodding.

(b) Implementation of structural measures in a timely manner to divert flows from exposed soils, temporarily store flows, or otherwise limit runoff and the discharge of pollutants from exposed areas of the site to minimize erosion and sediment runoff. Structures may include silt fence or coir rolls, stone silt check dams, temporary gravel construction entrances/exits, and/or riprap.

CM 2: Revegetation of disturbed areas immediately following completion of ground disturbing activities.

CM 3: Implementation of in-stream activities during periods of low flow.

CM 4: Use of in-stream work pads during lock and dam removal to minimize impacts to the river from equipment. The work pads will be located in areas that do not provide suitable habitat for the listed mussel species.

CM 5: Implementation of BMPs when operating machinery on the in-stream work pad or within the riparian area to avoid and minimize the potential for accidental spills, including a spill response plan to address accidental spills.

CM 6: Removal of and disposal of any remaining hydraulic fluid from the hydraulic piping system in the operations building and lock chamber and dispose of appropriately.

CM 7: Incremental removal of the dam to reduce the rate of water recession upstream of the dam.

CM 8: Monitoring the upstream portion of the Action Area during dam removal to locate exposed mussels and return individuals to areas of suitable habitat.

2.6 Proposed Disposal Site Determinations

2.6.1 Mixing Zone Determination

N/A

2.6.2 Determination of Compliance with Applicable Water Quality Standards

For the proposed Action, no violation of water quality standards is anticipated. Prior to the onset of construction/demolition activities, 401 Water Quality Certification, KPDES, and Floodplain permits from the Commonwealth of Kentucky will be obtained.

2.6.3 Potential Effects on Human Use Characteristics

Municipal and Private Water Supply

The proposed Action would not impact any municipal or private water supplies.

Recreational and Commercial Fisheries

The proposed Action would be expected to alter the fish community in the stretch of the Green River that was the former pool of BRLD1. Over time, the fish assemblages would be expected to transition back to consisting of more diverse native species that were present before the river was impounded. This may improve recreational fishing, although fishing methods may need to change to account for higher water velocities.

No impacts to commercial fishing are anticipated as the area is not utilized as a commercial fishery.

Water-related Recreation

Removal of the dam would result in greater water velocities at base flows, which has the potential to alter water-related recreation. The most popular activities on the Barren River are kayaking and canoeing which would likely benefit from removal of the dam. The removal of the dam would eliminate a barrier to movement up and down the river and eliminate safety concerns the are inherent with low head dams.

Aesthetics

Aesthetics would be expected to improve in the Action Area as the river returns to a more natural state, and the failing infrastructure of BRLD1 is removed.

Parks, National and Historic Monuments, National Seashores, Wilderness Areas, Research Sites, and Similar Preserves

No special sites would be negatively impacted by the proposed Action. The removal of BRLD1 has been coordinated with the Kentucky State Historic Preservation Office.

2.7 Determination of Cumulative Effects on the Aquatic Ecosystem

The purpose of the proposed Action is to improve passage for aquatic organisms and restore instream habitat above and below the dam for riverine fish and macroinvertebrates. Future activities, such as increased residential or commercial development, agricultural practices, increased traffic, or tourism, in the area are not reasonably certain to occur as a result of the Action. Based on these factors, no adverse cumulative effects to the aquatic ecosystem are anticipated as a result of the proposed Action.

2.8 Determination of Secondary Effects on the Aquatic Ecosystem

Secondary effects are effects on an aquatic ecosystem that are associated with a discharge of dredged or fill material but do not result from the actual placement of the material. No adverse significant secondary effects on the aquatic ecosystem should occur as a result of the proposed Action.

3 Findings of Compliance with Restrictions on Discharge with Section 404(b)(1) Guidelines

A. No significant adaptations of the Guidelines were made relative to the evaluation for this proposed Action.

B. The proposed Action represents the least environmentally damaging practicable alternative.

C. The discharges associated with the proposed Action alternative are not anticipated to cause or contribute to violation of any water quality standards. A Clean Water Act Section 401 water quality certification will be obtained from the Commonwealth of Kentucky before commencing any work in waters of the U.S. Additionally, the proposed Action alternative would not violate any toxic effluent standards of Section 307 of the Clean Water Act.

D. The proposed Action would not jeopardize the continued existence of any Federally listed threatened or endangered species or their critical habitat or violate any protective measures for any sanctuary.

E. The proposed Action would not result in adverse effects on human health and welfare, including municipal and private water supplies, recreation and commercial fishing, plankton, fish, wildlife, and special aquatic sites. There are no significant adverse impacts expected to the aquatic ecosystem diversity, productivity and stability, or recreational, aesthetic, and economic values.

F. Appropriate and practicable steps will be taken to minimize potential adverse impacts of discharge on the aquatic system.

Prepared by:

HAWKINS.JEFFREY.ALLEN.1586929522 Digitally signed by HAWKINS.JEFFREY.ALLEN.1586929522 Date: 2022.05.10 23:43:58 -04'00'

Jeffrey A. Hawkins — Date

Wildlife Biologist, Planning Section

U.S. Army Corps of Engineers, Louisville District

Approved by:

Nathan Moulder Digitally signed by Nathan Moulder Date: 2022.05.11 08:44:53 -04'00'

Nathan Moulder. — Date

Chief, Planning Section

U.S. Army Corps of Engineers, Louisville District

4 Works Cited

Haag, R. 2012. North American freshwater mussels: natural history, ecology, and conservation, first edition, Cambridge University Press, New York, NY.

United States Army Corps of Engineers (USACE). 2022. Biological Assessment Report: Barren River Lock and Dam Removal Project, Warren County, Kentucky. Prepared by RES, Kentucky LLC. 128pp.

United States Fish and Wildlife Service (USFWS). 2022. Demolition and Removal of Barren River Lock and Dam 1: Biological Opinion on the Rough Pigtoe (*Pleurobema plenum*) and Conference Opinion on the Pyramid Pigtoe (*Pleurobema rubrum*), FWS #: 2022-0005888. 71pp.

Appendix A
Project Plans

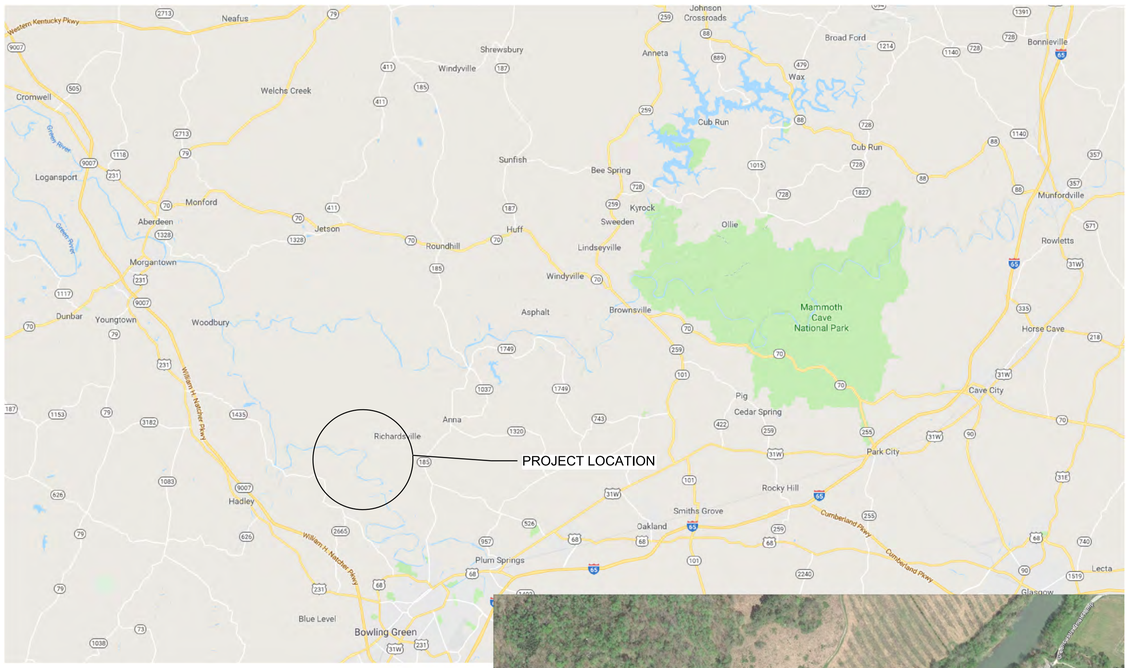
US Army Corps
of Engineers

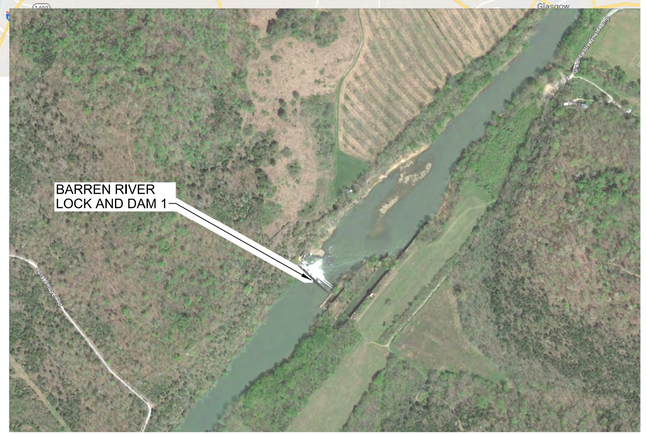
Louisville District

BARREN RIVER LOCK AND DAM 1 REMOVAL

GREENCASTLE, KENTUCKY

P2# 465345, FY 2018





US Army Corps of Engineers®

MARK	DESCRIPTION	APPR.	DATE

DESIGNED BY: T. SMITH
DRAWN BY: B. SAYLOR
CHECKED BY: B. DORSCH
SUBMITTED BY: M. MCCULDER
SIZE: ANSI D
ISSUE DATE: JULY 2018
SOLICITATION NO.:
CONTRACT NO.:
DRAWING CODE:

U.S. ARMY CORPS OF ENGINEERS
LOUISVILLE DISTRICT
600 DR. MARTIN LUTHER KING JR. PLACE
LOUISVILLE, KY 40202

FY 2018 P2465345
BARREN RIVER LOCK AND DAM 1 REMOVAL
GREENCASTLE, KENTUCKY

COVER SHEET

SHEET ID
BR1D
G-001

...\CAD\128624\128624\CAD_BIM_Sheets\465345_G-001xxx.dgn
11:15:33 AM 7/23/2018 LRL_pdf.pltcfg LRL_Screen.dscript

Sheet Filename	Sheet Ref No.	Sheet Description	Sheet No.
GENERAL			
465345_G001.DGN	G-001	COVER SHEET	1
465345_G002.DGN	G-002	DRAWING INDEX	2
CIVIL			
465345_CD101.DGN	CD101	OVERALL DEMOLITION PLAN	3
465345_CD102.DGN	CD102	LOCK DEMOLITION PLAN	4
465345_CD103.DGN	CD103	DAM DEMOLITION PLAN	5
465345_CD104.DGN	CD104	ESPLANADE AND CONTROL TOWER DEMOLITION PLAN	6
465345_CD301.DGN	CD301	DEMOLITION SECTIONS	7
465345_CS101.DGN	CS101	360' LOCK FILL PLAN	8
465345_CS301.DGN	CS301	360' LOCK FILL SECTION	9

US Army Corps of Engineers®

MARK	DESCRIPTION	APPR.	DATE

DESIGNED BY: T. SMITH
DRAWN BY: B. SAYLOR
CHECKED BY: B. DORSCH
SUBMITTED BY: M. MCCULDER
SIZE: ANSI D

ISSUE DATE: JULY 2018
SOLICITATION NO.:
CONTRACT NO.:
DRAWING CODE:

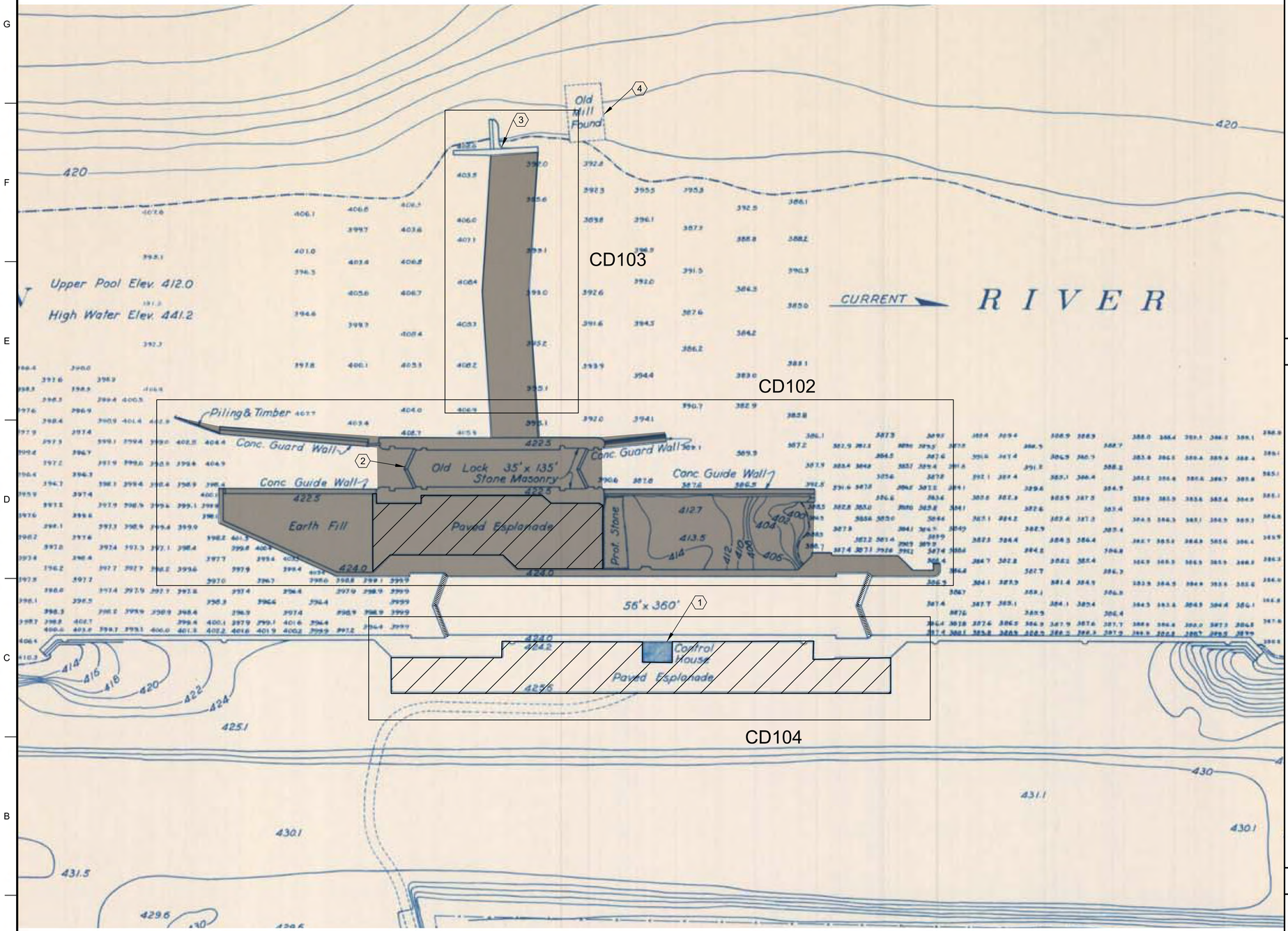
U.S. ARMY CORPS OF ENGINEERS
LOUISVILLE DISTRICT
600 DR. MARTIN LUTHER KING JR. PLACE
LOUISVILLE, KY 40202

FY 2018 P2465345
BARREN RIVER LOCK AND DAM 1 REMOVAL
GREENCASTLE, KENTUCKY

DRAWING INDEX

SHEET ID
BR1D
G-002

...\CAD\128624\128624\CAD_BIM_Sheets\465345_G-002xxx.dgn
11:15:35 AM 7/23/2018 LRL_pdf.pltcfg LRL_Screen.dscript



A1 OVERALL DEMOTION PLAN
NTS

GENERAL SHEET NOTES

1. DESIGN IS BASED ON CONDITION OF LOCK AND DAM AT THE TIME OF CONSTRUCTION OF THE 360' LOCK; SEE APPENDIX A
2. SEE APPENDIX B FOR INFORMATION ON CURRENT STATE OF LOCKS AND DAM.

SHEET KEYNOTES

1. CONTROL HOUSE TO BE DEMOLISHED.
2. REMOVE CONCRETE DAM BUILT ON UPSTREAM END OF 135' LOCK.
3. DAM ABUTMENT TO BE LEFT IN PLACE; DO NOT DISTURB.
4. REMAINING MILL STRUCTURES TO BE LEFT IN PLACE

LEGEND

- REMOVE TO ELEVATION SPECIFIED BY CROSS SECTIONS; SEE CD301
- REMOVE ESPLANADE CONCRETE
- REMOVE MITER GATES AND BURY IN PLACE

US Army Corps of Engineers®

MARK	DESCRIPTION	APPR.	DATE

DESIGNED BY: T. SMITH
DRAWN BY: B. SAYLOR
CHECKED BY: B. DORSCH
SUBMITTED BY: M. BOULDER
SIZE: ANSI D
ISSUE DATE: JULY 2018
SOLICITATION NO.:
CONTRACT NO.:
DRAWING CODE:

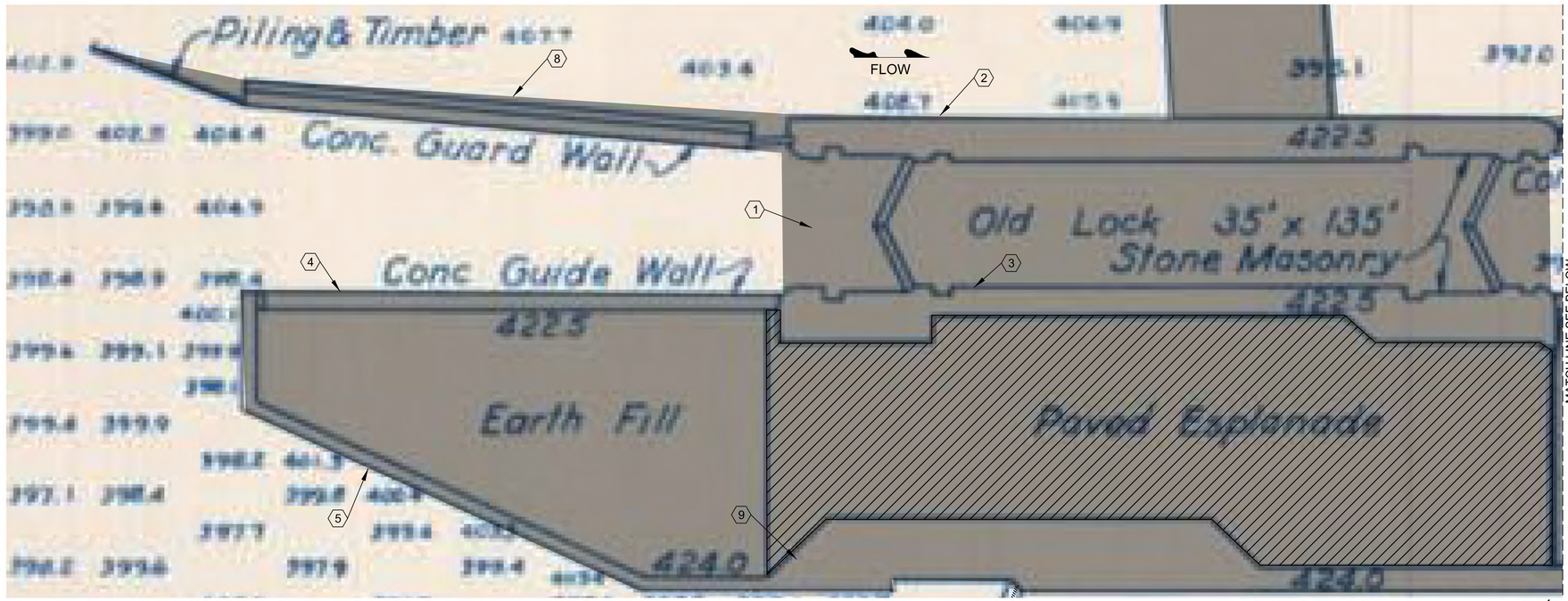
U.S. ARMY CORPS OF ENGINEERS
LOUISVILLE DISTRICT
600 DR. MARTIN LUTHER KING JR. PLACE
LOUISVILLE, KY 40202

FY 2018 P2465345
BARREN RIVER LOCK AND DAM 1 REMOVAL
GREENCASTLE, KENTUCKY

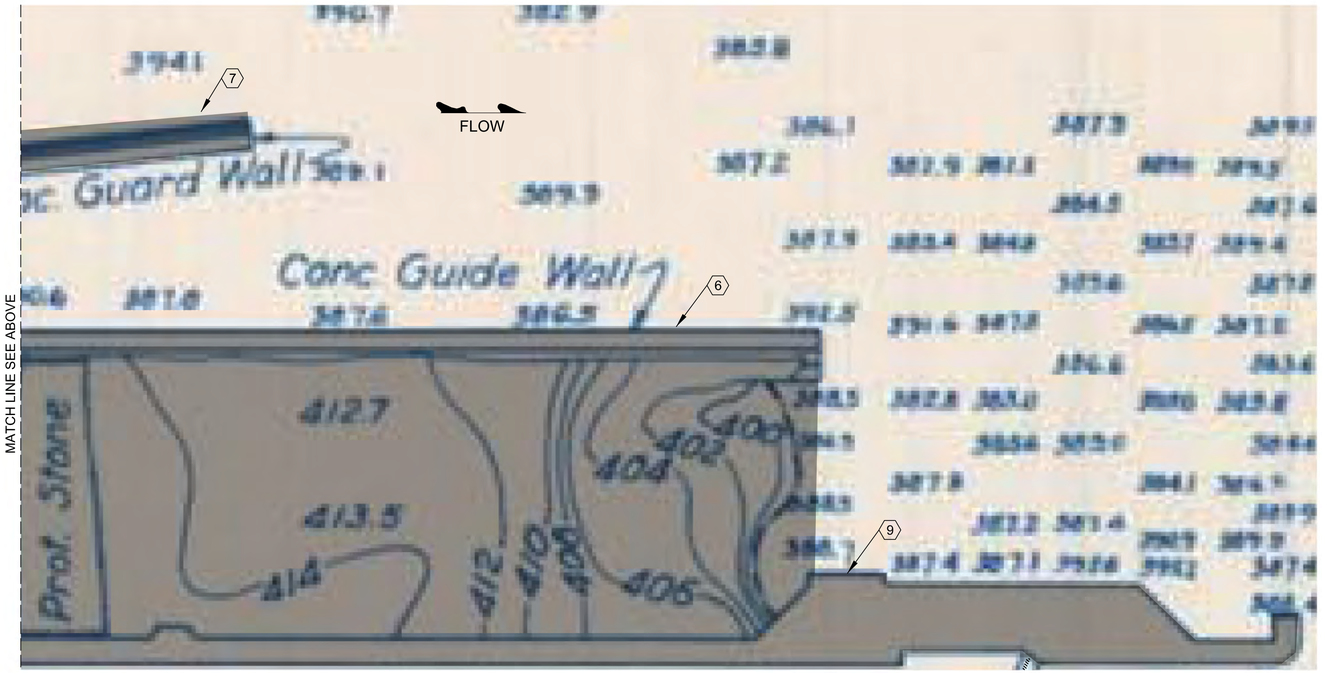
OVERALL DEMOLITION PLAN

SHEET ID
BR1D
CD101

...\CAD\128624\128624\CAD_BIM_Sheets\465345_CD101xxx.dgn
11:15:36 AM 7/23/2018 LRL_pdf.pltcfg LRL_Screen.dscript



D1 LOCK DEMOLITION PLAN
NTS



A1 LOCK DEMOLITION PLAN
NTS

GENERAL SHEET NOTES

1. DESIGN IS BASED ON CONDITION OF LOCK AND DAM AT THE TIME OF CONSTRUCTION OF THE 360' LOCK; SEE APPENDIX A
2. SEE APPENDIX B FOR INFORMATION ON CURRENT STATE OF LOCKS AND DAM.
3. MITER GATES FOR 135' LOCK WERE REMOVED AS PART OF A PREVIOUS PROJECT.

SHEET KEYNOTES

1. REMOVE CONCRETE DAM CONTRUCTED ON UPSTREAM END OF 135' LOCK.
2. REMOVE 135' LOCK RIVER WALL; SEE DETAIL C1, SHEET CD301.
3. REMOVE 135' LOCK LAND WALL; SEE DETAIL C1, SHEET CD301.
4. REMOVE 135' LOCK UPPER GUIDE WALL; SEE DETAIL F3, SHEET CD301.
5. REMOVE 360' LOCK UPPER GUIDE WALL; SEE DETAIL F5, SHEET CD301.
6. REMOVE 135' LOCK LOWER GUIDE WALL; SEE DETAIL F1, SHEET CD301.
7. REMOVE DOWNSTREAM CONCRETE GUARD WALL.
8. REMOVE UPSTREAM CONCRETE GUARD WALL AND PILIING AND TIMBER.
9. REMOVE 360' LOCK RIVER WALL; SEE DETAIL C1, SHEET CD301.

LEGEND

REMOVE TO ELEVATION SPECIFIED BY CROSS SECTIONS; SEE CD301

REMOVE ESPLANADE CONCRETE

US Army Corps of Engineers®

MARK	DESCRIPTION	APPR.	DATE

DESIGNED BY: T. SMITH
DRAWN BY: B. SAYLOR
CHECKED BY: B. DORSCH
SUBMITTED BY: M. MCCULDER
SIZE: ANSI D
ISSUE DATE: JULY 2018
SOLICITATION NO.:
CONTRACT NO.:
DRAWING CODE:

U.S. ARMY CORPS OF ENGINEERS
LOUISVILLE DISTRICT
600 DR. MARTIN LUTHER KING JR. PLACE
LOUISVILLE, KY 40202

FY 2018 P2465345
BARREN RIVER LOCK AND DAM 1 REMOVAL
GREENCASTLE, KENTUCKY

LOCK DEMOLITION PLAN

SHEET ID
BR1D
CD102

...\CAD\128624\128624\CAD_BIM_Sheets\465345_CD102xxx.dgn
11:15:44 AM 7/23/2018 LRL_pdf.pltcfg LRL_Screen.dscript

A1 DAM DEMOLITION PLAN
NTS

GENERAL SHEET NOTES

1. DESIGN IS BASED ON CONDITION OF LOCK AND DAM AT THE TIME OF CONSTRUCTION OF THE 360' LOCK; SEE APPENDIX A
2. SEE APPENDIX B FOR INFORMATION ON CURRENT STATE OF LOCKS AND DAM.
3. DAM ABUTMENT AND ANY REMAINING PORTIONS OF THE MILL SHALL NOT BE DISTURBED.

⬡ SHEET KEYNOTES

1. DEMOLISH DAM; SEE DETAIL A1, SHEET CD301.
2. DAM ABUTMENT TO REMAIN IN PLACE; DO NOT DISTURB.

LEGEND

REMOVE TO ELEVATION SPECIFIED BY CROSS SECTIONS; SEE CD301

US Army Corps of Engineers®

MARK	DESCRIPTION	APPR.	DATE

DESIGNED BY: T. SMITH
DRAWN BY: B. SAYLOR
CHECKED BY: B. DORSCH
SUBMITTED BY: N. MOULDER
SIZE: ANSI D

U.S. ARMY CORPS OF ENGINEERS
LOUISVILLE DISTRICT
600 DR. MARTIN LUTHER KING JR. PLACE
LOUISVILLE, KY 40202

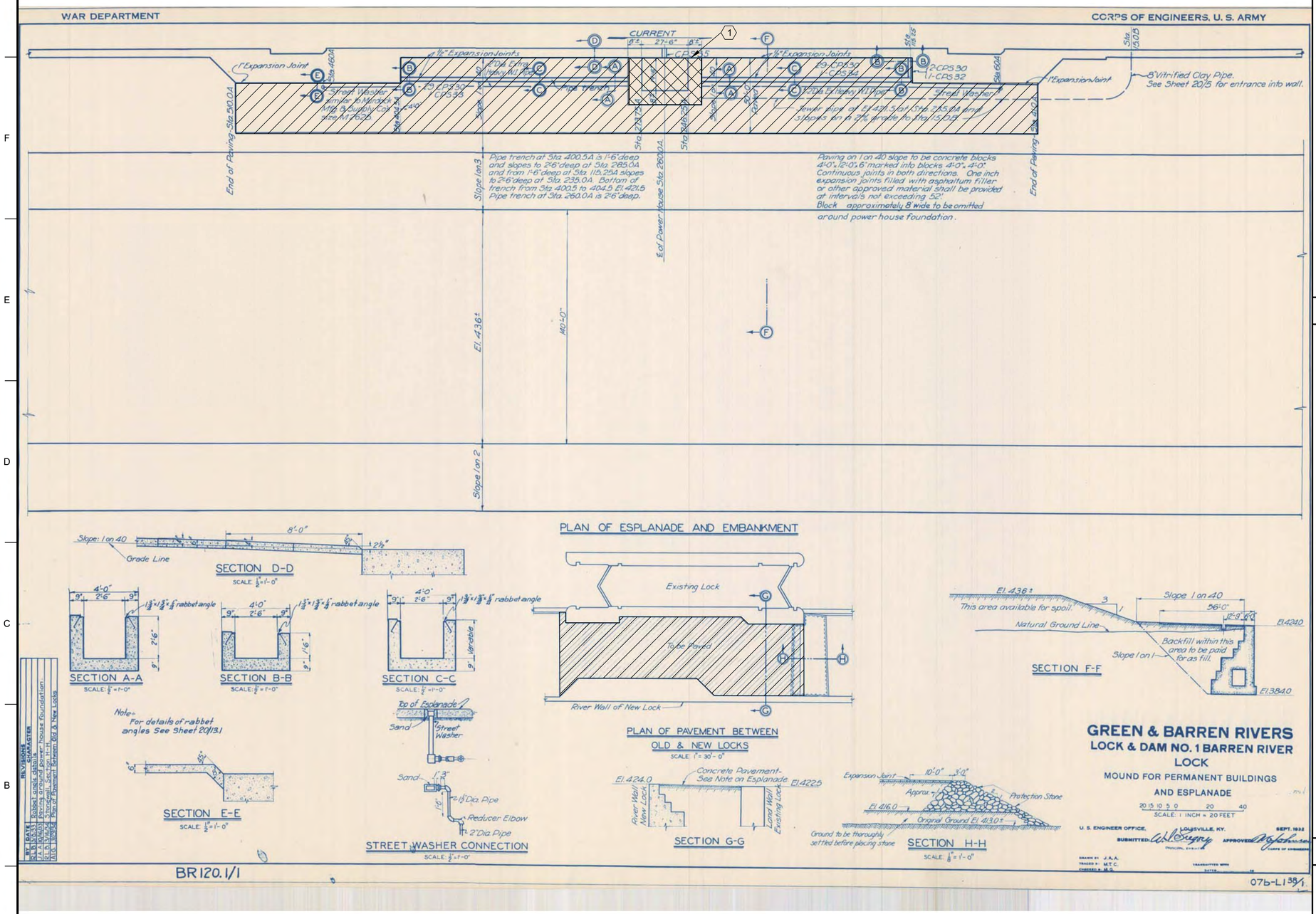
ISSUE DATE: JULY 2018
SOLICITATION NO.:
CONTRACT NO.:
DRAWING CODE:

FY 2018 P2465345
BARREN RIVER LOCK AND DAM 1 REMOVAL
GREENCASTLE, KENTUCKY

DAM DEMOLITION PLAN

SHEET ID
BR1D
CD103

...\CAD\128624\128624\CAD_BIM_Sheets\465345_CD103xxx.dgn
11:15:49 AM 7/23/2018 LRL_pdf.pltcfg LRL_Screen.dscript



GENERAL SHEET NOTES

1. DESIGN IS BASED ON CONDITION OF LOCK AND DAM AT THE TIME OF CONSTRUCTION OF THE 360' LOCK; SEE APPENDIX A
2. SEE APPENDIX B FOR INFORMATION ON CURRENT STATE OF LOCKS AND DAM.

⬡ SHEET KEYNOTES

1. CONTROL HOUSE TO BE DEMOLISHED.

LEGEND

- REMOVE TO ELEVATION SPECIFIED BY CROSS SECTIONS; SEE CD301
- REMOVE ESPLANADE CONCRETE
- BUILDING DEMOLITION

A1 ESPLANADE AND CONTROL TOWER DEMOLITION PLAN
NTS

US Army Corps of Engineers®

MARK	DESCRIPTION	APPR.	DATE

DESIGNED BY: T. SMITH
DRAWN BY: B. SAYLOR
CHECKED BY: B. DORSCH
SUBMITTED BY: M. SCHLUDER
SIZE: ANSI D
ISSUE DATE: JULY 2018
SOLICITATION NO.:
CONTRACT NO.:
DRAWING CODE:

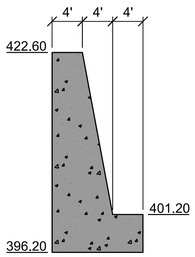
U.S. ARMY CORPS OF ENGINEERS
LOUISVILLE DISTRICT
600 DR. MARTIN LUTHER KING JR. PLACE
LOUISVILLE, KY 40202

FY 2018 P2465345
BARREN RIVER LOCK AND DAM 1 REMOVAL
GREENSCASTLE, KENTUCKY

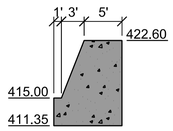
ESPLANADE AND CONTROL TOWER DEMOLITION PLAN

SHEET ID
BR1D
CD104

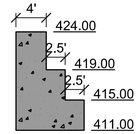
...\CAD\128624\128624\CAD_BIM_Sheets\465345_CD104xxx.dgn
11:15:54 AM 7/23/2018 LRL_pdf.pltcfg LRL_Screen.dscript



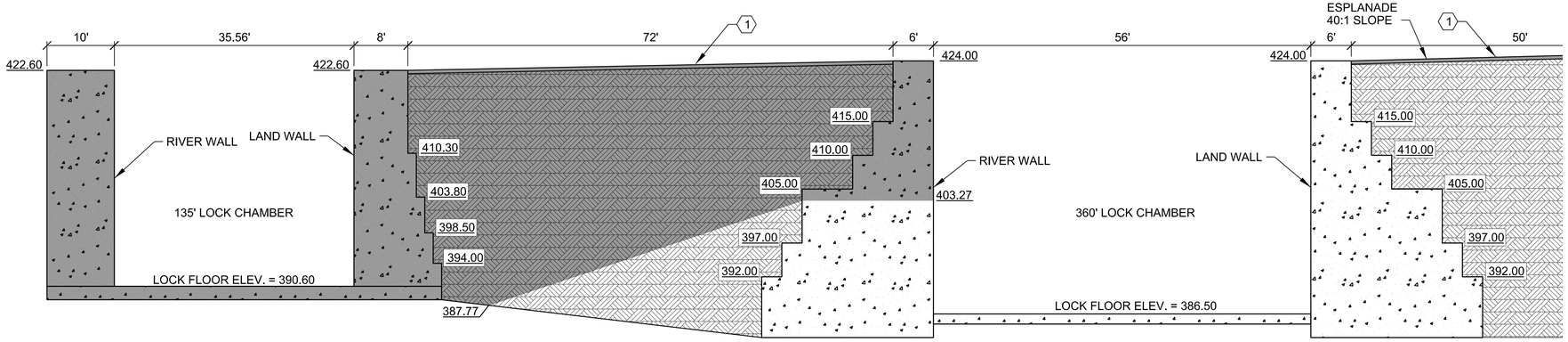
F1 135' LOCK LOWER GUIDE WALL
1"=10'



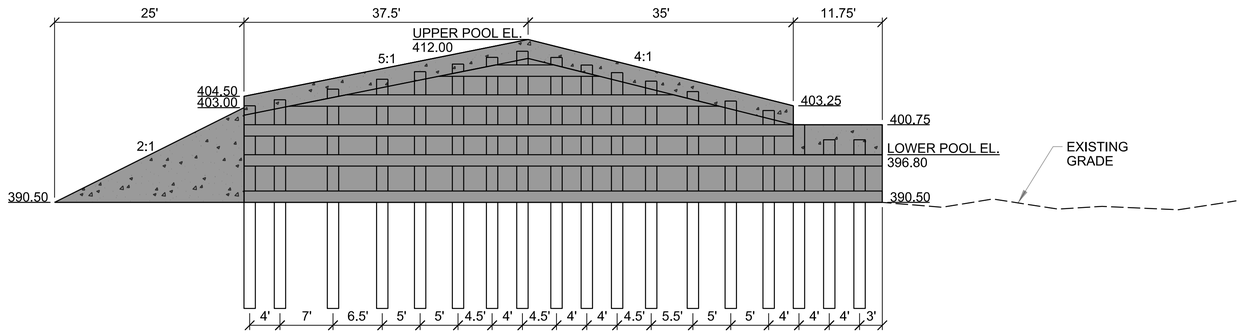
F3 135' LOCK UPPER GUIDE WALL
1"=10'



F5 360' LOCK UPPER GUIDE WALL
1"=10'



C1 LOCK DEMOLITION SECTION
1"=10'



A1 DAM DEMOLITION SECTION
1"=10'

GENERAL SHEET NOTES

1. DIMENSIONS FOR LOCKS AND DAMS HAVE BEEN APPROXIMATED USING AVAILABLE HISTORICAL REFERENCES. ACTUAL DIMENSIONS MAY VARY.
2. DEMOLITION SHALL BE TO TOP OF ROCK IF FOUND TO BE ABOVE SPECIFIED ELEVATION.

SHEET KEYNOTES

1. DEMOLISH ESPLANADE CONCRETE TO FULL DEPTH.

LEGEND

- REMOVE TO ELEVATION SPECIFIED
- EXISTING GROUND
- CONCRETE

US Army Corps of Engineers®

MARK	DESCRIPTION	APPR.	DATE

DESIGNED BY: T. SMITH
DRAWN BY: B. SAYLOR
CHECKED BY: B. DORSCH
SUBMITTED BY: M. MCCLOUDER
SIZE: ANSI D
ISSUE DATE: JULY 2018
SOLICITATION NO.:
CONTRACT NO.:
DRAWING CODE:

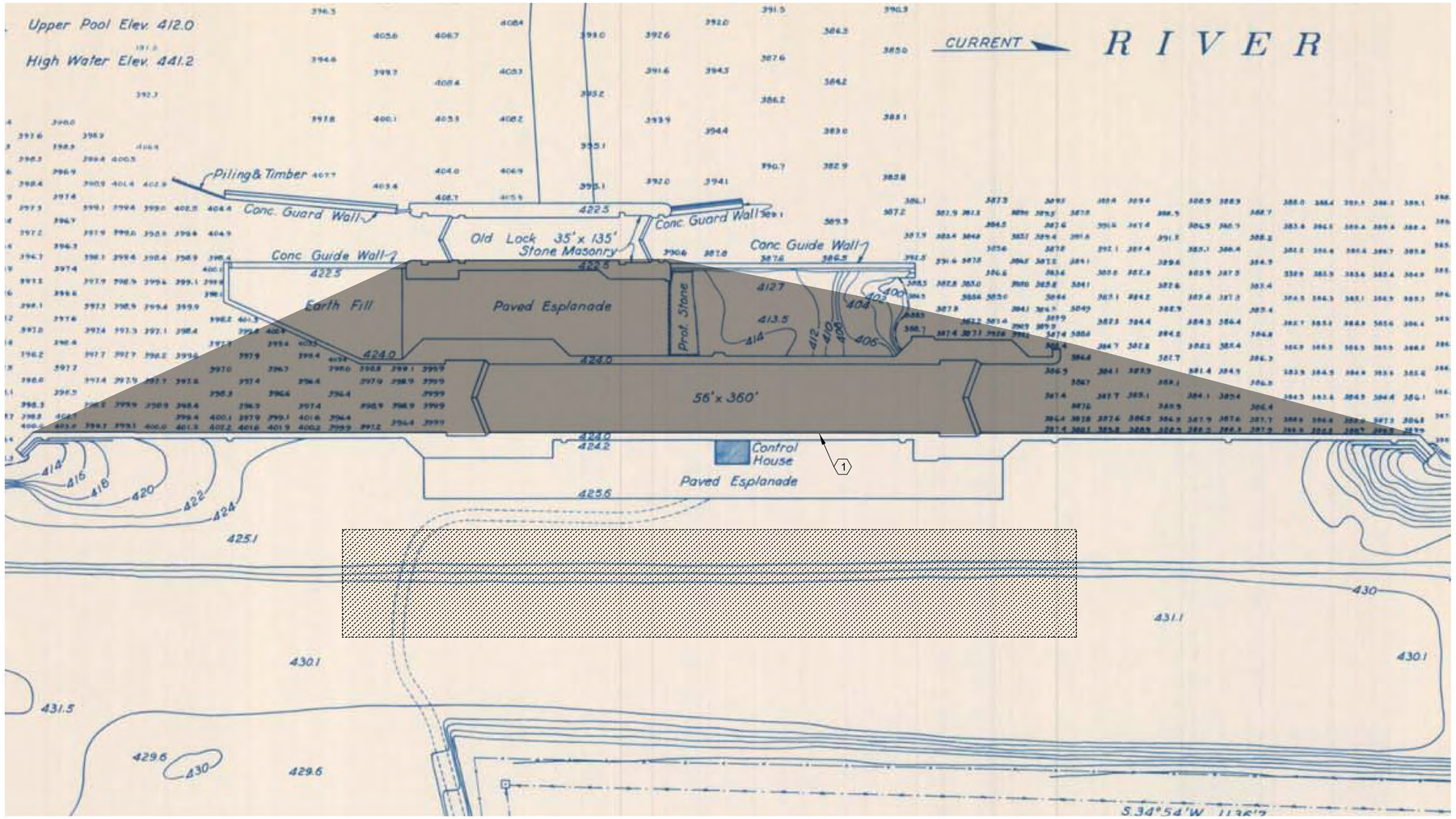
U.S. ARMY CORPS OF ENGINEERS
LOUISVILLE DISTRICT
600 DR. MARTIN LUTHER KING JR. PLACE
LOUISVILLE, KY 40202

FY 2018 P2465345
BARREN RIVER LOCK AND DAM 1 REMOVAL
GREENCASTLE, KENTUCKY

DEMOLITION SECTIONS

SHEET ID
BR1D
CD301

...\CAD\128624\128624\CAD_BIM_Sheets\465345_CD301xxx.dgn
9:12:12 AM 7/24/2018 LRL_pdf.pltcfg LRL_Screen.dscript



A1 LOCK FILL PLAN
NTS

GENERAL SHEET NOTES

1. DESIGN IS BASED ON CONDITION OF LOCK AND DAM AT THE TIME OF CONSTRUCTION OF THE 360' LOCK; SEE APPENDIX A
2. SEE APPENDIX B FOR INFORMATION ON CURRENT STATE OF LOCKS AND DAM.
3. MATERIAL DEMOLISHED FROM LOCKS AND DAM SHALL BE USED TO FILL REMAINING PORTION OF LOCK CHAMBER AND COVER GUIDE WALLS; SEE TYPICAL SECTION A1, SHEET CS301.
4. BORROW AREA SHALL NOT BE DISTURBED UNLESS ADDITIONAL MATERIAL IS REQUIRED TO COMPLETE FILL OPERATION.

SHEET KEYNOTES

1. FILL MATERIAL SHALL BE COVERED BY 3' OF SOIL.

LEGEND

LOCK FILL AREA; SEE LOCK FILL TYPICAL SECTION A1, SHEET CS301

BORROW AREA

US Army Corps of Engineers®

MARK	DESCRIPTION	APPR.	DATE

ISSUE DATE:	JULY 2018
SOLICITATION NO.:	
CONTRACT NO.:	
DRAWING CODE:	
DESIGNED BY:	T. SMITH
DRAWN BY:	B. SAYLOR
CHECKED BY:	B. DORSCH
SUBMITTED BY:	M. HOULDER
SIZE:	ANSI D

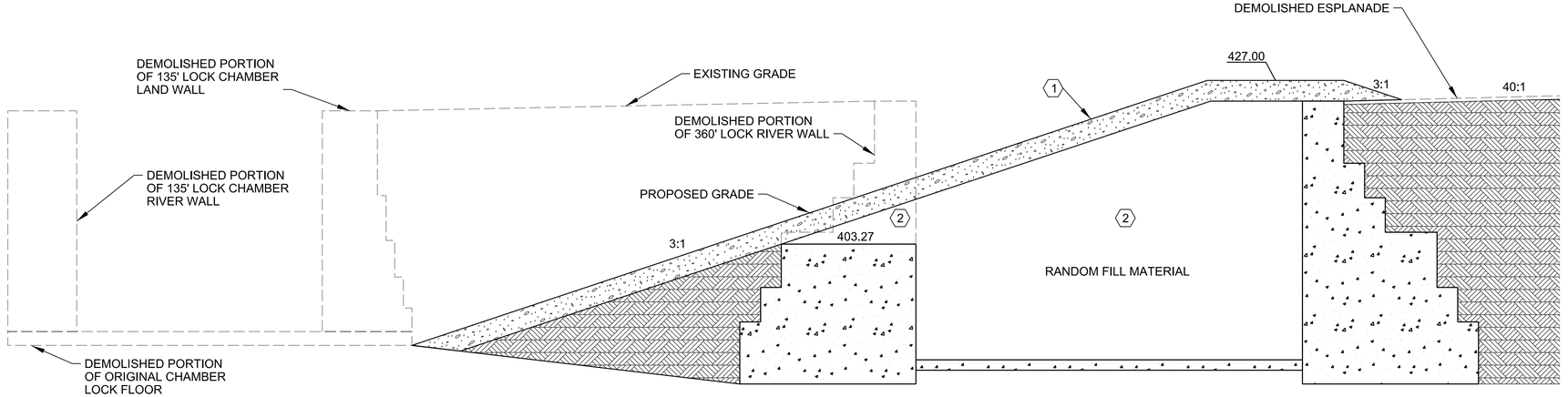
U.S. ARMY CORPS OF ENGINEERS
LOUISVILLE DISTRICT
600 DR. MARTIN LUTHER KING JR. PLACE
LOUISVILLE, KY 40202

FY 2018 P2465345
BARREN RIVER LOCK AND DAM 1 REMOVAL
GREENCASTLE, KENTUCKY

360' LOCK FILL PLAN

SHEET ID
BR1D
CS101

...\CAD\128624\128624\CAD_BIM_Sheets\465345_CS101xxx.dgn
11:16:03 AM 7/23/2018 LRL_pdf.pltcfg LRL_Screen.dscript



A1 LOCK FILL TYPICAL SECTION
NTS

GENERAL SHEET NOTES

⬡ SHEET KEYNOTES

1. 3' OF SOIL MINIMUM ATOP RANDOM FILL MATERIAL FROM DEMOLITION.
2. RANDOM FILL MATERIAL FROM DEMOLITION

LEGEND

- EXISTING GROUND
- CONCRETE
- 3' SOIL COVER

US Army Corps of Engineers®

MARK	DESCRIPTION	APPR.	DATE

DESIGNED BY: T. SMITH
DRAWN BY: B. SAYLOR
CHECKED BY: B. DORSCH
SUBMITTED BY: N. MCCULDER
SIZE: ANSI D
ISSUE DATE: JULY 2018
SOLICITATION NO.:
CONTRACT NO.:
DRAWING CODE:

U.S. ARMY CORPS OF ENGINEERS
LOUISVILLE DISTRICT
600 DR. MARTIN LUTHER KING JR. PLACE
LOUISVILLE, KY 40202

FY 2018 P2465345
BARREN RIVER LOCK AND DAM 1 REMOVAL
GREENCASTLE, KENTUCKY

LOCK FILL SECTION

SHEET ID
BR1D
CS301

Appendix B
2022 USACE Biological Assessment

Redwing is now RES

1139 South Fourth Street
Louisville, KY 40203
502.625.3009
Corporate Headquarters
6575 West Loop South, Suite 300
Bellaire, TX 77401
Main: 713.520.5400

VIA EMAIL

March 31, 2022

Mr. Jeffrey Hawkins
U.S. Army Corps of Engineers
Louisville District
600 Dr. Martin Luther King Place
Louisville, Kentucky 40201
Jeffrey.A.Hawkins@usace.army.mil

Subject: **Biological Assessment Report**
Barren River Lock and Dam 1 Removal Project
Warren County, Kentucky
USFWS Project Code: 2022-0005888
RES Project No.: 105106

Dear Mr. Hawkins:

RES Kentucky, LLC (RES) is pleased to submit this Biological Assessment Report to the U.S. Army Corps of Engineers in support of the removal of Barren River Lock and Dam 1 located in Warren County, Kentucky. This biological assessment evaluates potential impacts to federally listed species as a result of the proposed Action.

The proposed Action is anticipated to result in insignificant effects to the gray bat. Effects to the spectaclecase, fanshell, purple cat's paw, northern rifffleshell, snuffbox, longsolid, pink mucket, ring pink, sheepnose, clubshell, rabbitsfoot, and Price's potato-bean are considered discountable. Therefore, an effects determination of "may affect, not likely to adversely affect" has been made for these 13 species. Informal consultation with the U.S. Fish and Wildlife Service (USFWS) is proposed to address adverse effects to these species.

The proposed Action will result in adverse effects to the Indiana bat and northern long-eared bat from habitat loss associated with tree clearing. Adverse effects to both species will be mitigated through a payment to the Imperiled Bat Conservation Fund, utilizing the process set forth in the *Revised Conservation Strategy for Forest-Dwelling Bats in the Commonwealth of Kentucky* (June 2016). As a result, an effects determination of "may affect, likely to adversely affect" has been made for the Indiana and northern long-eared bats. Due to the use of the existing consultation to address adverse effects, informal consultation with the USFWS is proposed to address these two species.

Adverse effects are also anticipated to the rough pigtoe and pyramid pigtoe (currently Proposed Threatened) as a result of the proposed Action. Therefore, an effects determination of "may affect, likely to adversely affect" has been made for the rough pigtoe. Although adverse effects are also anticipated to the pyramid pigtoe, these effects are not likely to jeopardize the continued existence of this proposed species. Therefore, an effects determination of "may affect, not likely to jeopardize" has been made for the pyramid pigtoe. Formal consultation/conference with the USFWS is proposed to address adverse effects to the rough pigtoe and pyramid pigtoe.

We appreciate the opportunity to work with you on this project. Please contact Seth Bishop or Richard Clausen at (502) 625-3009 with any questions you have during your review of the attached report.

Sincerely,

Seth R. Bishop
Seth R. Bishop (Mar 31, 2022 15:23 EDT)
Seth R. Bishop
Project Manager II

Richard S. Clausen
Senior Project Manager

R:\Projects\105106-Barren River Lock and Dam 1 Removal\Reports\Cover Letter_BA Report_BRLD1

Redwing is now RES

BIOLOGICAL ASSESSMENT REPORT

BARREN RIVER LOCK AND DAM 1 REMOVAL PROJECT
WARREN COUNTY, KENTUCKY

Prepared for:

U.S. ARMY CORPS OF ENGINEERS
LOUISVILLE DISTRICT

MARCH 2022

BIOLOGICAL ASSESSMENT REPORT

BARREN RIVER LOCK AND DAM 1 REMOVAL PROJECT
WARREN COUNTY, KENTUCKY

Prepared for:

U.S. ARMY CORPS OF ENGINEERS
LOUISVILLE DISTRICT

Submitted to:

U.S. FISH AND WILDLIFE SERVICE
KENTUCKY FIELD OFFICE

Prepared by:

RES KENTUCKY, LLC

Seth R. Bishop
Seth R. Bishop (Mar 31, 2022 15:23 EDT)

Seth R. Bishop
Project Manager II

Richard S. Clausen
Senior Project Manager

March 31, 2022

EXECUTIVE SUMMARY

The proposed Action involves the removal of Barren River Lock and Dam 1 (BRLD1) located in the Barren River at River Mile 15. The proposed Action includes planning, demolition and removal of the lock, dam, and associated structures, and conveyance of the BRLD1 property from the U.S. Army Corps of Engineers to the Kentucky Department of Fish and Wildlife Resources. The purpose of the proposed Action is to improve passage for aquatic organisms and restore instream habitat above and below the dam for riverine fish and macroinvertebrates. The proposed Action will also alleviate safety concerns and eliminate costs associated with ownership and maintenance of the structure by the U.S. Army Corps of Engineers. The Action Area begins at Barren River Mile 14 near Greencastle, Kentucky and extends upstream to the Bowling Green Municipal Utilities rock dam in Bowling Green, Kentucky, just downstream of River Mile 38. The goal of this Biological Assessment Report is to address potential impacts to federally listed species as a result of the proposed Action.

Based on an official list of species obtained from the U.S. Fish and Wildlife Service's Information for Planning and Consultation website and recent biological surveys, federally listed species that may occur within the vicinity of the proposed Action include the gray bat (*Myotis grisescens*), northern long-eared bat (*Myotis septentrionalis*), Indiana bat (*Myotis sodalis*), 13 mussel species, and Price's potato-bean (*Apios priceana*). The Kentucky cave shrimp (*Palaemonias ganteri*) and critical habitat for the Indiana bat are also included on the official list of species; however, this species and critical habitat are not located within or near the Action Area and are not addressed further in the report.

An assessment was conducted within the Action Area to identify habitats and determine if suitable habitat is present for the listed species. The assessment included in-house and field components. During the habitat assessment, forested habitat within the Action Area was identified as suitable summer roosting, foraging, and commuting habitat for the Indiana and northern long-eared bats and suitable commuting habitat for the gray bat. The proposed Action will require the removal of up to 4.87 acres of forested habitat within the work area. Tree fall along the riverbanks upstream of the dam is also likely and is estimated at 33.39 acres. The Barren River was identified as suitable gray bat foraging habitat and suitable habitat for the federally listed mussel species. Jennings Creek, a tributary of the Barren River, was also identified as suitable foraging habitat for the gray bat. Due to the absence of occurrence records or lack of recent records for the spectaclecase (*Cumberlandia monodonta*), fanshell (*Cyprogenia stegaria*), purple cat's paw (*Epioblasma obliquata obliquata*), northern riffleshell (*Epioblasma torulosa rangiana*), snuffbox (*Epioblasma triquetra*), longsolid (*Fusconaia subrotunda*), pink mucket (*Lampsilis abrupta*), ring pink (*Obovaria retusa*), sheepnose (*Plethobasus cyphyus*), clubshell (*Pleurobema clava*), and rabbitsfoot (*Quadrula cylindrica cylindrica*) within the Action Area, these species are considered absent. No suitable habitat for Price's potato-bean was identified in the work area, and potential habitat for this species in the remainder of the Action Area will not be impacted. Additionally, no suitable habitat for the Kentucky cave shrimp is present in the Action Area. Critical habitat for the Indiana bat was identified as occurring in the Action Area; however, this habitat is located more than 18 miles east of the Action Area and will not be impacted by the project.

The habitat assessment also included an in-house review of available resources to identify karst features, abandoned mine portals, and other underground features in the vicinity of the proposed Action that could provide potential hibernacula or roosting habitat for the three listed bat species. Due to the construction components being limited to the work area, efforts were focused on locating potential hibernacula within and immediately adjacent to this area. No known features are mapped within 2.5 miles of the work area, and no features were identified in or immediately adjacent to the work area during the field survey. As a result, no potential hibernacula or non-winter roosting habitat for the three bat species are present in the work area. Seven bridges in the Action Area are considered to be suitable roosting habitat for these species; however, no work will occur on these structures. Multiple sinkholes are mapped adjacent to the Action Area that may provide hibernacula and/or roosting habitat for the three bat species; however, no adverse effects to these features are anticipated from the proposed Action.

A presence/probable absence survey for the 13 mussel species was performed in the Action Area. During the survey, two rough pigtoe individuals and four pyramid pigtoe individuals were found in the portion of the Action Area downstream of BRLD1. No individuals of federally listed mussel species were encountered in the Action Area upstream of BRLD1.

Based on the results of the biological assessment, effects to the gray bat from the proposed Action are considered insignificant. Effects to the spectaclecase, fanshell, purple cat's paw, northern rifffleshell, snuffbox, longsolid, pink mucket, ring pink, sheepnose, clubshell, rabbitsfoot, and Price's potato-bean are considered discountable. Therefore, an effects determination of "may affect, not likely to adversely affect" has been made for these 13 species, and informal consultation with the USFWS is proposed to address potential effects to these species.

The proposed Action will result in adverse effects to the Indiana and northern long-eared bats from habitat loss associated with tree clearing. Adverse effects to these two species will be mitigated through a payment to the Imperiled Bat Conservation Fund, utilizing the process set forth in the Conservation Strategy. As a result, an effects determination of "may affect, likely to adversely affect" has been made for the Indiana and northern long-eared bats. Informal consultation with the USFWS is proposed to address potential effects to these two species.

The proposed Action is expected to result in adverse effects to the rough pigtoe, and an effects determination of "may affect, likely to adversely affect" has been made for this species. Adverse effects are also anticipated to the pyramid pigtoe; however, these effects are not likely to jeopardize the continued existence of this proposed species. Therefore, an effects determination of "may affect, not likely to jeopardize" has been made for the pyramid pigtoe. Formal consultation/conference with the USFWS is proposed to address potential adverse effects to the rough pigtoe and pyramid pigtoe.

TABLE OF CONTENTS

Page

LIST OF FIGURES

Figure

LIST OF PHOTOGRAPHS

Photograph

1.0 INTRODUCTION

On behalf of the U.S. Army Corps of Engineers (USACE), RES Kentucky, LLC (RES) is pleased to submit this Biological Assessment Report to the U.S. Fish and Wildlife Service Kentucky Field Office (USFWS KFO) in support of the removal of Barren River Lock and Dam 1 located in Warren County, Kentucky. The proposed Action is presented in more detail below in terms of a description of the Action, the purpose and need for the Action, and identification of federally listed species for inclusion in the assessment.

1.1 PROPOSED ACTION

The proposed Action involves the removal of Barren River Lock and Dam 1 (BRLD1), located at Barren River Mile (RM) 15 near Greencastle, Kentucky (Figure 1). BRLD1 consists of a 276-foot long dam and two locks along the right descending bank. The original lock (inner lock) is connected to the east end of the dam and consists of a 135-foot-long by 35-foot-wide chamber bounded by a river wall and a land wall, with guide walls extending approximately 150 feet upstream and 200 feet downstream from the land wall. A concrete plug is present at the upstream end of the inner lock chamber. The newer lock (outer lock) is located east of the inner lock towards the right descending bank. The inner and outer locks are separated by a 360-foot-long by 72-foot-wide area of earthen fill partially covered by a concrete esplanade. The outer lock consists of a 360-foot-long by 56-foot-wide chamber bounded by a river wall and a land wall, with guide walls extending approximately 310 feet upstream and downstream of the land wall. Miter gates are present at the upstream and downstream ends of the outer lock chamber. A second concrete esplanade is located along the right descending bank that spans the length of the outer lock chamber. A two-story concrete control tower is present on the outer lock esplanade. The dam pool (Pool 1) extends approximately 23 miles upstream of BRLD1 to just downstream of RM 38, with a normal pool elevation of 412 feet above mean sea level (AMSL). The lock and dam structures are shown on Figure 2 and Sheet CD101 of the design plans in Appendix A.

The proposed Action will be limited to the “Action Area”, which encompasses the area where the effects of the Action may influence physical, chemical, or biological habitat components (Figure 3). The proposed Action and associated Action Area are discussed in greater detail in Section 2.0.

1.2 PURPOSE AND NEED

The purpose of the proposed Action is to improve passage for aquatic organisms and restore instream habitat above and below the dam for riverine fish and macroinvertebrates. The proposed Action will also alleviate safety concerns and eliminate costs associated with ownership and maintenance of the structure by the USACE.

The Commonwealth of Kentucky built the original lock and dam in 1841, and the Federal government acquired the facility in 1886. In 1933-1934, the USACE constructed a new lock east of the original lock along the right descending bank. Operation of the new lock began in 1934, and the original lock was taken out of service. A concrete plug was placed across the upstream end of the original lock chamber to prevent flow through the chamber. In 1965, the new lock was closed to traffic after failure of Green River Lock and Dam 4, located immediately downstream of the Barren and Green River confluence, which eliminated the possibility of commercial navigation into the Barren River.

Since the closure of BRLD1, the USACE has conducted multiple investigations to assess deauthorization and disposal of the lock and dam. The most recent study, entitled *Green River Locks and Dams 3, 4, 5 and 6 and Barren River Lock and Dam 1 Disposition Feasibility Study, Kentucky*, was completed in 2014. The study reevaluated the current uses of the Green and Barren River locks and dams, assessed potential impacts from loss of the dam pools, evaluated the condition and safety of the structures, and discussed potential disposal of the facilities in the future. The study recommended requesting Congressional deauthorization of commercial navigation for the locks and dams, as well as disposal of the facilities and associated properties through established USACE and General Services Administration procedures.

As part of the 2014 study, an Environmental Assessment was prepared to evaluate the environmental impacts associated with disposal of the Green and Barren River locks and dams. Although the removal of BRLD1 was not examined under the assessment, the removal of Green River Lock and Dam 6 (GRLD6) was included as one of the evaluated alternatives. GRLD6, which has since been removed, was located approximately 32 miles upstream of the Barren and Green River confluence and was similar in size and structure to BRLD1. The report concluded that the removal of GRLD6 would result in long-term benefits to the Green River by restoring 17 miles of river habitat upstream of the structure. Return of the pool upstream of the dam to free-flowing conditions would change the species composition by allowing lotic species to return to this portion of the river, resembling the natural community upstream. Habitat for mussels and other aquatic organisms would improve as accumulated sediment behind the dam moved downstream and exposed gravel bars and other favorable substrates. Lotic fish species would also move into the former pool, including fish hosts that would help recolonization of this area by mussels. Based on these conclusions and the similarities between GRLD6, BRLD1, and their associated and connected river systems, the removal of BRLD1 is expected to result in similar benefits to the Barren River ecosystem.

The removal of BRLD1 will also address safety concerns associated with the lock and dam structures. The western portion of the dam apron has been undermined from shifting and settling due to loss of the underlying fill and continues to deteriorate, increasing the potential for structural failure and impacts to downstream communities. The dam also poses a risk to boaters and other recreational users, who may inadvertently be carried over the dam and become trapped in the hydraulic effect at the dam base. A

drowning fatality occurred in April 2014 when a johnboat went over the dam, and another fatality occurred at the dam in July 2021. Removal of the locks and associated structures would also reduce safety concerns and the risk of injury from unauthorized entry of these structures from the east side of the river.

Removal of BRLD1 will also eliminate costs to the USACE associated with ownership and maintenance of the structure. After removal of BRLD1, ownership of the property will be conveyed to the Kentucky Department of Fish and Wildlife Resources (KDFWR), who will become responsible for managing and maintaining the property.

Based on the anticipated ecological, safety, and cost benefits discussed above, the proposed Action will meet the purpose and need of the proposed Action.

1.3 IDENTIFICATION OF LISTED SPECIES

The identification of species listed under the Endangered Species Act (ESA) for inclusion in the assessment was based on a review of occurrence records maintained by the U.S. Fish and Wildlife Service (USFWS). The identification process is described below in terms of resource agency coordination and species selection.

1.3.1 Resource Agency Coordination

The USFWS's Information for Planning and Consultation (IPaC) website was used to obtain an official list of species that may occur within the Action Area (USFWS Project Code: 2022-0005888) (USFWS IPaC 2022). The official species list fulfills the requirements of the USFWS under Section 7(c) of the ESA to provide information as to whether proposed or listed species may be present within the Action Area. The review identified 16 federally listed species that are known to occur or have the potential to occur in the Action Area. The review also identified critical habitat for the Indiana bat (*Myotis sodalis*) within the Action Area. The IPaC official species list is provided in Appendix B. Additionally, two mussel species proposed for listing under the ESA, the longsolid (*Fusconaia subrotunda*) and pyramid pigtoe (*Pleurobema rubrum*), were identified that have the potential to occur within the Action Area but are not included on the official species list. The 18 identified species are summarized in the following table.

Group	Scientific Name	Common Name	Federal Status
Bats	*Myotis grisescens*	gray bat	Endangered
	Myotis septentrionalis	northern long-eared bat	Threatened
	Myotis sodalis	Indiana bat	Endangered; Critical Habitat
Mussels	*Cumberlandia monodonta*	spectaclecase	Endangered
	Cyprogenia stegaria	fanshell	Endangered
	Epioblasma obliquata obliquata	purple cat's paw	Endangered
	Epioblasma torulosa rangiana	northern riffleshell	Endangered
	Epioblasma triquetra	snuffbox	Endangered
	Fusconaia subrotunda	longsolid	Proposed Threatened
	Lampsilis abrupta	pink mucket	Endangered
	Obovaria retusa	ring pink	Endangered
	Plethobasus cyphyus	sheepnose	Endangered
	Pleurobema clava	clubshell	Endangered
	Pleurobema plenum	rough pigtoe	Endangered
	Pleurobema rubrum	pyramid pigtoe	Proposed Threatened
	Quadrula cylindrica cylindrica	rabbitsfoot	Threatened
Crustacean	*Palaemonias ganteri*	Kentucky cave shrimp	Endangered
Plant	*Apios priceana*	Price's potato-bean	Threatened

The USFWS KFO also maintains maps of known habitat for the Indiana bat and northern long-eared bat in the state of Kentucky. Based on review of these maps, portions of the Action Area are located within "Known Swarming 2" habitat for both species (USFWS KFO 2019a, USFWS KFO 2019b) (Figure 4).

A list of USGS 7.5-minute topographic quadrangles in Kentucky that contain known maternity roost trees and/or hibernacula for the northern long-eared bat has also been prepared by the USFWS KFO. Based on this list, the majority of the Action Area is located within a quadrangle, Bowling Green North, that contains one or more known hibernacula for this species (USFWS KFO and KDFWR 2016) (Figure 4).

A data request was submitted to the Office of Kentucky Nature Preserves (OKNP) on January 6, 2022 requesting review of their Natural Heritage Program Database to determine if any endangered, threatened, or special concern plants and animals or exemplary natural communities occur within the vicinity of the proposed Action. The Standard Occurrence Report provided by the OKNP included occurrence records for 11 of the 18 listed and proposed species within or adjacent to the Action Area, including the gray bat, 11 of the 13 mussel species, and Price's potato-bean. Correspondence from the OKNP is included in Appendix B; however, the Standard Occurrence Report is not included based on the data request license agreement with the OKNP that prohibits release of this information.

1.3.2 Selection of Species for Study

The three bat species, 13 mussel species, and Price's potato-bean were evaluated under this assessment. These species were studied based on their known occurrence in the Action Area or possible occurrence based on the potential for suitable habitat in the Action Area.

The Kentucky cave shrimp was not evaluated under the assessment. This species is currently only known from 11 groundwater basins associated with the Green River. No portion of the Action Area influences drainage within these groundwater basins, and the closest point where a groundwater basin containing this species enters the Green River is approximately 43 miles upstream of the Green and Barren River confluence. As a result, the proposed Action does not have the potential to impact the Kentucky cave shrimp or its habitat, and this species is not addressed further in this report.

Critical habitat for the Indiana bat was also not evaluated under the assessment. Although the IPaC official species list states that critical habitat for the Indiana bat is located within the Action Area, this critical habitat is associated with Coach Cave located more than 18 miles east of the Action Area. The USFWS uses county-level mapping to protect the location of the cave and includes all of Warren, Edmonson, Hart, and Barren Counties as critical habitat. Due to the location of the Action Area in Warren County, the IPaC database included critical habitat associated with Coach Cave in the species list. Based on the location of Coach Cave outside the Action Area and the lack of potential impacts, designated critical habitat for the Indiana bat is not addressed further in this report.

1.3.3 Species for Informal Consultation

The proposed Action is anticipated to result in insignificant effects to the gray bat. Effects to the spectaclecase, fanshell, purple cat's paw, northern riffleshell, snuffbox, longsolid, pink mucket, ring pink, sheepnose, clubshell, rabbitsfoot, and Price's potato-bean are considered discountable. Therefore, an effects determination of "may affect, not likely to adversely affect" has been made for these 13 species. Informal consultation with the USFWS is proposed to address these species, which is discussed in Section 3.0.

The proposed Action will result in adverse effects to the Indiana bat from habitat loss associated with tree removal. Adverse effects to the Indiana bat will be mitigated through a payment to the Imperiled Bat Conservation Fund, utilizing the process set forth in the *Revised Conservation Strategy for Forest-Dwelling Bats in the Commonwealth of Kentucky* (Conservation Strategy) (USFWS KFO 2016). The proposed Action is consistent with the actions evaluated in the *2015 Biological Opinion: Kentucky Field Office's Participation in Conservation Memoranda of Agreement for the Indiana Bat and/or Northern Long-eared Bat* (2015

Biological Opinion) that supports the Conservation Strategy. Based on anticipated adverse effects to the Indiana bat, an effects determination of "may affect, likely to adversely affect" has been made for this species. Due to the use of the existing consultation to address adverse effects, the Indiana bat is included under informal consultation in Section 3.0.

The proposed Action will also result in adverse effects to the northern long-eared bat from habitat loss associated with tree removal. The northern long-eared bat is currently listed as Threatened with a 4(d) rule under the ESA; however, the USFWS is in the process of reviewing the current listing status to determine if an upgraded listing is warranted (e.g., Threatened with no 4(d) rule, Endangered). The potential change in listing status could occur during the life of the proposed project; therefore, adverse effects to the northern long-eared bat will be addressed through the Conservation Strategy to avoid the need to reconsult with the USFWS should the listing status change. The proposed Action is consistent with the actions evaluated in the 2015 Biological Opinion that supports the Conservation Strategy, and adverse effects to this species will be mitigated through the same payment to the Imperiled Bat Conservation Fund as the Indiana bat. Based on anticipated adverse effects to the northern long-eared bat, an effects determination of "may affect, likely to adversely affect" has been made for this species. Due to the use of the existing consultation to address adverse effects, the northern long-eared bat is included under informal consultation in Section 3.0.

1.3.4 Species for Formal Consultation/Conference

The proposed Action will result in adverse effects to the rough pigtoe and pyramid pigtoe; therefore, an effects determination of "may affect, likely to adversely affect" has been made for these two species. Formal consultation with the USFWS is proposed to address the rough pigtoe. Formal conference is proposed to address the pyramid pigtoe due to its status as a proposed species. Formal consultation/conference for these two species is discussed at the beginning of Section 4.0 and throughout the remainder of the report.

The effects determination and USFWS consultation method for all 17 species is summarized in the following table.

Group	Common Name	Effects Determination	USFWS Consultation
Bats	gray bat	NLTAA	Informal
	northern long-eared bat	LTAA*	Informal
	Indiana bat	LTAA*	Informal
Mussels	purple cat's paw	NLTAA	Informal
	northern riffleshell	NLTAA	Informal
	snuffbox	NLTAA	Informal
	longsolid	NLTAA	Informal
	clubshell	NLTAA	Informal
	pink mucket	NLTAA	Informal
	ring pink	NLTAA	Informal
	sheepnose	NLTAA	Informal
	spectaclecase	NLTAA	Informal
	fanshell	NLTAA	Informal
	rough pigtoe	LTAA	Formal
	pyramid pigtoe	LTAA	Formal Conference
	rabbitsfoot	NLTAA	Informal
Plant	Price's potato-bean	NLTAA	Informal

Note: NLTAA = may affect, not likely to adversely affect; LTAA = may affect, likely to adversely affect
* Use of the *Revised Conservation Strategy for Forest-Dwelling Bats in the Commonwealth of Kentucky*

2.0 PROPOSED ACTION

The proposed Action involves the removal of BRLD1 from the Barren River. The proposed Action is presented below in terms of identification of the Action Area and a description of the Action components.

2.1 ACTION AREA

The Action Area encompasses the area where removal of BRLD1 may influence physical, chemical, or biological habitat components. The Action Area begins at RM 14 near Greencastle, Kentucky and extends upstream to the Bowling Green Municipal Utilities rock dam in Bowling Green, Kentucky, located just downstream of RM 38 (Figure 3). The upstream portion of the Action Area also includes three perennial tributaries to the Barren River that are influenced by the presence of BRLD1. RM 14 was selected as the downstream extent of the Action Area to include a diverse mussel bed known to occur in this area. The Bowling Green Municipal Utilities rock dam is considered to be the upstream extent of Pool 1. This manmade structure is composed of large rock placed to impound water for the facility and is approximately six feet high. Water levels upstream of this point are affected by the rock dam rather than BRLD1; therefore, this structure was selected as the upstream extent of the Action Area.

All construction activities will be limited to a work area that includes portions of the right descending bank and Barren River adjacent to BRLD1 (Figure 5). The work area includes the dam, inner and outer locks and associated structures, access roads, and staging areas. The work area encompasses approximately 21.12 acres, including 6.41 acres within the river and 14.71 acres along the right descending bank and access roads. No construction components associated with the proposed Action will occur along the left descending bank of the Barren River; therefore, no access to this side of the river is required. The dam abutment and the remnants of an old mill are present along the left descending bank; however, these structures will not be removed.

2.2 PLANNING COMPONENT

The planning component is the initial component of the proposed Action and encompasses all necessary activities prior to construction. These activities include, but are not limited to: securing project funding; developing project timeframes and schedules; designing project plans; performing site visits; preparing preliminary assessments and reports; completing required consultations and permitting; and coordinating with the project team.

The planning component is considered an administrative action only and will not result in potential impacts to the federally listed or proposed species. As a result, this component will have no effect on these species and is not discussed further in this report.

2.3 CONSTRUCTION COMPONENT

The construction component is the second component of the proposed Action and includes three separate activities: site preparation, lock and dam removal, and site stabilization. Design plans for the proposed Action are provided as Appendix A, and each construction component is discussed in greater detail below.

2.3.1 Site Preparation

The initial construction component is site preparation. Activities associated with this construction component include: installation of erosion prevention and sediment control (EPSC) measures; improvement and construction of access roads; clearing and grubbing; and establishment of staging areas. These activities will require the use of heavy equipment (i.e., bulldozers, trackhoes, backhoes, trucks, etc.); however, disturbances within the Barren River are not expected.

EPSC measures will be installed to reduce erosion and minimize sediment input into waters of the Commonwealth. A site-specific Erosion Control Plan, including Best Management Practices (BMPs), will be developed by the project engineer, and appropriate measures will be installed prior to onsite activities to ensure continuous erosion control throughout the construction period.

BRLD1 will be accessed from the east side of the Barren River via Greencastle Road (Figure 5). The road ends at a bridge over Taylor Branch that connects to a gravel parking lot for a boat ramp. An existing dirt road extends from the boat ramp parking lot to the southern portion of the BRLD1 property. The existing road will be used as the main access road to BRLD1 and will be improved with a rock surface as necessary to facilitate construction equipment. A new portion of road will then be constructed from the end of the existing road to the concrete esplanade/outer lock. The new portion of road will be located in an existing pasture and constructed of rock as necessary. This route will be used by personnel, vehicles, and some construction equipment; however, the bridge over Taylor Branch has a weight limit of three tons, and construction equipment exceeding this weight will use an alternate route to access the site, as described below.

Construction equipment that exceeds the posted weight limit for the Taylor Branch bridge will access BRLD1 via a heavy equipment access road (Figure 6). The access road will begin on the south side of Greencastle Road immediately west of the intersection with Mount Zion Road, then follow an existing dirt

road used by the landowner to access a crop field. The road will follow the northern edge of the crop field, then continue south towards Taylor Branch. The landowner has established a vehicular crossing of the stream in a shallow area that will allow heavy construction equipment to drive across the stream. The stream will be crossed as necessary to access the site; however, crossings will be limited to as few times as possible. No culverts or other temporary structures will be added to the stream crossing. Additionally, no excavation or construction activities are anticipated within the stream channel, and any required excavation or grading of the stream banks will be completed above the ordinary high water mark of the stream. BMPs will be implemented at the crossing, and all disturbed areas will be stabilized to limit erosion and minimize sediment inputs into the stream.

After crossing Taylor Branch, the heavy equipment access road will continue to follow the existing dirt road along the south side of the stream to an open field. The access road will continue through the field, then begin following an existing UTV trail. Small trees and shrubs will need to be cleared along portions of the trail to facilitate the construction equipment, and one section may require the removal of up to 0.46 acre of mature trees (Figure 6). The heavy equipment access road will intersect the main access road in the boat ramp parking lot on the south side of the Taylor Branch bridge. Heavy equipment will then use the main access road to travel to BRLD1.

The contractor will establish staging areas for equipment and materials necessary for the proposed Action. The primary staging area will be located in the open field to the east of the outer lock structure and concrete esplanade (Figure 5). This staging area is expected to be utilized for construction trailers, equipment storage, parking, and other construction related activities. Additional staging areas may be established in other open fields and existing clearings of the Action Area as necessary.

Clearing and grubbing involves the removal and disposal of vegetation within the work area. Trees will be cleared as necessary, and stumps will either be removed or grubbed to a minimum of three feet below the proposed subgrade. Woody debris generated from this component will be prevented from entering the Barren River and will be burned on site, if permissible, or allowed to decay naturally.

2.3.2 Lock and Dam Removal

The second construction component is removal of BRLD1. This component will include demolition and removal of the dam, inner lock, upper portions of the outer lock river wall, land wall, and guide walls, outer lock miter gates, esplanade concrete, and control tower. The lower portions of the outer lock river wall, land wall, and guide walls will remain in place. The earth fill between the two locks will also be removed. These structures are shown on Figure 5 and depicted on the design plans in Appendix A. These plans are

conceptual designs based on the as-built drawings of BRLD1 and are subject to change based on site conditions and the actual condition of the lock and dam structures.

Demolition activities will be initiated on the right descending bank and will generally extend towards the river. The dam will be the first structure planned for demolition, and the start of demolition will be scheduled for a time of year when water levels and flow are expected to be low. To allow equipment to reach the dam, a work pad will be constructed across the existing locks and associated structures. The first section of the work pad from the right descending bank to the concrete esplanade between the locks will be constructed by demolishing the control tower and upper portion of the outer lock land wall and placing the material into the outer lock chamber. After crossing the outer lock chamber, equipment will drive across the existing concrete esplanade to the inner lock. The section of the work pad across the inner lock chamber will be constructed by placing material generated from demolition of the upper portion of the inner lock land wall into the chamber immediately downstream of the concrete plug. The completed work pad will be used to access the eastern end of the dam. The locks and associated structures are made of concrete and will either be demolished using hoe ram-equipped excavators or similar equipment or with controlled explosive charges.

After reaching the dam, a notch will be created to begin draining Pool 1. An in-stream work pad will then be constructed either on the downstream dam apron, immediately downstream of the dam, or along the upstream side of the dam to initiate dam demolition. Material from the dam will be used to continue the in-stream work pad across the river. Once the in-stream work pad is completed, additional material generated during dam demolition will be placed within or adjacent to the outer lock chamber.

The dam will be demolished in lifts, with the vertical extent of each lift determined by the water level to ensure that equipment is not working in more than two feet of water for safety reasons. Depths of greater than two feet reduce the stability of the equipment and may submerge portions of the engine, resulting in potential release of engine fluids or damage to the equipment. The dam will be removed to approximately 392 feet AMSL, which is the average anticipated depth of the river bottom under the dam. Dam sills and timber pilings will also be removed to approximately 392 feet AMSL, and steel reinforcement rods, if present, will be broken at the proposed final elevation and bent downstream to avoid snags. The remaining portion of the dam will also be notched to an elevation below 392 feet AMSL in several locations to maintain flow and facilitate passage by aquatic organisms and recreational users (e.g., boats, canoes, kayaks) during low river levels. The dam will be demolished to the dam abutment at the western end of the dam, which will be left in place. The remnants of the old mill downstream of the dam will also remain. After dam demolition is complete, the in-stream work pad material will be removed and placed within or adjacent to the outer lock chamber.

Demolition of the locks and associated structures will begin after initiation of dam demolition. The remainder of the inner lock river, land, and guide walls and lock floor will be removed to the same elevation as the remaining portion of the dam (approximately 392 feet AMSL). The concrete esplanade and earthen fill between the two locks will be removed, and the concrete from the esplanade will be placed within or adjacent to the outer lock chamber. The earthen fill will be placed adjacent to the outer lock chamber to help stabilize the bank. The outer lock river wall will be demolished to an elevation of approximately 399 to 404 feet AMSL, and the outer lock land wall and upstream and downstream guide walls will be removed to approximately 412 to 414 feet AMSL. Material from the walls will be placed within or adjacent to the outer lock chamber. The outer lock miter gates will also be removed and placed in the outer lock chamber. The outer lock chamber will be filled to the top of the lock land wall, then graded to create a constant 3:1 slope extending from the top of the land wall to the base of the former inner lock land wall. Material generated in excess of the volume of the outer lock chamber and not necessary for slope stabilization will be placed in the scour area below the dam, as necessary. Any soil generated during demolition and removal will be used to cover the fill material on the slope. The remainder of the slope is expected to be covered naturally over time by sediment deposition during flood events.

2.3.3 Site Stabilization

The third construction component is site stabilization. Following removal of the lock and dam, disturbed areas will be regraded, seeded, and mulched with straw or covered with erosion control blanket, if needed. The main access road will remain in place to provide continued access to the BRLD1 property. The heavy equipment access road and crossing of Taylor Branch will be restored and stabilized as necessary.

2.4 CONVEYANCE COMPONENT

The conveyance component is the third and final component of the proposed Action and involves conveyance of BRLD1 and the associated property from the USACE to the KDFWR. The conveyance will require a Disposal Report completed by the USACE that will include an Environmental Condition of Property Report and other documentation sufficient to show satisfaction of the requirements of NEPA, the Comprehensive Environmental Response, Compensation, and Liability Act, the National Historic Preservation Act, and other applicable environmental and historic preservation laws. The Disposal Report will also include a title report and will identify any terms and conditions of conveyance necessary to protect the interests of the United States.

Upon conveyance, the KDFWR will become responsible for managing the land and improvements associated with BRLD1. Conveyance is anticipated to occur within one year of project completion. The conveyance component is considered an administrative action only and will not result in potential impacts

to the federally listed species. As a result, this component will have no effect on these species and is not discussed further in this report.

2.5 CONSERVATION MEASURES

The following conservation measures are proposed to avoid and minimize impacts from the proposed Action to the rough pigtoe and pyramid pigtoe and their habitat.

(1) Implement EPSC measures in the work area, including but not limited to:

   a. Stabilization of disturbed areas as soon as practicable but no more than seven days after construction activities have temporarily or permanently ceased in any portion of the work area. At a minimum, interim and permanent practices implemented to stabilize disturbed areas will include: temporary and/or permanent seeding; erosion control matting; mulching, and/or sodding.
   b. Structural measures will be implemented to divert flows from exposed soils, temporarily store flows, or otherwise limit runoff and the discharge of pollutants from exposed areas of the site. These measures shall be implemented in a timely manner during the construction process to minimize erosion and sediment runoff. Structures may include silt fence or coir rolls, stone silt check dams, temporary gravel construction entrances/exits, and/or riprap.

(2) Revegetate disturbed areas immediately following completion of ground disturbing activities.

(3) Perform in-stream activities during periods of low flow.

(4) Use of in-stream work pad during lock and dam removal to minimize impacts to the river from equipment. The work pad will be located in areas that do not provide suitable habitat for the rough pigtoe or pyramid pigtoe.

(5) Implement BMPs when operating machinery on the in-stream work pad or within the riparian area to avoid and minimize the potential for accidental spills and have a spill response plan in place should an accidental spill occur.

(6) Remove any remaining hydraulic fluid from the hydraulic piping system in the control tower and outer lock chamber and dispose of appropriately.

(7) Incremental removal of the dam to reduce the rate of water recession upstream of the dam.

(8) Monitoring in the upstream portion of the Action Area during dam removal to locate exposed mussels and return individuals to areas of suitable habitat.

These measures will be implemented throughout the work area during construction, as necessary and appropriate. The conservation measures are anticipated to help avoid and minimize adverse effects to the rough pigtoe and pyramid pigtoe and their habitat; however, these measures are not expected to eliminate all adverse effects to these species that may result from the proposed Action.

2.6 INTERRELATED AND INTERDEPENDENT ACTIONS

As described in the ESA, interrelated actions are those that are part of a larger action and depend on the larger action for their justification. Interdependent actions are those that have no independent utility apart from the action under consideration (50 CFR 402.02). No projects that are directly related to the removal of BRLD1 are planned or currently being developed, and no interrelated or interdependent actions to the proposed Action are known at this time.

3.0 SPECIES FOR INFORMAL CONSULTATION

Species addressed under informal consultation include the gray bat, Indiana bat, northern long-eared bat, spectaclecase, fanshell, purple cat's paw, northern riffleshell, snuffbox, longsolid, pink mucket, ring pink, sheepnose, clubshell, rabbitsfoot, and Price's potato-bean. The following sections include an assessment of habitat for each species in the Action Area and an analysis of effects that may occur to these species as a result of the proposed Action.

3.1 LISTED SPECIES HABITAT

An assessment was conducted within the Action Area to determine if suitable habitat is present for the 15 listed species. The assessment included in-house and field components. A field survey of the work area was performed by RES on November 29, 2021. Habitat for each species in the Action Area is discussed in more detail in the following sections.

3.1.1 Gray Bat Habitat

During the in-house review, available resources were used to identify karst features, abandoned mine portals, and other underground features that could provide potential hibernacula or roosting habitat for the gray bat. Construction components will be limited to the work area; therefore, efforts were focused on locating potential hibernacula and roosting habitat within three miles of the work area. According to karst potential maps maintained by the Kentucky Geological Survey (KGS), the majority of the work area is located in a non-karst area that lacks sinkholes and other karst features. A small portion of the work area along Taylor Branch is located in an area with intense karst potential; however, no sinkholes or other karst features are mapped in this area (KGS 2022). USGS topographic and geologic maps and digital elevation mapping also do not show any sinkholes or other karst features within or immediately adjacent to the work area. Three quarries are mapped to the south of the work area on USGS topographic maps; however, these features are located 2.5 miles or greater from the work area. No mines or mine portals are located within three miles of the work area (KOMSL 2022). During the field survey, no caves, sinkholes, or other underground features were observed within the work area. Based on the results of the in-house review and field survey, no potential hibernacula or underground roosting habitat for the gray bat is present in the work area.

Due to the confinement of the Action Area to the banks of the Barren River outside the work area, no potential hibernacula or underground roosting habitat is present in the Action Area. However, portions of the Action Area are bordered by areas identified as karst prone or having intense karst potential, and multiple sinkholes are mapped in the floodplain adjacent to the Action Area that could potentially be used

as hibernacula or roosting habitat by gray bats (KGS 2022). These sinkholes may be connected to the Barren River through subsurface flow, and water levels in the features could be altered by the removal of BRLD1.

Bridges and culverts in the Action Area could also provide potential roosting habitat for the gray bat. Three roadway bridges span the Barren River within the upstream portion of the Action Area, including the Old Richardsville Road bridge (RM 30.4), the US 68/31W bridge (RM 37.4), and the River Street bridge (RM 37.7). A railroad bridge and a pedestrian bridge are also present near the US 68/31W and River Street bridges. Additionally, two roadway bridges are present over tributaries of the Barren River, including the Greencastle Road bridge over Taylor Branch in the work area and the US 68 bridge over Jennings Creek (Jennings Creek RM 1.2). These bridges include four concrete girder bridges and three truss bridges. Gray bats have been documented using these bridge types at other locations as day and night roosts; therefore, these bridges are assumed to provide suitable roosting habitat for this species.

Suitable foraging habitat for the gray bat in the Action Area includes the Barren River and Jennings Creek. The forested habitat along these streams and in the work area provides suitable commuting habitat for this species.

3.1.2 Indiana and Northern Long-eared Bat Habitat

Based on the absence of underground features, no potential hibernacula for the Indiana or northern long-eared bat are present in the work area. The seven bridges in the Action Area could be used as roosting habitat by these species. Additionally, these species could use the sinkholes adjacent to the Action Area as hibernacula or roosting habitat. The forested habitat in the work area and along the riverbanks in the Action Area provides suitable summer roosting, foraging, and commuting habitat for the Indiana and northern long-eared bats.

3.1.3 Mussel Habitat

During the habitat assessment, the Barren River was determined to be suitable habitat for the spectaclecase, fanshell, purple cat's paw, northern riffleshell, snuffbox, longsolid, pink mucket, ring pink, sheepnose, clubshell, and rabbitsfoot. A presence/probable absence survey was performed within the Action Area in support of the proposed Action. The survey is discussed in more detail in Section 3.2.

3.1.4 Price's Potato-bean Habitat

The in-house review and field survey for Price's potato-bean were limited to the work area. The Action Area outside of the work area will be confined within the banks of the Barren River, and no suitable habitat for Price's potato-bean is present in this area. During the in-house review, USGS topographic and geologic quadrangle maps and aerial photographs were used to locate forested habitat within and adjacent to the work area underlain with limestone and alluvium, with an emphasis on areas along the riverbanks and forest edges and openings. Geologic maps show that the work area is underlain with alluvium consisting of clay, silt, sand, and gravel (KGS 2022).

Forested habitat in the work area is limited to portions of the eastern riverbank, the existing access road, and heavy equipment access road. The forested areas along the riverbank were significantly disturbed during and after construction of the locks and dam based on photo documentation of the site, making it unlikely the species occurs in these areas. In addition, the areas along the banks are located in a flat floodplain with a dense canopy and ground and understory layers that contain many invasive shrub and herbaceous species. These areas are underlain by deep soils, and do not contain hillslopes with limestone outcrops or bluffs. The forested area between the two locks consists of smaller trees and shrubs that create a more open canopy. Open areas are interspersed among the trees and shrubs, most of which are covered with tall grasses and herbaceous species. Additionally, none of the associate plant species commonly found with Price's potato-bean were observed in these areas.

The majority of the existing access road is located at the base of a forested hillside underlain by St. Genevieve Limestone. Although the geology is favorable for Price's potato-bean, the hillside has a northwestern orientation and contains mature trees that shade the road corridor the majority of the day. A stand of younger trees is present on the west side of the road that blocks sunlight in the late afternoon. No large canopy openings are present, and the area does not receive sufficient sunlight for Price's potato-bean. The portion of the road in the southeastern portion of the work area extends away from the hillside and is bordered by only a single row of trees that do not provide the preferred conditions for this species.

Forested habitat is present along portions of the heavy equipment access road, including a section between Greencastle Road and the crop field and sections along the south side of Taylor Branch. The majority of the forested habitat in these sections has a dense canopy and does not receive sufficient sunlight for Price's potato-bean. Forest openings present along the road are associated with open fields and cleared areas that are regularly maintained and receive too much sunlight for this species. Additionally, the majority of forested habitat is located in a flat area along the Taylor Brach floodplain that does not contain hillslopes with limestone outcrops or bluffs.

3.2 MUSSEL SURVEY

The mussel survey of the Action Area was performed by Lewis Environmental Consulting, LLC (Lewis) in July and August 2021. Semi-quantitative and qualitative methods were utilized downstream of BRLD1, and semi-quantitative methods were used upstream of BRLD1. The downstream portion of the survey area extended from approximately 120 meters downstream of the dam to RM 14 and included nine transects at approximately 200-meter intervals. A total of 10 qualitative search areas were also surveyed. The upstream portion of the survey area included 28 transects at approximately one-mile intervals, beginning approximately 200 meters upstream of BRLD1 and ending at the upstream extent of the Action Area (Lewis 2021).

During the survey, a total of 3,637 live mussels from 29 unionid species were encountered in the downstream survey area, and a total of 165 live mussels from 22 unionid species were found in the upstream survey area. No live individuals of the 11 mussel species were found in the upstream or downstream survey areas. The shell of a clubshell was found in the downstream survey area (Lewis 2021).

In addition to the survey data, occurrence records from the OKNP and available data from previous surveys were reviewed for the Barren River from the confluence with the Green River upstream to Barren River Lake. No reported occurrences of the purple cat's paw or spectaclecase are known from this portion of the river, and no live individuals of the clubshell, northern riffleshell, rabbitsfoot, or ring pink have been reported since 1927 or longer. One record of a live sheepnose individual has been documented; however, the record has no date and is presumed to be historic. Live individuals of the snuffbox and fanshell have not been found since 1964 and 1989, respectively. Live longsolid and pink mucket individuals have been documented downstream of the Action Area within the last 14 years, including one longsolid in 2016. A longsolid individual was also reported from upstream of the Action Area in 2020. Based on this data, live individuals of these 11 species have either never been documented in the Action Area or have not been reported from the Action Area within the last 30 years. Shells from several of these species have been found in this portion of the Barren River within the last 40 years; however, the majority are only represented by a few shells and do not indicate the presence of viable, reproducing populations.

3.3 EFFECTS ANALYSIS

An analysis of potential effects to the gray bat, Indiana bat, northern long-eared bat, spectaclecase, fanshell, purple cat's paw, northern riffleshell, snuffbox, longsolid, pink mucket, ring pink, sheepnose, clubshell, rabbitsfoot, and Price's potato-bean from the proposed Action is presented below.

3.3.1 Gray Bat

Based on known occurrences in the vicinity of the proposed Action and the presence of suitable habitat in the Action Area, the gray bat is reasonably certain to occur within the Action Area. Therefore, potential effects to this species and its habitat from the Action are discussed below.

No potential hibernacula or underground roosting habitat for the gray bat is present within the work area. As a result, noise and vibrations associated with construction activities are unlikely to affect roosting gray bats. Explosive charges may be used in the work area during rubblization of the lock walls; however, vibrations generated by the charges are not expected to extend beyond the work area due to the minimal amount of explosive used and the reduction of vibrations as they travel through the river and underlying alluvium. Sinkholes and other karst features adjacent to the Action Area that are connected to the Barren River through subsurface flow will not be directly impacted by the project. Potential water level reductions in these features from removal of BRLD1 are not expected to adversely affect hibernating or roosting gray bats and could potentially increase the suitability of these features by exposing additional roosting locations. The highest potential for increased roost availability would occur within the karst features located along the pooled portion of the river upstream of BRLD1. The frequency and intensity of flooding in these karst features may also decrease, potentially enhancing the suitability of these features as roosting habitat.

The seven bridges in the Action Area are assumed to provide suitable non-winter roosting habitat for the gray bat. The bridge over Taylor Branch is located adjacent to the work area and will be crossed during construction activities. The bridge is located more than 1,600 feet from BRLD1, and noise and vibrations generated by demolition activities are not anticipated to disturb bats roosting on the bridge. In addition, noise levels produced during construction activities are expected to be lower than those associated with boats and people using the ramp and adjacent river. Daily traffic on the bridge will increase during construction; however, potential impacts to roosting bats will be similar to those currently produced by vehicles and trailers crossing the bridge to access the boat ramp. The remaining bridges are located at least 15 miles or more upstream of the work area and will not be impacted by construction activities. Lower water levels in the Barren River and streams under the six upstream bridges after removal of BRLD1 may have a positive effect on roosting habitat by increasing the distance between the underside of the bridge deck and the stream surface, providing better roost access and reducing the frequency of flooding. Based on the absence of hibernacula in the Action Area, the minimal, potentially positive impacts to hibernacula/roosting habitat adjacent to the Action Area, and the potentially positive impacts to the bridges, effects to hibernating and roosting gray bats and their habitats are considered insignificant.

The removal of BRLD1 will result in temporary and permanent impacts to gray bat foraging habitat in the Barren River. Installation of the in-stream work pad will result in temporary impacts to foraging habitat;

however, the work pad will remain at or below the elevation of the dam during demolition and is not anticipated to significantly alter foraging habitat or behavior. After demolition, the work pad will be removed to the same elevation as the dam below the water level.

Demolition of the dam and locks and associated noise and vibrations will be limited to daylight hours and will not occur when gray bats are actively foraging. Changes to foraging habitat will occur on a daily basis as existing structures are demolished and removed, altering the flyway over and along the Barren River. Gray bats that forage in the area are not anticipated to be affected by the removal of these structures, and those that are affected can avoid the work area and forage in other portions of the Barren River. Temporary impacts to foraging habitat in the remainder of the Action Area are expected to be minimal and are not anticipated to significantly affect foraging behavior.

Forage supply in and downstream of the work area may also be temporarily impacted due to water quality degradation from sediment disturbance and runoff. Tree removal and grading along the riverbanks during site preparation will disturb and expose sediment that could enter the river through stormwater runoff. Material that enters the river during demolition of the dam and locks and installation of the in-stream work pad will result in sediment disturbance, which could lead to sediment suspension and increased turbidity, decreased dissolved oxygen, or other changes to water chemistry. Suspended sediment will also be carried downstream, leading to deposition and potential changes to substrate composition. Spills and leaks from equipment working along the riverbanks or on the work pad may also enter the river. These impacts could negatively affect water quality and impact aquatic insect larvae and their habitats, reducing forage supply for gray bats. To minimize the effects of water quality degradation, EPSC measures will be implemented prior to and throughout demolition to minimize impacts to the Barren River. Potential releases anticipated during the project will also be limited, short-term impacts, rather than chronic, long-term impacts. Sediment that is deposited in and downstream of the work area is expected to be moved farther downstream with each high water event, dispersing the sediment over a larger area and restoring the affected areas to conditions that are similar to or improved from pre-demolition conditions. In addition, gray bats that are affected by impacts to forage supply can forage in the unaffected portions of the Barren River upstream and downstream of the work area. Based on utilization of EPSC measures and the short-term nature of the impacts, the project is not anticipated to result in significant impacts to gray bat forage supply.

The removal of BRLD1 is expected to improve gray bat foraging habitat in the Barren River and Jennings Creek after project completion. The dam will be removed to an elevation of approximately 392 feet AMSL and will be below the water surface the majority of the time. Removal of the dam will eliminate an obstacle in the river and allow gray bats to forage along this portion of the river without interruption. Removal of the inner lock and lowering of the central esplanade and outer lock river wall will also result in fewer obstacles in the river and create a wider flyway for foraging bats. Habitat at the dam location and upstream is also

expected to improve as the river transitions from an impounded pool to a free-flowing system, potentially increasing forage supply by improving conditions for aquatic insects.

The removal of trees from the work area and tree loss upstream following dam removal (see Section 3.2.2) will also alter gray bat foraging and commuting habitat. Tree removal will be limited to the work area and consist of removing trees along the linear riparian corridor on the east side of the Barren River. Removal of these trees will result in a minor increase to the existing gap in the riparian corridor along BRLD1; however, the clearing will not result in isolation of forested habitat and is not anticipated to significantly fragment commuting routes. The riparian corridor along the west side of the river will not be disturbed, and the remaining forested habitat within and adjacent to the work area will continue to provide commuting routes. After construction, portions of the work area will be allowed to reforest naturally over time, restoring forested habitat to the majority of the cleared areas. Due to these factors, the proposed tree removal is not anticipated to significantly affect foraging or commuting gray bats. Additionally, the loss of trees along portions of the riverbanks upstream of the dam after removal is unlikely to significantly alter foraging or commuting habitat.

Based on the lack of impacts to gray bat hibernacula and roosting habitat and minimal impacts anticipated to foraging habitat, forage supply, and commuting habitat, effects to the gray bat as a result of the proposed Action are considered insignificant.

3.3.2 Indiana and Northern Long-eared Bat

Based on known occurrences in the vicinity of the proposed Action and the presence of suitable habitat in the Action Area, the Indiana bat and northern long-eared bat are reasonably certain to occur within the Action Area. Therefore, potential effects to these species and their habitat from the Action are discussed below.

As discussed in the previous section, no potential hibernacula for the Indiana or northern long-eared bat are present within the work area, and noise and vibrations from demolition activities and explosives are not anticipated to result in impacts beyond the work area. The sinkholes and karst features adjacent to the Action Area and the seven bridges in the Action Area will not be directly impacted by the removal of BRLD1, and the lower water levels in the river after removal could potentially increase the suitability of these features as hibernacula and/or roosting habitat. Based on these factors, effects to hibernating and non-forest roosting Indiana and northern long-eared bats and their habitats are considered insignificant.

The proposed Action will result in the removal of up to 4.87 acres of suitable summer roosting, foraging, and commuting habitat for the Indiana and northern long-eared bats in the work area (Figures 5 and 6).

This amount includes tree clearing associated with the removal of BRLD1 (up to 4.41 acres) and along the heavy equipment access road (up to 0.46 acre). The final amount of tree removal will be determined by the USFWS KFO prior to construction. Some trees along the riverbank in Pool 1 are also expected to fall after removal of BRLD1 due to the loss of hydrostatic pressure from the pooled water. These trees are also considered to be suitable summer habitat for these two species. To estimate the amount of tree fall that will occur in Pool 1, tree fall that occurred in Pool 6 of the Green River after removal of GRLD6 was reviewed. This method was also used to calculate estimated tree fall in Pool 5 of the Green River during the biological assessment for the removal of Green River Lock and Dam 5. Tree fall that occurred in Green River Pool 6 after removal of GRLD6 was estimated by examining aerial photographs of the pool from before and after dam removal. The review began at the former location of GRLD6 and continued for 10 miles upstream and resulted in an average of 19 fallen trees per river mile. A similar amount of tree fall is expected in Barren River Pool 1 due to similarities between the two pools. The length of Pool 1 between BRLD1 and the upstream extent of the Action Area is approximately 22.7 miles. Areas with no trees along the banks and areas where the banks are comprised of rock cliffs and ledges where bank sloughing is not anticipated where excluded, reducing the tree fall estimate area to 19.5 miles. Based on this length, the estimated tree fall from the proposed Action is 371 trees. Using the single tree method for calculating habitat described in the Conservation Strategy where each individual tree is counted as 0.09 acre, 33.39 acres of trees are anticipated to fall along Pool 1 after removal of BRLD1.

The loss of suitable summer habitat will result in adverse effects to the Indiana and northern long-eared bats. As discussed in Section 1.3.3, adverse effects to both species will be mitigated through a payment to the Imperiled Bat Conservation Fund (IBCF), utilizing the process set forth in the Conservation Strategy. The proposed Action is consistent with the actions evaluated in the 2015 Biological Opinion that supports the Conservation Strategy. As a result, an analysis of effects to the Indiana and northern long-eared bats from the removal of suitable summer habitat as a result of the proposed Action is not included in this assessment.

The entire work area is located in “Known Swarming 2” habitat for the Indiana bat, and over half of the work area is location in “Known Swarming 2” habitat for the northern long-eared bat. Efforts will be made to remove trees in the work area during the unoccupied period for these habitats (November 15 to August 15); however, tree removal may occur during the occupied period (August 16 to November 14). Due to “Known Swarming 2” habitat for the Indiana bat covering the entirety of the work area, this habitat boundary was used to calculate the mitigation amount for the work area. As a result, a multiplier of 2.0 will be applied to the 4.87 acres of tree removal within the work area to mitigate for the potential removal of “Known Swarming 2” habitat for both species during the occupied period. To avoid impacts to non-volant young, tree removal will be restricted within the work area between June 1 and July 31.

Pool 1 is located within "Potential" and "Known Swarming 2" habitat for the Indiana and northern long-eared bats (Figure 4). "Known Swarming 2" habitat for the Indiana bat covers the same portions of Pool 1 as "Known Swarming 2" habitat for the northern long-eared bat, as well as additional areas; therefore, the Indiana bat "Known Swarming 2" habitat boundary was used to calculate the mitigation amounts for tree fall in Pool 1. Of the estimated 33.39 acres of tree fall in Pool 1, 19.71 acres are located in "Potential" habitat and 13.68 acres are located in "Known Swarming 2" habitat. Tree fall along Pool 1 may occur during any time of the year, including the occupied periods for "Potential" (April 1 to October 14) and "Known Swarming 2" (August 16 to November 14) habitat. Therefore, a multiplier of 1.0 will be applied to the 19.71 acres of "Potential" habitat, and a multiplier of 2.0 will be applied to the 13.68 acres of "Known Swarming 2" habitat to account for habitat loss during the occupied periods for these habitats.

Based on these acreages and multipliers, tree removal and tree fall for the proposed Action will result in a total payment to the IBCF of up to $227,240.00, as summarized in the table below.

Location	Habitat Type	Timeframe	Habitat Impact	Price Per Acre*	Multiplier	Payment
Work Area	Swarming 2	Occupied	4.87 acres	$4,000	2.0	$38,960.00
Action Area (13.4 mi)	Potential	Occupied	19.71 acres	$4,000	1.0	$78,840.00
Action Area (9.3 mi)	Swarming 2	Occupied	13.68 acres	$4,000	2.0	$109,440.00
					Total Payment Amount	**$227,240.00**

*current price per acre as determined by UK Department of Agricultural Economics in the Agricultural Situation and Outlook and subject to change

Noise and vibrations generated during tree removal are not anticipated to adversely affect Indiana or northern long-eared bats due to their ability to tolerate these disturbances. Tree removal for the proposed Action will occur during site preparation, and noise and vibrations will be limited to those produced by heavy equipment and the felling of trees. Studies have shown that Indiana bats will remain in an area where timber harvests and construction activities are on-going and often become habituated to these disturbances (Gardner et al. 1991, Hawkins et al. 2008). Noises and vibrations must typically be severe to cause bats to abandon roost trees and alter their behaviors, and individuals that abandon their roosts are likely to return later or find a suitable roosting location nearby due to the prevalence of roosting habitat in the surrounding area. Published data on the effects of noise and vibration on northern long-eared bats is lacking; however, this species is expected to react in a similar manner to Indiana bats due their similarities in life history and behaviors.

Noise and vibrations generated by demolition activities will occur after suitable Indiana and northern long-eared bat habitat has been removed, increasing the distance between these disturbances and other suitable habitat in or adjacent to work area. In addition, bats roosting in the vicinity of the work area are likely to become habituated to the noise and vibrations associated with site preparation and are less likely to abandon their roosts when demolition begins. The potential use of explosives during demolition will also

generate noise and vibrations; however, the amount and extent of explosive use will be minimal and is anticipated to produce noise and vibrations similar to other on-going activities.

3.3.3 Mussel Species

Based on the results of the mussel survey and lack of recent occurrence records, the spectaclecase, fanshell, purple cat's paw, northern riffleshell, snuffbox, longsolid, pink mucket, ring pink, sheepnose, clubshell, and rabbitsfoot are presumed absent from the Action Area. As a result, adverse effects to these species are not anticipated from the proposed Action.

3.3.4 Price's Potato-bean

Based on the lack of suitable habitat, this species is considered absent from the Action Area. As a result, effects to Price's potato-bean as a result of the proposed Action are considered discountable.

3.4 EFFECTS DETERMINATION

The effects determination for each of the listed species proposed for informal consultation is presented below.

3.4.1 Gray Bat

Based on the lack of negative impacts to hibernacula and roosting habitat and minimal impacts anticipated to foraging and commuting habitat, effects to this species from the proposed Action are considered insignificant. As a result, the effects determination for the gray bat as a result of the Action is "**may affect, not likely to adversely affect**".

3.4.2 Indiana Bat

Based on the lack of negative impacts to hibernacula and bridge roosting habitat and minimal impacts anticipated from construction noise and vibration, effects to the Indiana bat from lock and dam removal, site stabilization, and some site preparation activities are considered insignificant. However, the removal of trees during site preparation will result in adverse effects to this species from habitat removal. Adverse effects to the Indiana bat from tree removal have been analyzed through a programmatic intra-Service biological opinion (USFWS 2015b) prepared by the USFWS, and adverse effects from the proposed Action will be mitigated through a payment to the IBCF. Therefore, the effects determination for the Indiana bat as a result of the Action is "**may affect, likely to adversely affect**". However, because these effects have been analyzed under the 2015 Biological Opinion for this species, additional formal consultation is

unnecessary as long as the proposed Action is consistent with the actions evaluated in the 2015 Biological Opinion and implemented as planned, including all conservation measures.

3.4.3 Northern Long-Eared Bat

Based on the lack of negative impacts to hibernacula and bridge roosting habitat and minimal impacts anticipated from construction noise and vibration, effects to the northern long-eared bat from lock and dam removal, site stabilization, and some site preparation activities are considered insignificant. However, the removal of trees during site preparation will result in adverse effects to this species from habitat removal. Adverse effects to the northern long-eared bat from tree removal have been analyzed through a programmatic intra-Service biological opinion (USFWS 2015b) prepared by the USFWS, and adverse effects from the proposed Action will be mitigated through a payment to the IBCF. Therefore, the effects determination for the northern long-eared bat as a result of the Action is "**may affect, likely to adversely affect**". However, because these effects have been analyzed under the 2015 Biological Opinion for this species, additional formal consultation is unnecessary as long as the proposed Action is consistent with the actions evaluated in the 2015 Biological Opinion and implemented as planned, including all conservation measures.

3.4.4 Mussel Species

Based on the probable absence of the spectaclecase, fanshell, purple cat's paw, northern riffleshell, snuffbox, longsolid, pink mucket, ring pink, sheepnose, clubshell, and rabbitsfoot in the Action Area, effects to these species are considered discountable. Therefore, the effects determination for these 11 mussel species a result of the Action is "**may affect, not likely to adversely affect**".

3.4.5 Price's Potato-bean

Based on the probable absence of this species in the Action Area, effects to Price's potato-bean are considered discountable. Therefore, the effects determination for Price's potato-bean as a result of the Action is "**may affect, not likely to adversely affect**".

4.0 SPECIES FOR FORMAL CONSULTATION/CONFERENCE

Background information for the rough pigtoe and pyramid pigtoe is presented below, including species status, distribution, and habitat.

4.1 ROUGH PIGTOE

The rough pigtoe was listed as endangered under the ESA on June 14, 1976 (USFWS 1976). The historical distribution of the rough pigtoe includes the Ohio, Cumberland, and Tennessee River drainages in Alabama, Illinois, Indiana, Kentucky, Ohio, Pennsylvania, Tennessee, Virginia, and West Virginia. This species is believed to be extirpated from Pennsylvania, Ohio, West Virginia, Virginia, and Illinois. Currently, this species is known to occur downstream of three Tennessee River mainstem dams in Alabama and Tennessee, in the Clinch River in Tennessee, and in the Green and Barren Rivers in Kentucky. The species may also be present in the Cumberland River in Tennessee. In Kentucky, the rough pigtoe occurs in the Green River between Lock and Dam 4 and Lock and Dam 5 and in the Barren River below Lock and Dam 1 (USFWS 2014). Recent observations from the Barren River are discussed in Section 5.1. The rough pigtoe is found in medium to large rivers with sand, gravel, and cobble substrate but has also been found in flats and muddy sand in shallow water (USFWS 1984, USFWS 2014).

4.2 PYRAMID PIGTOE

The USFWS proposed to list the pyramid pigtoe as a threatened species with Section 4(d) rule under the ESA on September 7, 2021. The species is currently known to occur in Kentucky, Tennessee, Virginia, Ohio, Alabama, Oklahoma, Arkansas, Mississippi, and Louisiana, where extant populations are found in the Arkansas-White-Red, Lower Mississippi, Missouri, and Ohio River regions. The pyramid pigtoe is considered extirpated from Pennsylvania, West Virginia, Indiana, Illinois, Wisconsin, Minnesota, Iowa, Kansas, and Missouri (USFWS 2021). Recent observations from the Barren River are discussed in Section 5.1.

The pyramid pigtoe is found in medium to large rivers and prefers a mixture of sand, gravel, and cobble substrates. Individuals are commonly found at depths of three feet or less but have been found at depths of 13 to 20 ft in large rivers (Parmalee and Bogan 1998).

5.0 ENVIRONMENTAL BASELINE

The following sections include an analysis of past and on-going human and natural factors leading to the current status of the rough pigtoe and pyramid pigtoe, their habitat, and ecosystem within the Action Area. The environmental baseline is a "snapshot" of the species' health in the Action Area at this time and does not include the effects of this Action.

5.1 SPECIES STATUS WITHIN THE ACTION AREA

During the 2021 mussel survey of the Action Area, two rough pigtoe individuals and four pyramid pigtoe individuals were encountered in the downstream portion of the Action Area (Figure 3). Two of the pyramid pigtoe individuals were found approximately 950 feet and 1,800 feet, respectively, downstream of BRLD1. The other two pyramid pigtoe individuals and both rough pigtoe individuals were found approximately one mile downstream of BRLD1. A shell from a pyramid pigtoe was found in the upstream portion of the Action Area; however, no live individuals of these species were encountered upstream of BRLD1 (Lewis 2021).

During the survey, mussel abundance and diversity were low from immediately upstream of the dam (Transect BRU-01) to seven miles upstream (Transect BRU-09). Only 18 individuals of four non-listed species were encountered, with one to six individuals and one to three species at each transect (Lewis 2021). These species included the washboard (*Megalonaias nervosa*), mapleleaf (*Quadrula quadrula*), pink papershell (*Potamilus ohiensis*), and pistolgrip (*Tritogonia verrucosa*), all of which are tolerant of river impoundments and deep water (Parmalee and Bogan 1998, Grabarkiewicz and Davis 2008). These species were some of the most common species encountered during the survey, with the exception of the pink papershell. This impoundment-tolerant species was only found in this reach, where effects to the river from the impoundment are greatest.

Mussel abundance and diversity increased between 7.5 miles upstream of the dam (Transect BRU-10) and 10 miles upstream (Transect BRU-13), where a total of 49 individuals of nine non-listed species were found. Results ranged from six to 25 individuals and five to six species per transect (Lewis 2021). Species tolerant of impoundments continued to be the most abundant, including the addition of species from the genus *Lampsilis* and the pimpleback (*Cyclonaias pustulosa*) (Grabarkiewicz and Davis 2008).

Abundance and diversity decreased between 11 miles upstream of the dam (Transect BRU-14) and 16 miles upstream (Transect BRU-20), with similar numbers to the initial reach above BRLD1. Only one to five individuals of one to three species were encountered per transect (Lewis 2021).

The highest mussel abundance and greatest species diversity in the upstream survey area were found from 17 miles upstream of the dam (Transect BRU-21) to the upstream extent of the Action Area (Transect BRU-28). Lewis noted that this portion of the river is not impounded and exhibits more natural, free-flowing conditions with runs and shallow riffles. A total of 78 individuals of 18 non-listed species were encountered, including 10 species not found downstream of this area. These additional species typically prefer more lotic environments, such as the butterfly (*Ellipsaria lineolata*), pink heelsplitter (*Potamilus alatus*), kidneyshell (*Ptychobranchus fasciolaris*), and round pigtoe (*Pleurobema sintoxia*) (Parmalee and Bogan 1998, Grabarkiewicz and Davis 2008). Seven of these species were found within the same transects and search areas downstream of BRLD1 where the rough pigtoe and pyramid pigtoe individuals were found, including a species of the same genus (*Pleurobema sintoxia*) (Lewis 2021). These results indicate that the portion of the river at the upstream end of the Action Area begins to provide more suitable habitat for lotic species and may provide habitat for the rough pigtoe and pyramid pigtoe.

Based on the survey results, the portion of the Barren River from BRLD1 to seven miles upstream does not provide suitable habitat for the rough pigtoe or pyramid pigtoe (Figure 3). The portion of the river from seven miles upstream to 16 miles upstream may contain areas of marginal habitat for these species; however, the majority of this reach appears to provide poor-quality habitat. Mussel habitat appears to improve from 17 miles upstream through the upstream extent of the Action Area and appears to provide suitable habitat for these two species.

In 2008, Lewis conducted a survey of the Barren River immediately downstream of the Action Area to evaluate two areas impacted by a pipeline crossing. The survey included quantitative and qualitative survey methods at four sites located at RMs 7.7, 9.7, 12, and 14. During the survey, five pyramid pigtoes were encountered at RM 14 near the downstream extent of the Action Area (Lewis 2008).

Previous surveys performed by the Kentucky Department of Fish and Wildlife Resources Center for Mollusk Conservation have also documented the rough pigtoe and pyramid pigtoe downstream of BRLD1. During a survey in 2002, one rough pigtoe individual and one pyramid pigtoe individual were found approximately 1,800 feet downstream of the dam near the same location where a pyramid pigtoe was found during the 2021 mussel survey (Monte McGregor, KDFWR, personal communication, January 21, 2022). The OKNP report also includes a record of three rough pigtoe individuals at this location in 2001.

Based on the results of the 2021 survey and previous surveys, the rough pigtoe and pyramid pigtoe are expected to occur in the downstream portion of the work area, downstream of the work area, and upstream of the work area.

5.2 ACTION AREA NUMBERS, REPRODUCTION, AND DISTRIBUTION

The results of the 2021 mussel survey of the Action Area was used to calculate densities and estimate the number of individuals in the Action Area for the rough pigtoe and pyramid pigtoe. Data from the OKNP report was also used to supplement data from the 2021 survey.

5.2.1 Action Area Downstream of BRLD1

Semi-quantitative data from the 2021 survey was used to calculate mussel densities downstream of BRLD1. During the survey, 880 mussels were found along the nine transects, which included an area of 506 square meters. Based on these results, Lewis calculated an estimated density of 1.74 mussels per square meter within the semi-quantitative survey area. During the semi-quantitative survey, one rough pigtoe individual was found. Additionally, one rough pigtoe and four pyramid pigtoe individuals were encountered downstream of BRLD1 during the qualitative searches (Lewis 2021). To standardize data from the qualitative search areas with the semi-quantitative survey data, the total collection time for each survey type was used. The collection time during the qualitative searches was 1,263 minutes, which was nearly double the search time of 705 minutes during the semi-quantitative survey. Based on this difference, the total number of individuals encountered during the qualitative searches can be halved to estimate the total number of individuals that could be present in the semi-quantitative survey area, resulting in 0.5 rough pigtoe individuals and two pyramid pigtoe individuals. After rounding the rough pigtoe estimate up to one individual and adding the individual found during the semi-quantitative survey, two rough pigtoe individuals are estimated to be present within the semi-quantitative survey area. Two pyramid pigtoe individuals are also estimated within the semi-quantitative survey area. Based on these estimates, the estimated density for both species is 0.0040 mussels per square meter (2 individuals ÷ 506 m^2 in survey area = 0.0040 mussels/m^2). The estimated density calculated for these species is summarized in the following table.

Species	Estimated Density in 2021 Downstream Survey Area (mussels/m^2)
pyramid pigtoe	0.0040
rough pigtoe	0.0040

The estimated density calculated for the rough pigtoe and pyramid pigtoe for the semi-quantitative survey area is assumed to be similar throughout the Action Area downstream of BRLD1; therefore, these values were used to estimate the number of individuals of each species within the downstream portion of the Action Area. The portion of the Action Area downstream of BRLD1 totals approximately 146,740 square meters. To calculate the estimated number of individuals of each species in the Action Area downstream of BRLD1, the downstream Action Area size was multiplied by the estimated density for each species. For example, the calculation for the estimated number of rough pigtoe individuals is 0.0040 mussels/m^2 x 146,740 m^2 =

586.96 individuals. The estimated number of individuals for each species was then rounded up to the nearest whole number, as shown in the following table.

Species	Estimated Individuals in Action Area Downstream of BRLD1
pyramid pigtoe	587
rough pigtoe	587

5.2.2 Action Area Upstream of BRLD1

Semi-quantitative data from the 2021 survey was also used to calculate mussel densities upstream of BRLD1. During the survey, 165 live mussels were found along the 28 transects, which included an area of 1,684 square meters. Based on these results, Lewis calculated an estimated density of 0.10 mussels per square meter within the semi-quantitative survey area (Lewis 2021). Although no live individuals of the rough pigtoe or pyramid pigtoe were found in the upstream portion of the Action Area during the 2021 survey, the OKNP report contains a record for a live rough pigtoe individual from 1988 within this portion of the Barren River. Additionally, the OKNP report includes a 1993 record for a live pyramid pigtoe individual upstream of the Action Area. Based on these historic records and the known occurrence of these species in the downstream portion of the Action Area, one individual of each species is assumed to be present within the semi-quantitative survey area. Therefore, the estimated density for the rough pigtoe and pyramid pigtoe in the semi-quantitative survey area is 0.0006 mussels per square meter. The estimated density calculated for these species is summarized in the following table.

Species	Estimated Density in 2021 Upstream Survey Area (mussels/m^2)
pyramid pigtoe	0.0006
rough pigtoe	0.0006

The estimated density calculated for each species for the semi-quantitative survey area is assumed to be similar throughout the Action Area upstream of BRLD1; therefore, these values were used to estimate the number of individuals of each species within the upstream portion of the Action Area. The portion of the Action Area upstream of BRLD1 totals approximately 2,638,266 square meters. To calculate the estimated number of individuals of each species in the Action Area upstream of BRLD1, the Action Area size (2,638,266 square meters) was multiplied by the estimated density for each species (0.0006 mussels/square meter) and rounded up to the nearest whole number, resulting in an estimate of 1,583 individuals per species in the upstream portion of the Action Area.

As discussed in Section 5.1, the portion of the Barren River from BRLD1 to seven miles upstream does not provide suitable habitat for the rough pigtoe or pyramid pigtoe. Individuals of these species are unlikely to be present in this portion of the Action Area; therefore, the estimated number of individuals in the upstream

portion of the Action Area was adjusted to reflect the likely absence of individuals in the unsuitable portion. To calculate the estimated number of individuals of each species in the unsuitable portion of the Action Area, the size of the unsuitable portion (873,560 square meters) was multiplied by the estimated density for each species (0.0006 mussels/square meter) and rounded up to the nearest whole number, resulting in an estimate of 525 individuals per species. The estimated number of individuals in the unsuitable portion (525) was then subtracted from the estimated number of individuals in the entire upstream portion of the Action Area (1,583) to get the final estimated number of individuals (1,058) in the upstream portion of the Action Area. The estimated number of individuals for each species is summarized in the following table.

Species	Estimated Individuals in Action Area Upstream of BRLD1
pyramid pigtoe	1,058
rough pigtoe	1,058

5.3 ACTION AREA CONSERVATION NEEDS AND THREATS

The primary factor affecting the rough pigtoe and pyramid pigtoe in the Action Area is the presence of BRLD1. The dam acts as a barrier in the Barren River that affects flow, sediment deposition, water quality, and the movement of aquatic organisms. Construction of the dam caused a large portion of the river to become pooled upstream and altered the natural flow regime, causing riffles and shoals with clean sand and gravel substrate to be replaced by slow-flowing, silt-bottomed pools that do not provide suitable habitat for the listed mussel species. These conditions have been present in this portion of the Barren River since construction of the dam in 1841. The flow of water over the dam has also led to scouring, causing fine sediment to be removed and creating a deep area of unsuitable habitat at the base of the dam and immediately downstream. The plunging water has also caused suspension of fine sediment, which can increase turbidity, decrease dissolved oxygen levels, and cause other impacts to water quality that can affect mussels. Presence of the dam also acts as a barrier to fish movement, limiting contact between mussels and fish hosts and affecting mussel reproduction.

Other factors that could affect the rough pigtoe and pyramid pigtoe in the Action Area include sedimentation and inputs of contaminants. Runoff associated with agricultural and logging activities contributes sediment, suspended solids, pesticides, herbicides, fertilizers, petroleum-based products, and other contaminants to the Barren River. Point source releases from wastewater treatment and storm water discharge also cause contamination. Contaminants may also enter the Barren River through inputs of groundwater when petroleum-based products (e.g., fuel, oil, hydraulic fluid) from vehicles, trains, heavy equipment, and other sources enter the extensive karst system in the area. In addition, an Environmental Baseline Survey of BRLD1 conducted as part of the Green and Barren River Lock and Dam Disposition Study (USACE 2014) found hydraulic oil stains in the control tower and several locations in the lock chamber resulting from

vandalism to the hydraulic piping system, indicating that hydraulic oil has been released into the environment.

A potential biological threat to the rough pigtoe and pyramid pigtoe includes invasive species that compete with or prey upon native mussels. Asian carp, a collective reference to the bighead carp (*Hypophthalmichthys nobilis*), silver carp (*Hypophthalmichthys molitrix*), and black carp (*Mylopharyngodon piceus*), are known to occur in the Green River downstream and upstream of the confluence with the Barren River and may be present in the Barren River (KDFWR 2022). Bighead and silver carp are filter feeders that compete directly with native mussels for food. Black carp eat mollusks and present a predatory threat to native mussels. Although efforts are underway to control these invasive species, existing populations are expected to persist and expand into new areas (USDA 2020). In addition, isolated occurrences of the zebra mussel (*Dreissena polymorpha*) have been reported in the lower Green River (Haag and Cicerello 2016) and are likely moving farther upstream. This invasive mussel species attaches to native mussel shells and other hard surfaces by the thousands and outcompetes native mussels for food.

6.0 EFFECTS OF THE ACTION

The following sections include an analysis of effects that may occur as a result of the proposed Action to the rough pigtoe and pyramid pigtoe. Based on activities associated with the proposed Action and known threats to these species, the following stressors have been identified: 1) sediment disturbance; 2) water quality degradation; 3) changes to flow; 4) crushing or striking of individuals; 5) displacement of individuals; and 6) exposure of individuals. Each of these stressors is discussed in more detail below through Stressor-Exposure-Response pathways. The pathways identify the circumstances for an individual mussel to be impacted by the Action and summarize potential effects. Potential effects in the pathways are referred to as stressors (i.e., the overlap in time and space between an impact and an individual). The pathways also include conservation measures, when appropriate, to reduce the exposure probability of an individual mussel to the stressor or the severity of the stressor on an individual.

6.1 SEDIMENT DISTURBANCE

Site preparation, lock and dam removal, and site stabilization could result in sediment disturbance. Sediment disturbance along the riverbanks and adjacent areas could expose soil and increase erosion, allowing sediment to enter the Barren River through runoff. Sediment disturbance within the river could displace sediment in one location and deposit it in another location, potentially exposing or burying mussels. Potential impacts to the rough pigtoe and pyramid pigtoe from sediment disturbance in the work area, the Action Area upstream of the work area, and the Action Area downstream of the work area are discussed in the following sections.

Work Area

Improvement and construction of access roads, establishment of staging areas, and clearing and grubbing during site preparation will disturb soil near the Barren River. Prior to site preparation, EPSC measures will be implemented and maintained throughout the work area to reduce erosion and minimize sediment inputs into the Barren River. Vehicles and equipment used during site preparation will be limited to the riverbanks and adjacent areas and will not enter the river. Trees will not be felled into the river, and woody debris that enters the river is expected to consist of small limbs and leaves that are unlikely to result in sediment disturbance. Sediment displacement associated with the heavy equipment access road crossing of Taylor Branch will be minimal and is expected to settle in the stream channel prior to entering the Barren River.

Creation of the notch at the eastern end of the dam will concentrate flow along the right descending portion of the river, and the increased velocity and force could lead to scouring and displacement of sediment downstream. The area below the dam has been scoured by the force of water flowing over the dam, removing fine and smaller coarse sediments and leaving larger particles. Although the notch will increase

water velocity and force immediately below the dam, the increase is not anticipated to cause significant movement of these larger particles. Particles that do move are likely to only travel a short distance and would not move beyond the scour area below the dam. By the time water travels farther downstream, the increased force created by the concentrated flow at the notch is expected to dissipate and be similar to normal flow. Based on these factors, sediment disturbance from notching of the dam is considered unlikely.

The placement of material on the downstream dam apron or at the base of the dam to create the in-stream work pad and the placement of excess material into the scour area may cause some sediment disturbance; however, the amount of disturbance is expected to be minimal. As discussed above, the turbulence created by the force of water flowing over the dam has removed smaller sediments, leaving only larger particles. These large particles are not expected to move significant distances as additional material is overlain to create the work pad. Flow over the dam will also be reduced after notching of the dam, further limiting the movement of particles below the dam. Additionally, listed mussels are unlikely to be present at the base of the dam due to the constant turbulence and lack of suitable substrate from scouring, reducing the potential for sediment disturbance to impact individuals in this area. Any fine sediment that is disturbed at the base of the dam is expected to dissipate prior to reaching mussels downstream. Placement of material to create the in-stream work pad on the upstream side of the dam is likely to disturb sediment; however, sediment that is displaced will likely settle a short distance from the impact location due to the slow flow. As discussed in Section 5.1, the pooled area upstream of the dam represents unsuitable habitat for the rough pigtoe and pyramid pigtoe, and sediment disturbance is unlikely to impact listed mussels in this area. Any sediment that is transported through the notch in the dam will dissipate rapidly from the increased flow.

Demolition of the lock and dam structures will be performed in a manner that minimizes the amount of material that enters the Barren River; however, some material will fall into the river during these activities. Material that lands upstream of the dam could disturb sediment in Pool 1. As discussed above, sediment disturbance in the pooled area upstream of the dam is unlikely to impact the listed mussels. Material that falls on the downstream side of the dam is also not expected to result in significant sediment disturbance. Small particles have been scoured from the base of the dam, and fine sediment that is disturbed at the base of the walls will move downstream and disperse quickly due to the flow. Additionally, no mussels were found along the transect that directly abuts the outer lock river wall (Transect BRD-09), and no other live mussel occurrences are known from the areas around the lock and dam structures. As a result, sediment disturbance that occurs on the downstream side of the dam and around the downstream walls is unlikely to impact mussels.

Removal and placement of the outer lock miter gates and other material into the majority of the outer lock chamber is not anticipated to result in sediment disturbance due to the isolation of this area from the river channel and lack of flow into the river. However, placement of material in the downstream extent of the

lock chamber may cause sediment disturbance. Based on the Transect BRD-09 results, sediment displacement is unlikely to disturb or bury mussels, and fine sediment that enters the water column is expected to disperse rapidly and be deposited over a large area downstream. Soil placed over the filled lock chamber to create the final slope could wash into the river during periods of high water until vegetation is established; however, sediment movement will be minimized by utilizing BMPs for erosion control and stabilization.

During and immediately after dam removal, sediment that has accumulated upstream of the dam could move downstream when the river is restored to free-flowing conditions. Substrate information recorded during the 2021 mussel survey shows that the area immediately upstream of the dam consists of bedrock in the left descending portion of the channel, clay and silt in the central portion, and cobble and boulders in the right descending portion. An area of silt and gravel is present in the right descending portion of the channel upstream of the cobble/boulder area. The substrate data reveals that large amounts of fine sediment have not accumulated behind the dam; however, clay and silt are present upstream of the dam and are expected to move downstream after dam removal. Some of this sediment is expected to settle in the scour area immediately downstream of the dam, restoring small particles to this area and filling the spaces between larger pieces of dam material. Impacts to listed mussels are not anticipated from sediment accumulation at the base of the dam due to the lack of suitable habitat in this area. However, sediment that travels beyond the scour area could increase sediment deposition in areas where mussels were documented downstream of the dam. Based on the gradual removal of the dam in stages, accumulated sediment is anticipated to move downstream in small amounts over an extended period of time. Increased sediment deposition in the work area and areas immediately downstream is expected to be temporary as sediment is moved farther downstream; however, sediment from Pool 1 will likely move into the work area with each high flow event until the accumulated sediment is redistributed throughout the river. Although mussels may be able to respond to minimal, temporary sediment deposition, the combination of the initial movement of sediment from directly upstream of the dam combined with the subsequent influx of sediment from areas farther upstream may result in deposition too substantial to allow all individuals to adjust. Sediment deposition that occurs during periods of low water temperatures and decreased mussel activity will also reduce the ability of individuals to respond to deposition events.

Site stabilization activities after lock and dam removal will reduce the potential for sediment to enter the Barren River through seeding of disturbed areas and dressing of roads. Vehicles and equipment will be limited to the riverbanks and adjacent areas and will not enter the river. EPSC measures will also be maintained until the site is stabilized. As a result, sediment disturbance from this construction component is expected to be minimal.

The sediment disturbance described above could also result in impacts to habitat for fish hosts for the rough pigtoe and pyramid pigtoe. Sediment displacement and deposition may damage or bury habitat used by fish hosts for foraging, reproduction, and sheltering. The alteration or loss of habitat could cause fish hosts to move from the area, limiting their exposure to the mussel species and potentially affecting mussel reproduction and recruitment.

Action Area Upstream of Work Area

No construction components will occur in the Action Area upstream of the work area. Site preparation and stabilization activities in the work area are not expected to cause inputs of sediment into this area due to the direction of flow and use of EPSC measures, and inputs that do occur are anticipated to be minimal. The portion of the Action Area adjacent to and immediately upstream of the work area where the potential for impacts from lock and dam demolition are highest does not provide suitable habitat for the rough pigtoe or pyramid pigtoe. The movement and deposition of accumulated sediment in this area after dam removal will also occur in unsuitable habitat.

Action Area Downstream of Work Area

No construction components will occur in the Action Area downstream of the work area. As discussed above, site preparation and stabilization activities are not expected to cause inputs of sediment beyond the work area due to the use of EPSC measures. Inputs that do occur are anticipated to be minimal and will be dispersed quickly over a large area due to the flow of the river.

As discussed above, sediment that has accumulated upstream of the dam will move downstream during and after dam removal. Although the amount of accumulated sediment appears to be low, some sediment is expected to move into the Action Area downstream of the work area. The 2021 mussel survey documented mussel beds and a pyramid pigtoe individual approximately 950 feet downstream of the dam, and sediment deposition could occur in this area. Deposited sediment is anticipated to move farther downstream with each high flow event; however, sediment may persist for a sufficient amount of time after dam removal to smother mussels or render habitat unsuitable, causing individuals to move to other areas.

Applicable Science

Sedimentation is believed to adversely affect mussel populations that require clean, stable streams and has contributed to the decline of mussel populations nationwide (Vannote and Minshall 1982, Brim-Box and Mossa 1999). Specific biological effects to mussels from sedimentation include reduced feeding and respiratory efficiency from clogged gills, disrupted metabolic processes, reduced growth rates, limited burrowing activity, physical smothering, and disrupted host fish attraction mechanisms (Vannote and Minshall 1982, Waters 1995, Hartfield and Hartfield 1996). In addition, mussels may be indirectly affected if high turbidity levels significantly reduce the amount of light available for photosynthesis by potential food

items or impede the ability of mussels to attract host fishes (Kanehl and Lyons 1992). Sedimentation can also eliminate or reduce the recruitment of juvenile mussels by clogging interstitial spaces, interfering with feeding activity, and acting as a vector in delivering contaminants to streams (Brim-Box and Mossa 1999).

Dam removal results in the movement of sediment that has accumulated in the impounded or pooled area upstream of the dam. Accumulated sediment primarily consists of silt and sand, as coarser sediments typically settle out farther upstream (Kondolf 1997). Removal of a dam disturbs accumulated sediment, resulting in suspension and transport downstream (Doeg and Koehn 1994). The amount of accumulated sediment appears to be dependent on dam type, with dams associated with large impoundments (e.g., lakes, reservoirs, etc.) retaining more sediment behind the dam than run-of-river type dams. A study of four run-of-river dams in Illinois found no major accumulations of sediment behind the dams and concluded that the dams do not act as sediment traps (Csiki and Rhoads 2014).

The effects to mussels from downstream movement of accumulated sediment after dam removal have not been extensively studied; however, a few studies have examined these effects. A study by Sethi et al. (2004) in Wisconsin found that the movement and deposition of accumulated sediment downstream of a run-of-river dam after removal buried mussels and lead to mortality. Mussel densities in a bed 0.5 kilometer downstream of the dam declined from 3.80 mussels per square meter prior to dam removal to 2.60 mussels per square meter immediately after dam removal. In addition, the pimpleback (*Quadrula pustulosa*), a rare species in Wisconsin, was no longer found in the mussel bed after the dam was removed. Conversely, Heise et al. (2013) noted that survival rates of mussels downstream of a run-of-river dam in North Carolina remained unchanged before and after removal, even though the amount of sediment increased. Fine sediment below the dam increased from 38.3% before removal to 49.4% immediately after removal, but by three years post-removal had decreased to 24.7%. Survival rates of mussels remained similar throughout these changes, indicating that the increase in sediment movement and deposition after dam removal did not adversely affect mussels. The primary reason for the differences in these results appears to be the rate at which the pooled water was released. Dewatering of the Wisconsin dam was completed in 36 hours, compared to three weeks for the North Carolina dam. Although the Wisconsin dam was located in a larger river and likely had more accumulated sediment, the slower drawdown of the North Carolina dam appears to have reduced the detrimental effects of sediment movement and deposition downstream after dam removal.

The timing of dam removal may also alter the effects of sediment movement and deposition downstream of a dam. Removal of a dam during low flow may reduce the ability of the system to transport sediment downstream and cause accumulated sediment to move only a short distance from the dam (Kondolf 1997). During high flow, larger amounts of sediment are already moving through the system, which may prevent accumulated sediment at the dam from being carried farther downstream (Bednarek 2001).

Effects Pathway #1	
Activity: Site Preparation, Site Stabilization	
Stressor: Sediment Disturbance	
Exposure (time)	Duration of Activity
Exposure (space)	Work Area
Resource affected	Individuals (adults, juveniles), Habitat, Fish Hosts
Individual response	• Reduced respiration and feeding from clogged gills or smothering • Disruption of metabolic processes, leading to reduced fitness and growth rates • Reduced recruitment due to elimination of interstitial spaces used by juveniles • Movement due to alteration or loss of habitat • Displacement of fish hosts due to alteration or loss of habitat
Conservation Measures	• Implement EPSC measures in the work area. • Revegetate disturbed areas immediately following completion of ground disturbing activities.
Effect	Insignificant
Interpretation	Appropriate EPSC measures will be installed and maintained throughout the work area to reduce erosion and minimize sediment inputs into the Barren River. Vehicles and equipment will not enter the river, and no woody debris will be placed in the river.

Effects Pathway #2	
Activity: Lock and Dam Removal	
Stressor: Sediment Disturbance	
Exposure (time)	Duration of Activity
Exposure (space)	Work Area
Resource affected	Individuals (adults, juveniles), Habitat, Fish Hosts
Individual response	• Reduced respiration and feeding from clogged gills or smothering • Disruption of metabolic processes, leading to reduced fitness and growth rates • Reduced recruitment due to elimination of interstitial spaces used by juveniles • Movement due to alteration or loss of habitat • Displacement of fish hosts due to alteration or loss of habitat
Conservation Measures	• Perform in-stream activities during periods of low flow. • Use of in-stream work pad during lock and dam removal to minimize impacts to the river from equipment. The work pad will be located in areas that do not provide suitable habitat for the rough pigtoe or pyramid pigtoe.
Effect	Adverse (harm, mortality)
Interpretation	Accumulated sediment from upstream of the dam will move downstream during and after dam removal and could result in mussels located immediately downstream of the dam being buried or having to move to other areas.

Effects Pathway #3	
Activity: Site Preparation, Site Stabilization	
Stressor: Sediment Disturbance	
Exposure (time)	Duration of Activity
Exposure (space)	Action Area Upstream and Downstream of Work Area
Resource affected	Individuals (adults, juveniles), Habitat, Fish Hosts
Individual response	• Reduced respiration and feeding from clogged gills or smothering • Disruption of metabolic processes, leading to reduced fitness and growth

	rates • Reduced recruitment due to elimination of interstitial spaces used by juveniles • Movement due to alteration or loss of habitat • Displacement of fish hosts due to alteration or loss of habitat
Conservation Measures	• Implement EPSC measures in the work area. • Revegetate disturbed areas immediately following completion of ground disturbing activities.
Effect	Insignificant
Interpretation	No construction components will occur in the Action Area upstream or downstream of the work area. Inputs of sediment into these areas are not expected due to the use of EPSC measures, and inputs that do occur are anticipated to be minimal.

Effects Pathway #4	
Activity: Lock and Dam Removal	
Stressor: Sediment Disturbance	
Exposure (time)	Duration of Activity
Exposure (space)	Action Area Upstream of Work Area
Resource affected	Individuals (adults, juveniles), Habitat, Fish Hosts
Individual response	• Reduced respiration and feeding from clogged gills or smothering • Disruption of metabolic processes, leading to reduced fitness and growth rates • Reduced recruitment due to elimination of interstitial spaces used by juveniles • Movement due to alteration or loss of habitat • Displacement of fish hosts due to alteration or loss of habitat
Conservation Measures	• Perform in-stream activities during periods of low flow.
Effect	Insignificant
Interpretation	No construction components will occur in the Action Area upstream of the work area. Removal of the dam will cause sediment to move downstream out of this area, reducing the amount of accumulated sediment. In addition, the areas adjacent to and immediately upstream of the work area where the potential for impacts is highest do not provide suitable habitat for the rough pigtoe or pyramid pigtoe.

Effects Pathway #5	
Activity: Lock and Dam Removal	
Stressor: Sediment Disturbance	
Exposure (time)	Duration of Activity
Exposure (space)	Action Area Downstream of Work Area
Resource affected	Individuals (adults, juveniles), Habitat, Fish Hosts
Individual response	• Reduced respiration or smothering due to sediment deposition • Disruption of metabolic processes, leading to reduced fitness and growth rates • Reduced recruitment due to elimination of interstitial spaces used by juveniles • Movement due to alteration or loss of habitat • Displacement of fish hosts due to alteration or loss of habitat
Conservation Measures	• Perform in-stream activities during periods of low flow.
Effect	Adverse (harm, mortality)

Interpretation	The movement and initial deposition of sediment immediately after dam removal could smother mussels downstream of the work area or make habitat unsuitable, causing individuals to move to other areas.

6.2 WATER QUALITY DEGRADATION

Site preparation, lock and dam removal, and site stabilization could result in water quality degradation. Inputs of sediment or sediment disturbance in the Barren River could result in the suspension of fine sediment in the water column, leading to increased turbidity and decreased dissolved oxygen. These conditions could result in harm or mortality of mussels or cause individuals to move from an area if conditions persist for an extended period of time. High turbidity could affect the food supply of mussels by blocking sunlight needed by algae and phytoplankton and disrupt reproduction by reducing the visibility of mussel lures to fish hosts. Lower dissolved oxygen could affect the respiration of mussels and fish hosts. Petroleum-based contaminants from vehicles and equipment could also result in harm or mortality of mussels and their fish hosts. Potential impacts to the rough pigtoe and pyramid pigtoe from water quality degradation in the work area, the Action Area upstream of the work area, and the Action Area downstream of the work area are discussed in the following sections.

Work Area

Appropriate EPSC measures will be implemented and maintained throughout the work area prior to and during construction to reduce erosion and minimize sediment inputs into the Barren River. Sediment that enters the river downstream of the dam is not expected to remain suspended at sufficient concentrations to degrade water quality due to the flow of the river. Sediment that enters the pooled portion of the river upstream of the dam may remain suspended longer due to slower flow; however, this area does not provide suitable habitat for the rough pigtoe or pyramid pigtoe. Vehicles, equipment, and felled trees will also be prohibited from entering the river during site preparation. The heavy equipment access road crossing of Taylor Branch is not expected to cause water quality degradation in the Barren River due to the minimal amount of disturbed sediment and anticipated deposition of sediment in the stream channel prior to reaching the river.

Notching of the dam is not anticipated to result in water quality degradation. As discussed in Section 6.1, scouring at the base of the dam has removed the majority of fine sediment from this area and reduced the potential for sediment suspension. Any fine sediment that remains and becomes suspended would be carried downstream by the flow of the river before turbidity or dissolved oxygen levels could become detrimental to mussels. The increased flow from the notch is expected to dissipate a short distance downstream of the dam and is not anticipated to cause sediment disturbance or suspension downstream.

The placement of material on the downstream dam apron or at the base of the dam to create the in-stream work pad and the placement of excess material into the scour area is also not anticipated to degrade water quality. Fine sediment has been scoured from this area by the force of water flowing over the dam, making significant sediment suspension unlikely. Remaining fine sediment that becomes suspended would be transported downstream and dispersed before turbidity or dissolved oxygen levels could become detrimental to mussels.

Material that falls into the Barren River during lock and dam demolition will disturb sediment in some areas that could lead to degradation of water quality. Fine sediment above the dam may become suspended when material contacts the substrate during demolition. Disturbed sediment may increase turbidity for a longer period of time in this area due to slower flow; however, mussels are unlikely to be in this area due to the lack of suitable habitat. Suspended sediment that is transported downstream of the dam will disperse quickly due to the increased flow. Dam material that falls at the base of the dam and falling material from the inner lock downstream guide wall is also not expected to cause water quality degradation due to previous scouring of fine sediment from the base of the dam.

Falling material from the outer lock river wall and material placed in the downstream extent of the lock chamber may disturb and suspend sediment that has accumulated in the protected area downstream of the dam; however, suspended sediment is not expected to remain long enough to increase turbidity or decrease dissolved oxygen levels due to the flow of water through this area. Additionally, no mussels were encountered in this area during the survey of Transect BRD-09. Sediment that becomes suspended is expected to move downstream quickly and settle in existing depositional areas. Placement of the miter gates and other material into the outer lock chamber is not anticipated to result in water quality degradation due to the isolation of this area from the river channel and lack of flow into the river.

The movement of sediment that has accumulated upstream of the dam is likely to result in temporary water quality degradation in the work area. Although the amount of accumulated sediment appears to be low based on the substrate data collected during the 2021 mussel survey, sediment transport downstream is expected. The restoration of Pool 1 to free-flowing conditions will cause the suspension of fine sediments, which may lead to increased turbidity and decreased oxygen levels. These changes will likely persist during and immediately after dam removal as the accumulated sediment moves downstream. Changes in turbidity and oxygen levels upstream and at the dam location are not anticipated to affect listed mussels due to the unsuitable habitat in these areas; however, mussels located immediately downstream of the dam may be impacted. Due to the removal of the dam in small increments over a period of several weeks, the rapid movement of large amounts of suspended sediment into the work area is unlikely. Turbidity levels will likely increase gradually over time as more of the accumulated sediment upstream of the dam is exposed to increased flow. However, these levels may increase to the point that mussels, their food supply, and fish

hosts are affected. In addition, sediment that has settled in the work area may become resuspended during high flow events. The anticipated frequency and duration of these events, combined with the initial increase in suspended sediment immediately after dam removal, may cause turbidity levels to remain elevated long enough that mussels are adversely affected.

Site stabilization activities after lock and dam removal will reduce the potential for water quality degradation from sedimentation through seeding of disturbed areas and dressing of roads. EPSC measures will also be maintained until the site is stabilized. As a result, water quality degradation from this construction component is expected to be minimal.

Vehicles and equipment that contain petroleum-based products will be used in the work area during all construction components. During site preparation and stabilization, vehicles and equipment will operate along the riverbanks and will not enter the Barren River. Equipment operating from the in-stream work pad during lock and dam removal will only work in two feet of water or less to eliminate potential submersion of the engine compartment where most petroleum-based products are located. Petroleum-based products could enter the river through leaks and spills, which could harm or kill mussels, their food supply, and fish hosts. BMPs will be utilized throughout construction to reduce the potential for petroleum-based products to enter the river. The potential for leaks and spills will be further reduced by the minimal amount of equipment using the work pad and the short duration of the project. Additionally, any remaining hydraulic fluid in the hydraulic piping system in the control tower and outer lock chamber will be removed and appropriately disposed of prior to demolition of these structures. A spill response plan will be in place during construction, and any leaks or spills will be immediately cleaned up. If an accidental release does occur, the amount of petroleum-based product that enters the river is anticipated to be small and will be quickly dispersed and diluted by the flow of the river.

Water quality degradation from the construction components may also result in impacts to fish hosts for the rough pigtoe and pyramid pigtoe. Changes to water quality from sediment suspension or contaminants could cause fish hosts to abandon areas where mussels are present, reducing their exposure to mussels and limiting reproductive potential.

Action Area Upstream of Work Area

No construction components will occur in the Action Area upstream of the work area. Site preparation and stabilization activities in the work area are not expected to cause inputs of sediment into this area that could lead to water quality degradation due to the use of EPSC measures. The portion of the Action Area adjacent to and immediately upstream of the work area where the potential for water quality degradation from lock and dam demolition is highest does not provide suitable habitat for the rough pigtoe or pyramid pigtoe. The suspension of accumulated sediment in this area after dam removal will also occur in unsuitable habitat.

No vehicles or equipment will operate in the upstream portion of the Action Area; therefore, there is no potential for leaks or spills of petroleum-based products. Any releases of petroleum-based products in the work area would move downstream with the flow of the river. As a result, degradation of water quality from sediment disturbance and chemical contamination is not anticipated in the Action Area upstream of the work area.

Action Area Downstream of Work Area

No construction components will occur in the Action Area downstream of the work area. As discussed above, site preparation and stabilization activities are not expected to cause inputs of sediment beyond the work area due to the use of EPSC measures; therefore, degradation of water quality from sedimentation is unlikely. Inputs of sediment that do occur are anticipated to be minimal and will not lead to prolonged sediment suspension in one area due to the flow of the river. No vehicles or equipment will operate in the Action Area downstream of the work area, and the risk for petroleum-based products to flow downstream from the work area will be minimized by limiting the allowable water depth for equipment in the river and utilizing appropriate BMPs. Any releases of petroleum-based products in the work area would likely be diluted upon reaching the downstream portion of the Action Area.

Accumulated sediment upstream of the dam that becomes suspended is expected to move into the downstream portion of the Action Area during and after dam removal. This suspended sediment may cause turbidity levels to temporarily increase above existing conditions in this portion of the Action Area, which could potentially affect mussels. In addition, inputs of additional suspended sediment from farther upstream are also likely to occur during each high flow event, and the repeated occurrence of these events could adversely affect the rough pigtoe and pyramid pigtoe.

Applicable Science

Increased turbidity typically occurs during dam removals due to the disturbance and suspension of sediment that has accumulated behind the dam. Mussels may be impacted by high turbidity if the amount of light available for photosynthesis is reduced and potential food items like algae and phytoplankton decrease. The ability of fish hosts to detect mussel lures may also be impacted by low visibly from increased turbidity (Kanehl and Lyons 1992). Studies have shown that increased turbidity from dam removal is a temporary effect that subsides as sediment is flushed through the river system (Winter 1990, Kanehl et al. 1997). The amount of time required for high turbidity to decrease depends on several factors, including the amount of sediment that has accumulated behind the dam, the velocity of the river, the gradient of the riverbed, and the methods of dam removal. Turbidity increased after removal of a dam in Idaho but decreased within one week after removal, even though the impoundment was filled with sediment (Winter 1990). Accumulated sediment behind a run-of-river dam in Wisconsin took six months to move downstream, resulting in increased turbidity levels during this time (Nelson and Pajak 1990). The timing of dam removal can also

determine the severity and duration of increased turbidity, with high turbidity levels persisting longer if the dam is removed during low flow (Kondolf 1997).

Chemical contaminants that are released into waters are considered a major threat to mussel species (Strayer et al. 2004, Wang et al. 2010, Cope et al. 2008). Chemicals enter streams through point and non-point discharges, including spills, industrial and municipal effluents, and residential and agricultural runoff. These sources contribute organic compounds, heavy metals, nutrients, pesticides, pharmaceuticals, and a wide variety of other contaminants into the aquatic environment. Mussels are very intolerant of heavy metals (such as lead, zinc, cadmium, and copper) compared to other aquatic organisms. These heavy metals can cause mortality and affect biological processes, such as disrupting enzyme efficiency, altering filtration rates, reducing growth, and changing behavior of freshwater mussels (Naimo 1995, Jacobson et al. 1997, Valenti et al. 2005, Wang et al. 2010). Mussel recruitment may also be reduced in habitats with chronic heavy metal inputs (Naimo 1995, Ahlstedt and Tuberville 1997).

Another chemical that is particularly toxic to early life stages of mussels is ammonia from agricultural wastes, municipal wastewater treatment plants, and industrial waste (Augspurger et al. 2007). Polychlorinated biphenyls (PCBs) are also harmful to mussels based on their ability to bioaccumulate. PCBs are lipophilic, adsorb easily to soil and sediment, and are present in the sediment and water column in aquatic environments. These contaminants can cause oxidative stress, which damages all components of mussel cells (Lehmann et al. 2007).

Nutrients and pesticides from agriculture, timber harvest, and lawn management practices also have the potential to adversely impact mussel species. Nitrogen and phosphorus can enter streams through runoff from agricultural areas, post timber management activities, urban and suburban runoff, and residential lawns (Peterjohn and Correll 1984). Excessive nitrogen concentrations can result in shorter lifespans, reduced growth, and mortality (Bauer 1992). Nutrient enrichment can lead to increased algae respiration that depletes dissolved oxygen levels, which may be especially detrimental to juvenile mussels in interstitial spaces where dissolved oxygen concentrations are low (Sparks and Strayer 1998). Pesticides are often used during the reproductive and early life periods of mussels when their effects may be more pronounced. Elevated concentrations of pesticides occur in streams due to residential or commercial pesticide runoff, overspray application to row crops, and lack of adequate riparian buffers (Bringolf et al. 2007).

Effects Pathway #6	
Activity: Site Preparation, Site Stabilization	
Stressor: Water Quality Degradation (Turbidity)	
Exposure (time)	Duration of Activity
Exposure (space)	Work Area
Resource affected	Individuals (adults, juveniles), Habitat, Fish Hosts
Individual response	• Increased turbidity and low dissolved oxygen levels could lead to

	reduced fitness, reduced fecundity, and/or increased mortality. • Reduced reproduction due to inability of fish hosts to detect mussels due to increased turbidity • Reduced aquatic food organism diversity and abundance could negatively impact mussel growth, survival, and reproduction • Displacement of fish hosts due to alteration or loss of habitat
Conservation Measures	• Implement EPSC measures in the work area. • Revegetate disturbed areas immediately following completion of ground disturbing activities.
Effect	Insignificant
Interpretation	Appropriate EPSC measures will be implemented and maintained throughout the work area to minimize sediment inputs into the Barren River and maintain water quality. Vehicles and equipment will not enter the river, and no woody debris will be placed in the river.

Effects Pathway #7	
Activity: Lock and Dam Removal	
Stressor: Water Quality Degradation (Turbidity)	
Exposure (time)	Duration of Activity
Exposure (space)	Work Area
Resource affected	Individuals (adults, juveniles), Habitat, Fish Hosts
Individual response	• Increased turbidity and low dissolved oxygen levels could lead to reduced fitness, reduced fecundity, and/or increased mortality. • Increased turbidity results in inability of fish hosts to detect mussels, negatively affecting reproduction • Reduced aquatic food organism diversity and abundance could negatively impact mussel growth, survival, and reproduction • Displacement of fish hosts due to alteration or loss of habitat
Conservation Measures	• Perform in-stream activities during periods of low flow. • Use of in-stream work pad during lock and dam removal to minimize impacts to the river from equipment. The work pad will be located in areas that do not provide suitable habitat for the rough pigtoe or pyramid pigtoe.
Effect	Adverse (harm, mortality)
Interpretation	The suspension of fine sediments that have accumulated upstream of the dam is likely to cause increased turbidity in the work area during and immediately after dam removal. Turbidity levels will increase gradually over time as more of the accumulated sediment upstream of the dam is exposed to increased flow, potentially increasing to the point that mussels, their food supply, and fish hosts in the downstream portion of the work area are affected.

Effects Pathway #8	
Activity: Site Preparation, Site Stabilization	
Stressor: Water Quality Degradation (Turbidity)	
Exposure (time)	Duration of Activity
Exposure (space)	Action Area Upstream and Downstream of Work Area
Resource affected	Individuals (adults, juveniles), Habitat, Fish Hosts
Individual response	• Increased turbidity, low dissolved oxygen levels, and chemical contaminants could lead to reduced fitness, reduced fecundity, and/or increased mortality. • Increased turbidity results in inability of fish hosts to detect mussels, negatively affecting reproduction • Reduced aquatic food organism diversity and abundance could negatively

	impact mussel growth, survival, and reproduction • Increased harm or mortality of fish hosts • Displacement of fish hosts due to alteration or loss of habitat
Conservation Measures	• Implement EPSC measures in the work area. • Revegetate disturbed areas immediately following completion of ground disturbing activities.
Effect	Insignificant
Interpretation	No construction components will occur in the Action Area upstream or downstream of the work area. Water quality degradation from inputs of sediment into these areas are not expected due to the use of EPSC measures. Any inputs of sediment that occur in the upstream portion of the Action Area will be located in unsuitable habitat for the listed mussels, and inputs in the downstream portion will be dispersed by the river's flow before degradation of water quality occurs.

Effects Pathway #9	
Activity: Lock and Dam Removal	
Stressor: Water Quality Degradation (Turbidity)	
Exposure (time)	Duration of Activity
Exposure (space)	Action Area Upstream of Work Area
Resource affected	Individuals (adults, juveniles), Habitat, Fish Hosts
Individual response	• Increased turbidity and low dissolved oxygen levels could lead to reduced fitness, reduced fecundity, and/or increased mortality. • Increased turbidity results in inability of fish hosts to detect mussels, negatively affecting reproduction • Reduced aquatic food organism diversity and abundance could negatively impact mussel growth, survival, and reproduction • Displacement of fish hosts due to alteration or loss of habitat
Conservation Measures	• Perform in-stream activities during periods of low flow.
Effect	Insignificant
Interpretation	No construction components will occur in the Action Area upstream of the work area. The portion of the Action Area adjacent to and immediately upstream of the work area where the potential for water quality degradation is highest does not provide suitable habitat for the rough pigtoe or pyramid pigtoe.

Effects Pathway #10	
Activity: Lock and Dam Removal	
Stressor: Water Quality Degradation (Turbidity)	
Exposure (time)	Duration of Activity
Exposure (space)	Action Area Downstream of Work Area
Resource affected	Individuals (adults, juveniles), Habitat, Fish Hosts
Individual response	• Increased turbidity and low dissolved oxygen levels could lead to reduced fitness, reduced fecundity, and/or increased mortality. • Increased turbidity results in inability of fish hosts to detect mussels, negatively affecting reproduction • Reduced aquatic food organism diversity and abundance could negatively impact mussel growth, survival, and reproduction • Displacement of fish hosts due to alteration or loss of habitat
Conservation Measures	• Perform in-stream activities during periods of low flow.
Effect	Adverse (harm, mortality)
Interpretation	The suspension of fine sediments that have accumulated upstream of the dam is likely to cause increased turbidity downstream of the work area during and

	immediately after dam removal. Turbidity levels will increase gradually over time as more of the accumulated sediment upstream of the dam is exposed to increased flow, potentially increasing to the point that mussels, their food supply, and fish hosts downstream of the work area are affected.

Effects Pathway #11	
Activity: Site Preparation, Lock and Dam Removal, Site Stabilization	
Stressor: Water Quality Degradation (Chemical)	
Exposure (time)	Duration of Activity
Exposure (space)	Work Area, Action Area Downstream of Work Area
Resource affected	Individuals (adults, juveniles), Habitat, Fish Hosts
Individual response	• Reduced fitness, reduced fecundity, and/or increased mortality • Increased harm or mortality of fish hosts • Displacement of fish hosts due to alteration or loss of habitat
Conservation Measures	• Use of in-stream work pad during lock and dam removal to minimize impacts to the river from equipment. The work pad will be located in areas that do not provide suitable habitat for the rough pigtoe or pyramid pigtoe. • Implement BMPs when operating machinery on the in-stream work pad or within the riparian area to avoid and minimize the potential for accidental spills and have a spill response plan in place should an accidental spill occur. • Remove any remaining hydraulic fluid from the hydraulic piping system in the control tower and lock chamber and dispose of appropriately.
Effect	Insignificant
Interpretation	Vehicles and equipment will operate along the riverbanks during site preparation and stabilization. BMPs will be utilized when equipment is present on the in-stream work pad, and equipment will only operate in water depths of two feet or less to reduce the potential for petroleum-based products to enter the river. A spill response plan will be in place during construction, and any leaks or spills will be immediately cleaned up. If an accidental release does occur, the amount of petroleum-based product that enters the river is anticipated to be minimal and be quickly dispersed and diluted by the flow of the river. No vehicles or equipment will operate in the downstream portion of the Action Area; therefore, there is no potential for leaks or spills of petroleum-based products. Any products released in the work area would likely be diluted before reaching this portion of the Action Area.

Effects Pathway #12	
Activity: Site Preparation, Lock and Dam Removal, Site Stabilization	
Stressor: Water Quality Degradation (Chemical)	
Exposure (time)	Duration of Activity
Exposure (space)	Action Area Upstream of Work Area
Resource affected	Individuals (adults, juveniles), Habitat, Fish Hosts
Individual response	• Reduced fitness, reduced fecundity, and/or increased mortality • Increased harm or mortality of fish hosts • Displacement of fish hosts due to alteration or loss of habitat
Conservation Measures	• Use of in-stream work pad during lock and dam removal to minimize impacts to the river from equipment. The work pad will be located in areas that do not provide suitable habitat for the rough pigtoe or pyramid pigtoe. • Implement BMPs when operating machinery on the in-stream work pad or within the riparian area to avoid and minimize the potential for accidental

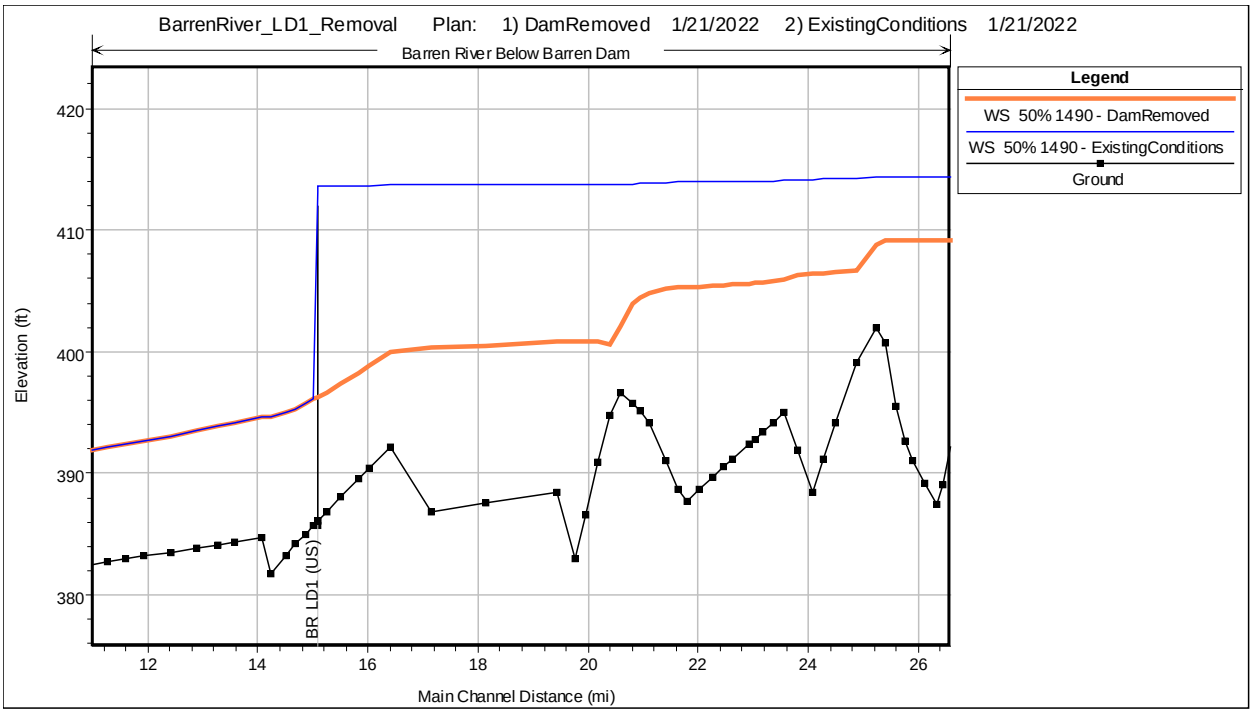
	spills and have a spill response plan in place should an accidental spill occur.
Effect	Discountable
Interpretation	No vehicles or equipment will operate in the upstream portion of the Action Area; therefore, there is no potential for leaks or spills of petroleum-based products. Any releases of petroleum-based products in the work area would move downstream away from this area.

6.3 CHANGES TO FLOW

Lock and dam removal is the only construction component that could result in changes to flow in the Barren River. Site preparation and stabilization will not result in changes to flow due to the lack of in-stream activities associated with these components. Changes to flow from lock and dam removal could impact mussels and their habitat by altering the morphology of the river channel, causing sediment degradation and aggradation, and affecting water quality. Potential impacts to the rough pigtoe and pyramid pigtoe from changes to flow in the work area, the Action Area upstream of the work area, and the Action Area downstream of the work area are discussed in the following sections.

Work Area

Changes to the hydraulic conditions in the Barren River after removal of BRLD1 were analyzed by the USACE based on available hydraulic modeling. A memorandum summarizing the findings was prepared by the USACE and is included as Appendix C. According to the memorandum, BRLD1 is a run-of-river type dam and does not significantly impound flood water within Pool 1. The crest of the dam is located at an elevation of approximately 412 feet AMSL, and the elevation of the associated floodplain is approximately 420 to 430 feet AMSL. Due to the difference between these elevations, the hydraulic capacity over the dam is large enough to allow the inflow and outflow of Pool 1 to be effectively equal. Flow downstream of the dam is not affected by the presence of the dam; therefore, removal of the dam is not anticipated to change downstream flow from existing conditions. This lack of change is demonstrated in the following exhibit from the memorandum.



The exhibit shows the water surface profiles for the existing conditions with the dam in place (blue line) and conditions after dam removal (orange line). Both profiles are identical downstream of the dam, indicating that downstream flow is not affected by the dam. In addition, the depth and water surface slope downstream of the dam will remain the same after dam removal.

As documented in the USACE memorandum, BRLD1 does not attenuate flow, change downstream depths, or impact downstream water surface slopes to a measurable degree; therefore, shear stress and sediment transport capacity downstream of the dam are also not affected by the structure and are not expected to change after its removal. As a result, increased scouring and sediment deposition from changes in flow are unlikely to occur downstream after dam removal. Conversely, removal of the dam is expected to reduce scouring downstream of the dam by reducing the turbulent conditions caused by water flowing over the dam. Elimination of the plunging, vertical flow at the dam is anticipated to significantly reduce or stop scouring at the former dam location. The restoration of more natural flow in this area will help retain the material placed in the scour area during dam demolition and allow fine sediments to accumulate in this area after dam removal.

Action Area Upstream of Work Area

Changes in flow will occur in the upstream portion of the Action Area as Pool 1 returns to free-flowing conditions. Although these changes will result in modifications to channel morphology and cause sediment degradation and aggradation in this area, the effects from these changes are expected to be minimal due to the location of the pool within the existing riverbanks and the gradual removal of the dam during a period

of low flow. Significant additional effects are also not anticipated during high flow events because floodwater is currently conveyed over the dam, causing the inflow and outflow of Pool 1 to be equal. As a result, effects that would occur to the river channel during high flows after dam removal are already occurring. In addition, effects from flow changes will primarily occur in unsuitable to poor quality habitat for the rough pigtoe and pyramid pigtoe, making it unlikely that individuals will be affected by these changes.

Action Area Downstream of Work Area

As discussed for the work area, changes in flow downstream of BRLD1 are not expected from removal of the dam. Significant changes in channel morphology and increased sediment degradation and aggradation in the downstream portion of the Action Area are not anticipated due to the lack of change in water depths, water surface slopes, shear stress, and sediment transport capacity downstream of the dam after removal.

Applicable Science

Dams alter flow by impounding or pooling long reaches of free-flowing rivers, resulting in changes to hydrology and channel morphology, increased sediment deposition, altered water quality, decreased habitat heterogeneity, altered flood patterns, and decreased movement of mussels and fish (Neves et al. 1997, Watters 2000). Habitat heterogeneity is often reduced from six to seven habitat types to three or four, some of which are highly modified from the existing habitat or new to the river system. Although the original channel remains upstream of the dam, increased depth and slower flow rapidly alter existing habitats. Decreased flow reduces sediment transport, causing fine sediment to settle and blanket the substrate with silt. Siltation of the river bottom can affect mussels through smothering, diminishing food supply by limiting light penetration, altering temperatures, and reducing recruitment (Watters 2000). Siltation can also change species composition in the impounded or pooled areas by reducing the presence of species intolerant of silt with silt-tolerant species (Holland-Bartels 1990, Parmalee and Hughes 1993).

Changes in flow downstream of dams leads to scouring and bank erosion, reduced dissolved oxygen, temperature fluctuations, and changes in mussel and fish composition (Neves et al. 1997, Watters 2000). The acceleration of water as it flows over a run-of-river dam results in scour of the stream bed and banks, often producing a scour area or plunge pool at the base of the dam (Csiki and Rhoads 2014, Pearson and Pizzuto 2015). Scouring at the base of the dam mobilizes fine sediments and smaller coarse sediments, leaving only cobble, boulders, and bedrock (Skalak et al. 2009, Csiki and Rhoads 2014). A mid-channel bar often forms downstream of the dam that consists of scoured materials (Csiki and Rhoads 2014). Scouring immediately below dams can be extensive and can eliminate or prevent mussels from inhabiting these areas (Miller and Payne 1992).

The removal of dams and restoration of natural river flow appear to have a positive impact on mussels. Mussels downstream of run-of-river dams have responded favorably to their removal, and in some cases, have made dramatic increases (Haag 2012).

Effects Pathway #13	
Activity: Lock and Dam Removal	
Stressor: Changes to Flow	
Exposure (time)	Indefinite
Exposure (space)	Work Area
Resource affected	Individuals (adults, juveniles), Habitat, Fish Hosts
Individual response	• Mortality due to alteration of loss of flow regime • Reduction or loss of fish hosts due to changes to flow regime
Conservation Measures	• N/A
Effect	Insignificant
Interpretation	Based on hydraulic analysis modeling by the USACE, the dam does not attenuate discharge, velocity, or shear stresses downstream; therefore, these conditions are not anticipated to change after removal of the dam. Elimination of the plunging, vertical flow at the dam is anticipated to result in positive effects by significantly reducing or stopping scouring in the area below the dam.

Effects Pathway #14	
Activity: Lock and Dam Removal	
Stressor: Changes to Flow	
Exposure (time)	Indefinite
Exposure (space)	Action Area Upstream of the Work Area
Resource affected	Individuals (adults, juveniles), Habitat, Fish Hosts
Individual response	• Mortality due to alteration of loss of flow regime • Reduction or loss of fish hosts due to changes to flow regime
Conservation Measures	• N/A
Effect	Insignificant
Interpretation	Changes in flow are expected to be minimal due to the gradual removal of the dam during a period of low flow. Removal of the dam will result in a more natural flow regime that will promote natural sediment movement and is expected to positively affect mussel species. Effects during high flow events are expected to be similar to existing conditions. These changes will also occur primarily within unsuitable to poor quality habitat for the rough pigtoe and pyramid pigtoe.

Effects Pathway #15	
Activity: Lock and Dam Removal	
Stressor: Changes to Flow	
Exposure (time)	Indefinite
Exposure (space)	Action Area Downstream of the Work Area
Resource affected	Individuals (adults, juveniles), Habitat, Fish Hosts
Individual response	• Mortality due to alteration of loss of flow regime • Reduction or loss of fish hosts due to changes to flow regime
Conservation Measures	• N/A
Effect	Insignificant

Interpretation	Based on hydraulic modeling by the USACE, the dam does not attenuate discharge, velocity, or shear stresses downstream; therefore, flow conditions are not anticipated to change after removal of the dam.

6.4 CRUSHING OR STRIKING OF INDIVIDUALS

Lock and dam removal is the only construction component that could result in crushing or striking of individuals. Site preparation and stabilization will not result in crushing or striking of individuals due to the lack of in-stream activities associated with these components. Material that is placed or falls on a mussel during lock and dam removal could result in harm if the individual is struck or mortality if the individual is crushed. The striking of mussels could also lead to mortality if an individual sustains severe damage. Potential impacts to the rough pigtoe and pyramid pigtoe from crushing or striking of individuals in the work area, the Action Area upstream of the work area, and the Action Area downstream of the work area are discussed in the following sections.

Work Area

The placement of material on the downstream dam apron or at the base of the dam to create the in-stream work pad and placement of excess material into the scour area could result in the crushing or striking of individuals. Although the presence of the rough pigtoe and pyramid pigtoe at the base of the dam is unlikely due to the constant turbulence generated by water flowing over the dam and the lack of suitable substrate from scouring, these species could be present immediately downstream of the dam. During the survey of Transect BRD-09, four non-listed individuals were found in the portion of the transect downstream of the dam, and other mussels could be present in this area. Material placed at the downstream edge of the fill area could extend into areas where mussels are located and crush or strike an individual. Mussels could also be crushed or struck by pieces of material from the work pad that move downstream during placement or are dislodged by equipment, as well as during transport of material from the dam to the lock chamber. Placement of material or material that falls into the river upstream of the dam is not anticipated to crush or strike individuals due to the lack of suitable habitat for the rough pigtoe and pyramid pigtoe in this area.

Falling material from the inner lock downstream guide wall and outer lock river wall and material placed in the downstream extent of the lock chamber are not anticipated to crush or strike mussels due to the lack of individuals encountered in this area during the survey of Transect BRD-09. Placement of the miter gates and material into the lock chamber is not anticipated to crush or strike individuals due to the lack of suitable habitat in the chamber.

During and after dam removal, the increased flow could cause the cobble and boulders observed immediately upstream of the dam to be transported downstream. Some of these rocks may settle in the

scour area at the base of the dam; however, others may continue downstream of the dam into areas where mussels are present, resulting in the crushing or striking of individuals.

Action Area Upstream and Downstream of Work Area

No construction components will occur in the Action Area upstream or downstream of the work area. Material that is placed or falls into the river during lock and dam removal is not expected to enter these areas. As a result, the crushing or striking of individuals in the upstream and downstream portions of the Action Area is not anticipated as a result of the project.

Applicable Science

Although evidence of mussels being crushed or struck by debris during removal of dams has not been reported, crushing and striking from other sources has been documented. A study on the effects of barge fleeting in the Illinois River found evidence that mussels had been crushed and struck by barges that grounded on the substrate. Mussel species with heavy shells exhibited scrapes and appeared to have been pushed down into the mud substrate when the barges made contact. Species with fragile shells appeared to be crushed completely based on shell fragments found under the barges. The study also noted that propellers may have hit the substrate and contributed to the scrapes observed on some mussel shells, as well as mortality (Sparks and Blodgett 1985). Another study on the Mississippi River also found evidence of mussels being crushed by barges along the shoreline (Millar and Mahaffy 1989).

Trampling of mussels by people, animals, and vehicles has also been reported. Crushed mussels, deformed shells, and shell fragments have been found in areas where livestock have access to streams. Fords where vehicles cross streams are often devoid of mussels, suggesting that individuals in these areas have been crushed or moved to other areas after being struck. Mussels may also be impacted by canoeists, kayakers, and other recreational users as they move over shallow riffles while portaging, fishing, or wading. These types of disturbances may be particularly detrimental to smaller mussel species, species with thin shells, and juveniles (Watters 2000). Based on this evidence, it is reasonable to assume that debris that enters the water during the removal of dams and locks could crush or strike individuals.

Effects Pathway #16	
Activity: Lock and Dam Removal	
Stressor: Crushing or Striking of Individuals	
Exposure (time)	Duration of Activity
Exposure (space)	Work Area
Resource affected	Individuals (adults, juveniles)
Individual response	• Harm or mortality from being crushed or struck by material
Conservation Measures	N/A
Effect	Adverse (harm, mortality)
Interpretation	Mussels could be crushed or struck during the placement of material downstream of the dam to create the in-stream work pad and fill the scour area. Material that falls during transport from the dam to the lock chamber

	could also crush or strike mussels. Mussels may also be crushed or struck by cobble and boulders located upstream of the dam moving downstream during and after dam removal.

Effects Pathway #17	
Activity: Lock and Dam Removal	
Stressor: Crushing or Striking of Individuals	
Exposure (time)	Duration of Activity
Exposure (space)	Action Area Upstream and Downstream of Work Area
Resource affected	Individuals (adults, juveniles)
Individual response	• Harm or mortality from being crushed or struck by material
Conservation Measures	N/A
Effect	Discountable
Interpretation	No construction components will occur in the Action Area upstream or downstream of the work area, and material from the work area is not anticipated to enter these areas.

6.5 DISPLACEMENT OF INDIVIDUALS

Lock and dam removal is the only construction component that could result in displacement of individuals. Site preparation and stabilization will not displace individuals due to the lack of in-stream activities associated with these components. During lock and dam removal, material that is placed or falls on the river bottom and disturbs the substrate could displace an adjacent individual. Displaced mussels could be moved to an area of unsuitable habitat, requiring the individual to move to a more suitable area and expend energy. Displacement may also lead to harm or mortality if the mussel is unable to find suitable habitat quickly. Potential impacts to the rough pigtoe and pyramid pigtoe from displacement of individuals in the work area, the Action Area upstream of the work area, and the Action Area downstream of the work area are discussed in the following sections.

Work Area

Notching of the dam could displace mussels located immediately downstream due to the increased velocity and force created by the concentrated flow. Scouring from increased flow could also displace mussels. As previously discussed, the area at the base of the dam does not provide suitable habitat for the rough pigtoe or pyramid pigtoe. Additionally, no mussels were found along the right descending portion of Transect BRD-09 downstream of the dam notch location. Any increased flows farther downstream of the notch are anticipated to be similar to conditions during flood events currently experienced by mussels in these areas. Based on these factors, displacement of individuals from notching of the dam is unlikely.

The placement of material on the downstream dam apron or at the base of the dam to create the in-stream work pad and placement of excess material into the scour area is unlikely to displace individuals due to the lack of suitable habitat in this area. Material that is placed at the downstream edge of the fill area or falls

off the work pad could enter areas of suitable mussel habitat; however, displacement of individuals is not anticipated. The size of the material will be similar to large cobble and small boulders and will have a small impact area, reducing the amount of substrate that will be displaced. Additionally, the substrate downstream of the dam is likely comprised of coarse sediments with little fine sediment due to the scouring effect created by the dam, and movement from material hitting the substrate is expected to be minimal. If a mussel is displaced, the individual will likely move a short distance and remain in suitable habitat. Material that falls into the river downstream of the dam during transport to the lock chamber is expected to have similar effects. Material that enters the river upstream of the dam is not anticipated to displace individuals due to the lack of suitable habitat for the rough pigtoe and pyramid pigtoe in this area.

Material that falls from the inner lock downstream guide wall and outer lock river wall and material placed in the downstream extent of the lock chamber are not anticipated to displace mussels due to the lack of individuals encountered in this area during the survey of Transect BRD-09. Placement of the miter gates and material into the lock chamber is not anticipated to displace individuals due to the lack of suitable habitat in the chamber.

Action Area Upstream of Work Area

No construction components will occur in the Action Area upstream of the work area. Increased flow may occur immediately upstream of the dam notch; however, these areas are unsuitable for mussels and will not displace individuals. As a result, the displacement of individuals in the Action Area upstream of the work area is not anticipated as a result of the project.

Action Area Downstream of Work Area

No construction components will occur in the Action Area downstream of the work area. The increased flow created by notching of the dam is expected to dissipate prior to reaching the downstream portion of the Action Area. Additionally, no mussels were found in the portion of the Action Area immediately downstream of the dam notch. Therefore, the displacement of individuals in the Action Area downstream of the work area is not anticipated.

Applicable Science

Published data on the displacement of mussels from dam removal is lacking; however, mussel displacement from turbulence created by boats has been noted. Studies have shown that turbulence generated by the surge of large vessels as they pass by or over mussels and from boat propellers (i.e., propeller wash) can displace mussels from the substrate (Sparks and Blodgett 1985, Aldridge et al. 1987, Millar and Mahaffy 1989, Watters 2000). The potential for displacement is highest in shallow areas, particularly near riverbanks. Based on these studies, concentrated flows of turbulent water, such as those that may occur during dam removal, have the potential to displace mussels from the substrate.

Effects Pathway #18	
Activity: Lock and Dam Removal	
Stressor: Displacement of Individuals	
Exposure (time)	Duration of Activity
Exposure (space)	Work Area
Resource affected	Individuals (adults, juveniles)
Individual response	• Harm or mortality if displaced to unsuitable habitat • Movement of displaced individuals to suitable habitat, which may lead to increased energy expenditure and decreased fitness
Conservation Measures	N/A
Effect	Insignificant
Interpretation	Notching of the dam is unlikely to displace individuals due to the lack of suitable habitat below the dam and absence of observed mussels immediately downstream. Material that enters the river upstream and downstream of the dam is unlikely to displace individuals due to either the lack of suitable habitat or low potential for substrate movement in these areas. Falling material from the inner lock downstream guide wall or outer lock river wall and the placement of material in the downstream extent of the outer lock chamber are not anticipated to displace mussels due to the lack of individuals encountered around these structures during the survey.

Effects Pathway #19	
Activity: Lock and Dam Removal	
Stressor: Displacement of Individuals	
Exposure (time)	Duration of Activity
Exposure (space)	Action Area Upstream and Downstream of Work Area
Resource affected	Individuals (adults, juveniles)
Individual response	• Harm or mortality if displaced to unsuitable habitat • Movement of individuals to suitable habitat, which may lead to increased energy expenditure and decreased fitness
Conservation Measures	N/A
Effect	Discountable
Interpretation	No construction components will occur in the Action Area upstream or downstream of the work area, and material from the work area is not anticipated to enter these areas.

6.6 EXPOSURE OF INDIVIDUALS

Lock and dam removal is the only construction component that could result in exposure of individuals. Site preparation and stabilization will not result in this stressor due to the lack of in-stream activities associated with these components. Removal of BRLD1 will lower the water level of the Barren River upstream of the dam, which could expose mussels in shallow areas as the water level recedes. Exposed mussels could be harmed if individuals are stressed and suffer increased energy expenditure or reduced fitness. Mortality may occur if mussels are unable to move to deeper water or move downward in the substrate to reach saturation zones. Potential impacts to the rough pigtoe and pyramid pigtoe from exposure of individuals in the work area, the Action Area upstream of the work area, and the Action Area downstream of the work area are discussed in the following sections.

Work Area

The removal of the dam will lower the water level of the river in the upstream portion of the work area. The work area upstream of the dam does not provide suitable habitat for the rough pigtoe or pyramid pigtoe; therefore, the lower water level in this area is not anticipated to expose individuals of these species.

Action Area Upstream of Work Area

Removal of the dam will lower the water level of the Barren River throughout the upstream portion of the Action Area. As discussed in Section 5.1, the portion of the river between BRLD1 and seven miles upstream was deemed to be unsuitable habitat for the rough pigtoe and pyramid pigtoe. Habitat generally improves from seven miles upstream of BRLD1 to the end of the Action Area, transitioning from poor-quality to suitable habitat for these species.

Based on the Hydrologic and Hydraulic Analysis included in the Disposition Study (USACE 2014), removal of BRLD1 will lower the water level seven miles upstream by approximately 12 feet based on the 100% duration flow for August (base flow). The difference in water level will decrease with increasing distance from BRLD1 to the end of the Action Area. After the dam is notched, the water level in Pool 1 is expected to recede slowly due to the small size of the opening(s); however, as larger sections of the dam are removed and more water flows through, the rate of recession is anticipated to increase beyond the normal rate of recession during seasonal periods of low water. The lower water level will expose areas of the river that have been inundated since the dam was constructed, potentially exposing mussels along the banks and in shallower areas. Lewis noted during the mussel survey that multiple survey transects in Pool 1 were located in relatively shallow areas that may become exposed after dam removal. Additionally, mussels were found in shallow areas near the riverbanks and shallow gravel bars in one to three feet of water. Based on these findings, Lewis concluded that the likelihood is high for mussels in these areas to become exposed or stranded after dam removal (Lewis 2021).

Action Area Downstream of Work Area

The water level of the Barren River in the downstream portion of the Action Area will not be influenced by the removal of BRLD1. As a result, the exposure of individuals from lock and dam removal is not anticipated in the Action Area downstream of the work area.

Applicable Science

Dam removal can expose mussels within the impounded or pooled area upstream of a dam as the water level is lowered. The number of mussels exposed during drawdown appears to be related to the rate at which the water level is lowered. After removal of a run-of-river dam in Wisconsin, Sethi et al. 2004 observed extensive mortality of mussels resulting from stranding, desiccation, and predation. Based on the number of dead mussels observed, the authors estimated that nearly 4,700 individuals had died from

exposure after drawdown of the pool upstream of the dam. These results appeared to be caused by the rapid dewatering of the pool, which occurred in approximately 36 hours, and the study recommended a slow drawdown period for pools to minimize mussel exposure. Similar results were found after removal of a run-of-river dam in New York, where the rapid draining of the dam pool resulted in the deaths of more than 2,800 mussels, or 77% of the estimated population, upstream of the dam. The 1.3-hectare reservoir was drained in 25 hours and lowered the water level by 47 centimeters at the reservoir center and 3.3 meters at the dam (Cooper 2011).

Exposure of mussels was documented upstream of GRLD6 after the breach of the dam in 2016. The Kentucky Department of Fish and Wildlife Resources, in cooperation with MCNP and other agencies, conducted a salvage survey over four days at six sites upstream of GRLD6 immediately after the dam breach. The sites included four islands and two associated areas where the lower water level exposed large areas of the river bottom that were previously covered by shallow water. During the survey, a total of 2,404 individual mussels were found exposed along shoals and bank edges, including 2,010 live individuals and 394 dead individuals. Five sheepnose individuals and one fanshell individual were among the live mussels that were encountered. Evidence of some individuals moving from exposed areas to deeper water was observed; however, mortality would likely have been higher if the salvage survey had not occurred (McGregor et al. 2016).

Conversely, slow drawdowns of dam pools during and after dam removal appear to reduce the amount of mussel exposure. Dewatering of the pool during removal of a North Carolina dam over a three week period resulted in only minimal exposure of mussels. The low number of exposed individuals was also attributed to the pool being confined within the banks of the river, reducing the amount of riverbed exposed after dam removal. Time of year was also a factor, as the dam was removed in the fall/winter when dissolved oxygen concentrations are highest and water temperatures are cool (Heise et al. 2013).

Effects Pathway #20	
Activity: Lock and Dam Removal	
Stressor: Exposure of Individuals	
Exposure (time)	Duration of Activity
Exposure (space)	Work Area, Action Area Downstream of Work Area
Resource affected	Individuals (adults, juveniles)
Individual response	• Harm or mortality if individual becomes exposed • Movement of individual to deeper water, which may lead to increased energy expenditure and decreased fitness
Conservation Measures	N/A
Effect	Discountable
Interpretation	The water level of the river in the downstream portion of the Action Area will not be lowered from the removal of BRLD1. Removal of the dam will lower the water level in the work area upstream of BRLD1; however, this area does not provide suitable habitat for the rough pigtoe or pyramid pigtoe.

Effects Pathway #21	
Activity: Lock and Dam Removal	
Stressor: Exposure of Individuals	
Exposure (time)	Duration of Activity
Exposure (space)	Action Area Upstream of Work Area
Resource affected	Individuals (adults, juveniles)
Individual response	• Harm or mortality if individual becomes exposed • Movement of individual to deeper water, which may lead to increased energy expenditure and decreased fitness
Conservation Measures	• Incremental removal of the dam to reduce the rate of water recession upstream of the dam • Monitoring in the upstream portion of the Action Area during dam removal to locate exposed mussels and return individuals to areas of suitable habitat
Effect	Adverse (harm, mortality)
Interpretation	The portion of the river from BRLD1 to seven miles upstream provides unsuitable habitat for the rough pigtoe and pyramid pigtoe; therefore, lowering the water level in this reach is unlikely to expose individuals of these species. However, suitable habitat for these species may be present from seven miles upstream of BRLD1 to the end of the Action Area, and the water level in this area will lower by approximately 12 feet after dam removal. The reduction in water level will expose portions of the river channel where mussels may occur, forcing exposed individuals to move to deeper water or down to saturation zones. Mortality is expected for individuals that are unable to move to suitable areas.

6.7 INVASIVE SPECIES

As discussed in Section 5.3, Asian carp and the zebra mussel may present a biological threat to the rough pigtoe and pyramid pigtoe. Although not considered to be a direct stressor from the proposed Action, the removal of BRLD1 may allow these species to expand their ranges farther upstream, which could potentially impact the rough pigtoe and pyramid pigtoe through competition and predation. Both invasive species have been documented in the Green River downstream of BRLD1; however, the abundance and range of these species are not known. Asian carp have been found in the Green River upstream of the confluence with the Barren River (Eggers 2019), and these species could presumably be in the lower Barren River. Zebra mussels have not been documented in the Barren River but are known from the lower Green River (Haag and Cicerello 2016). This species is not as mobile as Asian carp and would presumably take a longer time to expand its range into the Barren River. However, removal of BRLD1 would allow Asian carp and the zebra mussel to move freely upstream and expand their numbers and range in the Barren River.

The potential expansion of Asian carp and the zebra mussel in the Barren River after removal of BRLD1 could impact the rough pigtoe and pyramid pigtoe; however, the level of impact is difficult to discern based on available data. As a result, potential impacts to these two mussel species from invasive species are considered insignificant.

6.8 POSITIVE EFFECTS

In addition to the stressors identified in the previous sections, the proposed Action is expected to result in positive effects to the rough pigtoe and pyramid pigtoe. Dams result in physical, chemical, and biological impacts to rivers and streams, and the negative impacts of impoundments and pools on mussel assemblages, survival, and reproduction has been documented in this report. Removal of dams provides an opportunity to reverse these impacts and restore ecological functions to the ecosystem. Although few studies have examined the effects of dam removal to mussels and the overall ecosystem, the long-term benefits of dam removal are anticipated to outweigh the temporary, short-term impacts and help restore the system to more natural conditions (Sethi et al. 2004, Doyle et al. 2005, Sherman 2013).

The removal of BRLD1 is anticipated to improve mussel habitat in the Pool 1, restore a more natural flow regime, improve sediment and nutrient transport, improve water quality, and restore fish host passage in the Action Area. Removal of the dam will convert Pool 1 from lentic habitat back to lotic habitat (Sethi et al. 2004). As previously discussed, the pool does not currently provide suitable habitat for the rough pigtoe or pyramid pigtoe for many miles upstream of the dam, and the conversion of this reach to a free-flowing system will create more suitable habitat for mussels in the future. Restoration of a more natural flow regime will also help improve mussel habitat in the Action Area through improved sediment transport and distribution. Impounded rivers compensate for the absence of sediment downstream of the dam by eroding, incising, and scouring downstream reaches (Poff et al. 1997, Gilliam 2011) and depositing sediments in areas farther downstream (Collier et al 1996). After removal of BRLD1, fine sediment from upstream of the dam will be transported and redistributed downstream, restoring small particles to the scour areas downstream of the dam. In addition, the movement of accumulated sediment from Pool 1 will expose gravel, cobble, and boulders that have previously been covered by silt (Bednarek 2001). Although the movement of fine sediment downstream may result in adverse effects to mussels immediately after dam removal, this sediment is anticipated to be flushed farther downstream and be distributed over a larger area with each high water event. Nutrients and organic material will also be transported downstream, providing increased food supply for mussels.

Restoration of a more natural flow regime will also improve water quality in the Action Area. Turbidity is expected to increase from sediment suspension during and immediately after dam removal; however, the amount of suspended sediment is anticipated to decrease soon after substrate disturbance ceases, and suspended sediment will be transported downstream and settle over a large area. In the long term, turbidity levels are expected to remain low due to restoration of the free-flowing river. The unimpeded flow after dam removal is also anticipated to increase dissolved oxygen levels, particularly upstream of the dam. Temperatures upstream of the dam will also become more stable and consistent with other free-flowing portions of the river (Bednarek 2001).

Increased movement of fish hosts after removal of BRLD1 will further benefit the rough pigtoe and pyramid pigtoe. As Pool 1 returns to lotic conditions and habitat improves, fish hosts carrying glochidia are expected to move upstream and help establish mussel beds (Sethi et al. 2004). Populations of fish hosts that may have been previously separated by the dam will be able to intermingle, helping to increase their numbers and subsequently aiding in mussel reproduction.

6.9 CUMULATIVE EFFECTS

Cumulative effects are those that are reasonably certain to take place in the future as a result of activities unrelated to the proposed Action. The purpose of the proposed Action is to improve passage for aquatic organisms and restore instream habitat above and below the dam for riverine fish and macroinvertebrates. Future activities, such as increased residential or commercial development, agricultural practices, increased traffic, or tourism, in the area are not reasonably certain to occur as a result of the Action. Based on these factors, no cumulative effects to the rough pigtoe or pyramid pigtoe are anticipated as a result of the proposed Action.

6.10 SUMMARY OF EFFECTS

The proposed Action could expose the rough pigtoe and pyramid pigtoe to the stressors evaluated in the previous section. Anticipated adverse effects to these species are anticipated from: sediment disturbance and water quality degradation in the work area and the Action Area downstream of the work area during lock and dam removal; crushing or striking of individuals in the work area during lock and dam removal; and exposure of individuals in the Action Area upstream of the work area during lock and dam removal. These stressors and the remaining stressors are expected to have insignificant or discountable effects on these species throughout the remainder of the Action Area. Potential effects to the rough pigtoe and pyramid pigtoe are summarized in the following table.

Stressor	Action Component	Location	Effect	
			Adverse	Insignificant/Discountable
Sediment Disturbance	Site Preparation	Action Area		X
	Lock and Dam Removal	Action Area US of Work Area		X
		Work Area	X	
		Action Area DS of Work Area	X	
	Site Stabilization	Action Area		X
Water Quality Degradation	Site Preparation	Action Area		X
	Lock and Dam Removal	Action Area US of Work Area		X
		Work Area	X	
		Action Area DS of Work Area	X	
	Site Stabilization	Action Area		X
Changes to Flow	Site Preparation	Action Area		X
	Lock and Dam Removal	Action Area		X
	Site Stabilization	Action Area		X
Crushing/Striking of Individuals	Site Preparation	Action Area		X
	Lock and Dam Removal	Action Area US of Work Area		X
		Work Area	X	
		Action Area DS of Work Area		X
	Site Stabilization	Action Area		X
Displacement of Individuals	Site Preparation	Action Area		X
	Lock and Dam Removal	Action Area		X
	Site Stabilization	Action Area		X
Exposure of Individuals	Site Preparation	Action Area		X
	Lock and Dam Removal	Action Area US of Work Area	X	
		Work Area		X
		Action Area DS of Work Area		X
	Site Stabilization	Action Area		X

6.11 EFFECTS DETERMINATION

Potential impacts to the rough pigtoe and pyramid pigtoe have been minimized to the extent possible through the use of conservation measures; however, adverse effects to these species are expected as a result of the proposed Action. Based on these findings, an effects determination of **"may affect, likely to adversely affect"** has been made for the rough pigtoe. Although adverse effects are also anticipated to the pyramid pigtoe, these effects are not likely to jeopardize the continued existence of this proposed species. Therefore, an effects determination of "**may affect, not likely to jeopardize**" has been made for the pyramid pigtoe.

7.0 CONCLUSION

The biological assessment for the proposed Action included a habitat assessment and a mussel survey within the Action Area. During the habitat assessment, forested habitat within the Action Area was identified as suitable summer roosting, foraging, and commuting habitat for the Indiana and northern long-eared bats and suitable commuting habitat for the gray bat. The proposed Action will require the removal of up to 4.87 acres of forested habitat within the work area. Tree fall along the riverbanks upstream of the dam is also likely and is estimated at 33.39 acres. The Barren River was identified as suitable gray bat foraging habitat and suitable habitat for the federally listed mussel species. Jennings Creek, a tributary of the Barren River, was also identified as suitable foraging habitat for the gray bat. Due to the absence of occurrence records or lack of recent records for the spectaclecase, fanshell, purple cat's paw, northern riffleshell, snuffbox, longsolid, pink mucket, ring pink, sheepnose, clubshell, and rabbitsfoot within the Action Area, these species are considered absent. No suitable habitat for Price's potato-bean was identified in the work area, and potential habitat for this species in the remainder of the Action Area will not be impacted. Additionally, no suitable habitat for the Kentucky cave shrimp is present in the Action Area. Critical habitat for the Indiana bat was identified as occurring in the Action Area; however, this habitat is located more than 18 miles east of the Action Area.

The habitat assessment also included an in-house review of available resources to identify karst features, abandoned mine portals, and other underground features in the vicinity of the proposed Action that could provide potential hibernacula or roosting habitat for the three listed bat species. Due to the construction components being limited to the work area, efforts were focused on locating potential hibernacula within or near this area. No known features are mapped within 2.5 miles of the work area, and no features were identified in the work area during the field survey. As a result, no potential hibernacula or non-winter roosting habitat for the three bat species are present in the work area. Seven bridges in the Action Area are considered to be suitable roosting habitat for these species; however, no work will occur on these structures. Multiple sinkholes are mapped adjacent to the Action Area that may provide hibernacula and/or roosting habitat for the three bat species; however, no adverse effects to these features are anticipated from the proposed Action.

A presence/probable absence survey for the 13 mussel species was performed in the Action Area. During the survey, two rough pigtoe individuals and four pyramid pigtoe individuals were found in the portion of the Action Area downstream of BRLD1. No individuals of federally listed mussel species were encountered in the Action Area upstream of BRLD1.

Based on the results of the biological assessment, effects to the gray bat from the proposed Action are considered insignificant. Effects to the spectaclecase, fanshell, purple cat's paw, northern riffleshell,

snuffbox, longsolid, pink mucket, ring pink, sheepnose, clubshell, rabbitsfoot, and Price's potato-bean are considered discountable. Therefore, an effects determination of "may affect, not likely to adversely affect" has been made for these 13 species, and informal consultation with the USFWS is proposed to address potential effects to these species.

The proposed Action will result in adverse effects to the Indiana and northern long-eared bats from habitat loss associated with tree clearing. Adverse effects to these two species will be mitigated through a payment to the Imperiled Bat Conservation Fund, utilizing the process set forth in the Conservation Strategy. As a result, an effects determination of "may affect, likely to adversely affect" has been made for the Indiana and northern long-eared bats. Informal consultation with the USFWS is proposed to address potential effects to these two species.

The proposed Action is expected to result in adverse effects to the rough pigtoe, and an effects determination of "may affect, likely to adversely affect" has been made for this species. Adverse effects are also anticipated to the pyramid pigtoe; however, these effects are not likely to jeopardize the continued existence of this proposed species. Therefore, an effects determination of "may affect, not likely to jeopardize" has been made for the pyramid pigtoe. Formal consultation/conference with the USFWS is proposed to address potential adverse effects to the rough pigtoe and pyramid pigtoe.

8.0 REFERENCES

Ahlstedt, S.A. and J.D. Tuberville. 1997. Quantitative reassessment of the freshwater mussel fauna in the Clinch and Powell Rivers, Tennessee and Virginia. Pp. 72-97 in: K.S. Cummings, A.C. Buchanan, C.A. Mayer, and T.J. Naimo, eds. Conservation and management of freshwater mussels II: initiatives for the future. Proceedings of a UMRCC symposium, October 1995, St. Louis, Missouri. Upper Mississippi River Conservation Committee, Rock Island, IL.

Aldridge, D.W., B.S. Payne, and A.C. Miller. 1987. The effects of intermittent exposure to suspended solids and turbulence on three species of freshwater mussels. Environmental Pollution 45: 17-28.

Augspurger, T., F.J. Dwyer, C.G. Ingersoll, and C.M. Kane. 2007. Advances and opportunities in assessing containment sensitivity of freshwater mussel (Unionidae) early life stages. Environmental Toxicology and Chemistry 26(10): 2025-2028.

Bauer, G. 1992. Variation in the life span and size of the freshwater pearl mussel. Journal of Animal Ecology 61:425-436.

Bednarek, A.T. 2001. Undamming Rivers: A Review of the Ecological Impacts of Dam Removal. Environmental Management Vol. 27, No. 6, pp. 803–814.

Brim-Box, J.B. and J. Mossa. 1999. Sediment, land use, and freshwater mussels: prospects and problems. Journal of North American Benthological Society 18(1):99-117.

Bringolf, R.B., W.G. Cope, S. Mosher, M.C. Barnhart, and D. Shea. 2007. Contaminant sensitivity of freshwater mussels: Acute and chronic toxicity of glyphosphate compounds to glochidia and juveniles of Lampsilis siliquoidea (Unionidae). Environmental Toxicology and Chemistry 26(10):2094-2100.

Collier, M., R.H. Webb, and J.C. Schmidt. 1996. Dams and rivers; a primer on the downstream effects of dams. U.S. Geological Survey Circular, 94-94.

Cooper, J.E. 2011. Unionid Mussel Mortality from Habitat Loss in the Salmon River, New York, following Dam Removal. Advances in Environmental Research. Volume 14.

Cope, W.G., R.B. Bringolf, D.B. Buchwalter, T.J. Newton, C.G. Ingersoll, N. Wang, T. Augspurger, F.J. Dwyer, M.C. Barnhart, R.J. Neves, and E. Hammer. 2008. Differential exposure, duration, and sensitivity of unionoidean bivalve life stages to environmental contaminants. Journal of North American Benthological Society 27(2): 451-462.

Csiki S.R. and B.L. Rhoads. 2014. Influence of four run-of-river dams on channel morphology and sediment characteristics in Illinois, USA. Geomorphology 206: 215–229.

Doeg, T.J. and J.D. Koehn. 1994. Effects of draining and desilting a small weir on downstream fish and macroinvertebrates. Regulated Rivers: Research and Management 9: 263–277.

Doyle, M.W., E.H. Stanley, C.H. Orr, A.R. Selle, S.A. Sethi, and J.M. Harbor. 2005. Stream ecosystem response to small dam removal: Lessons from the Heartland. Geomorphology 71 (2005) 227–244.

Eggers, C. "Asian carp increasing in Mammoth Cave." Bowling Green Daily News (Bowling Green, KY), April 2, 2019. https://www.bgdailynews.com/news/asian-carp-increasing-in-mammoth-cave/article_e88b2a1a-cabf-52e8-8a8a-cc906359936a.html. Accessed August 27, 2020.

Gardner, J.E., J.D. Garner, and J.E. Hofmann. 1991. Summer roost selection and roosting behavior of Myotis sodalis (Indiana bat) in Illinois. Unpublished report to Region-3 U.S. Fish and Wildlife Service, Fort Snelling, MN. 56 pp.

Gilliam, E.A. 2011. Assessing Channel Change and Bank Stability Downstream of a Dam, Wyoming. Colorado State University. Fort Collins, CO.

Grabarkiewicz, J. and W. Davis. 2008. An introduction to freshwater mussels as biological indicators. EPA-260-R-08-015. U.S. Environmental Protection Agency, Office of Environmental Information, Washington, DC.

Haag, W.R. 2012. North American freshwater mussels: natural history, ecology, and conservation, first edition, Cambridge University Press, New York, NY.

Haag, W.R. and R.R. Cicerello. 2016. A Distributional Atlas of the Freshwater Mussels of Kentucky. Scientific and Technical Series 8. Kentucky State Nature Preserves Commission. Frankfort, KY.

Hawkins, J.A., P.L. Sewell, and M.W. Gumbert. 2008. Final Report: Indiana bat survey and anthropogenic stimuli study conducted at US Army Garrison Fort Knox and Brashears Creek study sites during summer 2007. Copperhead Environmental Consulting, Inc.

Heise, R.J., W.G. Cope, T.J. Kwak, C.B. Eads. 2013. Short-Term Effects of Small Dam Removal on a Freshwater Mussel Assemblage. Freshwater Mollusk Biology and Conservation 16(1): 41-52.

Holland-Bartels, L.E. 1990. Physical factors and their influence on the mussel fauna of a main channel border habitat of the upper Mississippi River. Journal of the North American Benthological Society 9: 327-335.

Jacobson, P.J., R.J. Neves, D.S. Cherry, and J.L. Farris. 1997. Sensitivity of glochidial stages of freshwater mussels (Bivalvia: Unionidae) to copper. Environmental Toxicology and Chemistry 16:2384-2392.

Kanehl, P. and J. Lyons. 1992. Impacts of in-stream sand and gravel mining on stream habitat and fish communities, including a survey on the Big Rib River, Marathon County, Wisconsin. Wisconsin Department of Natural Resources Research Report 155. 32 pp.

Kanehl, P. D., J. Lyons, and J. E. Nelson. 1997. Changes in the habitat and fish community of the Milwaukee River, Wisconsin, following removal of the Woolen Mills Dam. North American Journal of Fisheries Management 17:387–400.

Kentucky Department of Fish and Wildlife Resources (KDFWR). 2022. Invasive Carp Information. https://fw.ky.gov/Fish/Pages/Invasive-Carp-Information.aspx. Accessed January 2022.

Kentucky Geological Survey (KGS). 2022. Kentucky Geologic Map Information Service. Karst Potential Map. http://kgs.uky.edu/kgsmap/kgsgeoserver/viewer.asp. Accessed January 2022.

Kentucky Office of Mine and Safety Licensing. 2022. Kentucky Mine Mapping Information System. Kentucky Coal Mine Maps. https://eppcgis.ky.gov/minemapping. Accessed January 2022.

Kondolf, G.M. 1997. Hungry water: Effects of dams and gravel mining on river channels. Environmental Management 21(4): 533–551.

Lehmann D.W., J.F. Levine, J. M. Law. 2007. Polychlorinated biphenyl exposure causes gonadal atrophy and oxidative stress in Corbicula fluminea clams. Toxicology and Pathology 35:356-365.

Lewis Environmental Consulting, LLC. 2008. Mussel Surveys at Barren River Miles 7.7, 9.7, 12, and 14 in Warren County, Kentucky to Assess Pipeline Crossing Impacts to Mussel Beds. Prepared for Gulfstar Energy, LLC. Morgantown, KY 85 pp.

Lewis Environmental Consulting, LLC. 2021. Mussel Survey of Barren River Pool 1 and Downstream of Barren River Lock and Dam 1 in Warren County, Kentucky. Prepared for U.S. Fish and Wildlife Service – Kentucky Field Office. Frankfort, KY. 72 pp.

McGregor, M.A., K. Kern, R.S. Toomey, S.L. Carr, A. McDonald, T. Bailey, D. Cravens, and J. Jacobs. 2016. Salvage of Freshwater Mussels After Failure of Lock and Dam 6 on the Green River. Report prepared by the Kentucky Department of Fish and Wildlife Resources, Center for Mollusk Conservation, Frankfort, KY.

Millar, J.G. and M.S. Mahaffy. 1989. Background Study on the Environmental Impacts of Barge Fleeting. EMTC 89/04. U. S. Fish and Wildlife Service, Environmental Management Technical Center, Onalaska, WI.

Miller, A.C. and B.S. Payne. 1992. Characterization of a freshwater mussel (Unionidae) community immediately downstream of Kentucky Lock and Dam in the Tennessee River. Transactions of the Kentucky Academy of Science 53: 154-161.

Naimo, T.J. 1995. A Review of the Effects of Heavy Metals on Freshwater Mussels. Ecotoxicology 4(6): 341-362.

Nelson, J.E., and P. Pajak. 1990. Fish habitat restoration following dam removal on a warmwater river. Pages 57–65 in The restoration of Midwestern stream habitat. American Fisheries Society, North Central Division, Rivers and Streams Technical Committee Symposium Proceedings at the 52nd Midwest Fish and Wildlife Conference, 4–5 December 1990. Minneapolis, MN.

Neves, R.J., A.E. Bogan, J.D. Williams, S.A. Ahlstedt, and P.W. Hartfield. 1997. Chapter 3: Status of aquatic mollusks in the southeastern United States: a downward spiral of diversity in G. W. Benz, and D. E. Collins, editors. Aquatic fauna in peril: the southeastern perspective. Southeastern Aquatic Research Institute, Decatur, GA.

Parmalee, P.W. and A.E. Bogan. 1998. The Freshwater Mussels of Tennessee. University of Tennessee Press, Knoxville, TN. 328 pp.

Parmalee, P.W. and M.H. Hughes. 1993. Freshwater mussels (Mollusca:Pelecypoda:Unionidae) of Tellico Lake: twelve years after impoundment of the Little Tennessee River. Annals of the Carnegie Museum 62: 81-93.

Pearson, A.J. and J. Pizzuto. 2015. Bedload transport over run-of-river dams, Delaware, USA. Geomorphology 248: 382-395.

Peterjohn, W.T., and D.L. Correll. 1984. Nutrient Dynamics in an Agricultural Watershed: Observations on the Role of a Riparian Forest. Ecology 65(5): 1466-1475.

Poff, N.L., J.D. Allan, M.B. Bain, J.R. Karr, K.L. Prestegaard, B.D. Richter, R.E. Sparks, and J.C. Stromberg. 1997. The Natural Flow Regime. Bioscience 47:769-84.

Sethi, S.A., A.R. Selle, M.W. Doyle, E.H. Stanley, H.E. Kitchel. 2004. Response of unionid mussels to dam removal in Koshkonong Creek, Wisconsin. Hydrobiologia 525,157– 165.

Sherman, M. 2013. Potential impacts of small dam removal on fish and mussel communities in North Carolina. Master's Thesis. Nicholas School of the Environment of Duke University. Durham, NC. 57 pp.

Skalak, K., J. Pizzuto, and D. Hart. 2009. Influence of small dams on downstream channel characteristics in Pennsylvania and Maryland: Implications for the long-term geomorphic effects of dam removal. J Am Water Resour Assoc 45: 97–109.

Sparks, R.E. and K.D. Blodgett. 1985. Effects of Fleeting on Mussels. Interim Report to the Illinois Department of Conservation and the National Marine Fisheries Service.

Sparks, B.L. and D.L. Strayer. 1998. Effects of low dissolved oxygen on juvenile Elliptio complanata (Bivalvia: Unionidae). Journal of North American Benthological Society 17(1):129-134.

United States Army Corps of Engineers (USACE). 2014. Green River Locks and Dams 3, 4, 5 and 6 and Barren River Lock and Dam 1 Disposition Feasibility Study, Kentucky.

United States Department of Agriculture (USDA). 2022. National Invasive Species Information Center. https://www.invasivespeciesinfo.gov/aquatic/fish-and-other-vertebrates. Accessed January 2022.

United States Fish and Wildlife Service (USFWS). 1976. Endangered and Threatened Wildlife and Plants; Endangered Status for 159 Taxa of Animals. 41 FR 24062-24067.

United States Fish and Wildlife Service (USFWS). 1984. Rough Pigtoe Pearly Mussel Recovery Plan. U.S. Fish and Wildlife Service. Atlanta, GA. 51 pp.

United States Fish and Wildlife Service (USFWS). 2014. Rough Pigtoe (*Pleurobema plenum*) 5-Year Review: Summary and Evaluation. U.S. Fish and Wildlife Service, Frankfort, KY. 17 pp.

United States Fish and Wildlife Service (USFWS). 2015a. Endangered and Threatened Wildlife and Plants; Threatened Species Status for the Northern Long-Eared Bat with 4(d) Rule. Final rule, and interim rule with request for comments. 80 FR 17974-18033.

United States Fish and Wildlife Service (USFWS). 2015b. Biological Opinion for Kentucky Field Office's Participation in Conservation Memoranda of Agreement for the Indiana Bat and/or Northern Long-eared Bat. Southeast Regional Office. Atlanta, GA. 84 pp.

United States Fish and Wildlife Service (USFWS). 2021. Endangered and Threatened Wildlife and Plants; Threatened Species Status With Section 4(d) Rule for Pyramid Pigtoe. 86 FR 49989-50011.

United States Fish and Wildlife Service Information for Planning and Conservation (USFWS IPaC). 2022. Endangered, Threatened, Proposed, and Candidate Species listed under the Endangered Species Act. https://ecos.fws.gov/ipac. Accessed January 6, 2022.

United States Fish and Wildlife Service Kentucky Ecological Services Field Office (USFWS KFO). 2016. Revised Conservation Strategy for Forest-Dwelling Bats in the Commonwealth of Kentucky. Kentucky Ecological Services Field Office. Frankfort, KY. 32 pp.

United States Fish and Wildlife Service Kentucky Ecological Services Field Office (USFWS KFO). 2019a. Known Indiana bat habitat in Kentucky and within 20 miles (August 2019). Map. Kentucky Ecological Services Field Office. Frankfort, KY.

United States Fish and Wildlife Service Kentucky Ecological Services Field Office (USFWS KFO). 2019b. Known northern long-eared bat habitat in Kentucky and within 20 miles (August 2019). Map. Kentucky Ecological Services Field Office. Frankfort, KY.

United States Fish and Wildlife Service Kentucky Ecological Services Field Office (USFWS KFO) and Kentucky Department of Fish and Wildlife Resources (KDFWR). 2016a. Kentucky Topographic Quadrangles Containing Northern Long-eared Bat Roost Trees and/or Hibernaculum. Kentucky Ecological Services Field Office. Frankfort, KY. Kentucky Department of Fish and Wildlife Resources. Frankfort, KY. 3 pp.

Valenti, T.W., D.S. Cherry, R.J. Neves, and J. Schmerfeld. 2005. Acute and chronic toxicity of mercury to early life stages of the rainbow mussel, Villosa iris (Bivalvia: Unionidae). Environmental Toxicology and Chemistry 24(5):1242-1246.

Vannote, R.L. and G.W. Minshall. 1982. Fluvial processes and local lithology controlling abundance, structure, and composition of mussel beds. Proceedings of the National Academy of Science USA 79:4103-4107.

Wang, N., C.G. Ingersoll, C.D. Ivey, D.K. Hardesty, T.W. May, T. Augspurger, A.D. Roberts, E. Van Genderen, and M.C. Barnhart. 2010. Sensitivity of early lifestages of freshwater mussels (Unionidae) to acute and chronic toxicity of lead, cadmium, and zinc in water. Environmental Toxicology and Chemistry 29(9):2053-2063.

Watters, G.T. 2000. Freshwater mussels and water quality: A review of the effects of hydrologic and instream habitat alterations. Pages 261-274 in P. D. Johnson, and R. S. Butler, editors. Proceedings of the First Freshwater Mussel Conservation Society Symposium, 1999. The Ohio State University, Columbus, OH.

Winter, B.D. 1990. A brief review of dam removal efforts in Washington, Oregon, Idaho, and California. US Department of Commerce, NOAA Tech. Memo. NMFS F/NWR-28, 13 pp.

FIGURES

Source: USA Topo Maps, (2013) NGS, USGS 7.5-minute Topographic Map - Hadley and Bowling Green North, Kentucky Quadrangles.

BARREN RIVER LOCK AND DAM 1
REMOVAL PROJECT
WARREN COUNTY, KENTUCKY

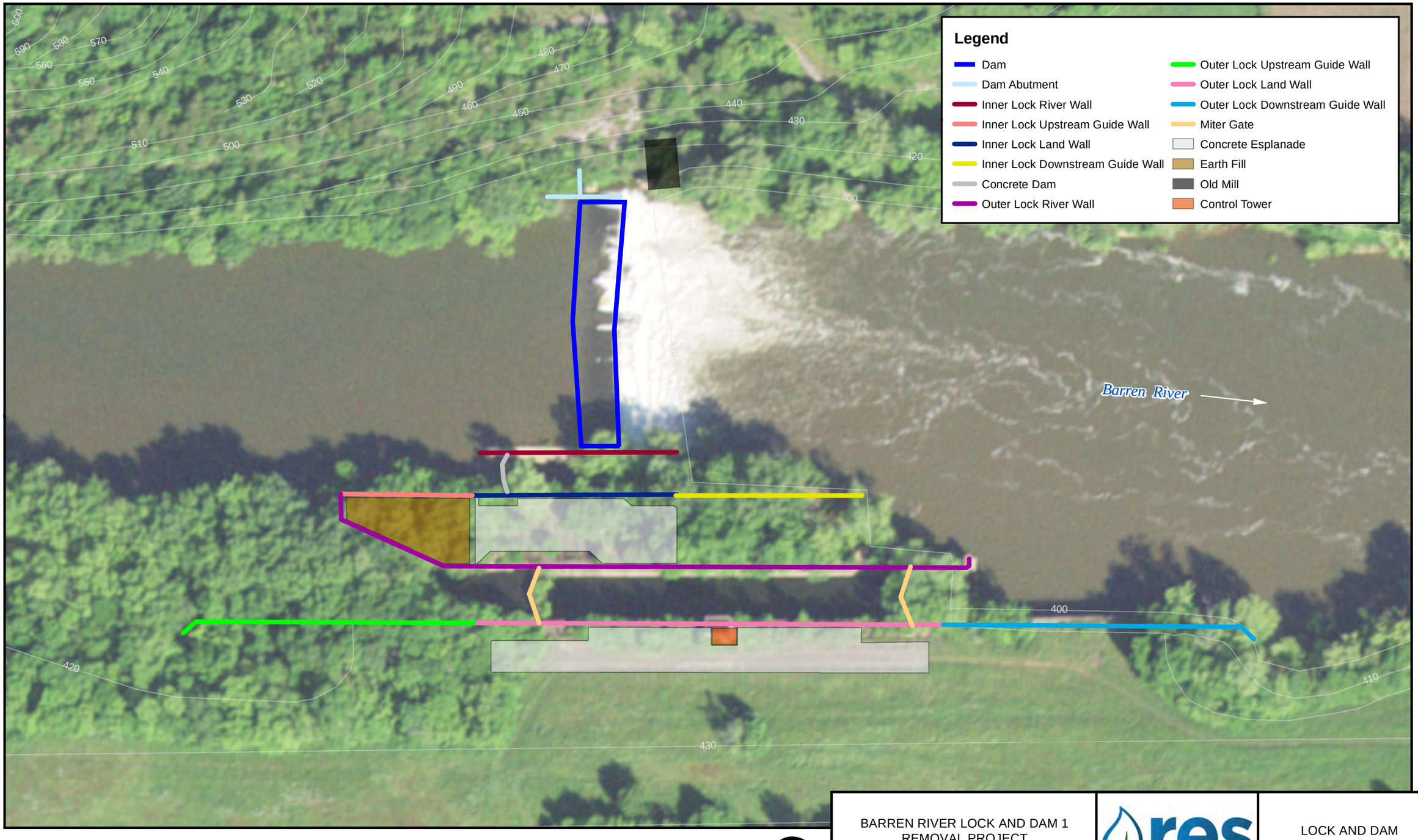
SITE LOCATION MAP

REVISED DATE: 01-11-22 | DRAWN BY: EDB

FIGURE 1

R:\Resgis\entgis\Projects\105106_Barren_River_Lock_and_Dam_1_Removal\MXD\SiteLocationMap.mxd, 01-11-2022, sbishop

Source: World Imagery Clarity - Esri and the GIS User Community (2018); Kentucky Tagged Vector Contour (TVC) by Kentucky Division of Geographic Information.



0 50 100 200 300 400 Feet

BARREN RIVER LOCK AND DAM 1
REMOVAL PROJECT
WARREN COUNTY, KENTUCKY

REVISED DATE:01-25-22 | DRAWN BY: EDB

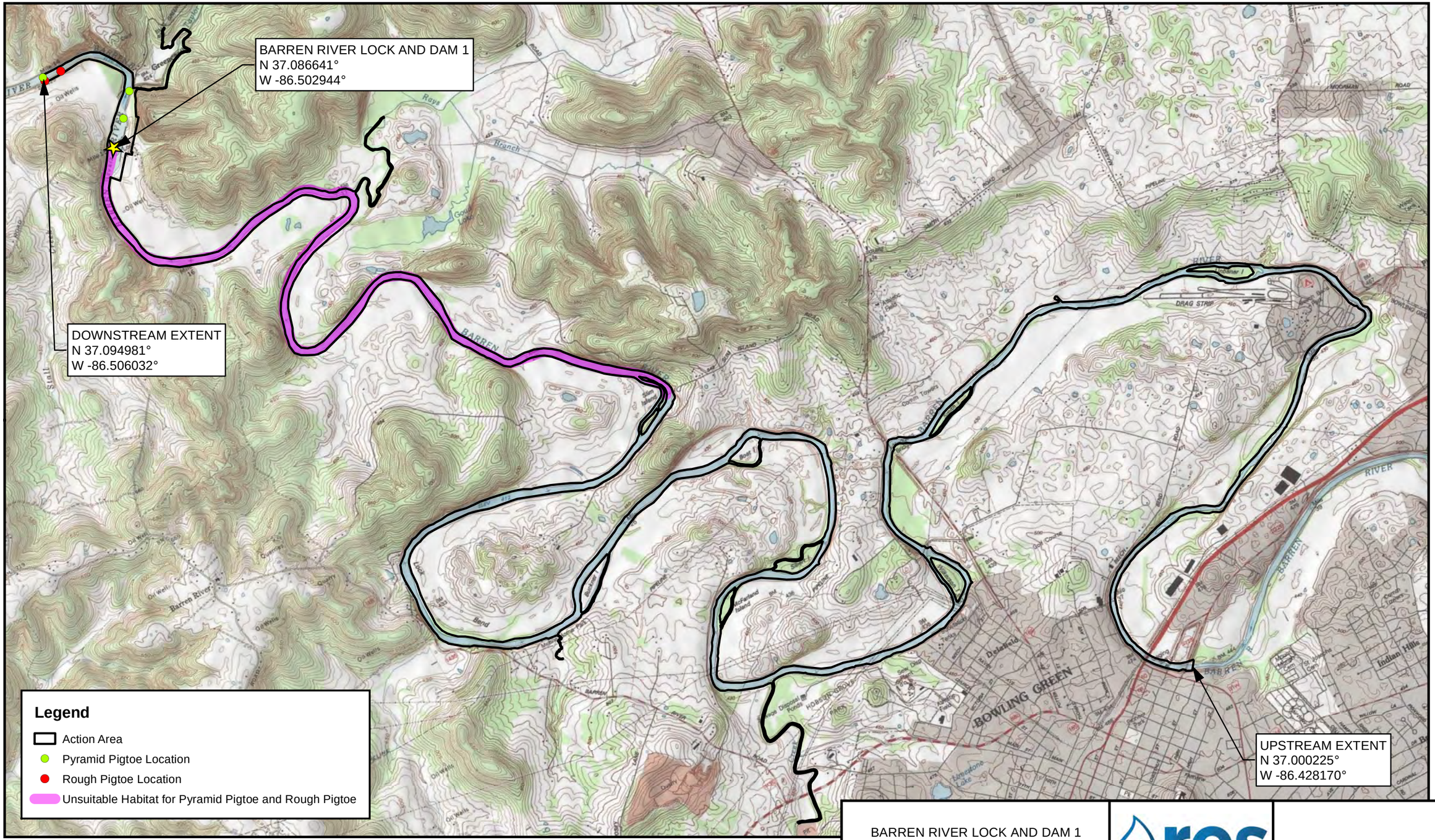
res

LOCK AND DAM
STRUCTURES MAP

FIGURE 2

R:\Resgis\entgis\Projects\105106_Barren_River_Lock_and_Dam_1_Removal\MXD\Lock and Dam Component Map.mxd, 02-3-2022, sbishop

Source: USA Topo Maps, (2013) National Geographic Society, USGS 7.5-minute Topographic Map - Hadley, Bowling Green North, Bristow, Rockfield, Bowling Green South, and Polkville, Kentucky Quadrangles.



BARREN RIVER LOCK AND DAM 1
REMOVAL PROJECT
WARREN COUNTY, KENTUCKY

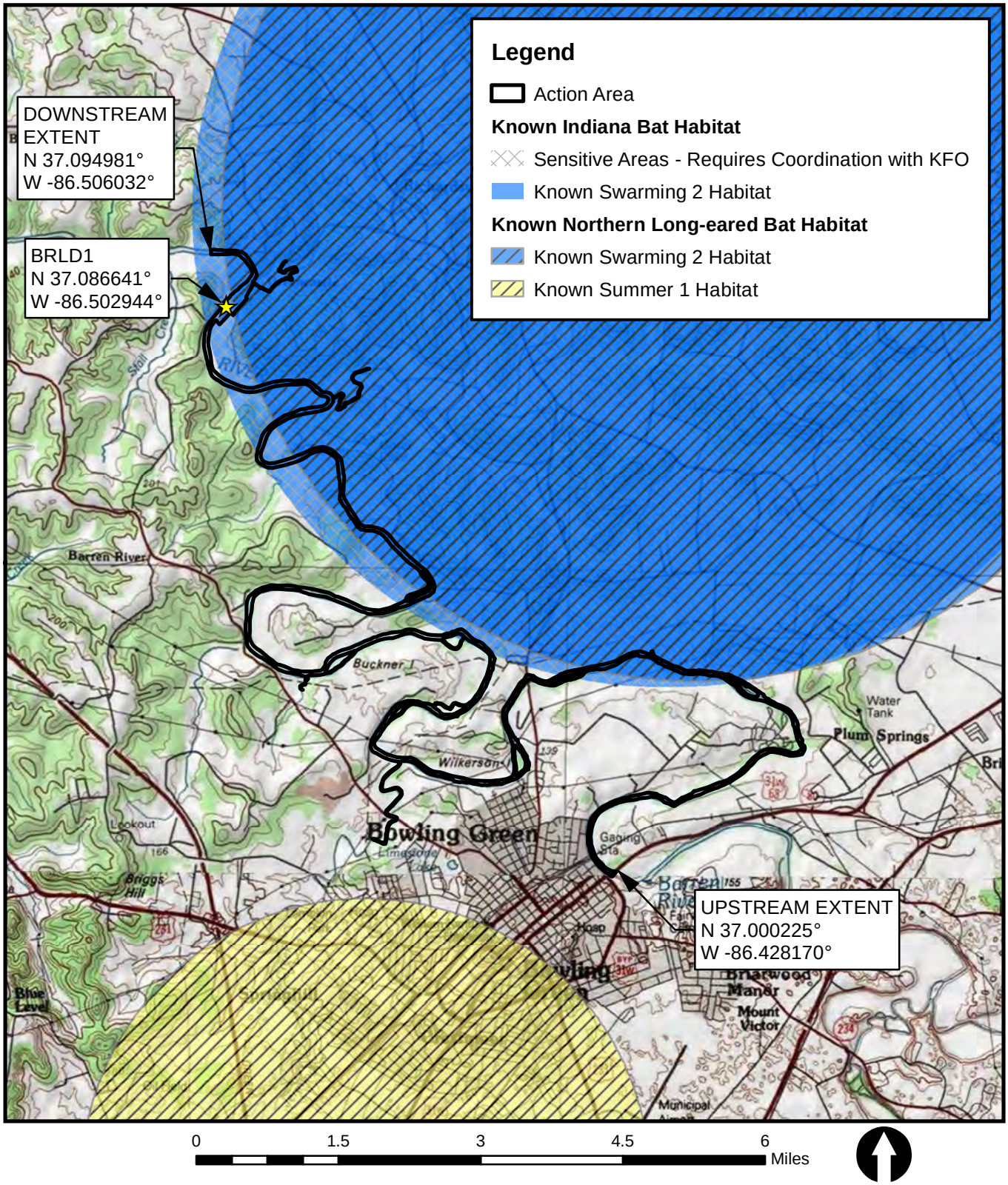
ACTION AREA MAP

REVISED DATE:02-25-22 | DRAWN BY: SRB/EDB

FIGURE 3

R:\Resgis\entgis\Projects\105106_Barren_River_Lock_and_Dam_1_Removal\MXD\Action Area Map.mxd, 02-25-2022, ebowman

Source: USA Topo Maps, (2013) NGS, USGS 7.5-minute Topographic Map - Hadley and Bowling Green North, Kentucky Quadrangles; USFWS Kentucky Field Office - Indiana and Northern Long-eared Bat Habitat (2019).



BARREN RIVER LOCK AND DAM 1
REMOVAL PROJECT
WARREN COUNTY, KENTUCKY

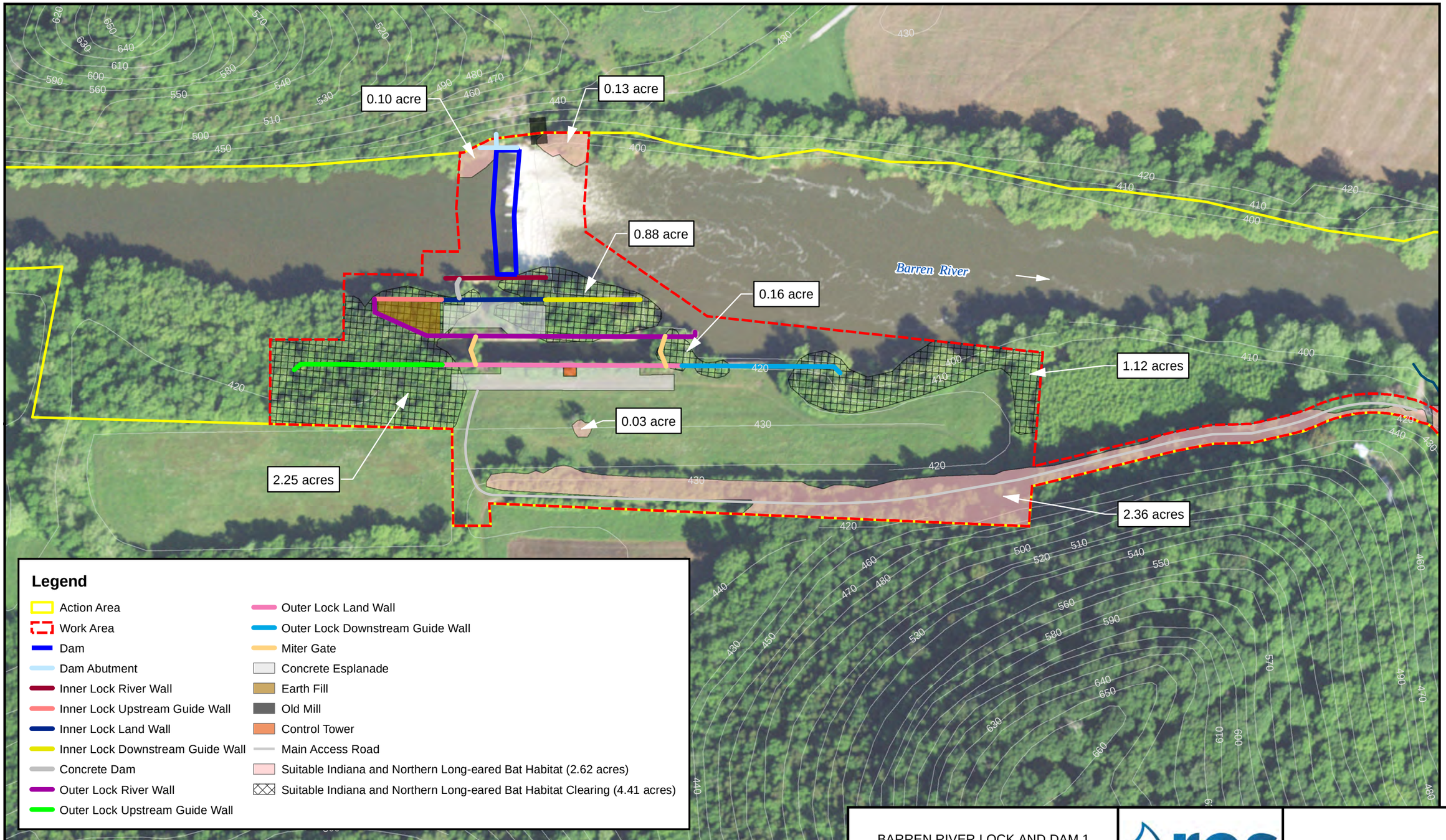
KNOWN INDIANA AND
NORTHERN LONG-EARED
BAT HABITAT MAP

REVISED DATE: 02-25-22 | DRAWN BY: EDB

FIGURE 4

R:\Resgis\entgis\Projects\105106_Barren_River_Lock_and_Dam_1_Removal\MXD\Known IBNLEB Habitat Map.mxd, 02-25-2022, ebowman

Source: World Imagery Clarity - Esri and the GIS User Community (2018); Kentucky Tagged Vector Contour (TVC) by Kentucky Division of Geographic Information.



Legend

- Action Area
- Work Area
- Dam
- Dam Abutment
- Inner Lock River Wall
- Inner Lock Upstream Guide Wall
- Inner Lock Land Wall
- Inner Lock Downstream Guide Wall
- Concrete Dam
- Outer Lock River Wall
- Outer Lock Upstream Guide Wall
- Outer Lock Land Wall
- Outer Lock Downstream Guide Wall
- Miter Gate
- Concrete Esplanade
- Earth Fill
- Old Mill
- Control Tower
- Main Access Road
- Suitable Indiana and Northern Long-eared Bat Habitat (2.62 acres)
- Suitable Indiana and Northern Long-eared Bat Habitat Clearing (4.41 acres)

0 100 200 400 600 800 Feet

NOTE: RES BIOLOGISTS PERFORMED A HABITAT ASSESSMENT OF THE WORK AREA ON NOVEMBER 29, 2021.

BARREN RIVER LOCK AND DAM 1
REMOVAL PROJECT
WARREN COUNTY, KENTUCKY

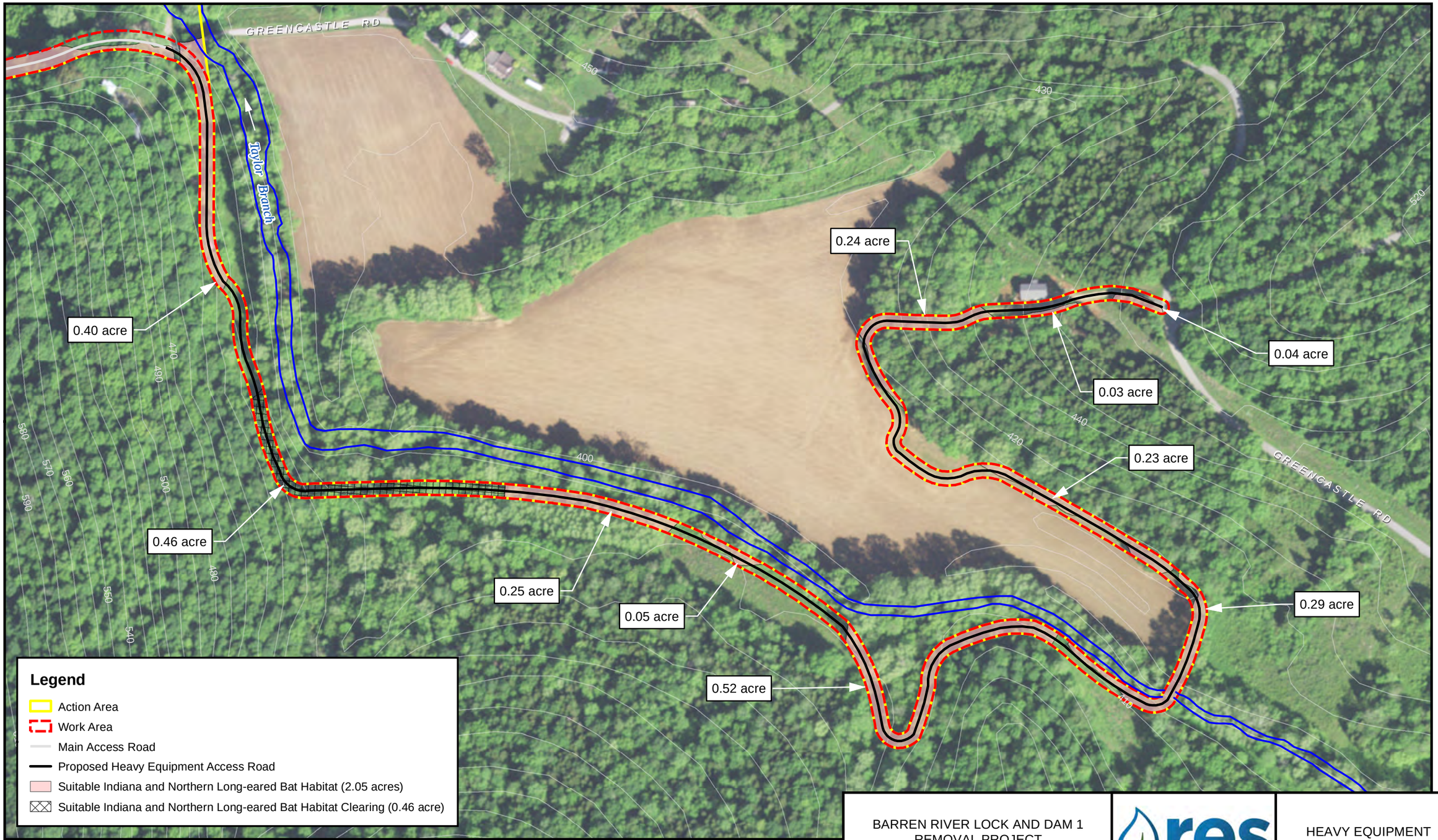
REVISED DATE:02-28-22 | DRAWN BY: EDB

PROJECT DEVELOPMENT MAP

FIGURE 5

R:\Resgis\entgis\Projects\105106_Barren_River_Lock_and_Dam_1_Removal\MXD\Project Development Map.mxd, 02-28-2022, sbishop

Source: World Imagery Clarity - Esri and the GIS User Community (2018); Kentucky Tagged Vector Contour (TVC) by Kentucky Division of Geographic Information.



BARREN RIVER LOCK AND DAM 1
REMOVAL PROJECT
WARREN COUNTY, KENTUCKY

REVISED DATE:02-28-22 | DRAWN BY: EDB

HEAVY EQUIPMENT
ACCESS MAP

FIGURE 6

R:\Resgis\entgis\Projects\105106_Barren_River_Lock_and_Dam_1_Removal\MXD\Heavy Equipment Access Map.mxd, 02-28-2022, sbishop

PHOTOGRAPHS

Photograph 1: View of the dam and outer lock, facing west from the outer lock downstream guide wall. November 29, 2021.

Photograph 2: View of the dam, facing west from the inner lock downstream guide wall. November 29, 2021.

Photograph 3: View of the dam, facing northwest from the inner lock river wall. November 29, 2021.

Photograph 4: View of the dam abutment and old mill along the left descending bank of the Barren River, facing northwest from the inner lock river wall. November 29, 2021.

Photograph 5: View of the inner lock chamber, river wall (left), and land wall (right), facing northeast (downstream) from the inner lock concrete plug. November 29, 2021.

Photograph 6: View of the concrete plug at the upstream end of the inner lock chamber, facing south from the inner lock river wall. The inner lock upstream guide wall is in the background upstream of the dam. November 29, 2021.

Photograph 7: View of the inner lock downstream guide wall, facing east from the inner lock river wall. November 29, 2021.

Photograph 8: View of the concrete esplanade between the inner and outer locks, facing southwest from the outer lock river wall. November 29, 2021.

Photograph 9: View of the outer lock chamber, river wall (left), and land wall (right), facing northeast (downstream) from the upstream end of the outer lock. November 29, 2021.

Photograph 10: View of the outer lock river wall (right) and outer lock upstream guide wall (left), facing southwest (upstream) from the upstream end of the outer lock. November 29, 2021.

Photograph 11: View of the downstream extent of the outer lock chamber, facing west (upstream) from the outer lock downstream guide wall. November 29, 2021.

Photograph 12: View of the concrete esplanade along the outer lock chamber, facing southwest. November 29, 2021.

Photograph 13: View of the control tower on the concrete esplanade along the outer lock chamber, facing west from the esplanade. November 29, 2021.

Photograph 14: View of the Barren River upstream of BRLD1, facing southwest from the inner lock river wall. The river is considered suitable habitat for the mussel species and foraging and commuting habitat for the gray bat. November 29, 2021.

Photograph 15: View of the Barren River downstream of BRLD1, facing northeast from the outer lock river wall. November 29, 2021.

Photograph 16: Example of forested habitat within the work area. This habitat is considered suitable summer roosting, foraging, and commuting habitat for the Indiana and northern long-eared bats and commuting habitat for the gray bat. November 29, 2021.

Photograph 17: Example of small trees and shrubs along portions of the concrete esplanades. These trees and shrubs do not represent suitable habitat for the three bat species. November 29, 2021.

Photograph 18: View of the existing access road to BRLD1, facing south. November 29, 2021.

Photograph 19: View of the existing bridge over Taylor Branch, facing northeast towards Greencastle Road. November 29, 2021.

Photograph 20: Profile view of the existing bridge and Taylor Branch, facing northeast. November 29, 2021.

APPENDIX B

RESOURCE AGENCY COORDINATION

United States Department of the Interior

FISH AND WILDLIFE SERVICE
Kentucky Ecological Services Field Office
J C Watts Federal Building, Room 265
330 West Broadway
Frankfort, KY 40601-8670
Phone: (502) 695-0468 Fax: (502) 695-1024
http://www.fws.gov/frankfort/

In Reply Refer To: February 10, 2022
Project Code: 2022-0005888
Project Name: Barren River Lock and Dam 1 Removal Project

Subject: List of threatened and endangered species that may occur in your proposed project location or may be affected by your proposed project

To Whom It May Concern:

The enclosed species list identifies threatened, endangered, proposed and candidate species, as well as proposed and final designated critical habitat, that may occur within the boundary of your proposed project and/or may be affected by your proposed project. The species list fulfills the requirements of the U.S. Fish and Wildlife Service (Service) under section 7(c) of the Endangered Species Act (Act) of 1973, as amended (16 U.S.C. 1531 *et seq.*).

New information based on updated surveys, changes in the abundance and distribution of species, changed habitat conditions, or other factors could change this list. Please feel free to contact us if you need more current information or assistance regarding the potential impacts to federally proposed, listed, and candidate species and federally designated and proposed critical habitat. Please note that under 50 CFR 402.12(e) of the regulations implementing section 7 of the Act, the accuracy of this species list should be verified after 90 days. This verification can be completed formally or informally as desired. The Service recommends that verification be completed by visiting the ECOS-IPaC website at regular intervals during project planning and implementation for updates to species lists and information. An updated list may be requested through the ECOS-IPaC system by completing the same process used to receive the enclosed list.

The purpose of the Act is to provide a means whereby threatened and endangered species and the ecosystems upon which they depend may be conserved. Under sections 7(a)(1) and 7(a)(2) of the Act and its implementing regulations (50 CFR 402 *et seq.*), Federal agencies are required to utilize their authorities to carry out programs for the conservation of threatened and endangered species and to determine whether projects may affect threatened and endangered species and/or designated critical habitat.

A Biological Assessment is required for construction projects (or other undertakings having similar physical impacts) that are major Federal actions significantly affecting the quality of the

human environment as defined in the National Environmental Policy Act (42 U.S.C. 4332(2)(c)). For projects other than major construction activities, the Service suggests that a biological evaluation similar to a Biological Assessment be prepared to determine whether the project may affect listed or proposed species and/or designated or proposed critical habitat. Recommended contents of a Biological Assessment are described at 50 CFR 402.12.

If a Federal agency determines, based on the Biological Assessment or biological evaluation, that listed species and/or designated critical habitat may be affected by the proposed project, the agency is required to consult with the Service pursuant to 50 CFR 402. In addition, the Service recommends that candidate species, proposed species and proposed critical habitat be addressed within the consultation. More information on the regulations and procedures for section 7 consultation, including the role of permit or license applicants, can be found in the "Endangered Species Consultation Handbook" at:

http://www.fws.gov/endangered/esa-library/pdf/TOC-GLOS.PDF

Migratory Birds: In addition to responsibilities to protect threatened and endangered species under the Endangered Species Act (ESA), there are additional responsibilities under the Migratory Bird Treaty Act (MBTA) and the Bald and Golden Eagle Protection Act (BGEPA) to protect native birds from project-related impacts. Any activity, intentional or unintentional, resulting in take of migratory birds, including eagles, is prohibited unless otherwise permitted by the U.S. Fish and Wildlife Service (50 C.F.R. Sec. 10.12 and 16 U.S.C. Sec. 668(a)). For more information regarding these Acts see https://www.fws.gov/birds/policies-and-regulations.php.

The MBTA has no provision for allowing take of migratory birds that may be unintentionally killed or injured by otherwise lawful activities. It is the responsibility of the project proponent to comply with these Acts by identifying potential impacts to migratory birds and eagles within applicable NEPA documents (when there is a federal nexus) or a Bird/Eagle Conservation Plan (when there is no federal nexus). Proponents should implement conservation measures to avoid or minimize the production of project-related stressors or minimize the exposure of birds and their resources to the project-related stressors. For more information on avian stressors and recommended conservation measures see https://www.fws.gov/birds/bird-enthusiasts/threats-to-birds.php.

In addition to MBTA and BGEPA, Executive Order 13186: *Responsibilities of Federal Agencies to Protect Migratory Birds*, obligates all Federal agencies that engage in or authorize activities that might affect migratory birds, to minimize those effects and encourage conservation measures that will improve bird populations. Executive Order 13186 provides for the protection of both migratory birds and migratory bird habitat. For information regarding the implementation of Executive Order 13186, please visit https://www.fws.gov/birds/policies-and-regulations/executive-orders/e0-13186.php.

We appreciate your concern for threatened and endangered species. The Service encourages Federal agencies to include conservation of threatened and endangered species into their project planning to further the purposes of the Act. Please include the Consultation Code in the header of this letter with any request for consultation or correspondence about your project that you submit to our office.

Attachment(s):

- Official Species List

Official Species List

This list is provided pursuant to Section 7 of the Endangered Species Act, and fulfills the requirement for Federal agencies to "request of the Secretary of the Interior information whether any species which is listed or proposed to be listed may be present in the area of a proposed action".

This species list is provided by:

Kentucky Ecological Services Field Office
J C Watts Federal Building, Room 265
330 West Broadway
Frankfort, KY 40601-8670
(502) 695-0468

Project Summary

Project Code: 2022-0005888
Event Code: None
Project Name: Barren River Lock and Dam 1 Removal Project
Project Type: Dam - Removal
Project Description: Removal of the existing locks and dam from the Barren River.
Project Location:

Approximate location of the project can be viewed in Google Maps: https://www.google.com/maps/@37.04745455,-86.46666821976592,14z

Counties: Warren County, Kentucky

Endangered Species Act Species

There is a total of 17 threatened, endangered, or candidate species on this species list.

Species on this list should be considered in an effects analysis for your project and could include species that exist in another geographic area. For example, certain fish may appear on the species list because a project could affect downstream species. Note that 4 of these species should be considered only under certain conditions.

IPaC does not display listed species or critical habitats under the sole jurisdiction of NOAA Fisheries[1], as USFWS does not have the authority to speak on behalf of NOAA and the Department of Commerce.

See the "Critical habitats" section below for those critical habitats that lie wholly or partially within your project area under this office's jurisdiction. Please contact the designated FWS office if you have questions.

---

1. NOAA Fisheries, also known as the National Marine Fisheries Service (NMFS), is an office of the National Oceanic and Atmospheric Administration within the Department of Commerce.

Mammals

NAME	STATUS
Gray Bat *Myotis grisescens*	Endangered
Indiana Bat *Myotis sodalis*	Endangered
Northern Long-eared Bat *Myotis septentrionalis*	Threatened

Gray Bat *Myotis grisescens* — Endangered

No critical habitat has been designated for this species.

This species only needs to be considered under the following conditions:

- The project area includes potential gray bat habitat.

Species profile: https://ecos.fws.gov/ecp/species/6329

General project design guidelines:
https://ipac.ecosphere.fws.gov/project/EHHIOOALLZDPTKVSAZMIICEUFU/documents/generated/6422.pdf

Indiana Bat *Myotis sodalis* — Endangered

There is **final** critical habitat for this species. Your location overlaps the critical habitat.

This species only needs to be considered under the following conditions:

- The project area includes 'potential' habitat. All activities in this location should consider possible effects to this species.
- The project area includes known 'swarming 2' habitat.

Species profile: https://ecos.fws.gov/ecp/species/5949

General project design guidelines:
https://ipac.ecosphere.fws.gov/project/EHHIOOALLZDPTKVSAZMIICEUFU/documents/generated/6422.pdf

Northern Long-eared Bat *Myotis septentrionalis* — Threatened

No critical habitat has been designated for this species.

This species only needs to be considered under the following conditions:

- The specified area includes areas in which incidental take would not be prohibited under the 4(d) rule. For reporting purposes, please use the "streamlined consultation form," linked to in the "general project design guidelines" for the species.

Species profile: https://ecos.fws.gov/ecp/species/9045

General project design guidelines:
https://ipac.ecosphere.fws.gov/project/EHHIOOALLZDPTKVSAZMIICEUFU/documents/generated/6422.pdf

Clams

NAME	STATUS
Clubshell *Pleurobema clava*	Endangered
Population: Wherever found; Except where listed as Experimental Populations No critical habitat has been designated for this species. Species profile: https://ecos.fws.gov/ecp/species/3789 General project design guidelines: https://ipac.ecosphere.fws.gov/project/EHHIOOALLZDPTKVSAZMIICEUFU/documents/generated/5639.pdf	
Fanshell *Cyprogenia stegaria*	Endangered
No critical habitat has been designated for this species. Species profile: https://ecos.fws.gov/ecp/species/4822 General project design guidelines: https://ipac.ecosphere.fws.gov/project/EHHIOOALLZDPTKVSAZMIICEUFU/documents/generated/5639.pdf	
Northern Riffleshell *Epioblasma torulosa rangiana*	Endangered
No critical habitat has been designated for this species. This species only needs to be considered under the following conditions: ▪ The species may be affected by projects that significantly impact, directly or indirectly, the following rivers: Green, Licking, or Ohio. Species profile: https://ecos.fws.gov/ecp/species/527 General project design guidelines: https://ipac.ecosphere.fws.gov/project/EHHIOOALLZDPTKVSAZMIICEUFU/documents/generated/5639.pdf	
Pink Mucket (pearlymussel) *Lampsilis abrupta*	Endangered
No critical habitat has been designated for this species. Species profile: https://ecos.fws.gov/ecp/species/7829 General project design guidelines: https://ipac.ecosphere.fws.gov/project/EHHIOOALLZDPTKVSAZMIICEUFU/documents/generated/5639.pdf	
Purple Cat's Paw (=purple Cat's Paw Pearlymussel) *Epioblasma obliquata obliquata*	Endangered
Population: Wherever found; Except where listed as Experimental Populations No critical habitat has been designated for this species. Species profile: https://ecos.fws.gov/ecp/species/5602 General project design guidelines: https://ipac.ecosphere.fws.gov/project/EHHIOOALLZDPTKVSAZMIICEUFU/documents/generated/5639.pdf	
Rabbitsfoot *Quadrula cylindrica cylindrica*	Threatened
There is **final** critical habitat for this species. The location of the critical habitat is not available. Species profile: https://ecos.fws.gov/ecp/species/5165 General project design guidelines: https://ipac.ecosphere.fws.gov/project/EHHIOOALLZDPTKVSAZMIICEUFU/documents/generated/5639.pdf	
Ring Pink (mussel) *Obovaria retusa*	Endangered
No critical habitat has been designated for this species.	

NAME	STATUS

Species profile: https://ecos.fws.gov/ecp/species/4128
General project design guidelines:
https://ipac.ecosphere.fws.gov/project/EHHIOOALLZDPTKVSAZMIICEUFU/documents/generated/5639.pdf

Rough Pigtoe *Pleurobema plenum* — Endangered
No critical habitat has been designated for this species.
Species profile: https://ecos.fws.gov/ecp/species/6894
General project design guidelines:
https://ipac.ecosphere.fws.gov/project/EHHIOOALLZDPTKVSAZMIICEUFU/documents/generated/5639.pdf

Sheepnose Mussel *Plethobasus cyphyus* — Endangered
No critical habitat has been designated for this species.
Species profile: https://ecos.fws.gov/ecp/species/6903
General project design guidelines:
https://ipac.ecosphere.fws.gov/project/EHHIOOALLZDPTKVSAZMIICEUFU/documents/generated/5639.pdf

Snuffbox Mussel *Epioblasma triquetra* — Endangered
No critical habitat has been designated for this species.
Species profile: https://ecos.fws.gov/ecp/species/4135

Spectaclecase (mussel) *Cumberlandia monodonta* — Endangered
No critical habitat has been designated for this species.
Species profile: https://ecos.fws.gov/ecp/species/7867
General project design guidelines:
https://ipac.ecosphere.fws.gov/project/EHHIOOALLZDPTKVSAZMIICEUFU/documents/generated/5639.pdf

Insects

NAME	STATUS

Monarch Butterfly *Danaus plexippus* — Candidate
No critical habitat has been designated for this species.
Species profile: https://ecos.fws.gov/ecp/species/9743

Crustaceans

NAME	STATUS

Kentucky Cave Shrimp *Palaemonias ganteri* — Endangered
There is **final** critical habitat for this species. The location of the critical habitat is not available.
Species profile: https://ecos.fws.gov/ecp/species/5008

Flowering Plants

NAME	STATUS
Prices Potato-bean *Apios priceana*	Threatened

Population:
No critical habitat has been designated for this species.
Species profile: https://ecos.fws.gov/ecp/species/7422

Critical habitats

There is 1 critical habitat wholly or partially within your project area under this office's jurisdiction.

NAME	STATUS
Indiana Bat *Myotis sodalis*	Final

https://ecos.fws.gov/ecp/species/5949#crithab

IPaC User Contact Information

Name: Seth Bishop
Address: 1139 S 4th Street
City: Louisville
State: KY
Zip: 40203
Email sbishop@res.us
Phone: 5026253009

ANDY BESHEAR
GOVERNOR

REBECCA W. GOODMAN
SECRETARY

SUNNI CARR
EXECUTIVE DIRECTOR

ENERGY AND ENVIRONMENT CABINET
OFFICE OF KENTUCKY NATURE PRESERVES

300 SOWER BOULEVARD
FRANKFORT, KENTUCKY 40601
TELEPHONE: 502-573-2886
TELEFAX: 502-564-7484

January 6, 2022

Seth Bishop
RES Kentucky, LLC
1139 S Fourth Street
Louisville, KY 40601

Project:	Barren River Lock and Dam 1 Removal
Project ID:	22-0107
Project Type:	Standard (*customers will be invoiced), 1 mile buffer ($120 fee)
Site Acreage:	705.93
Site Lat/Lon:	37.014304 / -86.449592
County:	Warren
USGS Quad:	BOWLING GREEN NORTH; BOWLING GREEN SOUTH; HADLEY
Watershed HUC12:	Clifty Creek-Barren River; Jennings Creek; Rays Branch-Barren River

Dear Seth Bishop,

This letter is in response to your data request for the project referenced above. We have reviewed our Natural Heritage Program Database to determine if any of the endangered, threatened, or special concern plants and animals or exemplary natural communities monitored by the Office of Kentucky Nature Preserves occur within your general project area. Your project does pose a concern at this time, therefore please see the attached reports and report key for more detailed information.

I would like to take this opportunity to remind you of the terms of the data request license, which you agreed upon in order to submit your request. The license agreement states "Data and data products received from the Office of Kentucky Nature Preserves, including any portion thereof, may not be reproduced in any form or by any means without the express written authorization of the Office of Kentucky Nature Preserves." The exact location of plants, animals, and natural communities, if released by the Office of Kentucky Nature Preserves, may not be released in any document or correspondence. These products are provided on a temporary basis for the express project (described above) of the requester, and may not be redistributed, resold or copied without the written permission of the Biological Assessment Branch (300 Sower Blvd - 4th Floor, Frankfort, KY, 40601. Phone: 502-782-7828).

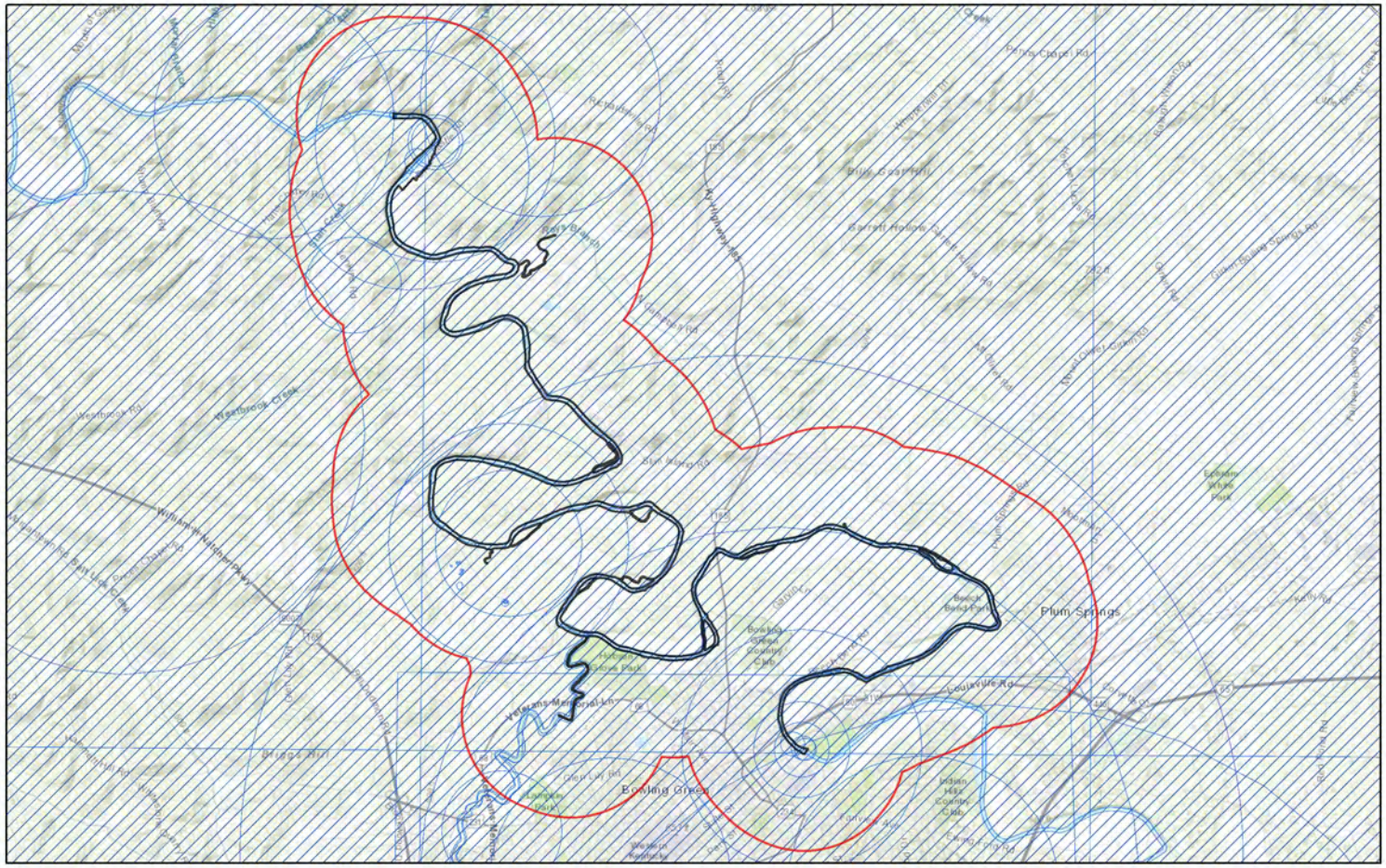
Please note that the quantity and quality of data collected by the Kentucky Natural Heritage Program are dependent on the research and observations of many individuals and organizations. In most cases, this information is not the result of comprehensive or site-specific field surveys; many natural areas in Kentucky have never been thoroughly surveyed and new plants and animals are still being discovered. For these reasons, the Kentucky Natural Heritage Program cannot provide a definitive statement on the presence, absence, or condition of biological elements in any part of Kentucky. Heritage reports summarize the existing information known to the Kentucky Natural Heritage Program at the time of the request regarding the biological elements or locations in question. They should never be regarded as final statements on the elements or areas being considered, nor should they be substituted for on-site surveys required for environmental assessments. We would greatly appreciate receiving any pertinent information obtained as a result of on-site surveys.

If you have any questions, or if I can be of further assistance, please do not hesitate to contact me.

Sincerely,

Alexis R Schoenlaub
Geoprocessing Specialist

Barren River Lock and Dam 1 Removal



January 6, 2022

- Project Boundary
- Buffered Project Boundary
- Element Occurences
- USFWS Critical Habitats

1:89,863

0 0.75 1.5 3 mi

0 1.25 2.5 5 km

Sources: Esri, HERE, Garmin, Intermap, increment P Corp., GEBCO, USGS, FAO, NPS, NRCAN, GeoBase, IGN, Kadaster NL, Ordnance Survey, Esri

APPENDIX C

USACE MEMORANDUM

DEPARTMENT OF THE ARMY
U.S. ARMY ENGINEER DISTRICT, LOUISVILLE
CORP OF ENGINEERS
P.O. BOX 59
LOIUSVILLE, KY 40201-0059

CELRL-EDT January 25, 2022

MEMORANDUM FOR RECORD

SUBJECT: Anticipated impacts on mussels due to dam removal and changing hydraulic conditions.

1. **Summary:** Removal of Lock and Dam #1 (L&D 1) on the Barren River is not anticipated to have significant negative impacts on federally listed mussels which are located nearby downstream. The dam and associated pool have disrupted many natural stream processes which can be restored to improve mussel and aquatic habitat on the Barren River. Given that L&D 1 is a run-of-river navigation structure that does not attenuate floodwaters, that dam removal will occur gradually, and that adverse sedimentation has not occurred upstream within the sediment sampling reaches, it is expected that removal of the dam will have minimal negative impact on freshwater mussels or their habitats.

2. **Background:** A series of locks and dams were constructed throughout the mid-1800's on the Green and Barren Rivers in an effort to facilitate shipping and navigation upstream and downstream in the Green River Watershed. These dams are run-of-river facilities, which increase flow depth and create large backwater pools that generally stretch from one dam upstream to the toe of the next dam in the watershed. The construction of these dams changed the flow regime from one of a largely free-flowing river, to one dominated by backwater pools and sluggish flows during low-flow periods. This flow regime describes Barren River L&D 1, as well as the other remaining navigation structures within the watershed.

The nature of the run-of-river dams within the Green River Basin, including Barren L&D 1, is such that flood water is not significantly impounded within the reservoir's pool. The dam's crest consists of a wide ogee-type weir that spans the channel width and is lower than the surrounding floodplain

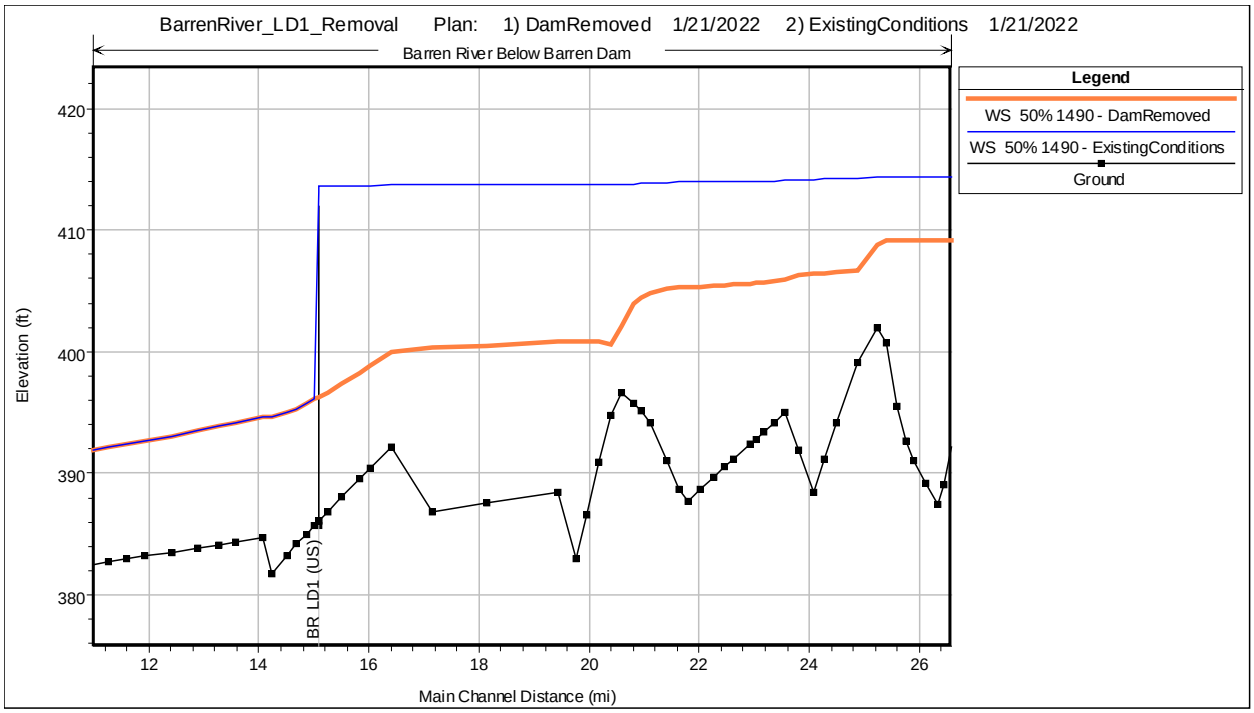
elevation (crest elevation is approximately 412', versus floodplain elevations ranging between 420' – 430'). Because of the large hydraulic capacity to convey flow over this weir, inflow and outflow of the pool created by L&D 1 are effectively equal. Since inflow and outflow are equal, and therefore downstream flow is unaffected by the presence of L&D 1, it can be said that flow conditions downstream of the dam are anticipated to be the same with the dam removed as with existing conditions. By extension, shear stress and therefore the sediment transport capacity for the reach downstream of the dam are similarly unaffected by the dam's presence. This can be shown through examination of the shear stress equation:

$$\tau = \gamma \cdot D \cdot S_w$$

Where:

τ = *Shear Stress*	{ *lb / ft²* }
γ = *Unit Weight of Water*	{ *lb / ft³* }
D = Flow Depth	{ *ft* }
S_w = *Water Surface Slope*	{ *ft / ft* }

Sediment transport capacity can be viewed as a function of shear stress, as this is the force of the water acting on the stream bed. Shear stress is a function of the weight of water (assumed constant), flow depth, and slope of the water surface. These variables and their response to removal of the dam were evaluated using the limited available hydraulic modeling that was available. The figure below shows water surface profiles along the Barren River for the existing condition with the dam in place (blue line), and dam removal condition (orange line). Barren River L&D 1 is located near river mile 15 in the figure. Both profiles are shown for the same flowrate of just under 1,500 cfs; however, there is nothing significant about this particular flowrate, and it was selected to illustrate trends gathered from modeling a full range of flows.



Note that downstream of L&D 1, water surface profiles are identical for both the with- and without-dam scenarios. This modeling, which is both 1-dimensional and steady-state, confirms that both the depth and water surface slope downstream of the dam are not influenced by the removal of the dam. Therefore, because L&D 1 does not attenuate flows, change downstream depths, or impact downstream water surface slopes to a measurable degree, shear stress and therefore sediment transport capacity below the dam are similarly unaffected.

A primary concern for vulnerable mussel species is their susceptibility to sedimentation and scour. Changing sediment conditions resulting in channel aggradation can bury mussel beds and reduce habitat suitability. Similar but opposite changes in sediment transport capacity can result in channel degradation, which can scour away substrate that the mussels require (i.e., mussel habitat). For these reasons, it is appropriate to qualitatively consider how removal of L&D 1 will alter sedimentation patterns downstream of the dam.

Based upon a 2021 mussel survey report prepared by Lewis Environmental Consulting for the US Fish and Wildlife Service, there is evidence of downstream mussel communities near the vicinity of the dam. This report also included sediment survey transects spanning approximately 15-miles of the Barren River from L&D 1 upstream to near the bridge at Old Richardsville Road. This 15-mile reach

is included entirely within the pool created by L&D 1. Throughout the entire upstream sampling reach, gravel substrates are present to some degree, which appears to indicate the reach has not been prone to extreme sediment deposition and siltation. Given the evidence that fine substrates have not been able to accumulate within the dam's pool, it is only logical to assume that sediment transport capacity downstream of the dam is adequate to prevent burial of the sensitive mussel beds.

Additionally, the slow and incremental nature of the dam's removal should be sufficient to avoid generating pulses of sediment which could overwhelm the mussel's limited ability to relocate to more suitable substrate conditions. While some degree of sediment transport associated with dam removal is inevitable, especially considering the unnatural state the pool has existed in for over a century, it is not anticipated that these changes will permanently threaten downstream mussels or significantly alter their habitat. Removal of the dam will shift the flow regime towards a much more natural state where the river can recuperate from historic alteration and sediment transport processes can begin to recover.

It should be noted that Barren River L&D 1 is currently in a state of disrepair, and its condition appears to be deteriorating rapidly. Without intervention, it can be assumed that the structure may fail on its own in the near-term. This failure would likely occur rapidly, resulting in a sudden loss of upstream pool as impounded water flows through the breach. This rapid discharge of water through the dam would result in increased shear stresses downstream, potentially increasing scour and erosion of streambed materials and substrates. Additionally, the rapid loss of pool has the potential to flush large plumes of sediment downstream, which could deposit in undesirable areas of the Barren River or father downstream in the Green River. The rapid failure of the structure and associated uncontrolled releases of water may have adverse impacts on downstream mussel communities and habitats. For this reason, it is imperative that dam removal occur gradually, minimizing rapid releases of water and sediments from upstream.

Regarding potential scour of the mussel beds, with the dam in place, there is a significant plunging flow that occurs as water falls over the dam. This plunging flow creates highly turbulent conditions and scouring currents which can threaten the mussels located nearby downstream. The plunging turbulent flow is most evident during low flows when a large waterfall is visible over the dam, but also exists during high flows and likely to a greater degree. Removal of the dam has the effect of

mostly eliminating these vertical flows, likely reducing erosive currents, restoring natural streamflow patterns to the reach, and potentially benefiting downstream mussels and habitat. Removal of the L&D also improves upstream-downstream connectivity of the Barren River through the removal of barriers, allowing fishes to navigate more freely, particularly during low-flow conditions. Many of these fishes play critical roles in the lifecycle and reproduction of freshwater mussel species.

Finally, it should be noted that natural riffle and bar habitats are almost entirely absent within L&D 1's pool. Removal of the dam and the upstream pool associated with it will likely expose historic riffle and bar habitats which have long been submerged. These emergent habitats can offer great colonization potential for the mussel species. Following the dam's removal, efforts will be taken to identify and relocate mussels which may have been stranded by reduced water levels. The number of mussels requiring relocation is anticipated to be small based upon 2021 mussel surveys, which identified no threatened mussel species in the pool upstream of L&D 1.

3. **Conclusion:** Based on these findings, it is expected that removal of L&D 1 will have minimal impacts on mussels. Restoration of more natural stream flow conditions will likely improve habitat for a number of aquatic species. This understanding is based on the fact that the navigation dam is run-of-river type and therefore does not attenuate discharge, velocity, or shear stresses downstream of the dam. Additionally, because of the gradual nature of the dam's removal, along with the absence of significant sediment deposits within the upstream pool, sedimentation is not anticipated to permanently threaten mussels or significantly alter habitat. The Louisville District Corps of Engineers therefore supports a plan to remove L&D 1 on the Barren River.

Appendix C
2022 USFWS Biological Opinion

Demolition and Removal of Barren River Lock and Dam 1

Biological Opinion on the Rough Pigtoe (*Pleurobema plenum*) and Conference Opinion on the Pyramid Pigtoe (*Pleurobema rubrum*)

FWS #: 2022-0005888

Prepared by:

U.S. Fish and Wildlife Service
South Atlantic-Gulf and Mississippi Basin Regions
1875 Century Boulevard
Atlanta, GA 30345

_____ _____

Catherine Phillips-Czarnecki Date
Assistant Regional Director – Ecological Services

TABLE OF CONTENTS

CONSULTATION HISTORY

This section lists key events and correspondence during the course of this consultation. A complete administrative record of this consultation is on file in the U.S. Fish and Wildlife Service's (Service) Kentucky Field Office (KFO).

November 19, 2021: The KFO held a discussion with representatives from RES Kentucky, LLC (RES) to discuss the proposed action and content of the biological assessment (BA) that would need to be developed for the U.S. Army Corps of Engineers (USACE).

November 29, 2021: The KFO and RES conducted a site visit to evaluate habitat within the work area and discuss the proposed action.

February 4, 2022: On behalf of the USACE, RES submitted a draft copy of the BA to the KFO for review and comment.

February 11, 2022: The KFO provided comments on the BA to RES.

February 28, 2022: On behalf of the USACE, RES provided a final draft BA to the KFO for review and comment. The KFO had no additional comments.

March 31, 2022: The USACE submitted the final BA to the KFO that determined the proposed action "may affect and is likely to adversely affect" Rough Pigtoe (*Pleurobema plenum*) and Pyramid Pigtoe (P*leurobema rubrum*). The USACE requested initiation of formal consultation on the Rough Pigtoe and formal conference on the Pyramid Pigtoe.

The USACE also determined that the proposed action "may affect, but is not likely to adversely affect" the gray bat (*Myotis grisescens*), Spectaclecase (*Cumberlandia monodonta*), Fanshell (*Cyprogenia stegaria*), Purple Cat's Paw (*Epioblasma obliquata obliquata*), Northern Riffleshell (*Epioblasma torulosa rangiana*), Snuffbox (*Epioblasma triquetra*), Clubshell (*Pleurobema clava*), Pink Mucket (*Lampsilis abrupta*), Rabbitsfoot (*Quadrula cylindrica cylindrica*), Ring Pink (*Obovaria retusa*), Sheepnose (*Plethobasus cyphyus*), Longsolid (*Fusconaia subrotunda*), and Price's potato-bean (*Apios priceana*). In addition, the USACE determined that the proposed action "may affect, and is likely to adversely affect the Indiana bat (*Myotis sodalis*) and northern long-eared bat (*Myotis septentrionalis*), but potential adverse effects to these species would be addressed under separate consultation processes.

April 12, 2022: The KFO concurred that the proposed action "may affect, and is likely to adversely affect" the Rough Pigtoe and Pyramid Pigtoe and initiated formal consultation on the action.

April 18, 2022: The KFO provided a combined document to the USACE for review and comment that included the draft biological opinion (BO) and conference opinion (CO) (or collectively (BO/CO).

April 18, 2022: The KFO also concurred that the proposed action "may affect, but is not likely to adversely affect" the gray bat, Spectaclecase, Fanshell, Purple Cat's Paw, Northern Riffleshell, Snuffbox, Clubshell, Pink Mucket, Rabbitsfoot, Ring Pink, Sheepnose, Longsolid, and Price's potato-bean and agreed that it was appropriate to address potential adverse effects to the Indiana bat and northern long-eared bat under a separate consultation process.

April 22, 2022: The USACE provided comments on the draft BO/CO and the KFO incorporated those comments.

BIOLOGICAL OPINION AND CONFERENCE OPINION

1.0 INTRODUCTION

A biological opinion (BO) is the document that states the opinion of the U.S. Fish and Wildlife Service (Service) under the Endangered Species Act of 1973, as amended (ESA), as to whether a federal action is likely to:

a) jeopardize the continued existence of species listed as endangered or threatened, or
b) result in the destruction or adverse modification of designated critical habitat.

The U.S. Army Corps of Engineers (USACE) proposes the removal of Barren River Lock and Dam 1 (BRLD1) (the Action). A BO that concludes a proposed Federal action is not likely to jeopardize the continued existence of listed species and is not likely to result in the destruction or adverse modification of critical habitat fulfills the Federal agency's responsibilities under §7(a)(2) of the ESA. "Jeopardize the continued existence means to engage in an action that reasonably would be expected, directly or indirectly, to reduce appreciably the likelihood of both the survival and recovery of a listed species in the wild by reducing the reproduction, numbers, or distribution of that species" (50 CFR §402.02). "Destruction or adverse modification means a direct or indirect alteration that appreciably diminishes the value of critical habitat as a whole for the conservation of a listed species" (50 CFR §402.02). There is no designated critical habitat within the Action Area, and therefore, this BO does not address critical habitat.

In addition, while consultation is required when a proposed action may affect listed species, a conference is only required when the proposed action is likely to jeopardize the continued existence of a proposed species or destroy or adversely modify proposed critical habitat. However, federal action agencies may request a conference on any proposed action that may affect proposed species or proposed critical habitat. Further, in the event that these proposed species are subsequently listed and/or critical habitat designated through final rulemakings, conference opinions may later serve as biological opinions, thus satisfying the USACE's obligations under ESA Section 7(a)(2). Therefore, this document includes both the Service's biological opinion on the Rough Pigtoe and our conference opinion (CO) on the Pyramid Pigtoe.

2.0 PROPOSED ACTION

The proposed Action involves the removal of BRLD1, originally built in 1841 and located in the Barren River at River Mile (RM) 15 in Warren County, Kentucky (Figure 1). BRLD1 consists of a 276-foot-long dam and two locks along the right descending bank of the Barren River. Miter gates are present at the upstream and downstream ends of the outer lock chamber. The dam pool (Pool 1) extends approximately 23 miles upstream of BRLD1 to just downstream of RM 38, with a normal pool elevation of 412 feet above mean sea level (AMSL). In 1965, BRLD1 was closed to navigation traffic after failure of Green River Lock and Dam 4, located immediately downstream of the Barren and Green River confluence, which eliminated the possibility of commercial navigation into the Barren River.

The proposed Action includes planning, demolition and removal of the lock, dam, and associated structures, and conveyance of the BRLD1 property from the USACE to the Kentucky

Department of Fish and Wildlife Resources (KDFWR). The USACE proposes the removal to improve passage for aquatic organisms, restore instream habitat for riverine fish and macroinvertebrates, alleviate safety concerns, and eliminate costs associated with ownership and maintenance of the structure. The USACE is the lead consulting agency for this Action; however, the Service is assisting the USACE by providing financial and technical assistance and assistance with demolition activities for the Action and is also a consulting agency for the purposes of this BO/CO.

2.1 Components of the Action

The Action includes a planning component, construction component, and conveyance component. The planning component encompasses all necessary activities prior to demolition and removal of the structure. These activities include, but are not limited to securing and directing project funding from the Service, which includes the Service's action to provide funding and technical assistance for the project, developing project timeframes and schedules, designing project plans, performing site visits, preparing preliminary assessments and reports, completing required consultations and permitting, and coordinating with the project team. The planning component is considered an administrative action that will not affect federally listed species and, therefore, is not discussed further in this BO/CO.

The conveyance component is the final component of the Action and involves conveyance of the land and improvements associated with BRLD1 from the USACE to the KDFWR. Upon conveyance, the USACE will no longer be involved or have ongoing discretionary control over land management or improvements, which means that after conveyance is completed we do not anticipate reinitiation of consultation with respect to this Action. The KDFWR will become responsible for managing the land, implementing any improvements associated with the BRLD1 site, and ensuring their activities comply with any relevant requirements of the ESA. Conveyance is anticipated to occur within one year of project completion. The conveyance component is also considered an administrative action that will not affect federally listed species and, therefore, is not discussed further in this BO/CO.

The construction component is the main component of the Action and includes three separate activities: site preparation, lock and dam removal, and site stabilization. All construction activities will be limited to a work area work area that includes portions of the right descending bank and Barren River adjacent to BRLD1 (Figure 2). The work area includes the dam, inner and outer locks and associated structures, access roads, and staging areas. The work area encompasses approximately 21.12 acres, including 6.41 acres within the river. The Service's actions to provide oversight of and assistance with demolition activities are also part of the construction component.

2.1.1 Site Preparation

Site preparation is the initial construction component of the Action and includes installation of erosion prevention and sediment control (EPSC) measures, improvement and construction of access roads, establishment of staging areas, and clearing and grubbing. These activities will require the use of heavy equipment (i.e., bulldozers, trackhoes, backhoes, trucks, etc.); however, disturbances within the Barren River are not expected during this phase.

EPSC: A site-specific Erosion Control Plan, including Best Management Practices (BMPs), will be developed by the project engineer, and appropriate measures will be installed prior to onsite activities to ensure continuous erosion control throughout the construction period.

Main Access Road: BRLD1 will be accessed from the east side of the Barren River via Greencastle Road (Figure 2 and Figure 3). The road ends at a bridge over Taylor Branch that connects to a gravel parking lot and existing dirt road extends from parking lot to the southern portion of the BRLD1 property. The existing road will be used as the main access road to BRLD1 and will be improved with a crushed rock surface, as necessary. A new portion of the access road will be constructed from a point on the existing access road to the concrete esplanade/outer lock at BRLD1. The new portion of road will be located in an existing pasture and constructed of crushed rock. While this road will be the primary access road, the bridge over Taylor Branch has a weight limit of three tons; therefore, construction equipment exceeding this weight will use an alternate route to access the site as described in the next paragraph.

Heavy Equipment Access Road: Construction equipment that exceeds the posted weight limit for the Taylor Branch bridge will access BRLD1 via a temporary heavy equipment access road (Figure 3). The access road will begin on the south side of Greencastle Road immediately west of the intersection with Mount Zion Road, then follow an existing dirt road used by the landowner on the north side of Taylor Branch to access a crop field. That landowner has established a vehicular crossing of the stream in a shallow area that will allow heavy construction equipment to drive across the stream. The stream will only be crossed as necessary. No culverts or temporary structures are proposed, and any necessary stream bank grading or stabilization measures will occur above the ordinary high-water mark. BMPs will be implemented at the crossing to minimize sediment and erosion.

After crossing Taylor Branch, the heavy equipment access road will continue to follow the existing dirt road along the south side of Taylor Branch to an open field. The access road will continue through the field, then begin following an existing UTV trail. A small number of trees will need to be removed along the UTV trail to get to the cleared portion of the property of the landowner on south side of Taylor Branch. The access road will then run through the cleared portion of the north landowner's property and intersect the main access road at the parking lot on the south side of the Taylor Branch bridge. Heavy equipment will then use the main access road to travel to the BRLD1 project site.

Staging Areas: Staging areas for equipment and the materials necessary for the proposed Action will be established. The primary staging area will be located in the open field to the east of the outer lock structure and concrete esplanade. This staging area is expected to be utilized for construction trailers, equipment storage, parking, and other construction related activities. Additional staging areas may be established in other open fields and existing clearings of the Action Area as necessary.

Clearing and Grubbing: Clearing and grubbing involves the removal and disposal of all vegetation within the work area. Approximately 4.87 acres of trees will be cleared as necessary, and stumps will either be removed or grubbed to a minimum of three feet below the proposed

subgrade. Woody debris generated from this component will be prevented from entering the Barren River, piled, and will be burned on site, if permissible, or allowed to decay naturally.

2.1.2 Lock and Dam Removal

This construction component will include demolition and removal of the dam, inner lock, upper portions of the outer lock river wall, land wall, and guide walls, outer lock miter gates, esplanade concrete, and control tower. The lower portions of the outer lock river wall, land wall, and guide walls will remain in place. The earth fill between the two locks will also be removed.

Demolition activities will be initiated on the right descending bank and will generally extend towards the river. The start of demolition will be scheduled for a time of year when water levels and flow are expected to be low. To allow equipment to reach the dam, a work pad will be constructed across the existing locks and associated structures. The first section of the work pad from the right descending bank to the concrete esplanade between the locks will be constructed by demolishing the control tower and upper portion of the outer lock land wall and placing the material into the outer lock chamber. After crossing the outer lock chamber, equipment will drive across the existing concrete esplanade to the inner lock. The section of the work pad across the inner lock chamber will be constructed by placing material generated from demolition of the upper portion of the inner lock land wall into the chamber immediately downstream of the concrete plug. The completed work pad will be used to access the eastern end of the dam. The locks and associated structures are made of concrete and will either be demolished using hoe ram-equipped excavators or similar equipment or with controlled explosive charges.

After reaching the dam, a notch will be created to begin draining Pool 1. An in-stream work pad will then be constructed either on the downstream dam apron, immediately downstream of the dam, or along the upstream side of the dam to initiate dam demolition. Material from the dam will be used to continue the in- stream work pad across the river. Once the in-stream work pad is completed, additional material generated during dam demolition will be placed within or adjacent to the outer lock chamber.

The dam will be demolished in lifts, with the vertical extent of each lift determined by the water level to ensure that equipment is not working in more than two feet of water for safety reasons. Depths of greater than two feet reduce the stability of the equipment and may submerge portions of the engine, resulting in potential release of engine fluids or damage to the equipment. The dam will be removed to approximately 392 feet AMSL, which is the average anticipated depth of the river bottom under the dam. Dam sills and timber pilings will also be removed to approximately 392 feet AMSL, and steel reinforcement rods, if present, will be broken at the proposed final elevation and either cut or bent downstream to avoid snags. The remaining portion of the dam will also be notched to an elevation below 392 feet AMSL in several locations to maintain flow and facilitate passage by aquatic organisms and recreational users (e.g., boats, canoes, kayaks) during low river levels. The dam will be demolished to the dam abutment at the western end of the dam, which will be left in place. The remnants of the old mill downstream of the dam on the west side of the river will also remain. After dam demolition is complete, the in-stream work pad material will be removed and placed within or adjacent to the outer lock chamber.

Demolition of the locks and associated structures will begin after initiation of dam demolition. The remainder of the inner lock river, land, and guide walls and lock floor will be removed to the same elevation as the remaining portion of the dam (approximately 392 feet AMSL). The concrete esplanade and earthen fill between the two locks will be removed, and the concrete from the esplanade will be placed within or adjacent to the outer lock chamber. The earthen fill will be placed adjacent to the outer lock chamber to help stabilize the bank. The outer lock river wall will be demolished to an elevation of approximately 399 to 404 feet AMSL, and the outer lock land wall and upstream and downstream guide walls will be removed to approximately 412 to 414 feet AMSL. Material from the walls will be placed within or adjacent to the outer lock chamber. The outer lock miter gates will also be removed and placed in the outer lock chamber. The outer lock chamber will be filled to the top of the lock land wall, then graded to create a constant 3:1 slope extending from the top of the land wall to the base of the former inner lock land wall. Concrete material generated in excess of the volume of the outer lock chamber and not necessary for slope stabilization will be placed in the scour area below the dam (right descending bank), as necessary. Any soil generated during demolition and removal will be used to cover the fill material on the slope and will not be placed in the river or scour area. The remainder of the slope is expected to be covered naturally over time by sediment deposition during flood events.

2.1.3 Site Stabilization

Following removal of the lock and dam, disturbed areas will be regraded, seeded, and mulched with straw and/or covered with erosion control blankets. The main access road will remain in place to provide continued access to the BRLD1 property. The heavy equipment access road and crossing of Taylor Branch will be restored and stabilized as necessary after the last of the heavy equipment is removed from the site.

2.2 Action Area

For purposes of consultation under ESA §7, the Action Area is defined as "all areas to be affected directly or indirectly by the Federal action and not merely the immediate area involved in the action" (50 CFR §402.02).

The Action Area encompasses approximately 24 miles of the Barren River, beginning near Greencastle, Kentucky downstream of BRLD1 at River Mile (RM) 14 and extending upstream to the Bowling Green Municipal Utilities rock dam in Bowling Green, Kentucky, located just downstream of RM 38 (Figure 4). The upstream portion of the Action Area also includes three perennial tributaries to the Barren River that are influenced by the presence of BRLD1. RM 14 was selected as the downstream extent of the Action Area, because it is the extent to which we anticipate that sediment disturbances and water quality degradation will occur; however, we do not expect any effects to listed species below RM 14, because the effects from sediment disturbances and water quality degradation would be minimal or undetectable past that point in the Barren River and not likely to affect any listed species. The Bowling Green Municipal Utilities rock dam was selected as the upstream extent of Action Area because water levels upstream of this point are affected by the six-foot, manmade rock dam rather than BRLD1.

2.3 Conservation Measures

Conservation measures (CM) are those proposed actions taken to minimize incidental take and benefit or promote the recovery of the species under review. Conservation measures are included as an integral portion of the Action. The USACE and Service have committed to implement the following conservation measures specific to the affected freshwater mussels as part of the Action:

CM 1: Implementation of EPSC measures in the work area, including but not limited to:

(a) Stabilization of disturbed areas as soon as practicable, but no more than seven days after construction activities have temporarily or permanently ceased in any portion of the work area. At a minimum, interim and permanent practices implemented to stabilize disturbed areas will include temporary and/or permanent seeding, erosion control matting, mulching, and/or sodding.

(b) Implementation of structural measures in a timely manner to divert flows from exposed soils, temporarily store flows, or otherwise limit runoff and the discharge of pollutants from exposed areas of the site to minimize erosion and sediment runoff. Structures may include silt fence or coir rolls, stone silt check dams, temporary gravel construction entrances/exits, and/or riprap.

CM 2: Revegetation of disturbed areas immediately following completion of ground disturbing activities.

CM 3: Implementation of in-stream activities during periods of low flow.

CM 4: Use of in-stream work pads during lock and dam removal to minimize impacts to the river from equipment. The work pads will be located in areas that do not provide suitable habitat for the listed mussel species.

CM 5: Implementation of BMPs when operating machinery on the in-stream work pad or within the riparian area to avoid and minimize the potential for accidental spills, including a spill response plan to address accidental spills.

CM 6: Removal of and disposal of any remaining hydraulic fluid from the hydraulic piping system in the operations building and lock chamber and dispose of appropriately.

CM 7: Incremental removal of the dam to reduce the rate of water recession upstream of the dam.

CM 8: Monitoring the upstream portion of the Action Area during dam removal to locate exposed mussels and return individuals to areas of suitable habitat.

3.0 STATUS OF THE SPECIES

This section summarizes the best available data about the biology and current condition of the Rough Pigtoe and Pyramid Pigtoe throughout their range that are relevant to formulating an opinion about the Action.

3.1 Rough Pigtoe

The Rough Pigtoe was listed as endangered on June 14, 1976 (Service 1976). The Rough Pigtoe is a medium sized mussel three to four inches in length with an inflated, triangular shaped shell. Shell color ranges from dark to yellowish brown and light green rays may be present on the shell of younger individuals. The color inside the shell varies from pearly white to pink (Service 1984). The Rough Pigtoe is found in medium to large rivers with sand, gravel, and cobble substrate, but has also been found in flats and muddy sand in shallow water (Service 2014). Reproduction requires a stable, undisturbed habitat and a sufficient population of host fish to complete the mussel's larval development. Ongoing threats to the species include water quality degradation from point and non-point sources, particularly in tributaries that have limited capability to dilute and assimilate sewage, agricultural runoff, and other pollutants. In addition, the species is affected by hydrologic and water quality alterations resulting from the operation of impoundments (Service 2014). The historical distribution of the Rough Pigtoe includes the Ohio, Cumberland, and Tennessee River drainages in Alabama, Illinois, Indiana, Kentucky, Ohio, Pennsylvania, Tennessee, Virginia, and West Virginia. This species is believed to be extirpated from Pennsylvania, Ohio, West Virginia, Virginia, and Illinois. Currently, this species is known to occur downstream of three Tennessee River mainstem dams in Alabama and Tennessee, in the Clinch River in Tennessee, and in the Green and Barren rivers in Kentucky. The species may also be present in the Cumberland River in Tennessee. In Kentucky, the Rough Pigtoe occurs in the Green River between Lock and Dam 4 and Lock and Dam 5 and in the Barren River below Lock and Dam 1 (Service 2014).

3.2 Pyramid Pigtoe

The Service proposed to list the Pyramid Pigtoe as a threatened species with Section 4(d) rule under the ESA on September 7, 2021 (Service 2021). The Pyramid Pigtoe is reddish to chestnut brown in color, with a smooth periostracum (outer shell surface) that darkens with age (Watters et al. 2009). The Pyramid Pigtoe is found in medium to large rivers and prefers a mixture of sand, gravel, and cobble substrates. Individuals are commonly found at depths of three feet or less but have been found at depths of 13 to 20 feet in large rivers (Parmalee and Bogan 1998). Past and current threats to the species include habitat degradation or loss from a variety of sources (*e.g.,* dams and other barriers, resource extraction); degraded water quality from chemical contamination and erosion from development, agriculture, and mining operations; direct mortality from dredging; residual impacts (reduced population size) from historical harvest; and the proliferation of invasive, nonnative species (Service 2021). The species is currently known to occur in Kentucky, Tennessee, Virginia, Ohio, Alabama, Oklahoma, Arkansas, Mississippi, and Louisiana, where extant populations are found in the Arkansas-White-Red, Lower Mississippi, Missouri, and Ohio River regions. The Pyramid Pigtoe is considered extirpated from Pennsylvania, West Virginia, Indiana, Illinois, Wisconsin, Minnesota, Iowa, Kansas, and Missouri (Service 2021).

4.0 ENVIRONMENTAL BASELINE

In accordance with 50 CFR 402.02, the environmental baseline refers to the condition of the listed species or its designated critical habitat in the Action Area, without the consequences to the listed species or designated critical habitat caused by the Action. The environmental baseline includes the past and present impacts of all Federal, State, or private actions and

other human activities in the Action Area, the anticipated impacts of all proposed Federal projects in the action area that have already undergone formal or early section 7 consultation, and the impact of State or private actions which are contemporaneous with the consultation in process. The consequences to listed species or designated critical habitat from ongoing agency activities or existing agency facilities that are not within the agency's discretion to modify are part of the environmental baseline.

Survey Data: A mussel survey of the Action Area was conducted in 2021 (Lewis 2021). The survey documented two Rough Pigtoe and four Pyramid Pigtoe in the downstream portion of the Action Area (Figure 4). Two of the Pyramid Pigtoe were found approximately 950 feet and 1,800 feet, respectively, downstream of BRLD1. In addition, two more Pyramid Pigtoe and both Rough Pigtoe individuals were found approximately one mile downstream of BRLD1. In 2008, a survey of the Barren River immediately downstream of the Action Area found five Pyramid Pigtoe at RM 14, near the downstream extent of the Action Area (Lewis 2008). Previous surveys performed by the KDFWR Center for Mollusk Conservation have also documented the Rough Pigtoe and Pyramid Pigtoe downstream of BRLD1. During a survey in 2002, one Rough Pigtoe and one Pyramid Pigtoe were found approximately 1,800 feet downstream of the dam near the same location where a Pyramid Pigtoe was found during the 2021 mussel survey (Monte McGregor, KDFWR, personal communication, January 21, 2022). The Office of Kentucky Nature Preserves (OKNP) Natural Heritage Database Report for the proposed Action Area (2022) also includes a record of three Rough Pigtoe individuals at this location in 2001. Based on the results of the 2021 survey and previous surveys, the Rough Pigtoe and Pyramid Pigtoe are reasonably certain to occur within the portion of the Action Area that occurs downstream of BRLD1, including the work area.

A shell from a Pyramid Pigtoe was found in the upstream portion of the Action Area during the 2021 survey; however, no live individuals of these species were encountered upstream of BRLD1 (Lewis 2021). During the 2021 survey, mussel abundance and diversity were low from immediately upstream of BRLD1 to seven miles upstream. Only 18 individuals of four non-listed species were encountered, all of which are tolerant of river impoundments and deep water (Parmalee and Bogan 1998, Grabarkiewicz and Davis 2008). Mussel abundance and diversity increased between 7.5 miles and 10 miles upstream of the BRLD1, where a total of 49 individuals of nine non-listed species were found. However, species tolerant of impoundments continued to be the most abundant in this area. Abundance and diversity then decreased between 11 miles and 16 miles upstream of BRLD1 and was similar to the reach immediately upstream of BRLD1 (Lewis 2021). The portion of the Barren River from BRLD1 to 7 miles upstream does not provide suitable habitat for the Rough Pigtoe or Pyramid Pigtoe and the portion of the river from 7 miles upstream to 16 miles upstream may have some marginal habitat for these species; however, the majority of this reach appears to provide poor-quality habitat. The BA determined that the Rough Pigtoe and Pyramid Pigtoe had the potential to occur within this portion of the Action Area from 7.5 to 10 miles upstream of BRLD1; however, given the results of the survey and the lower quality of the habitat in this area, the Service's scientific opinion is that the Rough Pigtoe and Pyramid Pigtoe are not reasonably certain to occur within the Action Area from BRLD1 to upstream 17 miles.

The highest mussel abundance and greatest species diversity in the upstream survey area were found from 17 miles upstream of the dam to the upstream extent of the Action Area. Lewis (2021) noted that this portion of the river is not impounded and exhibits more natural, free-flowing conditions with runs and shallow riffles. A total of 78 individuals of 18 non-listed species were encountered, including 10 species not found downstream of this area. Seven of these species were also found in the transects downstream of BRLD1, where the Rough Pigtoe and Pyramid Pigtoe were found (Lewis 2021). Given the similarity of habitat and species composition to the area downstream of BRLD1 and the diversity of species within this area, the Service believes that the Rough Pigtoe and Pyramid Pigtoe are reasonably certain to occur in this portion of the Action Area.

In summary, the Rough Pigtoe and Pyramid Pigtoe are reasonably certain to occur in the Action Area downstream of BRLD1 (including the work area) and from 17 miles upstream of BRLD1 to the Bowling Green Municipal Utilities rock dam.

4.1 Action Area Numbers, Reproduction, and Distribution

The results of the Lewis (2021) survey were used to calculate densities and estimate the number of individuals in the Action Area for the Rough Pigtoe and Pyramid Pigtoe. Data from the OKNP report (2022) was also used to supplement the 2021 survey.

4.1.1 Action Area Downstream of BRLD1

Semi-quantitative data from Lewis (2021) was used to calculate mussel densities downstream of BRLD1. During the survey, 880 mussels were found along nine transects that included an area of 506 square meters (m^2). Based on these results, Lewis (2021) calculated an estimated density of 1.74 mussels per m^2 within the semi-quantitative survey area. During the semi-quantitative survey, one Rough Pigtoe individual was found. Additionally, one Rough Pigtoe and four Pyramid Pigtoe were encountered downstream of BRLD1 during the qualitative searches (Lewis 2021). To standardize data from the qualitative search areas with the semi-quantitative survey data, the total collection time for each survey type was used. The collection time during the qualitative searches was 1,263 minutes, which was nearly double the search time of 705 minutes during the semi-quantitative survey.

Based on this difference, the total number of individuals encountered during the qualitative searches was halved to estimate the total number of individuals that could be present in the semi-quantitative survey area (0.5 Rough Pigtoe, rounded to 1 Rough Pigtoe, and 2 Pyramid Pigtoe). After adding the individual found during the semi-quantitative survey, two Rough Pigtoe and two Pyramid Pigtoe are estimated to occur in the semi-quantitative area. Based on these estimates, the approximate density for both species is 0.0040 mussels per m^2 (2 individuals ÷ 506 m^2 in survey area = 0.0040 mussels/ m^2).

The estimated density calculated for the Rough Pigtoe and Pyramid Pigtoe for the semi-quantitative survey area is assumed to be similar throughout the Action Area downstream of BRLD1; therefore, these values were used to estimate the number of individuals of each species within the downstream portion of the Action Area. The portion of the Action Area downstream of BRLD1 totals approximately 146,740 m^2 of suitable habitat. To calculate the estimated number of individuals of each species in the Action Area downstream of BRLD1, the downstream Action

Area size was multiplied by the estimated density for each species. The calculation for the estimated number of both species is 0.0040 mussels/m^2 x 146,740 m^2 = 586.96 individuals. In summary, we estimate that 587 Rough Pigtoe and 587 Pyramid Pigtoe occur within the downstream portion of the Action Area.

4.1.2 Action Area Upstream of BRLD1

Semi-quantitative data from the Lewis (2021) was used to calculate mussel densities upstream of BLRD1. During the survey, 165 live mussels were found along the 28 transects that included an area of 1,684 m^2. Based on these results, Lewis (2021) calculated an estimated density of 0.10 mussels per m^2within the semi-quantitative survey area. Although no live individuals of the Rough Pigtoe or Pyramid Pigtoe were found in the upstream portion of the Action Area during the 2021 survey, the OKNP report (2022) contains a 1988 record of a live Rough Pigtoe within this portion of the Barren River. Additionally, the OKNP report (2022) includes a 1993 record of a live Pyramid Pigtoe upstream of the Action Area. Based on these historic records and the known occurrences of these species in similar habitat and mussel communities in the downstream portion of the Action Area, one individual of each species is assumed to be present within the semi-quantitative survey area. Therefore, the estimated density for the Rough Pigtoe and Pyramid Pigtoe in the semi-quantitative survey area is 0.0006 mussels per m^2 (1 individual ÷ 1,684 m^2 in survey area = 0.0006 mussels per m^2).

The estimated density calculated for each species for the semi-quantitative survey area is assumed to be similar throughout the Action Area upstream of BRLD1; therefore, these values were used to estimate the number of individuals of each species within the upstream portion of the Action Area. The portion of the Action Area upstream of BRLD1 totals approximately 2,638,266 m^2. As discussed in Section 4.0, the portion of the Barren River from BRLD1 to 17 miles upstream (2,058,881 $m^{2)}$ does not provide suitable habitat for the Rough Pigtoe or Pyramid Pigtoe. Therefore, Rough Pigtoe and Pyramid Pigtoe are only likely to occur in approximately 579,385 m^2 of the upstream portion of the Action Area. To calculate the estimated number of individuals of each species in the Action Area upstream of BRLD1, the upstream portion of the Action Area that provides suitable habitat for these species was multiplied by the estimated density for each species and rounded to the nearest whole individual. The calculation for the estimated number of both species is 0.0006 mussels/m^2 x 579,385 m^2 =343 individuals. In summary, we estimate that 343 Rough Pigtoe and 343 Pyramid Pigtoe occur within upstream portion of the Action Area.

4.2 Action Area Conservation Needs and Threats

The Rough Pigtoe and Pyramid Pigtoe are likely exposed to the same threats within the Action Area that occur across their ranges. The primary factor affecting these species in the Action Area is the presence of BRLD1. Construction of the dam caused a large portion of the river to become pooled upstream and altered the natural flow regime, causing riffles and shoals with clean sand and gravel substrate to be replaced by slow-flowing, silt-bottomed pools that do not provide suitable habitat for these two mussel species. These conditions have been present in this portion of the Barren River to varying degrees since construction of the original dam in 1841. The flow of water over the dam has also led to scouring, causing fine sediment to be removed and creating a deep area of unsuitable habitat at the base of the dam and immediately downstream. The plunging water has also caused suspension of fine sediment, which can

increase turbidity, decrease dissolved oxygen levels, and cause other impacts to water quality that can affect mussels. Presence of the dam also acts as a barrier to fish movement under certain flow levels, limiting contact between mussels and fish hosts and potentially affecting the mussel reproduction process.

Other factors that could affect the mussel species in the Action Area include increased sedimentation and inputs of contaminants. Runoff associated with agricultural and logging activities contributes sediment, suspended solids, pesticides, herbicides, fertilizers, petroleum-based products, and other contaminants to the Barren River. Point source releases from wastewater treatment and storm water discharge also cause contamination. Contaminants may also enter the Barren River through inputs of groundwater when petroleum-based products (e.g., fuel, oil, hydraulic fluid) from vehicles, trains, heavy equipment, and other sources enter the extensive karst system in the area. In addition, an Environmental Baseline Survey of BRLD1 conducted as part of the Green and Barren River Lock and Dam Disposition Study (USACE 2014) found hydraulic oil stains in the operations building and several locations in the lock chamber resulting from vandalism to the hydraulic piping system, indicating that hydraulic oil has been released into the river and surrounding areas in the past.

A biological threat to the Rough Pigtoe and Pyramid Pigtoe includes invasive species that compete with or prey upon native mussels. The bighead carp (*Hypophthalmichthys nobilis*), silver carp (*Hypophthalmichthys molitrix*), and black carp (*Mylopharyngodon piceus*) are known to occur in the Green River, upstream and downstream of the Barren River confluence, and may be present in the Barren River (KDFWR 2022). Bighead and silver carp are filter feeders that compete directly with native mussels for food. Black carp eat mollusks and present a predatory threat to native mussels. Although efforts are underway to control these invasive species, existing populations are expected to persist and expand into new areas (USDA 2020). In addition, isolated occurrences of the zebra mussel (*Dreissena polymorpha*) have also been reported in the lower Green River (Haag and Cicerello 2016) and are likely moving upstream toward the Barren River. This invasive mussel species attaches to native mussel shells and other hard surfaces by the thousands and outcompetes native mussels for food.

5.0 EFFECTS OF THE ACTION

In accordance with 50 CFR 402.02, effects of the Action are all consequences to listed species or critical habitat that are caused by the Action, including the consequences of other activities that are caused by the Action. A consequence is caused by the proposed action if it would not occur "but for" the proposed action and it is reasonably certain to occur. Effects of the action may occur later in time and may include consequences occurring outside the immediate area involved in the Action (see § 402.17).

Based on the description of the Action and the species' biology, we identified seven stressor(s) that are reasonably certain to result from the Action: (1) sediment disturbance, (2) water quality degradation, (3) changes to flow, (4) crushing/striking individuals, (5) displacement of individuals, (6) exposure of individuals to air, and (7) invasive species. Below, we discuss the best available science relevant to each stressor. A discussion of each Stressor-Exposure-Response (SER) pathway is detailed below and summarized in Appendix A.

5.1 Sediment Disturbance

Site preparation, lock and dam removal, and site stabilization are expected to result in sediment disturbance. Sediment disturbance along the riverbanks and adjacent areas could expose soil and increase erosion, allowing sediment to enter Barren River. Sediment disturbance within the river could displace sediment in one location and deposit it in another location, potentially exposing or burying mussels. Potential impacts to Rough Pigtoe and Pyramid Pigtoe from sediment disturbance could occur in the work area, the Action Area upstream of the work area, and the Action Area downstream of the work area (See Pathways 1-5, Appendix A).

5.1.1 Work Area

Site Preparation: Clearing and grubbing, establishment of staging areas, and improvement and construction of access roads during site preparation will disturb soil near the Barren River. Prior to site preparation, EPSC measures will be implemented and maintained throughout the work area to reduce erosion and minimize sediment inputs into the Barren River. Vehicles and equipment used during site preparation will only be operated on the riverbanks and adjacent areas and will not enter the river. Trees will not be felled into the river, and woody debris that enters the river is expected to consist of small limbs and leaves that are unlikely to result in sediment disturbance. Sediment displacement associated with the heavy equipment access road crossing of Taylor Branch will be minimal and not expected to significantly affect the stream channel or Barren River.

Creation of the notch at the eastern end of the dam will concentrate flow along the right descending portion of the river, and the increased velocity and force could lead to scouring and displacement of sediment downstream. The area below the dam has been scoured by the force of water flowing over the dam during high flows, removing fine and smaller coarse sediments and leaving larger particles. Although the notch will increase water velocity and force immediately below the dam, the increase is not anticipated to be larger than normal high flows or cause significant movement of these larger particles. Particles that do move are likely to only travel a short distance and would not move beyond the scour area below the dam. By the time water travels farther downstream, the increased force created by the concentrated flow at the notch is expected to dissipate and be similar to normal flow. Based on these factors, sediment disturbance from notching of the dam is considered unlikely.

Lock and Dam Removal: The placement of material on the downstream dam apron or at the base of the dam to create the in-stream work pad, and the placement of excess material into the scour area may cause some sediment disturbance; however, the amount of disturbance is expected to be minimal. The turbulence created by the force of water flowing over the dam has scoured this area, removed fines and smaller coarse sediment and left larger particles. These large particles are not expected to move significant distances as additional material is overlain to create the work pad. Water will also no longer be flowing over the majority of the dam after notching, further limiting the movement of particles below the dam. Additionally, listed mussels are unlikely to be present at the base of the dam due to the constant turbulence and lack of suitable substrate from scouring, reducing the potential for sediment disturbance to impact individuals in this area.

Demolition of the lock and dam structures will be performed in a manner that minimizes the amount of material that enters the Barren River; however, some material will likely fall into the river during these activities. Demolition material and placement of material to create the in-stream work pad for demolition of the mooring cells could disturb sediment in Pool 1. As discussed previously, however, the pooled area upstream of the dam represents unsuitable habitat for mussel species; therefore, sediment disturbance is unlikely to impact listed mussels in this area. Sediment that is displaced there will likely settle a short distance from the impact location due to the slow flow. Any sediment that is transported through the notch in the dam will dissipate rapidly from the increased flow. Material that is deposited on the downstream side of the dam is also not expected to result in significant sediment disturbance due to the previous scouring of small particles from this area, the minimal movement of larger particles when material is overlain, and the reduced flow over the dam during this phase of demolition.

Removal and placement of the outer lock miter gates and other material into the majority of the outer lock chamber is not anticipated to result in sediment disturbance due to the isolation of this area from the river. However, placement of material in the downstream extent of the lock chamber may cause sediment disturbance. Fine sediment that enters the water column is expected to disperse rapidly and be deposited over a large area downstream. Soil placed over the filled lock chamber to create the final slope could wash into the river during periods of high water until vegetation is established; however, sediment movement will be minimized by utilizing BMPs for erosion control and stabilization.

During and immediately after dam removal, sediment that has accumulated upstream of the dam could move downstream when the river is restored to free-flowing conditions. Substrate information recorded during the 2021 mussel survey indicates that large amounts of fine sediment have not accumulated behind the dam; however, clay and silt are present upstream of the dam and are expected to move downstream after dam removal. Some of this sediment is expected to settle in the scour area immediately downstream of the dam, restoring small particles to this area and filling the spaces between larger pieces of dam material. Impacts to listed mussels are not anticipated from sediment accumulation at the base of the dam due to the lack of suitable habitat currently in this area. However, sediment that travels beyond the scour area could increase sediment deposition in areas where mussels were documented downstream of the dam. Based on the gradual removal of the dam in stages, accumulated sediment is anticipated to move downstream in small amounts over an extended period of time. Increased sediment deposition in the work area and areas immediately downstream is expected to be temporary as sediment is moved farther downstream; however, sediment from Pool 1 will likely move into the work area with each high flow event until the accumulated sediment is redistributed throughout the river. Although a gradual drawdown of BRLD1 is anticipated, some bank sloughing is expected to occur before the site is stabilized, resulting in additional sediment input from exposed banks within the work area. Although mussels may be able to respond to minimal, temporary sediment deposition, the combination of the initial movement of sediment from directly upstream of the dam combined with the subsequent influx of sediment from areas farther upstream may result in deposition too substantial to allow all individuals to adjust. Sediment deposition that occurs during periods of low water temperatures and decreased mussel activity will also reduce the ability of individuals to respond to deposition events.

Site Stabilization: Site stabilization activities after lock and dam removal will reduce the potential for sediment to enter the Barren River through seeding of disturbed areas and dressing of roads and parking areas. EPSC measures will be maintained until the site is stabilized. As a result, sediment disturbance from this construction component is expected to be minimal.

All Activities: The sediment disturbance from all activities discussed above that occur in the work area could also result in impacts to habitat for fish hosts for both mussel species. Sediment displacement and deposition may damage or bury habitat used by fish hosts for foraging, reproduction, and sheltering. The alteration or loss of habitat could cause fish hosts to move from the area, limiting their exposure to the mussel species and potentially affecting mussel reproduction and recruitment.

5.1.2 Action Area Upstream of Work Area

No construction components will occur in the Action Area upstream of the work area. Site preparation and stabilization activities are not expected to cause inputs of sediment into this area due to the direction of flow and use of EPSC measures, and inputs that do occur are anticipated to be minimal. The portion of the Action Area adjacent to and immediately upstream of the work area where the potential for impacts from lock and dam demolition are highest does not provide suitable habitat for the Rough Pigtoe or Pyramid Pigtoe. The movement and deposition of accumulated sediment in this area after dam removal will also occur in unsuitable habitat. Although a gradual drawdown of BRLD1 is anticipated, some bank sloughing is expected to occur upstream of the work area, resulting in additional sediment input from exposed banks; however, this sloughing is not expected to occur in the suitable mussel habitat that occurs in the Action Area upstream of the work area because that area has already exhibits riverine flows and stable streambanks.

5.1.3 Action Area Downstream of Work Area

No construction components will occur in the Action Area downstream of the work area. As discussed above, site preparation and stabilization activities are not expected to cause inputs of sediment beyond the work area due to the use of EPSC measures. Inputs that do occur are anticipated to be minimal and will be dispersed quickly over a large area due to the flow of the river.

As also discussed above, sediment that has accumulated upstream of the dam will move downstream during and after dam removal. Although the amount of accumulated sediment appears to be low, some sediment is expected to move into the Action Area downstream of the work area. The results of the 2021 survey documented mussel beds and a Pyramid Pigtoe approximately 950 feet downstream of the dam, and sediment deposition could occur in this area. Deposited sediment is anticipated to move farther downstream with each high flow event; however, sediment may persist for a sufficient amount of time after dam removal to smother mussels, render habitat unsuitable, or cause individuals to move in order to find suitable habitat areas.

5.1.4 Applicable Science

Sedimentation is believed to adversely affect mussel populations that require clean, stable streams and has contributed to the decline of mussel populations nationwide (Vannote and Minshall 1982; Brim-Box and Mossa 1999). Specific biological effects to mussels from sedimentation include reduced feeding and respiratory efficiency from clogged gills, disrupted metabolic processes, reduced growth rates, limited burrowing activity, physical smothering, and disrupted host fish attraction mechanisms (Vannote and Minshall 1982; Waters 1995; Hartfield and Hartfield 1996). In addition, mussels may be indirectly affected if high turbidity levels significantly reduce the amount of light available for photosynthesis by potential food items or impede the ability of mussels to attract host fishes (Kanehl and Lyons 1992). Sedimentation can also eliminate or reduce the recruitment of juvenile mussels by clogging interstitial spaces, interfering with feeding activity, and acting as a vector in delivering contaminants to streams (Brim-Box and Mossa 1999).

Dam removal results in the movement of sediment that has accumulated in the impounded or pooled area upstream of the dam. Accumulated sediment primarily consists of silt and sand, as coarser sediments typically settle out farther upstream (Kondolf 1997). Removal of a dam disturbs accumulated sediment, resulting in suspension and transport downstream (Doeg and Koehn 1994). The amount of accumulated sediment appears to be dependent on dam type, with dams associated with large impoundments (e.g., lakes, reservoirs, etc.) retaining more sediment behind the dam than run-of-river type dams, such as BRLD1. A study of four run-of-river dams in Illinois found no major accumulations of sediment behind the dams and concluded that the dams do not act as sediment traps (Csiki and Rhoads 2014).

The effects to mussels from downstream movement of accumulated sediment after dam removal have not been extensively studied; however, a few studies have examined these effects. A study by Sethi et al. (2004) in Wisconsin found that the movement and deposition of accumulated sediment downstream of a run-of-river dam after removal buried mussels and led to mortality. Mussel densities in a bed 0.5 kilometer downstream of the dam declined from 3.80 mussels per square meter prior to dam removal to 2.60 mussels per square meter immediately after dam removal. In addition, the pimpleback (*Quadrula pustulosa*), a rare species in Wisconsin, was no longer found in the mussel bed after the dam was removed. Conversely, Heise et al. (2013) noted that survival rates of mussels downstream of a run-of-river dam in North Carolina remained unchanged before and after removal, even though the amount of sediment increased. Fine sediment below the dam increased from 38.3% before removal to 49.4% immediately after removal, but by three years post-removal had decreased to 24.7%. Survival rates of mussels remained similar throughout these changes, indicating that the increase in sediment movement and deposition after dam removal did not adversely affect mussels. The primary reason for the differences in these results appears to be the rate at which the pooled water was released. Dewatering of the Wisconsin dam was completed in 36 hours, compared to three weeks for the North Carolina dam. Although the Wisconsin dam was located in a larger river and likely had more accumulated sediment, the slower drawdown of the North Carolina dam appears to have reduced the detrimental effects of sediment movement and deposition downstream after dam removal.

The timing of dam removal may also alter the effects of sediment movement and deposition downstream of a dam. Removal of a dam during low flow may reduce the ability of the system to transport sediment downstream and cause accumulated sediment to move only a short distance from the dam (Kondolf 1997). During high flow, larger amounts of sediment are already moving through the system, which may prevent accumulated sediment at the dam from being carried farther downstream (Bednarek 2001).

5.2 Water Quality Degradation

Site preparation, lock and dam removal, and site stabilization could result in water quality degradation. Inputs of sediment or sediment disturbance in the Barren River could result in the suspension of fine sediment in the water column, leading to increased turbidity and decreased dissolved oxygen. These conditions could result in harm or mortality of mussels or cause individuals to move from an area if they persist for an extended period of time. High turbidity could affect the food supply of mussels by blocking sunlight needed by algae and phytoplankton and disrupt reproduction by reducing the visibility of mussel lures to fish hosts. Lower dissolved oxygen could affect the respiration of mussels and fish hosts. Petroleum-based contaminants from vehicles and equipment could also result in harm or mortality of mussels and their fish hosts. Potential impacts to the two mussel species from water quality degradation could occur in the work area, the Action Area upstream of the work area, and the Action Area downstream of the work area (See Pathways 6-12, Appendix A).

5.2.1 Work Area

Site Preparation: Appropriate EPSC measures will be implemented and maintained throughout the work area prior to, and during, construction to reduce erosion and minimize sediment inputs into the Barren River. Sediment that enters the river downstream of the dam is not expected to remain suspended at sufficient concentrations to degrade water quality due to the flow of the river. Sediment that enters the pooled portion of the river upstream of the dam may remain suspended longer due to slower flow; however, this area does not provide suitable habitat for the mussel species. Vehicles, equipment, and felled trees will also be prohibited from entering the river during site preparation. If needed, the potential placement of the culvert in the intermittent stream is not expected to cause water quality degradation in the Barren River due to the minimal amount of disturbed sediment and low probability of sediment deposition in the stream channel prior to reaching the river.

Notching of the dam is not anticipated to result in water quality degradation because scouring at the base of the dam has removed the majority of fine sediment from this area and reduced the potential for sediment suspension. Any fine sediment that remains and becomes suspended would be carried downstream by the flow of the river before turbidity or dissolved oxygen levels could become detrimental to mussels. The increased flow from the notch is expected to dissipate a short distance downstream of the dam and is not anticipated to cause sediment disturbance or suspension downstream.

Lock and Dam Removal: The placement of material on the downstream dam apron or at the base of the dam to create the in-stream work pad, and the placement of excess material into the scour area is also not anticipated to significantly degrade water quality. Fine sediment has been scoured from this area by the force of water flowing over the dam, making significant sediment

suspension unlikely. Any fine sediment that remains and becomes suspended would be carried downstream by the flow of the river, with turbidity or dissolved oxygen levels unlikely to become detrimental to mussels due to the relatively low amount of sediment involved.

Material that falls into the Barren River during lock and dam demolition will disturb sediment in some areas that could lead to localized degradation of water quality. Fine sediment above the dam may become suspended when material contacts the substrate during demolition. Disturbed sediment may increase turbidity for a longer period of time in this area due to slower flow; however, mussels are unlikely to be in this area due to the lack of suitable habitat. Suspended sediment that is transported downstream of the dam will disperse quickly due to the increased flow. Dam material that falls at the base of the dam and falling material from the inner lock downstream guide wall is also not expected to cause significant water quality degradation due to previous scouring of fine sediment from the base of the dam and the low amount of sediment involved.

Falling material from the outer lock river wall and material placed in the downstream extent of the lock chamber may disturb and suspend sediment that has accumulated in the protected area downstream of the dam; however, suspended sediment is not expected to remain long enough to increase turbidity or decrease dissolved oxygen levels due to the flow of water through this area. Additionally, no mussels were encountered in this area during the survey. Sediment that becomes suspended is expected to quickly move downstream and settle in existing depositional areas. Placement of the miter gates and other material into the outer lock chamber is not anticipated to result in water quality degradation due to the isolation of this area from the river channel and lack of flow into the river.

The movement of sediment that has accumulated upstream of the dam is likely to result in temporary water quality degradation in the work area. Although the amount of accumulated sediment appears to be low based on the Lewis (2021) survey, sediment transport downstream is expected. The restoration of Pool 1 to free-flowing conditions will cause the suspension of fine sediments, which may lead to increased turbidity and decreased oxygen levels. These changes will likely persist during and immediately after dam removal as the accumulated sediment moves downstream. Changes in turbidity and oxygen levels upstream and at the dam location are not anticipated to affect listed mussels due to the unsuitable habitat in these areas; however, mussels located immediately downstream of the dam may be impacted. Due to the removal of the dam in small increments over a period of weeks, the rapid movement of large amounts of suspended sediment into the work area is unlikely. Turbidity levels will likely increase gradually over time as more of the accumulated sediment upstream of the dam is exposed to increased flow. These levels may increase to the point that mussels, their food supply, and fish hosts are affected. In addition, sediment that has settled in the work area may become re-suspended during high flow events. The anticipated frequency and duration of these events, combined with the initial increase in suspended sediment immediately after dam removal, may cause turbidity levels to remain elevated long enough that mussels are adversely affected. Although a gradual drawdown of BRLD1 is anticipated, some bank sloughing is expected to occur before the site is stabilized, resulting in additional sediment from exposed banks within the work area. The additional sediment is expected to temporarily increase turbidity.

Site Stabilization: Site stabilization activities after lock and dam removal will reduce the potential for water quality degradation from sedimentation through seeding of disturbed areas and dressing of roads and parking areas. EPSC measures will also be maintained until the site is stabilized. As a result, water quality degradation from this construction component is expected to be minimal. Vehicles and equipment that contain petroleum-based products will be used in the work area during all construction components. During site preparation and stabilization, vehicles and equipment will operate along the riverbanks and will not enter the Barren River. Equipment operating from the in-stream work pad during lock and dam removal will only work in two feet of water or less to eliminate potential submersion of the engine compartment where most petroleum-based products are located.

Petroleum-based products could enter the river through leaks and spills, which could harm or kill mussels, their food supply, and fish hosts. BMPs will be utilized throughout construction to reduce the potential for petroleum-based products to enter the river. The potential for leaks and spills will be further reduced by the small number of equipment using the work pads and the short duration of the project. Additionally, any remaining hydraulic fluid in the hydraulic piping system in the operations building and lock chamber will be removed and appropriately disposed of prior to demolition of these structures. A spill response plan will be in place during construction, and any leaks or spills will be immediately cleaned up. If an accidental release does occur, the amount of petroleum-based product that enters the river is anticipated to be small and will be quickly dispersed and diluted by the flow of the river.

All Activities: Water quality degradation from all activities discussed above that occur in the work area may also result in impacts to fish hosts for Rough Pigtoe and Pyramid Pigtoe. Changes to water quality from sediment suspension or contaminants could cause fish hosts to abandon areas where mussels are present, reducing their exposure to mussels and limiting reproductive potential.

5.2.2 Action Area Upstream of Work Area

No construction components will occur in the Action Area upstream of the work area. Site preparation and stabilization activities are not expected to cause inputs of sediment into this area that could lead to water quality degradation due to the use of EPSC measures. The portion of the Action Area adjacent to and immediately upstream of the work area where the potential for water quality degradation from lock and dam demolition is highest does not provide suitable habitat for either mussel species. The suspension of accumulated sediment in this area after dam removal will also occur in unsuitable habitat. Some bank sloughing is expected to occur within the Action Area upstream of the work area, resulting in additional sediment input from exposed banks that is likely to result in increased turbidity; however, the increased turbidity is not expected to occur in the upstream portion of the Action Area that is suitable for these species. No vehicles or equipment will operate in the upstream portion of the Action Area; therefore, there is no potential for leaks or spills of petroleum-based products. Any releases of petroleum-based products in the work area would move downstream with the flow of the river.

5.2.3 Action Area Downstream of Work Area

No construction components will occur in the Action Area downstream of the work area. As discussed above, site preparation and stabilization activities are not expected to cause inputs of

sediment beyond the work area due to the use of EPSC measures; therefore, degradation of water quality from sedimentation is unlikely. Inputs of sediment that do occur are anticipated to be minimal and will not lead to prolonged sediment suspension in one area due to the flow of the river. No vehicles or equipment will operate in the Action Area downstream of the work area, and the risk for releases of petroleum-based products will be minimized by limiting the allowable water depth for equipment in the river and utilizing appropriate BMPs. Any releases of petroleum-based products in the work area would likely be diluted upon reaching the downstream portion of the Action Area. Accumulated sediment upstream of the dam that becomes suspended is expected to move into the downstream portion of the Action Area during and after dam removal. This suspended sediment may cause turbidity levels to temporarily increase above existing conditions in this portion of the Action Area, which could potentially affect mussels. In addition, inputs of additional suspended sediment from further upstream are also likely to occur during each high flow event, and the repeated occurrence of these events could adversely affect the Rough Pigtoe and Pyramid Pigtoe.

5.2.4 Applicable Science

Increased turbidity typically occurs during dam removals due to the disturbance and suspension of sediment that has accumulated behind the dam. Mussels may be impacted by high turbidity if the amount of light available for photosynthesis is reduced and potential food items like algae and phytoplankton decrease. The ability of fish hosts to detect mussel lures may also be impacted by low visibly from increased turbidity (Kanehl and Lyons 1992). Studies have shown that increased turbidity from dam removal is a temporary effect that subsides as sediment is flushed through the river system (Winter 1990, Kanehl et al. 1997). The amount of time required for high turbidity to decrease depends on several factors, including the amount of sediment that has accumulated behind the dam, the velocity of the river, the gradient of the riverbed, and the methods of dam removal. Turbidity increased after removal of a dam in Idaho but decreased within one week after removal, even though the impoundment was filled with sediment (Winter 1990). Accumulated sediment behind a run-of-river dam in Wisconsin took six months to move downstream, resulting in increased turbidity levels during this time (Nelson and Pajak 1990). The timing of dam removal can also determine the severity and duration of increased turbidity, with high turbidity levels persisting longer if the dam is removed during low flow (Kondolf 1997).

Construction activities could result in accidental spills of hazardous materials into the surrounding environment (USEPA 2017). Due to mussels' filter feeding behavior, freshwater mussels can be exposed to chemicals via ingestion, with chemicals in the water column directly impacting mussel gills, mantle, and kidneys resulting in mortality, as they uptake everything in the water that surrounds them, with no way to avoid toxic chemicals (Zimmerman et al. 2002).

Nutrients and pesticides from agriculture, timber harvest, and lawn management practices also have the potential to adversely impact mussel species. Nitrogen and phosphorus can enter streams through runoff from agricultural areas, post timber management activities, urban and suburban runoff, and residential lawns (Peterjohn and Correll 1984). Excessive nitrogen concentrations can result in shorter lifespans, reduced growth, and mortality (Bauer 1992). Nutrient enrichment can lead to increased algae respiration that depletes dissolved oxygen levels, which may be especially detrimental to juvenile mussels in interstitial spaces where dissolved

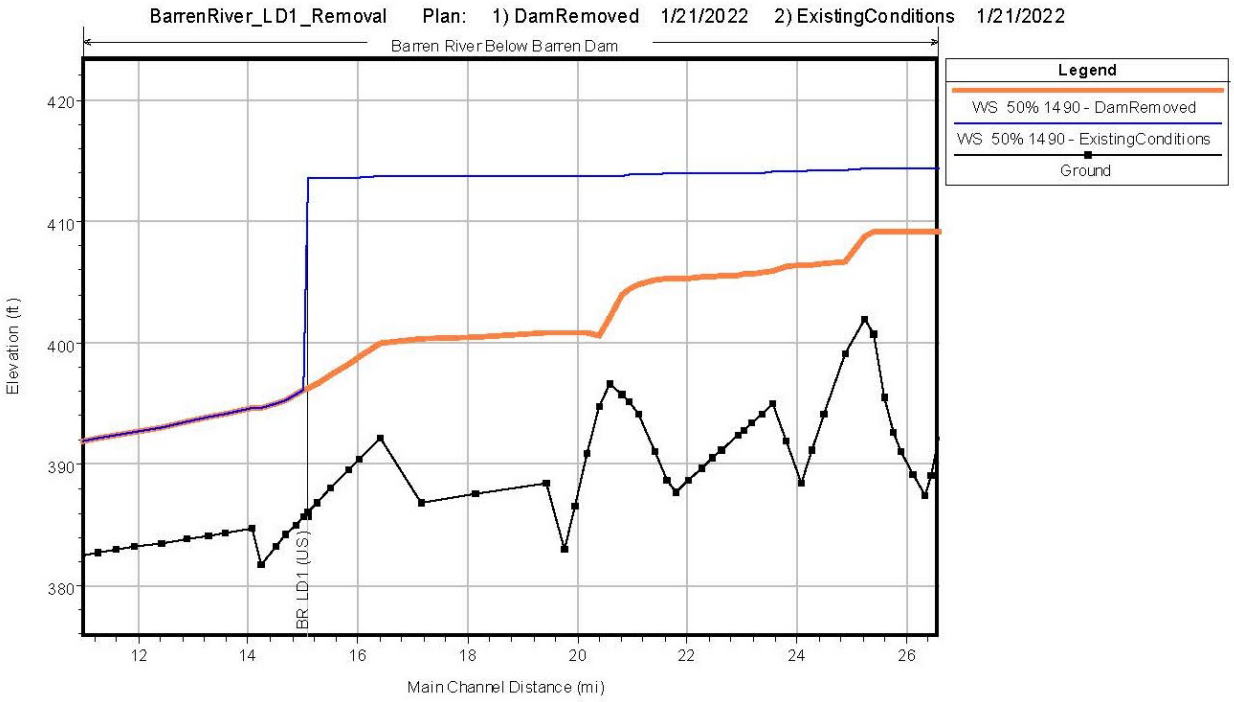
oxygen concentrations are low (Sparks and Strayer 1998). Pesticides are often used during the reproductive and early life periods of mussels when their effects may be more pronounced. Elevated concentrations of pesticides occur in streams due to residential or commercial pesticide runoff, overspray application to row crops, and lack of adequate riparian buffers (Bringolf et al. 2007).

5.3 Changes to Flow

Lock and dam removal is the only construction component that could result in changes to flow in the Barren River. Site preparation and site stabilization will not result in changes to flow due to the lack of in-stream activities associated with these components. Changes to flow from lock and dam removal could impact mussels and their habitat by altering the morphology of the river channel, causing sediment degradation and aggradation, and affecting water quality. Potential impacts to the mussel species from changes to flow could occur in the work area, the Action Area upstream of the work area, and the Action Area downstream of the work area (See Pathways 13-15, Appendix A).

5.3.1 Work Area

Changes to the hydraulic conditions in the Barren River after removal of BRLD1 were analyzed by the USACE based on previous hydraulic modeling. Based on the modeling, BRLD1 is a run-of-river type dam and does not significantly impound flood water within Pool 1. The crest of the dam is located at an elevation of approximately 412 feet AMSL, and the elevation of the associated floodplain is approximately 429 feet AMSL. Due to the difference between these elevations, the hydraulic capacity over the dam is large enough to allow the inflow and outflow of Pool 1 to be effectively equal. Flow downstream of the dam is not affected by the presence of the dam; therefore, removal of the dam is not anticipated to change downstream flow from existing conditions. This lack of change is demonstrated in the following exhibit from the memorandum.



The above graphic from the BA demonstrates the water surface profiles for the existing conditions (blue line) and conditions after dam removal (orange line). Both profiles are identical downstream of the dam, indicating that downstream flow is not affected by the dam. In addition, the depth and water surface slope downstream of the dam will remain the same after dam removal.

As documented by the USACE, BRLD1 does not attenuate flow, change downstream depths, or impact downstream water surface slopes to a measurable degree; therefore, shear stress and sediment transport capacity downstream of the dam are also not affected by the structure and are not expected to change after its removal. As a result, increased scouring and sediment deposition from changes in flow are unlikely to occur downstream after dam removal. Conversely, removal of the dam is expected to reduce scouring downstream of the dam by reducing the turbulent conditions caused by water flowing over the dam. Elimination of the plunging, vertical flow at the dam is anticipated to significantly reduce or stop scouring in the scour area currently located at the base of the dam. The restoration of more natural flow in this area will help retain the material placed in the scour area during dam demolition and allow fine sediments to accumulate in this area after dam removal.

5.3.2 Action Area Upstream of Work Area

Changes in flow will occur in the upstream portion of the Action Area as Pool 1 returns to free-flowing conditions. Although these changes will result in modifications to channel morphology and sediment degradation and aggradation in this area, the effects from these changes are expected to be minimal due to the location of the pool within the existing riverbanks and the gradual removal of the dam during a period of low flow. Significant additional effects are also

not anticipated during high flow events because floodwater is currently conveyed over the dam, causing the inflow and outflow of Pool 1 to be equal. As a result, effects that would occur to the river channel during high flows after dam removal are already occurring. In addition, mussels that occur in this area could benefit from flow changes that reduce pooling and increase flow.

5.3.3 Action Area Downstream of Work Area

Changes in flow downstream of BRLD1 are not expected from removal of the dam for the same reasons as discussed above for the work area. Significant changes in channel morphology and increased sediment degradation and aggradation in the downstream portion of the Action Area are not anticipated due to the lack of change in water depths, water surface slopes, shear stress, and sediment transport capacity downstream of the dam after removal.

5.3.4 Applicable Science

Dams alter flow by impounding or pooling long reaches of free-flowing rivers, resulting in changes to hydrology and channel morphology, increased sediment deposition, altered water quality, decreased habitat heterogeneity, altered flood patterns, and decreased movement of mussels and fish (Neves et al. 1997, Watters 2000). Habitat heterogeneity is often reduced from six to seven habitat types to three or four, some of which are highly modified from the existing habitat or new to the river system. Although the original channel remains upstream of the dam, increased depth and slower flow rapidly alter existing habitats. Decreased flow reduces sediment transport, causing fine sediment to settle and blanket the substrate with silt. Siltation of the river bottom can affect mussels through smothering, diminishing food supply by limiting light penetration, altering temperatures, and reducing recruitment (Watters 2000). Siltation can also change species composition in impounded or pooled areas by reducing the presence of species intolerant of silt with silt-tolerant species (Holland-Bartels 1990, Parmalee and Hughes 1993).

Changes in flow downstream of dams leads to scouring and bank erosion, reduced dissolved oxygen, temperature fluctuations, and changes in mussel and fish composition (Neves et al. 1997, Watters 2000). The acceleration of water as it flows over a run-of-river dam results in scour of the stream bed and banks, often producing a scour area or plunge pool at the base of the dam (Csiki and Rhoads 2014, Pearson and Pizzuto 2015). Scouring at the base of the dam mobilizes fine sediments and smaller coarse sediments, leaving only cobble, boulders, and bedrock (Skalak et al. 2009, Csiki and Rhoads 2014). A mid-channel bar often forms downstream of the dam that consists of scoured materials (Csiki and Rhoads 2014). Scouring immediately below dams can be extensive and can eliminate or prevent mussels from inhabiting these areas (Miller and Payne 1992). The removal of dams and restoration of natural river flow appear to have a positive impact on mussels. Mussels downstream of run-of-river dams have responded favorably to removals, and in some cases, have made dramatic increases (Haag 2012).

5.4 Crushing/Striking Individuals

Lock and dam removal is the only construction component that could result in crushing or striking of individuals. Site preparation and stabilization will not result in crushing or striking of individuals due to the lack of in-stream activities associated with these components. Material that is placed or falls on a mussel during lock and dam removal could result in harm if the individual is struck, or result in mortality if the individual is crushed. The striking of mussels could also

lead to mortality if an individual sustains severe damage. Potential impacts to both mussel species from crushing or striking of individuals could occur in the work area, but are not expected to occur in the Action Area upstream of the work area and the Action Area downstream of the work area (See Pathways 16-17, Appendix A).

5.4.1 Work Area

The placement of material at the base of the dam to fill the scour area and create the in-stream work pad could result in the crushing or striking of individuals. Although the presence of the Rough Pigtoe and Pyramid Pigtoe at the base of the dam is unlikely due to the constant turbulence generated by water flowing over the dam and the lack of suitable substrate from scouring, these species could be present immediately downstream of the dam. Material placed at the downstream edge of the fill area could extend into areas where mussels are located and crush or strike an individual. Pieces of material could also be dislocated from the work pad during placement or become dislodged by equipment or water flows and move downstream, crushing or striking an individual. Material being transported from the dam to the lock chamber may also fall into the river. Placement of material or material that falls into the river upstream of the dam is not anticipated to crush or strike individuals due to the lack of suitable habitat for these species in this area.

Falling material from the inner lock downstream guide wall and outer lock river wall and material placed in the downstream extent of the lock chamber are not anticipated to crush or strike mussels due to the lack of individuals encountered in this area during the 2021 survey. Placement of the miter gates and material into the lock chamber is not anticipated to crush or strike individuals due to the lack of suitable habitat in the chamber.

During and after dam removal, the increased flow could cause the cobble and boulders observed immediately upstream of the dam to be transported downstream. Some of these rocks may settle in the scour area at the base of the dam; however, others may continue downstream of the dam into areas where mussels are present, resulting in the crushing or striking of individuals.

5.4.2 Action Area Upstream and Downstream of Work Area

No construction components will occur in the Action Area upstream or downstream of the work area. Material that is placed or falls into the river during lock and dam removal is not expected to enter these areas. As a result, the crushing or striking of individuals in the upstream and downstream portions of the Action Area is not anticipated as a result of the project.

5.4.3 Applicable Science

Although evidence of mussels being crushed or struck by debris during removal of dams has not been reported, crushing and striking from other sources has been documented. A study on the effects of barge fleeting in the Illinois River found evidence that mussels had been crushed and struck by barges that grounded on the substrate. Mussel species with heavy shells exhibited scrapes and appeared to have been pushed down into the mud substrate when the barges made contact. Species with fragile shells appeared to be crushed completely based on shell fragments found under the barges. The study also noted that propellers may have hit the substrate and contributed to the scrapes observed on some mussel shells, as well as mortality (Sparks and

Blodgett 1985). Another study on the Mississippi River also found evidence of mussels being crushed by barges along the shoreline (Millar and Mahaffy 1989).

Trampling of mussels by people, animals, and vehicles has also been reported. Crushed mussels, deformed shells, and shell fragments have been found in areas where livestock have access to streams. Fords where vehicles cross streams are often devoid of mussels, suggesting that individuals in these areas have been crushed or moved to other areas after being struck. Mussels may also be impacted by canoeists, kayakers, and other recreational users as they move over shallow riffles while portaging, fishing, or wading. These types of disturbances may be particularly detrimental to smaller mussel species, species with thin shells, and juveniles (Watters 2000). Based on this evidence, it is likely that debris that enters the water during the removal of dams and locks could crush or strike individuals.

5.5 Displacement of Individuals

Lock and dam removal is the only construction component that could result in displacement of individuals. Site preparation and stabilization will not displace individuals due to the lack of in-stream activities associated with these components. During lock and dam removal, material that is placed or falls on the river bottom and disturbs the substrate could displace an adjacent individual. Displaced mussels could be moved to an area of unsuitable habitat, requiring the individual to move to a more suitable area and expend energy. Displacement may also lead to harm or mortality if the mussel is unable to find suitable habitat quickly. Potential impacts to the mussel species from displacement of individuals could occur in the work area, the Action Area upstream of the work area, and the Action Area downstream of the work area (See Pathways 18-19, Appendix A).

5.5.1 Work Area

Notching of the dam could displace mussels located near the base of the dam and immediately downstream due to the increased velocity and force created by the concentrated flow. Scouring from increased flow could also displace mussels. However, based on the location of notching and current conditions in this area, increased flow is not anticipated to displace mussels. The area at the base of the dam and immediately downstream does not provide suitable habitat for the listed mussel species. In addition, the anticipated conditions downstream of the notch are expected to be similar to flood events currently experienced within the river. As water travels farther into the main channel and downstream, the increased force created by the concentrated flow at the notch is expected to have dissipated and be similar to normal flow. Based on these factors, displacement of individuals from notching of the dam is unlikely.

The placement of material on the downstream dam apron or at the base of the dam to create the in-stream work pad, and placement of excess material into the scour area is unlikely to displace individuals due to the lack of suitable habitat in this area. Material that is placed at the downstream edge of the fill area or falls off the work pad could enter areas of suitable mussel habitat; however, displacement of individuals is not anticipated. The size of the material will be similar to large cobble and small boulders and will have a small impact area, reducing the amount of substrate that will be displaced. Additionally, the substrate downstream of the dam is likely comprised of coarse sediments with little fine sediment due to the scouring effect created by the dam, and movement from material hitting the substrate is expected to be minimal. If a

mussel is displaced, the individual will likely move a short distance and remain in suitable habitat. Material that falls into the river downstream of the dam during transport to the lock chamber is expected to have similar effects. Material that enters the river upstream of the dam is not anticipated to displace individuals due to the lack of suitable habitat for the mussel species in this area.

Material that falls from the inner lock downstream guide wall and outer lock river wall and material placed in the downstream extent of the lock chamber are not anticipated to displace mussels due to the lack of individuals encountered in this area during the 2021 survey. Placement of the miter gates and material into the lock chamber is also not anticipated to displace individuals due to the lack of suitable habitat in the chamber.

5.5.2 Action Area Upstream of Work Area

No construction components will occur in the Action Area upstream of the work area. Increased flow may occur immediately upstream of the dam near the notched portion; however, this area is unsuitable for mussels and is unlikely to displace individuals. As a result, the displacement of individuals in this area is not anticipated as a result of the project.

5.5.3 Action Area Downstream of Work Area

No construction components will occur in the Action Area downstream of the work area. The increased flow created by notching of the dam is expected to dissipate prior to reaching the downstream portion of the Action Area. Additionally, material placed in the river during demolition of the lock and dam is not expected to generate sufficient force to displace mussels from the substrate downstream of the work area. Therefore, the displacement of individuals in the Action Area downstream of the work area is not anticipated.

5.5.4 Applicable Science

Published data on the displacement of mussels from dam removal is lacking; however, mussel displacement from turbulence created by boats has been noted. Studies have shown that turbulence generated by the surge of large vessels as they pass by or over mussels and from boat propellers (i.e., propeller wash) can displace mussels from the substrate (Sparks and Blodgett 1985, Aldridge et al. 1987, Millar and Mahaffy 1989, Watters 2000). The potential for displacement is highest in shallow areas, particularly near riverbanks. Based on these studies, concentrated flows of turbulent water, such as those that may occur during dam removal, have the potential to displace mussels from the substrate.

5.6 Exposure of Individuals to Air

Lock and dam removal is the only construction component that could result in exposure of individuals. Site preparation and stabilization will not result in this stressor due to the lack of in-stream activities associated with these components. Removal of BRLD1 will lower the water level of the Barren River upstream of the dam, which could expose mussels in shallow areas as the water level recedes. Mussels exposed to air could be harmed if individuals are stressed and suffer increased energy expenditure or reduced fitness. Mortality may occur if mussels are unable to move to deeper water or move downward in the substrate to reach saturation zones. Potential impacts to the mussel species from exposure of individuals could occur in the work

area, the Action Area upstream of the work area, and the Action Area downstream of the work area (See Pathways 20-21, Appendix A) as described in the sections that follow.

5.6.1 Work Area

The removal of the dam will lower the water level of the river in the upstream portion of the work area. The work area upstream of the dam does not provide suitable habitat for the Rough Pigtoe or Pyramid Pigtoe; therefore, the lower water level is not anticipated to expose individuals of these species.

5.6.2 Action Area Upstream of Work Area

Removal of the dam will lower the water level of the Barren River throughout the upstream portion of the Action Area. Based on the Hydrologic and Hydraulic Analysis included in the Disposition Study (USACE 2014), removal of BRLD1 will lower the water level seven miles upstream of BRLD1 by approximately 12 feet based on the 100% duration flow for August (base flow). The difference in water level will decrease with increasing distance from BRLD1 to the end of the Action Area just below RM 38. After the dam is notched, the water level in Pool 1 is expected to recede slowly due to the small size of the opening; however, as larger sections of the dam are removed and more water flows through, the rate of recession is anticipated to increase beyond the normal rate of recession during seasonal periods of low water. The lower water level will expose areas of the river that are typically inundated, potentially exposing mussels along the banks and in shallower areas. When combined with the increased rate of recession, exposed mussels will be forced to quickly move to deeper water or saturation zones, expending additional energy and increasing stress. Mortality is expected for individuals that are unable to move to suitable areas. As stated previously, the portion of the river from BRLD1 to 17 miles upstream does not provide suitable habitat for the Rough Pigtoe or Pyramid Pigtoe; however, habitat improves beyond 17 miles upstream of BLRD1, and this area is reasonably certain to support these species. Because habitat in this area more closely resembles a natural riverine system, and given the distance from BRL1, exposure to air is less likely to occur, but cannot be completely discounted.

5.6.3 Action Area Downstream of Work Area

The water level of the Barren River in the downstream portion of the Action Area will not be influenced by the removal of BRLD1. As a result, the exposure of individuals from lock and dam removal is not anticipated in the Action Area downstream of the work area.

5.6.4 Applicable Science

Dam removal can expose mussels within the impounded or pooled area upstream of a dam as the water level is lowered. The number of mussels exposed during drawdown appears to be related to the rate at which the water level is lowered. After removal of a run-of-river dam in Wisconsin, Sethi et al. (2004) observed extensive mortality of mussels resulting from stranding, desiccation, and predation. Based on the number of dead mussels observed, the authors estimated that nearly 4,700 individuals had died from exposure after drawdown of the pool upstream of the dam. These results appeared to be caused by the rapid dewatering of the pool, which occurred in approximately 36 hours, and the study recommended a slow drawdown period for pools to minimize mussel exposure. Similar results were found after removal of a run-of-river dam in

New York, where the rapid draining of the dam pool resulted in the deaths of more than 2,800 mussels, or 77% of the estimated population, upstream of the dam. The 1.3-hectare reservoir was drained in 25 hours and lowered the water level by 47 centimeters at the reservoir center and 3.3 meters at the dam (Cooper 2011).

Exposure of mussels was documented upstream of Green River Lock and Dam 6 (GRLD6) after the uncontrolled breach of the dam in 2016. The KDFWR, in cooperation with Mammoth Cave National Park and other agencies, conducted a salvage survey over four days at six sites upstream of GRLD6 immediately after the dam breached and caused an expedited loss of pool. The sites included four islands and two associated areas where the lower water level exposed large areas of the river bottom that were previously covered by shallow water. During the survey, a total of 2,404 individual mussels were found exposed along shoals and bank edges, including 2,010 live individuals and 394 dead individuals. Evidence of some individuals moving from exposed areas to deeper water was observed; however, mortality would likely have been higher if the salvage effort had not occurred (McGregor et al. 2016).

Conversely, slow drawdowns of dam pools during and after dam removal appear to reduce the amount of mussel exposure. Dewatering of the pool during removal of a North Carolina dam over a three-week period resulted in only minimal exposure of mussels. The low number of exposed individuals was also attributed to the pool being confined within the banks of the river, reducing the amount of riverbed exposed after dam removal. Time of year was also a factor; as the dam was removed in the fall/winter when dissolved oxygen concentrations are highest and water temperatures are cool (Heise et al. 2013).

5.7 Invasive Species

The presence of invasive carp species and the zebra mussel in the Green River presents a biological threat to the Rough Pigtoe and Pyramid Pigtoe, though these invasive species have not been documented in the Barren River. Although not considered to be a direct stressor from the proposed Action, the removal of BRLD1 may allow these species to expand their range. Removal of BRLD1 could potentially allow carp to move freely upstream at any time and expand their numbers and range. While zebra mussels are not as mobile as the carp, this species has the potential to affect native mussel populations where it occurs. The potential expansion of invasive carp and zebra mussels in the Barren River after the removal of BRLD1 could affect the Rough Pigtoe and Pyramid Pigtoe; however, the level of impact is difficult to discern based on available data. As a result, potential impacts to the Rough Pigtoe and Pyramid Pigtoe from invasive species are considered insignificant and a stressor-exposure-response pathway summary is not included in Appendix A.

5.8 Beneficial Effects

In addition to the stressors identified in the previous sections, the proposed Action is expected to result in positive effects to the Rough Pigtoe and Pyramid Pigtoe; however, there are no wholly beneficial effects that will result from the proposed action. Dams result in physical, chemical, and biological impacts to rivers and streams, and the negative impacts of impoundments and pools on mussel assemblages, survival, and reproduction has been documented in this report. Removal of dams provides an opportunity to reverse these impacts and restore ecological functions to the ecosystem. Although few studies have examined the effects of dam removal to

mussels and the overall ecosystem, the long-term benefits of dam removal are anticipated to outweigh the temporary, short-term impacts and help restore the system to more natural conditions (Sethi et al. 2004, Doyle et al. 2005, Sherman 2013).

The removal of BRLD1 is anticipated to improve mussel habitat in the Pool 1, restore a more natural flow regime, improve sediment and nutrient transport, improve water quality, and restore fish host passage in the Action Area. The conversion of this reach to a free-flowing system will create more suitable habitat for mussels in the future. Restoration of a more natural flow regime will also help improve mussel habitat in the Action Area through improved sediment transport and distribution. Impounded rivers compensate for the absence of sediment downstream of the dam by eroding, incising, and scouring downstream reaches (Poff et al. 1997, Gilliam 2011) and depositing sediments in areas farther downstream (Collier et al 1996). After removal of BRLD1, fine sediment from upstream of the dam will be transported and redistributed downstream, restoring small particles to the scour areas downstream of the dam. In addition, the movement of accumulated sediment from Pool 1 will expose gravel, cobble, and boulders that have previously been covered by silt (Bednarek 2001). Although the movement of fine sediment downstream may result in adverse effects to mussels immediately after dam removal, this sediment is anticipated to either stabilize or, depending on flows, be flushed farther downstream and be distributed over a larger area with each storm event. Nutrients and organic material will also be transported downstream, providing increased food supply for mussels.

Restoration of a more natural flow regime will also improve water quality in the Action Area. Turbidity is expected to increase from sediment suspension during and immediately after dam removal; however, the amount of suspended sediment is anticipated to decrease soon after substrate disturbance ceases, and suspended sediment will be transported downstream and settle over a large area. In the long term, turbidity levels from the project are expected to remain low due to restoration of the free-flowing river and improved stability of the work site. The unimpeded flow after dam removal is also anticipated to increase dissolved oxygen levels, particularly upstream of the dam. Temperatures upstream of the dam will also become more stable and consistent with other free-flowing portions of the river (Bednarek 2001).

Increased movement of fish hosts after removal of BRLD1 will further benefit the Rough Pigtoe and Pyramid Pigtoe. As Pool 1 returns to lotic conditions and habitat improves, fish hosts carrying glochidia are expected to move upstream and help establish mussel beds (Sethi et al. 2004). Populations of fish hosts that may have been previously separated by the dam will be able to intermingle, helping to increase their numbers and subsequently aiding in mussel reproduction.

5.9 Cumulative Effects

Cumulative effects are those effects of future State or private activities, not involving Federal activities that are reasonably certain to occur within the action area of the Federal action subject to consultation. The purpose of the proposed Action is to improve passage for aquatic organisms and restore instream habitat above and below the dam for riverine fish and macroinvertebrates. Future activities, such as increased residential or commercial development, agricultural practices, increased traffic, or tourism, in the area are not reasonably certain to occur. Based on these

factors, no cumulative effects to the Rough Pigtoe and Pyramid Pigtoe are anticipated as a result of the proposed Action.

5.10 Summary of Effects

The proposed Action could expose the Rough Pigtoe and Pyramid Pigtoe to the stressors evaluated in the previous sections. We anticipate that adverse effects resulting from site preparation and site stabilization will be insignificant and/or discountable. Therefore, adverse effects to the Rough Pigtoe and Pyramid Pigtoe are limited to activities associated with the lock and dam removal. We expect lock and dam removal activities to result in adverse effects from sediment disturbance and water quality degradation in the work area and downstream of the work area. We also expect activities associated with the lock and dam removal to result in adverse effects from crushing or striking of individuals in the work area and exposure of individuals upstream of the work area. We do not expect the majority of adverse effects to result in mortality. We expect that the adverse effects, and potential for mortality, will be most significant immediately below BRLD1 and will incrementally decrease in intensity as the downstream distance from the work area increases. The majority of downstream adverse effects are considered temporary (e.g., short-term water quality degradation), and the Rough Pigtoe and Pyramid Pigtoe are ultimately expected to benefit from the project in the long-term. A summary of effects is included in Table 1.

Table 1. Summary of Effects

Stressor	Action Component	Location*	Effect	
			Adverse	Insignificant/Discountable
Sediment Disturbance	Site Preparation	AA		X
	Lock and Dam Removal	AA US of WA		X
		WA	X	
		AA DS of WA	X	
	Site Stabilization	AA		X
Water Quality Degradation	Site Preparation	AA		X
	Lock and Dam Removal	AA US of WA		X
		WA	X	
		AA DS of WA	X	
	Site Stabilization	AA		X
Changes to Flow	Site Preparation	AA		X
	Lock and Dam Removal	AA		X
	Site Stabilization	AA		X
Crushing/Striking of Individuals	Site Preparation	AA		X
	Lock and Dam Removal	AA US of WA		X
		WA	X	
		AA DS of WA		X
	Site Stabilization	AA		X
Displacement of Individuals	Site Preparation	AA		X
	Lock and Dam Removal	AA		X
	Site Stabilization	AA		X
Exposure of Individuals	Site Preparation	AA		X
	Lock and Dam Removal	AA US of WA	X	
		WA		X
		AA DS of WA		X
	Site Stabilization	AA		X

* - "AA" means Action Area; "AA US of WA" means Action Area Upstream of Work Area; "WA" means Work Area; and "AA DS of WA" means Action Area Downstream of Work Area.

6.0 INCIDENTAL TAKE STATEMENT

ESA §9(a)(1) and regulations issued under §4(d) prohibit the take of endangered and threatened fish and wildlife species without special exemption. The term "take" in the ESA means "to harass, harm, pursue, hunt, shoot, wound, kill, trap, capture, or collect, or to attempt to engage in any such conduct" (ESA §3). "Harm in the definition of "take" in the Act means an act which actually kills or injures wildlife. Such [an] act may include significant habitat modification or degradation where it actually kills or injures wildlife by significantly impairing essential behavioral patterns, including breeding, feeding, or sheltering" (50 CFR 17.3). Under the terms of ESA §7(b)(4) and §7(o)(2), taking that is incidental to and not intended as part of the agency action is not considered prohibited, provided that such taking is in compliance with the terms and conditions of an incidental take statement (ITS).

For the exemption in ESA §7(o)(2) to apply to the Action considered in this BO, the USACE must undertake the non-discretionary measures described in this ITS, and these measures must become binding conditions of any permit, contract, or grant issued for implementing the Action. The USACE has a continuing duty to regulate the activity covered by this ITS. The protective coverage of §7(o)(2) may lapse if the USACE fails to: (a) assume and implement the terms and conditions; or (b) require a permittee, contractor, or grantee to adhere to the terms and conditions of the ITS through enforceable terms that are added to the permit, contract, or grant document. In order to monitor the impact of incidental take, the USACE must report the progress of the Action and its impact on the species to the Service as specified in this ITS.

As a proposed species, the prohibitions against taking the Pyramid Pigtoe, as found in §9 of the ESA, do not apply until the species is listed. Therefore, this ITS does not become effective for the Pyramid Pigtoe unless the Service adopts the CO for this species as the biological opinion once a listing decision is final.

6.1 Amount or Extent of Take Anticipated

This section specifies the amount or extent of take of the Rough Pigtoe and Pyramid Pigtoe that the Action is reasonably certain to cause, which we estimated in the "Effects of the Action" section of this BO/CO, using the best available data.

We estimated the number of individuals reasonably certain to occur in the Action Area (Section 4.0, Environmental Baseline). We then evaluated the potential for these individuals to be exposed to the stressors resulting from the proposed Action. Finally, we evaluated how the individuals' responses to their exposure to these stressors would apply to the statutory and regulatory definition of take (Section 5.0, Effects of the Action). From our evaluation, the proposed Action is reasonably certain to cause the incidental take of the Rough Pigtoe and Pyramid Pigtoe within the Action Area and is consistent with the definition of harm (Table 2). We estimated the incidental take of all Rough Pigtoe and Pyramid Pigtoe individuals occurring downstream of BRLD1, including the work area, due to sediment disturbance, water quality degradation, and crushing/striking individuals. This would affect 587 individuals of each species.

Adverse effects upstream of BRLD1 are expected to result in incidental take of the Rough Pigtoe and Pyramid Pigtoe from exposure of individuals to air that results from the lowering of water

levels in the pool upstream of BRLD1. The portion of the Action Area upstream of BRLD1 totals approximately 2,638,266 m^2, but as discussed in Section 4.1.2, only approximately 579,385 m^2 is considered suitable for these species. The salvage survey conducted upstream of GRLD6 immediately after the dam breach (Section 5.6) observed 2,404 exposed mussels. No Rough Pigtoe or Pyramid Pigtoe were salvaged; however, the federally endangered Sheepnose (*Plethobasus cyphyus*) was salvaged and accounted for 0.21 percent of the exposed mussels. Because Sheepnose are typically found in the shallower areas of large rivers and are likely to be exposed by a reduction in water depth, the KFO believes it is reasonable to use the Sheepnose as a surrogate and assume that the number of exposed mussels will be similar to (or less than) that experienced after the failure of GRLD6. Therefore, using the best available commercial and scientific data, we anticipate that the incidental take of the Rough Pigtoe and Pyramid Pigtoe that occur upstream of BRLD1 will not exceed 0.21 percent of the total number of individuals estimated to occur in the upstream portion of the Action Area (i.e., 343 individuals of each species). Given these estimates, we would expect the incidental take of 1 Rough Pigtoe and 1 Pyramid Pigtoe as a result of exposure (for example, 343 Rough Pigtoe x 0.0021= 0.72, or1 individual when rounded to the next full individual).

Table 2. Summary of Expected Incidental Take

Species	# of Individuals	Take Type
Rough Pigtoe	Upstream: 1 Downstream: 587 **Total: 588**	Harm
Pyramid Pigtoe	Upstream: 1 Downstream: 587 **Total: 588**	Harm

We anticipate that monitoring the incidental take using the number of individuals is not practical because: the size and depth of the aquatic environment within the Action Area is difficult to monitor in its entirety; the mussel species are relatively small, cryptic, and are not easily detected; finding dead or injured specimens during the majority of project implementation is unlikely due to the riverine environment; and the majority of incidental take is expected to be in the form of non-lethal harm, such as reduced feeding or reproductive efficiency due to increased turbidity, that is difficult to observe. When it is not practical to monitor take in terms of individuals, the regulations at 50 CFR §402.14(i)(1)(i) indicate that an ITS may express the amount or extent of take using a surrogate provided that the Service also describes the causal link between the surrogate and take of the listed species and sets a clear standard for determining when the level of anticipated take has been exceeded.

Therefore, we have determined that it is appropriate to monitor the square meters of suitable habitat that will be affected by the Action to ensure the amount of incidental take is not exceeded. Our opinion is that this is appropriate because the mussel species are expected to occur in all areas of suitable habitat within the Action Area, square meters of suitable habitat was used to quantify the number of individuals within the Action Area for each species, and most incidental take associated with the Action is a result of habitat alteration/degradation. Incidental take is considered exceeded if the Action impacts more than the proposed 146,740 m^2 of

downstream suitable habitat with the Action Area and/or more than 579,385 m^2 of upstream suitable habitat with the Action Area (Table 3). We describe the procedures for monitoring in Section 6.4.

Table 3. Surrogate Measures for Monitoring Incidental Take

Species	Life Stages	Surrogate	Quantity
Rough Pigtoe Pyramid Pigtoe	All	Suitable habitat (m^2) within the Action Area downstream of BRLD1 (including the work area)	146,740 m^2
Rough Pigtoe Pyramid Pigtoe	All	Suitable habitat (m^2) within the Action Area upstream of BRLD1	579,385 m^2

6.2 Reasonable and Prudent Measures

The Action includes conservation measures to avoid and minimize impacts to the subject mussel species. The analysis of effects of the Action in this BO/CO considers that USACE will authorize, fund, or carry out all activities under the Action in a manner that is consistent with the description of activities provided in BA, including all applicable conservation measures. Due to the aforementioned commitments, our review of the Action, and conservation measures, the Service concludes that no reasonable and prudent measures are necessary or appropriate to minimize incidental take of the Rough Pigtoe caused by the Action. Similarly, no reasonable and prudent measures will be necessary for the Pyramid Pigtoe if the CO is adopted as the biological opinion for this species.

6.3 Terms and Conditions

No reasonable and prudent measures to minimize incidental take caused by the Action are provided in this BO/CO; therefore, no terms and conditions for carrying out such measures are necessary.

6.4 Monitoring and Reporting Requirements

The USACE will (1) ensure that all of the identified Conservation Measures are implemented and (2) inform the Service as soon as possible if the amount of take is exceeded or if any of the mussel species are observed, injured, or crushed within the Action Area. In order to monitor the impacts of incidental take, the USACE must report the progress of the Action and its impact on the species to the Service as specified in the ITS (50 CFR §402.14(i)(3)). The USACE should notify the Service once construction activities have commenced and provide a monthly project status summary that includes a brief summary of all activities that have been completed to date. This monitoring requirement will end once the dam demolition has been completed.

7.0 CONSERVATION RECOMMENDATIONS

§7(a)(1) of the ESA directs Federal agencies to use their authorities to further the purposes of the ESA by conducting conservation programs for the benefit of endangered and threatened species. Conservation recommendations are discretionary activities that an action agency may undertake

to avoid or minimize the adverse effects of a proposed action, implement recovery plans, or develop information that is useful for the conservation of listed species. The Service has not identified any conservation recommendations for this BO/CO.

8.0 RE-INITIATION NOTICE

Formal consultation for the Action considered in this BO/CO is concluded. Reinitiating consultation is required if the USACE retains discretionary involvement or control over the Action (or is authorized by law) when:

a) the amount or extent of incidental take is exceeded;
b) new information reveals that the Action may affect listed species or designated critical habitat in a manner or to an extent not considered in this BO/CO;
c) the Action is modified in a manner that causes effects to listed species or designated critical habitat not considered in this BO/CO; or
d) a new species is listed or critical habitat designated that the Action may affect.

This consultation was assigned FWS ID 22-0005888. Please refer to this number in any correspondence concerning this consultation.

LITERATURE CITED

Aldridge, D.W., B.S. Payne, and A.C. Miller. 1987. The effects of intermittent exposure to suspended solids and turbulence on three species of freshwater mussels. Environmental Pollution 45: 17-28.

Bauer, G. 1992. Variation in the life span and size of the freshwater pearl mussel. Journal of Animal Ecology 61:425-436.

Bednarek, A.T. 2001. Undamming Rivers: A Review of the Ecological Impacts of Dam Removal. Environmental Management Vol. 27, No. 6, pp. 803–814.

Brim-Box, J.B. and J. Mossa. 1999. Sediment, land use, and freshwater mussels: prospects and problems. Journal of North American Benthological Society 18(1):99-117.

Bringolf, R.B., W.G. Cope, S. Mosher, M.C. Barnhart, and D. Shea. 2007. Contaminant sensitivity of freshwater mussels: Acute and chronic toxicity of glyphosphate compounds to glochidia and juveniles of Lampsilis siliquoidea (Unionidae). Environmental Toxicology and Chemistry 26(10):2094-2100.

Collier, M., R.H. Webb, and J.C. Schmidt. 1996. Dams and rivers; a primer on the downstream effects of dams. U.S. Geological Survey Circular, 94-94.

Cooper, J.E. 2011. Unionid Mussel Mortality from Habitat Loss in the Salmon River, New York, following Dam Removal. Advances in Environmental Research. Volume 14.

Csiki S.R. and B.L. Rhoads. 2014. Influence of four run-of-river dams on channel morphology and sediment characteristics in Illinois, USA. Geomorphology 206: 215–229.

Doeg, T.J. and J.D. Koehn. 1994. Effects of draining and desilting a small weir on downstream fish and macroinvertebrates. Regulated Rivers: Research and Management 9: 263–277.

Doyle, M.W., E.H. Stanley, C.H. Orr, A.R. Selle, S.A. Sethi, and J.M. Harbor. 2005. Stream ecosystem response to small dam removal: Lessons from the Heartland. Geomorphology 71 (2005) 227–244.

Gilliam, E.A. 2011. Assessing Channel Change and Bank Stability Downstream of a Dam, Wyoming. Colorado State University. Fort Collins, CO.

Grabarkiewicz, J. and W. Davis. 2008. An introduction to freshwater mussels as biological indicators. EPA-260-R-08-015. U.S. Environmental Protection Agency, Office of Environmental Information, Washington, DC.

Haag, W.R. 2012. North American freshwater mussels: natural history, ecology, and conservation, first edition, Cambridge University Press, New York, NY.

Haag, W.R. and R.R. Cicerello. 2016. A Distributional Atlas of the Freshwater Mussels of Kentucky. Scientific and Technical Series 8. Kentucky State Nature Preserves Commission. Frankfort, KY.

Hartfield, P.W. and E. Hartfield. 1996. Observations on the conglutinates of Ptychobranchus greeni (Conrad 1834) (Mollusca: Bivalvia: Unionoidea). American Midland Naturalist 135:370-375.

Heise, R.J., W.G. Cope, T.J. Kwak, C.B. Eads. 2013. Short-Term Effects of Small Dam Removal on a Freshwater Mussel Assemblage. Freshwater Mollusk Biology and Conservation 16(1): 41-52.

Holland-Bartels, L.E. 1990. Physical factors and their influence on the mussel fauna of a main channel border habitat of the upper Mississippi River. Journal of the North American Benthological Society 9: 327-335.

Kanehl, P. and J. Lyons. 1992. Impacts of in-stream sand and gravel mining on stream habitat and fish communities, including a survey on the Big Rib River, Marathon County, Wisconsin. Wisconsin Department of Natural Resources Research Report 155. 32 pp.

Kanehl, P. D., J. Lyons, and J. E. Nelson. 1997. Changes in the habitat and fish community of the Milwaukee River, Wisconsin, following removal of the Woolen Mills Dam. North American Journal of Fisheries Management 17:387–400.

Kentucky Department of Fish and Wildlife Resources (KDFWR). 2022. Invasive Carp Information. https://fw.ky.gov/Fish/Pages/Invasive-Carp-Information.aspx. Accessed January 2022.

Kondolf, G.M. 1997. Hungry water: Effects of dams and gravel mining on river channels. Environmental Management 21(4): 533–551.

Lewis Environmental Consulting, LLC. 2021. Mussel Survey of Barren River Pool 1 and Downstream of Barren River Lock and Dam 1 in Warren County, Kentucky. Prepared for U.S. Fish and Wildlife Service – Kentucky Field Office. Frankfort, KY. 72 pp.

Lewis Environmental Consulting, LLC. 2008. Mussel Surveys at Barren River Miles 7.7, 9.7, 12, and 14 in Warren County, Kentucky to Assess Pipeline Crossing Impacts to Mussel Beds. Prepared for Gulfstar Energy, LLC. Morgantown, KY 85 pp.

McGregor, M.A., K. Kern, R.S. Toomey, S.L. Carr, A. McDonald, T. Bailey, D. Cravens, and J. Jacobs. 2016. Salvage of Freshwater Mussels After Failure of Lock and Dam 6 on the Green River. Report prepared by the Kentucky Department of Fish and Wildlife Resources, Center for Mollusk Conservation, Frankfort, KY.

Millar, J.G. and M.S. Mahaffy. 1989. Background Study on the Environmental Impacts of Barge Fleeting. EMTC 89/04. U. S. Fish and Wildlife Service, Environmental Management Technical Center, Onalaska, WI.

Miller, A.C. and B.S. Payne. 1992. Characterization of a freshwater mussel (Unionidae) community immediately downstream of Kentucky Lock and Dam in the Tennessee River. Transactions of the Kentucky Academy of Science 53: 154-161.

Nelson, J.E., and P. Pajak. 1990. Fish habitat restoration following dam removal on a warmwater river. Pages 57–65 in The restoration of Midwestern stream habitat. American Fisheries Society, North Central Division, Rivers and Streams Technical Committee Symposium Proceedings at the 52nd Midwest Fish and Wildlife Conference, 4–5 December 1990. Minneapolis, MN.

Neves, R.J., A.E. Bogan, J.D. Williams, S.A. Ahlstedt, and P.W. Hartfield. 1997. Chapter 3: Status of aquatic mollusks in the southeastern United States: a downward spiral of diversity in G. W. Benz, and D. E. Collins, editors. Aquatic fauna in peril: the southeastern perspective. Southeastern Aquatic Research Institute, Decatur, GA.

Parmalee, P.W. and M.H. Hughes. 1993. Freshwater mussels (Mollusca:Pelecypoda:Unionidae) of Tellico Lake: twelve years after impoundment of the Little Tennessee River. Annals of the Carnegie Museum 62: 81-93.

Pearson, A.J. and J. Pizzuto. 2015. Bedload transport over run-of-river dams, Delaware, USA. Geomorphology 248: 382-395.

Peterjohn, W.T., and D.L. Correll. 1984. Nutrient Dynamics in an Agricultural Watershed: Observations on the Role of a Riparian Forest. Ecology 65(5): 1466-1475.

Poff, N.L., J.D. Allan, M.B. Bain, J.R. Karr, K.L. Prestegaard, B.D. Richter, R.E. Sparks, and J.C. Stromberg. 1997. The Natural Flow Regime. Bioscience 47:769-84.

Sethi, S.A., A.R. Selle, M.W. Doyle, E.H. Stanley, H.E. Kitchel. 2004. Response of unionid mussels to dam removal in Koshkonong Creek, Wisconsin. Hydrobiologia 525,157– 165.

Sherman, M. 2013. Potential impacts of small dam removal on fish and mussel communities in North Carolina. Master's Thesis. Nicholas School of the Environment of Duke University. Durham, NC. 57 pp.

Skalak, K., J. Pizzuto, and D. Hart. 2009. Influence of small dams on downstream channel characteristics in Pennsylvania and Maryland: Implications for the long-term geomorphic effects of dam removal. Journal of the American Water Resources Association 45: 97–109.

Sparks, R.E. and K.D. Blodgett. 1985. Effects of Fleeting on Mussels. Interim Report to the Illinois Department of Conservation and the National Marine Fisheries Service.

Sparks, B.L. and D.L. Strayer. 1998. Effects of low dissolved oxygen on juvenile Elliptio complanata (Bivalvia: Unionidae). Journal of North American Benthological Society 17(1):129-134.

United States Army Corps of Engineers (USACE). 2014. Green River Locks and Dams 3, 4, 5 and 6 and Barren River Lock and Dam 1 Disposition Feasibility Study, Kentucky.

United States Department of Agriculture (USDA). 2020. National Invasive Species Information Center. https://www.invasivespeciesinfo.gov/aquatic/fish-and-other-vertebrates. Accessed September 2020.

U.S. Environmental Protection Agency. 2017. Section 404 of the Clean Water Act: How wetlands are defined and identified. Accessed at https://www.epa.gov/cwa-404/section-404-clean-water-act-how-wetlands-are-defined- and-identified

United States Fish and Wildlife Service. 1976. Endangered and Threatened Wildlife and Plants; Endangered Status for 159 Taxa of Animals. 41 FR 24062-24067.

United States Fish and Wildlife Service. 1984. Rough Pigtoe Pearly Mussel Recovery Plan. U.S. Fish and Wildlife Service. Atlanta, GA. 51 pp.

United States Fish and Wildlife Service. 2014. Rough Pigtoe (*Pleurobema plenum*) 5-Year Review: Summary and Evaluation. U.S. Fish and Wildlife Service, Frankfort, KY. 17 pp.

United States Fish and Wildlife Service. 2021. Endangered and Threatened Wildlife and Plants; Threatened Species Status With Section 4(d) Rule for Pyramid Pigtoe. 86 FR 49989-50011.

Vannote, R.L. and G.W. Minshall. 1982. Fluvial processes and local lithology controlling abundance, structure, and composition of mussel beds. Proceedings of the National Academy of Science USA 79:4103-4107.

Waters, T.F. 1995. Sediment in streams: sources, biological effects, and control. American Fisheries Society Monograph 7. 251 pp.

Watters, G.T. 2000. Freshwater mussels and water quality: A review of the effects of hydrologic and instream habitat alterations. Pages 261-274 in P. D. Johnson, and R. S. Butler, editors. Proceedings of the First Freshwater Mussel Conservation Society Symposium, 1999. The Ohio State University, Columbus, OH.

Watters, G.T., M.A. Hoggarth, and D.H. Stansbery. 2009. The Freshwater Mussels of Ohio. The Ohio State University Press, Columbus, OH. 421 pp.

Winter, B.D. 1990. A brief review of dam removal efforts in Washington, Oregon, Idaho, and California. US Department of Commerce, NOAA Technological Memorandum NMFS F/NWR-28, 13 pp.

Zimmermann, S., Alt, F., Messerschmidt, J., von Bohlen, A., Taraschewski, H. and Sures, B. 2002. Biological availability of traffic-related platinum-group elements (palladium, platinum, and rhodium) and other metals to the zebra mussel (Dreissena polymorpha) in water containing road dust. Environmental toxicology and chemistry, 21(12), pp.2713-2718.

FIGURES

Figure 1. Project Location

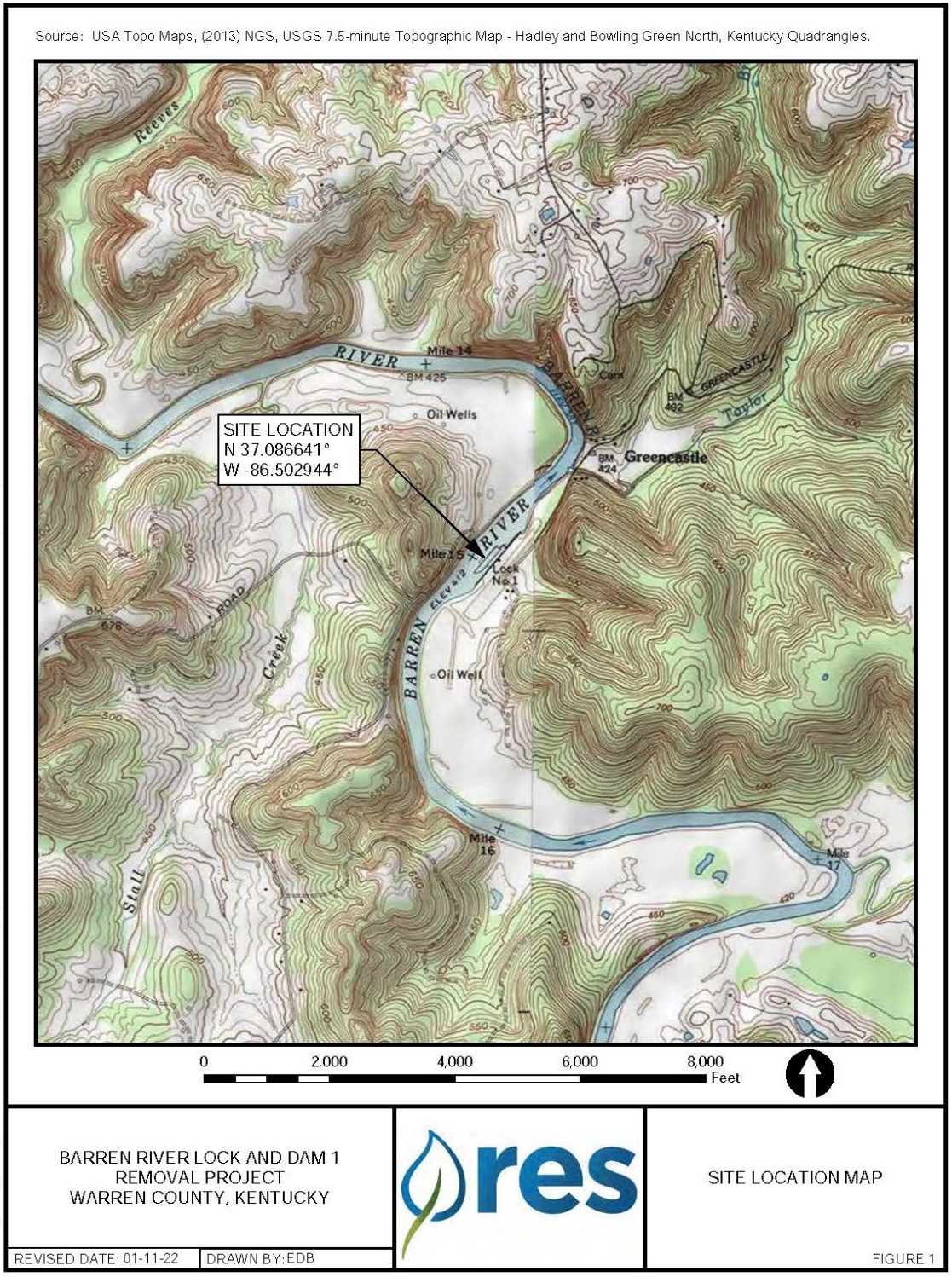


Figure 2. Work Area and Access Roads

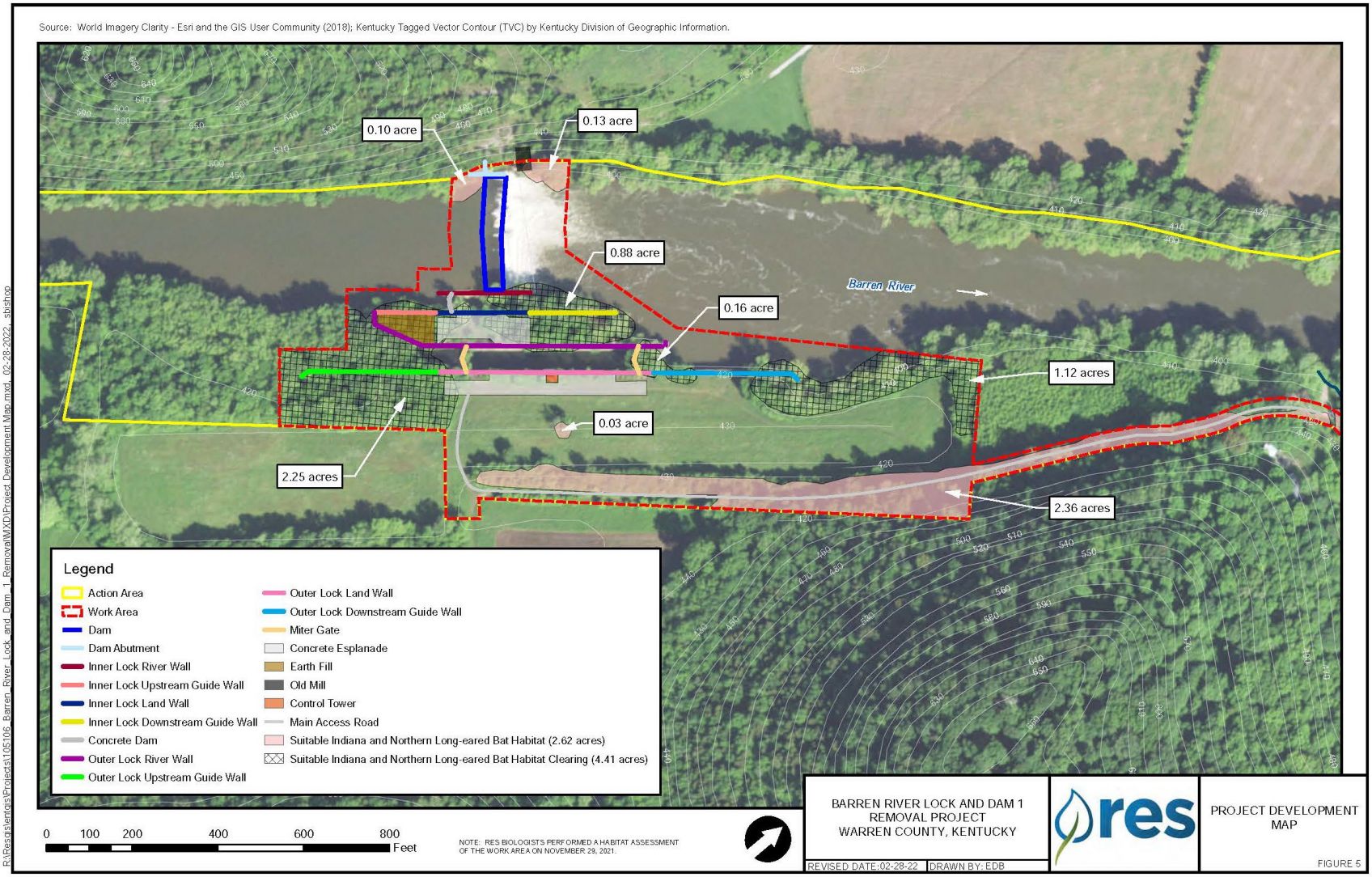


Figure 3. Access Roads

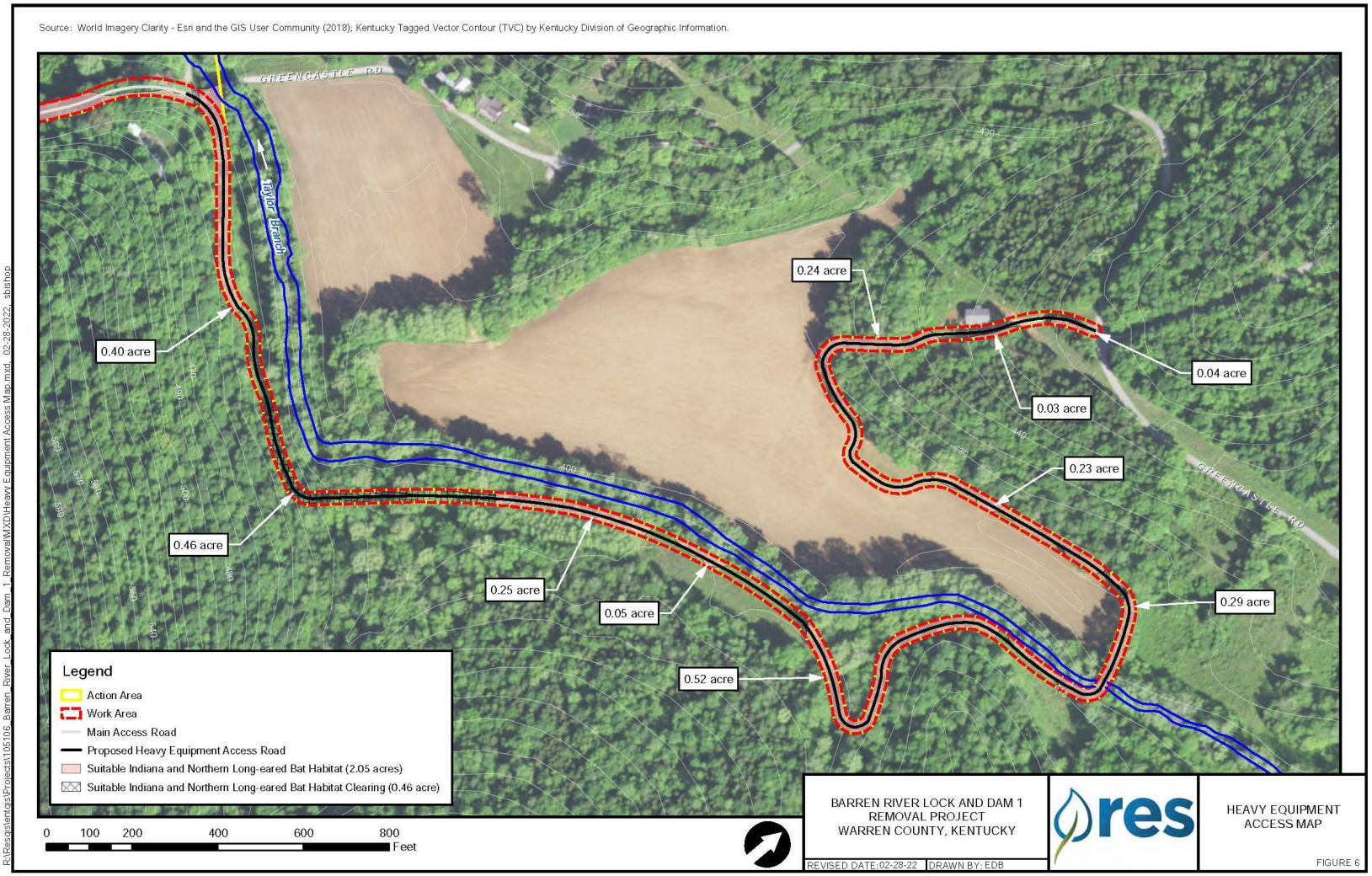
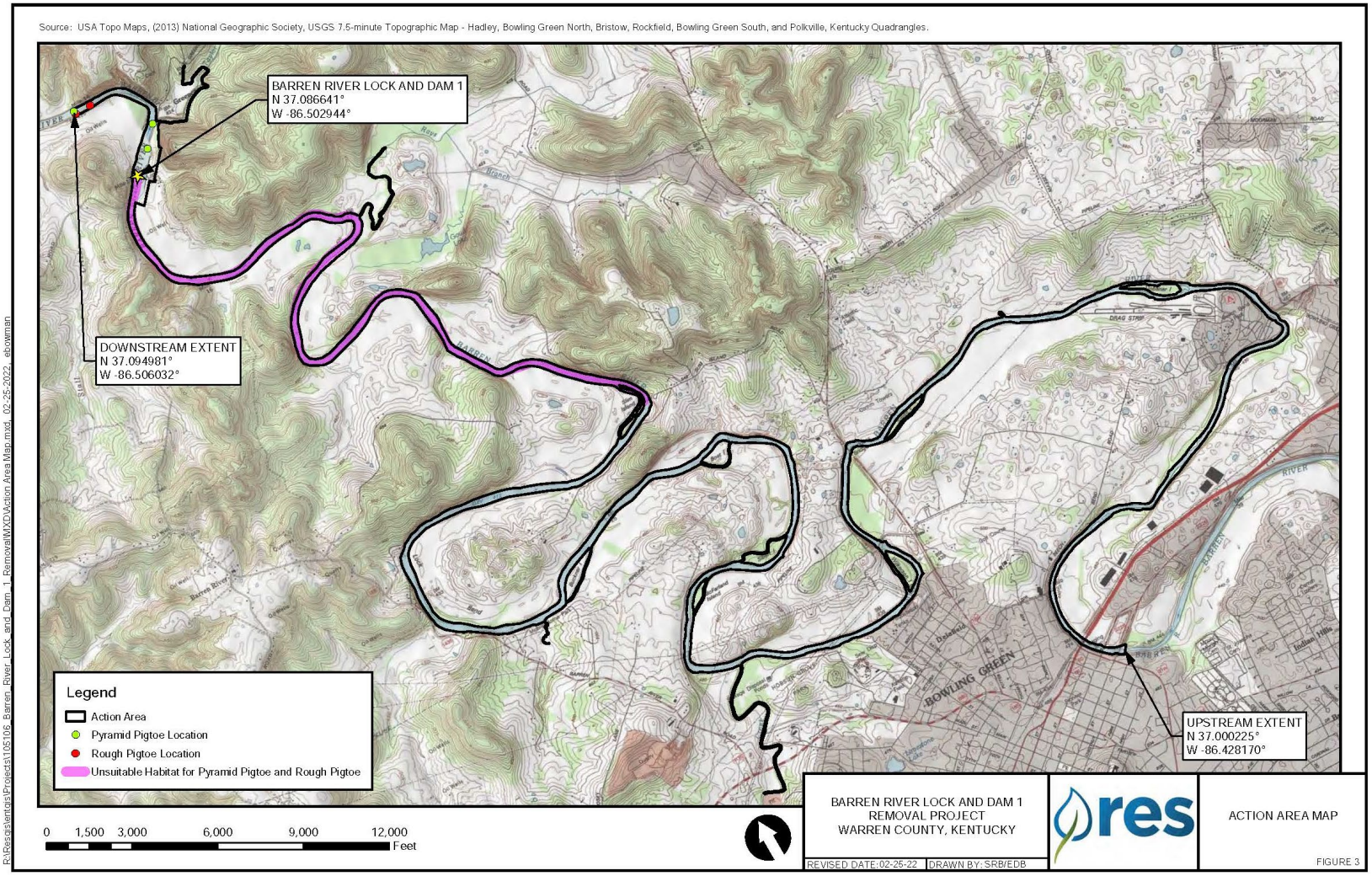


Figure 4. Action Area and Mussel Locations



APPENDIX A

Stressor-Exposure-Response Pathways

Effects Pathway 1 Section 5.1	
Activity: Site Preparation, Site Stabilization	
Stressor: Sediment Disturbance	
Exposure (time)	Duration of Activity
Exposure (space)	Work Area (Section 5.1.1)
Resource affected	Individuals (adults, juveniles), Habitat, Fish Hosts
Individual response	• Reduced respiration and feeding from clogged gills or smothering • Disruption of metabolic processes, leading to reduced fitness and growth rates • Reduced recruitment due to elimination of interstitial spaces used by juveniles • Movement due to alteration or loss of habitat • Displacement of fish hosts due to alteration or loss of habitat
Conservation Measures (Section 2.3)	• CM 1 • CM 2
Effect	Insignificant
Interpretation	Appropriate EPSC measures will be installed and maintained throughout the work area to reduce erosion and minimize sediment inputs into the Barren River. Vehicles and equipment will not enter the river, and no woody debris will be placed in the river. Effects from sediment disturbance caused by placement of the culvert, if needed, in the intermittent tributary are considered discountable.

Effects Pathway 2 Section 5.1	
Activity: Lock and Dam Removal	
Stressor: Sediment Disturbance	
Exposure (time)	Duration of Activity
Exposure (space)	Work Area (Section 5.1.1)
Resource affected	Individuals (adults, juveniles), Habitat, Fish Hosts
Individual response	• Reduced respiration and feeding from clogged gills or smothering • Disruption of metabolic processes, leading to reduced fitness and growth rates • Reduced recruitment due to elimination of interstitial spaces used by juveniles • Movement due to alteration or loss of habitat • Displacement of fish hosts due to alteration or loss of habitat
Conservation Measures (Section 2.3)	• CM 3 • CM 4
Effect	Adverse (harm, mortality)
Interpretation	Falling material from the lock river wall and downstream guide wall and placement of material in the downstream extent of the lock chamber could be deposited in areas of suitable mussel habitat and cause sediment disturbance, which could potentially impact listed mussels. Accumulated sediment from upstream of the dam and bank sloughing will move downstream during and after dam removal affecting water quality and habitat and could bury mussels located in the Action Area.

Effects Pathway 3 Section 5.1	
Activity: Site Preparation, Site Stabilization	
Stressor: Sediment Disturbance	
Exposure (time)	Duration of Activity
Exposure (space)	Action Area Upstream (Section 5.1.2) and Downstream of Work Area (Section 5.1.3)
Resource affected	Individuals (adults, juveniles), Habitat, Fish Hosts
Individual response	• Reduced respiration and feeding from clogged gills or smothering • Disruption of metabolic processes, leading to reduced fitness and growth rates • Reduced recruitment due to elimination of interstitial spaces used by juveniles • Movement due to alteration or loss of habitat • Displacement of fish hosts due to alteration or loss of habitat
Conservation Measures (Section 2.3)	• CM 1 • CM 2
Effect	Insignificant
Interpretation	No construction components will occur in the Action Area upstream or downstream of the work area. Inputs of sediment into these areas are not expected due to the use of EPSC measures, and inputs that do occur are anticipated to be minimal and only result in insignificant effects.

Effects Pathway 4 Section 5.1	
Activity: Lock and Dam Removal	
Stressor: Sediment Disturbance	
Exposure (time)	Duration of Activity
Exposure (space)	Action Area Upstream of Work Area (5.1.2)
Resource affected	Individuals (adults, juveniles), Habitat, Fish Hosts
Individual response	• Reduced respiration and feeding from clogged gills or smothering • Disruption of metabolic processes, leading to reduced fitness and growth rates • Reduced recruitment due to elimination of interstitial spaces used by juveniles • Movement due to alteration or loss of habitat • Displacement of fish hosts due to alteration or loss of habitat
Conservation Measures (Section 2.3)	• CM 3
Effect	Discountable
Interpretation	No construction components will occur in the Action Area upstream of the work area. Removal of the dam will cause sediment to move downstream out of this area, reducing the amount of accumulated sediment. In addition, the areas adjacent to and immediately upstream of the work area where the potential for impacts is highest do not provide suitable habitat for Rough Pigtoe or Pyramid Pigtoe.

Effects Pathway 5 Section 5.1	
Activity: Lock and Dam Removal	
Stressor: Sediment Disturbance	
Exposure (time)	Duration of Activity
Exposure (space)	Action Area Downstream of Work Area (Section 5.1.3)
Resource affected	Individuals (adults, juveniles), Habitat, Fish Hosts
Individual response	• Reduced respiration or smothering due to sediment deposition • Disruption of metabolic processes, leading to reduced fitness and growth rates • Reduced recruitment due to elimination of interstitial spaces used by juveniles • Movement due to alteration or loss of habitat • Displacement of fish hosts due to alteration or loss of habitat
Conservation Measures (Section 2.3)	• CM 3
Effect	Adverse (harm, mortality)
Interpretation	The movement and initial deposition of sediment immediately after dam removal is expected to create habitat conditions that could smother mussels, make habitat unsuitable, negatively affect reproduction, or cause individuals to move to other areas.

Effects Pathway 6 Section 5.2	
Activity: Site Preparation, Site Stabilization	
Stressor: Water Quality Degradation (Turbidity)	
Exposure (time)	Duration of Activity
Exposure (space)	Work Area (Section 5.2.1)
Resource affected	Individuals (adults, juveniles), Habitat, Fish Hosts
Individual response	• Increased turbidity and low dissolved oxygen levels could lead to reduced fitness, reduced fecundity, and/or increased mortality. • Reduced reproduction due to inability of fish hosts to detect mussels due to increased turbidity • Reduced aquatic food organism diversity and abundance could negatively impact mussel growth, survival, and reproduction • Displacement of fish hosts due to alteration or loss of habitat
Conservation Measures (Section 2.3)	• CM 1 • CM 2
Effect	Insignificant
Interpretation	Appropriate EPSC measures will be implemented and maintained throughout the work area to minimize sediment inputs into the Barren River and maintain water quality. Vehicles and equipment will not enter the river, and no woody debris will be placed in the river. Significant water quality degradation from establishing a crossing in the intermittent tributary for the temporary heavy equipment access road is considered unlikely.

Effects Pathway 7 Section 5.2	
Activity: Lock and Dam Removal	
Stressor: Water Quality Degradation (Turbidity)	
Exposure (time)	Duration of Activity
Exposure (space)	Work Area (Section 5.2.1)
Resource affected	Individuals (adults, juveniles), Habitat, Fish Hosts
Individual response	• Increased turbidity and low dissolved oxygen levels could lead to reduced fitness, reduced fecundity, and/or increased mortality. • Increased turbidity results in inability of fish hosts to detect mussels, negatively affecting reproduction • Reduced aquatic food organism diversity and abundance could negatively impact mussel growth, survival, and reproduction • Displacement of fish hosts due to alteration or loss of habitat
Conservation Measures (Section 2.3)	• CM 3 • CM 4
Effect	Adverse (harm, mortality)
Interpretation	Turbidity levels will increase gradually over time as more of the accumulated sediment upstream of the dam is exposed to increased flow, potentially increasing to the point that mussels, their food supply, and fish hosts are affected. The suspension of fine sediments that have accumulated upstream of the dam and that result from bank sloughing are likely to cause increased turbidity in the Action Area during and immediately after dam removal, but that project-related turbidity will decline over time.

Effects Pathway 8 Section 5.2	
Activity: Site Preparation, Site Stabilization	
Stressor: Water Quality Degradation (Turbidity)	
Exposure (time)	Duration of Activity
Exposure (space)	Action Area Upstream (Section 5.2.2) and Downstream of Work Area (Section 5.2.3)
Resource affected	Individuals (adults, juveniles), Habitat, Fish Hosts
Individual response	• Increased turbidity, low dissolved oxygen levels, and chemical contaminants could lead to reduced fitness, reduced fecundity, and/or increased mortality. • Increased turbidity results in inability of fish hosts to detect mussels, negatively affecting reproduction • Reduced aquatic food organism diversity and abundance could negatively impact mussel growth, survival, and reproduction • Increased harm or mortality of fish hosts • Displacement of fish hosts due to alteration or loss of habitat
Conservation Measures (Section 2.3)	• CM 1 • CM 2
Effect	Insignificant
Interpretation	No construction components will occur in the Action Area upstream or downstream of the work area. Water quality degradation from inputs of sediment into these areas are not expected due to the use of EPSC measures. Any inputs of sediment that occur in the upstream portion of the Action Area will be located in unsuitable habitat for the listed mussels, and inputs in the downstream portion will be dispersed by the river's flow before significant degradation of water quality occurs.

Effects Pathway 9 Section 5.2	
Activity: Lock and Dam Removal	
Stressor: Water Quality Degradation (Turbidity)	
Exposure (time)	Duration of Activity
Exposure (space)	Action Area Upstream of Work Area (Section 5.2.2)
Resource affected	Individuals (adults, juveniles), Habitat, Fish Hosts
Individual response	• Increased turbidity and low dissolved oxygen levels could lead to reduced fitness, reduced fecundity, and/or increased mortality. • Increased turbidity results in inability of fish hosts to detect mussels, negatively affecting reproduction • Reduced aquatic food organism diversity and abundance could negatively impact mussel growth, survival, and reproduction • Displacement of fish hosts due to alteration or loss of habitat
Conservation Measures (Section 2.3)	• CM 3
Effect	Discountable
Interpretation	No construction components will occur in the Action Area upstream of the work area. The portion of the Action Area adjacent to and immediately upstream of the work area where the potential for water quality degradation is highest does not provide suitable habitat for the mussel species so the effects are unlikely to affect the species.

Effects Pathway 10 Section 5.2	
Activity: Lock and Dam Removal	
Stressor: Water Quality Degradation (Turbidity)	
Exposure (time)	Duration of Activity
Exposure (space)	Action Area Downstream of Work Area (Section 5.2.3)
Resource affected	Individuals (adults, juveniles), Habitat, Fish Hosts
Individual response	• Increased turbidity and low dissolved oxygen levels could lead to reduced fitness, reduced fecundity, and/or increased mortality. • Increased turbidity results in inability of fish hosts to detect mussels, negatively affecting reproduction • Reduced aquatic food organism diversity and abundance could negatively impact mussel growth, survival, and reproduction • Displacement of fish hosts due to alteration or loss of habitat
Conservation Measures (Section 2.3)	• CM 3
Effect	Adverse (harm, mortality)
Interpretation	Turbidity levels will increase gradually over time as more of the accumulated sediment upstream of the dam is exposed to increased flow, potentially increasing to the point that mussels, their food supply, and fish hosts are affected. The suspension of fine sediments that have accumulated upstream of the dam and that result from bank sloughing are likely to cause increased turbidity in the Action Area during and immediately after dam removal until sediments stabilize relative to flows in the river.

Effects Pathway 11 Section 5.2	
Activity: Site Preparation, Lock and Dam Removal, Site Stabilization	
Stressor: Water Quality Degradation (Chemical)	
Exposure (time)	Duration of Activity
Exposure (space)	Work Area (Section 5.2.1) and Action Area Downstream of Work Area (Section 5.2.3)
Resource affected	Individuals (adults, juveniles), Habitat, Fish Hosts
Individual response	• Reduced fitness, reduced fecundity, and/or increased mortality • Increased harm or mortality of fish hosts • Displacement of fish hosts due to alteration or loss of habitat
Conservation Measures (Section 2.3)	• CM 4 • CM 5 • CM 6
Effect	Insignificant
Interpretation	Vehicles and equipment will operate along the riverbanks during site preparation and stabilization. BMPs will be utilized when equipment is present on the in-stream work pads, and equipment will only operate in water depths of two feet or less to reduce the potential for petroleum-based products to enter the river. A spill response plan will be in place during construction, and any leaks or spills will be immediately cleaned up. If an accidental release does occur, the amount of petroleum-based product that enters the river is anticipated to be minimal and be quickly dispersed and diluted by the flow of the river. No vehicles or equipment will operate in the downstream portion of the Action Area; therefore, there is no potential for leaks or spills of petroleum-based products. Any products released in the work area would likely be contained or diluted before reaching this portion of the Action Area.

Effects Pathway 12 Section 5.2	
Activity: Site Preparation, Lock and Dam Removal, Site Stabilization	
Stressor: Water Quality Degradation (Chemical)	
Exposure (time)	Duration of Activity
Exposure (space)	Action Area Upstream of Work Area (Section 5.2.2)
Resource affected	Individuals (adults, juveniles), Habitat, Fish Hosts
Individual response	• Reduced fitness, reduced fecundity, and/or increased mortality • Increased harm or mortality of fish hosts • Displacement of fish hosts due to alteration or loss of habitat
Conservation Measures	• CM 4 • CM 5
Effect	Discountable
Interpretation	No vehicles or equipment will operate in the upstream portion of the Action Area; therefore, there is very little potential for leaks or spills of petroleum-based products. Any releases of petroleum-based products in the work area would move downstream with the flow of the river.

Effects Pathway 13 Section 5.3	
Activity: Lock and Dam Removal	
Stressor: Changes to Flow	
Exposure (time)	Indefinite
Exposure (space)	Work Area (Section 5.3.1)
Resource affected	Individuals (adults, juveniles), Habitat, Fish Hosts
Individual response	• Mortality due to alteration of loss of flow regime • Reduction or loss of fish hosts due to changes to flow regime
Conservation Measures (Section 2.3)	• N/A
Effect	Insignificant
Interpretation	Based on hydraulic analysis modeling analyzed by the USACE, the dam does not attenuate discharge, velocity, or shear stresses downstream; therefore, these conditions are not anticipated to change after removal of the dam. Elimination of the plunging, vertical flow at the dam is anticipated to result in positive effects by significantly reducing or stopping scouring in the area currently located immediately downstream of the dam.

Effects Pathway 14 Section 5.3	
Activity: Lock and Dam Removal	
Stressor: Changes to Flow	
Exposure (time)	Indefinite
Exposure (space)	Action Area Upstream of the Work Area (Section 5.3.2)
Resource affected	Individuals (adults, juveniles), Habitat, Fish Hosts
Individual response	• Mortality due to alteration of loss of flow regime • Reduction or loss of fish hosts due to changes to flow regime
Conservation Measures (Section 2.3)	• N/A
Effect	Insignificant
Interpretation	Changes in flow are expected to be minimal due to the gradual removal of the dam during a period of low flow. Removal of the dam will result in a more natural flow regime that will promote natural sediment movement and is expected to positively affect mussel species. Effects during high flow events are expected to be similar to existing conditions. These changes will also occur within unsuitable habitat for the two mussel species.

Effects Pathway 15 Section 5.3	
Activity: Lock and Dam Removal	
Stressor: Changes to Flow	
Exposure (time)	Indefinite
Exposure (space)	Action Area Downstream of the Work Area (Section 5.3.3)
Resource affected	Individuals (adults, juveniles), Habitat, Fish Hosts
Individual response	• Mortality due to alteration of loss of flow regime • Reduction or loss of fish hosts due to changes to flow regime
Conservation Measures (Section 2.3)	• N/A
Effect	Insignificant
Interpretation	Based on hydraulic modeling analyzed by the USACE, the dam does not attenuate discharge, velocity, or shear stresses downstream; therefore, flow conditions are not anticipated to change after removal of the dam. As a result, no significant effects are expected.

Effects Pathway 16 Section 5.4	
Activity: Lock and Dam Removal	
Stressor: Crushing or Striking of Individuals	
Exposure (time)	Duration of Activity
Exposure (space)	Work Area
Resource affected	Individuals (adults, juveniles)
Individual response	• Harm or mortality from being crushed or struck by material
Conservation Measures (Section 2.3)	N/A
Effect	Adverse (harm, mortality)
Interpretation	Mussels could be crushed or struck during the placement of material downstream of the dam to create the in-stream work pad and fill the scour area. Material that falls into the river during demolition of the lock river wall and downstream guide wall or placement of material in the downstream extent of the lock chamber could also crush or strike mussels resulting in harm or mortality.

Effects Pathway 17 Section 5.4	
Activity: Lock and Dam Removal	
Stressor: Crushing or Striking of Individuals	
Exposure (time)	Duration of Activity
Exposure (space)	Action Area Upstream and Downstream of Work Area (Section 5.4.2)
Resource affected	Individuals (adults, juveniles)
Individual response	• Harm or mortality from being crushed or struck by material
Conservation Measures (Section 2.3)	N/A
Effect	Discountable
Interpretation	No construction components will occur in the Action Area upstream or downstream of the work area, and material from the work area is not anticipated to enter these areas.

Effects Pathway 18 Section 5.5	
Activity: Lock and Dam Removal	
Stressor: Displacement of Individuals	
Exposure (time)	Duration of Activity
Exposure (space)	Work Area (Section 5.5.1)
Resource affected	Individuals (adults, juveniles)
Individual response	• Harm or mortality if displaced to unsuitable habitat • Movement of displaced individuals to suitable habitat, which may lead to increased energy expenditure and decreased fitness
Conservation Measures (Section 2.3)	N/A
Effect	Insignificant
Interpretation	Notching of the dam and material that enters the river upstream and downstream of the dam are unlikely to displace individuals due to either the lack of suitable habitat or low potential for substrate movement. Mussels could be displaced from material falling into the river during demolition of the lock river wall and downstream guide wall or placement of material in the downstream extent of the lock chamber; however, displaced mussels will likely move only a short distance and remain in suitable habitat, thus resulting in insignificant effects.

Effects Pathway 19 Section 5.5	
Activity: Lock and Dam Removal	
Stressor: Displacement of Individuals	
Exposure (time)	Duration of Activity
Exposure (space)	Action Area Upstream (Section 5.5.2) and Downstream of Work Area (Section 5.5.3)
Resource affected	Individuals (adults, juveniles)
Individual response	• Harm or mortality if displaced to unsuitable habitat • Movement of individuals to suitable habitat, which may lead to increased energy expenditure and decreased fitness
Conservation Measures (Section 2.3)	N/A
Effect	Discountable
Interpretation	No construction components will occur in the Action Area upstream or downstream of the work area, and material from the work area is not anticipated to enter these areas.

Effects Pathway 20 Section 5.6	
Activity: Lock and Dam Removal	
Stressor: Exposure of Individuals	
Exposure (time)	Duration of Activity
Exposure (space)	Work Area (Section 5.6.1) and Action Area Downstream of Work Area (Section 5.6.3)
Resource affected	Individuals (adults, juveniles)
Individual response	• Harm or mortality if individual becomes exposed • Movement of individual to deeper water, which may lead to increased energy expenditure and decreased fitness
Conservation Measures (Section 2.3)	N/A
Effect	Discountable
Interpretation	The water level of the river in the downstream portion of the Action Area will not be lowered from the removal of BRLD1. Removal of the dam will lower the water level in the work area upstream of BRLD1; however, this area does not provide suitable habitat for the listed mussel species.

Effects Pathway 21 Section 5.6	
Activity: Lock and Dam Removal	
Stressor: Exposure of Individuals	
Exposure (time)	Duration of Activity
Exposure (space)	Action Area Upstream of Work Area (Section 5.6.2)
Resource affected	Individuals (adults, juveniles)
Individual response	• Harm or mortality if individual becomes exposed • Movement of individual to deeper water, which may lead to increased energy expenditure and decreased fitness
Conservation Measures (Section 2.3)	• CM 7 • CM 8
Effect	Adverse (harm, mortality)
Interpretation	The portion of the river from BRLD1 to 17 miles upstream provides unsuitable to poor-quality habitat for the Rough Pigtoe and Pyramid Pigtoe; therefore, lowering the water level in this reach is unlikely to expose individuals. However, suitable habitat for these species is present beyond 17 miles upstream of BRLD1 to the end of the Action Area just below RM 38. The reduction in water level in this area will likely be less than the area immediately above BRLD1, but could still expose portions of the river channel where mussels may occur, forcing exposed individuals to move to deeper water or down to saturation zones. Mortality is expected for individuals that are unable to move to suitable areas.