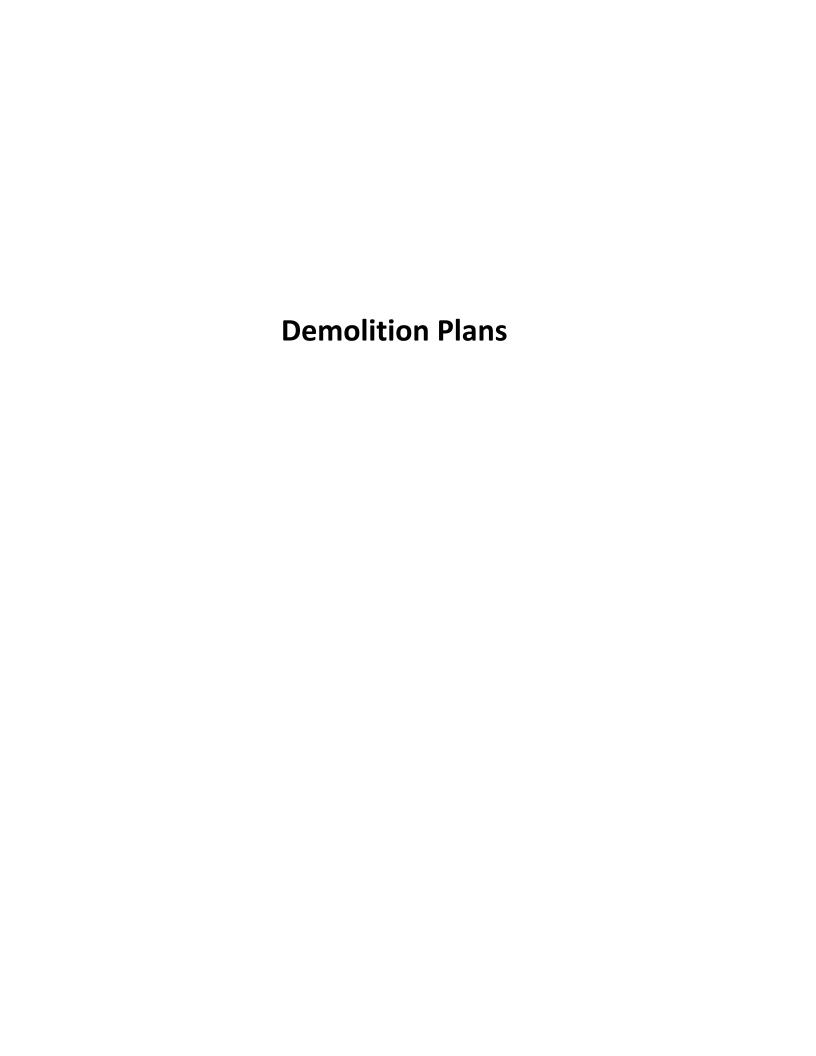
# **APPENDIX**

Green River L&D No.5 Demo

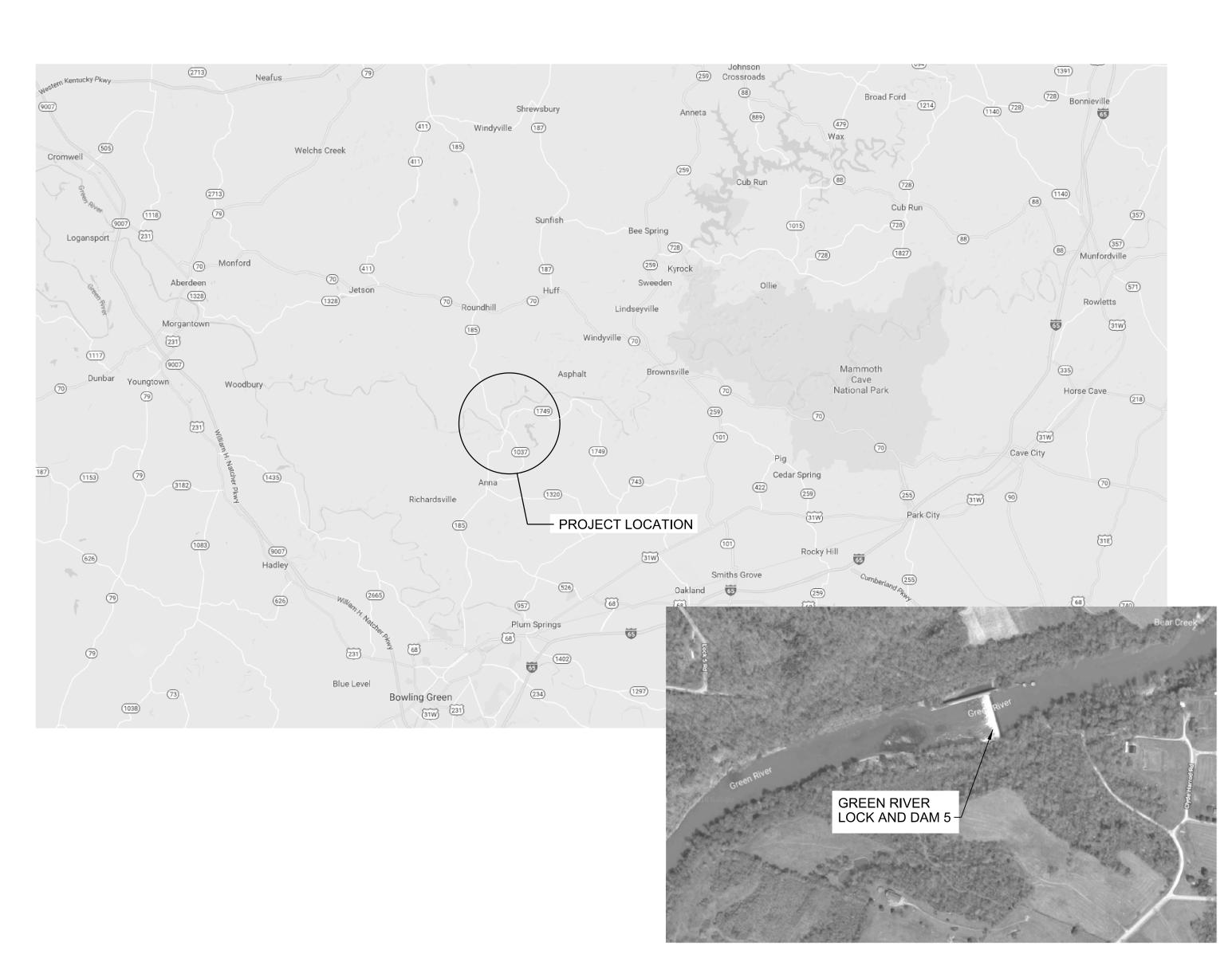




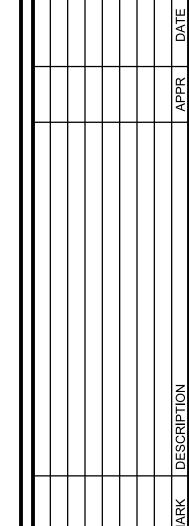
# GREEN RIVER LOCK AND DAM 5 REMOVAL

ROUNDHILL, KENTUCKY

P2# 465345, FY 2018







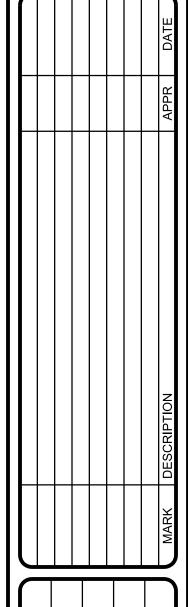
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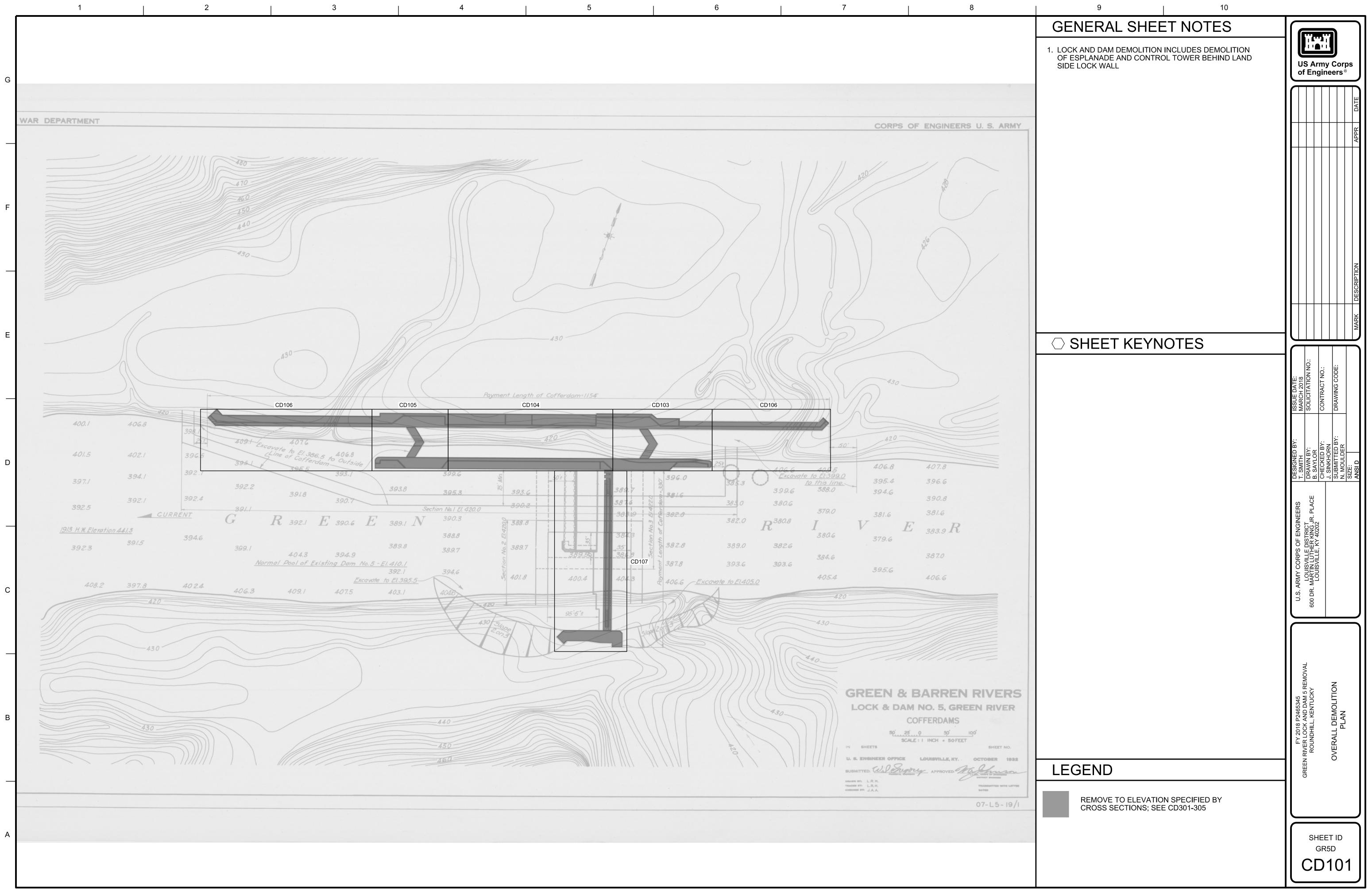
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ROUNDHILL, KENTUCKY
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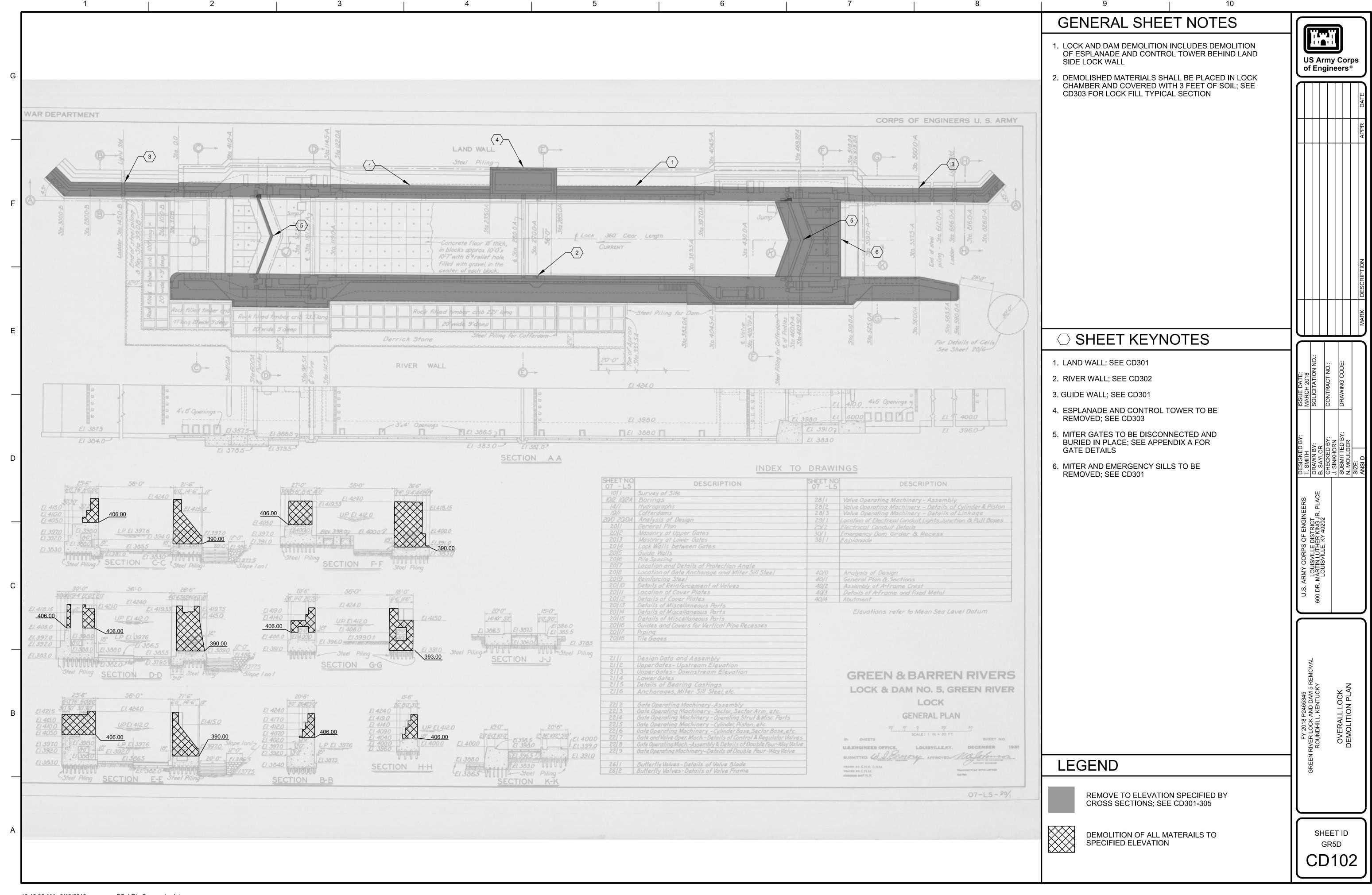
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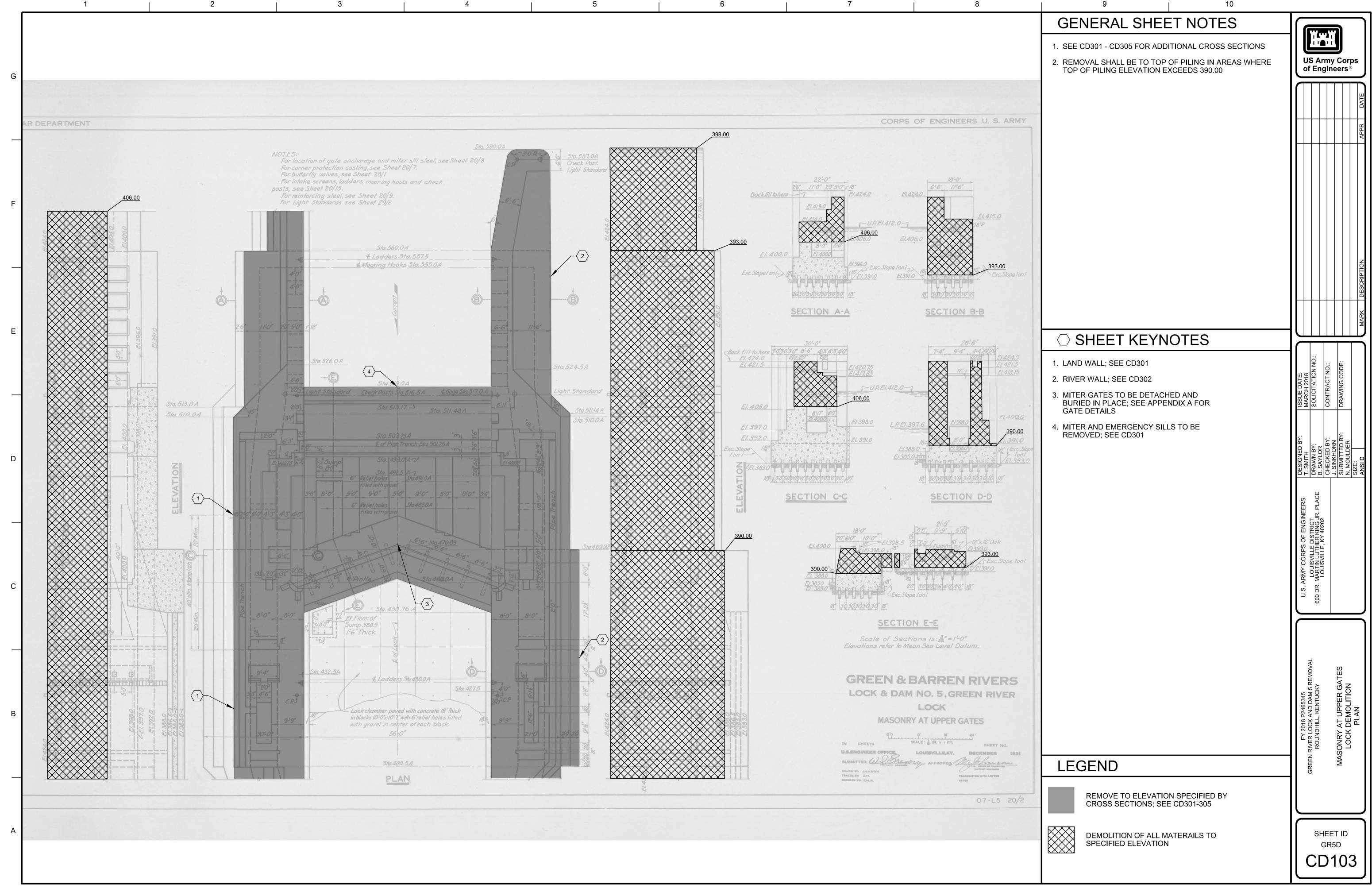
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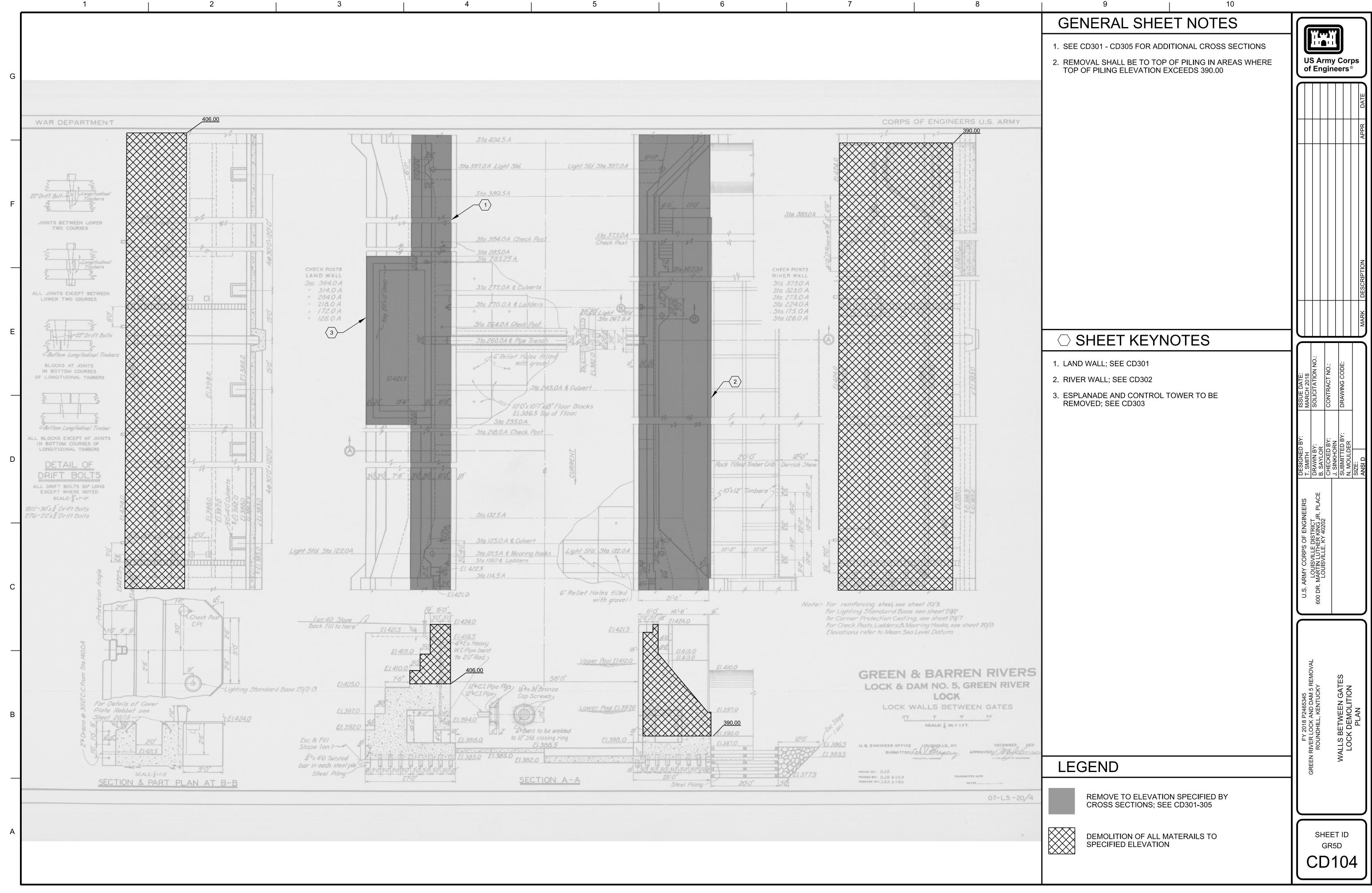
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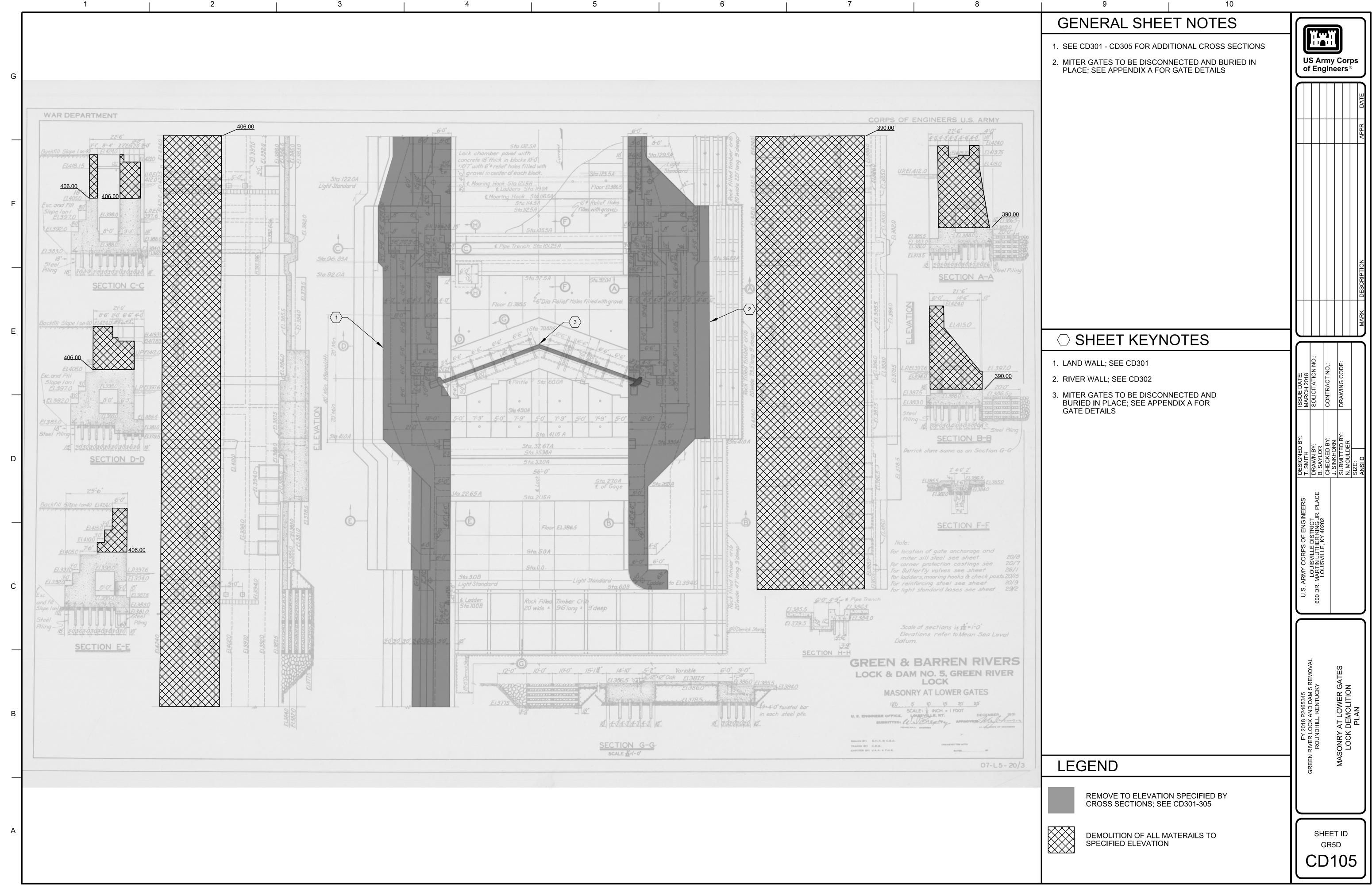


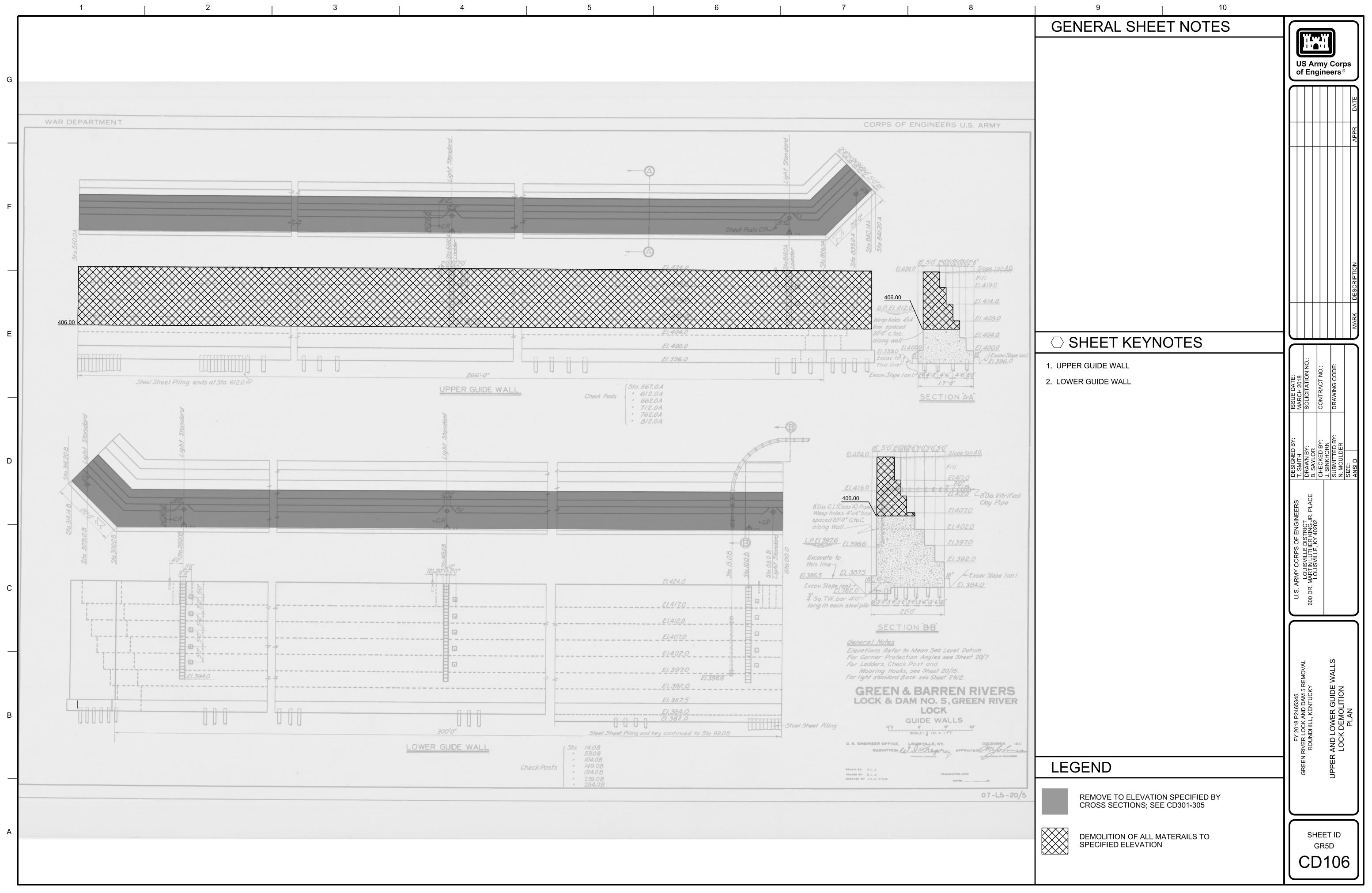


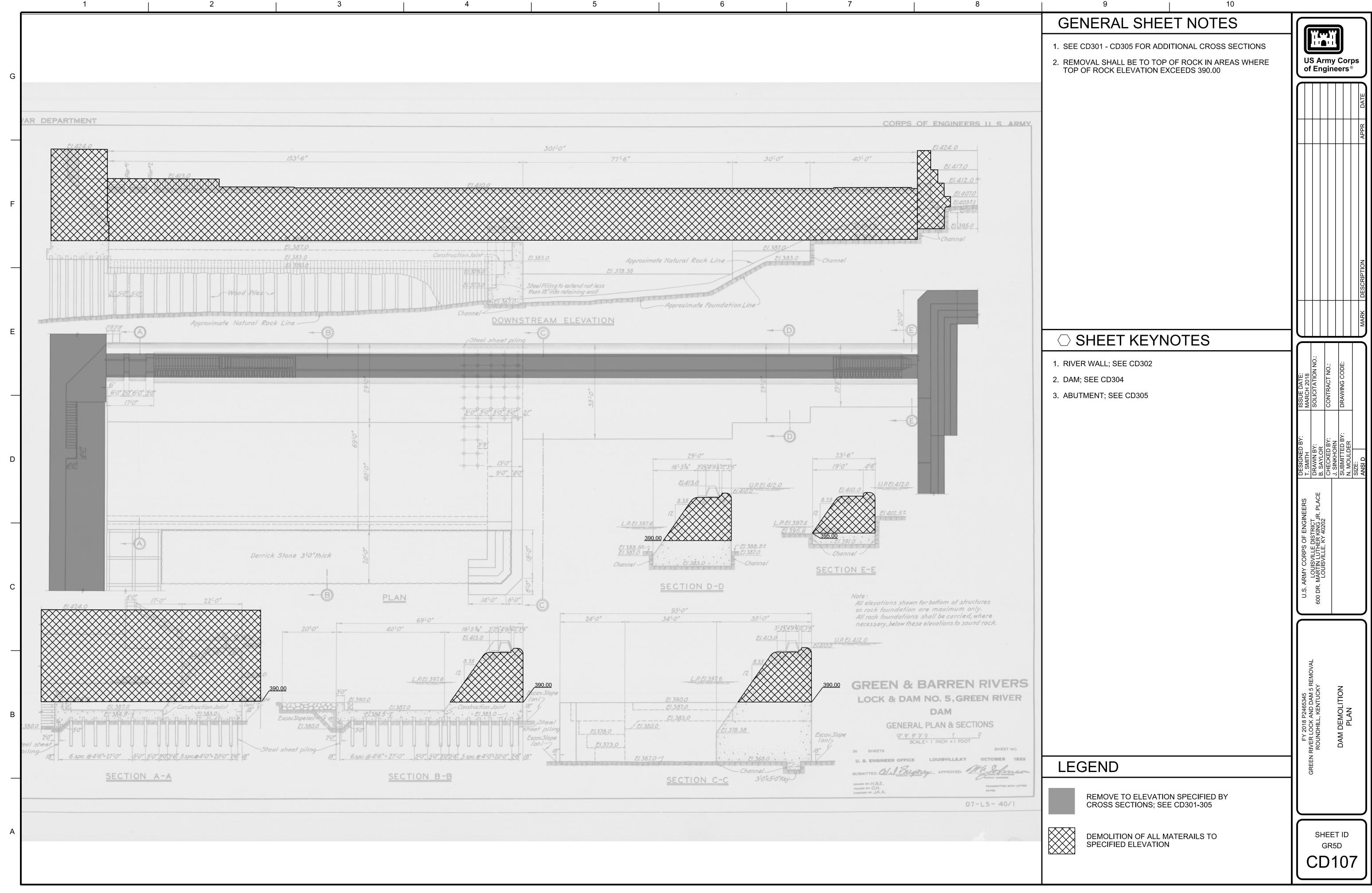


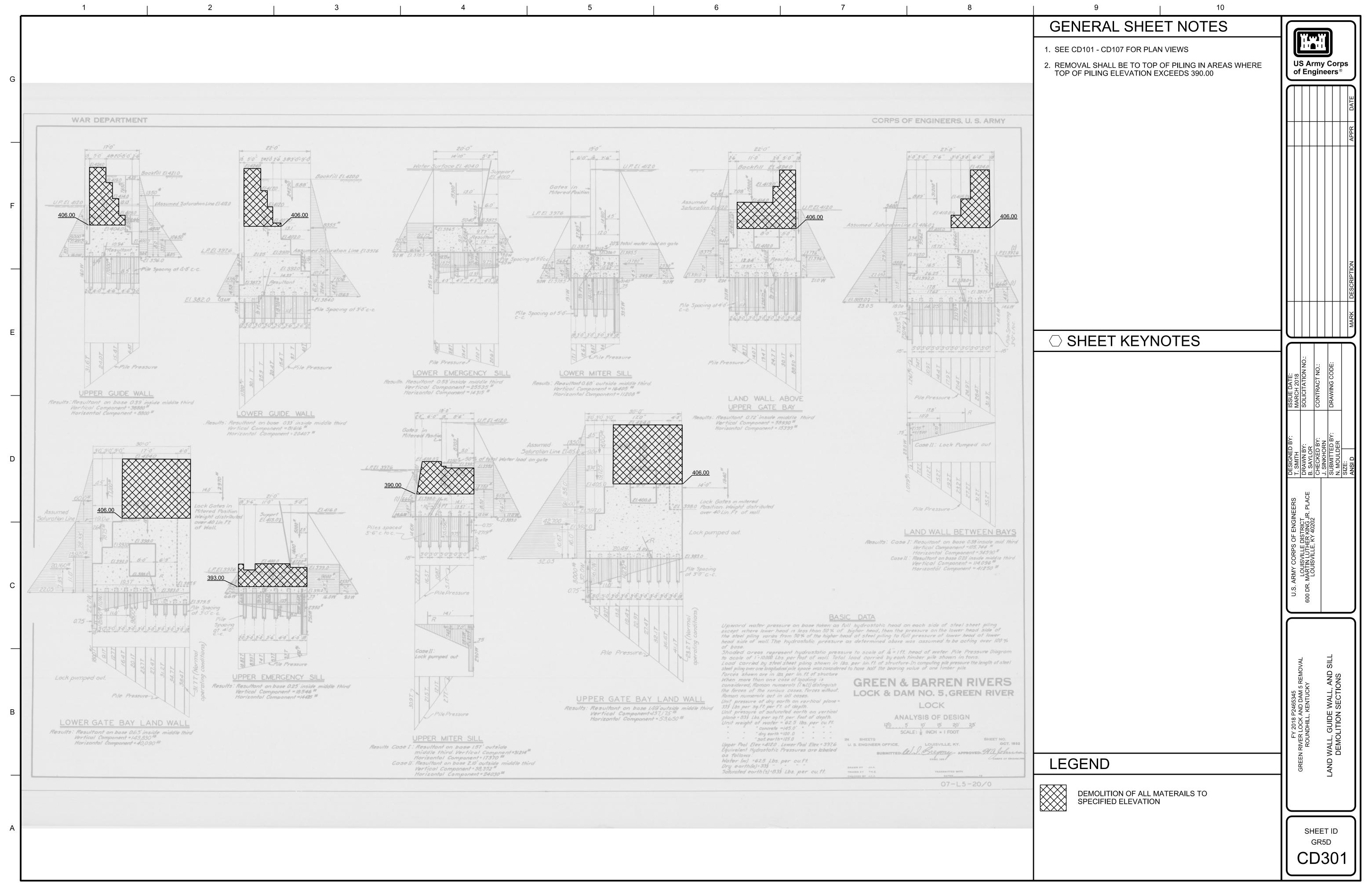


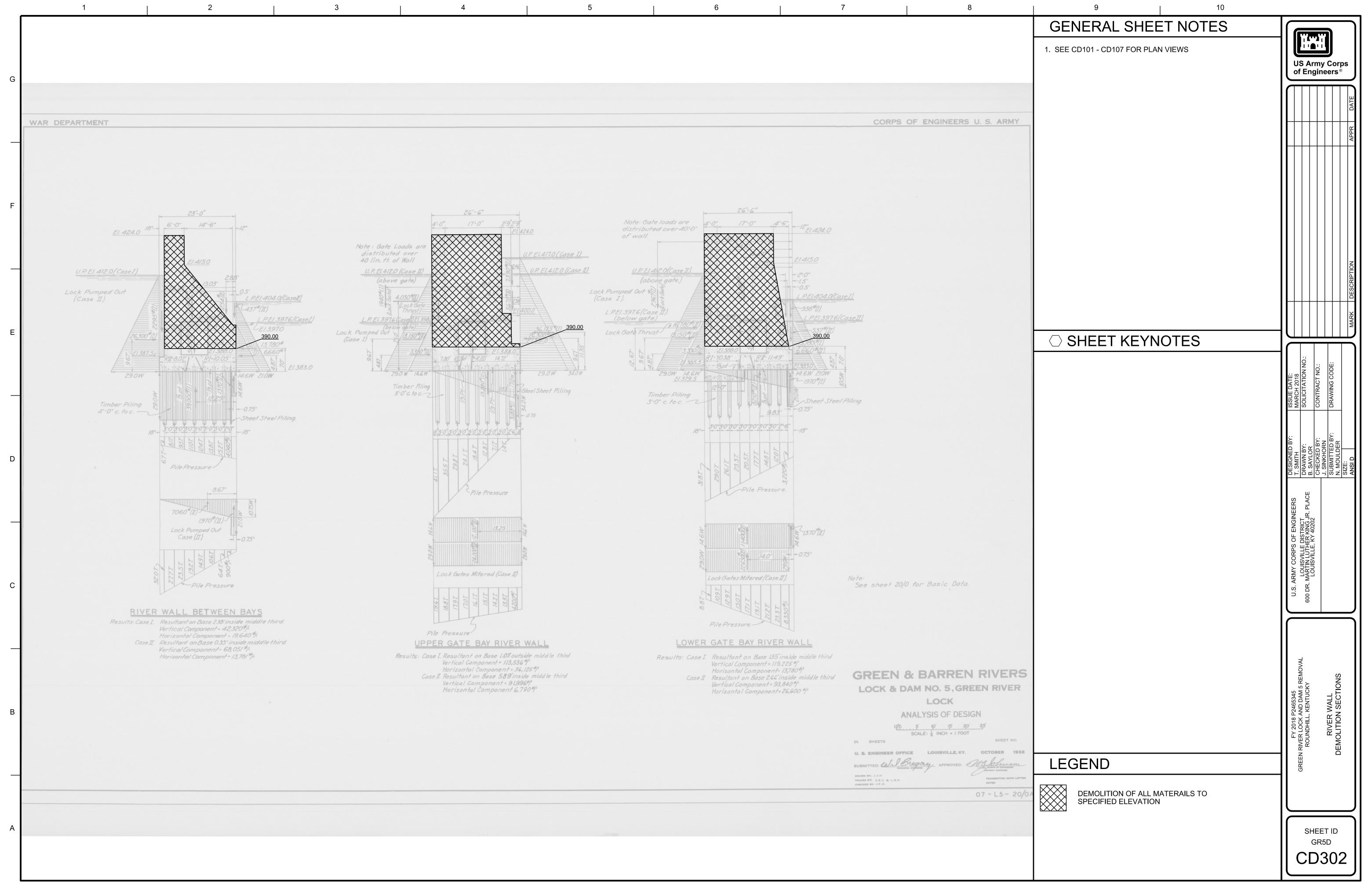


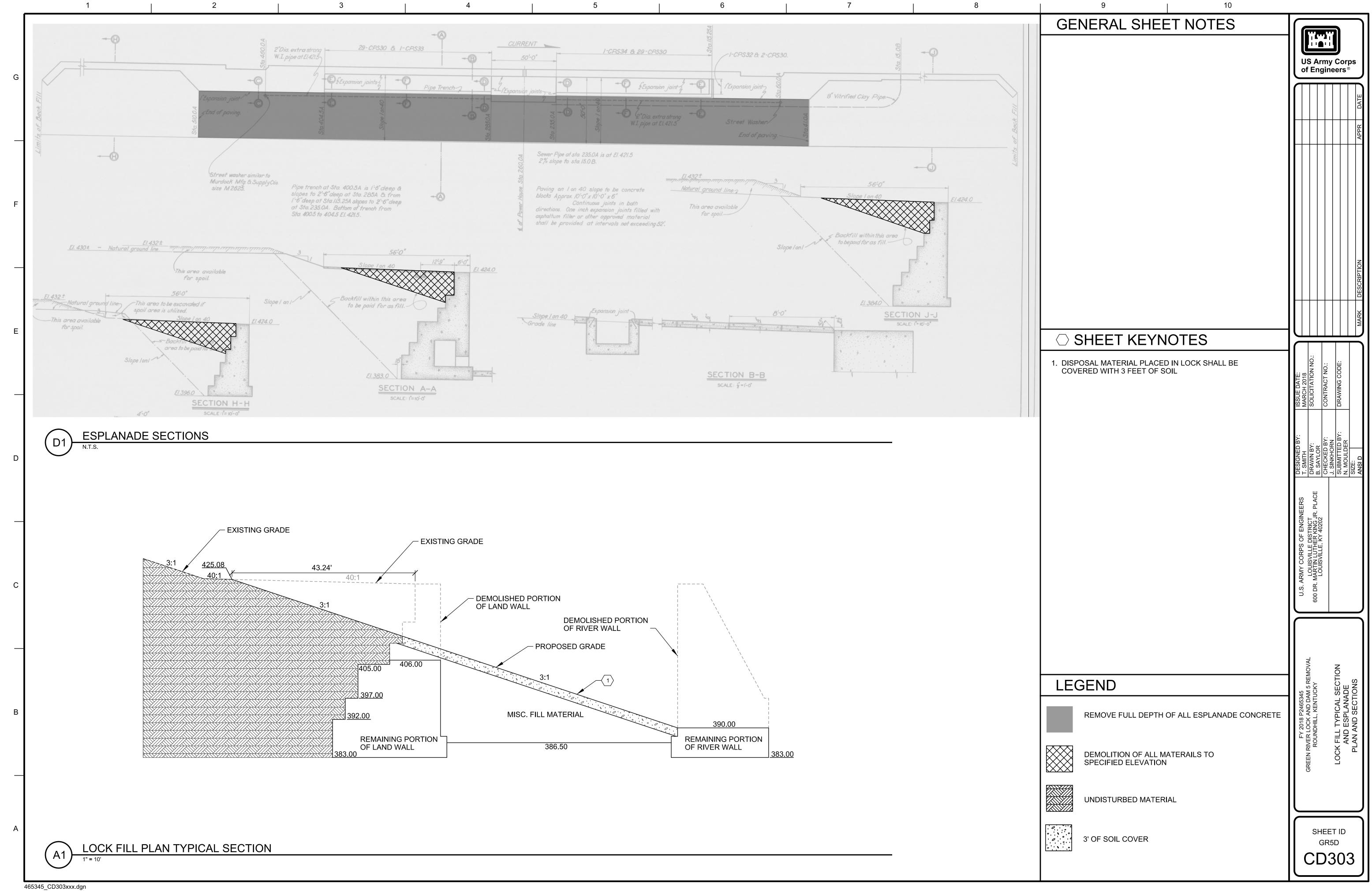


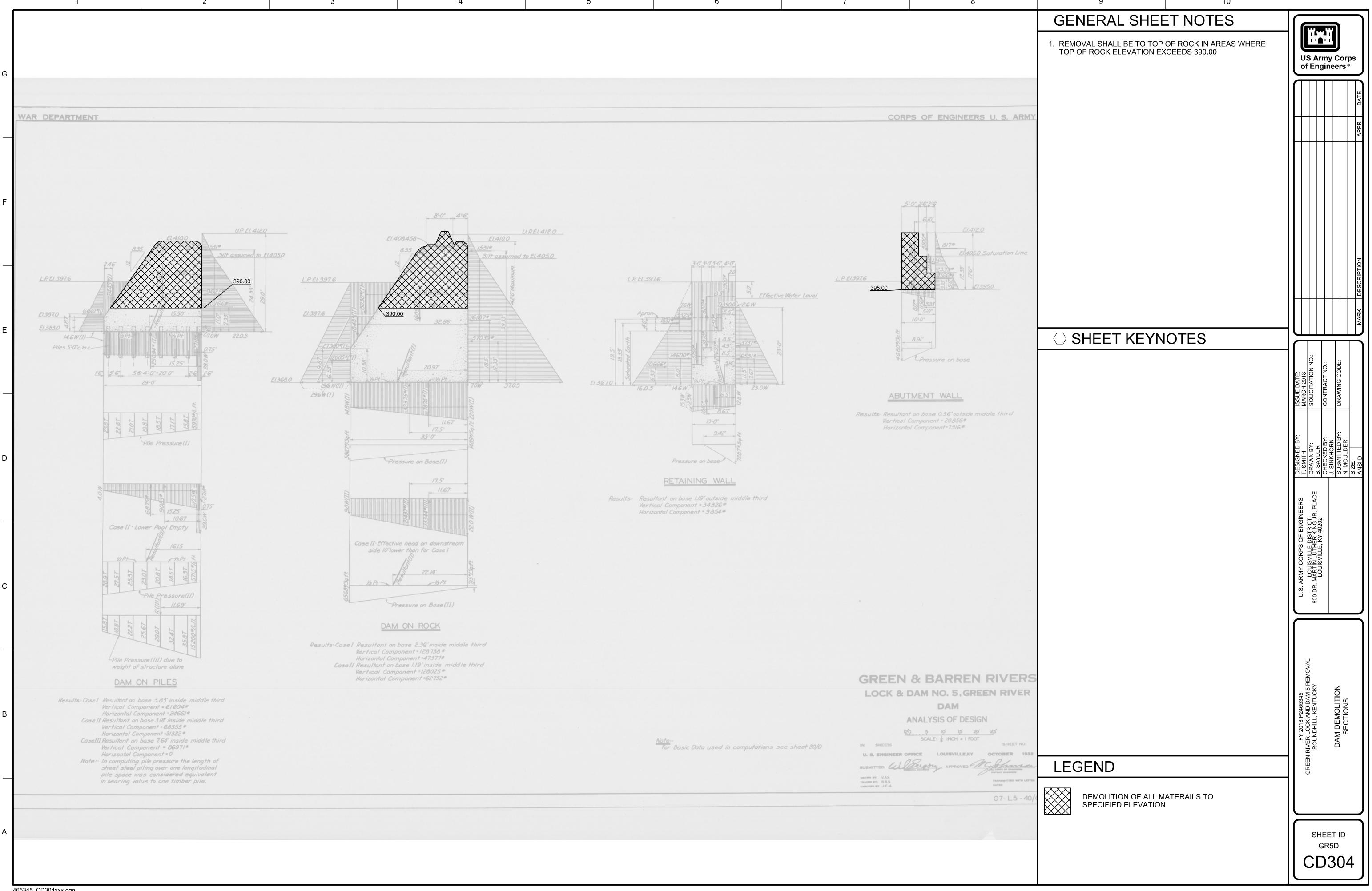


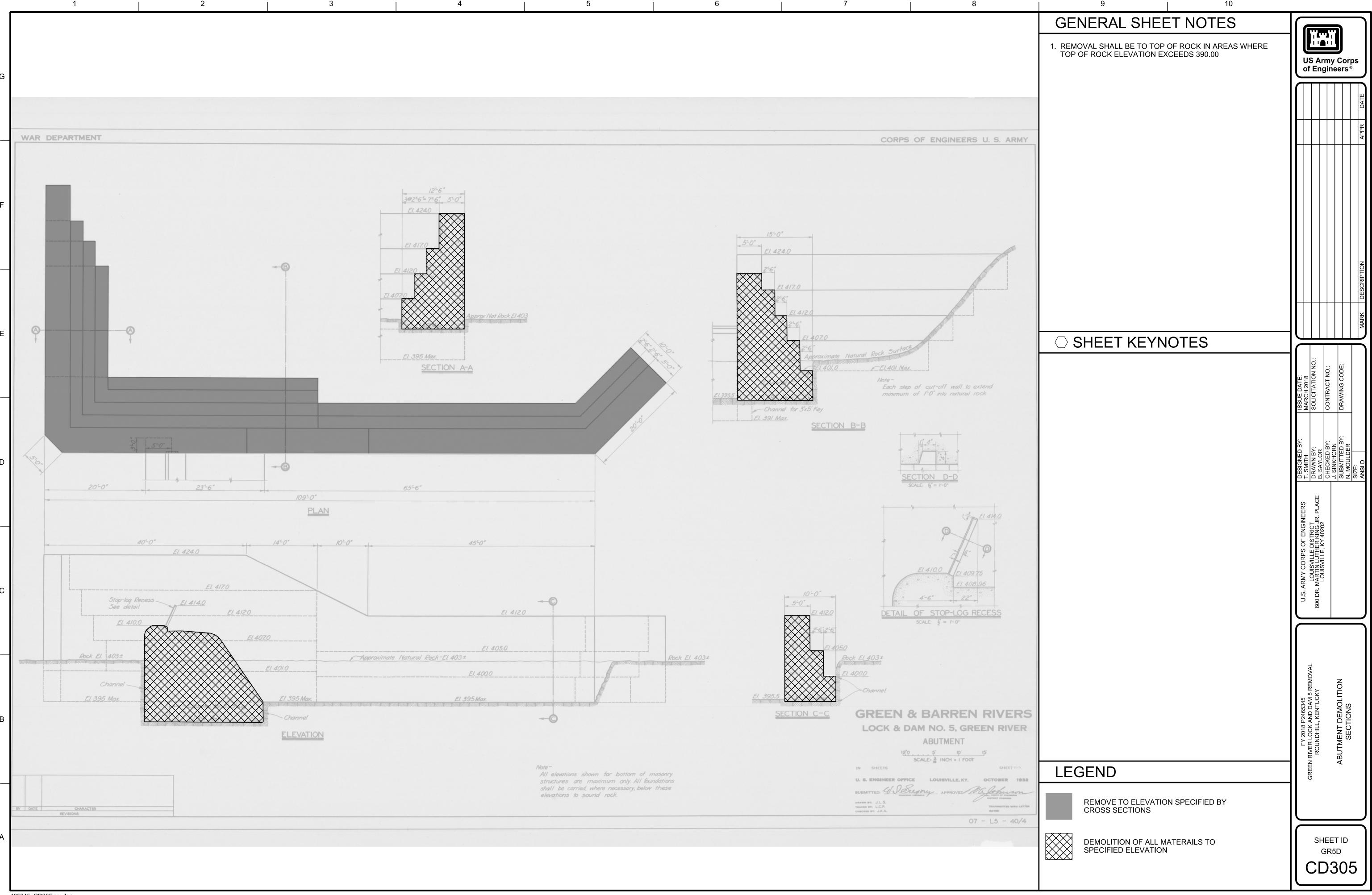










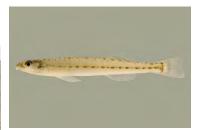


# 2017 Preliminary Ecological Assessment

# Preliminary ecological assessment of the Green and Nolin rivers in Mammoth Cave National Park, Kentucky, following the removal of lock and dam #6









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# **Table of Contents**

List of Tables	i
List of Appendices	i
List of Figures	ii
Introduction	2
Methods	3
Study Area	3
Riparian Zone	5
Macroinvertebrates	12
Freshwater mussels	15
Fish	17
In-stream habitat	19
Results	22
Sediment, bank exposure, slopes, and wetted width of stream	22
Vegetation	22
Macroinvertebrates	27
Freshwater mussels	28
Fish	29
In-stream habitat	30
Discussion	31
Vegetation	32
Macroinvertebrates	33
Freshwater mussels	33
Fish	34
In-Stream habitat	34
Management recommendations	35
Acknowledgements	35
Literature Cited	36
Appendices	39

# List of Tables

Fable 1. Vegetation site locations and survey dates	7
Table 2. Mammoth Cave river gauge (2017)	7
Table 3. Macroinvertebrate site locations, date collected, and Hester Dendy duration	. 14
Table 4. Mussel site location, habitat type, and date surveyed	. 16
Table 5. Fish site locations, sample date, and sample methods	. 19
Table 6. In-stream habitat survey locations and site hydrological classification	. 21
Table 7. Species recorded as dominant across all plots	. 23
Table 8. Trees recorded in plots (woody stem counts)	. 24
Table 9. Trees, shrubs, and woody vines recorded in the shrub zone of all plots (presence)	. 25
Table 10. # of Times a Species was Recorded in any Subplot/Quadrat	. 26
Fable 11. Diversity and abundance of macroinvertebrate samples	. 27
Fable 12. Comparison of macroinvertebrate richness within two hydrological sections of the Green         River	
Fable 13. Mussel diversity and abundance categorized by habitat type	28
Fable 14. Comparison of fish richness and abundance within two hydrological sections of the Green and Nolin rivers	
Table 15. Physical habitat measurements	. 31
List of Appendices	
Appendix A. Riparian vegetation field data sheet	. 39
Appendix B. Riparian vegetation species presence by site	. 40
Appendix C. Macroinvertebrate taxa presence by site	. 44
Appendix D. Macroinvertebrate taxa Hester-Dendy abundance by site	. 48
Appendix E. Macroinvertebrate taxa kick net abundance by site	. 50
Appendix F. Mussel species richness and abundance for each site surveyed	. 53
Appendix G. Fish taxa abundance by site	. 57
Appendix H. Stream wetted width, depth, and substrate type	62
Appendix I. Site large woody debris (LWD) presence and bank failure (%)	. 69

# List of Figures

Figure 1. Historical (A) and current (B) hydrology of the Green and Nolin rivers near Mammoth Cave	<u>;</u>
National Park (MCNP)	5
Figure 2. Riparian zone sites along the Green and Nolin rivers, MCNP (2017)	6
Figure 3. Vegetation site diagram	9
Figure 4. Example of photo points at site GR5 (A-C); and motorboat transport (F)	11
Figure 4A. GR5 CenterStream –North #77 (Plotside)	11
Figure 4B. GR5 CenterStream-South 76	11
Figure 4C. GR5 Primary-Bank- facing #81	11
Figure 4D. GR5 Primary-Downstream #80	11
Figure 4E. GR5 Primary-Upstream #79	11
Figure 4F. Brice Leech, MCNP staff: site transport	11
Figure 5. Macroinvertebrate site locations	13
Figure 6. Hester Dendy unit after colonization period showing variable spacing between the hardboard plates	14
Figure 7. Mussel survey locations among habitat type	16
Figure 8. Fish sampling locations	18
Figure 9. Site locations of in-stream habitat surveys	20
Figure 10. Presence of large woody debris and snags (A) and bank failure (B and C) within the	
study area	21
Figure 10A	21
Figure 10B	21
Figure 100	21

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### Introduction

It is estimated that there are nearly 90,000 dams that occur within the waterways of the United States, with approximately 1,100 dams within Kentucky (Bellmore et al. 2017). Although dams have provided benefits in navigation, flood control, and recreation, the presence of dams on the natural aquatic fauna, water quality, and the hydrology have been profoundly negative. Dams drastically alter the upstream habitat from cool, shallow, highly oxygenated flowing water to warmer, deeper, and less oxygenated standing water, which has been shown to decrease species richness and homogenize the local fauna (e.g., Guenther and Spacie 2006; Hayes et al. 2006; Winston et al. 1991). In particular, dams have decimated freshwater mussels, with dozens of species (e.g., *Epioblasma* spp.) going extinct (Haag 2012). In recent decades, however, the removal of dams has increased, because of liability and safety concerns, as well as a shift in policy toward biodiversity and habitat restoration.

In November 2016, lock and dam #6 (L&D 6) on the Green River near Brownsville, Kentucky, experienced increased structural malfunction. The dam was considered for removal prior to the recent breach because it was in disrepair for many decades, but its removal became imminent as safety concerns increased. A partnership between the U.S. Army Corps of Engineers (USACOE), U.S. Fish and Wildlife Service (USFWS), National Park Service (NPS), The Nature Conservancy (TNC), Kentucky Department of Fish and Wildlife Resource (KDFWR), and Kentucky Waterway Alliance (KWA) was established and the removal of the dam was scheduled for spring 2017. The objectives of the dam removal were to eliminate the safety hazards and to restore the immediate section of the Green River to more natural flow conditions.

The science of dam removal and our understanding of the recovery of stream habitats and the local fauna is sparse. Approximately 1,200 dams have been removed in the United States, but fewer than 10% of the dam removals have been scientifically assessed and published (Bellmore et al. 2017: Foley et al. 2017). In Kentucky, four dam removals have been documented, but no scientific review of the process has been published (Bellmore et al. 2017). The need to understand and document the recovery of stream habitat and the local fauna following dam removal is essential if resource managers are to optimize the benefits of removing dams (Oliver and Grant 2017). This is especially important for the recovery of the Green River and its fauna within Mammoth Cave National Park (MCNP) that were impacted by L&D 6. The Green River is considered a global bioreserve, harboring numerous rare and unique species; and Cicerello and Hannan (1991) suggested that the freshwater fauna within MCNP is the most diverse among the national park systems. Therefore, the potential recovery and range expansion of rare species - particularly

fishes, crayfishes, and mollusks - are great. To properly document and understand the recovery in its entirety it is critical to develop a monitoring program that obtains data that incorporates the river conditions and local fauna prior, immediately after, and long-term following the removal of a dam. Most dam removal projects fail in this endeavor, which has created a gap in our understanding of dam removals and the impact and potential benefits on the local fauna after the dams are gone (Bellmore et. al 2017).

In summer 2017, USFWS, MCNP, and Kentucky State Nature Preserves Commission (KSNPC) agreed to document the current conditions following the spring 2017 removal of L&D 6 on the Green River. The broad goals were to document the current physical conditions and inventory the riparian zone and aquatic fauna within the portion of Green and Nolin rivers upstream from the former location of L&D 6. No statistical analysis of the data was conducted. Specifically, the primary objectives were to:

- 1. Document the riparian zone conditions
- 2. Document the macroinvertebrate fauna
- 3. Document the freshwater mussel fauna
- 4. Document the fish fauna
- 5. Document the in-stream habitat conditions
- 6. Provide management recommendations

### Methods

### Study Area

The approximate 20 river kilometers of the Green River upstream of the former location of L&D 6 to the pool above Sand Cave Island (37.17948/-86.15418) and approximately three river kilometers upstream on the Nolin River from the Green River confluence was the focus of the study (Figure 1). All data collected were within the MCNP boundaries. The Green River enters MCNP from the east and flows westward approximately 40 km before leaving MCNP just upstream of L&D 6. Extensive karst topography primarily exists within the southern portion of MCNP and the only major tributary that joins the Green River is the Nolin River from the north. Most other sources of water that drain into the Green River come from underground streams and springs that percolate through the limestone. It is estimated that nearly 80 subsurface or surface springs drain into the Green River within MCNP (Pond 1996).

The former location of L&D 6 on the Green River (37.20641/-86.26083) was approximately three km downstream of the Nolin River confluence in Edmonson County, Kentucky. According to National Park Service (1983) the structures were built in 1906 and 1907. Navigation was the primary purpose for the

dam, but its services were eventually terminated by the USACOE (1981). Lock and dam 6 remained structurally, but its condition was often in disrepair and leaked until its removal in spring 2017.

Historically, based on the impoundment created by L&D 6, sections of the Green River that meandered through MCNP were designated into three hydrological categories: impounded, transitional, or free flowing (Cicerello and Hannan 1990; Pond 1996). Impounded was defined as river continuously impacted by L&D 6, where flow was laminar and minimal and depth the greatest, free flowing was defined as river that was not directly impacted from L&D 6 and contained riffle, run, and pool habitat sequences, and transitional was defined as river that would experience impounded conditions and free flowing conditions, with respect to seasonal changes. The extent of these categories varied based on seasonal water level changes and the status of the dam condition. When the dam was in good condition and during normal high-water the impounded section would extend upstream to the Green River Ferry and Cave Island vicinity (this marked the downstream extent of free flowing conditions). During extreme drought conditions and the dam being in disrepair, the water would rescind and only impound to Boardcut Island (downstream extent of transitional conditions). Under typical base flow conditions and with the dam in disrepair, the Green River would be impounded to the pool upstream of Sand Cave Island (Cicerello and Hannan 1991; Pond 1996). The impact of L&D 6 on the Nolin River was extensive and would reach to the Nolin River Dam during high water. This section of the Nolin River experienced only impounded or transitional conditions based on seasonal changes and the discharge from Nolin River reservoir.

The extent of the historical hydrological conditions has shifted downstream following the breach of November 2016 and the subsequent dam removal in spring 2017. Currently, the Green River is no longer impacted from L&D 6, but the influence from lock and dam 5 (L&D 5, 37.16867/-86.40328) still remains. The impounded river from L&D 5 extends to the downstream pool of Crump Island on the Green River and upstream on the Nolin River past Second Creek. It is currently unknown if the extent of pool 5 extends upstream of Crump Island during high water. The Green River upstream of Crump Island exhibited free flowing conditions during summer and fall 2017. The current study categorized sites within the Nolin River and Green River, from L&D 6 upstream to Crump Island as impounded (L&D 5), and sites within the Green River, upstream of Crump Island, as free flowing.

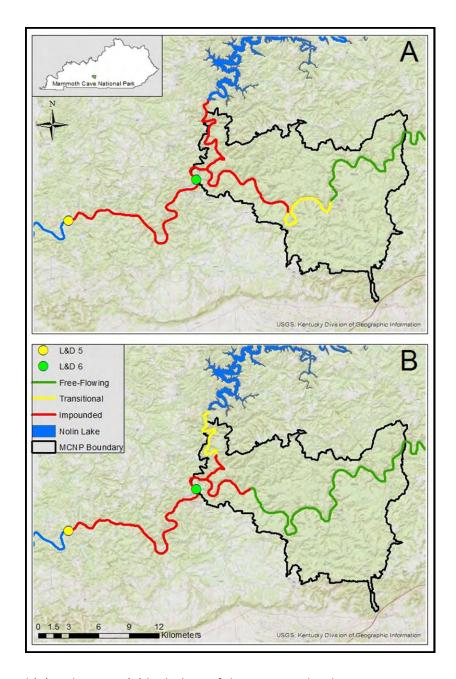


Figure 1. Historical (A) and current (B) hydrology of the Green and Nolin rivers near Mammoth Cave National Park (MCNP).

# Riparian Zone

The goal of assessing the riparian zone was to assess the current physical conditions and document the floral diversity and relative species abundances along the Green and Nolin rivers. A systematic approach was taken to obtain adequate coverage and account for the potential variability of the riparian zone along the 24 river kilometers within the study area. Thirteen Green River sites and two

Nolin River sites were established, with the first Green River site (GR1) approximately 0.8 kilometers upstream from L&D 6 and each subsequent site approximately 1.6 river kilometers upstream from the previous site (Figure 2). To reduce field time only one bank was surveyed for vegetation at a site, and determination of which bank, downstream facing left bank or downstream facing right bank, was done randomly prior to site visit to eliminate bias. At a site, a 2m x 12m plot was developed to obtain canopy closure, shrub cover, woody stem counts, mature tree identification and size, dominant species and % cover data. In addition, two (occasional three, if deemed necessary by lead investigator) quarter-meter quadrats were randomly placed within the larger plot at a site for species identification and % cover. Lastly, photo points, wetted stream width, field geographical coordinates were obtained at a site (Appendix A).

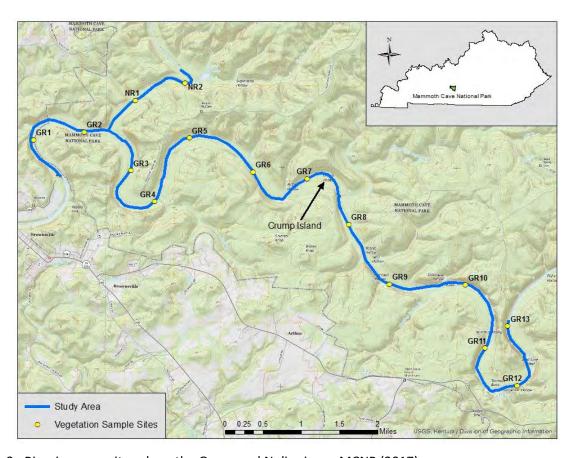


Figure 2. Riparian zone sites along the Green and Nolin rivers, MCNP (2017).

Data collection was conducted during a late summer index period, August 16 – September 21, 2017 (Table 1). A short time frame for obtaining the vegetation data is important to minimize any growth variation that may occur between sites. It is also important to make these data collections when the water levels are relatively equal. Large fluctuations in water levels can skew the perspective of the photo points.

Water level data at the Green River Ferry was provided by MCNP staff (Table 2). Future riparian zone sampling should target these relative water levels.

Table 1. Vegetation site locations and survey date.

Stream	Site	Latitude	Longitude	Date surveyed
Green River	GR1	37.211336	-86.267228	16-Aug-17
Green River	GR2	37.214908	-86.255235	16-Aug-17
Green River	GR3	37.207659	-86.244089	16-Aug-17
Green River	GR4	37.201786	-86.238470	17-Aug-17
Green River	GR5	37.213895	-86.023026	17-Aug-17
Green River	GR6	37.207498	-86.215082	21-Aug-17
Green River	GR7	37.206275	-86.202175	19-Aug-17
Green River	GR8	37.197640	-86.192253	19-Aug-17
Green River	GR9	37.186350	-86.182518	19-Aug-17
Green River	GR10	37.186247	-86.164570	19-Aug-17
Green River	GR11	37.174300	-86.159716	19-Aug-17
Green River	GR12	37.167208	-86.152122	19-Aug-17
Green River	GR13	37.178498	-86.154448	19-Aug-17
Nolin River	NR1	37.220987	-86.243089	20-Aug-17
Nolin River	NR2	37.224317	-86.231333	20-Aug-17

Table 2. Green River Ferry (MCNP) river gauge (2017).

Month	Date	Time	Gauge Level (ft)
August	16	6:04	0.1
August	16	13:54	0.0
August	17	7:09	-0.3
September	19	5:44	0.7
September	19	14:07	0.6
September	20	5:46	0.5
September	21	5:55	0.4
September	21	14:01	0.35

Sites GR1 thru GR5 were surveyed during August and accessed with a kayak and canoe. Sites GR6 thru GR13 and NR1 and NR2 were surveyed during September and accessed with a 16 ft jon boat with a jet engine motor. Geographical coordinates were obtained for each site (center stream site point) prior to field sampling using ArcMap software ver. 10.3 (Environmental Systems Research Institute, ESRI). Navigation to the specific geographical coordinates of a site was assisted with a digital map (live navigation) using an iPad mini 4 Bluetooth-linked to a Bad Elf GPS PRO+. The mapping software-application used for this was ESRI's "Collector".

Whether using canoe or motorboat, an anchor was essential to holding the boat in one relative location in the middle of the stream (Figure 3). Best accuracy was accomplished by dropping the anchor into the water several meters upstream of the point, with the flow pulling the boat downstream from the anchor (this holds the boat several meters downstream from where the anchor grabs into the stream bottom). A margin of error less the 20 meters was acceptable for recording center-stream location (the set of points created in office were locations used to navigate). If establishing the same plot is deemed important for long-term results, the points collected/installed can be used as the Bad Elf GPS PRO+ (refer to as GPS Pro) is capable of collecting points accurate to 8 feet (2.5 m). However, accuracy attained during sampling of center-stream points were mostly less than 20 feet but not less than 10 feet (multiple points were collected and averaged together). Accuracy information attained from GPS Pro was written on datasheets. Once points were collected in the center of stream, wetted stream width and two photo points of each bank were collected using a SIG Sauer rangefinder (model KILO2000) and a Panasonic Lumix camera (model DMC-TS30), respectively. The wetted width was obtained by aiming the SIG Sauer rangefinder at the water's edge of both banks and adding the two values together for the total wetted width of stream. Several aims at each bank were taken and then compared to strengthen confidence in the readings and eliminate the occasional error in the readings. Photos were taken by kneeling in the motorboat or simply sitting in the canoe, at a collection height of approximately 3 feet/1 m above the water (Figure 4A and 4B).

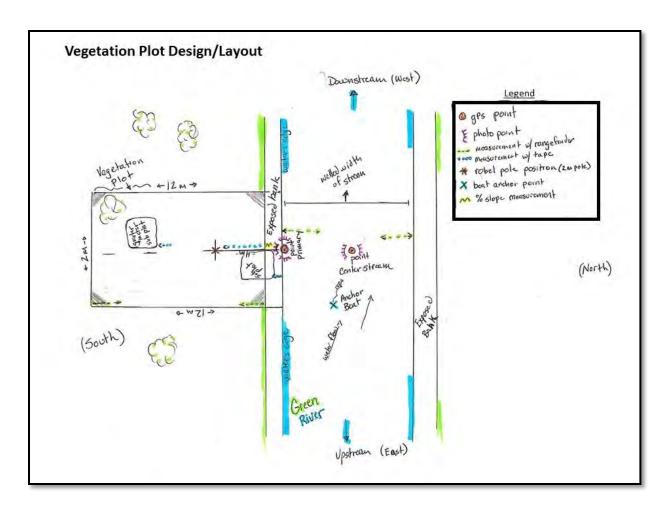


Figure 3. Vegetation site diagram.

A field crew of at least three members were used to established one 2m x 12m bank vegetation plot at a site. The specific bank (left bank or right bank) surveyed was determined randomly prior to the field visit. The vegetation plot at a site was perpendicular from the center stream location and the specific location was determined by visually locating a spot along the bank and holding it to memory until the watercraft could be maneuvered to a point that is right or left of the targeted spot, which allowed the field crew to operate without hindrance from the watercraft. At the plot, a crew member would stand on the bank at the water's edge and obtain the plot reference point with an iPad mini 4 linked to a Bad Elf GPS PRO+ using Collector. In addition, three photo points at eye level and oriented as bank-facing, upstream, and downstream were taken at the plot (Figure 4 C-E). A general rule in collecting upstream and downstream photo points was to have 1/3 water and 2/3 land visible in the photo, with a level horizon (Figure 4D and E). The presence of the watercraft in the upstream or downstream photo points was not desirable, but was hard to avoid. For the bank-facing photo, a 2-meter tall robel pole was included 4

meters from the plot reference point (this is for measuring structure/the shrub zone). It was efficient to have a crew member hold the robel pole while another crew member obtained the photo point. This was acceptable in 2017 due to minimal vegetation growing at 4 m (measured with a meter tape), but may need modification with changing vegetation growth (a temporary stake could be installed to hold the pole and let the collector exit the data view). It is important to note that the primary investigator was approximately 6 ft in height and if future collectors are shorter or taller by 3 inches slight adjustment might be needed for photo points. Associated azimuths were collected for the upstream and downstream photo points by matching the camera view angle with a compass azimuth (iPad mini was used: generic compass app). The plot boundary, especially the longest extent (12m) from the water's edge was checked using the rangefinder. The "distance to top of bank" measurement was also recorded in this area of the plot with the rangefinder; if the top of bank was beyond 12 meters, 12 m+ was recorded. If the top of bank was easy to maneuver, to beyond the 12 meters or if it was easy to see, a rangefinder was used and the measured distance recorded. The 2-meter plot boundary width was determined using a metertape/center line as reference and holding out the robel pole.

Identifying vegetation within the plots was the most advanced skill needed to complete the project. Once plants were identified, vegetation was recorded mostly as a percent cover, such as canopy closure, general shrub cover, five dominant species, individual shrub species cover, and the two quartermeter sub-plots/quadrats (Appendix A). Specific stem counts were recorded for all woody species taller than dbh (diameter at breast height: 1.3 m); this included trees and shrubs but excluded woody vines (woody vines were recorded in shrub species percent cover and as a part of the dominant five species, when applicable). For all plots, stem counts per category were less than ten stems per plot, but such low counts are expected to change. When recording the dominant five species in the plot, a sixth species was deemed acceptable when percent cover matched that of the fifth/last species, i.e. a clear "dominant fifth" was indiscernible. In addition, vegetation data was obtained from two, randomly placed, quarter-meter square quadrats. A third quadrat was optional if one of the two quadrats occurred within the non-vegetated bank zone. Location of the third quadrat was determined haphazardly by the botanist within the vegetated zone of the plot.





C: GR5 Primary-bank-facing #81



E: GR5 Primary-upstream #79



B. GR5 Center stream-South 76



D: GR5 Primary-downstream #80



F: Brice Leech, MCNP staff: site transport

Figure 4. Example of photo points at site GR5 (A-E); and motorboat transport (F). All photos by Brian Yahn (August 17, 2017).

In future studies, if the woody stem count significantly increases during the monitoring period of the dam removal then the estimated stem count classes should be utilized for the "Sapling 1" and "Sapling 2", and potentially the "Small Tree" categories (i.e., stem counts may change from a few to hundreds and the classes will help account for this). It is important to document that woody stems are increasing and

at a certain density, but a specific count is not necessary; this "counting in bunches" design increases sampling efficiency. Perhaps a seedling % cover parameter is needed in future sampling, (KSNPC is confident that everything sampled in 2017 had a seedling density less than 15% cover). And further, defining the term "seedling" as any woody tree or "newly sprouted" shrub that is shorter than dbh/1.3 m. Note: Any established/mature shrub (or tree for that matter) under 1.3 m would be recorded in individual shrub species cover and not seedling % cover because the target for the seedling category is for recruitment, i.e. germinating stems. Also, recording vegetation coverage on the robel pole may prove beneficial for future monitoring. 2017 showed minimal growth along the robel pole, 4 m from the water's edge (Figure 4C), but that has a high potential to change and would be readily available for adding to the sampling protocol.

### Macroinvertebrates

Five sites were selected to characterize the macroinvertebrate fauna (Figure 5). Two sites were selected within the impounded section of the Green River, below Crump Island, and two sites within the free flowing section (formally transitional) of the Green River, above Crump Island (Table 3). One site within the impounded section of the Nolin River was established. The sites were approximately 150 m in length and were considered typical locations that represented the broader reaches of river. Sampling techniques at each of the sites were standardized as much as possible based on the available, workable habitat. Overall, the goal was to capture a representative macroinvertebrate community at each site to establish baseline diversity and relative abundance data.

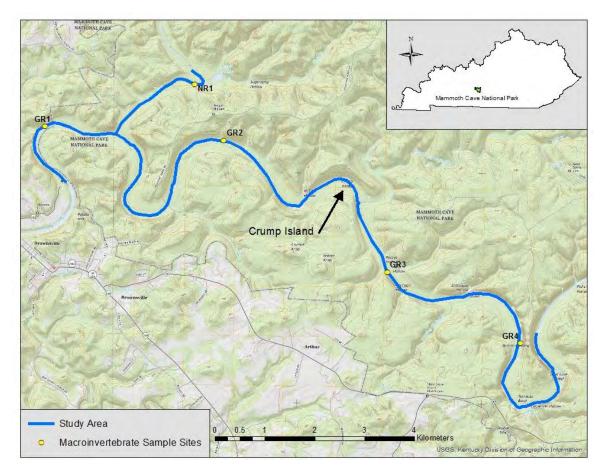


Figure 5. Macroinvertebrate site locations.

At each site, if available, qualitative samples of approximately 3 linear meters of 'weathered' wood (> 0.03 m in diameter), 5 rocks (b-axis > 64 mm), and 5 dip net (< 1000  $\mu$ m mesh size) sweeps into depositional areas were made, as well as a general search among other unique microhabitats (e.g., mid-channel snags). Quantitative sampling at each site consisted of deploying Hester Dendy (HD) artificial samplers. The HD samplers were attached to cinder blocks, which were placed in the erosional zone of the channel at each of the sites. Each cinder block had four HD units attached to them. Each HD unit was comprised of five 7.62 x 7.62 cm hardboard plates that were variably spaced apart (Figure 6). The total HD surface area for each site was 0.23 m². A buoy was attached to each cinder block for retrieval. The HD units were left in the river for macroinvertebrate colonization between 43-51 days. Semi-quantitative sampling was done only at the two free flowing sites. Four 0.25 m kick net (< 500  $\mu$ m mesh size) samples were taken in riffle habitat at the free flowing sites.



Figure 6. Hester Dendy unit after colonization period showing variable spacing between the hardboard plates.

Table 3. Macroinvertebrate site locations, date collected, and Hester Dendy duration.

				Date	Hester Dendy
Stream	Site	Latitude	Longitude	Collected	colonization (days)
Green River	GR1	37.21655	-86.26556	27-Sept-17	43
Green River	GR2	37.21420	-86.22507	27-Sept-17	45
Green River	GR3	37.19047	-86.18797	21-Sept-17	45
Green River	GR4	31.17772	-86.15781	21-Sept-17	45
Nolin River	NR1	37.22433	-86.23169	21-Sept-17	51

Note: All Hester Dendy samplers were deployed on September 11, 2017.

Sample processing in the field consisted of using forceps, pans, squirt bottles, buckets, and sieves (500 and 1000  $\mu$ m) to separate and condense material. The remaining material was placed in containers with 95% ethanol, labeled, and taken to the laboratory for further processing. Laboratory processing consisted of using microscopes, sieves (500  $\mu$ m), pans, and forceps to sort and identify any macroinvertebrate specimens from debris. Macroinvertebrates were identified to the taxonomic family level and enumerated. Laboratory processing and specimen identification was conducted by Natalia Maass at Eastern Kentucky University (EKU) under the supervision of Dr. Amy Braccia, who confirmed specimen identification. Initially, the qualitative microhabitat samples were kept separate by habitat type, but are reported as a qualitative composite at a site. Quantitative and semi-quantitative samples are reported as abundances for each site.

#### Freshwater Mussels

The goals of the mussel surveys were to generate baseline diversity and relative abundance data according to habitat type. The section of Green River below Crump Island and all of the Nolin River were considered impounded, because of the existing influence from L&D 5. The Green River upstream from Crump Island was considered free flowing. Mussel surveys were conducted within both sections, with the majority of surveys conducted within the free flowing section. Habitat within the free flowing section was designated as flowing or pool based on the hydrology. Sites within each habitat type were surveyed for live mussels, with the majority of surveys conducted within flowing habitat (Figure 7). Each survey consisted of searches along three transects that extended bank to bank. The precise site location for each mussel survey was determined randomly using geographical coordinates generated from GIS. The geographical coordinates represented the location of the middle transect (Table 4). The two remaining transects surveyed were 10 meters upstream and 10 meters downstream of the middle transect. The width of each transect was 1 m and the length varied based on the wetted width of the river. Therefore, a site surveyed represented three transects within a 20 meter longitudinal length of river. This provided an approximate 15% subsample of the area surveyed for each of the sites, regardless of the variable wetted width among the sites. Visual searches along each transect consisted of snorkel or dive techniques based on water depth and flow. Only the immediate surface of the river bottom was disturbed and surveyed for mussels. No excavation of material was conducted. All live mussels encountered along each transect were identified, measured, enumerated, and placed back in the river. Photo vouchers for each species were taken. The aggregation of the three transects represented the mussel fauna at a site and the data is reported as abundances. The mussel surveys were conducted by Lewis Environmental Consulting (Murray, Kentucky) with Chad Lewis as the principle investigator. No mussel surveys were conducted within the Nolin River or within the Green River downstream of the Nolin River, because river conditions were unsafe and excessively turbid due to water releases from the Nolin River dam.

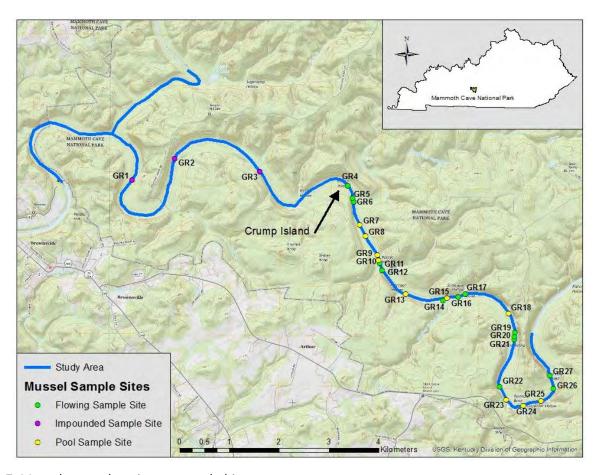


Figure 7. Mussel survey locations among habitat type.

Table 4. Mussel site location, habitat type, and date surveyed.

Stream	Site	Latitude	Longitude	Habitat type	Date surveyed
Green River	GR1	37.20694	-86.24488	Impounded	13-Oct-2017
Green River	GR2	37.21080	-86.23524	Impounded	13-Oct-2017
Green River	GR3	37.20854	-86.21601	Impounded	13-Oct-2017
Green River	GR4	37.20601	-86.19605	Flowing	13-Oct-2017
Green River	GR5	37.20381	-86.19495	Flowing	12-Oct-2017
Green River	GR6	37.20320	-86.19475	Flowing	12-Oct-2017
Green River	GR7	37.19897	-86.19329	Pool	12-Oct-2017
Green River	GR8	37.19693	-86.19205	Pool	12-Oct-2017
Green River	GR9	37.19352	-86.18933	Pool	12-Oct-2017
Green River	GR10	37.19263	-86.18899	Pool	11-Oct-2017
Green River	GR11	37.19207	-86.18877	Flowing	11-Oct-2017

Cont. Table 4. Mussel site location, habitat type, and date surveyed.

Green River	GR12	37.19077	-86.18820	Flowing	11-Oct-2017
Green River	GR13	37.18652	-86.18286	Pool	11-Oct-2017
Green River	GR14	37.18534	-86.17744	Flowing	10-Oct-2017
Green River	GR15	37.18586	-86.17348	Pool	10-Oct-2017
Green River	GR16	37.18600	-86.17096	Flowing	13-Oct-2017
Green River	GR17	37.18657	-86.16940	Flowing	11-Oct-2017
Green River	GR18	37.18310	-86.15956	Pool	10-Oct-2017
Green River	GR19	37.17962	-86.15809	Flowing	10-Oct-2017
Green River	GR20	37.17889	-86.15819	Flowing	9-Oct-2017
Green River	GR21	37.17841	-86.15825	Flowing	9-Oct-2017
Green River	GR22	37.16986	-86.16145	Flowing	9-Oct-2017
Green River	GR23	37.16743	-86.15997	Pool	10-Oct-2017
Green River	GR24	37.16641	-86.15614	Pool	13-Oct-2017
Green River	GR25	37.16726	-86.15213	Pool	10-Oct-2017
Green River	GR26	37.16958	-86.14930	Flowing	9-Oct-2017
Green River	GR27	37.17186	-86.15019	Flowing	11-Oct-2017

# Fish

Five sites were selected to characterize the potential longitudinal differences in the fish communities (Table 5). Two sites were selected within the impounded section of the Green River, below Crump Island, and two sites within the free flowing section (formally transitional) of the Green River, above Crump Island (Figure 8). One site within the impounded section of the Nolin River was established. The sites were approximately 600 m in length and were considered typical locations that represented the broader reaches of river. Sampling techniques at each of the sites were standardized as much as possible based on the available, workable habitat. Overall, the goal was to capture the representative fish fauna at each site to establish baseline diversity and relative abundance data.

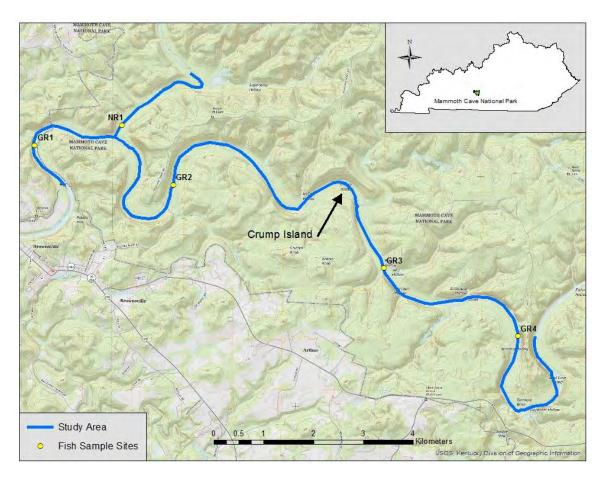


Figure 8. Fish sampling locations.

Boat electrofishing was conducted along each bank (downstream direction) for approximately 500 meters within the deeper areas of a site. The Nolin River site was much narrower than the four Green River sites and was shocked in a bank to bank zig-zag pattern for approximately 500 meters, instead of both banks being surveyed independently. At the two free flowing sites, riffle, run, and pool habitat sequences provided relatively shallow and workable areas, which were surveyed using a backpack electrofishing unit and a seine. Approximately 100-150 meters of the relatively shallow habitat was surveyed with these techniques. A Missouri trawl was used only at site GR2. Three hauls of the trawl were conducted to obtain the smaller fish within the benthic and pelagic zones of the deep mid channel area of the site. Technical issues prevented the use of the trawl within similar habitat at each of the sites. The fish community for each of the sites is the aggregation of the techniques and the data is reported as abundances.

Table 5. Fish site locations, sample date, and sample methods.

Stream	Site	Latitude	Longitude	Date	Methods
Green River	GR1	37.21370	-86.26759	22-Sept-17	Boat electrofish
Green River	GR2	37.20666	-86.23621	22-Sept-17	Boat electrofish and Missouri trawl
Green River	GR3	37.19182	-86.18853	24-Aug-17	Boat and backpack electrofish, and seine
Green River	GR4	37.17965	-86.15811	24-Aug-17	Boat and backpack electrofish, and seine
Nolin River	NR1	37.21739	-86.24785	22-Sept-17	Boat electrofish

### In-stream habitat

A stratified random approach was used to determine site locations for in-stream habitat data. The study area was designated into impounded and free flowing sections of river based on the current hydrology. The general location of the hydrological change was near Crump Island on the Green River (Figure 9). Seven random sites were chosen from the impounded section (below Crump Island) within the Green (5 sites) and Nolin (2) rivers and eleven random sites were chosen within the free flowing section of the Green River (above Crump Island) (Table 6). The random geographical locations were generated from GIS. More sites were surveyed within the free flowing section, because of the greater habitat variability within that section of river. A site was an approximate 100 m reach of river. Approximately a 10% random subsample of the available habitat was surveyed within the free flowing section of river and approximately a 5% random subsample was conducted within the impounded section of river. Overall, the goal was to survey enough reaches within the study area to capture the habitat variation and to characterize the habitat within the impounded and free flowing sections of the study area.

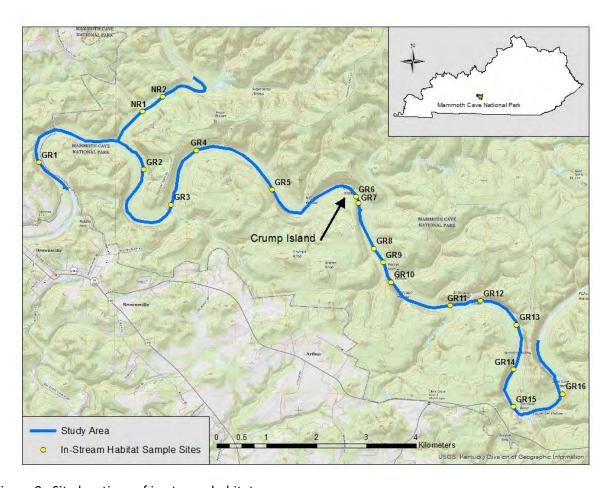


Figure 9. Site locations of in-stream habitat surveys.

For each site, data were collected along three bank to bank transects, which were located at the downstream boundary, the middle, and the upstream boundary of a site. Along each of the three transects, wetted width (m) was determined and at six evenly spaced points along each transect, water depth (m) and a substrate size category were determined. Data is reported as the mean wetted width, mean depth, and relative percentage of the substrate size categories from the respective sites of the two hydrological classifications. In addition, the middle transect was used to delineate between the downstream and upstream halves of a site. Within the downstream and upstream halves, the presence of large woody debris and snags (LWD, > 250 cm in diameter and > 2 m in length) were determined as present or absent (Figure 10A) and a percentage of bank failure was determined for the left and right descending banks (Figure 10B and C). Bank failure was defined as an obvious and a relatively recent bank collapse, which was perceived to be the result of quick and recent dewatering following the removal of L&D 6. Those data are reported as mean LWD relative frequency and mean percent bank failure for the two hydrological classifications.



Figure 10 (A-C). Presence of large woody debris and snags (A) and bank failure (B and C) within the study area.

Table 6. In-stream habitat survey locations and site hydrological classification.

Stream	Site	Latitude	Longitude	Hydrology
Green River	GR1	37.21128	-86.26720	Impounded
Green River	GR2	37.21010	-86.24390	Impounded
Green River	GR3	37.20375	-86.23730	Impounded
Green River	GR4	37.21361	-86.23170	Impounded
Green River	GR5	37.20657	-86.21450	Impounded
Green River	GR6	37.20540	-86.19550	Flowing
Green River	GR7	37.20424	-86.19500	Flowing
Green River	GR8	37.19605	-86.19150	Flowing
Green River	GR9	37.19352	-86.18930	Flowing
Green River	GR10	37.18994	-86.18750	Flowing
Green River	GR11	37.18577	-86.17420	Flowing
Green River	GR12	37.18668	-86.16730	Flowing
Green River	GR13	37.18236	-86.15910	Flowing
Green River	GR14	37.17429	-86.15980	Flowing
Green River	GR15	37.16757	-86.15980	Flowing
Green River	GR16	37.16988	-86.14867	Flowing
Nolin River	NR1	37.22061	-86.24389	Impounded
Nolin River	NR2	37.22328	-86.23930	Impounded

#### Results

Sediment, Bank Exposure, Slopes and Wetted Width of Stream

Twelve of 15 (80%) banks had exposed mud substrate, with GR9= mud + sand, GR11= sand, and GR12= cobble/boulder. The exposed bank measurement was greatest at plots along the downstream section (GR2 – GR5 averaged 4.4 m) as ponding when L&D 6 was functional would have been greatest along this section of the project and in general have a wider band of exposed bank than further upstream (this being less of the case in areas with steep cliffs or banks with less of a developed, wide floodplain). If you remove from the data GR10 due to a sand/mud bar-extension and GR11 due to a spot with irregular sediment buildup, then the stretch from GR6 through GR13 averaged just 3.1 meters. The steepest banks/slopes were scattered throughout the study area (GR2= 80% slope, GR6= 72% slope, GR8= 72% slope, GR12= 75% slope and GR13= 80% slope). Wetted stream width varied slightly across the study area with no distinctive narrowing from downstream to upstream, as might be evident over a longer span of stream corridor. Average wetted width distance on the Green River was 51.2 meters (13 plots), and 21.6 meters from the 2 plots on the Nolin River.

### Vegetation

Summary tables (tables 7-10) have been created to show the common to frequently recorded species found across all plots. Table 6 represents the number of times a species was found dominant (dominant five) across all plots. Oriental lady's thumb or bunchy knotweed (*Persicaria longiseta*) was a dominant 11 of 15 times, and within seven of these plots the species percent cover was more than 10% of the plot. *Persicaria longiseta* is an invasive non-native plant originating from Asia and considered a "Significant Threat" by the Kentucky Invasive Plant Council (CISEH 2013). It is capable of recruitment and spread along disturbed soils that maintain moisture. Its dominant growth is expected to continue during this initial "post-dam" period of instability along the banks, e.g. remaining aggressive in areas of bank failure and areas of canopy loss /mature tree loss. Indian woodoats (*Chasmanthium latifolium*) was also a dominant 11 of 15 times, and within six of these plots the species % cover was more than 10% of the plot. *Chasmanthium latifolium* is a native grass, often found along stream corridors, like in the study area. As documented, it is capable of competing with aggressive species like *Persicaria longiseta*. Mild water-pepper (*Polygonum hydropiperoides*) was a dominant nine of 15 times and within nine of these plots (highest), the species percent cover was more than 10% of the plot.

Table 7. Species recorded as dominant across all plots.

# of Xs a dominant

			and naving > 10%
Tree/Shrub/Herb	Species	# of times a dominant	cover
herb	Persicaria longiseta*	11	7
herb	Chasmanthium latifolium	11	6
herb	Polygonum hydropiperoides	9	8
herb	Microstegium vimineum*	9	6
herb	Leersia virginica	5	2
herb	Verbesina alternifolia	5	2
herb	Pilea pumila	5	1
herb	Amphicarpaea bracteate	4	0
herb	Ageratina altissima	3	1
herb	Polygonum punctatum	3	1
herb	Solidago rupestris**	2	1
shrub	Lindera benzoin	2	1
tree	Platanus occidentalis	1	1

All species names according to ITIS.; \* Non-native invasive species.; \*\*Species of conservation concern.

Polygonum hydropiperoides is another native species mostly restricted to wetland habitats (defined as a wetland obligate species throughout its range). As documented, it too is capable of competing with aggressive species like the associated *Persicaria longiseta*. Japanese stiltgrass (*Microstegium vimineum*) was a dominant nine of 15 times, and within six of these plots the species % cover was more than 10% of the plot. Considered a "Severe Threat" by the Kentucky Invasive Plant Council (CISEH 2013), this Asian intruder is one of the most abundant invasive plants throughout Mammoth Cave National Park (B. Yahn, field notes, 2012-2014, 2016). In conclusion, two of Kentucky's worst weeds are two of the most dominant species in the vegetation plots sampled; this expresses the degree of disturbance (soil erosion, bank failure, canopy loss, etc.) currently affecting the stream banks along the Green and Nolin Rivers.

Table 8 represents the number of times a tree species was recorded (woody stem counts) across all plots. Due to small plot size, few mature trees were captured along with low counts for saplings and

small trees (for all plots). Although limited in stem counts and thus presence, the dominant trees seen along the corridor during transport to and from plots, were also evident in the data; common trees sampled were sycamore (*Platanus occidentalis*) and silver maple (*Acer saccharinum*).

Table 8. Trees recorded in plots (woody stem counts).

		Mature tree(s)	Saplings & small	% cover
		species found in 15	tree(s) of each	(shrub
		plots: count 1 per	species found in 15	zone):
		plot, presence	plots: count 1 /plot,	presence
Tree/Shrub/Vine	Species	(absence)	presence (absence)	(absence)
	Platanus			
Tree	occidentalis	4	1	0
Tree	Acer saccharinum	3	0	1
Tree	Ulmus rubra	1	1	1
Tree	Acer negundo	1	1	0
Tree	Diospyros virginiana	0	1	1

All species names according to ITIS.

Table 9 represents the number of times a woody species was recorded in the shrub zone across all plots (taken from percent cover shrub data). Spicebush (*Lindera benzoin*) was by far the most common woody species in the shrub zone, recorded in 40% of all plots; this indicates that this native shrub is a common component in the streambank community but also has been known to increase after forest disturbances (B.Yahn, field notes, 2005-2017). Woolly dutchman's-pipe (*Aristolochia tomentosa*) was the second most common woody plant (a native woody vine) in the shrub zone, recorded in three plots, thus present 20% of the time. It is not known to be overly aggressive and thicket-forming but future monitoring should capture this species growth habits and response. Although giant cane (*Arundinaria gigantea*) was seen in healthy patches throughout the stream corridors, it was only recorded in the shrub zone of one plot. With *Arundinaria gigantea's* ability to colonize through spreading rhizomes, such a riparian species may be better equipped to increase/spread under current post-dam conditions (future monitoring should document such increases).

Table 9. Trees, shrubs, and woody vines recorded in the shrub zone of all plots (presence).

		% cover (shrub zone):	%
Tree/Shrub/Vine	Species	presence (absence)	# present/ # plots *100
Shrub	Lindera benzoin	6	40
shrub/vine	Aristolochia tomentosa	3	20
Tree	Acer saccharinum	1	7
shrub/graminoid	Arundinaria gigantean	1	7
Tree	Catalpa speciose	1	7
Tree	Celtis laevigata	1	7
Tree	Diospyros virginiana	1	7
Shrub	Hydrangea arborescens	1	7
Shrub	Hypericum prolificum	1	7
Tree	Ostrya virginiana	1	7
Tree	Ulmus rubra	1	7
Tree	Acer negundo	0	0
Tree	Platanus occidentalis	0	0

All species names according to ITIS.

Table 10 represents the number of times a species was recorded in any subplot/quadrat. First, the four most dominant species (listed above) were also at or near the highest frequency encountered (*Microstegium vimineum, Persicaria longiseta, Chasmanthium latifolium, Polygonum hydropiperoides,* respectively); this was an expected result for the dominant species of the project. But further, other species might have been frequently encountered (times present) but not necessarily dominant. Those species not recorded as dominant in more than 60% of the plots, but still with a high subplot/quadrat frequency, include: Virginia cutgrass (*Leersia virginica*), Canada clearweed (*Pilea pumila*), and American hog-peanut (*Amphicarpaea bracteata*). These are native species commonly found in Kentucky, especially in riparian or lowland mesic habitats, like the project setting (B.Yahn, field notes, 2005-2017). Their high frequency likely indicates that they are important plants making up the composition in the streambank community. In fact, population fluctuations or even loss of such species overtime might be an indicator of negative or unhealthy trends in long-term monitoring.

Table 10. # of Times a Species was Recorded in any Subplot/Quadrat

Tree/Shrub/Herb	Species	Subplots/ Quadrats
Herb	Microstegium vimineum*	15
Herb	Persicaria longiseta*	13
Herb	Leersia virginica	12
Herb	Chasmanthium latifolium	10
Herb	Pilea pumila	9
Herb	Polygonum hydropiperoides	8
Herb	Amphicarpaea bracteate	7
Herb	Ageratina altissima	4
Herb	Boehmeria cylindrica	4
Herb	Symphyotrichum sp.	4
Herb	Polygonum punctatum	3
Herb	Verbesina alternifolia	3
Herb	Adiantum pedatum	2
Bryophyte	Conocephalum conicum	2
Herb	Glechoma hederacea*	2
Shrub	Hydrangea arborescens	2
Herb	Polygonum hydropiperoides / P. punctatum	2
Herb	Symphyotrichum pilosum	2

All species names according to ITIS.; \* Non-native Invasive Species

These four summary tables provide an overall picture and general description of the vegetation strata that represents the project area along the Green and lower Nolin River. The canopy is dominated by sycamore (*Platanus occidentalis*) and silver maple (*Acer saccharinum*) with box elder (*Acer negundo*) and slippery elm (*Ulmus rubra*) also present. Understory trees are infrequent with the shrub zone also of low density but often with spicebush (*Lindera benzoin*) and sometimes Woolly dutchman's-pipe (*Aristolochia tomentosa*). The herbaceous layer is dense beyond the exposed bank zone (noticeable "line from ponding"- the impact of old dam #6), often with a mix of invasive exotics and wetland-riparian natives. Oriental lady's thumb or bunchy knotweed (*Persicaria longiseta*), Indian woodoats (*Chasmanthium latifolium*), mild water-pepper (*Polygonum hydropiperoides*) and Japanese stiltgrass (*Microstegium vimineum*) are the most frequently recorded dominants; with Virginia cutgrass (*Leersia*)

virginica), Canada clearweed (*Pilea pumila*), and American hog-peanut (*Amphicarpaea bracteata*) important components of the herbaceous layer as well.

# Macroinvertebrates

Approximately 7,500 macroinvertebrate specimens were collected from five quantitative, two semi-quantitative, and five qualitative samples from three impounded and two free flowing sites. The organisms represented 8 classes, 22 orders, 50 families, and 58 taxa (Appendix C). The most abundant and most diverse taxa group was the class Insecta, representing 8 orders and 38 families. Specifically, the families Chironomidae, Hydropsychidae, and Heptageniidae were the most abundant taxa from the Hester Dendy samples, comprising 88.2% – 97.3% of the assemblage across all sites (Appendix D). A few taxa were restricted to specific hydrological sections. Five taxa (Haliplidae, Psephenidae, Caenidae, Isonychiidae, and Taeniopterygidae) were only encountered at the two free flowing sites (GR3 and GR4) and weren't encountered at any of the impounded sites. In comparison, only one taxa, Pontoporeiidae, was encountered at each of the impounded sites, but absent from the free flowing sites. Overall, the assemblages among the sites were relatively similar, except for the Nolin River site (NR1)

The overall richness among the sites was greater at the free flowing sites (Table 11). The Nolin River was the least diverse and least abundant among all of the sites, regardless of sampling technique. Omitting the Nolin River site and only comparing the two impounded Green River sites (GR1 and GR2) to the two free flowing sites (GR3 and GR4), indicated that the overall richness was relatively the same (Table 12). Richness was slightly higher among the qualitative samples at the impounded sites, but slightly less diverse among the Hester Dendy samples. Richness and abundance from the kick net samples were greater at site GR3 than site GR4 (Appendix E).

Table 11. Diversity and abundance of macroinvertebrate samples.

Qualitative				Quan	titative
	Overall	Qualitative	Wood	Hester Dendy richness	Kick net
Sites	Richness	richness	richness	(abundance)	richness (abundance)
GR1	32	29	19	14 (1103)	
GR2	37	31	19	15 (1766)	
GR3	42	24	14	24 (1786)	22 (570)
GR4	38	25	14	19 (1266)	17 (214)
NR1	20	16	12	11 (144)	

Table 12. Comparison of macroinvertebrate richness within two hydrological sections of the Green River.

	Hydrology				
Parameter	Impounded (2 sites)	Flowing (2)			
Mean Richness:	34.5	40.0			
Range:	32-37	38-42			
Standard Deviation:	3.5	2.0			

#### Freshwater Mussels

From 27 surveys, 482 live mussels representing 27 species were encountered (Appendix F.). Seventy-three percent of the individuals found were comprised of one of five species (Table 13). *Potamilus alatus, Quadrula quadrula, Cyclonaias pustulosa, Obliquaria reflexa,* and *Tritogonia verrucosa* were the five most common species (in order of abundance, respectively). Only two species (*Potamilus alatus* and *Megalonaias nervosa*) from four individuals were encountered within the three impounded sites surveyed. Flowing habitat had the greatest richness and abundance, as well as, the greatest mean richness per site and mean abundance per site. Seventeen species were encountered within the flowing habitat and were absent from all other types of habitat. Ten species were encountered within pool habitat, but three species (*Potamilus alatus, Obliquaria reflexa,* and *Quadrula quadrula*) comprised nearly 84% of the total abundance. The only federally endangered mussel species encountered during the surveys were one specimen each of *Cyprogenia stegaria* and *Plethobasus cyphyus*. However, the specimens of both imperiled species were estimated to be less than ten years old of age.

Table 13. Mussel diversity and abundance categorized by habitat type.

				Flowing	Pool	Impounded
Family	Tribe	Species	Common Name	(n=14)	(n=10)	(n=3)
Unionid	ae					
	Anodontini					
		Lasmigona complanate	White Heelsplitter	2	1	
		Lasmigona costata	Flutedshell	1		
		Strophitus undulates	Creeper	2		
	Amblemini					
		Amblema plicata	Threeridge	2		
	Lampsilini					
		Actinonaias ligamentina	Mucket	16		
		Cyprogenia stegaria	Fanshell	1		

Cont. Table 13. Mussel diversity and abundance categorized by habitat type.

Laurence III - 1					
Lampsilini	FILL COLUMN	D 11 - 10	-		
	Ellipsaria lineolate	Butterfly	7		
	Lampsilis cardium	Plain Pocketbook	12		
	Lampsilis ovata	Pocketbook	18	1	
	Lampsilis siliquoidea	Fatmucket	1		
	Leptodea fragilis	Fragile Papershell	7	1	
	Ligumia recta	Black Sandshell	3	1	
	Obliquaria reflexa	Threehorn Wartyback	45	13	
	Potamilus alatus	Pink Heelsplitter	78	23	1
	Ptychobranchus fasciolaris	Kidneyshell	3		
	Truncilla truncate	Deertoe	4		
Pleurobemi	ni				
	Elliptio crassidens	Elephantear	1		
	Eurynia dilatate	Spike	5		
	Fusconaia subrotunda	Longsolid	1		
	Plethobasus cyphyus	Sheepnose	1		
	Pleurobema sintoxia	Round Pigtoe	2		
Quadrulini					
	Cyclonaias pustulosa	Pimpleback	61	1	
	Cyclonaias tuberculate	Purple Wartyback	1		
	Megalonaias nervosa	Washboard	28	3	3
	Quadrula Quadrula	Mapleleaf	76	11	
	Theliderma metanevra	Monkeyface	2		
	Tritogonia verrucose	Pistolgrip	42	1	
		Total richness:	27	10	2
		Mean richness/site:	9.29	2.70	0.67
		Total abundance:	422	56	4
		Mean abundance/site:	30.14	5.60	1.33
		,			_

Fish

Over 1,500 individuals representing 58 native species of fish were collected from five sites (Appendix G). *Notropis micropteryx*, *N. volucellus*, *Moxostoma erythrurum*, *Percina evides*, and *Lepomis megalotis* were the five most abundant species, in respective order. *Dorosoma cepedianum*, *Cyprinella spiloptera*, *N. atherinoides*, *M. erythrurum*, and *L. macrochirus* were common and encountered at each site. Ten species were only encountered at sites within the free flowing section of the river, such as *Erimystax dissimilis*, *Hybopsis amblops*, *N. ariommus*, *Phenacobius uranops*, and *Hypentelium nigricans*. No species were encountered strictly at sites located within the impounded section of the study area. Richness at free flowing sites was over twice as great as the impounded sites (Table 14). Mean abundance was approximately four times greater at flowing sites than impounded sites. However, this is most likely a combination of better habitat and the capability to use of a seine and backpack electrofishing unit during the collection of fishes at the flowing sites. *Notropis micropteryx* and *N. volucellus* were two species that

were common and easily captured with a seine, together those species comprised approximately 47% and 42% of the collection at sites GR3 and GR4, respectively.

Table 14. Comparison of fish richness and abundance within two hydrological sections of the Green and Nolin rivers.

	Hydrolo	gy
Parameter	Impounded (3 sites)	Flowing (2)
Mean richness:	20.0	44.0
Range:	14-24	39-49
Standard Deviation:	5.3	7.1
Mean abundance:	135.3	559.5
Range:	47-252	513-606
Standard Deviation:	105.4	65.7

# In-stream habitat

Physical habitat measurements were taken from seven impounded sites and eleven free flowing sites, which was an approximate 5% and 11% random subsample of the available habitat, respectively. The mean wetted width was greater at the free flowing sites than at the impounded sites. This is mostly an artifact that the Nolin River site, which is smaller than the Green River, was included among the impounded sites (Table 15). However, the mean depth was greater at the impounded site than at the free flowing sites.

The composition of the in-stream substrates differed drastically because of the large relative abundance of mud substrate within the impounded section of the river. The relative abundance of mud at the impounded sites was 67% and the aggregation of mud, sand and gravel comprised 94% of the available substrate within the impounded section of the river. Only 71% of the free flowing sites was comprised of mud, sand and gravel. Pebble, cobble, and boulder comprised a substantial amount of the available habitat, with nearly 30% composition. Overall, the substrates in the free flowing section were more evenly distributed and larger in size than at sites within the impounded section of the river.

Table 15. Physical habitat measurements.

	Flowing	Pool
Parameter	(11)	(7)
Mean wetted width (m)	50.2	45.2
Mean depth (m)	1.8	2.7
Mud (%)	0.25	0.67
Sand (%)	0.22	0.17
Gravel (%)	0.24	0.10
Pebble (%)	0.15	0.02
Cobble (%)	0.09	0.01
Boulder (%)	0.05	0.02
Bedrock (%)	0.01	0.01
Mean bank failure (%)	14.5	55.7
Mean LWD Relative frequency	0.80	0.82

The banks along the study area exhibited frequent areas of excessive erosion and collapse. Measurements of the recently exposed banks indicated that over 50% of the banks within the impounded section of the river have experienced substantial and recent bank failure. Sites within the free flowing section have experienced bank failure, but only an approximate 15% bank failure was estimated.

Large woody debris (LWD) and snags are a common habitat feature within the river. Measurements of the relative frequency of LWD and snags were made to estimate the prevalence of the habitat. Both the impounded and the free flowing sections of river exhibited a large presence of LWD. Both sections of river had a relative frequency of LWD over 80%.

# Discussion

For a thorough assessment of the environmental changes associated with a dam removal, it is recommended pre- and post- monitoring of the ecosystem be conducted for five to ten years (Kondolf 1995). Unfortunately, data prior to the removal of L&D 6 are sparse and no prior monitoring directly associated with the recent dam removal was made. Macroinvertebrate studies by Pond (1996) and Grubbs and Taylor (2004) are the only studies available that looked at the conditions of the Green River in anticipation of the removal of L&D 6. The compilation of physical and biological data obtained during

summer 2017 established baseline data for monitoring and assessing the environmental conditions of the Green and Nolin rivers following the removal of L&D 6.

# Vegetation

There was no apparent trend or longitudinal shift in the vegetation along the Green River. However, the most conservative species recorded in the study, rock goldenrod (*Solidago rupestris*), was only found upstream of Crump Island (GR8 and GR12; possibly at NR2 as well). Rock goldenrod is considered "secure" = S4 in Kentucky, but "critically imperiled" = S1 in Virginia and Tennessee, and "possibly extirpated" = SH in Pennsylvania and Maryland (NatureServe 2017). Although conjecture, this finding may presume that a less impacted and less flooded condition is more suitable to species that are unable to colonize and/or compete in a short period of time after disturbance (i.e., those more conservative species that tend to decline under anthropogenic disturbance, like dam removal), would benefit more favorably in such a condition. Thus, overall conditions of little soil disturbance and greater stability, with minimal bank failure and low tree mortality will support more conservative plant species creating a higher quality stream-side forest. The sites above Crump Island (GR8 – G13) may prove more stable and more distinguishable from the downstream sites as more time passes.

Although only two sites were surveyed along the Nolin River, the overall appearance of the riparian zone was noticeably different than the appearance of the Green River. Tree mortality was much higher in the lower section of Nolin River, creating an environment where more light was available to lower strata, which caused an increase in herbaceous vegetation growth. Much of this growth was invasive species, such as *Persicaria longiseta* and *Microstegium vimineum*, with *Microstegium vimineum* being the most dominant species recorded at both Nolin River sites. The Nolin River was not only influenced by L&D 5 and L&D 6, but also (still) influenced by repeated cold-flooding and scouring events when water is released upstream from Nolin River Dam.

This monitoring project is at the initial stage with this first season completed, as it is important to discuss the vegetation sampling schedule for any multi-season study. It is recommended that continued monitoring occur within the immediate growing season or at least as soon as the 2<sup>nd</sup> growing season after the 2017 sampling. One reason for this is to capture any changes in community strata as it happens. It is critical to sample within a close time frame because elements that show the response and function of the community (e.g. woody stem counts) may not be captured if intervals between monitoring events are too

long. Resampling of the 2017 sites with the potential to add a few other sites to the schedule are decisions that also need to be made before the sampling occurs.

#### Macroinvertebrates

The studies by Pond (1996) and Grubbs and Taylor (2004) indicated that the macroinvertebrate fauna within the free flowing section was distinct from the transitional and impounded sections of the river. After the removal of the dam the transitional section shifted to a free flowing section within the Green River. The overall richness between the contemporary free flowing and the impounded section of the Green River were relatively similar and the fauna was comprised mostly of the same three to five taxa among all of the Green River sites. This suggests that the macroinvertebrate fauna was largely an artifact of the prior conditions and the fauna has not shifted to indicate new free flowing hydrological conditions. Within these particular sections of river, Grubbs and Taylor (2004) found the historical transitional and impounded sections were ecological similar. Indicating that even though hydrological conditions may reveal run and riffle habitat seasonal, the seasonal impoundment of those habitats had a greater influence on the fauna. Recovery of the fauna within these sections of river may take a few years so that scouring of habitat and the redistribution of substrates can occur and stabilize.

The most distinct site was within the Nolin River. The fauna had the least diversity and abundance among all of the sites. The lower reach of the Nolin River experiences extreme hydrological conditions, frequently, and often within short periods of time. The lower reach is still impounded from L&D 5 and it periodically receives large amounts of hypolimnetic water from the Nolin River dam. This creates an environment where the stagnant water is periodically flushed at high velocities with cold water, which scours the channel. The macroinvertebrate fauna, especially from the Hester Dendy samples was indicative of the scouring. A few plates of the HD units were relatively free of colonization. It is not anticipated that the fauna will recover or change until the influences from L&D 5 and Nolin River dam are addressed.

### Freshwater mussels

Prior mussel studies (Cicerello and Hannan 1990; Layzer 2002) within the Green River at MCNP indicated that the fauna was diverse and impacted from the presence of L&D 6. Our results indicated the diversity and abundance of mussels were highly associated with the hydrological conditions. The mussel fauna within the section of river that is still impounded from L&D 5 (below Crump Island) was depauperate, while the free flowing section was more abundant and diverse, with the flowing habitat

being more diverse and abundant than the pool habitat. However, the fauna within the contemporary free flowing section was indicative of impoundment, at least seasonally. The majority of individuals encountered were comprised of pool tolerant species (i.e., *Potamilus alatus* and *Quadrula quadrula*) and only a few individuals from species that have a strong association with lotic habitats (i.e., *Amblema plicata*, *Actinonaias ligamentina*, and *Ptychobranchus fasciolaris*) were present. The reaches of river furthest from the footprint of L&D 6 most likely will recover the quickest and represent a fauna more indicative of lotic habitat (Vaughn and Taylor 1999; Tiemann et al. 2016). Mussel are relatively longer lived and have a longer life history per individual compared to other aquatic invertebrates so the shift from a lentic dominant fauna to a lotic dominant fauna most likely will take a couple decades.

# Fish

The overall fish fauna indicated that a diverse assemblage occurs within the Green River. The Nolin River site was the least diverse and least abundant site. The presence of the Nolin River dam and the influence from L&D 5 limits the faunal substantially. The free flowing sites on the Green River were greater in diversity and abundance than the impounded sites. Also, several species occurred within the free flowing section that were not encountered at the impounded sites. The greater diversity and abundance were a result of a more complex flow regime and habitat diversity found at the free flowing sites. It is unclear if the fish used these habitats previously when the historical transitional section experienced low water levels or if the fish have colonized these habitats immediately following dam removal. The lows numbers of benthic species suggest that the fish might be transient individuals. However, the abundance of pelagic minnow species that often associate with swift, rocky habitat suggest that their presence might have persisted within the former transitional section, even during higher water levels. Over time benthic species and abundance should increase within both sections of the river, but primarily within the free flowing section.

# In-stream habitat

No strong patterns were observed with the data except that substrates and bank failure were different among the impounded and free flowing sections of the river. The data also indicated that the Nolin River is heavily impacted from the Nolin River dam and L&D 5. The impounded section of the Green and Nolin rivers exhibited tremendous amount of bank failure. This is most likely because those sections were more greatly impacted from the inundation of pool 6 and when the dam was removed the soils that were once saturated dried and no longer supported that weight of vegetation, rock, and other material.

The free flowing section experienced bank failure too, but not to the extent encountered within the impounded section. It is unclear if the large volume of soil that fell into the impounded section contributed substantially to the large amount of mud substrate within the impounded section, or if the smaller substrate was the result of the dam minimizing the flow which caused suspended particles to settle, or both.

# Management implications

The removal of L&D 6 is perceived to have ecological benefits to the ecosystem. Without any prior dam removal data, it is not possible to compare before and after dam removal changes, but with continued monitoring it will be possible to draw inference on the changes that will occur over time and determine any trends that may occur. The rate of recovery will vary with each faunal group and could vary among sites and hydrological regime (Pollard and Reed 2004), but substantial changes could occur within as little as a few years. Burroughs et al. (2010) documented the recolonization of fishes following a dam removal within four years and Kanehl et al. (1997) documented improvements to select fishes within five years of dam removal. It is recommended that monitoring of the biological and physical habitat continue within the Green and Nolin rivers. Specifically, monitoring of vegetation (riparian zone), macroinvertebrate, fish, and in-stream habitat should be conducted on an annual basis for the next five years. In conjunction, monitoring of freshwater mussels should continue too, but at an interval of every five years for the next twenty years. Currently, no physical enhancements to habitats or augmentation of fish or mussel populations is recommended. It recommended that the macroinvertebrate collections from 2017 and future collections be identified to the genus taxonomic level, or further, to provide the necessary resolution for function feeding guild analysis. Lastly, it is recommended that with further monitoring efforts and the accumulation of data a statistical analysis of the data be conducted to fully understand the recovery of the river and its biological and physical features.

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# References

- Bellmore, J.R., J.J. Duda, L.S. Craig, S.L. Green, C.E. Torgersen, M.J. Collins, and K. Vittum. 2017. Status and trends of dam removal in the United States. Wiley Interdisciplinary Reviews: Water 4:e1164. Doi: 10.1002/wat2.1164.
- Burroughs, B.A., D.B. Hayes, K.D. Klomp, J.F. Hansen, and J. Mistak. 2010. The effects of the Stronach Dam removal on fish in the Pine River, Manistee County, Michigan. Transactions of the American Fisheries Society 139(5): 1595-1613.
- Cicerello, R.R. and R.R. Hannan. 1990. Survey of the freshwater unionids (mussels) (Bivalvia:

  Margaritiferidae and Unionidae) in the Green River in Mammoth Cave National Park, Kentucky.

  Frankfort: Kentucky State Nature Preserves Commission.
- Cicerello, R.R. and R.R. Hannan. 1991. Survey and review of the fishes of Mammoth Cave National Park, Kentucky. Frankfort: Kentucky State Nature Preserves Commission.
- [CISEH] Center for Invasive Species and Ecosystem Health. Kentucky Invasive Plant Council: Exotic Invasive Plants of Kentucky (2013). Retrieved November, 2017, from <a href="https://www.se-eppc.org/ky/KYEPPC">https://www.se-eppc.org/ky/KYEPPC</a> 2013list.pdf
- Foley, M.M. and ten coauthors. 2017. Landscape context and the biophysical response of rivers to dam removal in the United States. PLOS One <a href="https://doi.org/10.1371/journal.pone.0180107">https://doi.org/10.1371/journal.pone.0180107</a>.

- Guenther, C.B. and A. Spacie. 2006. Changes in fish assemblages structure upstream of impoundments within the upper Wabash River basin, Indiana. Transactions of the American Fisheries Society 135(3): 570-583.
- Grubbs, S.A. and J.M. Taylor. 2004. The influence of flow impoundment and river regulation on the distribution of riverine macroinvertebrates at Mammoth Cave National Park, Kentucky, U.S.A. Hydrobologia 520: 18-28.
- Haag, W.R. 2012. North American Freshwater Mussels: Natural History, Ecology, and Conservation.

  Cambridge University Press, New York. 505 pp.
- Hayes, D.B., H. Dodd, and J. Lessard. 2006. Effects of small dams on cold water stream fish communities. American Fisheries Society Symposium: 587-602.
- [ITIS] Integrated Taxonomic Information System on-line database. Retrieved November, 2017, from <a href="http://www.itis.gov">http://www.itis.gov</a>.
- Layzer, J.B. 2002. Status of the freshwater mussel fauna in the Green River within Mammoth Cave

  National Park a preliminary assessment. In proceedings of Mammoth Cave National Park's ninth
  science conference: 51-53.
- Kanehl, P.D., J. Lyons, and J.E. Nelson. 1997. Changes in habitat and fish community of the Milwaukee River, Wisconsin, following removal of the Woolen Mills Dam. North American Journal of Fisheries Management 17(2): 387-400.
- Kondolf, G.M. 1995. Managing bedload sediments in regulated rivers: Examples from California, USA. Geophysical Monograph 89:165–176.
- Oliver, M. and G. Grant. 2017. Liberated rivers: lessons from 40 years of dam removal. Science Findings 193. Portland, Oregon: United States Department of Agriculture, Forest Science, Pacific Northwest Research station. 5 pp.
- Pollard, A.I. and T. Reed. 2004. Benthic invertebrate assemblage change following dam removal in a Wisconsin stream. Hydrobiologia 513: 51-58.
- Pond, G.J. 1996. Upstream effects of a dam on the longitudinal and seasonal distribution of macroinvertebrate taxonomic and functional feeding guilds in the Green River within Mammoth

- Cave National Park, Kentucky. Masters Thesis, Eastern Kentucky University, Richmond, Kentucky. 125pp.
- Winston, M.R., C.M. Taylor, and J. Pigg. 1991. Upstream extirpation of four minnow species due to damming of a prairie stream. Transactions of the American Fisheries Society 120(1): 98-105.
- National Park Service. 1983. Mammoth Cave National Park general management plan. National Park Service, Denver, Colorado, U.S.A.
- NatureServe. 2017. NatureServe Explorer: An online encyclopedia of life [web application]. Version 7.1. Arlington, VA. http://www.natureserve.org/explorer/. Accessed January 2017.
- Tiemann J.S., S.A. Douglas, A.P. Stodola, and K.S. Cummings. 2016. Effects of lowhead dams of freshwater mussels in the Vermillion River basin, Illinois, with comments on a natural dam removal.

  Transactions of the Illinois State Academy of Science 109: 1-7.
- [USACOE] United States Army Corps of Engineers. 1981. Water resources development in Kentucky, 1981. United States Army Corps of Engineers, Louisville District, Louisville, Kentucky, U.S.A.
- Vaughn, C.C. and C.M. Taylor. 1999. Impoundments and the decline of freshwater mussels: a case study of an extinction gradient. Conservation Biology 13(4): 912-920.

Photo and Plot Sampling: Green River	Dam Removal	(within Mammoth	Cave NP)	$\times$	Quarter meter square: plot a	L
Date: 91917				>	Species	% cover
Surveyor(s): B. Youkka, Kanaca Oona	dd			$\rightarrow$	TOXPAD	0-5
Plot/Photopoint Station #: GR12				$\rightarrow$	MAIDEN HATE FERN	5-10
Distance from Dam removal (every 1 mi):	11.5 mi			$\rightarrow$	ASTER SPA (COLLECTED)	0-5
CCURACY INFACT	Middle of Stream		Photopoint#	$\rightarrow$	BOLFLE/SPH? (OUELT	10-15
Lat (DD): 37, 16720833		North or East PP	104	$\rightarrow$	CAMPORA	0-5
Long (DD):-86.15819167		South or West PP	103	$\rightarrow$	LIZARD SKIN (ID KENDALL)	20-30
Wetted Width of Stream (m) 39-1	CHATEROF	STEAM		$\rightarrow$	LEEVIR	0-5
Bank-facing direction (w robel pole)	photo #/name(s):10	5,106 A	cultey: BAB	et 🖂	SHYDARD	5-10
Azimuth 166	Lat (DD):37. 163	\$13083		×		
GR12_P	Long (DD): -86	15208750		$\triangleright$	<b></b>	
Downstream-facing direction	photo #/name(s): 15		Azimuth 248	_ >	<b></b>	
Upstream-facing direction	photo #/name(s): 10		Azimuth 93	_ >	<u> </u>	
exposed bank substrate (circle one)	sand, mud, gravel, 60	bble, boulder loam soil,		>		
exposed bank to veg "line": distance (m)	3.3	4	Street Street Street	5		
distance to top of bank (m)	15+	(?)		5		
% slope (water line to top of bank)	75% ,34°			S		
Plot #	1010 301			$\overline{}$		
Dominant 5 species (2 m x 12 m)	% cover			5	<b></b>	3
HIDARB	5-10		-	5	<b>&gt;</b>	
LINBEN	1-5		-	<u> </u>	Notes:	
SOLGRA! (conscret)	20-30		•	5	Quarter meter square: plot b	R
ASTERSPA (TOLLEGED)	5-10		•	5	Species	% cover
OSTANIR	1-5		-	5	MAIDENHAIR FERN	5-10
GHALAT	1-5	7.5.	5.4	5	BOECYL ?	₩ 0-5
Trees and Shrubs	110	0.00		5	ASTER SPA	0-5
	5% closed. 50-75% c	losed, 50-75% open, >7	5% open	S	LIZARD SKIN (ID KENDAL)	0-5
Short and Tall Shrub Strata (0.5 - 5 m) (circle one):	0%, 0-25%, 25-5			S	OTHER MOSSES	0-5
		Stem Counts		<u> </u>	HYDRANGER APPOPERORIS	NINUTE
Woody spp. in plot (Seedlings (NA))	Sapling 1: <2 cm dbh	Sapling 2:(>2 cm <5 cm	Small Tree (>5 cm <15 cm	(dbh)	DRYMAR? OR ATHEL	0-5
All shrubs and trees		1		×	STATINGE OF ALTERED	
	Medium Tree Count	Large Tree Count (>35 cm	X-Large Tree Cnt (>75		<b>&gt;</b>	
	MICUICITI LIGO COUNT			X	VICE TO SERVICE STATE OF THE PARTY OF THE PA	
	(>15 cm < 35 cm dbh)	< 75 cm dbh)	cm+ dbh)	/		
	(>15 cm < 35 cm dbh)	<75 cm dbh)	cm+ dbh)	5		
Individual mature trees	(>15 cm < 35 cm dbh)	<75 cm dbh)	cm+ dbh)	>	>	
Individual mature trees	(>15 cm < 35 cm dbh)	<75 cm dbh)	cm+ dbh)	*	<b>&gt;</b>	
Individual mature trees	(>15 cm < 35 cm dbh)	<75 cm dbh)	am+ dbh)	XX	<b>&gt;</b>	
Individual mature trees	(>15 cm < 35 cm dbh)	<75 cm dbh)		XXXX		
Individual mature trees  RAOCC  shrub spp.: % cover (circle one)	(>15 cm < 35 cm dbh)		5-7 m)	75%		
Individual mature trees  RACCC, shrub spp.: % cover (circle one)	(>15 cm < 35 cm dbh)  DERD SNANG  Short	and tall shrub strata (0.9	5-7 m). 50-75%	75%		
shrub spp.: % cover (circle one)  WINDEN 1-56	(>15 cm < 35 cm dbh)  DERD SNANG  Short  1-25%	and tall shrub strata (0.9	5-7 m) 50-75% > 50-75% >	-		

Appendix B. Riparian vegetation species presence by site.

Family	Species	Common Name	GR1	GR2	GR3	GR4	GR5	GR6	GR7	GR8	GR9	GR10	GR11	GR12	GR13	NR1	NR2
Anacaro	diaceae																
	Toxicodendron radicans	Poison Ivy												Х			
Apiacea	e																
	Cryptotaenia canadensis	Canada Honewort	Х														
Aristolo	chiaceae																
	Aristolochia tomentosa	Woolly Dutchman's-Pipe	Х				Χ	Х							Х		
Asterac	eae																
	Verbesina alternifolia	Wingstem		Χ					Х		Χ		Х		Х	Χ	Х
	Solidago rupestris	Rock Goldenrod								Χ				Х			
	Symphyotrichum dumosum	Rice Button Aster						Χ									
	Symphyotrichum ontarionis	Bottomland Aster						Χ									
	Symphyotrichum pilosum	Hairy White Oldfield Aster												Х			
	Symphyotrichum sp.	An Aster				Χ							Χ		Х		
	Ageratina altissima	White Snakeroot		Х												Х	Χ
	Bidens comosa	Three-Lobe Beggartick						Χ									
	Bidens sp.	A Beggartick								Χ							
Betulac	eae																
	Ostrya virginiana	Eastern Hop-Hornbeam												Х			
Bignoni	aceae																
	Campsis radicans	Trumpet-Creeper				Χ											
	Catalpa speciose	Northern Catalpa					Χ										
Brassica	aceae																
	Unknown Bassicaceae	A Mustard					Х										
Cannab	aceae																
	Celtis laevigata	Sugarberry							Χ								

Cont. A	ppendix B. Riparian vegetation	species presence by site.															
Family	Species	Common Name	GR1	GR2	GR3	GR4	GR5	GR6	GR7	GR8	GR9	GR10	GR11	GR12	GR13	NR1	NR2
Caprifol	iaceae																
	Triosteum aurantiacum	Coffer Tinker's-Weed													Χ		
Conoce	phalaceae																
	Conocephalum conicum	Conocephalum												Х			
Cyperac	ceae																
	Carex sp.	A Sedge	Х														
Dryopte	eridaceae																
	Dryopteris marginalis	Marginal Wood-Fern												Χ			
Ebenace	eae																
	Diospyros virginiana	Persimmon	Х														
Fabacea	ae																
	Amphicarpaea bracteate	American Hog-Peanut		Χ						Χ			Χ	Х		Χ	Χ
Hydrang	geaceae																
	Hydrangea arborescens	Wild Hydrangea												Х			
Hyperic	aceae																
	Hypericum mutilum	Slender St. John's-Wort	Х														
	Hypericum prolificum	Shrubby St. John's-Wort												Х			
	Hypericum sp.	A St. John's-Wort						Χ									
Lamiace	eae																
	Glechoma hederacea	Ground Ivy		Χ	Х												
	Lamium purpureum	Purple Deadnettle						Χ			Χ						
	Stachys sp.	A Hedge Nettle										Х					
Laurace	ae																
	Lindera benzoin	Spicebush	Х					Χ						Χ	Х	Χ	Χ

Cont. Ap	ppendix B. Riparian vegetation sp	ecies presence by site.															
Family	Species	Common Name	GR1	GR2	GR3	GR4	GR5	GR6	GR7	GR8	GR9	GR10	GR11	GR12	GR13	NR1	NR2
0 1:1																	
Oxalidad		Hardaha Vallani Wasad Cannal													.,		
DI .	Oxalis stricta	Upright Yellow Wood-Sorrel													Х		
Platanao																	
_	Platanus occidentalis	Sycamore					Х		Х		Χ			Х		Х	
Poaceae																	
	Leersia virginica	Virginia Cutgrass	Х	Х	Χ	Х	Х				Х	Х	Х	Х	Х		
Poaceae		. Cuit	v		.,				.,	.,	.,	.,	.,			.,	
	Microstegium vimineum	Japanese Stiltgrass	Х		Х		Х	Х	Х	Х	Х	Х	Х			Х	Χ
	Arundinaria gigantean	Giant Cane					Х										
	Chasmanthium latifolium	Indian Woodoats	Х	Х	Χ		Х	Х	Χ	Χ	Х		Χ	Х	Х	Χ	
	Cinna arundinacea	Sweet Woodreed															Χ
	unknown Poaceae	A Grass															Χ
Polygon	aceae																
	Polygonum cespitosum	Oriental Lady's Thumb	Χ		Χ	Χ		Χ	Χ	Χ	Χ	Χ	Χ		Χ	Χ	Χ
	Polygonum hydropiperoides	Mild Water Pepper		Χ			Χ	Χ	Χ	Χ	Χ	Χ					
Polygon	aceae																
	Polygonum hydropiperoides +																
	P. punctatum	n/a			Χ	Χ											
	Polygonum punctatum	Dotted Smartweed	Χ				Х						Χ				
	Polygonum virginianum	Jumpseed				Χ											
Pteridad	reae																
	Adiantum pedatum	Northern Maidenhair-Fern												Х			
Ranuncı	ulaceae																
	Clematis sp.	A Clematis														Х	

Cont. A	opendix B. Riparian vegetation spe																
Family	Species	Common Name	GR1	GR2	GR3	GR4	GR5	GR6	GR7	GR8	GR9	GR10	GR11	GR12	GR13	NR1	NR2
Sapinda	ceae																
	Acer negundo	Box Elder				Χ									Χ		
	Acer saccharinum	Silver Maple		Χ	Χ								Х				Χ
Smilaca	ceae																
	Smilax tamnoides	Bristly Greenbrier													Χ		
Solanac	eae																
	Physalis virginiana	Virginia Ground-Cherry								Χ							
Ulmace	ae																
	Ulmus rubra	Slippery Elm			Х		Χ										
Urticace	eae																
	Pilea pumila	Canada Clearweed	Χ	Χ	Х	Χ	Χ	Х				Х	Χ			Χ	Χ
	Boehmeria cylindrica	Smallspike False Nettle			Х					Χ		Х		Х			
Verbena	aceae																
	Verbena urticifolia	White Vervain						Χ									
Violacea	ae																
	Viola sororia	Woolly Blue Biolet				Χ											
Vitacea	2																
	Parthenocissus quinquefolia	Virginia Creeper					Χ										
Other																	
	Unknown Snag/Recently Dead	n/a													Х		
	Unknown Mosses	n/a												Х			
	Unknown Spp.	n/a			Х												Χ
	Unknown Forb	n/a													Х		

Appendix C. Macroinvertebrate taxa presence by site.

Class Order	Family	GR1	GR2	GR3	GR4	NR1
Turbellaria						
	Unknown Turbellarian		Χ	Χ	Χ	Χ
(Phylum) Nemate	oda					
	Unknown Nematode			Χ		
Clitellata						
Haplotax	ida					
	Tubificidae	Χ	Χ		Χ	Χ
Lumbricu	lida					
	Lumbriculidae	Χ		Χ	Χ	Χ
Bivalvia						
	Unknown Bivalve		Χ			
Veneroid	ea					
	Corbiculidae	Χ		Χ	Χ	
	Sphaeriidae	Χ		Χ		
Gastropoda						
Basomma	atomorpha					
	Ancylidae (Planorbidae)	Χ	Χ	Χ	Χ	Χ
	Physidae		Χ	Χ		
	Planorbidae	Χ	Χ			
Neotaeni	oglossa					
	Hydrobiidae	Χ				
	Pleuroceridae	Χ	Χ	Χ	Χ	Χ
Arachnida						
Trombidi	formes					
	Hydracarina	Χ	Χ	Χ	Χ	
Insecta						
Coleopte	ra					
	Dryopidae		Χ	X	Χ	
	Elmidae	Χ	X	Χ	Χ	Х

Cont. Appendix C. Macroinvertebrate taxa presence by site.

Class	Order	Family	GR1	GR2	GR3	GR4	NR1
Insect	a						
	Coleoptera	a de la companya de					
		Gyrinidae			Χ		
		Haliplidae			Χ	Χ	
		Hydrophilidae	Χ	Χ	Χ	Χ	
		Psephenidae			Χ	Χ	
		Scirtidae	Χ				
	Diptera						
		Ceratopogonidae	Χ	Χ	Χ	Χ	
		Chironomidae	Χ	Χ	Χ	Χ	Χ
		Empididae	Χ	Χ	Χ	Χ	
		Simuliidae			Χ		Χ
		Tipulidae	Χ				
	Ephemero	ptera					
		Baetidae	Χ	Χ	Χ	Χ	Χ
		Caenidae			Χ	Χ	
		Ephemerellidae			Χ		
		Ephemeridae	Χ	Χ	Χ		
		Heptageniidae	Χ	Χ	Χ	Χ	Χ
		Isonychiidae			Χ	Χ	
		Leptohyphidae	Χ	Χ	Χ	Χ	Χ
	Hemiptera						
		Corixidae		Χ			
		Gerridae			Χ	Χ	Χ
	Megalopte	era					
		Corydalidae	Χ		Χ	Χ	
	Odonata						
		Aeshnidae		Χ	Χ		
		Coenagrionidae	Χ	Χ	Χ	Χ	Χ

Cont. Appendix C. Macroinvertebrate taxa presence by site.

Class	Order	Family	GR1	GR2	GR3	GR4	NR1
		Corduliidae	Х	Х	Х	Х	Х
		Gomphidae	Χ	Χ	Χ	Χ	
		Macromiidae			Χ	Χ	Χ
	Plecoptera	r					
		Perlidae	Х	Χ	Χ	X	
		Pteronarcyidae	Х	Χ	Χ	X	
Insect	a						
	Plectopter	a					
		Taeniopterygidae			Χ	Χ	
		Unknown Plecopteran A (Pteronarcyidae?)		Χ			
		Unknown Plecopteran B (Taeniopterygidae?)		Χ			
		Unknown Plecopteran C (Capniidae or Taeniopterygidae?)			Χ		
		Unknown Plecopteran D (Perlidae or Perlodidae?)				Χ	
	Trichopter	a					
		Brachycentridae		Χ		Χ	
		Hydropsychidae	Χ	Χ	Χ	Χ	Χ
		Hydroptilidae	Χ	Χ	Χ	Χ	
		Leptoceridae	Χ	Χ	Χ	Χ	
		Polycentropodidae	Χ	Χ	Χ	Χ	Χ
		Unknown Trichopotera A (Lepidostomatidae?)				Χ	
		Unknown Trichopteran B (Hydropsychidae?)		Χ			
Malac	ostraca						
	Amphipod	a					
		Gammaridae		Χ			
		Pontoporeiidae	Χ	Χ			Χ
	Decapoda						
		Cambaridae			Χ	X	Χ
		Palaemonidae - Palaemonetes kadiakensis		X			

Cont. Appendix C. Macroinvertebrate taxa presence by site.

Class Order	Family	GR1	GR2	GR3	GR4	NR1
Malacostraca						
Isopoda						
	Asellidae	Х	Х		Χ	Х

Appendix D. Macroinvertebrate taxa Hester-Dendy abundance by site.

Class	Order	Family	GR1	GR2	GR3	GR4	NR1
Turbellaria	l						
		Unknown Turbellarian					2
(Phylum) N	Nematoda						
		Unknown Nematode			2		
Clitellata							
	Haplotaxid	a					
		Tubificidae	1				3
	Lumbriculi	da					
		Lumbriculidae			1		1
Gastropod	a						
	Basommat	omorpha					
		Ancylidae (Planorbidae)	2	2	1		
	Neotaenio	glossa					
		Pleuroceridae				1	3
Arachnida							
	Trombidifo	rmes					
		Hydracarina			2	7	
Insecta							
	Coleoptera						
		Elmidae		2	10	3	
		Hydrophilidae				1	
	Diptera						
		Ceratopogonidae	1		5		
		Chironomidae	1003	961	735	931	106
		Empididae	4	2	20	5	
		Simulidae					2
	Ephemero	otera					
		Baetidae		12	14	10	
		Caenidae			3		

Cont. Appendix D. Macroinvertebrate taxa Hester-Dendy abundance by site.								
Class	Order	Family	GR1	GR2	GR3	GR4	NR1	
Insecta								
	Ephemerop	otera						
		Ephemerellidae			2			
		Heptageniidae	58	140	316		5	
		Isonychiidae			16			
		Leptohyphidae		29	27	29	1	
	Megalopte	ra						
		Corydalidae			1	1		
	Odonata							
		Coenagrionidae	2		1			
		Corduliidae	3					
Insecta								
	Plecoptera							
		Perlidae	2		3	3		
		Pteronarcyidae	1	1	1	4		
		Taeniopterygidae			13	12		
		Unknown Plecopteran A (Pteronarcyidae?)		2				
		Unknown Plecopteran B (Taeniopterygidae?)		41				
		Unknown Plecopteran C (Capniidae or						
		Taeniopterygidae?)			2			
		Unknown Plecopteran D (Perlidae or Perlodidae?)				1		
	Trichoptera	1						
		Brachycentridae				3		
		Hydropsychidae	17	516	564	178	16	
		Hydroptilidae		24	29	64		
		Leptoceridae	1	1	8	4		
		Polycentropodidae	7	23	10	8		
		. Unknown Trichopoteran A (Lepidostomatidae?)				1		
		Unknown Trichopteran B (Hydropsychidae?)		10				

Cont. Appendix D. Macroinvertebrate taxa Hester-Dendy abundance by site.

Class	Order	Family	GR1	GR2	GR3	GR4	NR1		
Malacostraca									
	Amphipoda								
		Pontoporeiidae					1		
	Isopoda								
		Asellidae	1				4		

Appendix E. Macroinvertebrate taxa kick net abundance by site.

Class	Order	Family	GR3	GR4
Turbel	laria			
		Unknown Turbellarian		1
Clitella	ta			
	Haplota	axida		
		Tubificidae		5
	Lumbri	culida		
		Lumbriculidae		1
Bivalvi	a			
	Venero	idea		
		Corbiculidae	60	3
Gastro	poda			
	Basomr	matomorpha		
		Ancylidae (Planorbidae)	3	2
	Neotae	nioglossa		
		Pleuroceridae		7
Arachr	nida			
	Trombi	diformes		
		Hydracarina	1	
Insecta	Э			
	Coleop	tera		
		Elmidae	66	49
		Hydrophilidae	1	
		Psephenidae	10	1
	Diptera			
		Ceratopogonidae	2	1
		Chironmidae	38	
		Simuliidae	1	
	Ephem	eroptera		
		Baetidae	68	47

Cont. Appendix E. Macroinvertebrate taxa kick net abundance by site.

Class	Order	Family	GR3	GR4			
Insecta	1						
	Ephem	Ephemeroptera					
		Caenidae	6	1			
		Heptageniidae	127	59			
		Isonychiidae	4	1			
		Leptohyphidae	56	9			
	Megalo	ptera					
		Corydalidae	1				
	Odonat	ra e					
		Coenagrionidae	1				
		Gomphidae	6				
Insecta	1						
	Plecopt	rera					
		Perlidae	2	8			
		Pteronarcyidae	2				
	Trichop	tera					
		Hydropsychidae	98	10			
		Hydroptilidae	16	9			
Malaco	ostraca						
	Decapo	da					
		Cambaridae	1				

Appendix F. Mussel species abundance for each site surveyed.

	Site Number and Habitat Type							
-	GR1	GR2	GR3	GR4	GR5	GR6	GR7	GR8
Species	IMP	IMP	IMP	Flow	Flow	Flow	Pool	Pool
Actinonaias ligamentina				1		1		
Amblema plicata								
Cyclonaias tuberculata								
Cyprogenia stegaria								
Ellipsaria lineolate				3				
Elliptio crassidens								
Elliptio dilatate								
Fusconaia subrotunda								
Lampsilis cardium				1	1	2		
Lampsilis ovata				2		2		
Lampsilis siliquoidea								
Lasmigona complanata					1	1	1	
Lasmigona costata								
Leptodea fragilis								
Ligumia recta								
Megalonaias nervosa		3		3		1		
Obliquaria reflexa				9		3	4	1
Plethobasus cyphyus								
Pleurobema sintoxia								
Potamilus alatus			1	7	8	3	15	2
Ptychobranchus fasciolaris								
Quadrula metanevra								
Quadrula pustulosa				7		1	1	
Quadrula quadrula				8	6	12	2	
Strophitus undulates				1		1		
Tritogonia verrucose				3	1	1		
Truncilla truncate				1				
Number of mussels collected:	0	3	1	46	17	28	23	3
Number of species collected:	0	1	1	12	5	11	5	2
Sample Time (minutes):	13	15	14	46	28	33	38	30
CPUE (mussels per minute):	0.00	0.20	0.07	1.00	0.61	0.85	0.61	0.10

Cont. Appendix F. Mussel species abundance for each site surveyed.

	Site number and habitat type							
•	GR9	GR10	GR11	GR12	GR13	GR14	GR15	GR16
Species	Pool	Pool	Flow	Flow	Pool	Flow	Pool	Flow
Actinonaias ligamentina			2			1		
Amblema plicata						1		
Cyclonaias tuberculate								
Cyprogenia stegaria								
Ellipsaria lineolate			1					
Elliptio crassidens								
Elliptio dilatate								
Fusconaia subrotunda								
Lampsilis cardium			4	1		2		
Lampsilis ovata		1	1	2		3		
Lampsilis siliquoidea								
Lasmigona complanate								
Lasmigona costata								
Leptodea fragilis				1	1			
Ligumia recta								
Megalonaias nervosa			7	2	1	4		1
Obliquaria reflexa		1	10	2	6	3		2
Plethobasus cyphyus								
Pleurobema sintoxia								
Potamilus alatus	1	1	14	7	1	4	1	1
Ptychobranchus fasciolaris			2					
Quadrula metanevra						1		
Quadrula pustulosa			11	2		2		1
Quadrula quadrula		2	19	2	5	4	1	2
Strophitus undulates								
Tritogonia verrucose			11	1	1			2
Truncilla truncate								
Number of mussels collected:	1	5	82	20	15	25	2	9
Number of species collected:	1	4	11	9	6	10	2	6
Sample Time (minutes):	28	11	41	32	17	26	17	24
CPUE (mussels per minute):	0.04	0.45	2.00	0.63	0.88	0.96	0.12	0.38

Cont. Appendix F. Mussel species richness and abundance for each site surveyed.

	Site Number and Habitat Type							
•	GR17	GR18	GR19	GR20	GR21	GR22	GR23	GR24
Species	Flow	Pool	Flow	Flow	Flow	Flow	Pool	Pool
Actinonaias ligamentina	3			1	6	1		
Amblema plicata					1			
Cyclonaias tuberculate					1			
Cyprogenia stegaria					1			
Ellipsaria lineolate	1			1	1			
Elliptio crassidens				1				
Elliptio dilatate	2			1	1			
Fusconaia subrotunda				1				
Lampsilis cardium	1							
Lampsilis ovata	1		1	2	3	1		
Lampsilis siliquoidea	1							
Lasmigona complanate								
Lasmigona costata						1		
Leptodea fragilis	3				1	1		
Ligumia recta				1	1	1		1
Megalonaias nervosa	5				4	1		1
Obliquaria reflexa	5	1		1	8			
Plethobasus cyphyus						1		
Pleurobema sintoxia	1				1			
Potamilus alatus	6			10	14	3	1	1
Ptychobranchus fasciolaris	1							
Quadrula metanevra					1			
Quadrula pustulosa	11		1	7	11	4		
Quadrula quadrula	3			4	11	4		1
Strophitus undulates								
Tritogonia verrucose	11			4	4	1		
Truncilla truncate					2			
Number of mussels collected:	55	1	2	34	72	19	1	4
Number of species collected:	15	1	2	12	18	11	1	4
Sample Time (minutes):	54	13	106	40	56	25	28	23
CPUE (mussels per minute):	1.02	0.08	0.02	0.85	1.29	0.76	0.04	0.17

Cont. Appendix F. Mussel species richness and abundance for each site surveyed.

	Site Num	ber and Hal	oitat Type
•	GR25	GR26	GR27
Species	Pool	Flow	Flow
Actinonaias ligamentina			
Amblema plicata			
Cyclonaias tuberculate			
Cyprogenia stegaria			
Ellipsaria lineolate			
Elliptio crassidens			
Elliptio dilatate		1	
Fusconaia subrotunda			
Lampsilis cardium			
Lampsilis ovata			
Lampsilis siliquoidea			
Lasmigona complanate			
Lasmigona costata			
Leptodea fragilis		1	
Ligumia recta			
Megalonaias nervosa	1		
Obliquaria reflexa		2	
Plethobasus cyphyus			
Pleurobema sintoxia			
Potamilus alatus		1	
Ptychobranchus fasciolaris			
Quadrula metanevra			
Quadrula pustulosa		3	
Quadrula quadrula			1
Strophitus undulates			
Tritogonia verrucose		3	
Truncilla truncate		1	
Number of mussels collected:	1	12	1
Number of species collected:	1	7	1
Sample Time (minutes):	20	27	17
CPUE (mussels per minute):	0.05	0.44	0.06

Appendix G. Fish taxa and abundance by site.

Order	Family	Species	Common Name	GR1	GR2	GR3	GR4	NR1	Total
Lepisosteif	ormes								
	Lepisostei	dae							
		Lepisosteus osseus	Longnose Gar	5	5	4	4		18
Osteogloss	sifomores								
	Hiodontid	ae							
		Hiodon tergisus	Mooneye			3	2	1	6
Clupeiform	nes								
	Clupeidae								
		Dorosoma cepedianum	Gizzard Shad	21	44	5	2	6	78
Cypriniforn	nes								
	Cyprinidae	e							
		Campostoma oligolepis	Largescale Stoneroller			7			7
		Cyprinella spiloptera	Spotfin Shiner	3	2	9	56	2	72
		Erimystax dissimilis	Streamline Chub			5	12		17
		Hybopsis amblops	Bigeye Chub			31	9		40
		Luxilus chrysocephalus	Striped Shiner			4	2		6
		Notropis ariommus	Popeye Shiner			20	3		23
		Notropis atherinoides	Emerald Shiner	1	1	2	6	15	25
		Notropis micropteryx	Highland Shiner		6	141	209		356
		Notropis photogenis	Silver Shiner			6	2	1	9

Cont. Appendix G. Fish taxa abundance by site.

Order	Family	Species	Common Name	GR1	GR2	GR3	GR4	NR1	Total
Cypriniforme	es								
	Cyprinidae	9							
		Notropis volucellus	Mimic Shiner		3	100	45		148
		Phenacobius uranops	Stargazing Minnow			2	4		6
		Pimephales notatus	Bluntnose Minnow			20	11		31
		Pimephales vigilax	Bullhead Minnow		37	7	10	1	55
	Catostom	idae							
		Carpiodes carpio	River Carpsucker		6		2	1	9
		Carpiodes cyprinus	Quillback			2		2	4
		Hypentelium nigricans	Northern Hog Sucker			3	22		25
		Ictiobus bubalus	Smallmouth Buffalo	4	4	6	3		17
		Minytrema melanops	Spotted Sucker	11	5	1		2	19
		Moxostoma anisurum	Silver Redhorse	4	10	1	1		16
		Moxostoma breviceps	Smallmouth Redhorse			7	5		12
Cypriniforme	es								
	Catostom	idae							
		Moxostoma carinatum	River Redhorse			3	5		8
		Moxostoma duquesnei	Black Redhorse				1		1
		Moxostoma erythrurum	Golden Redhorse	7	47	25	39	6	124

Cont. Appendix G. Fish taxa abundance by site.

Order	Family	Species	Common Name	GR1	GR2	GR3	GR4	NR1	Total
Siluriformes									
	Ictaluridae								
		Ictalurus punctatus	Channel Catfish		2	3	5		10
		Noturus eleutherus	Mountain Madtom				3		3
		Noturus miurus	Brindled Madtom	1			1		2
		Noturus nocturnus	Freckled Madtom				1		1
		Pylodictis olivaris	Flathead Catfish		1	1	3		5
Salmoniforn	nes								
	Esocidae								
		Esox masquinongy	Muskellunge		1				1
Atheriniforn	nes								
	Atherinidae	2							
		Labidesthes sicculus	Brook Silverside			2			2
Cyprinodont	iformes								
	Fundulidae								
		Fundulus catenatus	Northern Studfish			1			1
		Fundulus notatus	Blackstrip Topminnow			1			1
Scorpaenifo	rmes								
	Cottidae								
		Cottus carolinae	Banded Sculpin	1		19	17		37

Cont. Appendix G. Fish taxa abundance by site.

Order	Family	Species	Common Name	GR1	GR2	GR3	GR4	NR1	Total
Perciformes									
	Moronidae								
		Morone chrysops	White Bass			1			1
		Morone chrysops x saxatilis	Hybrid			1			1
	Centrachida	ae							
		Ambloplites rupestris	Rock Bass			1	6		7
		Lepomis macrochirus	Bluegill	7	1	6	3	1	18
Perciformes									
	Centrarchic	dae							
		Lepomis megalotis	Longear Sunfish	22	19	16	23	2	82
		Lepomis microlophus	Redear Sunfish			1			1
		Micropterus dolomieu	Smallmouth Bass	1		3			4
		Micropterus punctulatus	Spotted Bass	11	5	7	9	5	37
		Micropterus salmoides	Largemouth Bass	1	3	3	2		9
		Pomoxis nigromaculatus	Black Crappie	1					1
Perciformes									
	Percidae								
		Ammocrypta clara	Western Sand Darter		1	2			3
		Etheostoma bellum	Orangefin Darter			1			1

Cont. Appendix G. Fish taxa abundance by site.

Order	Family	Species	Common Name	GR1	GR2	GR3	GR4	NR1	Total
Perciformes									
	Percidae								
		Etheostoma blennioides	Greenside Darter			1			1
		Etheostoma caeruleum	Rainbow Darter	1					1
		Etheostoma nigrum	Johnny Darter			5			5
		Etheostoma zonale	Banded Darter				1		1
		Percina caprodes	Logperch	1		2	3	2	8
		Percina copelandi	Channel Darter			1			1
		Percina evides	Gilt Darter		33	10	66		109
		Percina phoxocephala	Slenderhead Darter	1	2	2	5		10
		Percina sciera	Dusky Darter	1	2	1	3		7
		Sander vitreus	Walleye	1		1			2
	Sciaenidae								
		Aplodinotus grunniens	Freshwater Drum	1	12	7			20
			Native Richness:	22	24	49	39	14	58
			Abundance:	107	252	513	606	47	1525

Appendix H. Stream wetted width, depth, and substrate type.

GR1	Upsti	ream	Mic	ldle	Downstream		
Wetted Width (m)	53	.1	5	1	5	6	
	Depth (m)	Substrate	Depth (m)	Substrate	Depth (m)	Substrate	
LB 1	0.6	Mud	0.5	Mud	0.25	Mud	
LB 2	3	Mud	4.4	Mud	4.5	Mud	
LB 3	4.75	Sand	6.4	Mud	5.7	Mud	
RB 3	6.4	Gravel	6.75	Mud	6.5	Boulder	
RB 2	5	Pebble	3.75	Bedrock	6.15	Mud	
RB 1	1	Mud	0.5	Mud	0.25	Mud	
			! !		! I _		
GR2	Upsti			ldle	Downs		
Wetted Width (m)	5	4	5	5		5	
	Depth (m)	Substrate	Depth (m)	Substrate	Depth (m)	Substrate	
LB 1	0.5	Mud	0.5	Mud	0.15	Mud	
LB 2	1.8	Mud	1.5	Mud	2.4	Mud	
LB 3	5	Mud	4.35	Sand	5	Sand	
RB 3	5.75	Boulder	4.35	Mud	5.5	Mud	
RB 2	5.25	Mud	3.5	Mud	5	Cobble	
RB 1	0.4	Mud	0.25	Mud	0.3	Mud	
			! !		! !		
GR3	Upsti	ream	Mic	ldle	Downs	stream	
Wetted Width (m)	5	7	5	4	6	0	
	Depth (m)	Substrate	Depth (m)	Substrate	Depth (m)	Substrate	
LB 1	0.1	Mud	0.5	Mud	0.25	Mud	
LB 2	3.25	Mud	3.25	Mud	3.25	Mud	
LB 3	3.4	Sand	3.35	Sand	3.25	Gravel	
RB 3	3.15	Sand	3.35	Sand	3.15	Sand	
RB 2	3.25	Mud	3.5	Mud	2.75	Sand	
RB 1	0.5	Mud	0.5	Mud	0.5	Mud	

Cont. Appendix H. Stream wetted width, depth, and substrate type.

GR4	Upstream		Middle		Downstream	
Wetted Width (m)	5	6	5	8	5	2
	Depth (m)	Substrate	Depth (m)	Substrate	Depth (m)	Substrate
LB 1	0.8	Mud	0.75	Mud	0.8	Mud
LB 2	3.4	Mud	3.9	Mud	3.1	Mud
LB 3	4.75	Mud	4.75	Sand	5.15	Sand
RB 3	5.3	Gravel	5.5	Gravel	3.5	Pebble
RB 2	3.5	Sand	3.7	Mud	1.75	Gravel
RB 1	0.9	Mud	0.9	Mud		Mud
005	Heat		' 	L.II.	' !	
GR5	Upstream			ddle	Downstream	
Wetted Width (m)		50 53				9
	Depth (m)	Substrate	Depth (m)	Substrate	Depth (m)	Substrate
LB 1	1	Mud	0.8	Mud	0.8	Mud
LB 2	4.25	Gravel	3.8	Pebble	4.4	Sand
LB 3	4	Sand	4.1	Sand	4	Sand
RB 3	4	Sand	4.3	Sand	4.1	Sand
RB 2	4.25	Sand	2.6	Mud	4.35	Mud
RB 1	0.7	Mud	1	Mud	0.75	Mud
CDC	Llock		' 	المالم	Dawe	
GR6	Upstream		Middle		Downstream	
Wetted Width (m)		3	65		53	
		Substrate	Depth (m)	Substrate	Depth (m)	
LB 1	0.5	Mud	0.4	Mud	0.1	Pebble
LB 2	1.4	Gravel	1.4	Gravel	0.35	Pebble
LB 3	2.1	Gravel	1.3	Cobble	1.15	Pebble
RB 3	2.4	Gravel	1.75	Pebble	2.25	Pebble
RB 2	2.8	Mud	3.5	Mud	2.5	Pebble
RB 1	0.5	Mud	0.5	Mud	1.75	Mud

Cont. Appendix H. Stream wetted width, depth, and substrate type.

GR7	Upst	ream	Middle		Downstream	
Wetted Width (m)	5	2	57	<b>7</b> .5	54	1.5
	Depth (m)	Substrate	Depth (m)	Substrate	Depth (m)	Substrate
LB 1	0.75	Mud	0.8	Mud	0.7	Mud
LB 2	2.25	Gravel	2.25	Gravel	1.9	Gravel
LB 3	2.8	Sand	2.8	Sand	2.6	Gravel
RB 3	2.7	Gravel	2.8	Sand	2.8	Gravel
RB 2	2.4	Mud	2.7	Mud	3.3	Gravel
RB 1	0.7	Mud	1	Mud	0.7	Mud
			' 		' I _	
GR8	Upst			ddle	Downstream	
Wetted Width (m)	58			3		5
	Depth (m)	Substrate	Depth (m)	Substrate	Depth (m)	Substrate
LB 1	1	Mud	1.9	Mud	1	Mud
LB 2	2.4	Gravel	2.7	Gravel	2.4	Sand
LB 3	2.4	Gravel	2.4	Gravel	2.5	Sand
RB 3	2.2	Sand	2.5	Sand	2.5	Sand
RB 2	2.2	Gravel	2.4	Gravel	2.6	Sand
RB 1	0.65	Mud	0.5	Mud	0.4	Mud
CDO	Llook			المالم	Dawe	
GR9	Upst				Downstream	
Wetted Width (m)	5			5.5		).5
	Depth (m)	Substrate	Depth (m)	Substrate	Depth (m)	Substrate
LB 1	0.7	Mud	0.6	Mud	0.75	Mud
LB 2	2.4	Sand	2.4	Gravel	2.4	Gravel
LB 3	3.4	Sand	3.3	Sand	2.8	Sand
RB 3	3.4	Sand	2.6	Sand	3.3	Sand
RB 2	3.15	Sand	3.7	Sand	2.6	Sand
RB 1	3.3	Boulder	3.5	Boulder	1.4	Boulder

Cont. Appendix H. Stream wetted width, depth, and substrate type.

GR10	Upst	ream	Middle		Downstream	
Wetted Width (m)	5	7	5	2	5	9
	Depth (m)	Substrate	Depth (m)	Substrate	Depth (m)	Substrate
LB 1	0.85	Boulder	0.6	Mud	0.6	Mud
LB 2	2.4	Pebble	2.4	Gravel	2.3	Pebble
LB 3	2.2	Gravel	2.2	Gravel	1.7	Pebble
RB 3	1.9	Cobble	2.4	Cobble	2	Sand
RB 2	1.7	Mud	1.9	Cobble	2.2	Gravel
RB 1	0.75	Mud	0.4	Mud	0.65	Mud
GR11	Unct	ream	'   Naic	ddle	l Down	stroom
	•	0		2		stream 51
Wetted Width (m)						
10.4	Depth (m)		Depth (m)		Depth (m)	Substrate
LB 1	0.4	Mud	0.5	Mud	0.3	Mud
LB 2	2	Gravel	1.9	Gravel	1.8	Gravel
LB 3	2.4	Gravel	2	Gravel	1.8	Pebble
RB 3	2.4	Gravel	1.85	Gravel	1.85	Gravel
RB 2	2.15	Gravel	1.7	Gravel	1.6	Gravel
RB 1	0.7	Mud	0.5	Mud	0.3	Mud
GR12	Upst	ream	Mic	ddle	Downs	stream
Wetted Width (m)	4		44		52	
	Depth (m)	Substrate	Depth (m)	Substrate	Depth (m)	Substrate
LB 1	1.15	Mud	0.4	Mud	0.75	Mud
LB 2	2.5	Sand	3	Sand	1.8	Sand
LB 3	3.85	Gravel	3	Gravel	2.2	Gravel
RB 3	3.25	Cobble	3	Pebble	2.25	Gravel
RB 2	2	Cobble	2.5	Pebble	2.4	Pebble
RB 1	1	Cobble	1	Boulder	1.4	Cobble

Cont. Appendix H. Stream wetted width, depth, and substrate type.

GR13	Upst	ream	Middle		Downstream		
Wetted Width (m)	54		4	9		.0	
	Depth (m)	Substrate	Depth (m)	Substrate	Depth (m)	Substrate	
LB 1	0.6	Mud	0.9	Mud	0.9	Mud	
LB 2	2.1	Sand	2.7	Sand	2.6	Gravel	
LB 3	2.15	Sand	2.7	Sand	2.5	Gravel	
RB 3	2.7	Gravel	2.7	Pebble	2.5	Gravel	
RB 2	1.75	Sand	2.7	Cobble	2.6	Cobble	
RB 1	0.6	Cobble	0.7	Cobble	0.85	Cobble	
			1		1		
GR14	Upstream			ldle		stream	
Wetted Width (m)	6	1	47	<b>'</b> .3	31.5		
	Depth (m)	Substrate	Depth (m)	Substrate	Depth (m)	Substrate	
LB 1	0.7	Mud	0.1	Pebble	0.25	Pebble	
LB 2	1.3	Pebble	0.25	Pebble	1.26	Pebble	
LB 3	1.1	Gravel	0.65	Pebble	2.25	Pebble	
RB 3	1.3	Gravel	1.5	Pebble	2.25	Pebble	
RB 2	2	Sand	1.75	Pebble	1.8	Pebble	
RB 1	1.25	Mud	1.5	Mud	0.5	Mud	
GR15	Unst	ream	Mic	ldle	Downs	stream	
Wetted Width (m)	4	Upstream		44		Downstream 47.8	
wetted width (iii)			Depth (m)				
LB 1	1.75	Boulder	0.65	Boulder	0.8	Bedrock	
LB 2	2.3	Cobble	1.9	Cobble	2.3	Sand	
LB 3	3.6	Pebble	3.5	Pebble	3.4	Pebble	
RB 3	3.15	Sand	3.2	Sand	2.9	Sand	
RB 2	2.7	Sand	2.25	Sand	2.5	Sand	
RB 1	0.4	Sand	0.25	Sand	0.6	Mud	

Cont. Appendix H. Stream wetted width, depth, and substrate type.

GR16	Upstream		Middle		Downstream	
Wetted Width (m)	31	7	5	9		7
	Depth (m)	Substrate	Depth (m)	Substrate	Depth (m)	Substrate
LB 1	0.5	Boulder	0.5	Boulder	0.6	Cobble
LB 2	2.2	Cobble	1.75	Pebble	2.25	Pebble
LB 3	1	Gravel	2.5	Sand	2	Gravel
RB 3	1.5	Gravel	3.3	Sand	2.6	Sand
RB 2	0.75	Sand	1.1	Gravel	1.9	Sand
RB 1	0.4	Sand	0.6	Mud	1.15	Mud
			1		! !	
NR1	Upstream			ddle		stream
Wetted Width (m)	23	3.6	2	2	18	
	Depth (m)	Substrate	Depth (m)	Substrate	Depth (m)	Substrate
LB 1	0.6	Mud	0.75	Mud	0.75	Mud
LB 2	1.7	Mud	2.8	Mud	3	Mud
LB 3	3.4	Gravel	3.25	Gravel	3.5	Mud
RB 3	3.75	Gravel	3.9	Gravel	2.6	Mud
RB 2	2.4	Mud	1.5	Mud	1.6	Mud
RB 1	1	Mud	1	Mud	1	Mud
NDS	II		' 	L.II.	' !	.1
NR2	Upst		Middle		Downstream	
Wetted Width (m)	2		20		20	
	Depth (m)	Substrate	Depth (m)	Substrate	Depth (m)	Substrate
LB 1	0.75	Mud	1.25	Mud	0.75	Mud
LB 2	3.15	Mud	2.9	Mud	2.4	Mud
LB 3	3.5	Sand	3.1	Gravel	3.25	Gravel
RB 3	4	Sand	2.85	Mud	2.6	Mud
RB 2	1.4	Mud	2.4	Mud	1.9	Mud
RB 1	0.75	Mud	1	Mud	1.1	Mud

Note: LB/RB 1 refers to measurements taken closest to the Left/Right bank, with LB/RB 3 being closer to the middle of the stream

Appendix I. Site large woody debris (LWD) presence and bank failure (%).

	Upstream					Downstrea	ım		
		LB	RB	Left	Right	LB	RB	Left	Right
Code	Hydrology	Failure (%)	Failure (%)	LWD	LWD	Failure (%)	Failure (%)	LWD	LWD
GR1	Pool	0	50		Х	0	0	Х	Х
GR2	Pool	100	0	Х		100	0	Χ	Х
GR3	Pool	0	85		Х	75	0	Χ	Х
GR4	Pool	100	0	Х	Х	90	0	Χ	Х
GR5	Pool	0	75	Х	Х	0	90	Χ	Х
GR6	Flowing	0	0	Х	Х	0	0	Χ	Х
GR7	Flowing	0	35	Х	Х	0	12	Χ	Х
GR8	Flowing	0	0	Х	Х	40	0	Χ	Х
GR9	Flowing	100	0			85	0		Х
GR10	Flowing	0	70	Х	Х	0	0	Х	Х
GR11	Flowing	0	0	Х	Х	70	0	X	Х
GR12	Flowing	65	0	Х		0	0	Χ	
GR13	Flowing	32	0	Х	Х	100	0	X	Х
GR14	Flowing	0	30	Х	Χ	0	0		Х
GR15	Flowing	0	0		Χ	0	0		Х
GR16	Flowing	0	0		Х	0	0	Х	Х
NR1	Pool	100	100	Х	Х	100	100	Х	Х
NR2	Pool	95	100		X	100	100		Х



#### **VIA EMAIL**

January 15, 2021

Mr. Rob Bullard The Nature Conservancy Tennessee Chapter 210 25th Avenue North, Suite 810 Nashville, Tennessee 37203 ebullard@tnc.org

Subject: Biological Assessment Report

Green River Lock and Dam 5 Removal Project Butler, Warren, and Edmonson Counties, Kentucky USFWS Consultation Code: 04EK1000-2021-SLI-0097

Redwing Project: 20-086

Dear Mr. Bullard:

Redwing Ecological Services, Inc. is pleased to submit this Biological Assessment Report to The Nature Conservancy in support of the removal of Green River Lock and Dam 5. Green River Lock and Dam is located in Butler and Warren Counties, Kentucky, with the pool upstream of the structure (Pool 5) extending into Edmonson County. 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 and Kentucky cave shrimp. Effects to the purple cat's paw, northern riffleshell, snuffbox, clubshell, 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 seven 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 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* (June 2016). As a result, an effects determination of "may affect, likely to adversely affect" has been made for the Indiana bat. Adverse effects to the northern long-eared bat will be addressed using the 4(d) rule for this species. An effects determination of "may affect, likely to adversely affect", but take is not prohibited under the 4(d) rule, has been made for this species. Informal consultation with the U.S. Fish and Wildlife Service is requested to address adverse effects to these nine species.

Adverse effects are also anticipated to the spectaclecase, fanshell, pink mucket, ring pink, sheepnose, rough pigtoe, and rabbitsfoot as a result of the proposed Action. Therefore, an effects determination of "may affect, likely to adversely affect" has been made for these seven mussel species. Formal consultation with the U.S. Fish and Wildlife Service is requested to address adverse effects to these seven species.

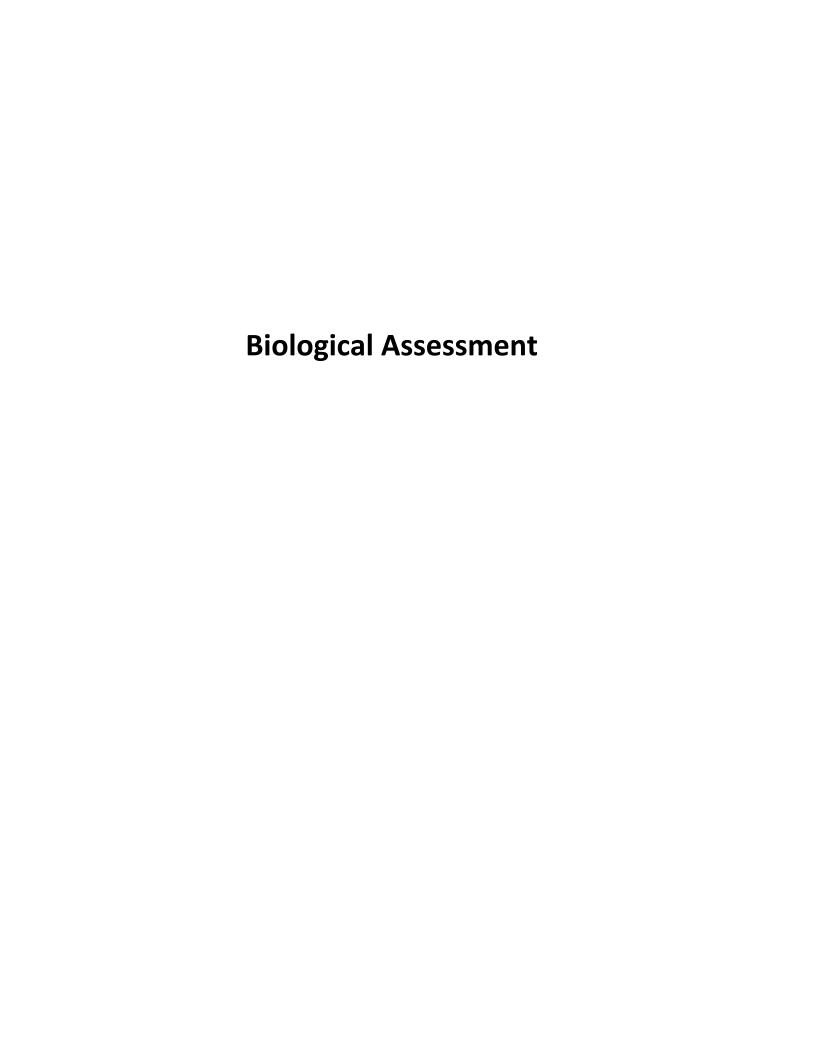
We appreciate the opportunity to work with you on this project. Please contact Seth Bishop or Richard Clausen at (502) 625-3009 with any questions you have during your review of the attached report.

Sincerely,

Seth R. BISHOP Seth R. Bishop (Jan 15, 2021 13:53 EST)

Seth R. Bishop Senior Ecologist Richard S. Clausen Principal Senior Ecologist

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### **BIOLOGICAL ASSESSMENT REPORT**

# GREEN RIVER LOCK AND DAM 5 REMOVAL PROJECT

# BUTLER, WARREN, AND EDMONSON COUNTIES, KENTUCKY

**Prepared for:** 

THE NATURE CONSERVANCY

In Conjunction with:

# U.S. ARMY CORPS OF ENGINEERS LOUISVILLE DISTRICT

January 2021

#### **BIOLOGICAL ASSESSMENT REPORT**

## GREEN RIVER LOCK AND DAM 5 REMOVAL PROJECT BUTLER, WARREN, AND EDMONSON COUNTIES, KENTUCKY

Submitted to:

U.S. FISH AND WILDLIFE SERVICE KENTUCKY FIELD OFFICE

**Prepared for:** 

THE NATURE CONSERVANCY

In Conjunction with:

U.S. ARMY CORPS OF ENGINEERS LOUISVILLE DISTRICT

Prepared by:

REDWING ECOLOGICAL SERVICES, INC.

Seth R. Bishop (Jan 15, 2021 13:53 EST)

Seth R. Bishop Senior Ecologist Richard S. Clausen

Principal

Senior Ecologist

January 15, 2021

#### **EXECUTIVE SUMMARY**

The U.S. Army Corps of Engineers (USACE) proposes to remove Green River Lock and Dam 5 (GRLD5) located in the Green River at River Mile 168.1. The proposed Action includes planning, demolition and removal of the lock, dam, and associated structures, and conveyance of the GRLD5 property from the USACE to The Nature Conservancy (TNC). 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 Action Area begins at the Kentucky Highway 185 bridge over the Green River downstream of GRLD5 and extends upstream to River Mile 195. The upstream portion of the Action Area also includes several tributaries to the Green River, including the Nolin River to approximately River Mile 6.0. The USACE is the lead federal agency for the proposed Action and will submit this Biological Assessment Report to the U.S. Fish and Wildlife Service (USFWS) to address potential impacts to federally listed species as a result of the Action.

Based on an official list of species obtained from the USFWS's Information for Planning and Consultation website, 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*), 11 mussel species, Kentucky cave shrimp (*Palaemonias ganteri*), and Price's potato-bean (*Apios priceana*). Designated critical habitat for the Indiana bat is also included on the official list of species; however, this habitat is located more than five miles southeast of the Action Area and is 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. Forested habitat in the southern portion of the work area along the Green River was also identified as suitable habitat for Price's potato-bean. The proposed Action will require the removal of up to 9.72 acres of forested habitat within the work area. Tree fall along the riverbanks upstream of the dam is also anticipated after dam removal and is estimated at 36.72 acres. The Green River was identified as suitable gray bat foraging habitat and suitable habitat for the federally listed mussel species. Due to the lack of records for the purple cat's paw, northern riffleshell, snuffbox, and clubshell within and near the Action Area, these species are considered absent from the Action Area.

The habitat assessment also included an in-house review of available resources to identify known caves, abandoned mine portals, sinkholes, 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. The bridges over Beaverdam Creek and Little Beaverdam Creek are considered to be suitable roosting habitat for these species; however, these bridges are located outside the work area, and no work will occur on these structures. Multiple sinkholes and several caves are mapped adjacent to the Action Area that are known or potential 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 Price's potato-bean was conducted in the southern portion of the work area. No individuals of this species were found during the survey. The northern portion of the work area does not provide suitable habitat for Price's potato-bean.

Based on the results of the biological assessment, effects to the gray bat and Kentucky cave shrimp from the proposed Action are considered insignificant. Effects to the purple cat's paw, northern riffleshell, snuffbox, clubshell, 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 seven species, and informal consultation with the USFWS is requested 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 this 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 bat. Use of the 4(d) rule is proposed to address adverse effects to the northern long-eared bat; therefore, an effects determination of "may affect, likely to adversely affect", but take is not prohibited, has been made for this species. Informal consultation with the USFWS is requested to address potential effects to these two species.

The proposed Action is expected to result in adverse effects to the spectaclecase, fanshell, pink mucket, ring pink, sheepnose, rough pigtoe, and rabbitsfoot. Therefore, an effects determination of "may affect, likely to adversely affect" has been made for these seven mussel species. Formal consultation with the USFWS is requested to address potential adverse effects to these species.

### **TABLE OF CONTENTS**

	Page
EXECUTIVE SUMMARY	ii
LIST OF FIGURES	vi
LIST OF PHOTOGRAPHS	vii
1.0 INTRODUCTION	1
1.1 PROPOSED ACTION	
1.2 PURPOSE AND NEED	
1.3 IDENTIFICATION OF LISTED SPECIES	3
1.3.1 Resource Agency Coordination	
1.3.2 Selection of Species for Study	
1.3.3 Species for Informal Consultation	
1.3.4 Species for Formal Consultation	5
2.0 PROPOSED ACTION	7
2.1 ACTION AREA	7
2.2 PLANNING COMPONENT	
2.3 CONSTRUCTION COMPONENT	
2.3.1 Site Preparation	
2.3.2 Lock and Dam Removal	9
2.3.3 Site Stabilization	
2.3 CONVEYANCE COMPONENT	
2.4 CONSERVATION MEASURES	
3.0 SPECIES FOR INFORMAL CONSULTATION	
3.1 LISTED SPECIES HABITAT	
3.1.1 Gray Bat Habitat	
3.1.2 Indiana and Northern Long-eared Bat Habitat	
3.1.3 Mussel Habitat	15
3.1.5 Price's Potato-bean Habitat	
3.2 PRICE'S POTATO-BEAN SURVEY	
3.3 EFFECTS ANALYSIS	
3.3.1 Gray Bat	
3.3.2 Indiana Bat	
3.3.3 Northern Long-eared Bat	
3.3.4 Purple Cat's Paw, Northern Riffleshell, Snuffbox, and Clubshell.	
3.3.5 Kentucky Cave Shrimp	23
3.3.6 Price's Potato-bean	
3.4 EFFECTS DETERMINATION	
3.4.1 Gray Bat	
3.4.2 Indiana Bat	
3.4.3 Northern Long-Eared Bat	
3.4.4 Purple Cat's Paw, Northern Riffleshell, Snuffbox, and Clubshell. 3.4.5 Kentucky Cave Shrimp	
3.4.6 Price's Potato-bean	
4.0 SPECIES FOR FORMAL CONSULTATION	
4.1 SPECTACLECASE	
4.2 FANSHELL	
4.3 PINK MUCKET	
4.4 RING PINK	
4.6 ROUGH PIGTOE	
4.7 RABBITSFOOT	

5.0 ENVIRONMENTAL BASELINE	
5.1 SPECIES STATUS WITHIN THE ACTION AREA	
5.2 ACTION AREA NUMBERS, REPRODUCTION, AND DISTRIBUTION	
5.2.1 Action Area Downstream of GRLD5	
5.2.2 Action Area Upstream of GRLD5	
5.3 ACTION AREA CONSERVATION NEEDS AND THREATS	38
6.0 EFFECTS OF THE ACTION	39
6.1 SEDIMENT DISTURBANCE	39
6.2 WATER QUALITY DEGRADATION	46
6.3 CHANGES TO FLOW	
6.4 CRUSHING OR STRIKING OF INDIVIDUALS	58
6.5 DISPLACEMENT OF INDIVIDUALS	60
6.6 EXPOSURE OF INDIVIDUALS	
6.7 INVASIVE SPECIES	
6.8 POSITIVE EFFECTS	
6.9 CUMULATIVE EFFECTS	
6.10 SUMMARY OF EFFECTS	67
6.11 EFFECTS DETERMINATION	68
7.0 CONCLUSION	69
8.0 REFERENCES	7

FIGURES
PHOTOGRAPHS
APPENDIX A – PROJECT DESIGN PLANS
APPENDIX B – RESOURCE AGENCY COORDINATION
APPENDIX C – USACE MEMORANDUM

#### **LIST OF FIGURES**

### **Figure**

- 1. Site Location Map
- 2. Action Area Map
- 3. Known Indiana Bat Habitat Map
- 4. Known Northern Long-eared Bat Habitat Map
- 5. Kentucky Cave Shrimp Map
- 6. Project Development Map

#### **LIST OF PHOTOGRAPHS**

#### **Photograph**

- View of the dam and upstream portion of the lock river wall, facing north from the left descending bank of the Green River.
- 2. View of the dam and downstream portion of the lock river wall, facing northwest from the left descending bank of the Green River.
- 3. View of the mooring cells and upstream guide wall (behind mooring clls), facing northeast from the left descending bank of the Green River.
- 4. View of the lock chamber showing the lock river wall (left side) and lock land wall (right side), facing west from the upstream end of the chamber.
- 5. View of the miter gates at the upstream end of the lock chamber, facing east.
- 6. View of the miter gates at the downstream end of the lock chamber, facing east from outside the chamber.
- 7. View of the operations building adjacent to the lock land wall.
- 8. View of the downstream guide wall, facing west from the end of the lock river wall.
- 9. View of the existing access road in the northern portion of the work area near Lock 5 Road.
- 10. View of the existing access road in the northern portion of the work area near the lock.
- 11. View of the forested habitat along the lock land wall.
- 12. Example of the forested habitat in the northern portion of the work area.
- 13. View of the thick ground and understory layers dominated by invasive shrub and herbaceous species in the forested habitat in the northern portion of the work area.
- 14. View of the dam and dam abutment on the left descending bank of the Green River, facing south.
- 15. View of the boulders along the left descending bank downstream of the dam abutment, facing west from the dam abutment.
- 16. View of the exposed rock at the base of the dam that extends along the dam abutment to the boulders, facing northeast from the left descending bank.
- View of suitable habitat for Price's potato-bean in the southern portion of the work area, facing southwest.
- 18. View of the intermittent tributary to the Green River where a temporary crossing will be required during construction of the access road in the southern portion of the work area.
- View of Pool 5 upstream of the dam, facing northeast from the left descending bank of the Green River.
- 20. View of Pool 4 downstream of the dam, facing southwest from the end of the lock river wall.

#### 1.0 INTRODUCTION

The Nature Conservancy (TNC), in conjunction with the U.S. Army Corps of Engineers (USACE), is pleased to submit this Biological Assessment Report in support of the removal of Green River Lock and Dam 5. The lock and dam structures are located in Butler and Warren counties, Kentucky, with the pool associated with the structure (Pool 5) extending into Edmonson County. 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 Green River Lock and Dam 5 (GRLD5). GRLD5 is located on the Green River at River Mile (RM) 168.1 near the confluence with Bear Creek (Figure 1). GRLD5 consists of a 301-foot long dam, a 360-foot long by 56-foot wide lock chamber along the right descending bank, two approximately 30-foot diameter mooring cells located upstream of the lock chamber, a 266-foot long upstream guide wall, and a 300-foot long downstream guide wall. A two-story concrete operations building is located adjacent to the lock chamber on the right descending bank. Pool 5 extends 13.6 miles upstream of GRLD5, with a normal pool elevation of 411 feet above mean sea level (AMSL). The design plans for the removal of GRLD5 are included as 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 2). 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.

GRLD5 is one of four locks and dams on the upper Green River that were constructed and operated by the USACE for navigation purposes. The current lock and dam were constructed in 1933-1934 to replace the failing structure installed in 1900, and operation of the lock began in 1934. Operation of GRLD5 ceased in 1951 due to a decline in navigational traffic and increasing operation and maintenance costs. Since that time, the USACE has conducted multiple investigations to assess deauthorization and disposal of the Green River Locks and Dams. 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 and reevaluated the current uses of the 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 these properties and facilities 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 River Locks and Dams. Although the removal of GRLD5 was not examined under the assessment, the removal of Green River Lock and Dam 6 (GRLD6) was included as one of the evaluated alternatives. 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 (Pool 6) 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.

The report also concluded that threatened and endangered species in Mammoth Cave National Park (MCNP) would benefit from the removal of GRLD6. Restoration of natural flow in the Green River would improve habitat for the Kentucky cave shrimp by reducing sediment accumulation in underground passages and returning pools inhabited by this species to more natural conditions. Lowering of the water level in the river would also allow Indiana and gray bats to access cave entrances and passages that had been flooded for over 100 years. Additionally, cave-dwelling species would benefit from restoration of more natural microclimate conditions inside the cave systems.

Removal of GRLD6 would also increase wetlands along the riverbanks as the water level upstream of the dam receded and exposed areas adjacent to the river channel. Dormant seeds in these areas would be exposed, increasing wetland vegetation and expanding these linear wetlands. Native tree species would also grow on the newly exposed banks, helping to stabilize these areas.

Based on the conclusion in the 2014 Environmental Assessment that the removal of GRLD6 would provide numerous benefits to the Green River ecosystem, the removal of GRLD5 is expected to result in similar benefits. As a result, the removal of GRLD5 will meet the purpose and need for 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 Consultation Code: 04EK1000-2021-SLI-0097) (USFWS IPaC 2020). 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. As summarized in the following table, 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 designated critical habitat for the Indiana bat (*Myotis sodalis*) within the Action Area. The IPaC official species list is provided in Appendix B.

Group	Scientific Name	Common Name	Federal Status
	Myotis grisescens	gray bat	Endangered
Bats	Myotis septentrionalis	northern long-eared bat	Threatened
	Myotis sodalis	Indiana bat	Endangered; Critical Habitat
	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
Mussels	Lampsilis abrupta	pink mucket	Endangered
	Obovaria retusa	ring pink	Endangered
	Plethobasus cyphyus	sheepnose	Endangered
	Pleurobema clava	clubshell	Endangered
	Pleurobema plenum	rough pigtoe	Endangered
	Quadrula cylindrica cylindrica	rabbitsfoot	Threatened
Crustacean	Palaemonias ganteri	Kentucky cave shrimp	Endangered
Plant	Apios priceana	Price's potato-bean	Threatened

The USFWS Kentucky Field Office (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 the known habitat map for the Indiana bat, the Action Area is located within "Known Swarming 1", "Known Swarming 2", and "Known Summer 1", habitat for this species (USFWS KFO 2019a) (Figure 3). The known northern long-eared bat habitat map

shows that the Action Area is located within "Known Swarming 2" and "Known Summer 1" habitat for this species (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 Action Area is located in two quadrangles, Rhoda and Mammoth Cave, that contain one or more known maternity roost trees and one or more known hibernacula (USFWS KFO and KDFWR 2016) (Figure 4).

A data request was submitted to the Office of Kentucky Nature Preserves (OKNP) on July 2, 2020 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 14 of the 16 listed species within or adjacent to the Action Area, including the gray bat, northern long-eared bat, Indiana bat, 10 of the 11 mussel species, and the Kentucky cave shrimp. 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

All 16 species included on the IPaC official species list 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. Designated critical habitat for the Indiana bat was not evaluated under the assessment. Although the IPaC official species list states that designated critical habitat for the Indiana bat is located within the Action Area, the actual location of this critical habitat is located outside the Action Area. The critical habitat referred to in the species list is Coach Cave, which is a Priority 1 hibernacula for this species located more than five miles southeast of the Action Area. The USFWS uses county-level mapping to protect the location of critical habitat for this species; therefore, the IPaC database includes all of Warren, Edmonson, Hart, and Barren Counties as critical habitat for the Indiana bat. Due to the location of the Action Area in Warren and Edmonson Counties, the IPaC database included this Indiana bat critical habitat 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 and Kentucky cave shrimp. Effects to the purple cat's paw, northern riffleshell, snuffbox, clubshell, 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 seven species. Informal consultation with the USFWS is requested 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* (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 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 agreement to address adverse effects, the Indiana bat is included under informal consultation, as discussed 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. Use of the 4(d) rule is proposed to address adverse effects to this species; therefore, an effects determination of "may affect, likely to adversely affect", but take is not prohibited, has been made for the northern long-eared bat. Due to the use of the 4(d) rule to address adverse effects, the northern long-eared bat is included under informal consultation, as discussed in Section 3.0.

#### 1.3.4 Species for Formal Consultation

The proposed Action will result in adverse effects to the spectaclecase, fanshell, pink mucket, ring pink, sheepnose, rough pigtoe, and rabbitsfoot; therefore, an effects determination of "may affect, likely to adversely affect" has been made for these seven species. Formal consultation with the USFWS is requested to address these seven species, as discussed beginning in Section 4.0 and throughout the remainder of the report.

The effects determination and USFWS consultation method for all 16 species is summarized in the following table.

Group	Common Name	Effects Determination	USFWS Consultation
	gray bat	NLTAA	Informal
Bats	northern long-eared bat	LTAA*	Informal
	Indiana bat	LTAA**	Informal
	purple cat's paw	NLTAA	Informal
	northern riffleshell	NLTAA	Informal
	snuffbox	NLTAA	Informal
	clubshell	NLTAA	Informal
	pink mucket	LTAA	Formal
Mussels	ring pink	LTAA	Formal
	sheepnose	LTAA	Formal
	spectaclecase	LTAA	Formal
	fanshell	LTAA	Formal
	rough pigtoe	LTAA	Formal
	rabbitsfoot	LTAA	Formal
Crustacean	Kentucky cave shrimp	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 4(d) rule to address adverse effects to the northern long-eared bat

\*\* Use of the Revised Conservation Strategy for Forest-Dwelling Bats in the Commonwealth of Kentucky to mitigate for adverse effects to the Indiana bat

### 2.0 PROPOSED ACTION

The proposed Action involves the removal of GRLD5 from the Green 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 GRLD5 may influence physical, chemical, or biological habitat components. The Action Area begins at the Kentucky Highway (KY) 185 bridge downstream of GRLD5 at RM 166.7 and extends upstream to RM 195, located within Mammoth Cave National Park (Figure 2). The upstream portion of the Action Area also includes several tributaries to the Green River, including the Nolin River to approximately RM 6.0. The extent of the upstream portion of the Action Area was determined based on a Hydrologic and Hydraulic Analysis included in the Green and Barren Lock and Dam Disposition Study prepared by the USACE (USACE 2014). Comparison of model output with GRLD6 removed with the output from both GRLD6 and GRLD5 removed shows decreases in the 100% duration flow for August (base flow) to RM 195; therefore, RM 195 was identified as the upstream extent of the Action Area. Mussel surveys performed for the USFWS KFO in 2017 and 2019 documented the presence of a diverse mussel bed extending from GRLD5 downstream to approximately 1,200 feet upstream of the KY 185 bridge (LEC 2017, LEC 2019); therefore, the KY 185 bridge was used as the downstream extent of the Action Area to assess potential impacts to this mussel bed.

All construction activities will be limited to a work area adjacent to GRLD5 on both sides of the Green River (Figure 6). The work area includes the dam, lock walls, guide walls, and mooring cells, as well as access roads and staging areas. The work area encompasses approximately 13.45 acres, including 3.80 acres within the river, 8.14 acres on the north side of the river, and 1.51 acres on the south side.

# 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 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; clearing and grubbing; establishment of staging areas; and improvement and construction of access roads. These activities will require the use of heavy equipment (i.e., bulldozers, trackhoes, backhoes, trucks, etc.); however, disturbances within the Green River are not expected.

Prior to construction activities, 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.

Following installation of the EPSC measures, the contractor will establish staging areas for equipment and materials necessary for the proposed Action. Three staging areas are expected within the work area, including an area on the south side of the river, an area on the north side of the river adjacent to the existing lock structure, and an area located off Lock 5 Road on the north side of the river. The majority of construction activities will occur on the north side of the river where the lock structure is located; therefore, the staging area adjacent to the lock is expected to be the largest and most active. The staging area located off Lock 5 Road is expected to be utilized for construction trailers, parking, and as a potential area to store equipment if a flood event occurs during construction activities. The staging area on the south side of the river will allow equipment to create a notch in the dam prior to removal and to assist in removal of the abuttment wall.

Clearing and grubbing involves the removal and disposal of all vegetation within the work area (Figure 6). 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 Green River and will be burned on site, if permissible, or allowed to decay naturally.

Roads will be required to access each side of the Green River at the lock and dam location. An existing access road approximately 10 to 15 feet wide is located on the north side of the river that extends from

Lock 5 Road to the upstream extent of the lock chamber. The portion of the road near Lock 5 Road is covered with gravel and rock; however, the remaining portion of the road does not have an improved surface and exhibits extensive rutting and ponding. During site preparation, the road will be widened, where needed, and improved with a rock surface along its entire length to allow access for personnel, construction equipment, and maintenance equipment.

Access to the south side of the dam will be obtained using an existing gravel road off County Road 1201 that terminates at a boat ramp maintained by the Kentucky Department of Fish and Wildlife Resources. The existing road is approximately 15 feet wide and will require improvements to allow use by heavy equipment. Construction of an access road leading from the existing gravel road to the dam will be required, including a temporary crossing of an unnamed intermittent tributary to the Green River. It is anticipated that the temporary tributary crossing will be completed using a culvert that will be removed upon completion of the Action, and a permanent crossing of this feature is not proposed.

#### 2.3.2 Lock and Dam Removal

The second construction component is removal of GRLD5. This component will include demolition and removal of all structures, including the dam, dam abutment, lock river wall, lock land wall, upstream and downstream guide walls, mooring cells, and operations building. The locations of these components are shown on Figure 6 and depicted on the demolition plans (Appendix A). Generally, demolition activities will be initiated on the north side of the river and will extend toward the south side. Two existing structures associated with GRLD5 will not be removed as part of the proposed Action, including an area of derrick stone overlaying wood piles on the downstream side of the dam adjacent to the lock river wall and a guide wall associated with the former lock and dam located along the right descending bank approximately 400 feet downstream.

The initial step in the demolition process will be the creation of a notch at the southern end of the dam to partially drain Pool 5. Equipment will access the dam from the work area on the south side the river and begin by demolishing the dam abutment to the elevation of the existing dam. Once the dam elevation has been reached, a notch extending four to five feet vertically from the top of the dam will be created. The horizontal extent of the notch will be limited by the reach of the equipment but is expected to extend approximately 15 feet from the abutment. The material removed to create the notch will be deposited in the scour area immediately below the dam or used to help build a temporary work pad for equipment.

While Pool 5 is draining, demolition will be initiated in the work area on the north side of the Green River. Clean material from the demolition of the operations building, the lock land wall, and the guide walls will be placed in the lock chamber to construct a work pad to the lock river wall. These structures are made of

concrete and will either be demolished using hoe ram-equipped excavators or similar equipment or with controlled explosive charges. As presented in the demolition plans, the lock land wall will only be removed to an elevation of 406 feet AMSL to create a constant slope to the inner toe of the lock river wall. The existing bank behind the lock land wall will also be graded to create a stable slope, and the grading is expected to extend approximately 45 to 50 feet landward from the lock land wall. The upstream and downstream miter gates will be removed and placed in the bottom of the lock chamber.

Once the work pad has been constructed, demolition of the lock river wall will commence utilizing hoe ramequipped excavators or controlled explosive charges. During this phase of demolition, the lock river wall will be removed to the elevation of the top of the dam (approximately 412 feet AMSL). After the dam is removed, the remainder of the lock river wall will be removed to an elevation of approximately 390 feet AMSL. Clean material generated from removal of the lock river wall will be used to construct the initial portion of an in-stream work pad along the downstream face of the dam. The work pad may be installed on the upstream side of the dam if required to address safety concerns or if deemed more efficient; however, this approach is not typically used in dam removals.

Equipment will utilize the in-stream work pad to remove the upper portion of the dam that is exposed after partial draining of Pool 5. Material from the dam will be used to fill the scour area at the base of the dam and complete the in-stream work pad. The dam will be demolished in lifts, with the vertical extent of each lift determined by the water level to ensure that the 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 equipment. Once the instream work pad has been constructed across the river, additional material generated during demolition will be placed within the lock chamber. The dam and in-stream work pad will be removed to an elevation of approximately 390 feet AMSL. Dam sills and pilings will not be removed, and steel reinforcement rods, if present in the dam, will be broken at the proposed final elevation and bent downstream to avoid snags. The dam will also be notched to an elevation below 390 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 abutment on the southern side of the river will be removed to an elevation of approximately 395 feet AMSL or less.

Following removal of the dam and abutment, the remainder of the lock river wall will be removed to the same elevation as the remaining portion of the dam (approximately 390 feet AMSL). The material generated from final removal of the lock river wall will be used to construct a second in-stream work pad to the mooring cells. These structures are constructed of steel sheet piling driven into the river bottom. The center portion of the mooring cell is expected to be filled with sand, and the top is capped with concrete. During demolition, the sheet piles will be pulled from the bed and disposed of within the lock chamber. The

sand material within the mooring cells will be excavated to the extent possible and used to cover the material within the lock chamber or in other areas where erosion of the material can be avoided. Once the mooring cells have been removed, the work pad will be removed to the extent possible, and the remaining portions of the lock land wall and guide walls will be removed to an elevation of approximately 406 feet AMSL. The banks behind these walls will also be graded to create a stable slope. Soil material generated from bank grading will be used, to the extent possible, to cover the material in the lock chamber.

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

#### 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 access road to the work area on the south side of the river will be removed, including the culvert in the unnamed intermittent tributary. The north side of the river is intended to be used as a public canoe launch and will contain a parking area and ramp access to the river. The majority of the access road from Lock 5 Road will remain to provide access to the canoe launch; however, portions of the access road not required to access the launch will be removed and revegetated.

# 2.3 CONVEYANCE COMPONENT

The conveyance component is the third and final component of the proposed Action and involves conveyance of the land and improvements associated with GRLD5 from the USACE to TNC. 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, TNC will become responsible for managing the land and improvements associated with GRLD5. TNC intends to make the land areas available for conservation and public recreation as discussed in the previous section, in accordance with the provisions of Section 1315 of the 2016 Water Infrastructure Improvements for the Nation Act. 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.

#### 2.4 CONSERVATION MEASURES

The following conservation measures are proposed to avoid and minimize impacts from the proposed Action to the seven mussel species proposed for formal consultation 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 (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 in-stream activities during periods of low flow.
- (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 seven mussel species.
- (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 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 the seven mussel species and their habitat; however, these measures are not expected to eliminate all adverse effects that may result from the proposed Action.

# 2.5 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 GRLD5 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, purple cat's paw, northern riffleshell, snuffbox, clubshell, Kentucky cave shrimp, 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 listed species. The assessment included in-house and field components. A field survey of the work area was performed by Redwing Ecological Services, Inc. (Redwing) on August 13, 2020. Habitat for each listed 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 caves, abandoned mine portals, sinkholes, and other underground features that could provide potential hibernacula or roosting habitat for the gray bat within and adjacent to the Action Area. Construction components will be limited to the work area; therefore, efforts were focused on locating potential hibernacula within or near this portion of the Action Area. According to karst potential maps maintained by the Kentucky Geological Survey (KGS), an area of very high karst potential is located along the left descending bank in the southern portion of the work area; however, no sinkholes or other karst features are present (KGS 2020). The remaining portions of the work area are classified as non-karst. USGS topographic and geologic maps do not show any caves or sinkholes within or adjacent to the work area; however, several rockshelters are located southwest of the southern portion of the work area. One abandoned strip mine and two abandoned quarries are present to the north but are located 2.5 miles or greater from the work area. During the field survey, no caves, abandoned mine portals, 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 roosting habitat for the gray bat is present in the work area.

Although no caves, sinkholes, or other underground features are present in the work area, areas of high karst potential and multiple sinkholes are mapped in the Green River floodplain adjacent to the Action Area. These sinkholes could potentially be used as hibernacula or roosting habitat by gray bats. In addition, the upstream portion of the Action Area is located in MCNP, where several caves with known bat populations are located along the Green River (Rick Toomey, MCNP, personal communication, July 20, 2020).

Bridges and culverts located in the Action Area could also provide potential roosting habitat for the gray bat. Two bridges are present within the Action Area, including a concrete girder bridge over Little Beaverdam Creek and a concrete box beam bridge over Beaverdam Creek. Both bridges are located immediately upstream of the Green River. 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 Green River and Nolin River, as well as six tributaries to the Green River: Bear Creek, Little Beaverdam Creek, Crooked Branch, Honey Creek, Alexander Creek, and Beaverdam Creek. These streams and associated riparian corridors are also considered to be suitable commuting habitat for this species.

# 3.1.2 Indiana and Northern Long-eared Bat Habitat

Based on the absence of underground features within and adjacent to the work area, no potential hibernacula for the Indiana or northern long-eared bat are present. The two 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 and are known to use caves along the Green River in MCNP (Rick Toomey, MCNP, personal communication, July 20, 2020). 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 Green River was determined to be suitable habitat for all 11 mussel species. A survey for these species was not performed for the proposed Action due to the prevalence of surveys in Green River Pools 4, 5, and 6 over the last 10 years that have documented the majority of these species.

# 3.1.4 Kentucky Cave Shrimp Habitat

The Kentucky cave shrimp is currently known from 11 groundwater basins in the MCNP region of central Kentucky, including the Echo River, Ganter Bluehole, Great Onyx, McCoy Bluehole, Mile 205.7, Pike, River Styx, Running Branch, Suds, Turnhole, and Turnhole–Double Sink groundwater basins (Rick Toomey, MCNP, personal communication, August 21, 2020). The Double Sink basin is a sub-basin of the Turnhole basin; however, the sub-basin is considered to be separate from the remainder of the Turnhole basin because it receives surface water from separate sources (Rick Toomey, MCNP, personal communication,

September 15, 2020). The Roaring River passage of Mammoth Cave, located in the Echo River groundwater basin, has been designated as critical habitat for this species (USFWS 1983). The Echo River basin emerges at Echo River Spring, which flows into the Green River approximately 2.3 miles upstream of the Action Area (Figure 5). The Roaring River passage is located more than one mile upstream of the spring. As a result, critical habitat for the Kentucky cave shrimp is not located within the Action Area. Additionally, no suitable habitat for this species is present in the Action Area; however, the Turnhole–Double Sink, Turnhole, and Ganter Bluehole groundwater basins drain to the Green River within the upstream portion of the Action Area (Figure 5).

#### 3.1.5 Price's Potato-bean Habitat

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 northern portion of the work area is underlain with alluvium consisting of clay, silt, sand, and gravel. The southern portion of the work area is underlain by the same alluvium as the northern portion, as well as Glen Dean Limestone and the Tradewater and Caseyville Formations, which consist of sandstone, siltstone, shale, coal, clay, and limestone (KGS 2020).

The field survey showed that the northern portion of the work area does not provide suitable habitat for Price's potato-bean. The riverbank consists almost entirely of the lock land wall and guide walls, with only a small amount of natural bank. The forest edge along the walls and bank is densely shaded by overhanging trees, with a thick layer of vine, shrub, and tall herbaceous species along the ground and growing on the walls. Due to the presence of the walls, the riverbank does not receive periodic disturbance from scouring, flooding, or tree fall to create openings suitable for Price's potato-bean. The forested habitat beyond the riverbank is a flat floodplain with a dense canopy and ground and understory layers dominated by invasive shrub and herbaceous species. The area is underlain by deep soils, and no hillslopes with limestone outcrops or bluffs are present. The existing access road to the lock is bordered by the same dense canopy as the adjacent forest, and the corridor is too narrow to receive sufficient sunlight for Price's potato-bean.

The southern portion of the work area contains the dam abutment along part of the bank; however, natural riverbank is present upstream and downstream of the abutment. The bank upstream of the abutment is located at the base of a hillslope where the Glen Dean Limestone and Tradewater and Caseyville Formations meet the alluvium layer along the river. Although the underlying geology is favorable for Price's potato-bean, dense forest is present along the bank with large trees that overhang the river. When combined with the north-facing orientation of the bank, this area does not receive sufficient sunlight for this

species. The bank downstream of the abutment contains a flat area at the base of a hillslope that appears to receive periodic disturbance during flooding. The canopy is less dense than in the other portions of the work area, with a more open understory and areas of exposed rock and bare ground. This area was determined to provide suitable habitat for Price's potato-bean, and a presence/probable absence survey for the species was performed.

# 3.2 PRICE'S POTATO-BEAN SURVEY

The presence/probable absence survey for Price's potato-bean was conducted on August 13, 2020 during the typical flowering period for this species (mid-July through mid-August) (USFWS 1993). The survey consisted of a pedestrian survey along the southern portion of the work area downstream of the dam abutment. Several common associate species of Price's potato-bean were observed, including sugar maple (*Acer saccharum*), poison ivy (*Toxicodendron radicans*), and Virginia creeper (*Parthenocissus quinquefolia*); however, no Price's potato-bean was found in the area during the survey. Groundnut (*Apios americana*), a close relative of Price's potato-bean, was observed west of the survey area.

#### 3.3 EFFECTS ANALYSIS

An analysis of potential effects to the gray bat, Indiana bat, northern long-eared bat, purple cat's paw, northern riffleshell, snuffbox, clubshell, Kentucky cave shrimp, 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 roosting habitat for the gray bat is present within or near 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 river wall; 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 caves adjacent to the Action Area that are connected to the Green River through subsurface flow will not be directly impacted by the project. Removal of GRLD5 will lower the base water level of the Green River and could subsequently reduce water levels in these features; however, water level reductions 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 sinkholes located along the pooled portion of the river upstream of GRLD5. Features located upstream of the pooled area will likely exhibit little to no increase in roost availability. The frequency and intensity of flooding in sinkholes and caves may also decrease, potentially enhancing the suitability of these features as roosting habitat.

The bridges over Little Beaverdam Creek and Beaverdam Creek are assumed to provide suitable non-winter roosting habitat for the gray bat. No work will be performed on these structures as part of the project, and both bridges are located more than five miles upstream of the work area. Lower water levels in these streams from the removal of GRLD5 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 GRLD5 will result in temporary and permanent impacts to gray bat foraging habitat in the Green River. Installation of the in-stream work pad will result in temporary impacts to foraging habitat; however, the work pad will remain 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.

During removal of the lock and dam, changes to foraging habitat will occur on a daily basis as these structures are demolished. More of these obstacles will be removed each day, altering the flyway over and along the Green River. Demolition and associated noise and vibrations will be limited to daylight hours and will not occur when bats are actively foraging. Although unlikely, gray bats that are affected by the demolition activities can avoid the work area and forage in other portions of the Green 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 lock and dam and installation of the 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 the 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 Green River (Section 2.3). 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 Green 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 GRLD5 is expected to improve gray bat foraging habitat in the Green River and the other streams in the Action Area after project completion. The dam will be removed to an elevation of approximately 390 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 lock river wall and mooring cells 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 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 edges of large forest blocks on both sides of the Green River. Removal of these trees will not result in significant fragmentation of commuting routes or the isolation of forested habitat. After construction, the southern portion of the work area and much of the northern portion will be allowed to reforest naturally over time, restoring forested habitat to the majority of the cleared areas. The public canoe launch and associated access road and parking area in the northern portion of the work area will be maintained as open areas; however, these areas will provide corridors and forest openings that can be utilized by gray bats for foraging and commuting. Due to these factors, the proposed tree removal is not anticipated to significantly affect foraging or commuting gray bats. The loss of trees along portions of the riverbanks upstream of the dam after removal is unlikely to 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 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 is reasonably certain to occur within the Action Area. Therefore, potential effects to this species and its habitat from the Action are discussed below.

As discussed in the previous section, no potential hibernacula for the Indiana bat are present within the Action Area, and noise and vibrations from demolition activities and explosives are not anticipated to result in impacts beyond the work area. The sinkholes and caves adjacent to the Action Area and the Little Beaverdam and Beaverdam Creek bridges will not be directly impacted by the removal of GRLD5, 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 bridge-roosting Indiana bats and their habitats are considered insignificant.

The proposed Action will result in the removal of up to 9.72 acres of suitable summer roosting, foraging, and commuting habitat for the Indiana bat in the work area (Figure 6). The final amount of tree removal will be determined prior to construction; however, removal of all 9.72 acres is assumed in this report. Some trees along the riverbank in Pool 5 are also expected to fall after removal of GRLD5 due to the loss of hydrostatic pressure from the pooled water. These trees are also considered to be suitable summer habitat for the Indiana bat. To estimate the amount of tree fall that will occur in Pool 5, aerial photographs of Pool 6 were reviewed from before and after removal of GRLD6. The review began at the former location of GRLD6 and continued for 10 miles upstream. An average of 19 fallen trees per river mile was estimated for this reach, and a similar amount of tree fall is expected in Pool 5. The length of Pool 5 between GRLD5 and GRLD6 is 13.6 miles; therefore, the estimated tree fall from the proposed Action is 258 trees. Using the single tree method for calculating habitat described in the *Revised Conservation Strategy for Forest-Dwelling Bats in the Commonwealth of Kentucky* (USFWS KFO 2016) where each tree is 0.09 acre, 23.22 acres of trees are anticipated to fall along Pool 5 after removal of GRLD5.

The loss of suitable summer habitat will result in adverse effects to the Indiana bat. Adverse effects will be mitigated through a payment to the Imperiled Bat Conservation Fund (IBCF), utilizing the process set forth in the *Revised Conservation Strategy for Forest-Dwelling Bats in the Commonwealth of Kentucky* (June 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* that supports the conservation strategy. As a result, an analysis of effects to the Indiana bat from the removal of suitable summer habitat as a result of the proposed Action is not included in this assessment.

The work area is located in "Known Swarming 2" habitat for the Indiana bat. Efforts will be made to remove trees in the work area during the unoccupied period for this habitat (November 15 to August 15); however, based on the construction schedule and site conditions, tree removal may occur during the occupied period (August 16 to November 14). As a result, a multiplier of 2.0 will be applied to the 9.72 acres of tree removal within the work area to mitigate for the potential removal of "Known Swarming 2" habitat 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. If tree removal activities for the Action are necessary between these dates, further consultation with the USFWS KFO will be initiated.

Pool 5 is located in two habitat types, including 18.27 acres located in "Potential" habitat and 4.95 acres located in "Known Swarming 1" habitat. Tree fall along Pool 5 may occur during any time of the year, including the occupied periods for "Potential" (April 1 to October 14) and "Known Swarming 1" (August 16 to November 14) habitat. A multiplier of 1.0 will be applied to the 18.27 acres of "Potential" habitat, and a multiplier of 2.5 will be applied to the 4.95 acres of "Known Swarming 1" 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 \$196,333.20, as summarized in the table below.

Location	Habitat Type	Timeframe	Habitat Impact	Price Per Acre*	Multiplier	Payment
Work Area	Swarming 2	Occupied	9.72 acres	\$3,920	2.0	\$76,204.80
Action Area (10.7 mi)	Potential	Occupied	18.27 acres	\$3,920	1.0	\$71,618.40
Action Area (2.9 mi)	Swarming 1	Occupied	4.95 acres	\$3,920	2.5	\$48,510.00
				Total Payme	ent Amount	\$196,333.20

\*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 bats due to their ability to tolerate these disturbances. Tree removal for the proposed Action will occur during site preparation, and noises 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.

Noise and vibrations generated by demolition activities will occur after suitable Indiana bat habitat has been removed, increasing the distance between these disturbances and suitable habitat outside the 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 of the lock river wall 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 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 northern long-eared bat is reasonably certain to occur within the Action Area. As discussed in Section 1.3.1, the Action Area is located in two quadrangles, Rhoda and Mammoth Cave, that contain one or more known maternity roost trees and one or more known hibernacula (Figure 4). Redwing contacted the USFWS KFO to determine the proximity of the Action Area to these features, and the USFWS KFO confirmed that the Action Area is located greater than 0.25 mile from the known hibernacula and 150 feet from the known maternity roost trees (Carrie Allison, USFWS, personal communication, August 11, 2020). These conditions are considered to be consistent with and addressed via the northern long-eared bat final 4(d) rule (USFWS 2015a) and the USFWS's January 5, 2016 Intra-Service Programmatic Biological Opinion on the final 4(d) rule for the northern long-eared bat (USFWS 2015b). Therefore, use of the 4(d) rule is proposed to address adverse effects to the northern long-eared bat from the proposed Action.

# 3.3.4 Purple Cat's Paw, Northern Riffleshell, Snuffbox, and Clubshell

Although the Green River provides suitable habitat for the 11 mussel species, the purple cat's paw, northern riffleshell, snuffbox, and clubshell have either never been documented in this portion of the river or are only known from historic records. The OKNP report includes records for the clubshell and northern riffleshell within and/or upstream of the Action Area; however, these records do not have a date, and no recent occurrences have been documented. No records for the purple cat's paw are included in the OKNP report. Records for the snuffbox are included in the OKNP report, including one record within the Action Area from 1987 and one record upstream from 1989. However, based on the age of these records and the lack of live snuffbox individuals or relic shells encountered in Green River Pools 4, 5, and 6 during surveys over the last 10 years, the presence of this species in the Action Area is considered unlikely (Chad Lewis, Lewis Environmental Consulting, Inc., personal communication, October 15, 2020). Based on this data, these four mussel species are unlikely to be present in the Action Area. As a result, adverse effects to these species are not anticipated from the proposed Action.

# 3.3.5 Kentucky Cave Shrimp

Critical habitat for the Kentucky cave shrimp is not located within the Action Area, and the Echo River groundwater basin, where the habitat is located, drains into the Green River more than two miles upstream of the Action Area (approximately RM 197.2). The Hydrologic and Hydraulic Analysis included in the Disposition Study (USACE 2014) shows that the 100% duration flow for August (base flow) at RM 197 is anticipated to remain the same after removal of GRLD5. Based on the distance of the Echo River groundwater basin from the Action Area and lack of measurable difference in the river level at the basin confluence after dam removal, the proposed Action is not anticipated to impact critical habitat for the Kentucky cave shrimp.

No suitable habitat for the Kentucky cave shrimp is present in the Action Area; however, the Turnhole—Double Sink, Turnhole, and Ganter Bluehole groundwater basins drain to the Green River in the upstream portion of the Action Area and could be impacted by the proposed Action. Therefore, potential effects to this species and its habitat from the Action are discussed below.

The Turnhole–Double Sink, Turnhole, and Ganter Bluehole groundwater basins emerge at springs adjacent to the Green River. The springs for the Turnhole–Double Sink and Turnhole basins emerge adjacent to each other along the left descending bank of the Green River at approximately RM 192.8 (Figure 5). The Turnhole–Double Sink basin emerges at three adjacent springs located above the riverbank, including Stilling Well Spring, Notch Spring, and Knab Spring. Groundwater from this basin also emerges from Sandhouse Cave, located immediately east of these springs. Water typically surfaces and remains pooled at the back of the cave; however, water flows through a stream channel into the river during high flows. The Turnhole basin emerges from Turnhole Spring, located immediately east of Sandhouse Cave. Groundwater flows from a subterranean passage below the elevation of the Green River and forms a large pool that connects directly to the Green River. The Ganter Bluehole basin emerges at Ganter Bluehole, located in the floodplain adjacent to the Green River at approximately RM 194.8 (Figure 5). Groundwater surfaces at the bluehole, then flows approximately 90 feet before reaching the river.

Based on the connection of the springs to the Green River, the hydrology of the groundwater basins is influenced by the water level of the river. When the river exhibits low or normal flow, groundwater flows from the springs into the river. During high flow, water from the river may backflow into the basins through the springs, depending on the force of the river and the amount of groundwater flowing from the basin. When water backflows into the groundwater basins, sediment, detritus, and other organic material from the river are deposited in the basins. The input of these materials is vital to the survival and food supply of the Kentucky cave shrimp, and one flooding event can provide food for weeks or months after the water has subsided (Leitheuser et al. 1984). Changes to water levels in the river from the removal of GRLD5 could

alter the hydrology and base water level of the groundwater basins, potentially resulting in impacts to the Kentucky cave shrimp and its habitat.

The portion of the Green River where the Turnhole–Double Sink, Turnhole, and Ganter Bluehole groundwater basins flow into the river was previously affected by GRLD6. The presence of GRLD6 and seasonal variations in the water level caused this portion of the river to fluctuate between pooled and free-flowing conditions. During pooled periods when the water level in the river was higher, the base water level in the groundwater basins was also higher. When the river was free-flowing, base water levels in the groundwater basins lowered and resembled more natural conditions. A breach in the dam in 2016 caused the water level upstream to drop by approximately 10 feet, and removal of GRLD6 in 2017 restored this portion of the river to free-flowing conditions (KSNPC 2017). As a result, the base water level in the river is lower than it has been since the dam was constructed over 100 years ago. Due to the hydrologic connection between the river and groundwater basins, the base water level in the three groundwater basins is also lower than it has been since dam construction.

Although the base water level of the Green River and the Turnhole–Double Sink, Turnhole, and Ganter Bluehole groundwater basins is lower since removal of GRLD6, the change does not appear to have significantly altered habitat for the Kentucky cave shrimp in the groundwater basins. The Kentucky cave shrimp typically inhabits the bottoms of deep, base level pools that have a direct hydrologic connection to the river and are therefore more permanent than pools at higher elevations in the basins that only receive water when the river floods or during precipitation events (USFWS 1988). Although the base level of basin pools inhabited by this species may be lower, evidence suggests that these pools maintain sufficient amounts of water and depth to support the Kentucky cave shrimp.

Observations of the pool at the back of Sandhouse Cave revealed that the base water level is lower since the removal of GRLD6; however, the size and depth of the pool indicate that base water levels in the Turnhole–Double Sink basin remain high enough for the Kentucky cave shrimp (Rick Toomey, MCNP, personal communication, December 3, 2020). The pool formed by Turnhole Spring adjacent to the river is also lower since dam removal; however, the spring emerges below the elevation of the river bottom, and the subterranean passages that connect the Turnhole basin to the river remain inundated. Although direct observations of the basin interior have not been performed, the water level of the Turnhole Spring pool and known morphology of the basin indicate that suitable habitat for the Kentucky cave shrimp has not been significantly impacted. Observations at Ganter Bluehole also revealed a reduction in water level; however, the amount and depth of water in the pool appear to be sufficient to maintain suitable habitat for this species in the Ganter Bluehole basin (Rick Toomey, MCNP, personal communication, December 3, 2020).

The removal of GRLD6 and restoration of this portion of the Green River to free-flowing conditions has restored the basins to more historic conditions that have greater similarity to the natural environment where the species evolved. According to the current five-year review for this species prepared by the USFWS in 2016, the presence of GRLD6 was considered to have an adverse effect on the Kentucky cave shrimp due to the loss of free-flowing conditions in the Green River, which caused siltation of suitable habitat within the groundwater basins inhabited by the species. This increased sediment covered areas of the sand and gravel substrates where individuals feed, as well as inhibited the transport of organic matter downstream through the karst system. The review also cites assessments and reviews completed by three federal agencies that concluded that removal of GRLD6 would benefit the Kentucky cave shrimp by restoring the Green River to free-flowing conditions and reducing sedimentation of habitat for this species (USFWS 2016).

The biology of the Kentucky cave shrimp also suggests that the species is unlikely to have been significantly affected by the lowering of base water levels in the Turnhole–Double Sink, Turnhole, and Ganter Bluehole groundwater basins. The amount and distribution of water in the basins fluctuates frequently as river levels change and runoff from precipitation enters the karst system. This species evolved in these fluctuating conditions and is habituated to the changes in flow and water levels that occur in the basins. Kentucky cave shrimp are free-swimming, and their mobility allows individuals to move as required to remain in suitable areas (USFWS 1988). Surveys of accessible pools have shown that individuals may be present during one survey, absent during the next survey, then present again during a subsequent survey, showing that the species frequently moves throughout the basins as the hydrology changes (USFWS 1988). Based on these factors, individuals were likely able to react to the reduction in base water levels in the basins as they would to natural water level fluctuations.

Based on the presumed lack of significant impacts to the Kentucky cave shrimp and its habitat in the Turnhole–Double Sink, Turnhole, and Ganter Bluehole groundwater basins after the failure and removal of GRLD6 and the positive effects anticipated from restoration of the Green River to free-flowing conditions, the removal of GRLD5 is not anticipated to result in significant impacts to this species or its habitat. The springs that connect the three basins to the Green River are located at the upstream extent of the Action Area approximately 24.7 miles or greater from GRLD5. Based on the Hydrologic and Hydraulic Analysis included in the Disposition Study (USACE 2014), the removal of GRLD5 will result in minimal change to the existing water level of the Green River at the location of the basins. Comparison of model output with GRLD6 removed to model output with GRLD6 and GRLD5 removed shows a difference of only 0.3 feet in elevation for the 50% duration flow for August (lowest modeled river level) at the springs for the Turnhole–Double Sink and Turnhole groundwater basins. The same modeling shows a difference of only 0.2 feet in elevation at Ganter Bluehole. Due to the minimal change in water level in the Green River after removal of GRLD5, changes to the base water level in the groundwater basins is expected to be even less significant.

Reduction of base water levels will also occur more slowly during removal of GRLD5 than occurred after failure of GRLD6 due to the incremental demolition of the dam. As a result, the incremental changes to base water levels in the groundwater basins after removal of GRLD5 will be considerably reduced compared to the changes after removal of GRLD6. Based on the minimal impacts anticipated to the Turnhole–Double Sink, Turnhole, and Ganter Bluehole groundwater basins from removal of GRLD5, effects to the Kentucky cave shrimp as a result of the proposed Action are considered insignificant.

#### 3.3.6 Price's Potato-bean

Based on the lack of suitable habitat in the northern portion of the work area and the lack of Price's potatobean found in the southern portion of the work area, 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".

# 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 the proposed Action are considered to be consistent with and addressed via the northern long-eared bat final 4(d) rule (USFWS 2015a) and the USFWS's January 5, 2016 Intra-Service Programmatic Biological Opinion on the final 4(d) rule for the northern long-eared bat (USFWS 2015b). Therefore, use of the 4(d) rule is proposed to address adverse effects to the northern long-eared bat from the proposed Action. As a result, the effects determination for the northern long-eared bat as a result of the Action is "may affect, likely to adversely affect", but take is not prohibited under the 4(d) rule.

# 3.4.4 Purple Cat's Paw, Northern Riffleshell, Snuffbox, and Clubshell

Based on the presumed absence of the purple cat's paw, northern riffleshell, snuffbox, and clubshell in the Action Area, effects to these species are considered discountable. Therefore, the effects determination for these four mussel species a result of the Action is "may affect, not likely to adversely affect".

# 3.4.5 Kentucky Cave Shrimp

Based on the absence of this species in the Action Area and minimal impacts anticipated to habitat within the Turnhole–Double Sink, Turnhole, and Ganter Bluehole groundwater basins, effects to the Kentucky cave shrimp are considered insignificant. Therefore, the effects determination for the Kentucky cave shrimp as a result of the Action is "may affect, not likely to adversely affect".

# 3.4.6 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

Background information for the seven mussel species proposed for formal consultation is presented below, including species status, distribution, and habitat.

# 4.1 SPECTACLECASE

The spectaclecase was listed as endangered under the ESA on April 12, 2012 (USFWS 2012). Historically, the spectaclecase occurred in at least 45 streams in the Mississippi, Ohio, and Missouri River basins in 15 states, including Alabama, Arkansas, Illinois, Indiana, Iowa, Kansas, Kentucky, Minnesota, Missouri, Nebraska, Ohio, Tennessee, Virginia, West Virginia, and Wisconsin (NatureServe 2020). Extant populations of the spectaclecase are only known from 20 streams in 11 states. These streams include: the Tennessee River in Alabama; Mulberry and Ouachita Rivers in Arkansas; Mississippi and Ohio Rivers in Illinois; Mississippi River in Iowa; Ohio, Green, and Cumberland Rivers in Kentucky; Mississippi and St. Croix Rivers in Minnesota and Wisconsin; Mississippi, Meramec, Bourbeuse, Big, Gasconade, Sac, Osage, and Big Piney Rivers and Osage Fork in Missouri; Tennessee, Clinch, Nolichucky, and Duck Rivers in Tennessee; Clinch River in Virginia; and Kanawha River in West Virginia. Of the 20 extant populations, six are represented by only one or two recent specimens and are likely declining, and some may be extirpated. Most surviving populations face significant threats, are highly fragmented, and restricted to short stream reaches (USFWS 2012).

In Kentucky, the spectaclecase is known from the Ohio, Green, and Cumberland Rivers. Since this species was first recorded in the Green River in the mid-1960s, it has been collected sparingly. Currently, a small population of this species remains in the upper Green River from below Lock and Dam 5 upstream through MCNP and into western Hart County. Most recent specimens have been reported from the upstream portion of this reach, where it is generally distributed from MCNP upstream to western Hart County. The long-term sustainability of the Green River population is questionable and its status is currently unknown (USFWS 2012).

The spectaclecase generally inhabits large rivers and is found in microhabitats sheltered from the main force of current. It occurs in substrates from mud and sand to gravel, cobble, and boulders, in relatively shallow riffles and shoals with a slow to swift current (NatureServe 2020).

# 4.2 FANSHELL

The fanshell was listed as endangered under the ESA on June 21, 1990 (USFWS 1990). Its historic distribution includes the Ohio, Wabash, Cumberland, and Tennessee Rivers and their larger tributaries in Alabama, Illinois, Indiana, Kentucky, Ohio, Pennsylvania, Tennessee, Virginia, and West Virginia (USFWS)

1991a); however, less than 10 percent of its historic range is still occupied (Jones and Neves 2002). Extant populations currently exist in portions of the Muskingum River in Ohio, Kanawha River in West Virginia, Ohio River between Cincinnati and Pittsburgh, Wabash River in Illinois and Indiana, East Fork White and Tippecanoe Rivers in Indiana, Tennessee River in Tennessee, and Green, Licking, and Rolling Fork Rivers in Kentucky. The best remaining populations occur in the Licking, Green, and Rolling Fork Rivers in Kentucky and in the Clinch River in Tennessee and Virginia (USFWS KFO 2009), with reproducing populations known from the upper Clinch, Green, and Licking Rivers (Jones and Neves 2002). Small remnant populations may also exist in the Muskingum River, Walhonding River, Wabash River, Tippecanoe River, Kanawha River, Tygarts Creek, Barren River, Cumberland River, and Tennessee River (USFWS 1991a). The fanshell inhabits gravel substrate in medium to large rivers with moderate current.

# 4.3 PINK MUCKET

The pink mucket was listed as endangered under the ESA on June 14, 1976 throughout its entire range in Alabama, Arkansas, Illinois, Indiana, Kentucky, Louisiana, Missouri, Ohio, Pennsylvania, Tennessee, Virginia, and West Virginia (USFWS 1976). Historically, this species was known from the Mississippi, Tennessee, Ohio, and Cumberland River systems; however, this species has never been collected in large numbers and has usually been considered rare (USFWS 1985). The pink mucket is still geographically widespread but remains in only 16 of the 25 rivers it once inhabited (NatureServe 2020). This species has been reported from: the Clinch River in Tennessee; lower Ohio and Green Rivers in Kentucky; Big, Black, Little Black, and Gasconade Rivers in Missouri; and the Current River in Arkansas. Rivers with evidence of pink mucket recruitment include the Tennessee, Cumberland, Paint Rock, and Meramec (USFWS 1985). This species is considered extirpated from Ohio, except for possibly small parts of the Ohio River, and from Pennsylvania (NatureServe 2020). The pink mucket likely occurred over the lower half of the Green River but is now uncommon (USFWS 2018).

The pink mucket inhabits large rivers with swift currents and is found at depths of 1.6 feet to 26.2 feet in mixed sand, gravel, and cobble substrate. This species appears to have adapted to reservoir-type conditions in the upper reaches of some impoundments and prefers mud and sand substrates in these slower waters (USFWS 1985).

#### 4.4 RING PINK

The ring pink was listed as endangered under the ESA on September 29, 1989 throughout its entire range in Alabama, Indiana, Kentucky, Pennsylvania, and Tennessee (USFWS 1989). Historically, the ring pink was widely distributed in the Ohio, Cumberland, and Tennessee River systems in Pennsylvania, West Virginia, Ohio, Illinois, Indiana, Kentucky, Tennessee, and Alabama (USFWS 2011, USFWS 2017);

however, it is currently believed to have been extirpated from all but five river reaches in Kentucky, Tennessee, and West Virginia. These reaches are located in the Tennessee River in Kentucky and Tennessee, the Green River in Kentucky, the Cumberland River in Tennessee, and the Kanawha River in West Virginia. The remaining populations within these rivers are not considered to be reproducing (USFWS 1991b, USFWS 2011, USFWS 2017). In Kentucky, the ring pink is known to occur in the Tennessee River in McCracken, Livingston, and Marshall Counties and in the Green River in Hart and Edmonson Counties (USFWS 2011). The ring pink inhabits large rivers in shallow water with gravel and sand substrate (USFWS 2017).

#### 4.5 SHEEPNOSE

The sheepnose was listed as endangered under the ESA on April 12, 2012 throughout its entire range in Alabama, Illinois, Indiana, Iowa, Kentucky, Minnesota, Mississippi, Missouri, Ohio, Pennsylvania, Tennessee, Virginia, West Virginia, and Wisconsin (USFWS 2012). Historically, the sheepnose was known to occur throughout much of the Mississippi River system (NatureServe 2020); however, this species has been extirpated from over 65 percent of its historical range (25 streams currently from 77 streams historically), including thousands of miles of the Mississippi, Wisconsin, Illinois, Ohio, Cumberland, and Tennessee Rivers and their tributaries. Of the 25 extant populations, nine are thought to be stable and eight are considered to be declining. The Allegheny River in Ohio and the Green River in Kentucky are the only locations where the species is considered to be improving in population status. Six other populations are considered extant; however, the status of these populations is unknown. In Kentucky, populations exist in the Ohio, Licking, Kentucky, and Green Rivers (USFWS 2012).

The sheepnose is generally considered a large-river species; however, it also inhabits medium-sized rivers. The species is typically found in deep water (greater than two meters) with slight to swift currents and mud, sand, or gravel bottoms. The sheepnose may also inhabit riffles with gravel/cobble substrates, and appears capable of surviving in reservoirs (NatureServe 2020).

# 4.6 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). 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).

#### 4.7 RABBITSFOOT

The rabbitsfoot was listed as threatened under the ESA on October 17, 2013. Historically, this species is known from 140 streams within the Lower Great Lakes Sub-basin and Mississippi River Basin, which includes portions of Alabama, Arkansas, Georgia, Illinois, Indiana, Kansas, Kentucky, Louisiana, Mississippi, Missouri, Ohio, Oklahoma, Pennsylvania, Tennessee, and West Virginia. The current range of the rabbitsfoot includes 51 streams in 13 states, representing a 64 percent decline in streams with extant populations (USFWS 2013).

In Kentucky, rabbitsfoot populations are considered to be present in the Ohio River, Green River, South Fork Kentucky River, Barren River, Rough River, Red River, and Tennessee River. Populations appear to be declining in these rivers, with the exception of the Ohio River, Tennessee River, and Green River (USFWS 2015c). Populations in the Green River span nearly 150 river miles, with historical records dating back to the early 1900s. Recent surveys in the Green River have resulted in high numbers of individuals in Adair, Hart, and Green Counties, Kentucky, and populations appear to be increasing based on evidence of recruitment (Butler 2005). To protect these populations, 109.1 river miles (175.6 river km) of the Green River, from Green River Lake Dam in Taylor County, Kentucky to Maple Springs Ranger Station Road in MCNP, Edmonson County, Kentucky, have been designated as critical habitat for the rabbitsfoot (USFWS 2015c).

The rabbitsfoot typically inhabits small to large rivers with moderate to swift currents and also occurs in smaller streams with swift currents (Gordon and Layzer 1989). The species is found in shallow water areas along banks and bars, as well as deep water runs at depths of up to 12 feet (3.7 m) (Parmalee 1967). Substrates in these areas primarily consist of sand, gravel, and cobble (Parmalee and Bogan 1998). Individuals seldom burrow into the substrate, instead lying on their sides on top of the substrate (Fobian 2007).

#### 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 seven mussel species, 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

Numerous mussel surveys have been conducted in Green River Pools 4, 5, and 6 in the past 10 years. During these surveys, multiple individuals of the fanshell, pink mucket, rough pigtoe, and sheepnose were documented within, upstream, and downstream of the Action Area. Multiple individuals of the spectaclecase were documented upstream and downstream of the Action Area, and one ring pink was found upstream of the Action Area.

The OKNP report includes one recent record (2012) for the spectaclecase in the Action Area and one record (1989) for the ring pink upstream of the Action Area. The survey results and occurrence records are summarized in the following table.

Species	Downstream of Action Area	Action Area	Upstream of Action Area	No Records
fanshell	X	Х	X	
pink mucket	X	Х	X	
rabbitsfoot				Х
ring pink		X*	X	
rough pigtoe	X	Х	X	
sheepnose	X	Х	X	
spectaclecase	X	Х	X	

<sup>\*</sup> no date listed in the OKNP report

As shown in the table, six of the seven mussel species have been documented within the Action Area. The ring pink was documented upstream of the Action Area in 1989 and 2015, and relic shells have been found in Pool 4 downstream of GRLD5 during recent surveys (Chad Lewis, Lewis Environmental Consulting, Inc., personal communication, October 15, 2020). As a result, this species has the potential to occur within the Action Area. No records for the rabbitsfoot are known from within or near the Action Area; however, based on the prevalence of this species in the upper Green River and the presence of designated critical habitat approximately two miles upstream of the Action Area, this species has the potential to occur within the Action Area. The results of mussel surveys performed within the Action Area are discussed further below.

Surveys were performed within the portion of Pool 4 within the Action Area by Lewis Environmental Consulting, LLC (Lewis) in 2017 and 2019. The 2017 survey consisted of qualitative searches in four areas immediately downstream of GRLD5, including one area adjacent to the lock wall and three areas in a gravel bar located approximately 300 feet downstream of the dam. During the survey, a total of 1,245 live mussels from 25 unionid species were encountered. Two fanshell individuals and one rough pigtoe individual were found in the gravel bar more than 400 feet downstream of the dam.

During the 2019 survey, Lewis utilized semi-quantitative and qualitative methods to survey an area in Pool 4 from 0.2 mile to 1.1 mile downstream of GRLD5. The semi-quantitative portion consisted of eight transects at approximately 200 meter intervals. The qualitative portion included searches of eight areas with the most significant mussel populations. A total of 6,629 live mussels from 33 unionid species were found during the survey. Federally listed individuals included 105 fanshells, 25 rough pigtoes, two pink muckets, and one sheepnose. Fanshell and rough pigtoe individuals were found throughout the survey area, beginning approximately 0.3 mile downstream of GRLD5. The sheepnose individual and two pink mucket individuals were found near the downstream extent of the survey area. One juvenile fanshell (i.e., <5 years old) was encountered during the survey, as well as 19 five-year old fanshell individuals.

Lewis conducted a mussel survey in Pool 5 in 2017 that included 13.5 miles of the Green River from approximately 0.25 mile upstream of GRLD5 to the previous location of GRLD6. Semi-quantitative methods were primarily used during the survey, including 28 transects located approximately 800 meters apart. Five qualitative searches were also performed in the upstream extent of the survey area where significant mussel populations were found. During the survey, a total of 539 live mussels from 27 unionid species were encountered.

The semi-quantitative portion of the survey resulted in a total of 279 live mussels representing 23 species. Only two non-listed mussels, the threehorn wartyback (*Obliquaria reflexa*) and pink papershell (*Potamilus ohiensis*), were found from the dam to approximately 1.6 miles upstream. These two species are often found in slackwater or pooled areas and are tolerant of river impoundments (Grabarkiewicz and Davis 2008, Watters et. al 2009).

Mussel abundance and diversity remained low from 1.6 miles to 4.6 miles upstream, where only one to six individuals were found along each transect. Species found in this reach included the pocketbook (*Lampsilis ovata*), washboard (*Megalonaias nervosa*), and pink heelsplitter (*Potamilus alatus*), all of which are tolerant of impoundments and dam pools (Parmalee and Bogan 1998). Abundance and diversity increased slightly from 4.6 miles to 12.6 miles upstream, with one to 14 individuals of one to five species per transect. Species tolerant of impoundments and pools continued to comprise the majority of individuals encountered in this reach, with a few individuals typical of more lotic habitats also observed, such as the plain pocketbook

(Lampsilis cardium), yellow sandshell (Lampsilis teres), and black sandshell (Ligumia recta) (Parmalee and Bogan 1998). Only above 12.6 miles upstream of GRLD5 did mussel abundance and diversity begin to compare with those found downstream of GRLD5 in 2019. Species composition began to favor species found in lotic environments, and one fanshell individual was encountered approximately 13.4 miles upstream of GRLD5.

Based on the survey results, the portion of the Green River from GRLD5 to approximately 4.6 miles upstream does not provide suitable habitat for the seven mussel species. The portion of the river between approximately 4.6 miles and 12.6 miles may contain areas of marginal habitat for these species; however, the majority of this reach appears to provide poor-quality or unsuitable habitat. Beyond 12.6 miles upstream of GRLD5, suitable habitat for the seven mussel species appears to be present.

The Kentucky Department of Fish and Wildlife Resources Center for Mollusk Conservation has also conducted surveys and monitoring in the Action Area. The Center for Mollusk Conservation established and monitors a release site for propagated mussels in Pool 4 approximately 1.3 miles downstream of GRLD5. Surveys are performed every five years to monitor the mussel population at the site. In 2006, seven rough pigtoe individuals were found at the site, and in 2011, three rough pigtoe individuals and three fanshell individuals were encountered. The most recent survey in 2016 documented 10 rough pigtoe individuals, five fanshell individuals, and one pink mucket individual.

The Center for Mollusk Conservation also performed surveys in the portion of Pool 6 within the Action Area in 2016 and 2017. During the 2016 survey, one fanshell individual and one sheepnose individual were found approximately 20.4 miles upstream of GRLD5. Three other sheepnose individuals were encountered approximately 22.9 miles, 23.9 miles, and 24.4 miles, respectively, upstream of GRLD5. The 2017 survey found one sheepnose individual approximately 22.8 miles upstream of GRLD5, as well as a sheepnose individual and a fanshell individual approximately 23.8 miles upstream of GRLD5.

# 5.2 ACTION AREA NUMBERS, REPRODUCTION, AND DISTRIBUTION

The results of the previous mussel surveys were used to calculate densities and estimate the number of individuals in the Action Area for the seven mussel species. Mussel survey data from Pool 4 was used for the portion of the Action Area downstream of GRLD5, and data from Pool 5 was used for the portion of the Action Area upstream of GRLD5.

### 5.2.1 Action Area Downstream of GRLD5

Semi-quantitative data from the 2019 Lewis survey of Pool 4 was used to calculate mussel densities downstream of GRLD5. During the survey, 1,481 mussels were found along the eight transects, which included an area of 422 square meters. Based on these results, Lewis calculated a density of 3.51 mussels per square meter in the semi-quantitative survey area. A total of 22 fanshell individuals were found during the semi-quantitative survey; therefore, the estimated density for this species is 0.0521 mussels per square meter (22 individuals  $\div$  422 m² in survey area = 0.0521 mussels/m²). Three rough pigtoe individuals were also encountered during the survey, resulting in an estimated density of 0.0071 mussels per square meter.

Although not found during the semi-quantitative survey, two pink mucket individuals and one sheepnose individual were encountered during the qualitative searches. The spectaclecase was not found during the 2019 survey; however, this species has been documented within the Action Area downstream of GRLD5. Based on the occurrence of these three species in the Action Area, one individual of each species is likely to be present within the semi-quantitative survey area, resulting in an estimated density of 0.0024 mussels per square meter. No individuals of the rabbitsfoot or ring pink were encountered during the survey, and these species have not been documented in this portion of the Green River. Although presence of these two species has not been confirmed, these species could potentially occur in this portion of the river and are likely to be present. Therefore, one individual each of the rabbitsfoot and ring pink is likely to be present in the semi-quantitative survey area. The estimated density for these species is 0.0024 mussels per square meter. The estimated density calculated for each species in the semi-quantitative survey area downstream of GRLD5 is summarized in the following table.

Species	Estimated Density in Pool 4 Survey Area (mussels/m²)
fanshell	0.0521
pink mucket	0.0024
rabbitsfoot	0.0024
ring pink	0.0024
rough pigtoe	0.0071
sheepnose	0.0024
spectaclecase	0.0024

The estimated density calculated for each species for the semi-quantitative survey area is assumed to be similar throughout the Action Area downstream of GRLD5; 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 GRLD5 totals approximately 222,694 square meters. To calculate the estimated number of individuals of each species in the Action Area downstream of GRLD5, the Action Area size was multiplied by the estimated density for each species, which is summarized in the following table.

For example, the calculation for the estimated number of fanshell individuals is 0.0521 mussels/m<sup>2</sup> x 222,694 m<sup>2</sup> = 11,602 fanshell individuals. Each value was rounded up to the nearest whole number.

Species	Estimated Individuals in Action Area Downstream of GRLD5
fanshell	11,603
pink mucket	535
rabbitsfoot	268
ring pink	268
rough pigtoe	1,559
sheepnose	535
spectaclecase	535

# 5.2.2 Action Area Upstream of GRLD5

Semi-quantitative data from the 2017 Lewis survey of Pool 5 was used to calculate mussel densities upstream of GRLD5. A total of 279 mussels were found along the 28 transects, which encompassed an area of 2,020 square meters. Based on these results, Lewis calculated a density of 0.14 mussels per square meter. One fanshell was found during the semi-quantitative survey; therefore, the estimated density for this species is 0.0005 mussels per square meter. Although not found during the 2017 survey, the sheepnose has been documented in the portion of the Action Area upstream of GRLD5. Based on this occurrence, one sheepnose individual is likely to be present within the semi-quantitative survey area, resulting in an estimated density of 0.0005 mussels per square meter. The pink mucket, ring pink, rough pigtoe, and spectaclecase were not found during the 2017 survey; however, these four species have been documented within one to five miles upstream of the Action Area. Based on the occurrence of these four species upstream of the Action Area, one individual of each species is likely to be present within the semiquantitative survey area, resulting in an estimated density of 0.0005 mussels per square meter. No individuals of the rabbitsfoot were encountered during the survey, and this species has not been documented in this portion of the Green River. Although presence of the rabbitsfoot has not been confirmed, this species could potentially occur in this portion of the river and is likely to be present. Therefore, one individual of this species is likely to be present in the semi-quantitative survey area, with an estimated density of 0.0005 mussels per square meter. The estimated density calculated for each species in the semi-quantitative survey area upstream of GRLD5 is summarized in the following table.

Species	Estimated Density in Pool 5 Survey Area (mussels/m²)
fanshell	0.0005
pink mucket	0.0005
rabbitsfoot	0.0005
ring pink	0.0005
rough pigtoe	0.0005
sheepnose	0.0005
spectaclecase	0.0005

The estimated densities calculated for each species for the semi-quantitative survey area upstream of GRLD5 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 GRLD5 totals approximately 3,900,525 square meters. To calculate the estimated number of individuals of each species in the Action Area upstream of GRLD5, the Action Area size (3,900,525 square meters) was multiplied by the estimated density for each species (0.0005 mussels/square meter), which results in an estimate of 1,950 individuals per species in the upstream portion of the Action Area.

As discussed in Section 5.1, the portion of the Green River from GRLD5 to approximately 4.6 miles upstream does not provide suitable habitat for the seven mussel species. 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 (825,232 square meters) was multiplied by the estimated density for each species (0.0005 mussels/square meter), resulting in an estimate of 413 individuals per species. The estimated number of individuals in the unsuitable portion (413) was then subtracted from the estimated number of individuals in the entire upstream portion of the Action Area (1,950), which is summarized in the following table. Each value was rounded up to the nearest whole number.

Species	Estimated Individuals in Action Area Upstream of GRLD5
fanshell	1,537
pink mucket	1,537
rabbitsfoot	1,537
ring pink	1,537
rough pigtoe	1,537
sheepnose	1,537
spectaclecase	1,537

### 5.3 ACTION AREA CONSERVATION NEEDS AND THREATS

The primary factor affecting the seven mussel species in the Action Area is the presence of GRLD5. The dam acts as a barrier in the Green 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 Green River since construction of the dam in 1934. 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, potentially limiting contact between mussels and fish hosts and limiting reproduction.

Other factors that could affect the seven 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 Green River. Point source releases from wastewater treatment and storm water discharge also cause contamination. Contaminants may also enter the Green 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 GRLD5 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.

A biological threat to the seven mussel species 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 and have recently been observed more frequently and in greater numbers (Eggers 2019). 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. These species are expected to persist and expand in the Green River, although efforts are underway to control these invasive species (USDA 2020). Isolated occurrences of the zebra mussel (*Dreissena polymorpha*) have also been reported in the lower Green River (Haag and Cicerello 2016). 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 seven mussel species. 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 Green 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 seven mussel species 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

Clearing and grubbing, establishment of staging areas, and improvement and construction of access roads during site preparation will disturb soil near the Green 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 Green 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 installation of the culvert in the intermittent tributary to the Green River will be minimal and is expected to settle in the stream channel prior to entering the river.

Creation of the notch at the southern end of the dam will concentrate flow along the left descending bank of the river, and the increased velocity and force could lead to scouring and displacement of sediment downstream. Based on the original construction plans for GRLD5, the southern end of the dam is constructed on bedrock, and an area of exposed rock extends above the water surface for approximately

40 feet along the base of the dam during normal flow. The exposed rock also extends approximately 80 feet downstream of the dam to an area of boulders that were installed to stabilize the riverbank. Water that flows over this portion of the dam hits the rock and flows downstream, then flows riverward over the side of the exposed rock into the channel. The notch in the dam is anticipated to extend approximately 15 feet from the dam abutment, causing flow from the notch to be directed onto the exposed rock. As a result, the exposed rock, dam abutment, and boulders downstream are expected to receive the majority of force from the increased flow and will help dissipate flow before it enters the main channel of the river. During normal flow, water falls approximately two feet from the exposed rock into the river channel, which has likely caused scouring in this area. The bedrock in this area lies eight feet below the elevation of the exposed rock, and the force of the plunging water as it hits the substrate has likely removed the majority of fine sediment. As a result, significant additional scouring and sediment disturbance in this area is not anticipated. By the time water travels farther into the main channel and 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 at the base of the dam to fill the scour area and create the in-stream work pad 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, removing fines and smaller coarse sediment and leaving 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 Green River; however, some material will fall into the river during these activities. Material that lands upstream of the dam and placement of material to create the in-stream work pad for the mooring cells could disturb sediment in Pool 5. As discussed in Section 5.1, the pooled area upstream of the dam represents unsuitable habitat for the seven mussel species, and sediment disturbance is unlikely to impact listed mussels in this area. Sediment that is displaced 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 minimal amount of water flowing over the dam during this phase of demolition.

Material that falls from the lock river wall or downstream guide wall in the downstream portion of the work area could land in areas of suitable mussel habitat and cause sediment disturbance. The 2017 survey of Pool 4 showed that mussels are located near these structures, and falling material could displace sediment or cause sediment deposition in areas where individuals are located. Displaced sediment may also be transported and deposited downstream, affecting mussels beyond the impact area.

Placement of the miter gates and material into the 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 outside the miter gate may cause sediment disturbance. Similar to material falling into the river from the lock river wall and downstream guide wall, placement of material in this area could cause sediment to bury nearby mussels or affect mussels downstream. Soil placed over the filled lock chamber to create the final slope could also wash into the river during periods of high water until vegetation is established, leading to sedimentation downstream.

During and immediately after dam removal, sediment that has accumulated upstream of the dam will be moved downstream when the river is restored to free-flowing conditions. As documented in a memorandum prepared by USACE hydraulic engineers regarding changes to hydraulic conditions in the river from dam removal (Appendix C), sediment sampling was conducted by TNC upstream of the dam in 2017. The sampling results revealed that large amounts of fine sediment have not accumulated behind the dam, and that the substrate is relatively clean and free of silt. Although large amounts of fine sediment were not documented upstream of the dam, the USACE memorandum states that downstream sediment transport is expected to occur. 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 are located immediately 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 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 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 Green River through seeding of disturbed areas and dressing of roads and parking areas. 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 seven 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.

# 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 seven mussel species. 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 results of the 2017 survey of Pool 4 documented mussel beds with listed species beginning approximately 300 feet downstream of the dam, and sediment deposition could occur in areas where listed mussels are present. 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 – Muss	Effects Pathway – Mussel Species #1	
Activity: Site Preparation, Site Stabilization		
Stressor: Sediment Dist	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 Green	
	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 in the intermittent tributary are considered	
	discountable.	

Effects Pathway – Mussel Species #2	
Activity: Lock and Dam	Removal
Stressor: Sediment Dist	turbance
Exposure (time)	Duration of Activity
Exposure (space)	Work Area
Resource affected	Individuals (adults, juveniles), Habitat, Fish Hosts
Individual response	<ul> <li>Reduced respiration and feeding from clogged gills or smothering</li> <li>Disruption of metabolic processes, leading to reduced fitness and growth rates</li> <li>Reduced recruitment due to elimination of interstitial spaces used by juveniles</li> <li>Movement due to alteration or loss of habitat</li> <li>Displacement of fish hosts due to alteration or loss of habitat</li> </ul>
Conservation Measures	Perform in-stream activities during periods of low flow.

	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 seven mussel species.
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 will move downstream during and after dam removal and could bury mussels located immediately downstream of the dam.

Effects Pathway – Mussel Species #3		
Activity: Site Preparation, Site Stabilization		
Stressor: Sediment Dist	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  Conservation Measures	<ul> <li>Reduced respiration and feeding from clogged gills or smothering</li> <li>Disruption of metabolic processes, leading to reduced fitness and growth rates</li> <li>Reduced recruitment due to elimination of interstitial spaces used by juveniles</li> <li>Movement due to alteration or loss of habitat</li> <li>Displacement of fish hosts due to alteration or loss of habitat</li> <li>Implement EPSC measures in the work area.</li> <li>Revegetate disturbed areas immediately following completion of ground disturbing activities.</li> </ul>	
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 – Mussel Species #4	
Activity: Lock and Dam Removal	
Stressor: Sediment Dist	turbance
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 seven
mussel species.

Effects Pathway – Mussel Species #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 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 Green 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 seven mussel species 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 Green 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 seven mussel species. Vehicles, equipment, and felled trees will also be prohibited

from entering the river during site preparation. Placement of the culvert in the intermittent stream is not expected to cause water quality degradation in the Green 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, the notch will be located at the southern end of the dam where an area of exposed rock is present. The exposed rock, dam abutment, and boulders in this area are expected to receive the majority of force from the increased flow created by the notch and will help dissipate flow before it enters the main channel of the river. Additionally, scouring has likely occurred in the portion of the river channel below the exposed rock, removing the majority of fine sediment from this area and reducing the potential for sediment suspension. The increased flow from the notch is expected to dissipate after entering the main channel and is not anticipated to cause sediment disturbance or suspension downstream.

The placement of material downstream of the dam to create the in-stream work pad and fill 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. 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.

Material that falls into the Green 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 or the placement of material for the in-stream work pad to the mooring cells. 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. Material that is deposited on the downstream side of the dam is also not expected to cause water quality degradation due to the low potential for sediment suspension as a result of previous scouring of fine sediment from this area.

Material that falls from the lock river wall or downstream guide wall into the downstream portion of the work area could land in areas of suitable mussel habitat and cause sediment disturbance, which could degrade water quality. Material placed in the downstream extent of the lock chamber outside the miter gate could also lead to reduced water quality in this area. Based on the location of these areas in flowing water downstream of the dam, suspended sediment is not expected to remain in one area long enough to cause increased turbidity or decreased dissolved oxygen. Sediment that becomes suspended in this area is expected to move downstream quickly and settle to the bottom in existing depositional areas. Placement

of the miter gates and material into the 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 2017 sediment sampling performed by TNC, sediment transport downstream is expected. The restoration of Pool 5 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 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 Green River. During lock and dam removal, equipment will operate from the in-stream work pads downstream of the dam and at the mooring cells and will only operate 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 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.

Water quality degradation from the construction components may also result in impacts to fish hosts for the seven mussel species. 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 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 seven mussel species. 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 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 farther upstream are also likely to occur during each high flow event, and the repeated occurrence of these events could adversely affect these species.

# **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 – Muss	sel Species #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	<ul> <li>Increased turbidity and low dissolved oxygen levels could lead to reduced fitness, reduced fecundity, and/or increased mortality.</li> <li>Reduced reproduction due to inability of fish hosts to detect mussels due to increased turbidity</li> <li>Reduced aquatic food organism diversity and abundance could negatively impact mussel growth, survival, and reproduction</li> <li>Displacement of fish hosts due to alteration or loss of habitat</li> </ul>
Conservation Measures	<ul> <li>Implement EPSC measures in the work area.</li> <li>Revegetate disturbed areas immediately following completion of ground disturbing activities.</li> </ul>
Effect	Insignificant
Interpretation	Appropriate EPSC measures will be implemented and maintained throughout the work area to minimize sediment inputs into the Green River and maintain water quality. Vehicles and equipment will not enter the river, and no woody debris will be placed in the river. Water quality degradation from placement of the culvert in the intermittent tributary is considered unlikely.

Effects Pathway – Mussel Species #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	<ul> <li>Increased turbidity and low dissolved oxygen levels could lead to reduced fitness, reduced fecundity, and/or increased mortality.</li> <li>Increased turbidity results in inability of fish hosts to detect mussels, negatively affecting reproduction</li> <li>Reduced aquatic food organism diversity and abundance could negatively impact mussel growth, survival, and reproduction</li> <li>Displacement of fish hosts due to alteration or loss of habitat</li> </ul>
Conservation Measures	<ul> <li>Perform in-stream activities during periods of low flow.</li> <li>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 seven mussel species.</li> </ul>
Effect	Adverse (harm, mortality)

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 are affected.
lish hosts are affected.

Effects Pathway – Mussel Species #8	
Activity: Site Preparation	on, 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	<ul> <li>Increased turbidity, low dissolved oxygen levels, and chemical contaminants could lead to reduced fitness, reduced fecundity, and/or increased mortality.</li> <li>Increased turbidity results in inability of fish hosts to detect mussels, negatively affecting reproduction</li> <li>Reduced aquatic food organism diversity and abundance could negatively impact mussel growth, survival, and reproduction</li> <li>Increased harm or mortality of fish hosts</li> <li>Displacement of fish hosts due to alteration or loss of habitat</li> </ul>
Conservation Measures	<ul> <li>Implement EPSC measures in the work area.</li> <li>Revegetate disturbed areas immediately following completion of ground disturbing activities.</li> </ul>
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 – Mussel Species #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	<ul> <li>Increased turbidity and low dissolved oxygen levels could lead to reduced fitness, reduced fecundity, and/or increased mortality.</li> <li>Increased turbidity results in inability of fish hosts to detect mussels, negatively affecting reproduction</li> <li>Reduced aquatic food organism diversity and abundance could negatively impact mussel growth, survival, and reproduction</li> <li>Displacement of fish hosts due to alteration or loss of habitat</li> </ul>
Conservation Measures	Perform in-stream activities during periods of low flow.
Effect	Insignificant
Interpretation	No construction components will occur in the Action Area downstream 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 seven mussel species.

Effects Pathway – Mussel Species #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	<ul> <li>Increased turbidity and low dissolved oxygen levels could lead to reduced fitness, reduced fecundity, and/or increased mortality.</li> <li>Increased turbidity results in inability of fish hosts to detect mussels, negatively affecting reproduction</li> <li>Reduced aquatic food organism diversity and abundance could negatively impact mussel growth, survival, and reproduction</li> <li>Displacement of fish hosts due to alteration or loss of habitat</li> </ul>	
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 in the downstream portion 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 are affected.	

Effects Dathwey Must			
Effects Pathway – Muss	on, Lock and Dam Removal, Site Stabilization		
Stressor: Water Quality			
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	<ul> <li>Reduced fitness, reduced fecundity, and/or increased mortality</li> <li>Increased harm or mortality of fish hosts</li> <li>Displacement of fish hosts due to alteration or loss of habitat</li> </ul>		
Conservation Measures	<ul> <li>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 seven mussel species.</li> <li>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.</li> <li>Remove any remaining hydraulic fluid from the hydraulic piping system in the operations building and lock chamber and dispose of appropriately.</li> </ul>		
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 t	the work a	area would	likely be	diluted
before rea	ching this porti	on of the Action	on Area.		•	

Effects Pathway – Mussel Species #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	<ul> <li>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 seven mussel species.</li> <li>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.</li> </ul>		
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 with the flow of the river.		

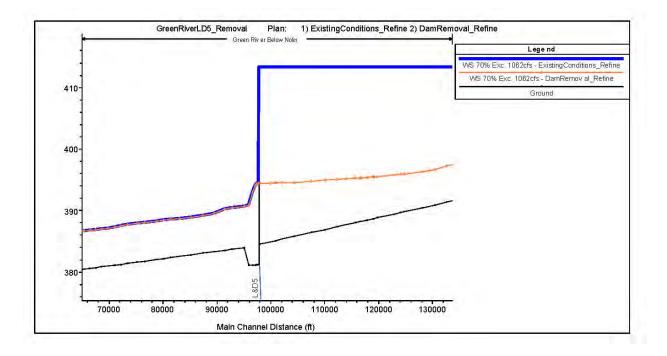
### 6.3 CHANGES TO FLOW

Lock and dam removal is the only construction component that could result in changes to flow in the Green 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 seven mussel species 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 Green River after removal of GRLD5 were analyzed by the USACE based on previous hydraulic modeling. The memorandum prepared by the USACE summarizes the findings and is included as Appendix C. According to the USACE memorandum, GRLD5 is a run-of-river type dam and does not significantly impound flood water within Pool 5. 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 5 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 USACE memorandum.



The exhibit shows 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 in the USACE memorandum, GRLD5 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.

## Action Area Upstream of Work Area

Changes in flow will occur in the upstream portion of the Action Area as Pool 5 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 5 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 occur in unsuitable habitat for the seven mussel species, 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 GRLD5 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 – Mussel Species #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 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 – Mussel Species #14		
Activity: Lock and Dam Removal		
Stressor: Changes to F	low	
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 within unsuitable habitat for the seven mussel species.	

Effects Pathway – Mussel Species #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 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.

#### 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 seven mussel species 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 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. The spectaclecase is known to occur in mud between large rocks and under slab boulders and bedrock shelves and could potentially be present within sheltered portions of the dam or the areas of boulders and bedrock immediately downstream (USFWS 2012). The presence of the other six listed mussels 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; however, 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 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 the seven mussel species in this area.

Material that falls from the lock river wall or downstream guide wall and the placement of material in the downstream extent of the lock chamber could also crush or strike individuals, as mussels have been found near these structures. 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.

## 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 – Mussel Species #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	
<u>Effect</u>	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.	

Effects Pathway – Mussel Species #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 seven mussel species 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 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. Based on the location of notching and current conditions in this area described in Section 6.1, 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 due to the exposed rock present in this area. The exposed rock, dam abutment, and boulders downstream are expected to receive most of the force from the increased flow in the work area and will help dissipate flow before it enters the main channel of the river. The area where water flows from the exposed rock into the main channel is also unsuitable for mussels due to the force and turbulence of the flow as it drops from the rock. 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 at the base of the dam to fill the scour area and create the in-stream work pad 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 seven mussel species in this area.

Material that falls from the lock river wall or downstream guide wall and the placement of material in the downstream extent of the lock chamber may have a greater potential to displace individuals due to the presence of more fine sediment in these areas; however, displaced individuals are anticipated to remain in close proximity to their original location within suitable habitat. Displacement of individuals during placement of the miter gates and material into the lock chamber is unlikely 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 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.

## 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 along the left descending bank 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.

## 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 – Mussel Species #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 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.	

Effects Pathway – Mussel Species #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	
<u>Effect</u>	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 GRLD5 will lower the water level of the Green 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 seven mussel species 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 seven mussel species; therefore, the lower water level 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 Green River throughout the upstream portion of the Action Area. As discussed in Section 5.1, the portion of the river between GRLD5 and 12.6 miles upstream was deemed to provide unsuitable to poor-quality habitat for the seven mussel species. Habitat improves beyond 12.6 miles upstream of GRLD5, and this area appears to provide suitable habitat for the listed species. Based on the Hydrologic and Hydraulic Analysis included in the Disposition Study (USACE 2014), removal of GRLD5 will lower the water level 12.6 miles upstream by approximately 10 to 12 feet based on the 100% duration flow for August (base flow). The difference in water level will decrease with increasing distance from GRLD5 to the end of the Action Area at RM 195. After the dam is notched, the water level in Pool 5 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.

# Action Area Downstream of Work Area

The water level of the Green River in the downstream portion of the Action Area will not be influenced by the removal of GRLD5. 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 – Mussel Species #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			
	<ul> <li>Movement of individual to deeper water, which may lead to increased energy expenditure and decreased fitness</li> </ul>			
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 GRLD5. Removal of the dam will lower			

the water level in the work area upstream of GRLD5; however, this area does
not provide suitable habitat for the listed mussel species.

Effects Pathway – Mussel Species #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	<ul> <li>Incremental removal of the dam to reduce the rate of water recession upstream of the dam</li> <li>Monitoring in the upstream portion of the Action Area during dam removal to locate exposed mussels and return individuals to areas of suitable habitat</li> </ul>			
Effect	Adverse (harm, mortality)			
Interpretation	The portion of the river from GRLD5 to 12.6 miles upstream provides unsuitable to poor-quality habitat for the seven mussel species; therefore, lowering the water level in this reach is unlikely to expose individuals of listed species. However, suitable habitat for the seven mussel species is present beyond 12.6 miles upstream of GRLD5 to the end of the Action Area at RM 195, and the water level in this area will lower by 10 to 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, the presence of invasive carp species and the zebra mussel in the Green River presents a biological threat to the seven mussel species. Although not considered to be a direct stressor from the proposed Action, the removal of GRLD5 may allow these species to expand their range farther upstream, which could potentially impact the seven mussel species through competition and predation. Both invasive species have been documented in the Green River; however, the abundance and range of these species are not known. Carp have been found in MCNP many miles upstream of GRLD5, indicating that the species can get over the dam during high flows (Eggers 2019). Removal of GRLD5 would potentially allow carp to move freely upstream at any time and expand their numbers and range in the Green River.

Zebra mussels do not appear to be as common in the Green River as in the Ohio River, lower Kentucky River, and lakes in the state (Haag and Cicerello 2016). This species is not as mobile as the carp species and would take longer to expand its range upstream of GRLD5 after removal. However, this species has the potential to drastically affect native mussel populations where it occurs.

The potential expansion of carp and the zebra mussel in the Green River after removal of GRLD5 could impact the seven mussel species; however, the level of impact is difficult to discern based on available data. As a result, potential impacts to the seven 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 seven mussel species. 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 GRLD5 is anticipated to improve mussel habitat in the Pool 5, 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 5 from lentic habitat back to lotic habitat (Sethi et al. 2004). As previously discussed, the pool does not currently provide suitable habitat for the seven mussel species 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 GRLD5, 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 5 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 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 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 GRLD5 will further benefit the seven mussel species. As Pool 5 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 seven mussel species are anticipated as a result of the proposed Action.

## 6.10 SUMMARY OF EFFECTS

The proposed Action could expose the seven mussel species to the stressors evaluated in the previous section. Anticipated adverse effects to the seven mussel species are limited to: 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 these species throughout the remainder of the Action Area. Potential effects to the seven mussel species are summarized in the following table.

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

## **6.11 EFFECTS DETERMINATION**

Potential impacts to the seven mussel species have been minimized to the extent possible through the use of conservation measures; however, adverse effects to the mussel species are expected as a result of the proposed Action. Therefore, the effects determination for the spectaclecase, fanshell, pink mucket, ring pink, sheepnose, rough pigtoe, and rabbitsfoot as a result of the Action is "may affect, likely to adversely affect".

#### 7.0 CONCLUSION

The biological assessment for the proposed Action included a habitat assessment and a survey for Price's potato-bean. 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. Forested habitat in the southern portion of the work area along the Green River was also identified as suitable habitat for Price's potato-bean. The proposed Action will require the removal of up to 9.72 acres of forested habitat within the work area. Tree fall along the riverbanks upstream of the dam is also anticipated and is estimated at 36.72 acres. The Green River was identified as suitable gray bat foraging habitat and suitable habitat for the federally listed mussel species. Due to the lack of records for the purple cat's paw, northern riffleshell, snuffbox, and clubshell within and near the Action Area, these species are considered absent from the Action Area. Critical habitat for the Indiana bat was identified as occurring in the Action Area; however, this habitat is located more than five miles southeast of the Action Area.

The habitat assessment also included an in-house review of available resources to identify known caves, abandoned mine portals, sinkholes, 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. The bridges over Beaverdam Creek and Little Beaverdam Creek are considered to be suitable roosting habitat for these species; however, these bridges are located outside the work area, and no work will occur on these structures. Multiple sinkholes and several caves are mapped adjacent to the Action Area that are known or potential 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 Price's potato-bean was conducted in the southern portion of the work area. No individuals of this species were found during the survey. The northern portion of the work area does not provide suitable habitat for Price's potato-bean.

Based on the results of the biological assessment, effects to the gray bat and Kentucky cave shrimp from the proposed Action are considered insignificant. Effects to the purple cat's paw, northern riffleshell, snuffbox, clubshell, 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 seven species, and informal consultation with the USFWS is requested 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 this 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 bat. Use of the 4(d) rule is proposed to address adverse effects to the northern long-eared bat; therefore, an effects determination of "may affect, likely to adversely affect", but take is not prohibited, has been made for this species. Informal consultation with the USFWS is requested to address potential effects to these two species.

The proposed Action is expected to result in adverse effects to the spectaclecase, fanshell, pink mucket, ring pink, sheepnose, rough pigtoe, and rabbitsfoot. Therefore, an effects determination of "may affect, likely to adversely affect" has been made for these seven mussel species. Formal consultation with the USFWS is requested to address potential adverse effects to these species.

#### 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.
- Ahlstedt, S.A., J.R. Powell, R.S. Butler, M.T. Fagg, D.W. Hubbs, S.F. Novak, S.R. Palmer & P.D. Johnson, 2004. Historical and current examination of freshwater mussels (Bivalvia: Margaritiferidae, Unionidae) in the Duck River basin, Tennessee. Tennessee Wildlife Resources Agency, Nashville, TN.
- 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.
- Butler, R.S. 2005. Status assessment report for the rabbitsfoot, *Quadrula cylindrica cylindrica*, a freshwater mussel occurring in the Mississippi River and Great Lakes basins. Unpublished report prepared by the Ohio River Valley Ecosystem Team Mollusk Subgroup, Asheville, NC. 204 pp.
- 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.
- Fobian, T.B. 2007. Reproductive biology of the rabbitsfoot mussel (Quadrula cylindrica) (Say, 1817) in the upper Arkansas River system, White River system, and the Red River system. Unpublished M.S. thesis. Missouri State University, Springfield, MO. 104 pp.
- 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.
- Gordon, M.E. and J.B. Layzer. 1989. Mussels (Bivalvia: Unionoidea) of the Cumberland River review of life histories and ecological relationships. U.S. Fish and Wildlife Service Biological Report, 89(15):1-99
- 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: Biyalvia: Unionoidea). American Midland Naturalist 135:370-375.
- 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.
- Hubbs, D., S. Chance & L. Colley. 2011. 2010 Duck River quantitative mussel survey. Report 11-04. Tennessee Wildlife Resources Agency, Nashville, TN.
- 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.
- Jones, J.W. and R.J. Neves. 2002. Life history and propagation of the endangered fanshell pearlymussel, Cyprogenia stegaria Rafinesque (Bivalvia:Unionidae). Journal of the North American Benthological Society 21(1):76-78.

- 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 Geological Survey (KGS). 2020. Kentucky Geologic Map Information Service. Karst Potential Map. http://kgs.uky.edu/kgsmap/kgsgeoserver/viewer.asp. Accessed September 2020.
- Kentucky State Nature Preserves Commission. 2017. Preliminary ecological assessment of the Green and Nolin rivers in Mammoth Cave National Park, Kentucky, following the removal of lock and dam #6. Kentucky State Nature Preserves Commission. Frankfort, KY.
- Kondolf, G.M. 1997. Hungry water: Effects of dams and gravel mining on river channels. Environmental Management 21(4): 533–551.
- Konrad, C.P., A. Warner, and J.V. Higgins, 2012. Evaluating dam re-operation for freshwater conservation in the sustainable rivers project. River Research and Applications 28: 777–792.
- 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.
- Leitheuser, A.T., J.R. Holsinger, R. Olson, N.R. Pace, and R.L. Whitman. 1984. Ecological Analysis of the Kentucky Cave Shrimp, *Palaemonias ganteri* Hay, at Mammoth Cave National Park (Phase V Progress Report). Norfolk, VA: Old Dominion University Research Foundation, U.S. Dept. of the Interior, National Park Service Contract Number CX-5000-1-037, ii + 15 pp.
- Lewis Environmental Consulting, LLC. 2017. Mussel Survey of Green River Pool 5 in Butler, Warren, and Edmonson Counties, Kentucky. Prepared for U.S. Fish and Wildlife Service Kentucky Field Office. Frankfort, KY.
- Lewis Environmental Consulting, LLC. 2019. Mussel Survey of the Green River Downstream of Lock and Dam 5, Butler and Warren Counties, Kentucky. Prepared for U.S. Fish and Wildlife Service Kentucky Field Office. Frankfort, KY.
- 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.
- NatureServe. 2020. NatureServe Explorer: An online encyclopedia of life [web application]. Version 7.1. NatureServe, Arlington, VA. http://explorer.natureserve.org. Accessed August 2020.

- 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 52<sup>nd</sup> 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. 1967. The Freshwater Mussels of Illinois. Illinois State Museum, Popular Science Series 8:1-108.
- 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). 2020. National Invasive Species Information Center. https://www.invasivespeciesinfo.gov/aquatic/fish-and-other-vertebrates. Accessed September 2020.
- 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). 1983. Endangered and Threatened Wildlife and Plants; Determination of Endangered Status and Designation of Critical Habitat for the Kentucky Cave Shrimp. 48 FR 46337-46342.
- 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). 1985. Recovery Plan Pink Mucket Pearly Mussel (*Lampsilis orbiculata*). U.S. Fish and Wildlife Service, Atlanta, GA. 47 pp.
- United States Fish and Wildlife Service (USFWS). 1988. Kentucky Cave Shrimp Recovery Plan. U.S. Fish and Wildlife Service. Atlanta, GA. 47 pp.
- United States Fish and Wildlife Service (USFWS). 1989. Endangered and Threatened Wildlife and Plants; Designation of the Ring Pink Mussel as an Endangered Species. 54 FR 40109-40112.
- United States Fish and Wildlife Service (USFWS). 1990. Endangered and Threatened Wildlife and Plants; Designation of the Freshwater Mussel, the Fanshell as an Endangered Species. 55 FR 25591-25596.
- United States Fish and Wildlife Service (USFWS). 1991a. Recovery Plan for Fanshell (*Cyprogenia stegaria* (=*C. irrorata*)). U.S. Fish and Wildlife Service, Atlanta, GA. 37 pp.
- United States Fish and Wildlife Service (USFWS). 1991b. Ring Pink Mussel Recovery Plan. U.S. Fish and Wildlife Service, Atlanta, GA. 24 pp.
- United States Fish and Wildlife Service (USFWS). 1993. Recovery Plan for *Apios priceana*. Jackson, MS. 43 pp.
- United States Fish and Wildlife Service (USFWS). 2011. Ring Pink (*Obovaria retusa*) 5-Year Review: Summary and Evaluation. U.S. Fish and Wildlife Service, Frankfort, KY. 14 pp.
- United States Fish and Wildlife Service (USFWS). 2012. Endangered and Threatened Wildlife and Plants; Determination of Endangered Status for the Sheepnose and Spectaclecase Mussels Throughout Their Range. 77 FR 14914-14949.
- United States Fish and Wildlife Service (USFWS). 2013. Endangered and Threatened Wildlife and Plants; Endangered Status for the Neosho Mucket and Threatened Status for the Rabbitsfoot. 78 FR 57076-57097.
- 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 Longeared Bat. Southeast Regional Office. Atlanta, GA. 84 pp.
- United States Fish and Wildlife Service (USFWS). 2015c. Endangered and Threatened Wildlife and Plants; Designation of Critical Habitat for Neosho Mucket and Rabbitsfoot. 80 FR 24691-24774.
- United States Fish and Wildlife Service (USFWS). 2016. 5-Year Review: Summary and Evaluation. Kentucky Cave Shrimp (*Palaemonias ganteri*). U.S. Fish and Wildlife Service, Frankfort, KY. 18 pp.

- United States Fish and Wildlife Service (USFWS). 2017. Ring Pink (*Obovaria retusa*) 5-Year Review: Summary and Evaluation. U.S. Fish and Wildlife Service, Frankfort, KY. 6, 8 pp.
- United States Fish and Wildlife Service (USFWS). 2018. 5-Year Review: Summary and Evaluation. Pink Mucket Pearly Mussel (*Lampsilis orbiculata*). U.S. Fish and Wildlife Service, Asheville, NC. 21 pp.
- United States Fish and Wildlife Service Information for Planning and Conservation (USFWS IPaC). 2020. Endangered, Threatened, Proposed, and Candidate Species listed under the Endangered Species Act. https://ecos.fws.gov/ipac. Accessed June 12, 2020.
- United States Fish and Wildlife Service Kentucky Ecological Services Field Office (USFWS KFO). 2009. Fanshell Mussel Recovery Action Plan. Kentucky Ecological Services Field Office, Frankfort, KY.
- 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.
- 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 Tech. Memo. NMFS F/NWR-28, 13 pp.

# **FIGURES**

P:\2020 Projects\20-086-Green River Lock & Dam 5\Figures\SiteLocationMap.mxd, 10-23-2020, Temp

DRAWN BY: EDB/CRM

REVISED DATE: 10-23-20



FIGURE 1

FIGURE 4

Temp

P:\2020 Projects\20-086-Green River Lock & Dam 5\Figures\Known NLEB Habitat Map.mxd, 09-11-2020,

REVISED DATE: 09-11-20

DRAWN BY: EDB/CRM

## **PHOTOGRAPHS**



Photograph 1: View of the dam and upstream portion of the lock river wall, facing north from the left descending bank of the Green River. August 14, 2020.



Photograph 2: View of the dam and downstream portion of the lock river wall, facing northwest from the left descending bank of the Green River. August 20, 2020.



Photograph 3: View of the mooring cells and upstream guide wall (behind mooring cells), facing northeast from the left descending bank of the Green River. August 14, 2020.



Photograph 4: View of the lock chamber showing the lock river wall (left side) and lock land wall (right side), facing west from the upstream end of the chamber. August 14, 2020.



Photograph 5: View of the miter gates at the upstream end of the lock chamber, facing east. August 14, 2020.



Photograph 6: View of the miter gates at the downstream end of the lock chamber, facing east from outside the chamber. August 14, 2020.



Photograph 7: View of the operations building adjacent to the lock land wall. August 14, 2020.



Photograph 8: View of the downstream guide wall, facing west from the end of the lock river wall. August 14, 2020.



Photograph 9: View of the existing access road in the northern portion of the work area near Lock 5 Road. August 20, 2020.



Photograph 10: View of the existing access road in the northern portion of the work area near the lock. August 14, 2020.



Photograph 11: View of the forested habitat along the lock land wall. This habitat was identifed as suitable summer habitat for the Indiana and northern long-eared bats. August 14, 2020.



Photograph 12: Example of the forested habitat in the northern portion of the work area. This habitat was identified as suitable summer habitat for the Indiana and northern long-eared bats. August 14, 2020.



Photograph 13: View of the thick ground and understory layers dominated by invasive shrub and herbaceous species in the forested habitat in the northern portion of the work area. This habitat was determined to be unsuitable for Price's potato-bean. August 20, 2020.



Photograph 14: View of the dam and dam abutment on the left descending bank of the Green River, facing south. August 14, 2020.



Photograph 15: View of the boulders along the left descending bank downstream of the dam abutment, facing west from the dam abutment. August 20, 2020.



Photograph 16: View of the exposed rock at the base of the dam that extends along the dam abutment to the boulders, facing northeast from the left descending bank. August 14, 2020.



Photograph 17: View of suitable habitat for Price's potato-bean in the southern portion of the work area, facing southwest. No Price's potato-bean was found during the survey of this area. August 14, 2020.



Photograph 18: View of the intermittent tributary to the Green River where a temporary crossing will be required during construction of the access road in the southern portion of the work area. August 14, 2020.



Photograph 19: View of Pool 5 upstream of the dam, facing northeast from the left descending bank of the Green River. August 14, 2020.



Photograph 20: View of Pool 4 downstream of the dam, facing southwest from the end of the lock river wall. August 14, 2020.

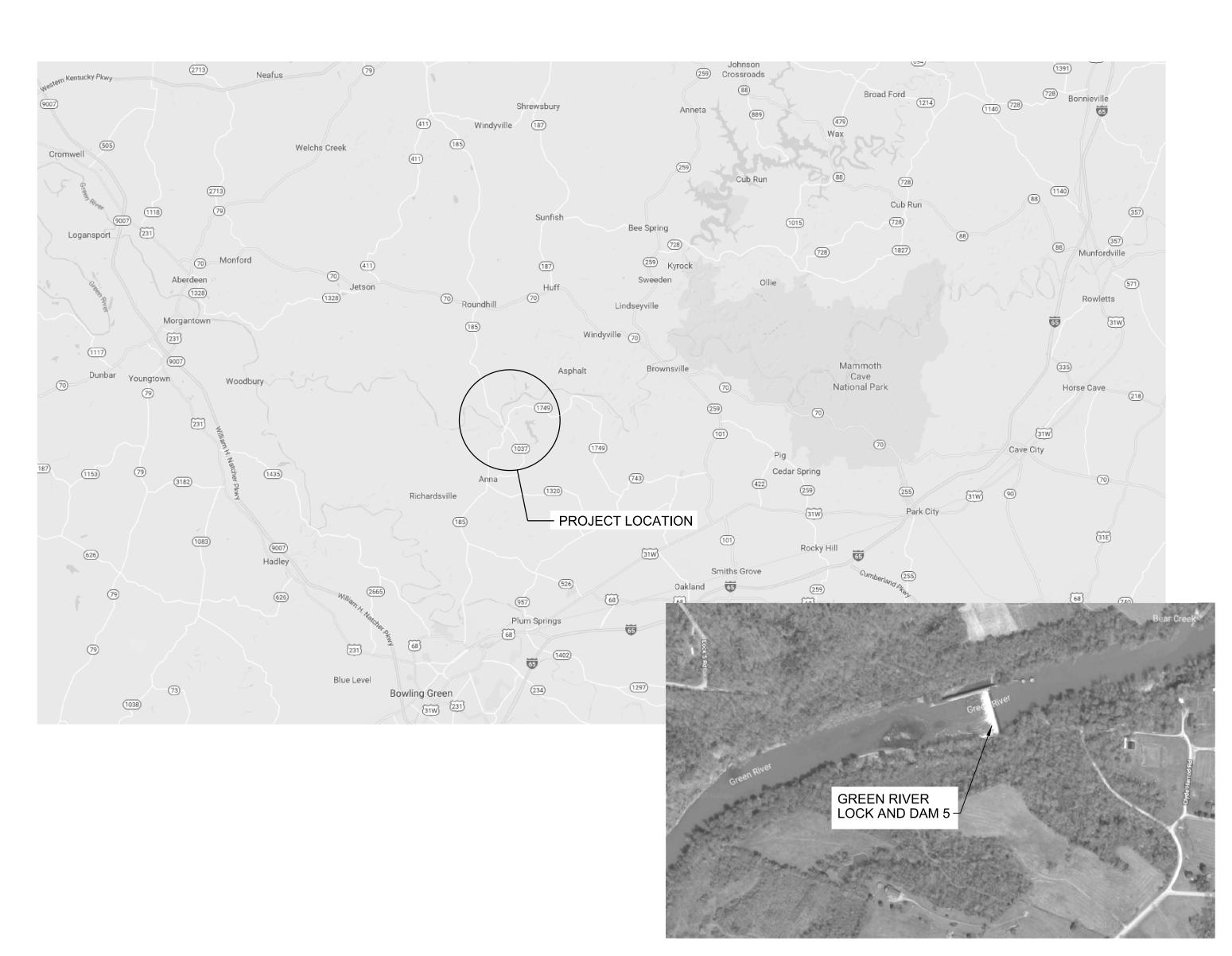
# APPENDIX A PROJECT DESIGN PLANS



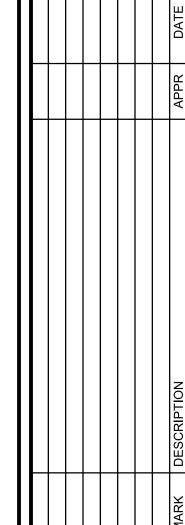
# GREEN RIVER LOCK AND DAM 5 REMOVAL

ROUNDHILL, KENTUCKY

P2# 465345, FY 2018







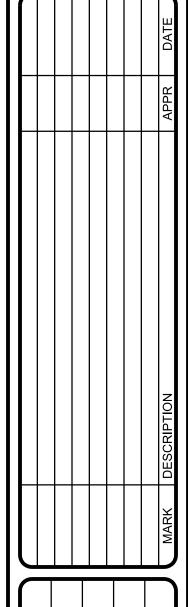
	DESIGNED BY:	ISSUE DATE:
CORPS OF ENGINEERS	T. SMITH	MARCH 2018
UISVILLE DISTRICT	DRAWN BY:	SOLICITATION NO.:
UISVILLE KY 40202	B. SAYLOR	
	CHECKED BY:	CONTRACT NO.
	J. SINKHORN	
	SUBMITTED BY:	DRAWING CODE:
	N. MOULDER	
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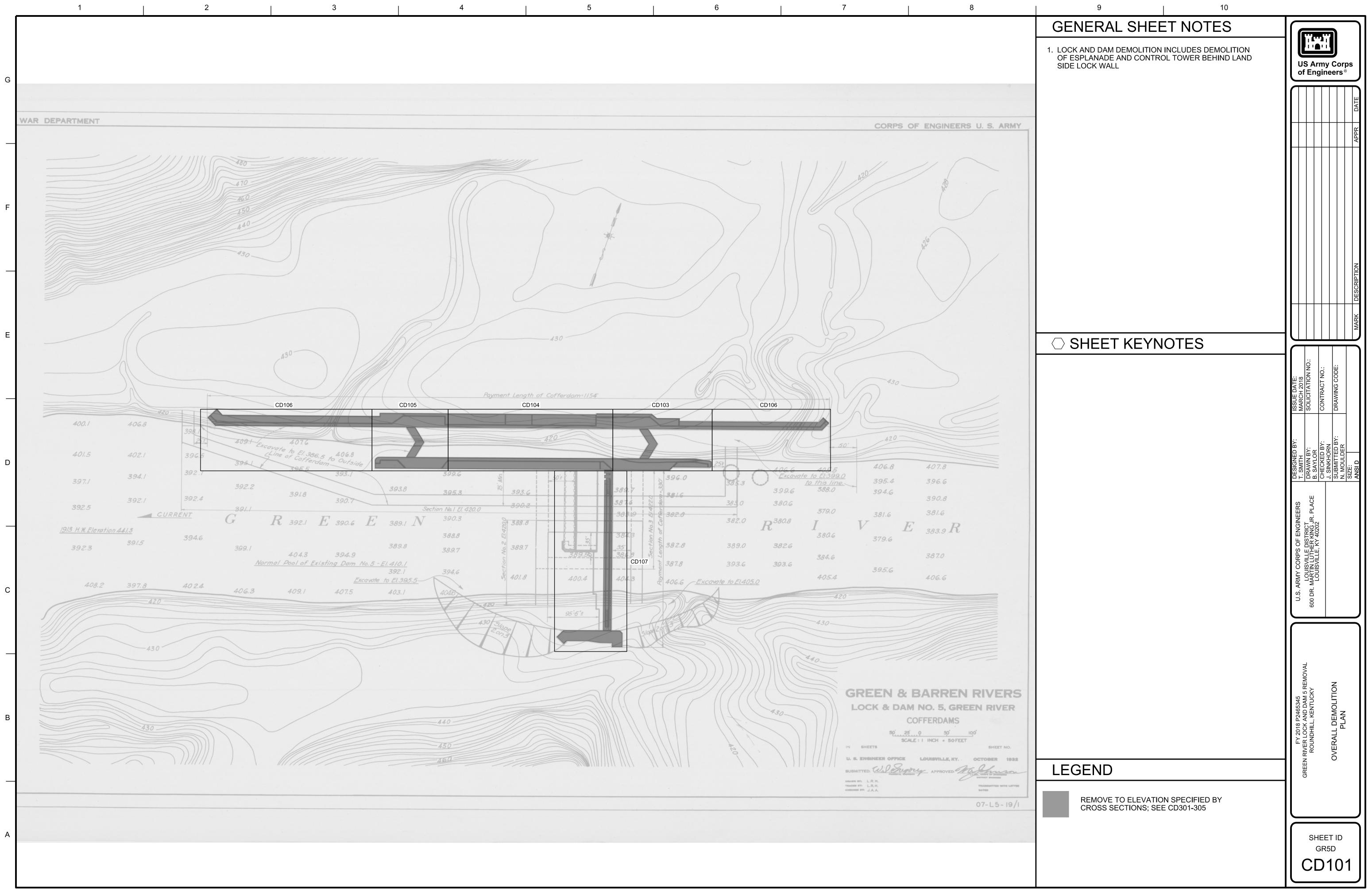
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GREEN RIVER LOCK AND DAM 5 REMOVAL
ROUNDHILL, KENTUCKY
COVER SHEET

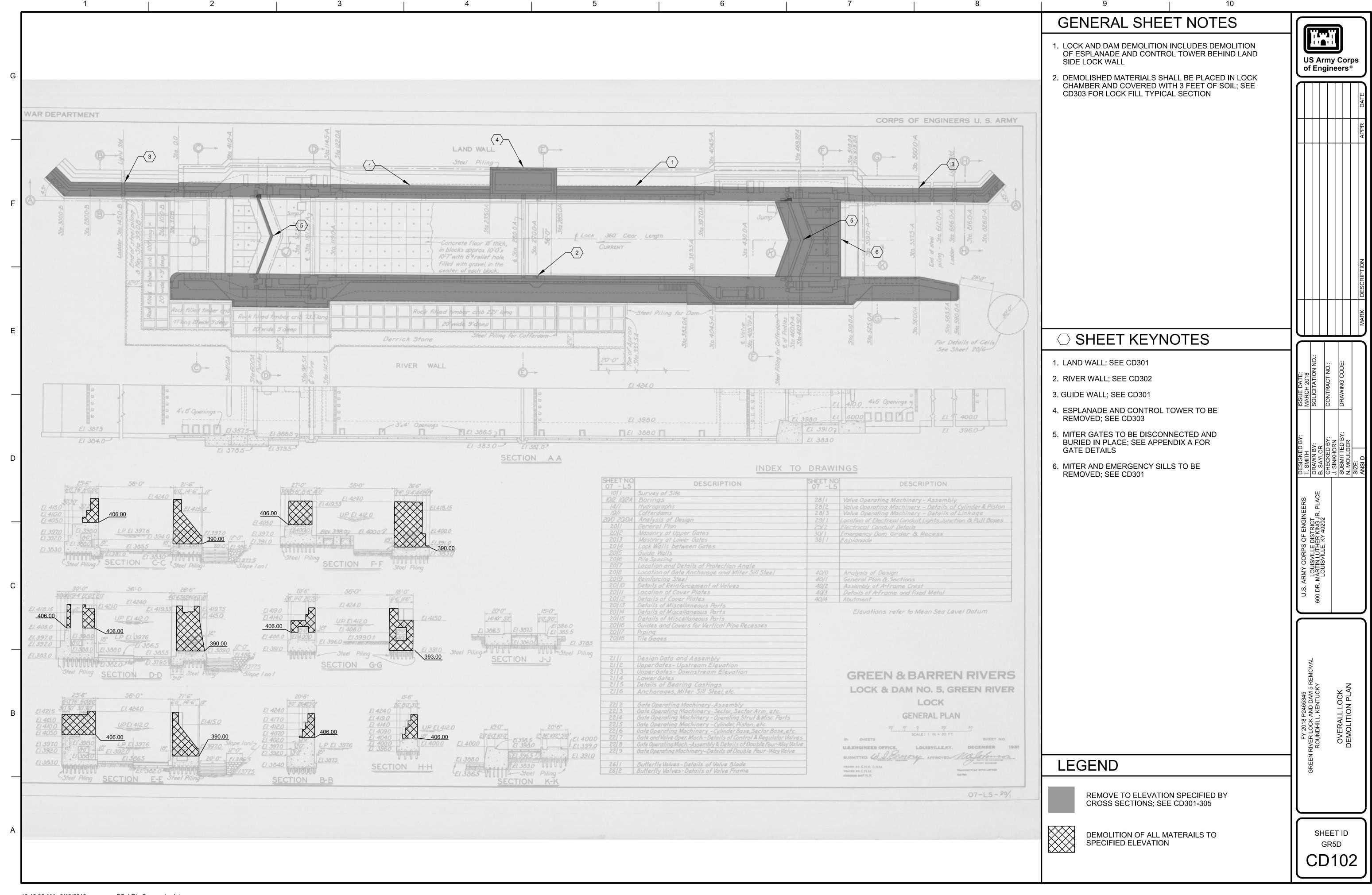
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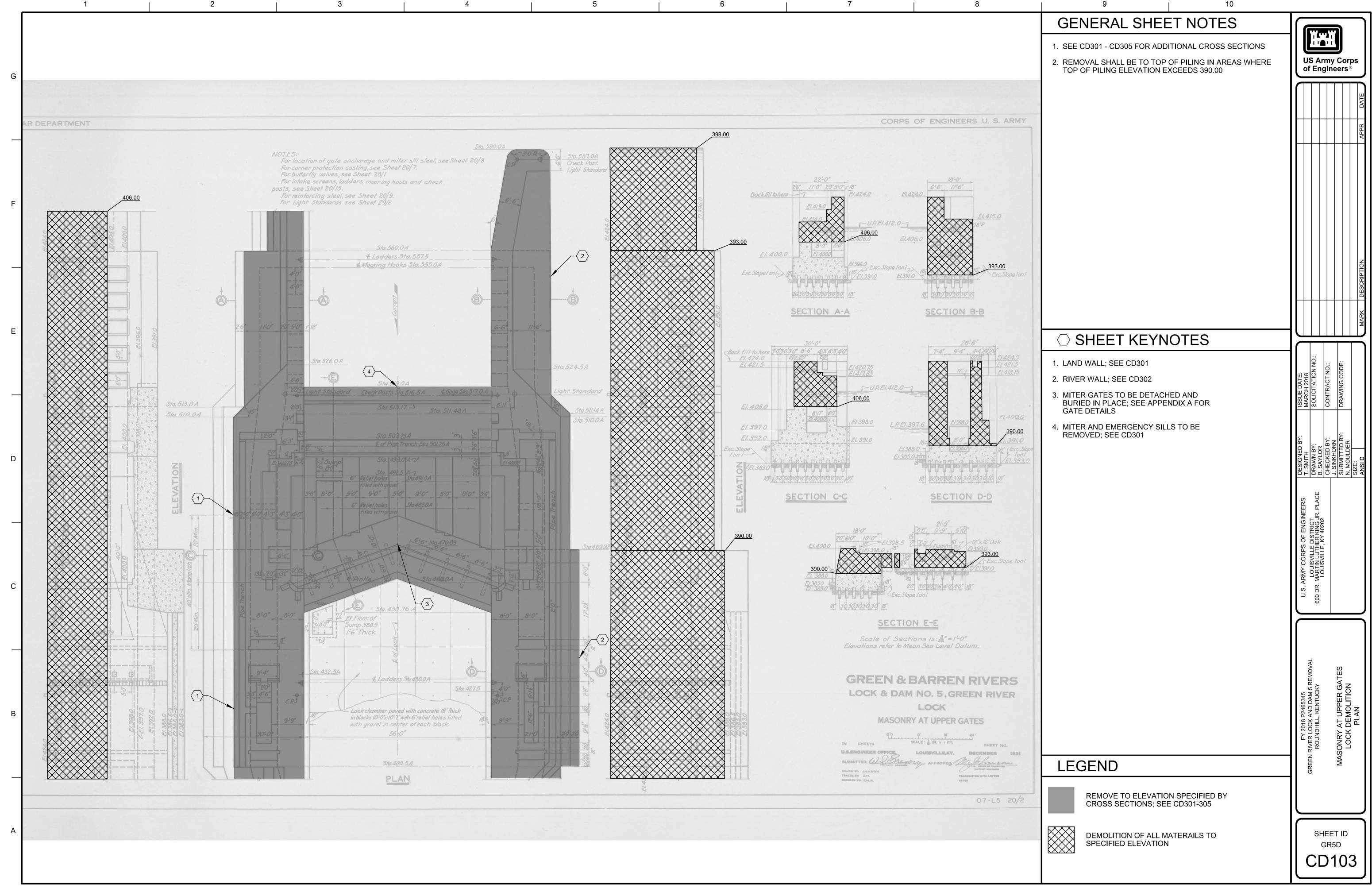
Sheet Filename Sheet Ref No. Sheet Description Sheet No. **GENERAL** 465345\_G001.DGN G-001 **COVER SHEET** 465345\_G002.DGN G-002 DRAWING INDEX CIVIL 465345\_CD101.DGN OVERALL DEMOLITION PLAN 465345\_CD102.DGN CD102 OVERALL LOCK DEMOLITION PLAN 465345\_CD103.DGN CD103 MASONRY AT UPPER GATES LOCK DEMOLITION PLAN 465345\_CD104.DGN CD104 WALLS BETWEEN GATES LOCK DEMOLITION PLAN 465345\_CD105DGN MASONRY AT LOWER GATES LOCK DEMOLITION PLAN 465345\_CD106.DGN CD106 UPPER AND LOWER GUIDE WALLS LOCK DEMOLITION PLAN 465345\_CD107.DGN DAM DEMOLITION PLAN CD107 465345\_CD301.DGN CD301 LAND WALL, GUIDE WALL, AND SILL DEMOLITION SECTIONS 11 465345\_CD302.DGN RIVER WALL DEMOLITION SECTIONS 12 465345\_CD303.DGN LOCK FILL TYPICAL SECTION AND ESPLANADE PLAN AND SECTIONS 465345\_CD304.DGN 13 DAM DEMOLITION SECTIONS CD304 14 465345\_CD305.DGN ABUTMENT DEMOLITION SECTIONS CD305 DESIGNED BY
T. SMITH
DRAWN BY:
B. SAYLOR
CHECKED BY:
J. SINKHORN
SUBMITTED B'
N. MOULDER
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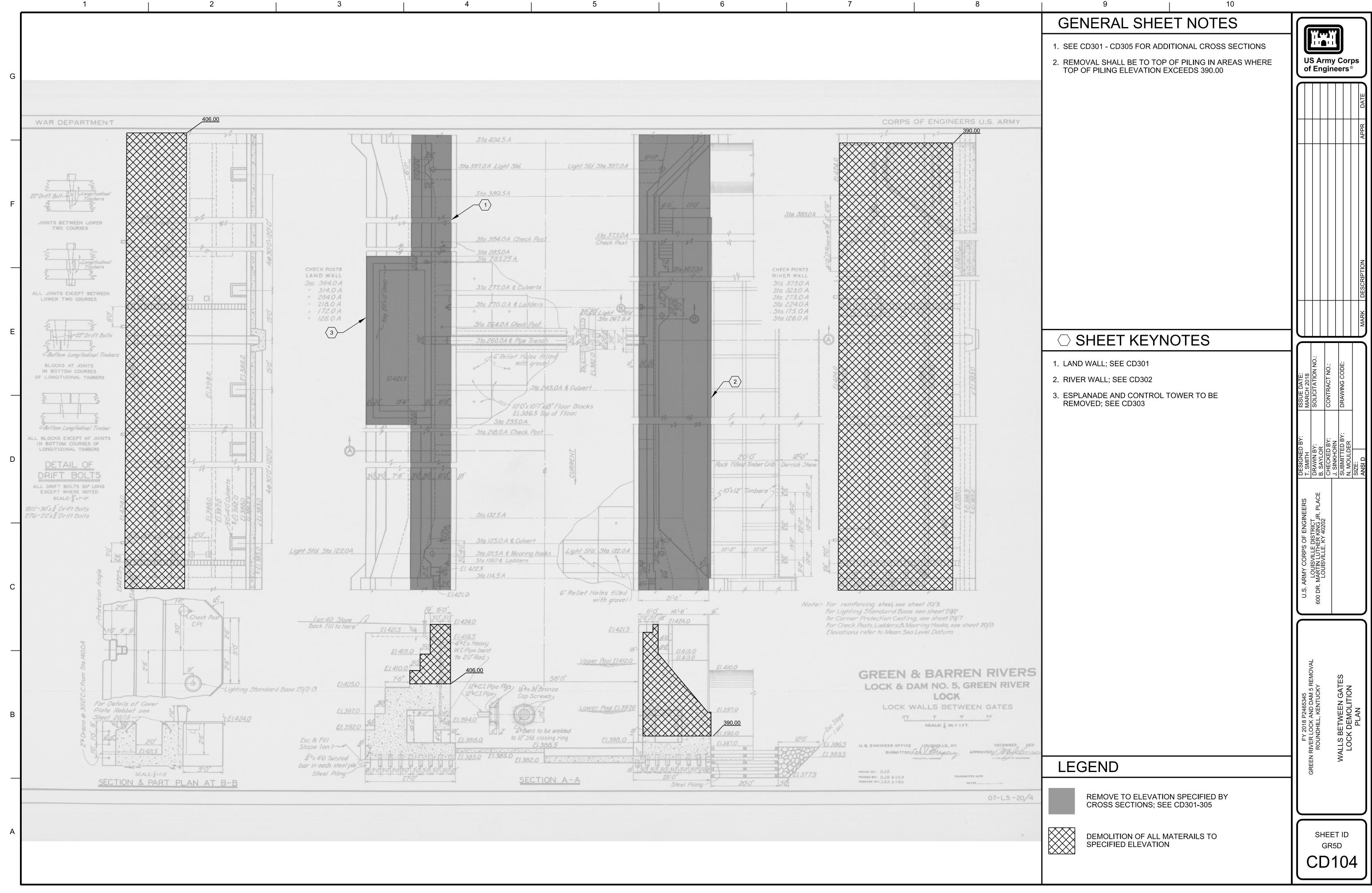
US Army Corps of Engineers®

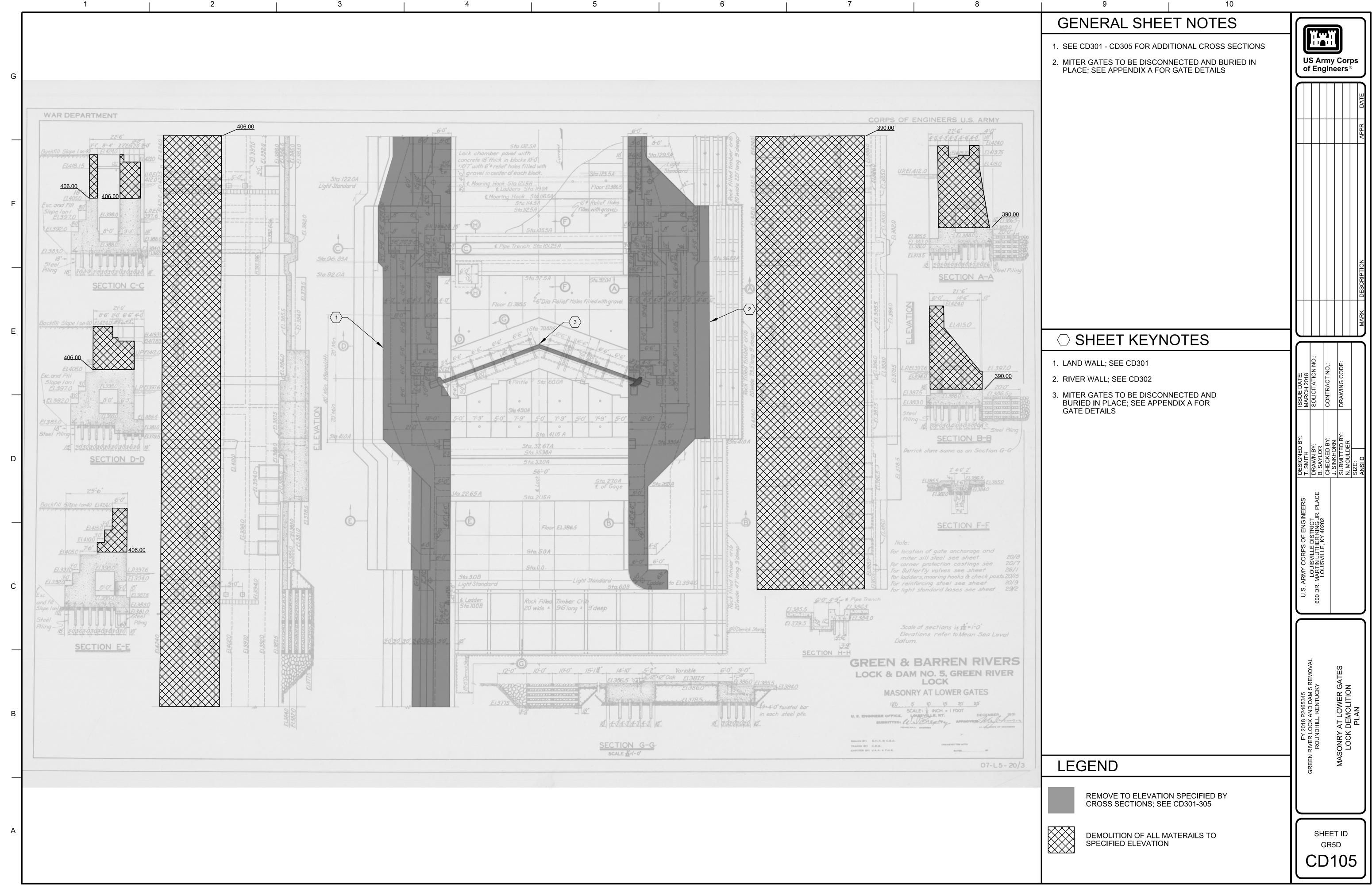


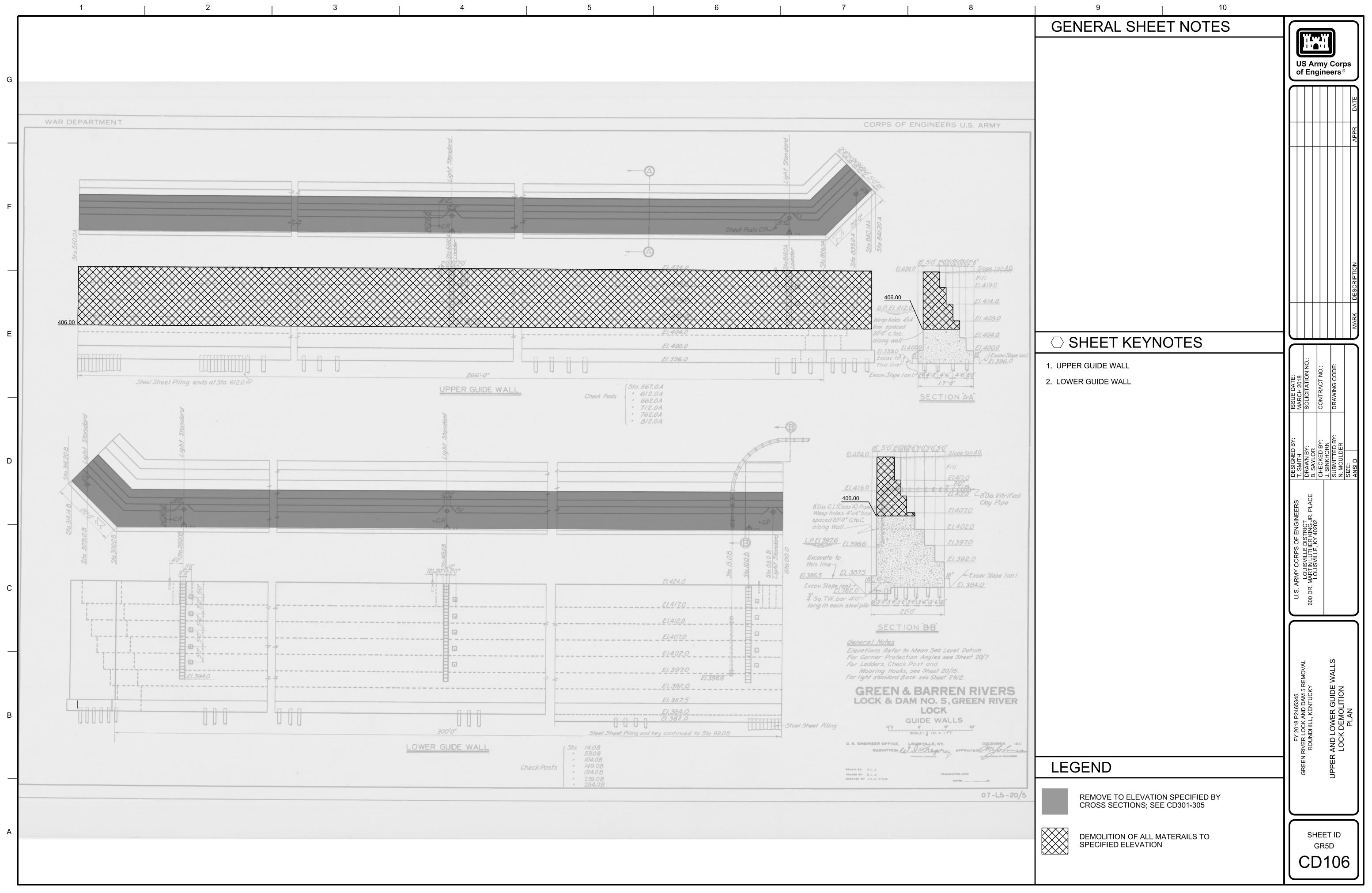


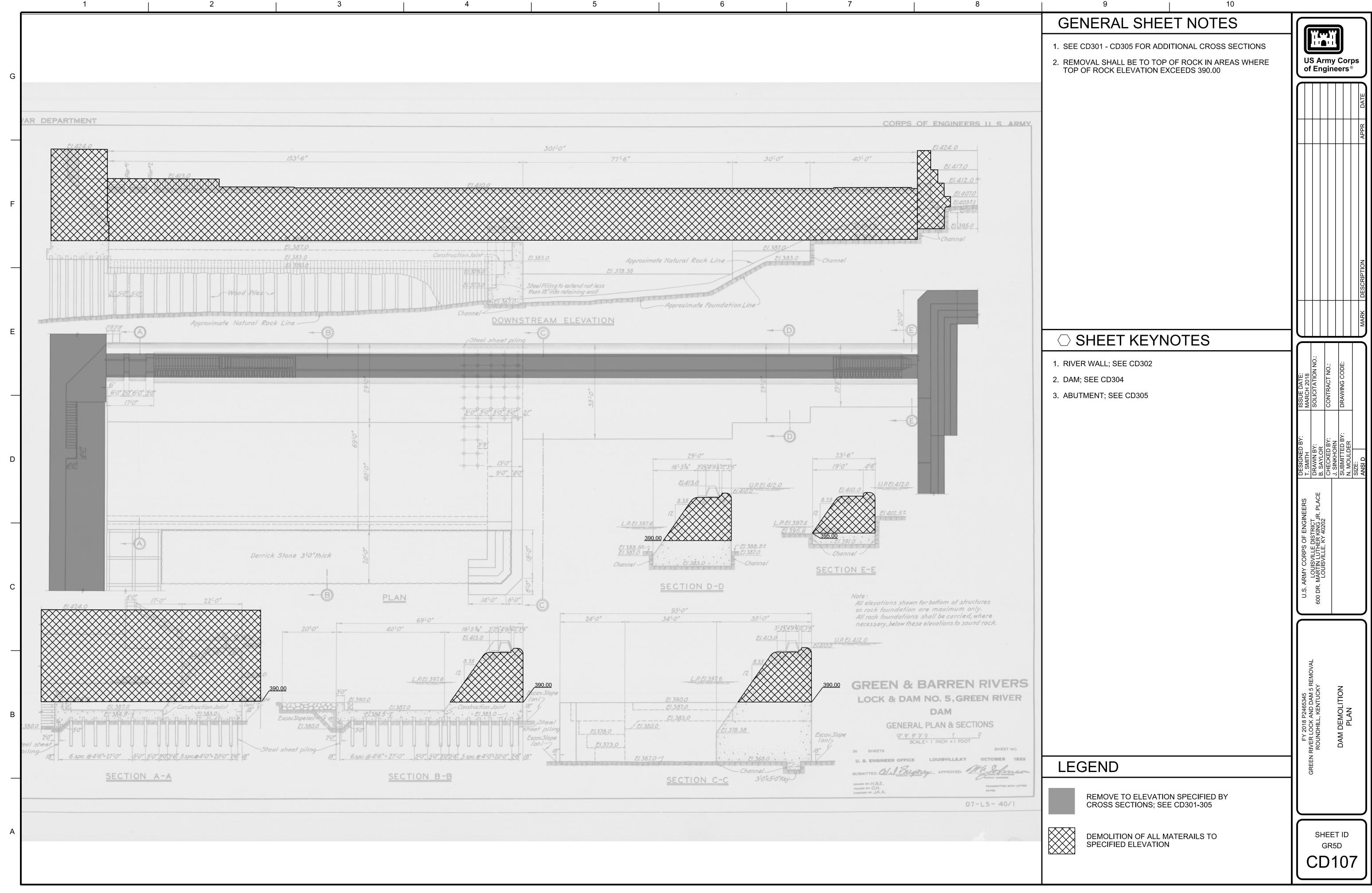


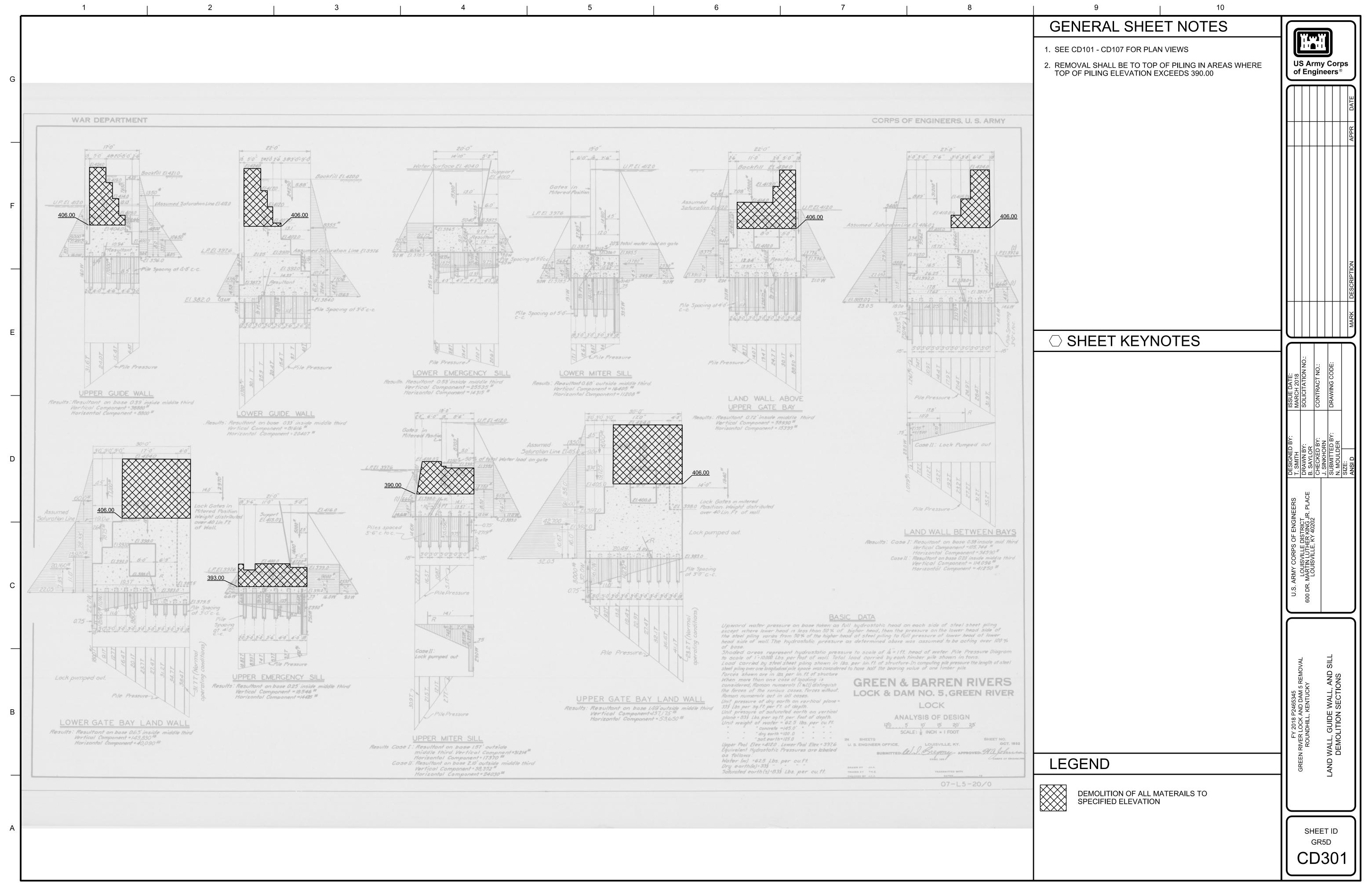


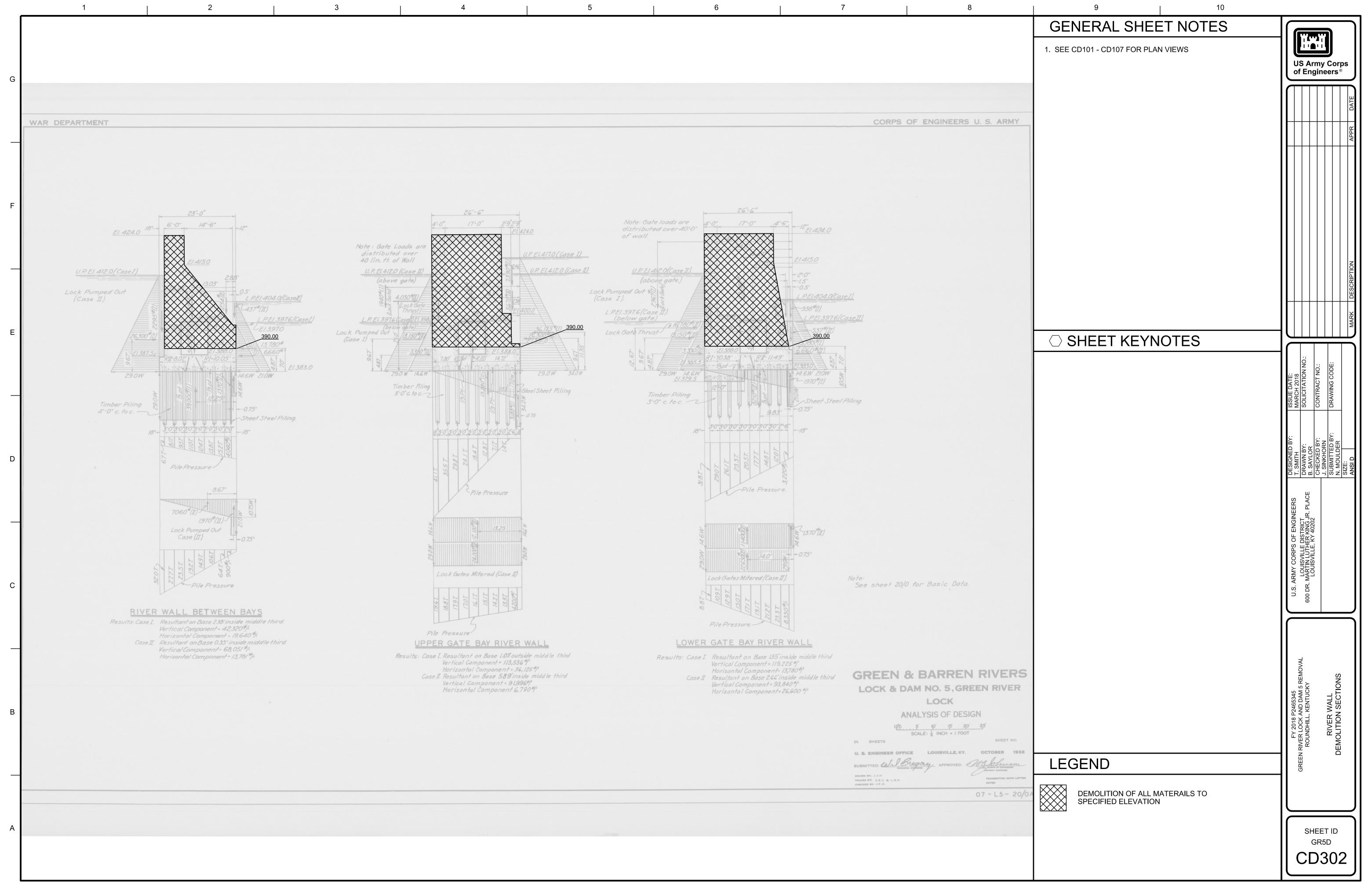


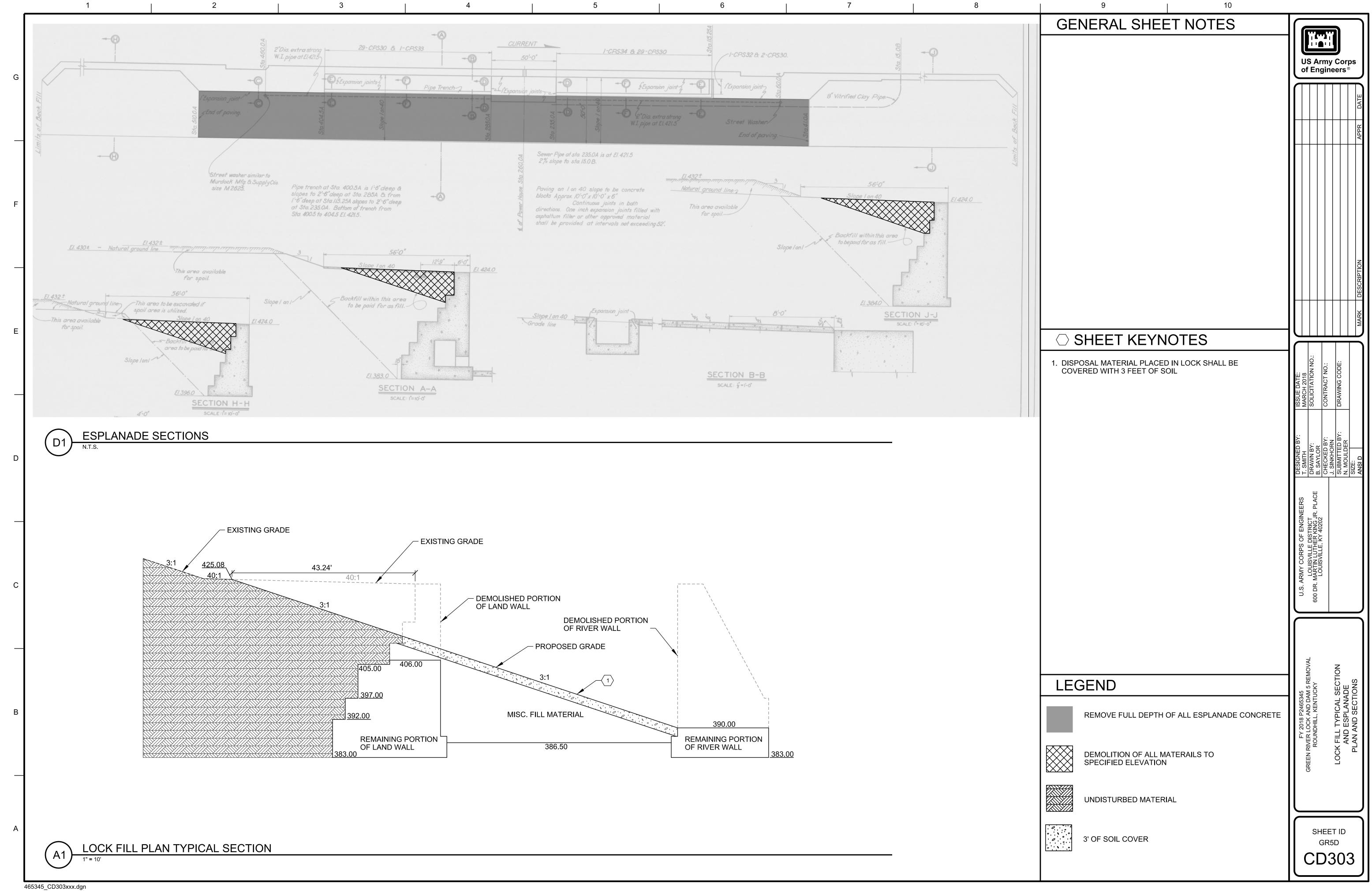


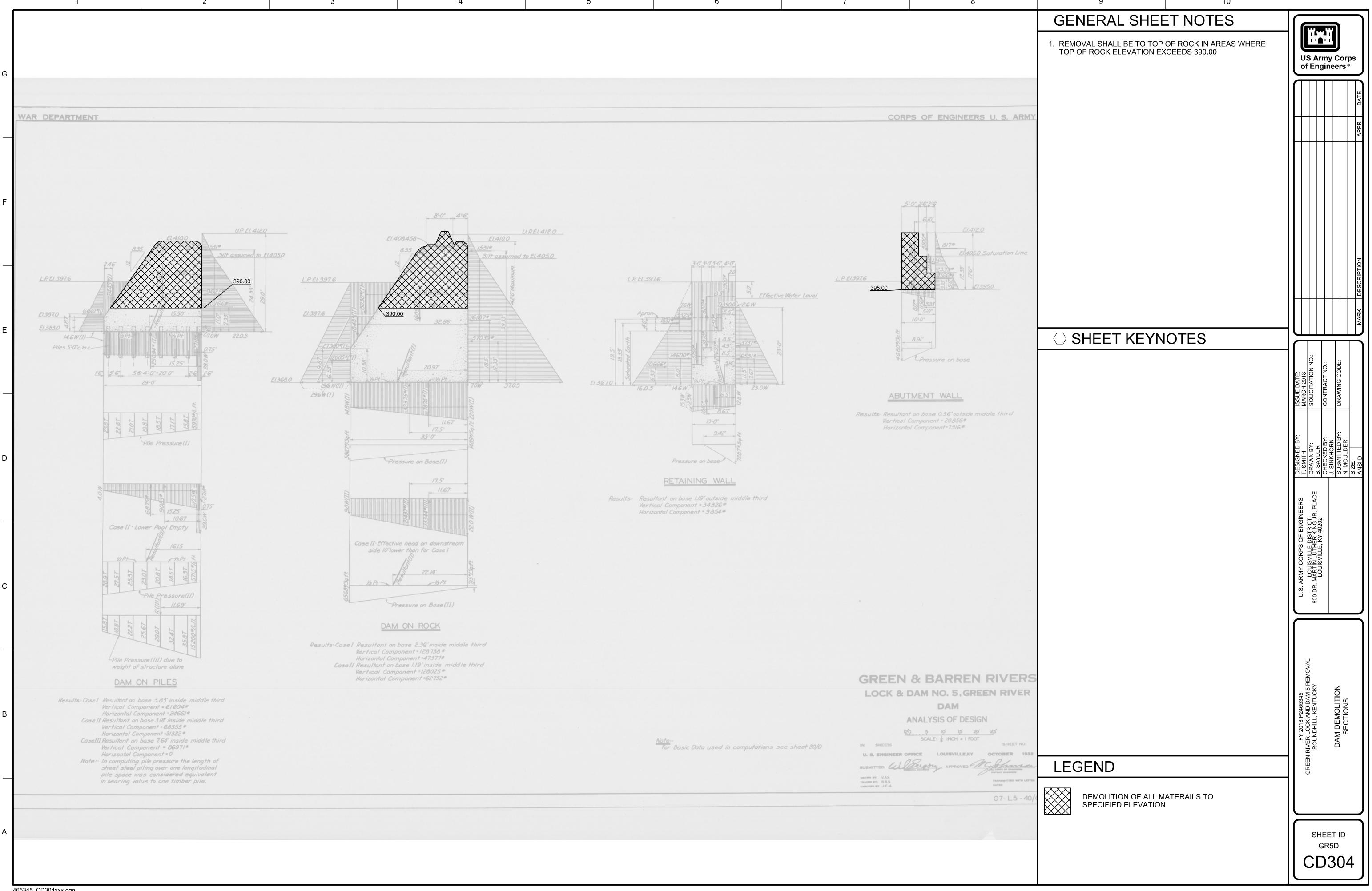


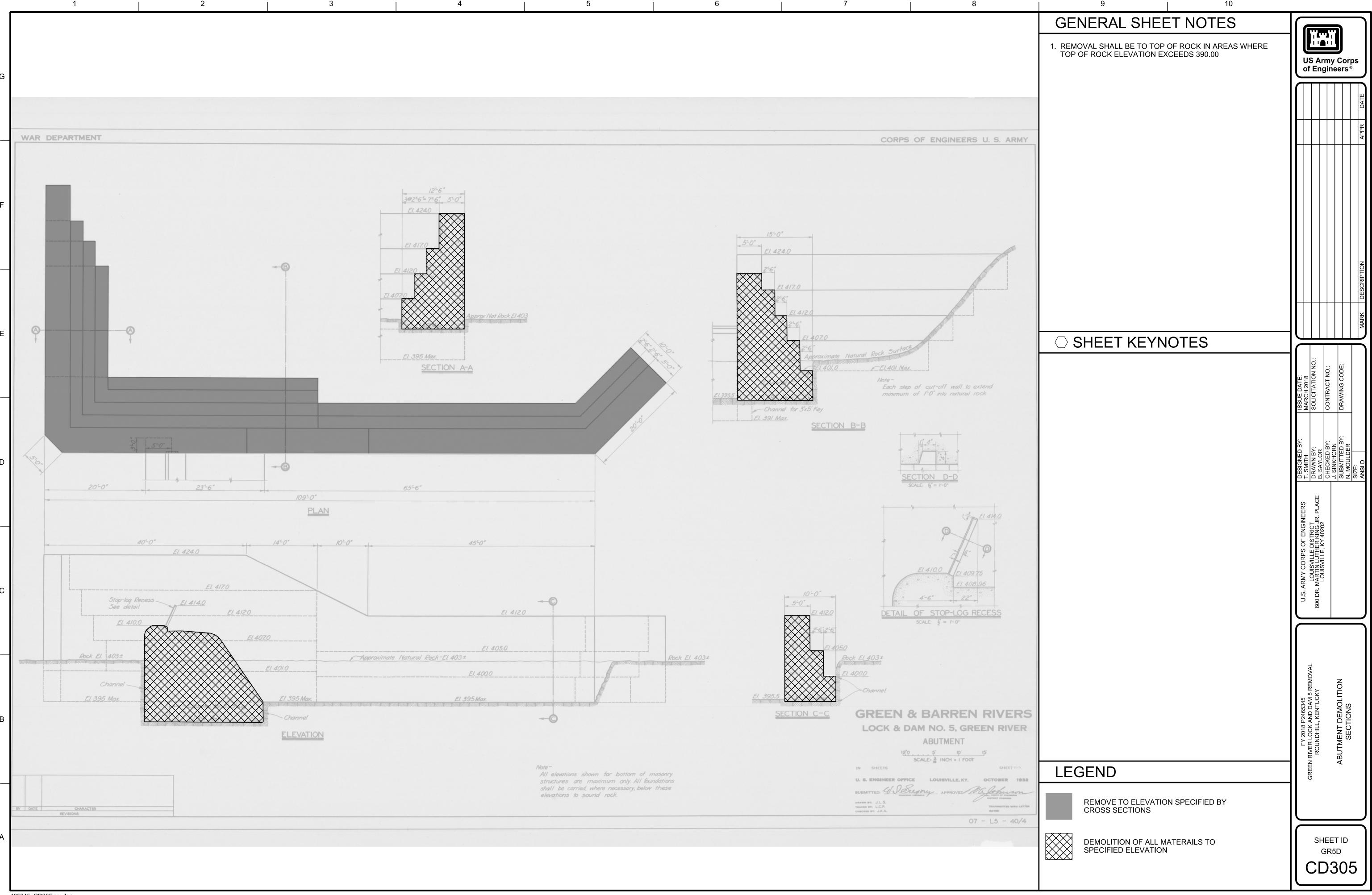












# APPENDIX B RESOURCE AGENCY COORDINATION



### 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: October 26, 2020

Consultation Code: 04EK1000-2021-SLI-0097

Event Code: 04EK1000-2021-E-00326

Project Name: Green River Lock and Dam 5 Removal Project

Subject: List of threatened and endangered species that may occur in your proposed project

location, and/or may be affected by your proposed project

#### To Whom It May Concern:

Your concern for the protection of endangered and threatened species is greatly appreciated. The purpose of the Endangered Species Act (ESA) of 1973, as amended (16 U.S.C. 1531 et seq.) (ESA) is to provide a means whereby threatened and endangered species and the ecosystems upon which they depend may be conserved. The species list attached to this letter fulfills the requirements of the U.S. Fish and Wildlife Service (Service) under section 7(c) of the ESA to provide information as to whether any proposed or listed species may be present in the area of a proposed action. This is not a concurrence letter; additional consultation with the Service may be required.

#### The Information in Your Species List:

The enclosed species list identifies federal trust species and critical habitat that may occur within the boundary that you entered into IPaC. For your species list to most accurately represent the species that may potentially be affected by the proposed project, the boundary that you input into IPaC should represent the entire "action area" of the proposed project by considering all the potential "effects of the action," including potential direct, indirect, and cumulative effects, to federally-listed species or their critical habitat as defined in 50 CFR 402.02. This includes effects of any "interrelated actions" that are part of a larger action and depend on the larger action for their justification and "interdependent actions" that have no independent utility apart from the action under consideration (e.g.; utilities, access roads, etc.) and future actions that are reasonably certain to occur as a result of the proposed project (e.g.; development in response to a new road). If your project is likely to have significant indirect effects that extend well beyond the project footprint (e.g., long-term impacts to water quality), we highly recommend that you

coordinate with the Service early to appropriately define your action area and ensure that you are evaluating all the species that could potentially be affected.

We must advise you that our database is a compilation of collection records made available by various individuals and resource agencies available to the Service and may not be all-inclusive. This information is seldom based on comprehensive surveys of all potential habitats and, thus, does not necessarily provide conclusive evidence that species are present or absent at a specific locality. 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 note that "critical habitat" refers to specific areas identified as essential for the conservation of a species that have been designated by regulation. Critical habitat usually does not include all the habitat that the species is known to occupy or all the habitat that may be important to the species. Thus, even if your project area does not include critical habitat, the species on the list may still be present.

Please note that under 50 CFR 402.12(e) of the regulations implementing section 7 of the ESA, the accuracy of this species list should be verified after 90 days. 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 associated information. To re-access your project in IPaC, go to the IPaC web site (<a href="https://ecos.fws.gov/ipac/">https://ecos.fws.gov/ipac/</a>), select "Need an updated species list?", and enter the consultation code on this letter.

#### **ESA Obligations for Federal Projects:**

Under sections 7(a)(1) and 7(a)(2) of the ESA 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.

If a Federal project (a project authorized, funded, or carried out by a federal agency) may affect federally-listed species or critical habitat, the Federal agency is required to consult with the Service under section 7 of the ESA, 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: <a href="http://www.fws.gov/endangered/esa-library/pdf/TOC-GLOS.PDF">http://www.fws.gov/endangered/esa-library/pdf/TOC-GLOS.PDF</a>

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)). Recommended contents of a Biological Assessment are described at 50 CFR 402.12. 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.

#### **ESA Obligations for Non-federal Projects:**

Proposed projects that do not have a federal nexus (non-federal projects) are not subject to the obligation to consult under section 7 of the ESA. However, section 9 of the ESA prohibits certain activities that directly or indirectly affect federally-listed species. These prohibitions apply to all individuals subject to the jurisdiction of the United States. Non-federal project proponents can request technical assistance from the Service regarding recommendations on how to avoid and/or minimize impacts to listed species. The project proponent can choose to implement avoidance, minimization, and mitigation measures in a proposed project design to avoid ESA violations.

#### **Additional Species-specific Information:**

In addition to the species list, IPaC also provides general species-specific technical assistance that may be helpful when designing a project and evaluating potential impacts to species. To access this information from the IPaC site (<a href="https://ecos.fws.gov/ipac/">https://ecos.fws.gov/ipac/</a>), click on the text "My Projects" on the left of the black bar at the top of the screen (you will need to be logged into your account to do this). Click on the project name in the list of projects; then, click on the "Project Home" button that appears. Next, click on the "See Resources" button under the "Resources" heading. A list of species will appear on the screen. Directly above this list, on the right side, is a link that will take you to pdfs of the "Species Guidelines" available for species in your list. Alternatively, these documents and a link to the "ECOS species profile" can be accessed by clicking on an individual species in the online resource list.

#### **Next Steps:**

Requests for additional technical assistance or consultation from the Kentucky Field Office should be submitted following guidance on the following page <a href="http://www.fws.gov/frankfort/">http://www.fws.gov/frankfort/</a>
PreDevelopment.html and the document retrieved by clicking the "outline" link at that page.
When submitting correspondence about your project to our office, please include the Consultation Tracking Number in the header of this letter. (There is no need to provide us with a copy of the IPaC-generated letter and species list.)

#### 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**

Consultation Code: 04EK1000-2021-SLI-0097

Event Code: 04EK1000-2021-E-00326

Project Name: Green River Lock and Dam 5 Removal Project

Project Type: DAM

Project Description: Removal of Green River Lock and Dam 5.

## **Project Location:**

Approximate location of the project can be viewed in Google Maps: <a href="https://www.google.com/maps/place/37.202354051759215N86.20893852152096W">https://www.google.com/maps/place/37.202354051759215N86.20893852152096W</a>



Counties: Butler, KY | Edmonson, KY | Warren, KY

## **Endangered Species Act Species**

There is a total of 16 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 3 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<sup>1</sup>, 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. <u>NOAA Fisheries</u>, 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

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.
- The project area includes a half-mile buffer around a known gray bat bibernacula and/or roost.

Species profile: <a href="https://ecos.fws.gov/ecp/species/6329">https://ecos.fws.gov/ecp/species/6329</a>

General project design guidelines:

https://ecos.fws.gov/ipac/guideline/design/population/21/office/42431.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 1' habitat.
- The project area includes known 'swarming 2' habitat.
- The project area includes known 'summer 1' habitat.
- The project area includes known 'summer 2' habitat.

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

General project design guidelines:

https://ecos.fws.gov/ipac/guideline/design/population/1/office/42431.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.
- Contact the KFO to discuss possible impacts to the species. The specified area includes or
  is in the vicinity of a known hibernaculum and/or maternity roost tree.

Species profile: <a href="https://ecos.fws.gov/ecp/species/9045">https://ecos.fws.gov/ecp/species/9045</a>

General project design guidelines:

https://ecos.fws.gov/ipac/guideline/design/population/10043/office/42431.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://ecos.fws.gov/ipac/guideline/design/population/352/office/42431.pdf Endangered Fanshell *Cyprogenia stegaria* No critical habitat has been designated for this species. Species profile: <a href="https://ecos.fws.gov/ecp/species/4822">https://ecos.fws.gov/ecp/species/4822</a> General project design guidelines: https://ecos.fws.gov/ipac/guideline/design/population/368/office/42431.pdf Northern Riffleshell *Epioblasma torulosa rangiana* Endangered No critical habitat has been designated for this species. Species profile: https://ecos.fws.gov/ecp/species/527 General project design guidelines: https://ecos.fws.gov/ipac/guideline/design/population/374/office/42431.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://ecos.fws.gov/ipac/guideline/design/population/331/office/42431.pdf Purple Cat's Paw (=purple Cat's Paw Pearlymussel) *Epioblasma obliquata* Endangered obliquata Population: Wherever found; Except where listed as Experimental Populations No critical habitat has been designated for this species. Species profile: <a href="https://ecos.fws.gov/ecp/species/5602">https://ecos.fws.gov/ecp/species/5602</a> General project design guidelines: https://ecos.fws.gov/ipac/guideline/design/population/323/office/42431.pdf Threatened Rabbitsfoot *Quadrula cylindrica cylindrica* There is **final** critical habitat for this species. Your location is outside the critical habitat. Species profile: <a href="https://ecos.fws.gov/ecp/species/5165">https://ecos.fws.gov/ecp/species/5165</a> General project design guidelines: https://ecos.fws.gov/ipac/guideline/design/population/3645/office/42431.pdf Ring Pink (mussel) *Obovaria retusa* Endangered No critical habitat has been designated for this species. Species profile: https://ecos.fws.gov/ecp/species/4128 General project design guidelines: https://ecos.fws.gov/ipac/guideline/design/population/341/office/42431.pdf Endangered Rough Pigtoe *Pleurobema plenum* 

No critical habitat has been designated for this species.

Endangered

Endangered

Endangered

Endangered

Threatened

Event Code: 04EK1000-2021-E-00326

NAME STATUS

Species profile: <a href="https://ecos.fws.gov/ecp/species/6894">https://ecos.fws.gov/ecp/species/6894</a>

General project design guidelines:

https://ecos.fws.gov/ipac/guideline/design/population/338/office/42431.pdf

Sheepnose Mussel *Plethobasus cyphyus* 

No critical habitat has been designated for this species. Species profile: <a href="https://ecos.fws.gov/ecp/species/6903">https://ecos.fws.gov/ecp/species/6903</a>

General project design guidelines:

https://ecos.fws.gov/ipac/guideline/design/population/7816/office/42431.pdf

Snuffbox Mussel *Epioblasma triquetra* 

No critical habitat has been designated for this species. Species profile: <a href="https://ecos.fws.gov/ecp/species/4135">https://ecos.fws.gov/ecp/species/4135</a>

Spectaclecase (mussel) Cumberlandia monodonta

No critical habitat has been designated for this species. Species profile: <a href="https://ecos.fws.gov/ecp/species/7867">https://ecos.fws.gov/ecp/species/7867</a>

General project design guidelines:

https://ecos.fws.gov/ipac/guideline/design/population/4490/office/42431.pdf

**Crustaceans** 

NAME STATUS

Kentucky Cave Shrimp *Palaemonias ganteri* 

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

Species profile: <a href="https://ecos.fws.gov/ecp/species/5008">https://ecos.fws.gov/ecp/species/5008</a>

**Flowering Plants** 

NAME STATUS

Prices Potato-bean *Apios priceana* 

No critical habitat has been designated for this species. Species profile: <a href="https://ecos.fws.gov/ecp/species/7422">https://ecos.fws.gov/ecp/species/7422</a>

**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

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

Final



ANDY BESHEAR GOVERNOR REBECCA W. GOODMAN SECRETARY

> ZEB WEESE 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

July 2, 2020

Kaitlin Ilnick Redwing Ecological Services, Inc. 1139 South Fourth Street Louisville, KY 40203

Project: Green River Lock & Dam #5; 20-086

Project ID: 21-0003

Project Type: Standard (\*customers will be invoiced), 1 mile buffer

(\$120 fee)

Site Acreage: 1,018.87

Site Lat/Lon: 37.196264 / -86.278416
County: Butler; Edmonson; Warren

USGS Quad: BEE SPRING; BROWNSVILLE; NOLIN LAKE;

REEDYVILLE; RHODA

Watershed HUC12: Beaverdam Creek-Green River; Buffalo Creek-Green

River; Bylew Creek-Nolin River; Cub Creek-Bear Creek;

Echo River-Green River +

## Dear Kaitlin Ilnick,

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).

Project ID: 21-0003 July 2, 2020 Page 2

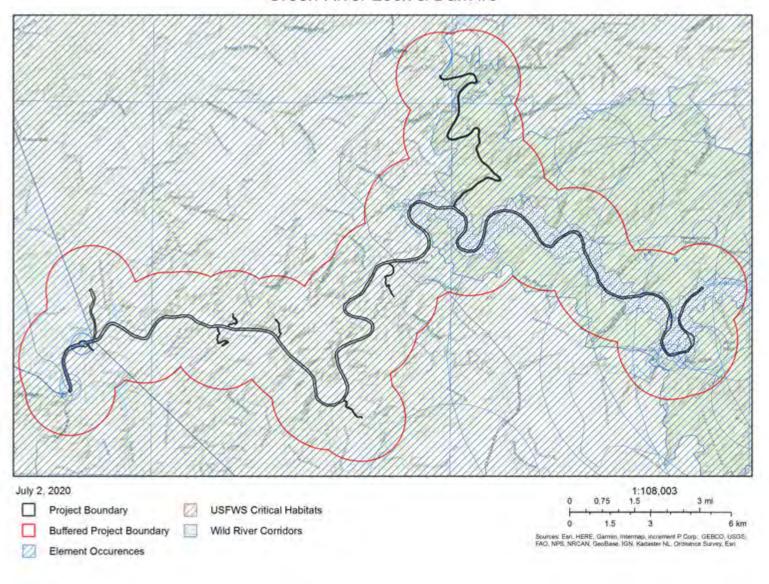
Please note that the quantity and quality of data collected by the Kentucky Natural Heritage Program are dependent on the research and observations of many individuals and organizations. In most cases, this information is not the result of comprehensive or site-specific field surveys; many natural areas 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,

Elizabeth Mason Geoprocessing Specialist

## Green River Lock & Dam #5



# 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 October 28, 2020

## MEMORANDUM FOR RECORD

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

- 1. <u>Summary</u>: Removal of Lock and Dam #5 (L&D 5) on the Green 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 Green River. Given that L&D 5 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 downstream mussels.
- 2. <u>Background</u>: A series of locks and dams were constructed throughout the mid-1800's on the Green River in an effort to facilitate shipping and navigation up and downstream on the river. These dams are the run-of -river type, which increase flow depth and create large backwater pools that generally stretch from one dam upstream to the toe of the next dam higher 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 L&D 5, as well as many of the other structures along the Green River.

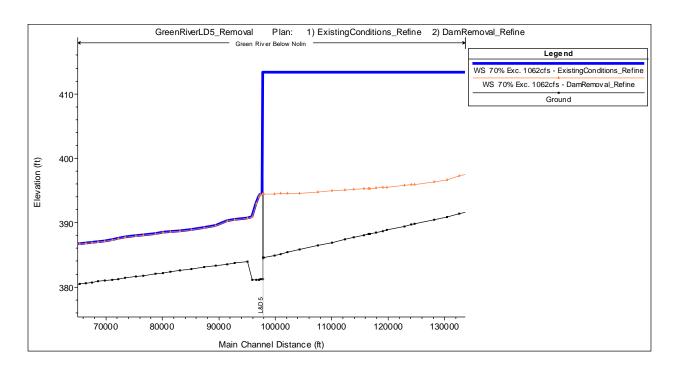
The nature of the run-of-river dams along the Green River, including L&D 5, is such that flood water is not significantly impounded within the reservoir's pool. The dam's crest consists of a wide ogee-type weir that spans the channel width and is lower than the surrounding floodplain elevation (crest elevation is approximately 412', versus floodplain elevations around 429'). Because of the large hydraulic capacity to convey flow over this weir, inflow and outflow of the pool created by

### SUBJECT: IMPACTS ON DOWNSTREAM MUSSELS DUE TO DAM REMOVAL

L&D 5 are effectively equal. Since inflow and outflow are equal, and therefore downstream flow is unaffected by the presence of L&D 5; 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:

$$au = \gamma \cdot D \cdot S_w$$
 Where:  $au = Shear\ Stress$  {  $lb\ /ft^2$  }  $y = Unit\ Weight\ of\ Water$  {  $lb\ /ft^3$  }  $D = Flow\ Depth$  {  $ft\ \}$  }  $S_w = Water\ Surface\ Slope$  {  $ft\ /ft$  }

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 a removal of the dam were evaluated with limited available hydraulic modeling. The figure below shows water surface profiles along the Green River for the existing condition with the dam in place (blue line), and dam removal condition (orange line). Green River L&D 5 is located near river station 98,000 in the figure. Both profiles are shown for the same flowrate of just over 1,000 cfs, however there is nothing significant about this particular flowrate and it was selected to illustrate trends which were gathered from modeling a full range of flows.



Note that downstream of L&D 5, water surface profiles are identical for both the with- and without-dam scenarios. This modeling, which is both 1-dimentional 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 5 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 the 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. For these reasons, it is appropriate to qualitatively consider how removal of L&D 5 will alter sedimentation patterns downstream of the dam.

Based upon September 2017 sediment sampling conducted by The Nature Conservancy in L&D 5's pool, all indications point to the substrate within the dam's pool being relatively clean and free of the fine sediments which could otherwise threaten the mussels downstream. 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 that the pool has been configured 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 stands a chance to recuperate from historic alteration and sediment transport processes can begin to recover.

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

### SUBJECT: IMPACTS ON DOWNSTREAM MUSSELS DUE TO DAM REMOVAL

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.

Finally, it should be noted that natural riffle and bar habitats are almost entirely absent within L&D 5'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.

3. <u>Conclusion</u>: Based on these findings, it is expected that removal of L&D 5 will have minimal impacts on downstream 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 Lock and Dam 5 on the Green River.