AMERICAN ELECTRIC POWER
BOUNDLESS ENERGY

Appalachian Power Company
P. O. Box 2021
Roanoke, VA 24022-2121
aep.com

Via Electronic Filing   April 14, 2022

Kimberly D. Bose, Secretary
Federal Energy Regulatory Commission
888 First Street, N.E.
Washington, D.C. 20426

Subject: Byllesby-Buck Hydroelectric Project (FERC No. 2514)
Final License Application Supplemental Information - Revised Study Reports

Dear Secretary Bose:

Appalachian Power Company (Appalachian or Licensee), a unit of American Electric Power (AEP), is the Licensee, owner, and operator of the two-development Byllesby-Buck Hydroelectric Project (Project) (Project No. 2514), located on the upper New River in Carroll County, Virginia.

The Project is currently licensed by the Federal Energy Regulatory Commission (FERC or Commission). The Project underwent relicensing in the early 1990s, and the current operating license for the Project expires on February 29, 2024. Accordingly, Appalachian is pursuing a new license for the Project pursuant to the Commission's Integrated Licensing Process (ILP), as described at 18 Code of Federal Regulations (CFR) Part 5. Appalachian filed the Final License Application (FLA) for the Project on February 28, 2022.

Appalachian stated in the FLA that due to the additional time needed to address numerous comments on the Updated Study Report and Draft License Application, two of the revised (final) study reports would be filed within 45 days, or by April 14, 2022. Appalachian is hereby filing the revised Aquatic Resources and Bypass Reach Flow and Aquatic Habitat study reports. The reports have been revised since the versions provided in the Updated Study Report to address the comments summarized in Appalachian's February 14, 2022 request for extension of time filed with the Commission. At this time, Appalachian does not propose any changes to the protection, mitigation, and enhancement (PM&E) measures proposed in the FLA as a result of the conclusions in these revised study reports.

If there are any questions regarding this filing, please do not hesitate to contact me at (540) 985-2441 or via email at ebparcell@aep.com.

Sincerely,

Elizabeth Parcell
Process Supervisor
American Electric Power Service Corporation

cc: Jonathan Magalski (AEP)

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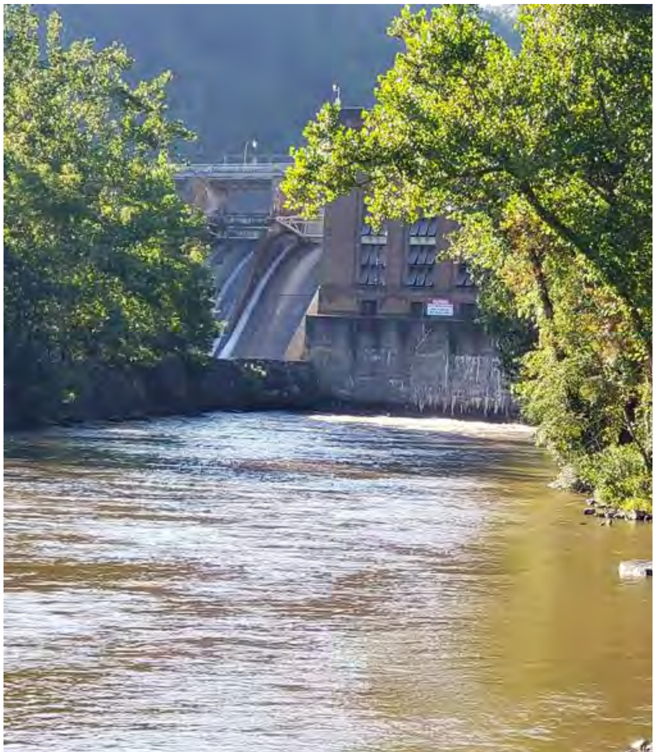

Aquatic Resources Study Report

Byllesby-Buck Hydroelectric Project (FERC No. 2514)

April 14, 2022

Prepared by:

HDR

Prepared for:

Appalachian Power Company

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1 Project Introduction and Background

Appalachian Power Company (Appalachian or Licensee), a unit of American Electric Power (AEP), is the Licensee, owner, and operator of the two-development Byllesby-Buck Hydroelectric Project (Project) (Project No. 2514), located on the upper New River in Carroll County, Virginia. The Byllesby development is located about 9 miles north of the city of Galax, and the Buck development is located approximately 3 river miles downstream of Byllesby and 43.5 river miles upstream of Claytor Dam.

The Project is currently licensed by the Federal Energy Regulatory Commission (FERC or Commission). The Project underwent relicensing in the early 1990s, including conversion to run-of-river operations and incorporating additional protection, mitigation, and enhancement (PM&E) measures (FERC 1994). The current operating license for the Project expires on February 29, 2024. Accordingly, Appalachian is pursuing a subsequent license for the Project pursuant to the Commission's Integrated Licensing Process (ILP), as described at 18 Code of Federal Regulations (CFR) Part 5. In accordance with FERC's regulations at 18 CFR §16.9(b), the licensee must file its final application for a new license with FERC no later than February 28, 2022.

In accordance with 18 CFR §5.11 of the Commission's regulations, Appalachian developed a Revised Study Plan (RSP) for the Project that was filed with the Commission and made available to stakeholders on October 18, 2019. On November 18, 2019 FERC issued the Study Plan Determination (SPD). On December 12, 2019, Appalachian filed a clarification letter on the SPD with the Commission. On December 18, 2019, Appalachian filed a request for rehearing of the SPD. The SPD was subsequently modified by FERC by an Order on Rehearing dated February 20, 2020.

On July 27, 2020, Appalachian filed an updated ILP study schedule and a request for extension of time to file the Initial Study Report (ISR) to account for Project delays resulting from the COVID-19 pandemic. The request was approved by FERC on August 10, 2020, and the filing deadline for the ISR for the Project was extended from November 17, 2020 to January 18, 2021. On December 23, 2020, FERC issued Scoping Document 3 (SD3) for the Project, to account for updates about how Commission staff intend to conduct their National Environmental Policy Act (NEPA) review in accordance with the Council on Environmental Quality's (CEQ) new NEPA regulations at 40 CFR Part 1500-1518.

Appalachian filed the ISR on January 18, 2021, conducted a virtual ISR Meeting on January 28, 2021, and filed the ISR Meeting summary with the Commission on February 12, 2021. Stakeholders provided written comments in response to Appalachian's filing of the ISR meeting summary, which were addressed in the Updated Study Report (USR). The USR was filed with the FERC on November 17, 2021, and the USR meeting was held on December 1, 2021; the meeting summary was filed on December 16, 2021. The following parties provided written comments in response to Appalachian's filing of the USR meeting summary: FERC staff (January 18, 2022), U.S. Fish and Wildlife Service (USFWS) (January 18, 2022), and Virginia Department of Wildlife Resources (VDWR) (January 18, 2022). On February 14, 2022, Appalachian filed with FERC a response to comments on the USR and a request for extension of time to file the revised Aquatic Resources Study Report, given the additional time and effort needed to address comments received on the USR. The Final License Application was filed on February 28, 2022.

This revised Aquatic Resources Study report is being filed as supplemental information to the FLA and describes the methods and results of the Aquatics Resources Study conducted in support of preparing an application for new license for the Project.

2 Study Goals and Objectives

The goals and objectives of the Aquatic Resources Study are to:

- Collect a comprehensive baseline of existing aquatic resources in the vicinity of the Project.
- Compare current aquatic resources data to historical data to determine any significant changes to species composition or abundance.
- Confirm intake velocities for fish entrainment potential.

3 Study Components

The Aquatic Resources Study report comprises the following study reports:

1. 2020-2021 Fish Community Study Report – Attachment 1
2. Impingement and Entrainment Study Report – Attachment 2
3. 2020-2021 Macroinvertebrate and Crayfish Community Study Report – Attachment 3
4. Mussel Community Study Report – Attachment 4

For existing background information, study methods, study results, and analyses, please refer to the individual study reports in Attachments 1 through 4.

Germane correspondence is provided in Attachment 5 and includes the following:

- On April 3, 2020, HDR's sub-contractor (Edge Engineering and Science, LLC [EDGE]) sent the tentative walleye gill net methods and sampling sites to the Virginia Department of Wildlife Resources (VDWR) (formally the Virginia Department of Game and Inland Fisheries) as a response to VDWR's request on March 31, 2020.
- On September 29, 2020, HDR's sub-contractor (Stantec Consulting services, Inc. [Stantec]) sent an e-mail to the VDWR confirming completed mussel survey locations and requesting advice on completing the survey. On October 8, 2020, the VDWR confirmed that Stantec should re-deploy and complete the surveyed locations.
- On October 8, 2020, EDGE sent notification to the U.S. Fish and Wildlife Service and VWDR indicating that while conducting the benthic macroinvertebrate survey, multiple freshwater mussels including Virginia state listed Pistolgrip (*Tritogonia verrucosa*) were discovered in the surveyed substrates.
- On November 4, 2020, HDR e-mailed the VDWR to provide an update on the Fish Community Study and to confirm that performing the gillnet survey in November would be acceptable to the agency. On November 9, 2020, the VDWR concurred with HDR and

EDGE's plan of action and confirmed that gill net surveying could be performed through early December.

- Informal email and telephone communications (January-February 2022) with VDWR regarding fishery (walleye body depth) data and documentation of past stranding incidents in the Buck bypass reach, as well as the potential for occurrence of Eastern hellbender in each bypass reach.
- Virtual (WebEx) meetings with representatives from VDWR, USFWS, and VDEQ on February 1, 2022 and February 16, 2022 to discuss comments received in response to the USR and Draft License Application (DLA).
- Response to USFWS comment, received January 18, 2022, requesting stream flow data for the Byllesby and Buck bypass reaches on dates that sampling was performed for the Fish Community Study.

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Attachment 1

Attachment 1 – 2020 -2021
Fish Community Study
Report

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Byllesby-Buck Hydroelectric Project
(FERC Project No. 2514)

Prepared for:

AMERICAN ELECTRIC POWER
BOUNDLESS ENERGY

2020-2021 Fish Community Survey Results, Virginia

Byllesby-Buck → HDR2020-0001

October 12, 2021

Prepared by:
EDGE ENGINEERING & SCIENCE
further insight.

Edge Engineering and Science, LLC
Cincinnati, Ohio

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APPENDICES

Appendix A. Scientific Collection Permits

Appendix B. Representative Photographs

Appendix C. Raw Data

LIST OF ACRONYMS

AEP	American Electric Power – Client
Appalachian	Appalachian Power Company
CFS	Cubic feet per second
CPUE	Catch per unit effort
DO	Dissolved oxygen
EDGE	Edge Engineering and Science, LLC
EF	Electrofishing
FERC	Federal Energy Regulatory Commission
HDR	HDR, Inc. – Client
ISR	Initial Study Report
LDB	Left descending bank
NRSA	National Rivers and Streams Assessment
Project	Byllesby-Buck Hydroelectric Project
RDB	Right descending bank
RSP	Revised Study Plan
SAV	Submerged aquatic vegetation
TL	Total length
USFWS	U.S. Fish and Wildlife Service
USR	Updated Study Report
VAC	Virginia Administrative Code
VDCR	Virginia Department of Conservation and Recreation
VDEQ	Virginia Department of Environmental Quality
VDWR	Virginia Department of Wildlife Resources (formerly VDGIF)

1.0 INTRODUCTION

The Byllesby and Buck Dams form the 30.1-megawatt Byllesby-Buck Hydroelectric Project (Project) located on the New River in Carroll County, Virginia. Appalachian Power Company (a unit of American Electric Power; AEP) is pursuing a new license from the Federal Energy Regulatory Commission (FERC) for the Project as their existing license expires in 2024. Aquatic biological studies were completed to satisfy their existing FERC license and results of these studies are ultimately used as a record and reference for current relicensing efforts. The New River, along with the two contiguous impoundments resulting from the Project, harbors a diverse community of aquatic biota where aquatic biological studies are required to survey and document the contemporary community of organisms present within the Project area (Figure 1). The New River and lower reaches of tributary streams are included in the Project survey area. The information gained from the Fish Community Study will provide a comprehensive baseline of the current fish community (i.e., abundance, diversity, and distribution) near the Project. These resulting data will be compared to historical data to identify temporal trends in fish community abundance, diversity, or distribution near the Project.

Study scoping with state and federal agencies resulted in the development and approval of a project specific Revised Study Plan (RSP) that identified two objectives for Project studies (AEP 2019) pertaining to the fish community.

Goals and Objectives

1) Collect a comprehensive baseline of existing aquatic resources in the vicinity of the Project.
2) Compare current aquatic resources data to historical data to determine any significant changes to species composition or abundance.

In accordance with the RSP, field sampling efforts were necessary to satisfy each of the two objectives. Some of the objectives were not accomplished during the 2020 calendar year due to delays resulting from unforeseeable circumstances including heavy precipitation and high flows and the COVID-19 global pandemic; therefore, an Initial Study Report (ISR) was submitted on January 18, 2021. This report serves as the Update Study Report (USR) now that all field sampling efforts within the RSP have been completed.

2.0 METHODS

The RSP provided guidance on the sampling framework for the Project that included general fish community methodologies. Fish community sampling conducted in 2020 employed boat electrofishing and gillnetting to target representative fish habitats throughout the Project area. Backpack electrofishing surveys were not completed in 2020; therefore, these methods and results were not discussed in the ISR but are included herein. Fish community sampling conducted in 2021 employed boat and backpack electrofishing and gillnetting to target representative fish habitats throughout the Project area. The selected sampling methods include a combination of equipment, techniques, seasonality, and number and location of sample sites, to provide a contemporary representation of the Project area and correspond to previous sampling efforts (Appalachian and AEP 1991) for comparison.

2.1 Fish Community Sampling

The fish community study, detailed in the RSP, consists of two temporally independent efforts (one fall survey and one spring survey). Sampling methods were derived from the National Rivers and Streams Assessment (NRSA) Field Operations Manual (USEPA 2019), which guides standardized electrofishing methods in lotic waterbodies of variable sizes. Gillnet methods were established in coordination with the Virginia Department of Wildlife Resources (VDWR). Within the constraints of the Project's objectives and geographic limits, boat and backpack electrofishing and gillnetting techniques were employed to most-effectively target specific sites based on the habitat types present in the Project area. Boat electrofishing was used to target near-shore pool habitats (i.e., non-wadeable), backpack electrofishing was used to target riffle/run habitats (i.e., wadeable), and gillnetting was used to target mid-channel pool habitats. Seven boat electrofishing sites were in the Byllesby Pool and 10 were in the Buck Pool. Three backpack electrofishing sites were located upstream of Byllesby Dam, six were located between Byllesby Dam and Buck Dam, and four were located below Buck Dam. Six gillnetting sites were in the Byllesby Pool to specifically target Walleye (*Sander vitreus*), as recommended by VDWR.

Sampling techniques are described further in subsequent sections. Specific sampling dates are based on factors including (but not limited to) weather conditions, water temperatures, river flows and reservoir elevations, and safety of field staff and the public. Site naming conventions are as follows: Location-Seasonality-Method-Site Number. For example, BFB1 = Byllesby-Buck Fall Boat Site 1, BSBP1 = Byllesby-Buck Spring Backpack Site 1, and BFG1 = Byllesby-Buck Fall Gillnet Site 1. Site numbers increase in the downstream direction.

2.1.1 Boat Electrofishing

Boat electrofishing techniques were used to survey the fish community at 17 pool sites (i.e., BFB and BSB site names) along 100-meter transects. Upon arrival at boat electrofishing sites (Figures 1-8), transects were delineated in pool habitat and the start and endpoint coordinates were recorded. The effectiveness of boat electrofishing is reduced in deeper water (i.e., greater than three meters), especially during daylight hours; therefore, sampling was performed within 30 meters of shore. Site photos were taken in four directions (upstream, downstream, left descending bank [LDB], and right descending bank [RDB]; all 90 degrees to one another) and substrate, and field conditions were recorded (e.g., time, date, air temperature, precipitation, cloudy/overcast, etc.). At each sample site, habitat characteristics (e.g., substrate, estimated water velocity, depth, and instream cover) and water quality parameters (e.g., pH, water temperature, dissolved oxygen [DO], and conductivity) were measured and recorded. Additionally, a Secchi disk reading was taken at each sample site at the time of sampling. Multiple points for habitat and water quality measurements were taken if there was large variation within a single site. Prior to initiating sample collection, electrofishing equipment was calibrated based on the water conductivity at each sample site. Sampling effort (i.e., electrofishing time) was also recorded during each sampling event.

Starting at the downstream end of the transect and moving upstream, all available habitat types (i.e., shallow shoreline, deep shoreline, emergent vegetation, submerged wood, etc.) were candidates for sampling throughout the reach and particular care was taken to thoroughly sample complex habitat and instream structures. During sampling, a boat driver maneuvered the boat along each transect (nosing into and then away from the bank) while two field personnel or netters collected stunned fish in dip nets and one person guided the driver. For each 100-meter transect, a minimum of five minutes electrofishing was required, and more time may have been necessary depending on the complexity of the habitat. Fish were placed in live wells until sampling for that transect had concluded and then returned to the stream at the survey location. Each fish was identified to the lowest taxonomic level practicable, enumerated, and examined for signs of external parasites, disease, or physical abnormalities. In addition, the total length (TL) and weight was recorded for the first 30 individuals of a species per sample site. All captured individuals were enumerated. If more than 30 individuals of a single species were collected at a given sample site, the additional fish were counted, and length measurements were recorded for specimens that exceed the upper or lower maximum recorded lengths from the 30 individuals previously measured. Photos were taken in the field for a representative specimen of each fish taxon collected during the study and for those fish that could not be identified to species (e.g., minnows, juvenile Moxostoma sp.), representative specimens were preserved and identified in a laboratory setting based on sampling permit specifications.

2.1.2 Backpack Electrofishing

Backpack electrofishing surveys of the fish community occurred at 13 riffle/run sites (i.e., BSBP site names) along 100-meter transects (or two 50-meter transects if habitat was limited longitudinally). Upon arrival at wadeable sites (Figure 1 and Figures 9-13), transects were delineated in riffle/run habitat and the start and endpoint coordinates were recorded. Site photos, field conditions, habitat characteristics, and water quality parameters were recorded in the same manner as boat electrofishing sites (see Section 2.1.1). Multiple points for habitat and water quality measurements were taken if there was large variation within a single site. Prior to initiating sample collection, electrofishing equipment was calibrated based on the conductivity of the water at each sample site. Sampling effort (i.e., electrofishing time) was also recorded during each sampling event.

Starting at the downstream end of the transect and moving upstream, all riffle/run habitats were candidates for sampling throughout the reach. All major habitat types identified within the transect were sampled and particular care was taken to thoroughly sample complex habitat and instream structures, while a netter(s) actively captured stunned fish with a dip net. In areas of elevated stream velocities, a stationary seine (2.4-meters-wide by 1.8-meters-tall with 0.48-centimeter mesh) was positioned downstream of the sample location perpendicular to stream flow and the operator of the backpack electrofishing unit simultaneously performed kicks/sweeps in a downstream manner toward the seine. Stunned fishes were driven into the net with the aid of stream currents and the seine was then swept upward and fish retrieved for processing. For each 100-meter transect, a minimum of five minutes electrofishing time was expended, and more time may have been necessary depending on the complexity of the habitat. All collected fish were kept in aerated buckets and/or instream live wells during surveys and processed in the same manner as boat electrofishing methods (see Section 2.1.1) before being returned to the stream at the survey location.

2.1.3 Gillnetting

Gillnetting techniques were used to survey the fish community at six pool sites (i.e., BFG and BSG site names) with 36.5-meter-long by 2.4-meter-deep gillnets. Each gillnet was comprised of eight 4.6-meter-long panels with mesh sizes of 1.9, 2.5, 3.2, 3.8, 5.1, 6.4, 7.6, and 10.2 centimeters. Upon arrival at gillnet sites (Figure 1 and Figures 14-16), gillnets were anchored with a cinder block, so the top of the net was at least 0.5 meter below the surface. Starting on the shoreward side, and with the smallest mesh size, gillnets were pulled taught as the boat operator moved towards the channel and slightly downstream of and perpendicular to shore. The start and endpoint coordinates were recorded for each gillnet deployment. Site photos, field conditions, habitat characteristics, and water quality parameters were recorded in the same manner as boat electrofishing sites (see Section 2.1.1). Nets were set for 24 hours before they were retrieved with a grappling hook and checked for fish, which were placed in live wells for processing. Nets were reset in the same location and fish were processed in the same manner as boat electrofishing methods (see Section 2.1.1), except processed fish were released at least 100 meters from the site so they did not immediately become entangled when the gillnets were reset. Nets soaked for another 24 hours before being checked again and pulled from the location after a total of 48 hours of soak time per site.

2.2 Deviations from Revised Study Plan

2.2.1 COVID-19 Delays

The initial field plan included spring and fall 2020 sampling events (boat electrofishing, backpack electrofishing, and gillnetting); however, the COVID-19 pandemic, and subsequent restrictions on non-essential travel and safety considerations for field staff, prohibited spring 2020 field efforts. As a result, AEP requested, and was granted, an extension to accommodate the change in schedule as VDWR, Virginia Department of Environmental Quality (VDEQ), U.S. Fish and Wildlife Service (USFWS), and Virginia Department of Conservation and Recreation (VDCR) all concurred with adaptable schedule revisions. EDGE was contracted and given notice to proceed with fieldwork at the beginning of September 2020 and was able to complete the fall 2020 boat electrofishing and gillnet sampling efforts. Fall 2020 backpack electrofishing methods were postponed due to weather delays. Spring boat and backpack electrofishing and gillnetting methods occurred in 2021.

2.2.2 Weather Delays

Periodic delays associated with weather and stream conditions plagued the fall 2020 sampling season. Average rainfall for Galax, Virginia (collected at this station since 1981) is approximately 26 centimeters between September 1 and December 1 (US Climate Data 2020); yet during the same three-month period in 2020, Galax accumulated over 37 centimeters of rain (USGS 2020), a 42 percent increase. Therefore, the fall 2020 boat electrofishing and gillnet sampling efforts were completed the baseflows around 2,000-2,500 cubic feet per second (cfs), which at the time were the assumed baseflows for 2020. As a result of the 42 percent increase from average precipitation that occurred in 2020, the study area portion of the New River remained elevated well above the average annual baseflow conditions throughout the fall 2020 field study season. The relatively high discharge did not impact boat electrofishing and gillnet methods, but riffle/run habitat within the Project area remained too swift and deep to effectively and safely sample using backpack electrofishing methods. Thus, the backpack electrofishing surveys that were proposed for completion in 2020 (along with boat electrofishing and gillnetting) occurred in spring 2021. Spring 2021 flows more closely matched average flows during the sampling period.

2.2.3 Sampling Locations

At the time of sampling, multiple proposed locations did not correspond well with the targeted habitats identified during the desktop-based site selection process. As such, sampling methods for those locations were adjusted in the field to provide the best possible sample collection effort from the sampling locations identified in the RSP. Two sites upstream of a high-gradient riffle complex, located between Byllesby Dam and Buck Dam (originally identified as boat electrofishing sites) were switched to backpack electrofishing methods based on the presence of boulder habitat with swift currents. All backpack electrofishing sites (between Byllesby Dam and Buck Dam) were chosen based on available habitat and site accessibility. A range of habitats found in this area (e.g., variable depths, substrate size, instream cover, etc.) were sampled to get a comprehensive illustration of the fish community. Furthermore, one proposed backpack electrofishing site (at the mouth of Crooked Creek in the Byllesby Pool) was replaced with boat electrofishing methods as the site consisted of pool habitat and was not conducive to backpack electrofishing methods. All site adjustments carried over into spring 2021 sampling efforts.

3.0 RESULTS

The fish community results were divided and analyzed in three distinct sections to directly evaluate potential differences in the fish community throughout the Project Area – upstream of Byllesby Dam, between Byllesby Dam and Buck Dam, and downstream of Buck Dam. Backpack electrofishing results (from spring 2021) were compared between these three sections. Boat electrofishing results (from fall 2020 and spring 2021) were compared between the Byllesby Pool and Buck Pool. Gillnetting results in the Byllesby Pool were primarily used to investigate the presence and distribution of Walleye. Understanding how the fish community changes throughout the Project area provides insight into the impact, or lack thereof, that the Project has on the New River.

3.1 Fish Community Sampling

Boat electrofishing surveys were conducted between October 22 and 24-25, 2020, and April 25-26 and May 27, 2021. Backpack electrofishing surveys were conducted between April 20-23, 2021. Gillnet surveys were conducted between November 9-11 and 18-20, 2020, and April 20-24, 2021. All surveys followed methods outlined in the RSP and occurred during relatively low-flow and clear stream conditions. Sampling was performed by EDGE's state permitted fish biologist under Virginia Scientific Collecting Permit No. 070705 (Appendix A). There were differences in habitat type and substrates observed between sites (Appendix B); however, differences in sampling dates, time of day, and low number of intra- and inter-site samples do not facilitate statistical comparison of physiochemical properties between sites. Results of physiochemical data collected at sample sites met the state water quality standards established for the New River, indicating that water quality within the Project area is capable of supporting fish communities (this will be detailed further in the Project-specific USR water quality study report referencing Virginia Administrative Code [VAC] Chapter 260).

3.1.1 Boat Electrofishing

A total of 597 fish were collected, representing 32 species, using boat electrofishing methods at 17 sites throughout the Project area (sampled fall 2020 and spring 2021) and nine species were collected exclusively using this method. The raw field sampling data for both seasons and all sample sites are provided in Appendix C. A total of 410 fish were collected, representing 24 species, using backpack electrofishing methods at 13 sites throughout the Project area (sampled spring 2021) and seven species were collected exclusively using this method. A total of 112 fish were collected, representing 10 species, using gillnet methods at six sites in the Byllesby Pool (sampled fall 2020 and spring 2021) and Walleye was the only species collected exclusively using this method.

The substrate at boat electrofishing sites within the Byllesby Pool generally consisted of sand (70%), silt (20%), gravel (5%), and boulder (5%). Many of the sites along the LDB exhibited a low-gradient, vegetated floodplain whereas many of the sites along the RDB exhibited a high-gradient, rock face (Appendix B). Both sides of the impoundment displayed shoreline habitat that rapidly descended towards the center of the channel. The habitat structure at most sites within the Byllesby Pool generally consisted of sparse woody debris, submerged aquatic vegetation (SAV), and scattered boulders. Water quality parameters (temperature, pH, DO, velocity, and conductivity) remained relatively consistent throughout the Byllesby Pool except velocity was slightly higher in the two upstream most sites toward the head of the impoundment (Appendix C).

The substrate at boat electrofishing sites within the Buck Pool generally consisted of sand (60%), silt (20%), boulder (15%), and gravel (5%). Many of the sites along the LDB exhibited a low-gradient, vegetated floodplain whereas many of the sites along the RDB exhibited a high-gradient, rock face (Appendix B). The upstream portion of the Buck Pool was relatively shallow with a consistent depth across the width of the stream whereas the downstream portion of the pool had shallow banks that rapidly descended towards the center of the channel. There was very little habitat structure at most sites within the Buck Pool, but scattered woody debris, SAV, and boulders were present. Water quality parameters remained relatively consistent throughout the impoundment except DO and velocity were higher toward the upstream end of the impoundment, just below a section of high-gradient riffles.

A total of 244 fish were collected, representing 20 species, in the Byllesby Pool from seven boat electrofishing sites. A total of 353 fish were collected, representing 24 species, in the Buck Pool from 10 boat electrofishing sites. The most abundant species collected during boat electrofishing surveys in the Byllesby Pool were Telescope Shiner (*Notropis telescopus*) (29.5%), Bluegill (*Lepomis macrochirus*) (15.2%), and Redbreast Sunfish (*Lepomis auritus*) (9.8%); however, Telescope Shiner were only collected at one site. The most abundant species collected during boat electrofishing surveys in the Buck Pool were Redbreast Sunfish (28.9%), Smallmouth Bass (*Micropterus dolomieu*) (20.4%), and Whitetail Shiner (*Cyprinella galactura*) (11.6%), each of which being captured at a minimum of five sites. Distribution of individuals was relatively consistent throughout each pool and correlates with habitat preference and complexity. The Byllesby Pool was dominated by the invertivore-piscivore trophic guild and the water column habitat guild, whereas the Buck Pool was dominated by the invertivore trophic guild and the water column habitat guild (McCormick et al. 2001).

Overall, species diversity resulting from boat electrofishing surveys was negligibly higher in the Byllesby Pool (H' = 2.32) than in the Buck Pool (H' = 2.26). Similarly, catch per unit effort (CPUE) ranged from 0.3 to 14.2 individuals per minute in the Byllesby Pool (averaging 2.9) and CPUE ranged from 0.5 to 9.5 individuals per minute in the Buck Pool (averaging 2.8). CPUE was 54% higher in the spring than the fall in the Byllesby Pool and 214% higher in the spring than the fall in the Buck Pool. Representative site and fish photos are provided in Appendix B and raw data for fish collections are provided in Appendix C.

3.1.2 Backpack Electrofishing

The substrate at backpack electrofishing sites upstream of the Byllesby Dam generally consisted of bedrock (25%), boulder (25%), cobble (20%), gravel (15%), and sand (15%). Two sites were along the RDB, and one site was along the LDB, but all three sites were in the first riffle/run section above the Byllesby Pool (approximately 5.5 km upstream of the Byllesby Dam) (Figure 9). Habitat structure at these sites primarily consisted of well-developed, swift riffles varying from a few centimeters to a meter in depth. The substrate at backpack electrofishing sites between the Byllesby Dam and the Buck Dam was consistent to that in the first three sites, except higher percent bedrock at site BSBP4 (Bypass Reach), higher percent cobble at site BSBP5 (Figure 10), and higher percent gravel at site BSBP6 (Figure 11). All types of riffle/run habitat present between the dams was surveyed, from low-gradient riffles with relatively small substrate and no instream cover to high-gradient riffles with relatively large substrate and substantial instream cover. The substrate downstream of the Buck Dam generally consisted of bedrock (35%), boulder (25%), cobble (20%), gravel (15%), and sand (5%) in the two Bypass Reach sites (Figure 12) where the primary habitat is well-developed riffle. Bedrock (25%), boulder (25%), cobble (20%), gravel (15%), and sand (15%) were dominant substrates in the two sites downstream of the Bypass Reach (Figure 13) where the primary habitat structure is more run than riffle, with sporadic undercut banks and overhanging vegetation. Water quality parameters (temperature, pH, DO, velocity, and conductivity) remained relatively consistent throughout all backpack electrofishing sites except velocity (Appendix C), which often changes drastically within a single transect.

A total of 48 fish were collected, representing 11 species, upstream of the Byllesby Dam from three backpack electrofishing sites. A total of 156 fish were collected, representing 18 species, between the Byllesby Dam and Buck Dam from six backpack electrofishing sites. A total of 206 fish were collected, representing 17 species, downstream of the Buck Dam from four backpack electrofishing sites. The most abundant species collected during backpack electrofishing surveys upstream of the Byllesby Dam were Whitetail Shiner (39.6%) and Rosyface Shiner (*Notropis rubellus*) (16.7%), with Whitetail Shiner being the only species captured at all three sites. The most abundant species collected during backpack electrofishing surveys between the Byllesby Dam and Buck Dam were Telescope Shiner (43.6%) and Whitetail Shiner (14.7%) with the least productive site occurring in the Bypass Reach (BSBP4; only accounting for 2.5% of total abundance between the dams). The most abundant species collected during backpack electrofishing surveys downstream of the Buck Dam were Central Stoneroller (*Campostoma anomalum*) (28.6%) and Telescope Shiner (25.7%). In contrast to the two Bypass Reach sites below Byllesby Dam (accounting for 14 individuals), the Bypass Reach sites below Buck Dam accounted for 142 individuals.

Overall, species diversity resulting from backpack electrofishing surveys was comparable between the sites upstream of the Byllesby Dam, between the Byllesby Dam and Buck Dam, and downstream of the Buck Dam (H' = 1.92, 1.97, and 1.98, respectively). In contrast, the average CPUE for sites upstream of the Byllesby Dam was 1.7 individuals per minute, between the Byllesby Dam and Buck Dam was 3.5 individuals per minute, and downstream of the Buck Dam was 7.6 individuals per minute. The doubling of CPUE moving downstream through the Project area may have resulted from availability of preferred habitat or efficacy of sampling techniques in select habitats; however, it is understood that dams may limit upstream movement of fish and abundance generally increases in the downstream direction of most rivers. Representative site and fish photos are provided in Appendix B and raw data for fish collections are provided in Appendix C.

3.1.3 Gillnetting

The substrate at gillnetting sites within the Byllesby Pool generally consisted of sand (70%), silt (25%), and gravel (5%); however, the near-shore substrates ranged from vertical rock face and boulder to sand and silt flats. Many of the sites along the LDB exhibited a low-gradient, vegetated floodplain whereas many of the sites along the RDB exhibited a high-gradient, rock face (Appendix B). Both sides of the impoundment displayed shoreline habitat that rapidly descended towards the center of the channel (Figure 1 and Figures 14-16). Water quality parameters (temperature, pH, DO, velocity, and conductivity) remained relatively consistent throughout the Byllesby Pool except velocity was slightly higher in the two upstream most sites toward the head of the impoundment (Appendix C). No fish were captured at site BFG1/BSG1, which exhibited relatively swift current as it was located within the thalweg of the river on the outside bank of a meander and may not be suitable for consistent fish utilization.

A total of 112 fish were collected, representing 10 species, in the Byllesby Pool from six gillnet sites. The most abundant species collected during gillnet surveys in the Byllesby Pool were Common Carp (*Cyprinus carpio*) (51.8%), Channel Catfish (*Ictalurus punctatus*) (24.1%), White Sucker (*Catostomus commersonii*) (8.0%), and Walleye (8.0%) (Appendix C). Distribution of individuals was relatively consistent throughout the Byllesby Pool and likely correlates with habitat preference and complexity; however, a large majority of the Common Carp (most abundant species) were collected at one site (BFG3/BSG3).

Overall, species diversity (H' = 1.43) resulting from gillnetting surveys in the Byllesby Pool was relatively low, although there were no direct comparisons to be made as gillnetting did not occur anywhere else in the Project area. CPUE ranged from 0.5 to 22 individuals per net set (averaging 6.2), and like boat electrofishing methods, CPUE was 62% higher in spring than in fall. Representative site and fish photos are provided in Appendix B and raw data for fish collections are provided in Appendix C.

4.0 DISCUSSION

4.1 Fish Community

A total of 404 fish were collected, representing 26 species, upstream of Byllesby Dam from seven boat electrofishing sites (sampled fall 2020 and spring 2021), three backpack electrofishing sites (sampled spring 2021), and six gillnet sites (sampled fall 2020 and spring 2021). The raw field sampling data for both seasons and all sample sites are provided in Appendix C. Five species were collected exclusively upstream of Byllesby Dam. A total of 509 fish were collected, representing 33 species, between Byllesby Dam and Buck Dam from 10 boat electrofishing sites (sampled fall 2020 and spring 2021) and six backpack electrofishing sites (sampled spring 2021). Seven species were collected exclusively between Byllesby Dam and Buck Dam. A total of 206 fish were collected, representing 17 species, below Buck Dam from four backpack electrofishing sites (sampled spring 2021). Two species were collected exclusively below Buck Dam.

With regards to boat electrofishing, 20 species were collected in the Byllesby Pool from seven sites and 24 species were collected in the Buck Pool from 10 sites; however, species diversity was negligibly higher in the Byllesby Pool than in the Buck Pool and CPUE was nearly identical. The additional species may be attributable to a greater number of sites being surveyed or slight differences in habitat availability. Overall, the Byllesby Pool and Buck Pool exhibit similar fish community characteristics. Boat electrofishing yielded two game fish species in the Byllesby Pool that were not present in the Buck Pool (i.e., Muskellunge [*Esox masquinongy*] and Rainbow Trout [*Oncorhynchus mykiss*]). In contrast, boat electrofishing in the Buck Pool yielded nine species of darters, minnows, shiners, suckers, and sunfish that were not present in the Byllesby Pool (Appendix C).

With regards to backpack electrofishing, 11 species were collected upstream of the Byllesby Dam from three sites, 18 species were collected between the Byllesby Dam and Buck Dam from six sites, and 17 species were collected downstream of the Buck Dam from four sites. These differences in species richness may result from differences in effort between the Project areas; however, differences in species diversity were negligible between each Project area. The general abundance of fish in riffle/run habitats increased in the downstream direction, with CPUE doubling from upstream sites to middle sites and doubling again from middle sites to downstream sites. For example, the two sites in the Bypass Reach of the Byllesby Dam yielded less than 10-percent of the individuals compared to the two sites in the Bypass Reach of Buck Dam. No fish species were exclusively collected using backpack electrofishing methods upstream of Byllesby Dam; however, Kanawha Darter (*Etheostoma kanawhae*) and Saffron Shiner (*Notropis rubricroceus*) were only collected between Byllesby Dam and Buck Dam and Kanawha Sculpin (*Cottus kanawhae*) and White Shiner (*Luxilus albeolus*) were only collected downstream of the Buck Dam (Appendix C).

Gillnetting methods were only implemented in the Byllesby Pool, by request from VDWR, to target Walleye. Walleye was the only species of fish exclusively captured using gillnets as all other species captured using gillnets were also captured with either boat or backpack electrofishing methods. A total of nine Walleye were captured at three of six gillnet sites. The three sites where they were capture had primarily sand and silt substrates with lower-gradient bed slope compared to the three sites where they were not captured, which had larger substrates near the shore and higher-gradient bed slope towards the channel. Further, the three sites where Walleye were captured were in the upper, middle, and lower sections of the Byllesby Pool, indicating that they are using the entire length of the pool. Six Walleye were collected in fall 2020 and three were collected in spring 2021. Six of the nine Walleye were collected at the downstream most site in the Byllesby Pool, indicating that they may be occupying the deeper sections more often.

In a previous study in the Project area, Appalachian and AEP (1991) employed boat electrofishing, gillnetting, and hoop netting techniques. Although they did not use backpack electrofishing techniques, they used boat electrofishing techniques in both pool and riffle habitat. The total number and spatial distribution of sample sites is comparable between the current and historical studies. However, the historical study sampled each site six times, resulting in 216 total samples, compared to 59 samples in the current study. Additionally, for each pair of sites surveyed in Appalachian and AEP (1991), one was sampled during the day and the other at night. The current study does not include nighttime electrofishing due to safety concerns. These differences in methodology do not appear to have impacted the results of the study drastically and conclusions can still be drawn between the two.

The historical study (Appalachian and AEP 1991) collected a total of 2,679 individuals representing 34 species, compared to the current study which collected 1,119 individuals representing 40 species. Therefore, despite the lower effort in the present study, there was an increase in overall richness of fish species within the Project area. Both studies documented a low incidence of parasites and physical abnormalities. Four species were captured in the previous study that were not captured in the current study including Johnny Darter (*Etheostoma nigrum*), Silver Redhorse (*Moxostoma anisurum*), Bluehead Chub (*Nocomis leptocephalus*), and Silver Shiner (*Notropis photogenis*), which may simply be a result of fewer sampling types and sampling events, sampling seasonality, or absence of nighttime electrofishing; however, 11 species were captured in the current study that were not captured in the previous study (Appendix C). The overall diversity of the fish community was greater in the current study (H'=2.91) than in the previous study (H'=2.53). Smallmouth Bass and Redbreast Sunfish were two of the four most abundant species in both studies and many of the other mutual species were found in similar relative abundance. Walleye were not captured during the previous study, but multiple specimens were collected in the current study, which is a good sign for the popular fishery. No state or federally listed threatened or endangered species were collected in this study or the historical study. Overall, fish species distribution, richness, and abundance throughout the Project area during the current study closely matched that of Appalachian and AEP (1991). For example, the highest average CPUE and richness per sample for riffle/run habitat was recorded downstream of the Buck Dam in both studies.

For Appalachian and AEP (1991) fish community studies, fish abundance was not reported separately for electrofishing of pool and riffle habitats. Additionally, gill and hoop net results were not reported separately. For the purposes of this report, a comparison of species richness at boat electrofishing sites in 2020/2021 and Appalachian and AEP (1991) were used to help identify any trends in the fish community within the Project area. Species richness observed in the current study during boat electrofishing in pool habitats were 20 species and 24 species in the Byllesby Pool and Buck Pool, respectively. Species richness observed in the previous study during boat electrofishing in pool habitats were 9 species and 11 species in the Byllesby Pool and Buck Pool, respectively. Overall, fish community composition was quite similar between the two studies, but richness in the Project area seems to have increased indicating that the Project area is just as capable (if not more capable) of hosting an abundant and diverse fishery.

Water quality parameters and trends throughout the Project area did not change markedly from Appalachian and AEP (1991) (Appendix C). Information regarding effects of Project operations on the fish community (e.g., fish length frequency, effects on spawning habitat, etc.) can be referenced in Appalachian and AEP (1991) and in the USR.

5.0 LITERATURE CITED

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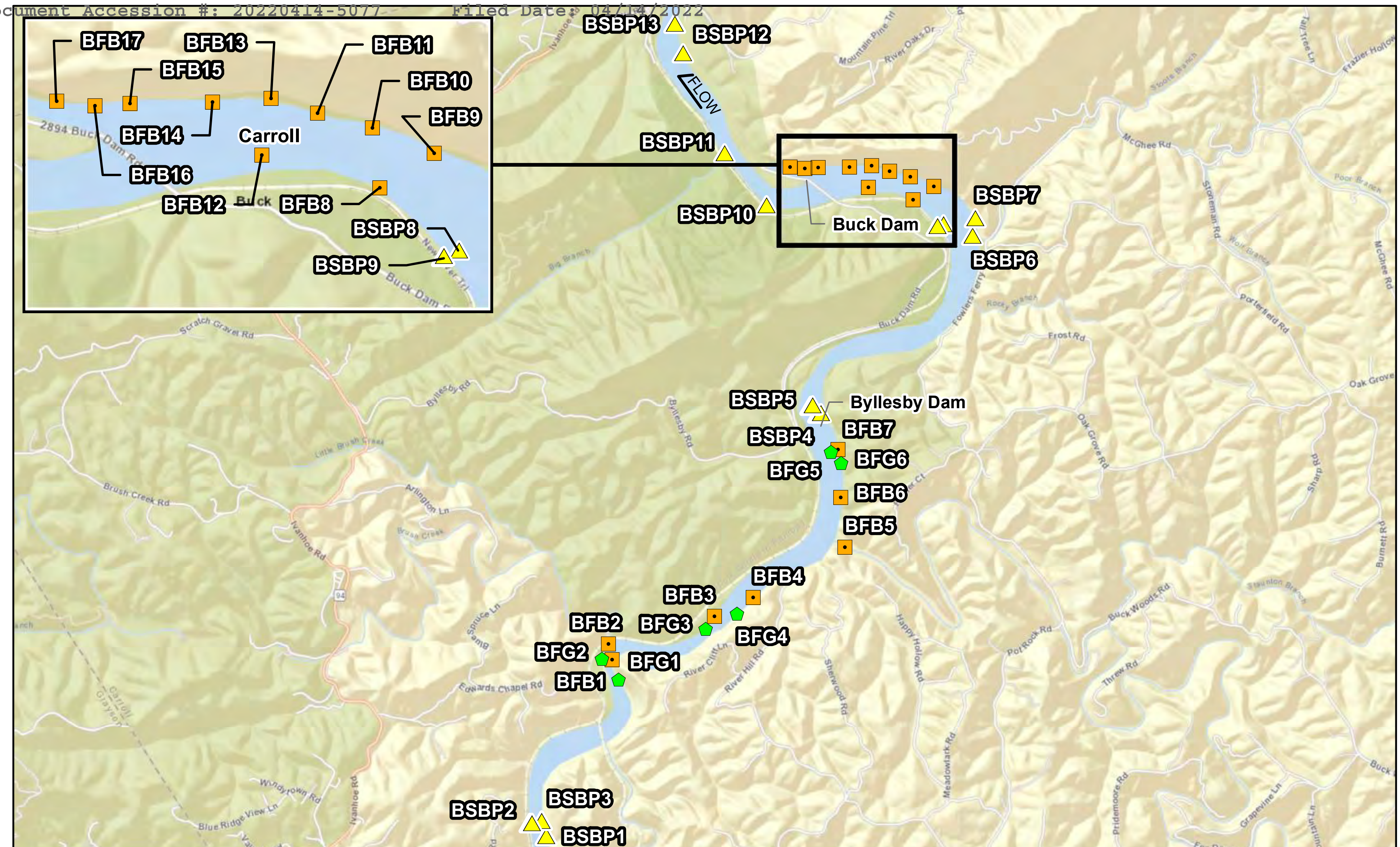
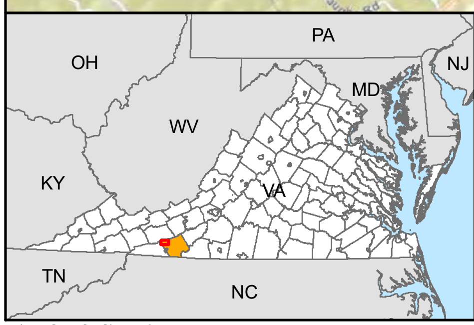
Figures





Legend

Fish Sample Location

- Backpack electrofishing
- Boat Electrofishing - 100-meter survey extent
- Gillnet - 36.5-meter survey extent

N

0 0.6 1.2
Kilometers

Scale: 1:51,181

AMERICAN ELECTRIC POWER

EDGE ENGINEERING & SCIENCE

American Electric Power
Byllesby-Buck Dam Fish Community Study

Figure 1
Overall Byllesby-Buck project area including backpack electrofishing (BSBP), boat electrofishing (BFB), and gillnet (BFG) survey sites on the New River in Carroll County, Virginia

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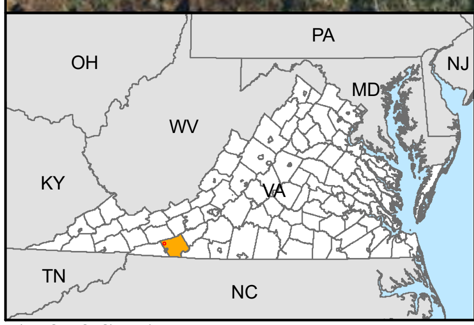

Legend

- Boat Electrofishing - 100-meter survey extent
- Boat Electrofishing - 100-meter survey extent

N

0 50 100
Meters

Scale: 1:3,937

American Electric Power
Byllesby-Buck Dam Fish Community Study

Figure 2
Boat electrofishing 100-meter survey extent in pool habitat in Carroll County, Virginia.

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Legend

- Boat Electrofishing - 100-meter survey extent (point)
- Boat Electrofishing - 100-meter survey extent (line)

N

0 50 100
Meters

Scale: 1:3,937

AMERICAN ELECTRIC POWER
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Byllesby-Buck Dam Fish Community Study

Figure 3
Boat electrofishing 100-meter survey extent in pool habitat in Carroll County, Virginia.

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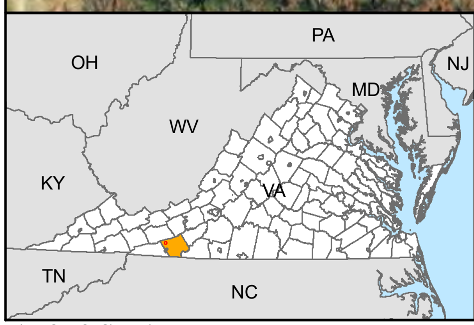

Legend

Boat Electrofishing - 100-meter survey extent

Boat Electrofishing - 100-meter survey extent

N

0 50 100

Meters

Scale: 1:3,937

AMERICAN ELECTRIC POWER

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American Electric Power
Byllesby-Buck Dam Fish Community Study

Figure 4
Boat electrofishing 100-meter survey extent in pool habitat in Carroll County, Virginia.

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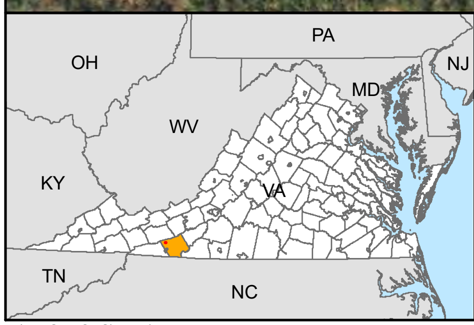

Legend

- Boat Electrofishing - 100-meter survey extent
- Boat Electrofishing - 100-meter survey extent

N

0 50 100

Meters

Scale: 1:3,937

AMERICAN ELECTRIC POWER

EDGE ENGINEERING & SCIENCE

American Electric Power
Byllesby-Buck Dam Fish Community Study

Figure 5
Boat electrofishing 100-meter survey extent in pool habitat in Carroll County, Virginia.

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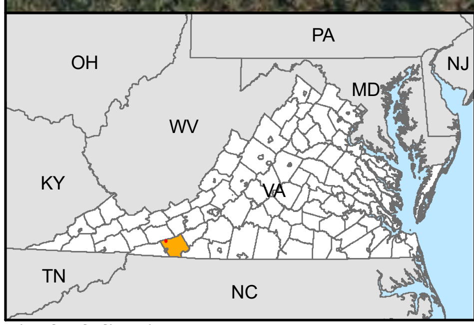

Legend

- Boat Electrofishing - 100-meter survey extent
- Boat Electrofishing - 100-meter survey extent

N

0 50 100
Meters

Scale: 1:3,937

AMERICAN ELECTRIC POWER
BOUNDLESS ENERGY

EDGE ENGINEERING & SCIENCE

American Electric Power
Byllesby-Buck Dam Fish Community Study

Figure 6
Boat electrofishing 100-meter survey extent in pool habitat in Carroll County, Virginia.

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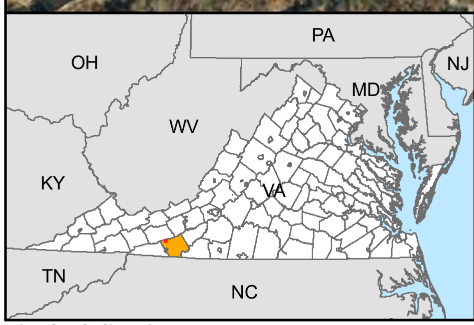

Legend

- Boat Electrofishing - 100-meter survey extent (point)
- Boat Electrofishing - 100-meter survey extent (line)

N

0 50 100
Meters

Scale: 1:3,937

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Figure 7
Boat electrofishing 100-meter survey extent in pool habitat in Carroll County, Virginia.

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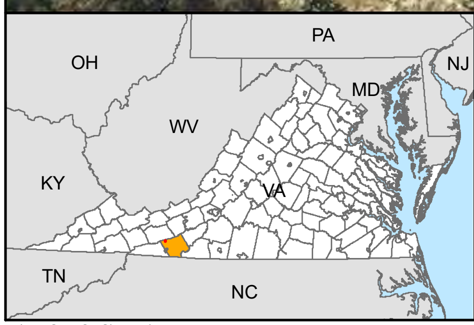

Legend

- Boat Electrofishing - 100-meter survey extent (point)
- Boat Electrofishing - 100-meter survey extent (line)

N

0 50 100
Meters

Scale: 1:3,937

American Electric Power
Byllesby-Buck Dam Fish Community Study

Figure 8
Boat electrofishing 100-meter survey extent in pool habitat in Carroll County, Virginia.

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Legend

- ▲ Backpack electrofishing
- — Backpack electrofishing

N

0 50 100
Meters

Scale: 1:3,937

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Figure 9
Backpack electrofishing survey extent in riffle habitat in Carroll County, Virginia..

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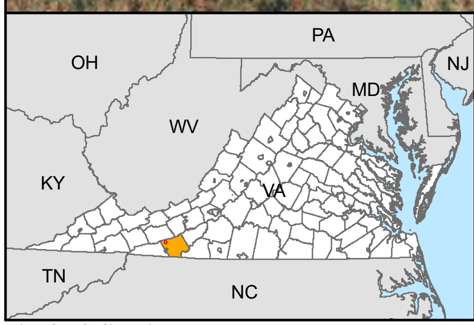

Legend

- ▲ Backpack electrofishing
- — Backpack electrofishing

N

0 50 100
Meters

Scale: 1:3,937

American Electric Power
Byllesby-Buck Dam Fish Community Study

Figure 10
Backpack electrofishing survey extent in riffle habitat in Carroll County, Virginia..

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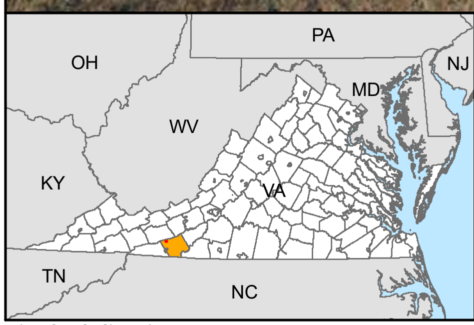

Legend

- △ Backpack electrofishing
- — Backpack electrofishing

N

0 50 100
Meters

Scale: 1:3,937

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Byllesby-Buck Dam Fish Community Study

Figure 11
Backpack electrofishing survey extent in riffle habitat in Carroll County, Virginia..

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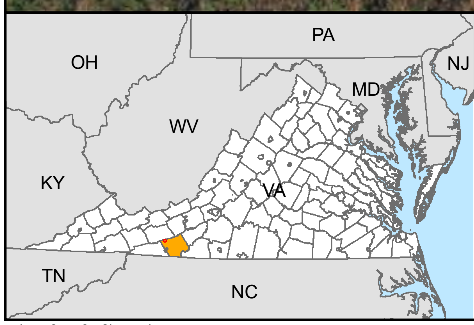

Legend

- △ Backpack electrofishing
- ― Backpack electrofishing

N

0 50 100
Meters

Scale: 1:3,937

AMERICAN ELECTRIC POWER

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Byllesby-Buck Dam Fish Community Study

Figure 12
Backpack electrofishing survey extent in riffle habitat in Carroll County, Virginia..

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Legend

- △ Backpack electrofishing
- ― Backpack electrofishing

N

0 50 100
Meters

Scale: 1:3,937

American Electric Power
Byllesby-Buck Dam Fish Community Study

Figure 13
Backpack electrofishing survey extent in riffle habitat in Carroll County, Virginia..

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Legend

- Gillnet - 36.5-meter survey extent (point)
- Gillnet - 36.5-meter survey extent (line)

N

0 50 100
Meters

Scale: 1:3,937

American Electric Power
Byllesby-Buck Dam Fish Community Study

Figure 14
Gillnet 36.5-meter survey extent in pool habitat in Carroll County, Virginia.

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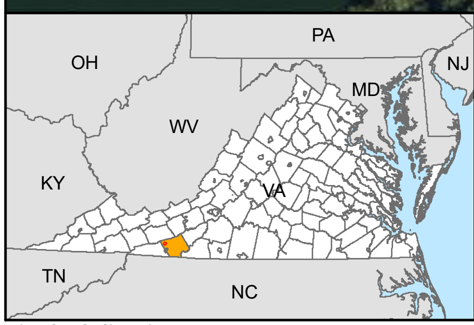

Legend

- Gillnet - 36.5-meter survey extent (point)
- Gillnet - 36.5-meter survey extent (line)

N

0 50 100
Meters

Scale: 1:3,937

American Electric Power
Byllesby-Buck Dam Fish Community Study

Figure 15
Gillnet 36.5-meter survey extent in pool habitat in Carroll County, Virginia.

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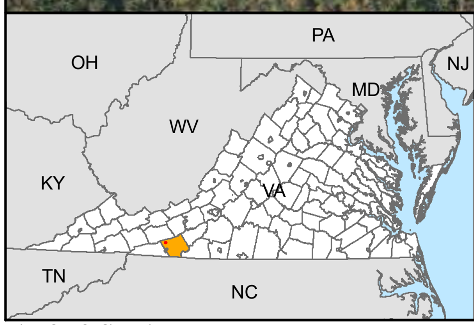

Legend

- Gillnet - 36.5-meter survey extent (point)
- Gillnet - 36.5-meter survey extent (line)

N

0 50 100
Meters

Scale: 1:3,937

American Electric Power

EDGE ENGINEERING & SCIENCE

American Electric Power
Byllesby-Buck Dam Fish Community Study

Figure 16
Gillnet 36.5-meter survey extent in pool habitat in Carroll County, Virginia.

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Appendix A

SCIENTIFIC COLLECTION PERMITS

Virginia Department of Game and Inland Fisheries

7870 Villa Park Drive, P.O. Box 90778, Henrico, VA 23228-0778
(804) 367-1000 (V/TDD)
Under Authority of § 29.1-412, § 29.1-417, & § 29.1-418 of the Code of Virginia

Scientific Collection Permit

Permit Type: **New** Fee Paid: **$40.00** VADGIF Permit No. **070705**

Permittee: **Jonathan Studio**
Address: **36550 Chester Road, Apt. 4801**
Avon, OH 44011
Email: **jastudio@edge-es.com**

Home:
Office: **(440) 413-4609**
City/County:

Business: **Edge Engineering & Science, LLC**
4005 Ponder Drive
Cincinnati, OH 45245

Niagara Hydroelectric Project/Byllesby-Buck Hydroelectric Project

Authorized Collection Methods: By Hand/Dip Nets/Electrofishing/Gill Nets/Trawl Nets/Nets-Traps (Fyke/Hoop/D-Frame)/Seine Nets/Drift Nets
Authorized Waterbodies: Roanoke River/Tinker Creek/New River
Authorized Marking Techniques: N/A

SPECIAL CONDITIONS: No electrofishing in Roanoke Logperch TOYR unless requested and approved by both USFWS and DWR. Mussels may not be targeted and any inadvertently collected must be returned to the point-of-capture after the individual is identified (if ID is possible).

Permittee MUST notify DWR within the 7 day period prior to each sampling event. Notification must be made via email to: collectionpermits@dwr.virginia.gov

Report Due: 31 January 2022, 31 January 2023

ANNUAL REPORTS MUST BE SUBMITTED VIA: https://vafwis.dgif.virginia.gov/collection_permits/

STANDARD CONDITIONS ATTACHED APPLY TO THIS PERMIT.

Authorized Counties / Cities:
Carroll
Roanoke

Authorized Species:

Description	ID Number	Scientific Name
Aquatic Insects		
Crayfish		
Freshwater Fish		
Other Aquatic Invertebrates		

Annual Report Due End of Each Year

Authorized Sub-Permittees:
See Attached Sheet

Approved by: [signature]

Applicants may appeal permit decisions within 30 days of issuance. The appeal must be in writing to the Director, Department of Game and Inland Fisheries.

Title: **Randall T. Francis - Permits Manager** **Date: 3/2/2021**

Virginia Department of Game and Inland Fisheries

7870 Villa Park Drive, P.O. Box 90778, Henrico, VA 23228-0778
(804) 367-1000 (V/TDD)

Under Authority of § 29.1-412, § 29.1-417, & § 29.1-418 of the Code of Virginia

Scientific Collection Permit

Permit Type: **New** Fee Paid: **$40.00** VADGIF Permit No. **070705**

20 Permit Effective **3/2/2021** through **12/31/2022** **22**

Virginia Department of Game and Inland Fisheries
7870 Villa Park Drive, P.O. Box 90778, Henrico, VA 23228-0778
(804) 367-1000 (V/TDD)

Under Authority of § 29.1-412, § 29.1-417, & § 29.1-418 of the Code of Virginia

Scientific Collection Permit

Permit Type: **New**   FeePaid: **$40.00**   VADGIF Permit No. **070705**

Authorized Sub-Permittees:

Sarah Messer, Edge Engineering & Science, LLC
John Spaeth, Edge Engineering & Science, LLC
Aaron Prewitt, Edge Engineering & Science, LLC
Adam Benshoff, Edge Engineering & Science, LLC
David Foltz, Edge Engineering & Science, LLC
Mitchell Kriege, Edge Engineering & Science, LLC
Alyssa Jones, Edge Engineering & Science, LLC
David Ford, Edge Engineering & Science, LLC
Tim Brust, Edge Engineering & Science, LLC

Virginia Department of Wildlife Resources
P O Box 3337 Henrico, VA 23228-3337
(804) 367-6913

Under Authority of § 29.1-412, § 29.1-417, & § 29.1-418 of the Code of Virginia

SCIENTIFIC COLLECTION PERMIT – STANDARD CONDITIONS

1. Permits are issued to permittees with the understanding that if the principal permittee leaves the project the permit will be null and void and anyone desiring to continue the activities must apply for a new permit.

2. This permit, or a copy, must be carried by the permittee(s) during collection activities.

3. Permittee MUST notify the Virginia Department of Wildlife Resources (VDWR) within the seven (7) day period prior to EACH sampling event. Notification must be made via email to: collectionpermits@DWR.virginia.gov.)

4. The permittee is required to submit to this Department a report of all specimens collected under this permit by the report due date. Report form may be found at https://vafwis.DWR.virginia.gov/collection_permits/. FAILURE TO RETURN THIS REPORT WILL RESULT IN NON-ISSUANCE OF FUTURE PERMITS. If no activity occurs under this permit, an email should be sent to collectionpermits@DWR.virginia.gov containing the following statement: No activity occurred under Permit #*insert permit ID* during insert year (i.e. 2017). Permit reports are due by January 31.

5. Permittees shall give any and all changes of name, address, and/or phone number to the VDWR Permits Section within no more than seven (7) days of those changes. All permittees (to include sub-permittees) shall provide DWR with a complete home address, contact telephone number (home or cellular), and a valid e-mail address.

6. This permit does not support any activities outside of those associated with the application and proposal submitted to and approved by DWR.

7. No species currently listed by the U.S. Fish and Wildlife Service or VDWR as threatened or endangered may be intentionally collected under this permit. If incidental d*eath or injury* of threatened or endangered species does occur, the permittee is required to notify VDWR at collectionpermits@DWR.virginia.gov within twenty-four (24) hours of occurrence. The following information must be reported: collector, date, species, location (county, quad, waterbody, and latitude and longitude to nearest second), and number collected.

8. If incidental *observation or collection and live release* of threatened or endangered species occurs, the permittee is required to notify VDWR at collectionpermits@DWR.virginia.gov within four (4) working days, providing the same information as the Condition No. 7.

9. If incidental *mortality or injury of specimens intended to be taken live* occurs, the permittee is required to notify VDWR at collectionpermits@DWR.virginia.gov within 48 hours, providing the same information as the above conditions. In addition, the permittee must provide the cause of mortality or injury and steps that are being taken to address the problem.

10. No species may be retained unless specifically authorized by this permit.

11. Game birds/game mammals/game fish protected by State and/or Federal laws must be taken during authorized hunting and trapping seasons and under applicable daily and seasonal bag/number limits by properly licensed persons unless otherwise specifically authorized. A valid Virginia fishing license is required for each person collecting samples by hook-and-line.

12. All traps must be marked with the name and address of the trapper or an identification number issued by VDWR (Code of Virginia §29.1-521.7). Steel foothold traps, Conibear-style body gripping traps, and snares must be marked with a nonferrous metal tag bearing this information (Virginia Administrative Code 4 VAC 15-40-170).

13. All traps must be checked at least once a day and all captured animals removed, except completely submerged body-gripping traps which must be checked at least once every 72 hours (Code of Virginia §29.1-521.9).

14. The permittee is required to report any incidences of wildlife deaths or diseases observed during the course of collection activities. Reports should be made to: collectionpermits@DWR.virginia.gov within four (4) working days.

15. This permit satisfies only VDWR's requirement for collection permits and is issued with the understanding that no collections will be made on Federal, state, or private property without the prior approval and necessary permits from the landowners involved. The permittee is responsible for obtaining any additional permits required for collection.

16. Sampling gear, boats, or trailers which have been used in states harboring zebra mussels must be cleaned and prepared following accepted guidelines for removal of zebra mussels, prior to being used in Virginia.

17. For safety reasons, it is recommended that all permittees display at least 100 square inches of solid blaze orange material at shoulder level within body reach and visible from 360 degrees, especially during hunting season.

Appendix B

REPRESENTATIVE PHOTOGRAPHS

BFB1 - Downstream
Boat Electrofishing Sample Site

BFB2 - Downstream
Boat Electrofishing Sample Site

BFB3 - Upstream
Boat Electrofishing Sample Site

BFB4 - Right Descending Bank
Boat Electrofishing Sample Site

BFB5 - Upstream
Boat Electrofishing Sample Site

BFB6 - Right Descending Bank
Boat Electrofishing Sample Site

BFB7 - Downstream
Boat Electrofishing Sample Site

BFB8 - Left Descending Bank
Boat Electrofishing Sample Site

BFB9 - Upstream
Boat Electrofishing Sample Site

BFB10 - Upstream
Boat Electrofishing Sample Site

BFB11 - Upstream
Boat Electrofishing Sample Site

BFB12 - Upstream
Boat Electrofishing Sample Site

BFB13 - Downstream
Boat Electrofishing Sample Site

BFB14 - Right Descending Bank
Boat Electrofishing Sample Site

BFB15 - Downstream
Boat Electrofishing Sample Site

BFB16 - Right Descending Bank
Boat Electrofishing Sample Site

BFB17 - Downstream
Boat Electrofishing Sample Site

BFBP1 - Upstream
Backpack Electrofishing Sample Site

BFBP2 - Downstream
Backpack Electrofishing Sample Site

BFBP3 - Upstream
Backpack Electrofishing Sample Site

BFBP4 - Upstream
Backpack Electrofishing Sample Site

BFBP5 - Downstream
Backpack Electrofishing Sample Site

BFBP6 - Downstream
Backpack Electrofishing Sample Site

BFBP7 - Downstream
Backpack Electrofishing Sample Site

BFBP8 - Upstream
Backpack Electrofishing Sample Site

BFBP9 - Upstream
Backpack Electrofishing Sample Site

BFBP10 - Upstream
Backpack Electrofishing Sample Site

BFBP11 - Upstream
Backpack Electrofishing Sample Site

BFBP12 - Upstream
Backpack Electrofishing Sample Site

BFBP13 - Downstream
Backpack Electrofishing Sample Site

BFG1 – Upstream
Gillnetting Sample Site

BFG2 - Downstream
Gillnetting Sample Site

BFG3 - Left Descending Bank
Gillnetting Sample Site

BFG4 - Downstream
Gillnetting Sample Site

BFG5 - Right Descending Bank
Gillnetting Sample Site

BFG6 - Downstream
Gillnetting Sample Site

Rock Bass
(*Ambloplites rupestris*)

Central Stoneroller
(*Campostoma anomalum*)

White Sucker
(*Catostomus commersonii*)

Kanawha Sculpin
(*Cottus kanawhae*)

Whitetail Shiner
(*Cyprinella galactura*)

Spotfin Shiner
(*Cyprinella spiloptera*)

Common Carp
(*Cyprinus carpio)*

Muskellunge
(*Esox masquinongy*)

Greenside Darter
(*Etheostoma blennioides*)

Fantail Darter
(*Etheostoma flabellare*)

Kanawha Darter
(*Etheostoma kanawhae*)

Northern Hog Sucker
(*Hypentelium nigricans*)

Channel Catfish
(*Ictalurus punctatus*)

Redbreast Sunfish
(*Lepomis auritus*)

Green Sunfish
(*Lepomis cyanellus*)

Pumpkinseed
(*Lepomis gibbosus*)

Bluegill
(*Lepomis macrochirus*)

White Shiner
(*Luxilus albeolus*)

Rosefin Shiner
(*Lythrurus ardens*)

Smallmouth Bass
(*Micropterus dolomieu*)

Spotted Bass
(*Micropterus punctulatus*)

Largemouth Bass
(*Micropterus salmoides*)

Bigmouth Chub
(*Nocomis platyrhynchus*)

Spottail Shiner
(*Notropis hudsonius*)

Swallowtail Shiner
(*Notropis procne*)

Rosyface Shiner
(*Notropis rubellus*)

Saffron Shiner
(*Notropis rubricroceus*)

New River Shiner
(*Notropis scabriceps*)

Telescope Shiner
(*Notropis telescopus*)

Mimic Shiner
(*Notropis volucellus*)

Margined Madtom
(*Noturus insignis*)

Rainbow Trout
(*Oncorhynchus mykiss*)

Logperch
(*Percina caprodes*)

Sharpnose Darter
(*Percina oxyrhynchus*)

Bluntnose Minnow
(*Pimephales notatus*)

Black Crappie
(*Pomoxis nigromaculatus*)

Flathead Catfish
(*Pylodictis olivaris*)

Walleye
(*Sander vitreus*)

Appendix C

RAW DATA

Fish species captured by method (EF = Electrofishing) and Project location (US = Upstream and DS = Downstream). Highlighted cells indicate species exclusively captured using that method or in that location.

Species	Method			Location		
	Boat EF	Backpack EF	Gillnet	US Byllesby	Between Dams	DS Buck
Ambloplites rupestris	X	X	X	X	X	
Campostoma anomalum		X		X	X	X
Catostomus commersonii	X		X	X		
Cottus kanawhae		X				X
Cyprinella galactura	X	X		X	X	X
Cyprinella spiloptera	X	X		X	X	X
Cyprinus carpio	X		X	X	X	
Esox masquinongy	X		X	X		
Etheostoma blennioides	X	X		X	X	X
Etheostoma flabellare	X	X			X	X
Etheostoma kanawhae		X			X	
Hypentelium nigricans	X	X			X	X
Ictalurus punctatus	X		X	X	X	
Lepomis auritus	X	X		X	X	X
Lepomis cyanellus	X			X	X	
Lepomis gibbosus	X				X	
Lepomis macrochirus	X		X	X	X	
Lepomis sp.	X	X		X	X	X
Luxilus albeolus		X				X
Lythrurus ardens	X				X	
Micropterus dolomieu	X	X	X	X	X	X
Micropterus punctulatus	X			X	X	
Micropterus salmoides	X			X	X	
Nocomis platyrhynchus	X	X		X	X	
Nocomis sp.	X	X		X	X	
Notropis hudsonius	X				X	
Notropis procne	X				X	
Notropis rubellus	X	X		X	X	X
Notropis rubricroceus		X			X	
Notropis scabriceps	X	X		X	X	X
Notropis telescopus	X	X		X	X	X
Notropis volucellus	X	X		X	X	
Noturus insignis		X			X	X
Oncorhynchus mykiss	X			X		
Percina caprodes	X	X			X	X
Percina oxyrhynchus		X			X	X
Pimephales notatus	X				X	
Pomoxis nigromaculatus	X		X	X		
Pylodictis olivaris	X	X	X	X	X	
Sander vitreus			X	X		
Total Number of Exclusive Species	9	7	1	5	7	2

Water quality parameters at boat electrofishing sites in fall 2020 (BFB site names) and spring 2021 (BSB site names). Sites above the dashed line are in Byllesby Pool and below dashed line are in Buck Pool.

Date	Site ID	Water Temp. (C)	pH	DO (%)	Velocity (m/s)	Conductivity (us/cm)
10/25/2020	BFB1	16.3	7.2	87.3	0.05	65.8
10/25/2020	BFB2	16.3	7.2	87.3	0.09	65.8
10/25/2020	BFB3	16.5	7.0	88.1	0.03	55.2
10/24/2020	BFB4	16.1	7.3	96.9	0.03	55.0
10/25/2020	BFB5	15.0	7.5	95.2	0.05	52.2
10/24/2020	BFB6	16.4	7.5	87.9	0.02	56.4
10/24/2020	BFB7	16.4	7.5	87.9	0.02	56.4
4/25/2021	BSB1	10.1	7.6	99.0	0.12	58.6
4/25/2021	BSB2	10.1	7.6	99.0	0.06	58.6
4/25/2021	BSB3	9.6	7.0	97.8	0.06	59.8
4/25/2021	BSB4	9.6	7.0	97.8	0.06	59.8
4/25/2021	BSB5	9.6	7.3	100.2	0.04	50.3
4/25/2021	BSB6	9.7	7.0	102.3	0.09	59.4
4/25/2021	BSB7	9.7	7.0	102.3	0.09	59.4
10/22/2020	BFB8	15.9	7.9	105.3	0.08	67.1
10/22/2020	BFB9	15.9	7.4	104.6	0.08	55.2
10/22/2020	BFB10	15.9	7.4	104.6	0.06	55.2
10/22/2020	BFB11	14.5	7.5	99.3	0.03	65.5
10/22/2020	BFB12	15.5	7.5	107.2	0.02	66.5
10/22/2020	BFB13	14.5	7.5	99.3	0.03	65.6
10/22/2020	BFB14	14.5	7.5	99.3	0.02	65.6
10/22/2020	BFB15	14.4	6.8	97.7	0.02	51.6
10/22/2020	BFB16	14.4	6.8	97.7	0.02	51.6
10/22/2020	BFB17	14.4	6.8	97.7	0.02	51.6
5/27/2021	BSB8	26.8	7.9	97.5	0.09	31.5
5/27/2021	BSB9	26.8	7.9	97.5	0.09	31.5
5/27/2021	BSB10	26.8	7.9	97.5	0.09	31.5
5/27/2021	BSB11	26.8	7.9	97.5	0.09	31.5
5/27/2021	BSB12	26.8	7.9	97.5	0.09	31.5
5/27/2021	BSB13	25.1	8.1	93.2	0.03	35.0
5/27/2021	BSB14	25.1	8.1	93.2	0.03	35.0
5/27/2021	BSB15	25.1	8.1	93.2	0.03	35.0
4/26/2021	BSB16	11.5	7.4	95.9	0.08	58.2
4/26/2021	BSB17	11.5	7.4	95.9	0.08	58.2

Boat electrofishing results (total number of fish) from Byllesby Pool in fall 2020 (BFB site names; left of solid line) and spring 2021 (BSB site names; right of solid line).

Common Name	**Species**	**BFB1**	**BFB2**	**BFB3**	**BFB4**	**BFB5**	**BFB6**	**BFB7**	**BSB1**	**BSB2**	**BSB3**	**BSB4**	**BSB5**	**BSB6**	**BSB7**	**Total**	**Rel. Abund.**
Rock Bass	*Ambloplites rupestris*	1	-	-	-	-	1	-	1	-	-	-	-	-	-	3	1.2%
White Sucker	*Catostomus commersonii*	-	-	-	-	-	-	-	-	-	-	-	1	-	-	1	0.4%
Whitetail Shiner	*Cyprinella galactura*	1	1	-	-	-	-	4	-	-	-	-	-	-	4	10	4.1%
Spotfin Shiner	*Cyprinella spiloptera*	-	-	-	-	-	-	-	-	-	-	3	-	-	-	3	1.2%
Common Carp	*Cyprinus carpio*	-	1	-	-	6	-	-	-	-	-	-	-	-	1	8	3.3%
Muskellunge	*Esox masquinongy*	-	-	-	-	-	-	-	-	-	1	1	-	-	-	2	0.8%
Redbreast Sunfish	*Lepomis auritus*	3	2	-	3	-	5	6	1	-	-	2	-	-	2	24	9.8%
Green Sunfish	*Lepomis cyanellus*	2	-	-	-	-	-	-	8	1	-	1	-	-	-	12	4.9%
Bluegill	*Lepomis macrochirus*	9	15	-	2	-	-	1	3	4	-	-	-	1	2	37	15.2%
Sunfish	*Lepomis sp.*	4	-	-	1	-	-	3	7	4	1	1	-	-	-	21	8.6%
Smallmouth Bass	*Micropterus dolomieu*	6	1	-	1	-	3	2	4	-	-	1	-	1	-	19	7.8%
Spotted Bass	*Micropterus punctulatus*	-	1	-	-	-	-	1	-	-	-	-	-	-	-	2	0.8%
Largemouth Bass	*Micropterus salmoides*	-	1	-	-	-	1	1	-	1	-	-	1	1	3	9	3.7%
Rosyface Shiner	*Notropis rubellus*	-	-	-	-	-	-	-	-	-	-	1	-	-	-	1	0.4%
New River Shiner	*Notropis scabriceps*	-	-	-	-	-	-	-	-	-	-	1	-	-	-	1	0.4%
Telescope Shiner	*Notropis telescopus*	-	-	-	-	-	-	-	-	-	-	72	-	-	-	72	29.5%
Mimic Shiner	*Notropis volucellus*	-	-	-	-	-	-	-	-	-	9	5	-	-	-	14	5.7%
Rainbow Trout	*Oncorhynchus mykiss*	-	-	-	-	-	-	-	-	-	1	-	-	-	-	1	0.4%
Black Crappie	*Pomoxis nigromaculatus*	-	-	-	-	1	-	-	1	-	-	-	-	-	-	2	0.8%
Flathead Catfish	*Pylodictis olivaris*	-	-	-	1	-	-	-	-	-	-	-	-	1	-	2	0.8%
	Total	26	22	0	8	7	10	18	25	10	12	88	2	4	12	**244**	
	Rel. Abund.	10.7%	9.0%	0.0%	3.3%	2.9%	4.1%	7.4%	10.2%	4.1%	4.9%	36.1%	0.8%	1.6%	4.9%		

Boat electrofishing results (total number of fish) from Buck Pool in fall 2020 (BFB site names; left of solid line) and spring 2021 (BSB site names; right of solid line).

Common Name	**Species**	**BFB8**	**BFB9**	**BFB10**	**BFB11**	**BFB12**	**BFB13**	**BFB14**	**BFB15**	**BFB16**	**BFB17**	**BSB8**	**BSB9**	**BSB10**	**BSB11**	**BSB12**	**BSB13**	**BSB14**	**BSB15**	**BSB16**	**BSB17**	**Total**	**Rel. Abund.**
Rock Bass	*Ambloplites rupestris*	-	1	1	-	-	-	1	-	-	-	3	1	2	2	-	2	3	5	-	-	21	5.9%
Whitetail Shiner	*Cyprinella galactura*	4	7	-	-	-	6	5	7	-	-	8	2	-	-	2	-	-	-	-	-	41	11.6%
Spotfin Shiner	*Cyprinella spiloptera*	1	3	-	-	-	-	-	-	-	-	3	-	-	-	1	-	-	-	-	-	8	2.3%
Common Carp	*Cyprinus carpio*	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	2	-	3	0.8%
Greenside Darter	*Etheostoma blennioides*	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	1	0.3%
Fantail Darter	*Etheostoma flabellare*	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	1	0.3%
Northern Hog Sucker	*Hypentelium nigricans*	-	3	1	-	1	-	-	-	-	-	13	2	-	-	-	-	-	-	-	-	20	5.7%
Channel Catfish	*Ictalurus punctatus*	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	1	0.3%
Redbreast Sunfish	*Lepomis auritus*	-	-	1	1	-	6	1	-	1	-	1	18	7	4	-	9	16	29	2	6	102	28.9%
Green Sunfish	*Lepomis cyanellus*	-	-	1	-	-	-	-	-	-	-	-	-	2	-	-	-	-	2	1	1	7	2.0%
Pumpkinseed	*Lepomis gibbosus*	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	1	0.3%
Bluegill	*Lepomis macrochirus*	-	1	1	-	-	1	-	-	-	-	1	2	-	-	2	1	3	-	17	2	31	8.8%
Rosefin Shiner	*Lythrurus ardens*	1	-	-	-	3	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	4	1.1%
Smallmouth Bass	*Micropterus dolomieu*	-	1	-	5	-	3	2	-	1	-	11	11	6	2	1	9	11	7	2	-	72	20.4%
Spotted Bass	*Micropterus punctulatus*	-	-	-	-	-	-	-	-	-	-	-	3	-	-	-	-	2	-	3	-	8	2.3%
Largemouth Bass	*Micropterus salmoides*	-	-	1	-	-	-	-	-	1	-	-	-	-	-	1	1	-	-	2	2	8	2.3%
Bigmouth Chub	*Nocomis platyrhynchus*	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	0.3%
Chub	*Nocomis sp.*	-	2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2	0.6%
Spottail Shiner	*Notropis hudsonius*	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	0.3%
Swallowtail Shiner	*Notropis procne*	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	0.3%
New River Shiner	*Notropis scabriceps*	1	-	-	-	-	-	-	-	-	-	10	-	-	-	-	-	-	-	-	-	11	3.1%
Logperch	*Percina caprodes*	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	1	0.3%
Bluntnose Minnow	*Pimephales notatus*	-	-	-	-	-	-	-	-	-	-	5	-	-	-	-	-	-	-	-	-	5	1.4%
Flathead Catfish	*Pylodictis olivaris*	-	-	-	-	-	-	-	-	-	-	-	1	-	1	-	-	-	-	-	-	2	0.6%
	Total	9	18	6	7	4	16	9	7	3	0	55	43	17	9	7	23	35	43	30	12	**353**	
	Rel. Abund.	2.5%	5.1%	1.7%	2.0%	1.1%	4.5%	2.5%	2.0%	0.8%	0.0%	15.6%	12.2%	4.8%	2.5%	2.0%	6.5%	9.9%	12.2%	8.5%	3.4%		

Diversity (H' = Shannon diversity index) of the fish community by location within the Project area. Sites above the first dashed line are upstream of Byllesby Dam, sites below the first dashed line are between Byllesby and Buck Dam, and sites below the second dashed line are downstream of Buck Dam. CPUE is individuals per minute for electrofishing (EF) and individuals per net set for gillnetting.

Method	Location	Abundance	Richness	Diversity (H')	Evenness	Effort	CPUE
Boat EF	US Byllesby	244	20	2.32	0.77	91.4	2.7
Backpack EF	US Byllesby	48	11	1.92	0.80	27.8	1.7
Gillnet	US Byllesby	112	10	1.43	0.62	24.0	4.7
Boat EF	Between Dams	353	24	2.26	0.71	136.0	2.6
Backpack EF	Between Dams	156	18	1.97	0.68	45.9	3.5
Backpack EF	DS Buck	206	17	1.98	0.70	27.0	7.6

Water quality parameters at backpack electrofishing sites in spring 2021. Sites above the first dashed line are upstream of Byllesby Dam, sites below the first dashed line are between Byllesby and Buck Dam, and sites below the second dashed line are downstream of Buck Dam.

Date	Site ID	Water Temp. (C)	pH	DO (%)	Velocity (m/s)	Conductivity (us/cm)
4/20/2021	BSBP1	13.5	7.9	105.4	0.82	56.6
4/20/2021	BSBP2	12.6	7.7	100.4	0.33	58.8
4/20/2021	BSBP3	14.4	8.0	100.6	0.30	56.7
4/21/2021	BSBP4	13.7	7.6	95.6	0.17	57.7
4/21/2021	BSBP5	13.7	7.4	93.2	0.48	57.9
4/23/2021	BSBP6	6.9	7.6	102.8	0.40	58.8
4/23/2021	BSBP7	9.5	7.6	99.5	0.46	58.5
4/21/2021	BSBP8	13.8	7.5	101.6	0.71	57.8
4/21/2021	BSBP9	13.8	7.5	101.6	0.10	57.8
4/22/2021	BSBP10	13.0	7.9	99.3	0.08	57.6
4/22/2021	BSBP11	10.4	7.7	108.0	0.17	38.2
4/23/2021	BSBP12	11.0	7.8	105.7	0.19	64.4
4/23/2021	BSBP13	11.2	7.9	101.3	0.44	60.0

Backpack electrofishing results (total number of fish) from upstream of Byllesby Dam.

Common Name	Species	BSBP1	BSBP2	BSBP3	Total	Rel. Abund.
Rock Bass	*Ambloplites rupestris*	1	-	3	4	8.3%
Central Stoneroller	*Campostoma anomalum*	-	-	1	1	2.1%
Whitetail Shiner	*Cyprinella galactura*	1	1	17	19	39.6%
Greenside Darter	*Etheostoma blennioides*	3	-	-	3	6.3%
Redbreast Sunfish	*Lepomis auritus*	-	-	1	1	2.1%
Smallmouth Bass	*Micropterus dolomieu*	2	-	3	5	10.4%
Bigmouth Chub	*Nocomis platyrhynchus*	2	-	-	2	4.2%
Chub	*Nocomis sp.*	-	-	2	2	4.2%
Rosyface Shiner	*Notropis rubellus*	-	-	8	8	16.7%
Mimic Shiner	*Notropis volucellus*	-	-	2	2	4.2%
Flathead Catfish	*Pylodictis olivaris*	1	-	-	1	2.1%
	Total	10	1	37	**48**	
	Rel. Abund.	20.8%	2.1%	77.1%		

Backpack electrofishing results (total number of fish) from between Byllesby Dam and Buck Dam.

Common Name	Species	BSBP4	BSBP5	BSBP6	BSBP7	BSBP8	BSBP9	Total	Rel. Abund.
Rock Bass	*Ambloplites rupestris*	-	1	-	1	-	-	2	1.3%
Central Stoneroller	*Campostoma anomalum*	-	2	1	-	1	-	4	2.6%
Whitetail Shiner	*Cyprinella galactura*	-	-	20	-	3	-	23	14.7%
Greenside Darter	*Etheostoma blennioides*	-	1	-	-	-	-	1	0.6%
Fantail Darter	*Etheostoma flabellare*	-	1	6	11	1	-	19	12.2%
Kanawha Darter	*Etheostoma kanawhae*	1	-	-	-	-	-	1	0.6%
Northern Hog Sucker	*Hypentelium nigricans*	-	-	2	-	1	-	3	1.9%
Sunfish	*Lepomis sp.*	-	-	-	-	-	1	1	0.6%
Smallmouth Bass	*Micropterus dolomieu*	2	1	-	2	2	4	11	7.1%
Bigmouth Chub	*Nocomis platyrhynchus*	-	2	-	-	-	3	5	3.2%
Chub	*Nocomis sp.*	-	-	3	1	-	-	4	2.6%
Rosyface Shiner	*Notropis rubellus*	-	-	1	-	4	-	5	3.2%
Saffron Shiner	*Notropis rubricroceus*	-	-	-	1	-	-	1	0.6%
New River Shiner	*Notropis scabriceps*	-	-	1	-	-	-	1	0.6%
Telescope Shiner	*Notropis telescopus*	-	-	8	-	60	-	68	43.6%
Mimic Shiner	*Notropis volucellus*	-	-	2	-	-	-	2	1.3%
Margined Madtom	*Noturus insignis*	1	1	1	1	-	-	4	2.6%
Sharpnose Darter	*Percina oxyrhynchus*	-	1	-	-	-	-	1	0.6%
	Total	4	10	45	17	72	8	**156**	
	Rel. Abund.	2.6%	6.4%	28.8%	10.9%	46.2%	5.1%		

Backpack electrofishing results (total number of fish) from below Buck Dam.

Common Name	Species	BSBP10	BSBP11	BSBP12	BSBP13	Total	Rel. Abund.
Central Stoneroller	*Campostoma anomalum*	22	36	-	1	59	28.6%
Kanawha Sculpin	*Cottus kanawhae*	1	-	1	6	8	3.9%
Whitetail Shiner	*Cyprinella galactura*	11	8	4	-	23	11.2%
Spotfin Shiner	*Cyprinella spiloptera*	-	-	1	-	1	0.5%
Greenside Darter	*Etheostoma blennioides*	-	3	1	1	5	2.4%
Fantail Darter	*Etheostoma flabellare*	-	-	6	-	6	2.9%
Northern Hog Sucker	*Hypentelium nigricans*	-	-	2	1	3	1.5%
Redbreast Sunfish	*Lepomis auritus*	-	-	-	1	1	0.5%
Sunfish	*Lepomis sp.*	-	-	-	3	3	1.5%
White Shiner	*Luxilus albeolus*	1	-	1	-	2	1.0%
Smallmouth Bass	*Micropterus dolomieu*	-	1	2	1	4	1.9%
Rosyface Shiner	*Notropis rubellus*	-	-	1	-	1	0.5%
New River Shiner	*Notropis scabriceps*	-	1	-	-	1	0.5%
Telescope Shiner	*Notropis telescopus*	42	3	8	-	53	25.7%
Margined Madtom	*Noturus insignis*	2	8	13	10	33	16.0%
Logperch	*Percina caprodes*	1	-	-	-	1	0.5%
Sharpnose Darter	*Percina oxyrhynchus*	1	1	-	-	2	1.0%
	Total	81	61	40	24	**206**	
	Rel. Abund.	39.3%	29.6%	19.4%	11.7%		

Water quality parameters at gillnet sites in Byllesby Pool in fall 2020 (BFG site names; above solid line) and spring 2021 (BSG site names; below solid line).

Date	Site ID	Water Temp. (C)	pH	Velocity (m/s)	Conductivity (us/cm)
11/18/2020	BFG1	6.5	7.1	0.11	37.7
11/9/2020	BFG2	10.8	7.2	0.05	62.4
11/18/2020	BFG3	6.6	7.3	0.05	37.5
11/9/2020	BFG4	10.9	6.8	0.04	62.6
11/18/2020	BFG5	6.0	7.6	0.04	36.7
11/9/2020	BFG6	11.4	6.8	0.04	61.5
4/22/2021	BSG1	9.8	7.5	0.12	60.2
4/20/2021	BSG2	12.1	7.5	0.05	59.1
4/22/2021	BSG3	10.2	7.5	0.04	59.1
4/20/2021	BSG4	12.1	7.5	0.05	59.0
4/22/2021	BSG5	10.9	7.5	0.05	59.2
4/20/2021	BSG6	12.5	7.5	0.04	59.9

Gillnet results (total number of fish) from Byllesby Pool in fall 2020 (BFG site names; left of solid line) and spring 2021 (BSG site names; right of solid line).

Common Name	**Species**	**BFG1**	**BFG2**	**BFG3**	**BFG4**	**BFG5**	**BFG6**	**BSG1**	**BSG2**	**BSG3**	**BSG4**	**BSG5**	**BSG6**	**Total**	**Rel. Abund.**
Rock Bass	*Ambloplites rupestris*	-	-	-	-	-	-	-	-	3	-	-	-	3	2.7%
White Sucker	*Catostomus commersonii*	-	-	1	-	1	1	-	-	3	1	2	-	9	8.0%
Common Carp	*Cyprinus carpio*	-	2	9	-	3	-	-	-	34	5	5	-	58	51.8%
Muskellunge	*Esox masquinongy*	-	-	-	-	-	-	-	-	1	-	-	-	1	0.9%
Channel Catfish	*Ictalurus punctatus*	-	-	1	-	-	10	-	1	2	-	5	8	27	24.1%
Bluegill	*Lepomis macrochirus*	-	-	1	-	-	-	-	-	-	-	-	-	1	0.9%
Smallmouth Bass	*Micropterus dolomieu*	-	1	-	-	-	-	-	-	-	-	-	-	1	0.9%
Black Crappie	*Pomoxis nigromaculatus*	-	-	-	-	-	-	-	-	-	-	1	-	1	0.9%
Flathead Catfish	*Pylodictis olivaris*	-	-	-	-	-	1	-	-	-	-	1	-	2	1.8%
Walleye	*Sander vitreus*	-	1	1	-	4	-	-	-	1	-	2	-	9	8.0%
	Total	0	4	13	0	8	12	0	1	44	6	16	8	**112**	
	Rel. Abund.	0.0%	3.6%	11.6%	0.0%	7.1%	10.7%	0.0%	0.9%	39.3%	5.4%	14.3%	7.1%		

Comparison of methods used (EF = Electrofishing) and number of sites and samples in each Project area (US = Upstream and DS = Downstream) between the current relicensing study and the previous relicensing study.

Area	Method	Current Study			Appalachian and AEP 1991		
		Number of Sites	Samples per Site	Total	Number of Sites	Samples per Site	Total
US Byllesby	Pool EF	7	2	14	6	6	36
	Riffle EF	3	1	3	2	6	12
	Gillnet	6	2	12	6	6	36
	Hoop Net	-	-	-	6	6	36
Between Dams	Pool EF	10	2	20	6	6	36
	Riffle EF	6	1	6	2	6	12
	Hoop Net	-	-	-	6	6	36
DS Buck	Riffle EF	4	1	4	2	6	12
		36	Total Samples	59	36	Total Samples	216

Riffle EF only occurred during spring 2021 sampling due to high flows and safety concerns during fall 2020 sampling period.

Abundance, average length, and average weight of each species captured throughout the Project area in fall 2020 and spring 2021.

Common Name	Scientific Name	Count	Average Length (mm)	Average Weight (g)	Rel. Abund.
Rock Bass	*Ambloplites rupestris*	33	97.3	34.4	2.9%
Central Stoneroller	*Campostoma anomalum*	64	91.8	9.9	5.7%
White Sucker	*Catostomus commersonii*	10	404.5	825.0	0.9%
Kanawha Sculpin	*Cottus kanawhae*	8	86.9	9.1	0.7%
Whitetail Shiner	*Cyprinella galactura*	116	56.8	2.3	10.4%
Spotfin Shiner	*Cyprinella spiloptera*	12	58.0	2.2	1.1%
Common Carp	*Cyprinus carpio*	69	406.2	1158.0	6.2%
Muskellunge	*Esox masquinongy*	3	538.7	820.0	0.3%
Greenside Darter	*Etheostoma blennioides*	10	61.3	2.6	0.9%
Fantail Darter	*Etheostoma flabellare*	26	53.2	1.7	2.3%
Kanawha Darter	*Etheostoma kanawhae*	1	41.0	1.4	0.1%
Northern Hog Sucker	*Hypentelium nigricans*	26	111.4	17.3	2.3%
Channel Catfish	*Ictalurus punctatus*	28	374.9	580.1	2.5%
Redbreast Sunfish	*Lepomis auritus*	128	82.6	18.8	11.4%
Green Sunfish	*Lepomis cyanellus*	19	97.3	22.8	1.7%
Pumpkinseed	*Lepomis gibbosus*	1	112.0	21.1	0.1%
Bluegill	*Lepomis macrochirus*	69	60.4	8.7	6.2%
Sunfish	*Lepomis sp.*	25	58.1	5.6	2.2%
White Shiner	*Luxilus albeolus*	2	88.5	8.3	0.2%
Rosefin Shiner	*Lythrurus ardens*	4	36.3	0.4	0.4%
Smallmouth Bass	*Micropterus dolomieu*	112	111.8	34.1	10.0%
Spotted Bass	*Micropterus punctulatus*	10	80.7	6.8	0.9%
Largemouth Bass	*Micropterus salmoides*	17	185.9	255.2	1.5%
Bigmouth Chub	*Nocomis platyrhynchus*	8	105.5	24.2	0.7%
Chub	*Nocomis sp.*	8	61.4	2.7	0.7%
Spottail Shiner	*Notropis hudsonius*	1	83.0	4.3	0.1%
Swallowtail Shiner	*Notropis procne*	1	62.0	1.8	0.1%
Rosyface Shiner	*Notropis rubellus*	15	51.5	1.2	1.3%
Saffron Shiner	*Notropis rubricroceus*	1	66.0	2.7	0.1%
New River Shiner	*Notropis scabriceps*	14	44.9	0.9	1.3%
Telescope Shiner	*Notropis telescopus*	193	54.2	1.5	17.2%
Mimic Shiner	*Notropis volucellus*	18	47.8	1.1	1.6%
Margined Madtom	*Noturus insignis*	37	70.4	3.9	3.3%
Rainbow Trout	*Oncorhynchus mykiss*	1	490.0	1250.0	0.1%
Logperch	*Percina caprodes*	2	114.0	12.5	0.2%
Sharpnose Darter	*Percina oxyrhynchus*	3	90.7	5.8	0.3%
Bluntnose Minnow	*Pimephales notatus*	5	54.0	3.6	0.4%
Black Crappie	*Pomoxis nigromaculatus*	3	146.7	41.9	0.3%
Flathead Catfish	*Pylodictis olivaris*	7	283.1	754.4	0.6%
Walleye	*Sander vitreus*	9	342.4	356.7	0.8%

The raw data from the 2020-2021 Byllesby-Buck Fish Community Survey is included as a Microsoft Excel spreadsheet.

Filed separately: "**Byllesby-Buck_General Fish Community Raw Data.xlsx"**

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Attachment 2

Attachment 2 – Fish Impingement and Entrainment Study Report

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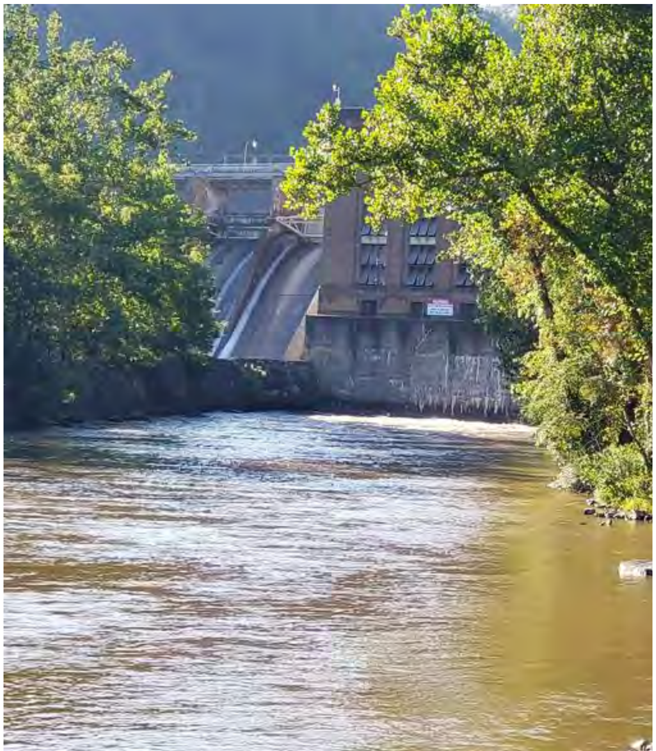

Fish Impingement and Entrainment Study Report

Byllesby-Buck Hydroelectric Project (FERC No. 2514)

April 14, 2022

Prepared by:

HDR

Prepared for:

Appalachian Power Company

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Appendix I – Additional Intake Drawings

Acronyms and Abbreviations

ADCP	acoustic Doppler current profiler
AEP	American Electric Power
Appalachian or Licensee	Appalachian Power Company
AOI	Area of Influence
CFR	Code of Federal Regulations
cfs	cubic feet per second
EPRI	Electric Power Research Institute
FERC or Commission	Federal Energy Regulatory Commission
fps	feet per second
ft	feet/foot
FLA	Final License Application
hr	hour
ILP	Integrated Licensing Process
ISR	Initial Study Report
m	meter
PM&E	protection, mitigation, and enhancement
Project	Byllesby-Buck Hydroelectric Project
RSP	Revised Study Plan
SPD	Study Plan Determination
TBSA	Turbine Blade Strike Analysis
USFWS	U.S. Fish and Wildlife Service
USGS	U.S. Geological Survey
USR	Updated Study Report
VDGIF	Virginia Department of Game and Inland Fisheries
VDWR	Virginia Department of Wildlife Resources

1 Project Introduction and Background

1.1 Introduction

Appalachian Power Company (Appalachian or Licensee), a unit of American Electric Power (AEP), is the Licensee, owner, and operator of the two-development Byllesby-Buck Hydroelectric Project (Project) (Project No. 2514), located on the upper New River in Carroll County, Virginia. The Byllesby Development is located about 9 miles north of the city of Galax, and the Buck Development is located approximately 3 river miles downstream of Byllesby and 43.5 river miles upstream of Claytor Dam.

The Project is currently licensed by the Federal Energy Regulatory Commission (FERC or Commission). The Project underwent relicensing in the early 1990s, including conversion to run-of-river operations and incorporating additional protection, mitigation, and enhancement (PM&E) measures. The current operating license for the Project expires on February 29, 2024. Accordingly, Appalachian is pursuing a subsequent license for the Project pursuant to the Commission's Integrated Licensing Process (ILP), as described at 18 Code of Federal Regulations (CFR) Part 5. In accordance with FERC's regulations at 18 CFR §16.9(b), the licensee must file its final application for a new license with FERC no later than February 28, 2022.

In accordance with 18 CFR §5.11, Appalachian developed a Revised Study Plan (RSP) for the Project that was filed with the Commission and made available to stakeholders on October 18, 2019. On November 18, 2019 FERC issued the Study Plan Determination (SPD). On December 18, 2019, Appalachian filed a request for rehearing of the SPD. The SPD was subsequently modified by FERC by an Order on Rehearing dated February 20, 2020.

On July 27, 2020, Appalachian filed an updated ILP study schedule and a request for extension of time to file the Initial Study Report (ISR) to account for Project delays resulting from the COVID-19 pandemic. The request was approved by FERC on August 10, 2020, and the filing deadline for the ISR for the Project was extended from November 17, 2020 to January 18, 2021. Appalachian conducted a virtual ISR Meeting on January 28, 2021 and filed the ISR Meeting summary with the Commission on February 12, 2021. Stakeholders provided written comments in response to Appalachian's filing of the ISR meeting summary, which were addressed in the Updated Study Report (USR), which was filed November 17, 2021. The USR meeting was held on December 1, 2021 and the meeting summary was filed on December 16, 2021. The following parties provided written comments in response to Appalachian's filing of the USR meeting summary: FERC staff (January 18, 2022), U.S. Fish and Wildlife Service (USFWS) (January 18, 2022), and Virginia Department of Wildlife Resources (VDWR) (January 18, 2022). On February 14, 2022, Appalachian filed with FERC a response to comments on the USR and a request for extension of time to file the revised Aquatic Resources Study Report, given the additional time and effort needed to address comments received on the USR.

Appalachian has conducted studies in accordance with 18 CFR §5.15, as provided in the RSP and as subsequently modified by FERC. This updated study report is being provided as supplemental information to the Final License Application (FLA) and describes the methods and results of the Fish Impingement and Entrainment Study conducted in support of preparing an application for new license for the Project.

1.2 Background

A desktop entrainment study was conducted for the Project during the previous relicensing (Appalachian 1991a). Electric Power Research Institute (EPRI) data, project characteristics, as well as the behavioral and life history characteristics and preferred habitat of the resident fish were used to assess entrainment potential. The fish species and life stages likely to be entrained are those most likely to occur in forebay areas within the area of influence of the intake structure.

Several of the species in the Centrarchidae family (black basses and sunfishes) and the Ictaluridae family (catfishes) prefer habitat types with structure and cover, such as rocks, logs, stumps, and aquatic vegetation. These species are also generally nest or cavity spawners, depositing adhesive or demersal eggs in beds created by males and often guarded until hatching. Unless these habitats are found within the forebay of the dams and near the intake structures, it is unlikely that these species, regardless of life stage, would occur in the vicinity of the Project intakes, thus minimizing their potential for entrainment. Exceptions to this may include White Crappie (*Pomoxis annularis*) or Black Crappie (*P. nigromaculatus*); which construct nests in the littoral zone, but developing larvae are pelagic until they mature into the juvenile stage and move inshore (Rohde et al. 2009). Habitat generalists, pelagic species, or benthic species may be more likely to occur within the forebay areas, such as clupeids (ex. Gizzard Shad [*Dorosoma cepedianum*]), cyprinids (shiners, minnows, chubs, or carp), catostomids (suckers), or moronids (temperate basses). Some of these species, such as clupeids and some cyprinids, are broadcast spawners. Broadcast spawners, unlike nesting centrarchids, scatter or release eggs in the water column where they can be carried into the intake, and thus are more susceptible to entrainment. However, even if fish larvae and eggs become entrained through the Project, it is unlikely that turbine passage would cause harm under optimal design conditions and if cavitation is not excessive (Appalachian 1991b).

Muskellunge (*Esox masquinongy*) is a popular game fish and a species of interest for the Virginia Department of Wildlife Resources (VDWR) in terms of stocking as well as scientific research (VDWR 2020). The susceptibility of Muskellunge to entrainment at the Project likely varies throughout the year due to variations in predatory behavior (Cook and Solomon 1987). Immediately following spawning in the spring and through midsummer, Muskellunge typically exhibit crepuscular prey-seeking behaviors at a variety of water depths and across a range of habitat types; as such, Muskellunge may enter the forebay area in pursuit of forage fish (i.e., pelagic species). In late summer, Muskellunge become sedentary ambush predators with a strong association with vegetated areas. Although Muskellunge may occur in the forebay area during certain times of year, the age and size (and subsequent swimming ability) at which they would be seeking forage fish (i.e., older/larger individuals), would likely allow them to avoid entrainment into the turbines (EPRI 2000).

Appalachian (1991b) determined that, for juvenile or larger fish potentially drawn into the facility turbines, the occurrence of pressure changes, turbulence, shear, and cavitation would be minimal and unlikely to cause substantial harm. Additionally, the study concluded that fish likely swim against the current as they enter through the stay vanes and wicket gates and, therefore, are unlikely to contact the vanes perpendicularly.

The Appalachian (1991b) study also evaluated the probability of contact with a runner blade based on the Byllesby and Buck turbine dimensions and concluded that the probability of collision with runner blades was less than five percent for most species, particularly for the smaller fish exhibiting the greatest likelihood of entrainment. Mortality would, therefore, be lower than five percent, assuming blade strikes can range from slight glancing blows to head-on collisions. Considering behavioral characteristics, habitat preferences (including spawning habitat), and life-history characteristics of resident fish species, the prior study concluded that the likelihood of substantial numbers of fish occurring in the forebays was minimal and the potential for entrainment effects was expected to be low (Appalachian 1991b). Further, angled-bar trash-racks with close spacing, such as those installed at the Project developments, are a common protection measure in place at hydroelectric projects to reduce entrainment. Based on the results of the previous entrainment study and accounting for the trash racks already installed at the Project intakes, Appalachian does not propose any additional measures to address impingement and entrainment. Appalachian expects to operate the Project in the existing run-of-river mode and with the existing minimum flows and ramping rate. Operating the Project in this manner provides a relatively stable reservoir elevation and protects shoreline stability and water quality for the benefit of fish and other resources.

1.3 Proposed Turbine Unit Upgrades

During the new license term, Appalachian proposes to modernize the Byllesby and Buck developments to include replacement of Byllesby Units 1, 2 and 4 and Buck Units 1 and 3. All but one (Buck Unit 2) of the seven turbine-generator units installed at the Project are the original major components of the Project as constructed in 1912. The existing vertical Francis units would be replaced by fixed blade Kaplan units. Unit upgrade activities would be confined to within the powerhouse, and there would be minimal changes to operating parameters for the Project. Following completion of the upgrades, the authorized installed capacities for the Byllesby and Buck developments will be 20,389.5 kW and 9,435 kW, respectively, with maximum hydraulic capacities of 5,511 cfs and 3,570 cfs, respectively. Due to efficiencies of the Kaplan units and modern components, the upgrades are expected to increase average annual generation at the Project compared to existing conditions by approximately 25,927 MWh.

Given the regulatory context, project background, and considering the planned upgrades from Francis to Kaplan turbines, this study report presents a desktop evaluation of entrainment potential for the two-development Project that involves reexamining and updating (as applicable) certain aspects of the prior evaluations of entrainment potential at the intake structures and evaluating blade strike probabilities under existing and proposed turbine design and operating conditions. Upgraded turbine and generator specifications are included in Exhibit A of the FLA, which was filed with the FERC on February 28, 2022.

2 Study Goals and Objectives

In accordance with Appalachian's October 18, 2019 RSP and the Commission's November 18, 2019 SPD for the Project, the goal of this study is to verify or update certain aspects pertaining to the Project operations and to examine entrainment potential at the two-development Project. Additionally, planned unit upgrades are proposed for both Byllesby and Buck developments, which would influence the results of the turbine blade strike analysis. Therefore, the study objectives were updated to incorporate additional scenarios using the proposed design and operations of the developments with the new turbines installed.

The study objectives are to:

- Confirm flow velocities at the Byllesby and Buck dam intake structures located to facilitate a desktop assessment of entrainment and impingement potential at the Project.
- Perform an updated desktop review of entrainment potential at the Project during hydropower generation.
- Perform a blade strike evaluation of the existing and proposed turbine configurations at the two-development Project using the USFWS Turbine Blade Strike Analysis (TBSA) Model (2020). This model is a probabilistic Excel-based Visual Basic for Applications implementation of the methods outlined by Franke et al. (1997) for evaluating fish mortalities due to turbine entrainment.

3 Study Area

The study area includes the lower reach of the Reservoir located just upstream of each of the two developments as shown in Figure 3-1 and Figure 3-2.

Figure 3-1. Fish Impingement and Entrainment Analysis Study Area for the Byllesby Development Intake at the Byllesby-Buck Hydroelectric Project

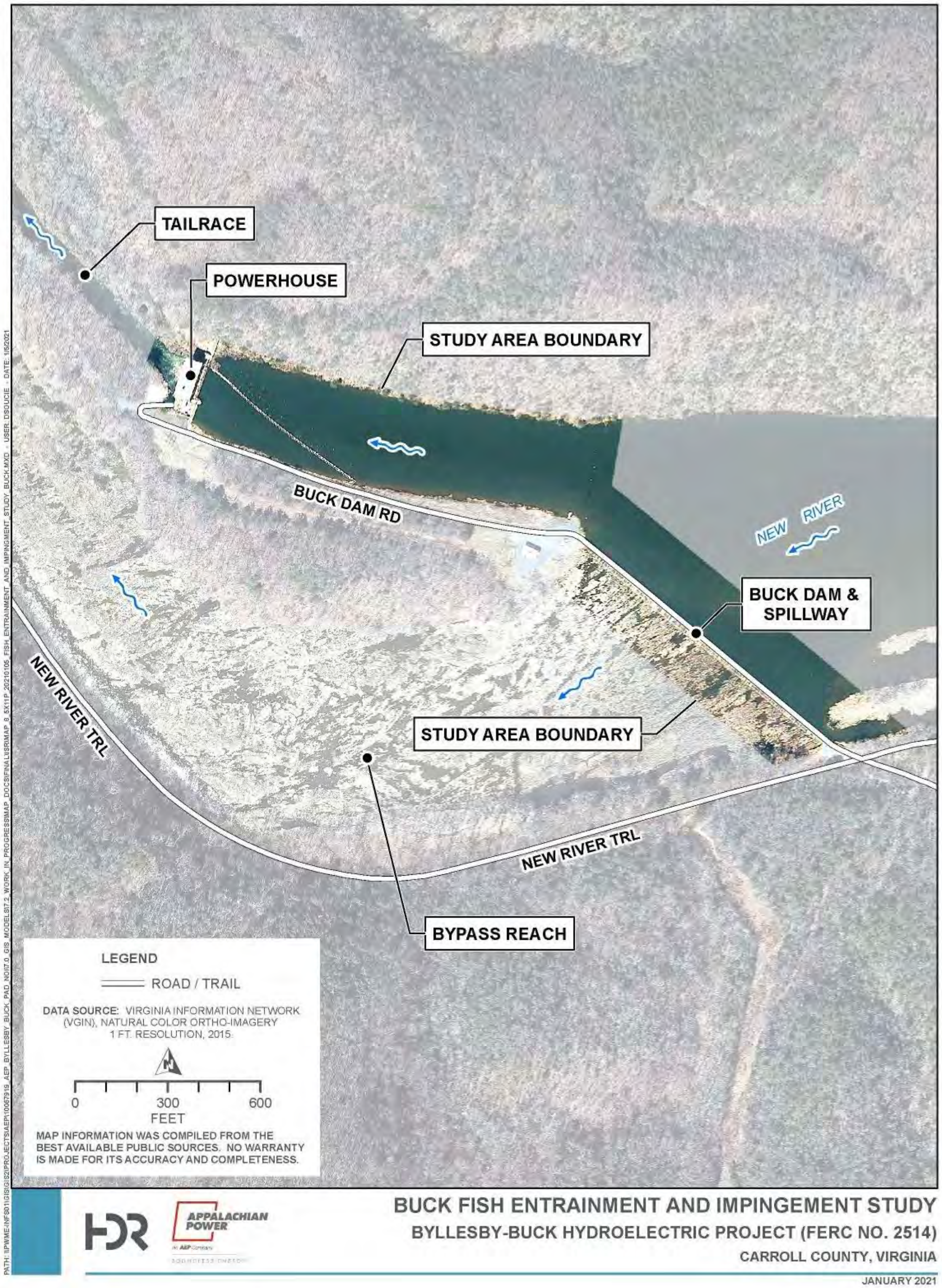


Figure 3-2. Fish Impingement and Entrainment Analysis Study Area for the Buck Development Intake at the Byllesby-Buck Hydroelectric Project

4 Methodology

4.1 Intake Structure, Velocities, and Turbine Characteristics

The physical specifications of the turbines and each intake structure at the Project developments were compiled and used to calculate velocities at the intake structures. Approach velocities (i.e., at a point approximately one foot (ft) upstream of the trashracks) were calculated using site-specific intake dimensions. Per the Project RSP and Commission's SPD, intake velocities were to be measured using an acoustic Doppler current profiler (ADCP) along the upstream face of the angled trash racks to determine the approximate approach velocity immediately upstream of the intake structure. During the 2020 field season, a combination of high flow events and inoperable units prevented field data collection efforts. As a result, approach velocity was calculated using the intake structure and trash rack dimensions along with the design maximum flow capacity of the generating units.

4.2 Desktop Review of Impingement and Entrainment Potential

The potential for fish to become entrained or impinged at a hydroelectric facility is dependent on a variety of factors such as fish life history, size and swimming ability, water quality, operating regimes, inflow, and intake/turbine configurations (Cada et al. 1997). Impingement occurs when a fish is held against or entrapped on the exterior intake structure screen (i.e., trash racks) due to forces created by the intake velocities. Entrainment occurs when the fish passes through the trash racks and is withdrawn into the intake structure.

The potential for fish entrainment is variable throughout a given year depending on species periodicity, life stage and body size, and project-specific operations. Early life stage and smaller-sized fish may be more abundant during certain portions of the year, thus increasing their susceptibility to entrainment. In addition, diurnal and seasonal movements of both small and large fish may bring them in close proximity to intake structures. Physical and operational characteristics of a given project, including trash rack bar spacing, intake velocities, intake depth, waterbody stratification, and intake proximity to feeding and rearing habitats also affect the potential for a fish to become entrained. These factors were used to make general assessments of entrainment and impingement potential at the Project using a desktop study approach.

A targeted species list was developed based on recent (Appalachian 2021) and historical (Appalachian 1991b) fish community studies, as well as a species list developed by the former Virginia Department of Games and Inland Fisheries (VDGIF), recently renamed the Virginia Department of Wildlife Resources (VDWR), for the New River at the time of the historical fish community study (Appalachian 1991). The list includes consideration of fish community composition and abundance of the New River and any other species of interest to or under protection of state and/or federal agencies, or with angler significance. Selected species were evaluated for potential of entrainment and impingement based on swim speed, behavior, habitat preferences, life stages, and seasonal or temperature-dependent behavioral changes in relation to Project design and operations.

4.2.1 Intake Avoidance and Impingement Risk

Intake avoidance and impingement was considered at both intakes based on the calculated approach velocities and 2.28-inch clear bar spacing of trash racks at each of the Project developments. This process involved comparing fish swim speeds with calculated intake velocities, as well as estimating minimum fish lengths that would be excluded or impinged by the trash racks for each of the target fish species. A scaling factor relating fish length to body width was used for the impingement assessment to determine minimum sizes of the target fish species that would physically be excluded by the trash racks (Smith 1985).

4.2.2 Fish Entrainment Potential

4.2.2.1 Fish Entrainment Rate Calculation

A database developed by EPRI (1997) provides detailed results of fish entrainment studies from 43 hydroelectric projects. This database was designed specifically to facilitate the desktop analysis of available data to assess entrainment and impingement impacts at a hydroelectric facility.

Although some facilities included in the EPRI database may not match the exact specifications of the developments at the Project, using as many data points as possible from the EPRI database allows the analysis to account for the natural variability of aquatic ecosystems and fish populations, while providing a robust dataset for calculating average monthly entrainment rates for a wide range of species. This is a commonly applied approach in desktop entrainment evaluations and has been readily accepted by FERC in relicensing efforts for other projects.

Site characteristics (i.e., reservoir size, usable storage, plant capacity, operating mode, average velocity at trash racks, trash rack spacing) and available data (i.e., entrainment data, collection efficiency) were reviewed for applicability to the Project using the EPRI (1997) database. Entrainment data from five facilities were eliminated for having trash rack clear bar spacing that was considerably wider (e.g., double the clear spacing) than specifications at the Project. Therefore, data from 33 facilities were retained for use in this analysis with the understanding that entrainment rates developed for the Project would be conservative (i.e., overestimated) since some fish species may be excluded by the trash racks at the Project, which have a narrower open bar spacing than many of the facilities in the EPRI database (Appendix A).

The EPRI (1997) entrainment database provides results from field studies conducted at hydroelectric facilities using full-flow tailrace netting by placing a conical net in the immediate tailrace to collect the entire discharge on a seasonal or monthly basis. This results in the calculation of entrainment rates (fish/volume of water if recorded, or fish/hour (hr)/cubic feet per second [cfs] of sampled unit capacity), including the number, species, and size of entrained fish.

The studies included in the EPRI (1997) database recorded number of hours sampled and hydraulic capacity of the sampled units. Using this information, data was standardized to the number of fish/hr of unit capacity, and then used to calculate fish entrainment rates (fish/hr) at maximum turbine discharge at the Projects based on existing development-specific turbine design capacity (5,868 cfs for the Byllesby Development and 3,540 cfs for the Buck Development). Entrainment rates were calculated and summarized by month, season (winter = December, January, and February; spring = March, April, and May; summer = June, July, and August; and fall = September, October, and November) and annually.

4.2.2.2 Qualitative Turbine Entrainment Risk

While the use of the EPRI (1997) database provides a means to quantitatively estimate entrainment risk at the Project at multiple time scales (i.e., month, season, year) based on empirical data collected at comparable hydroelectric projects; it is important to note that the resultant entrainment rate estimates do not consider the other site-specific factors likely to influence species-specific entrainment risk at the Project. Various comprehensive reviews of entrainment and mortality data (FERC 1995) as well as fish behavior relative to turbine passage (Coutant and Whitney 2000) suggest that one or more factors may influence the risk of turbine entrainment or mortality.

Therefore, an additional traits-based qualitative assessment modified from Cada and Schweizer (2012) of entrainment risk at the Project was performed that ranks entrainment risk as low, moderate, or high based upon break points in relative entrainment risk. The overall risk categories are defined as:

- Low: species-life stage is generally not present in the forebay; utilizes shallow, shoreline habitats away from the intake structures; and/or not susceptible to approach intake velocities
- Moderate: species-life stage may routinely or seasonally occupy the forebay or utilize habitats near the intake structures; and some life stages/ages may be susceptible to intake velocities
- High: pelagic species that reside or spawn in or near the forebay and intake structures and are susceptible to intake velocities, species with life stages that are expected to reside in the forebay or encounter intake structures during seasonal activities, and species-life stages that broadcast spawn buoyant eggs in open waters in lake or reservoir habitats

These qualitative risk categories were utilized to describe entrainment potential of the target fish species on a monthly basis. A matrix of monthly Project entrainment risk for the target species was constructed using the empirical seasonal entrainment rates estimated from the EPRI (1997) database using maximum turbine discharge frequency (full generation), swim burst speed comparison to intake velocities, size exclusion by trash racks, species periodicity, abundance, habitat utilization, migratory behavior, and expected distributions.

4.2.2.3 Turbine Blade Strike and Spillway Survival Assessment

The turbine blade strike evaluation used the most recent version of the TBSA Model created by the USFWS (2020), which is a probabilistic Excel-based Visual Basic for Applications implementation of the methods outlined by Franke et al. (1997) for evaluating fish mortalities due to turbine entrainment, as well as through non-turbine routes. The TBSA tool allows for the estimation of turbine passage and survival based on mortality from blade strikes based on site-specific information (i.e., turbine type, number of units, bar rack spacing, etc.) and length distributions for target species. Using the model, fish can be subjected up to 20 hazards, or routes, including 3 turbine types and bypasses, incorporating the Franke et al. (1997) equations into a Monte Carlo simulation that produces estimates of blade strike (mortalities) and passage (survival) probabilities for turbine and non-turbine pathways.

The TBSA tool was used to model the downstream passage survival under two operational scenarios for each of the Project developments: 1) fish that are subject to dam passage through the powerhouse and turbines, and required bypass flow only, or 2) fish that are subject to dam passage through the powerhouse and turbines or the spillway leading into the bypass channel. The probability of a fish passing through a turbine or via spill was assumed to be in direct proportion to the volume of flow passing through each route. A spillway and bypass passage survival rate of 97 percent was assumed based on the average of 136 survival tests conducted with juvenile salmonids on the Columbia River (Amaral et al. 2013).

Based on a review of the spillway design drawings, the vertical distance from the downstream extent of the Byllesby and Buck spillway aprons to bedrock is approximately 3.0 ft or less, depending on exact location (see Exhibit F-2, Sheet 2 and 3 of 5 from Exhibit F of the FLA). Since these distances represent the dewatered condition, the drop is less (or non-existent) as spillway flows cover the bedrock and elevations approach or exceed that of the spillway aprons at each of the dams; therefore, fish are not likely to experience a material vertical drop (if any), depending on spillway flows. As such, the absence of a plunge pool is not expected to result in increased mortality risk for fish passing over the spillway during spill events. Based on similar apron-to-bedrock dimensions at the facilities described in Amaral et al. (2013) a bypass passage survival rate of 97 percent from Amaral et al. (2013) is a valid, representative passage survival rate for performing the turbine blade strike analysis at the Project.

The drawings from the facilities referenced in Amaral et al (2013) are not publicly available; however, it is reasonable to assume that the similar apron-to-bedrock dimension at those facilities are not appreciably less than that of Byllesby or Buck. As such, the bypass passage survival rate of 97 percent from Amaral et al. (2013) is a valid, representative passage survival rate for performing the turbine blade strike analysis.

Flow exceedance percentile data were reviewed to determine the volume of spillage at the range of percentiles where river discharge exceeded turbine capacity. Downstream passage survival was estimated by the model for each spillage scenario.

Two scenarios were evaluated for existing conditions at each Project development and rerun for proposed conditions (proposed turbine upgrades) at each Project development:

1. Typical/normal conditions (i.e., no spill beyond required bypass minimum flow)
    a. Byllesby existing condition:
        i. Routes: Turbine Units 1 through 4, each with 25 percent of flow (1,467 cfs/unit).
        ii. Fish size classes: 2, 4, 6, 8, 10, 15, 20, 25, and 30 inches.
    b. Byllesby proposed condition:
        i. Routes: Three Kaplan (Proposed Kaplan) turbine Units with 24.7 percent of flow each (1,348 cfs/unit and a single existing Francis (Existing Francis) turbine unit with 26.0 percent flow (1,467 cfs).
        ii. Fish size classes: 2, 4, 6, 8, 10, 15, 20, 25, and 30 inches.
    c. Buck existing condition:
        i. Routes: Turbine Units 1 through 3, each with 33 percent of flow (1,180 cfs/unit).
        ii. Fish size classes: 2, 4, 6, 8, 10, 15, 20, 25, and 30 inches.
    d. Buck proposed condition

i. Routes: Two Proposed Kaplan turbine units (1,195 cfs/unit) and one Existing Francis turbine unit (1,180 cfs); each with 33 percent of flow.

ii. Fish size classes: 2, 4, 6, 8, 10, 15, 20, 25, and 30 inches.

2. Spilling conditions - Flow exceedance percentile data were reviewed to determine the volume of spillage at the range of percentiles where river discharge exceeded turbine capacity. A downstream passage survival estimate was calculated for each spillage scenario and based on the average length of Walleye collected in the 2020 – 2021 Fish Community Survey (Appalachian 2021) conducted in the Project area.

   a. Byllesby existing condition:

      i. Routes: Turbine Units 1 through 4, each with equal amounts of flow (1,467 cfs/unit) and spillage at 4, 3, 2, and 1 percent exceedance.

      ii. The fish length input (mean=18.5 inches and standard deviation=1.5 inches) for Walleye was based on the maximum likely length anticipated to be susceptible to entrainment through the bar racks or unable to overcome approach velocities at the intake or spillway.

   b. Byllesby proposed condition:

      i. Routes: Three Kaplan (Proposed Kaplan) turbine Units with 24.7 percent of flow each (1,348 cfs/unit and a single existing Francis (Existing Francis) turbine unit with 26.0 percent flow (1,467 cfs) and spillage at 4, 3, 2, and 1 percent exceedance.

      ii. The fish length input (mean=18.5 inches and standard deviation=1.5 inches) for Walleye was based on the maximum likely length anticipated to be susceptible to entrainment through the bar racks or unable to overcome approach velocities at the intake or spillway.

   c. Buck existing condition:

      i. Route: Turbine Units 1 through 3, each at 1,180 cfs/unit and spillage at 12, 10, 8, 6, 4, 2, and1 percent exceedance.

      ii. The fish length input (mean=18.5 inches and standard deviation=1.5 inches) for Walleye was based on the maximum likely length anticipated to be susceptible to entrainment through the bar racks or unable to overcome approach velocities at the intake or spillway.

   d. Buck proposed condition:

      i. Route: Two Proposed Kaplan turbine units (1,195 cfs/unit) and one Existing Francis turbine unit (1,180 cfs) and spillage at 12, 10, 8, 6, 4, 2, and1 percent exceedance.

      ii. The fish length input (mean=18.5 inches and standard deviation=1.5 inches) for Walleye was based on the maximum likely length anticipated to be susceptible to entrainment through the bar racks or unable to overcome approach velocities at the intake or spillway.

5 Study Results

5.1 Intake Structure, Velocities, and Turbine Characteristics

Pursuant to the SPD, Appalachian compiled information on the key physical characteristics, identified from Project drawings, along with operational information (intake flows and pathways) associated with the Project. These data are summarized in the following sections and were used to calculate intake velocities for the Byllesby and Buck developments.

5.1.1 Byllesby Development

5.1.1.1 Intake Specifications and Flows

The Byllesby intake, located immediately upstream of the powerhouse, consists of four inlet bays. Each bay has a 14-ft-high by 23-ft-wide headgate, which is used during maintenance periods. A 3-ft-wide, reinforced-concrete pier is set vertically in the middle of each inlet bay to support the headgate. Each headgate is closed and opened by a gear and screw lift shaft assembly powered by an electric motor. Each bay admits water to a concrete volute casing, which channels flow to a vertical-shaft Francis hydraulic turbine direct-connected to a generator on the upper level of the powerhouse. Flow through the four turbines passes to concrete draft tubes and into the New River on the downstream side of the powerhouse.

The intake structure at the Byllesby development is approximately 143 ft wide and is equipped with 3/8-inch by 3.5-inch rectangular steel bars. The bars are 47.5 ft long and are inclined toward the powerhouse at approximately 15 degrees. The bars are spaced 2.66 inches center-to-center and have a clear space of 2.28 inches.

The design maximum flow capacity of the four existing generating units at Byllesby development is 1,420 cfs each, for a total existing plant capacity of 5,868 cfs. An evaluation of U.S. Geological Survey (USGS) gage data (USGS 03165500 New River at Ivanhoe) from February 1996 to August 2020 showed that average monthly river flows rarely exceed total plant capacity (Figure 5-1); however, spillage to the bypass (reflecting opportunity for maximum operations) may occur up to eight percent of the time during winter and spring months (January to April) for average flow years, and up to 59 percent of the time during wet years..

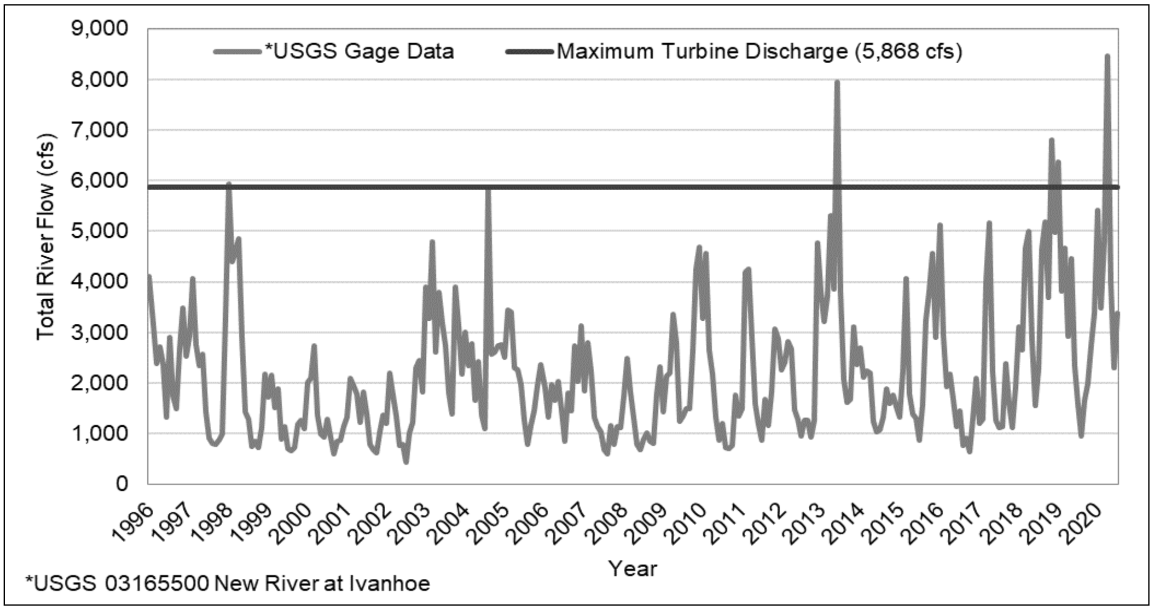


Figure 5-1.USGS 03165500 Gage Data versus Maximum Turbine Discharge (5,868 cfs) at Byllesby Development

5.1.1.2 Turbine Specifications

A summary of the turbine design and operational specifications for the existing conditions and proposed conditions (after replacement of 3 Francis units with 3 Kaplan units) for the Byllesby Development is provided in Table 5-1.

Table 5-1. Turbine Design and Operational Specifications for the Byllesby Development

Term	Units	Description	Byllesby (Existing)	Byllesby (Proposed)	
Type	(-)	Francis, Kaplan, propeller, or bypass	Vertical shaft Francis	Kaplan	Vertical shaft Francis
Turbines	(#)	Number of Turbines	4	3	1
Blades	(#)	Number of blades on the turbine runner	16	5	16
Net Head	(ft)	Net head on the turbine; headwater to tailwater, less head loss through system	56	54	56
Runner Dia. at Discharge	(ft)	Diameter at the outlet of the runner (typically before the draft tube; see Figure 4.3.2-3 in Franke et al., 1997)	9.8	--	9.8
Runner Dia. at Inlet	(ft)	Diameter at the intake of the runner (typically beyond the guide vanes)	8.8	--	8.8
Runner Diameter	(ft)	Nominal diameter of runner; maximum radius is assumed to be half of diameter	7.52	8.70	7.52

Term	Units	Description	Byllesby (Existing)	Byllesby (Proposed)	
Runner Height	(ft)	Runner height at inlet	3.06	--	3.06
Speed	(rpm)	Runner revolutions per minute	116	189.5	116
Turbine Discharge (Q)	(cfs)	Hydraulic capacity or discharge for each turbine	1,467	1,348	1,467
Turbine Efficiency	(-)	Ratio of output shaft power to input fluid power; typ. from vendor curves or index testing	0.89	0.917	0.89
Turbine $Discharge_{OPT}$	(cfs)	Turbine discharge at optimal efficiency	1,120	1,248	1,120
Percent Discharge at Opt. Efficiency	%	Ratio of turbine discharge at best efficiency to hydraulic capacity	79.0%	92%	79.0%
Swirl Coefficient	(-)	Ratio between Q or turbine discharge (cfs) with no exit swirl and Q_{OPT} (recommended x=1.1 for Francis turbines)	1.1	--	1.1
Model Routes		Unit 1, Unit 2, Unit 3, Unit 4, spillway At the Byllesby Project replacement of three existing Francis units with Kaplan units is proposed, one of the original Francis units will be retained for a total of 4 units.			
Bypass spill mortality		A spillway and bypass passage survival rate of 97 percent (3 percent mortality) was assumed based on the average of 136 survival tests conducted with juvenile salmonids on the Columbia river (Amaral et al. 2013).			

5.1.1.3 Intake Velocities

The approach velocity was calculated by determining the area of influence (AOI) directly in front of the headgate opening and dividing that area into the maximum turbine discharge capacity. For existing turbine conditions at Byllesby, a conservation calculation of intake approach velocity was made using only the lower portion of the intake structure that remains below the water surface elevation under normal operating conditions[1]. The calculation assumed that the height of the AOI is approximately 150 percent of the headgate opening height (i.e., 14-ft x 1.5) and the width was based on the width of the intake structure (i.e., 143 ft). As a result, the calculated approach velocity in front of the intake structure is approximately 2.0 ft per second (fps) (i.e., 5,868 cfs / (143 ft x 14 ft x 1.5)). This approach velocity is within the range estimated for the previous relicensing effort (Appalachian 1991). This velocity is also comparable to the range of river velocities measured at riffle/run complexes above and below the project (Appalachian 1991). Because no substantial changes have o

[1] The portion of the intake structure that extends above the water surface elevation under normal operating conditions was not factored into the approach velocity calculation. Instead, the approach velocity calculation is based on the lower 21 ft of the water column in front of the intake structure (i.e., 14-ft headgate opening height multiplied by a factor of 1.5 to account for the hydraulic zone of influence which extends above the top of the headgate opening). Using the lower 21 ft of the water column, instead of the full depth of the water column in front of the intake structure is conservative (i.e., may actually overestimate the calculated approach velocity).

ccurred in this area of the New River since the last relicensing, flow conditions in these areas are expected to be the similar to historical conditions. Therefore, it is likely that fish in the vicinity of the intake can navigate intake flows similar to normal river conditions.

Under the proposed turbine upgrade conditions, a reduction in turbine capacity from 5,868 to 5,511 cfs would reduce the intake approach velocity to 1.84 fps (i.e., 5,511 cfs / (143 ft x 14 ft x 1.5)). The anticipated reduction to intake velocity would provide a further reduction in the susceptibility of fish to entrainment or impingement at the Byllesby intake.

5.1.2 Buck Development

5.1.2.1 Intake Specifications and Flows

The Buck intake section, which is immediately upstream of the powerhouse, is of concrete construction and consists of three inlet bays. Each bay has a 14-ft-high by 23-ft-wide headgate which is used during maintenance periods. A 3-ft-wide, reinforced-concrete pier is set vertically in the middle of each inlet bay to support the headgate. Each gate is operated by a gear and threaded lift shaft assembly powered by an electric motor. The bays admit water to a concrete volute casing, which channels flow to a vertical-shaft Francis hydraulic turbine, direct-connected to a generator on the upper level of the powerhouse. Flow through the three turbines passes to concrete draft tubes and into the New River downstream of the powerhouse.

The Buck intake structure is approximately 104 ft wide and is equipped with 3/8-inch by 3.5-inch rectangular steel bars. The screen is 39.2 ft high and is inclined toward the powerhouse at approximately 15 degrees to the vertical. The bars are spaced 2.66 inches center-to-center and have a clear space of 2.28 inches.

The design maximum flow capacity of the three existing generating units at the Buck Development is 1,180 cfs each, for a total existing plant capacity of 3,540 cfs. An evaluation of USGS gage data (USGS 03165500 New River at Ivanhoe) from February 1996 to August 2020 showed that average monthly river flows regularly exceed plant capacity, indicating opportunity for maximum operation at Buck. An evaluation of spillage to the bypass reach suggests that maximum operations could occur up to 25 percent of the time in an average year during the wetter months (January to May), and up to 98 percent of the time during wet years.

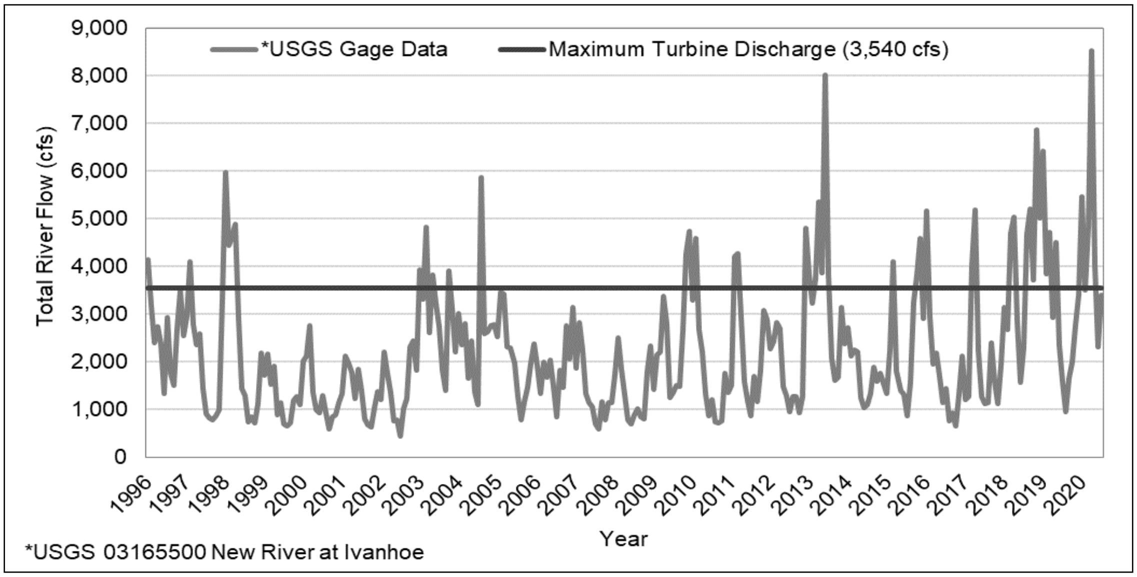


Figure 5-2. USGS 03165500 Gage Data versus Maximum Turbine Discharge (3,540 cfs) at Buck Development Hydroelectric Project

5.1.2.2 Turbine Specifications

A summary of the turbine design and operational specifications for the existing conditions and proposed conditions (after replacement of 2 Francis units with 2 Kaplan units) for the Buck Development is provided in Table 5-2.

Table 5-2. Turbine Design and Operational Specifications for the Buck Development

Term	Units	Description	Buck (Existing)	Buck (Proposed)	
Type	(-)	Francis, Kaplan, propeller, or bypass	Vertical shaft Francis	Kaplan	Vertical shaft Francis
Turbines	*(#)*	Number of Turbines	3	2	1
Blades	*(#)*	Number of blades on the turbine runner	16	5	16
Net Head	(ft)	Net head on the turbine; headwater to tailwater, less head loss through system	40	42.4	40
Runner Dia. at Discharge	*(ft)*	Diameter at the outlet of the runner (typically before the draft tube; see Figure 4.3.2-3 in Franke et al., 1997)	9.8	--	9.8
Runner Dia. at Inlet	*(ft)*	Diameter at the intake of the runner (typically beyond the guide vanes; see Figure 4.3.2-3 in Franke et al., 1997)	8.8	--	8.8
Runner Diameter	*(ft)*	Nominal diameter of runner; maximum radius is assumed to be 1/2 of diameter	7.52	8.7	7.52
Runner Height	*(ft)*	Runner height at inlet (see Figure 4.3.2-3 in Franke et al., 1997 for clarification)	3.06	--	3.06

Term	Units	Description	Buck (Existing)	Buck (Proposed)	
Speed	*(rpm)*	Runner revolutions per minute (model automatically converts to radians per second)	97	156.5	97
Turbine Discharge (Q)	*(cfs)*	Hydraulic capacity or turbine discharge	1,180	1,195	1,180
Turbine Efficiency	*(-)*	Ratio of output shaft power to input fluid power; typically, from vendor curves or index testing	0.85	0.92	0.85
Turbine $Discharge_{OPT}$	*(cfs)*	Turbine discharge at optimal efficiency	956	930	956
Percent Discharge at Opt. Efficiency	*%*	Ratio of turbine discharge at best efficiency to hydraulic capacity	90%	77.8	90.0%
Swirl Coefficient	*(-)*	Ratio between Q or turbine discharge (cfs) with no exit swirl and Q_{OPT} (recommended x=1.1 for Francis turbines)	1.1	--	1.1
Model Routes		Unit 1, Unit 2, Unit 3, spillway At the Buck Project replacement of two Francis units with Kaplan units is proposed, one of the existing Francis units will be retained for a total of 3 units.			
Bypass/Spillway Mortality		A spillway and bypass passage survival rate of 97 percent (3 percent mortality) was assumed based on the average of 136 survival tests conducted with juvenile salmonids on the Columbia river (Amaral et al. 2013).			

5.1.2.3 Intake Velocities

The approach velocity was calculated by determining the AOI directly in front of the headgate opening and dividing that area into the maximum turbine discharge capacity. For Buck, it was assumed that the height of the AOI is approximately 150 percent of the headgate opening height (i.e., 14-ft x 1.5) and the width was based on the width of the intake structure (i.e., 104 ft). As a result, the calculated approach velocity in front of the intake structure is approximately 1.6 fps (i.e., 3,540 cfs / (104 ft x 14 ft x 1.5)). This approach velocity is within the range calculated in the historical report (Appalachian 1991). This velocity is also within range of river velocities measured at various locations during the prior fish community study (Appalachian 1991). Because no substantial changes have occurred in this area of the New River since the last relicensing and conditions are not anticipated to have changed, it is likely that fish in the vicinity of the intake can navigate intake flows similarly as expected normal river conditions.

Under the proposed turbine upgrade conditions, a change in turbine capacity from 3,540 cfs to 3,570 cfs would result in a fractional increase in the intake approach velocity from 1.6 to 1.63 fps (i.e., 3,570 cfs / (143 ft x 14 ft x 1.5)). The anticipated small increase in the intake approach velocity is not expected to result in a measurable change to the susceptibility of fish to entrainment or impingement at the Buck intake; as such, most fish in the vicinity of the intake are still expected to avoid intake approach velocities.

5.2 Desktop Review of Impingement and Entrainment Potential

5.2.1 Fish Community and Target Species

A Fish Community Study was performed by Edge Engineering and Science, LLC (EDGE) at the Project between October 2020 and May 2021 to characterize the New River fishery in the vicinity of the Project, details of the methods and results of the study are presented in the Byllesby Buck 2020-2021 Fish Community Survey Report (Appalachian 2021)(Appendix C). Boat electrofishing surveys were conducted between October 22 and 24-25, 2020, and April 25-26 and May 27, 2021. Backpack electrofishing surveys were conducted between April 20-23, 2021 and gillnet surveys were performed between November 9-11 and 18-20, 2020 and April 20-24, 2021. All surveys followed methods outlined in the RSP and occurred during relatively low-flow and clear stream conditions. Sampling was performed by EDGE's fish biologists under Virginia Scientific Collecting Permit No. 070705. Results of physiochemical data collected at sample sites met the state water quality standards established for the New River, indicating that water quality within the Project area is capable of supporting fish communities.

The Project is in a rural area within a relatively large watershed, which may contribute to potential issues pertaining to water quality and habitat degradation in this portion of the New River that are independent of the Project. Byllesby and Buck dams influence habitat availability in the Project area, which determines species diversity and distribution by impounding the existing riffle and run habitats and creating the pool habitats now present in the Project reservoirs. However, study data demonstrate that the habitats available within the Project area support a relatively healthy and diverse fish community.

Between fall 2020 and spring 2021, a total of 404 fish from 26 species were collected upstream of Byllesby Dam from seven boat electrofishing sites (244 fish from 20 species), six gillnet sites (112 fish from 10 species), and three backpack electrofishing sites (sampled spring 2021, 48 fish from 11 species). Five species were collected exclusively upstream of Byllesby Dam. Between fall 2020 and spring 2021, a total of 509 fish representing 33 species were collected between Byllesby Dam and Buck Dam from 10 boat electrofishing sites (353 fish from 24 species) and six backpack electrofishing sites sampled during spring 2021 (156 fish from 18 species). Seven species were collected exclusively between Byllesby Dam and Buck Dam. A total of 206 fish, representing 17 species, were collected below Buck Dam from four backpack electrofishing sites (sampled spring 2021). Two species were collected exclusively below Buck Dam. A summary of the fish species collected by each method and location is provided in Table 5-3.

Table 5-3. Fish Species Captured by Sampling Method and Location during the 2020-2021 Fish Community Study at the Byllesby-Buck Project

Species		Method			Location		
Common Name	**Scientific Name**	**Boat EF[1]**	**Backpack EF[1]**	**Gillnet**	**US Byllesby[2]**	**Between Dams[3]**	**DS Buck[4]**
Rock Bass	*Ambloplites rupestris*	X	X	X	X	X	
Central Stoneroller	*Campostoma anomalum*		X		X	X	X
White Sucker	*Catostomus commersonii*	X		X	X		
Kanawha Sculpin	*Cottus kanawhae*		X				X
Whitetail Shiner	*Cyprinella galactura*	X	X		X	X	X
Spotfin Shiner	*Cyprinella spiloptera*	X	X		X	X	X
Common Carp	*Cyprinus carpio*	X		X	X	X	
Muskellunge	*Esox masquinongy*	X		X	X		
Greenside Darter	*Etheostoma blennioides*	X	X		X	X	X
Fantail Darter	*Etheostoma flabellare*	X	X			X	X
Kanawha Darter	*Etheostoma kanawhae*		X			X	
Northern Hogsucker	*Hypentelium nigricans*	X	X			X	X
Channel Catfish	*Ictalurus punctatus*	X		X	X	X	
Redbreast Sunfish	*Lepomis auritus*	X	X		X	X	X
Green Sunfish	*Lepomis cyanellus*	X			X	X	
Pumpkinseed	*Lepomis gibbosus*	X				X	
Bluegill	*Lepomis macrochirus*	X		X	X	X	
Sunfish Species	*Lepomis* spp.	X	X		X	X	X
White Shiner	*Luxilus albeolus*		X				X
Rosefin Shiner	*Lythrurus ardens*	X				X	
Smallmouth Bass	*Micropterus dolomieu*	X	X	X	X	X	X
Spotted Bass	*Micropterus punctulatus*	X			X	X	
Largemouth Bass	*Micropterus salmoides*	X			X	X	
Bigmouth Chub	*Nocomis platyrhynchus*	X	X		X	X	
Chub Species	*Nocomis* spp.	X	X		X	X	
Spottail Shiner	*Notropis hudsonius*	X				X	
Swallowtail Shiner	*Notropis procne*	X				X	

Species		Method			Location		
Common Name	Scientific Name	Boat EF[1]	Backpack EF[1]	Gillnet	US Byllesby[2]	Between Dams[3]	DS Buck[4]
Rosyface Shiner	*Notropis rubellus*	X	X		X	X	X
Saffron Shiner	*Notropis rubricroceus*		X			X	
New River Shiner	*Notropis scabriceps*	X	X		X	X	X
Telescope Shiner	*Notropis telescopus*	X	X		X	X	X
Mimic Shiner	*Notropis volucellus*	X	X		X	X	X
Margined Madtom	*Noturus insignis*		X			X	X
Rainbow Trout	*Oncorhynchus mykiss*	X			X		
Logperch	*Percina caprodes*	X	X			X	X
Sharpnose Darter	*Percina oxyrhynchus*		X			X	X
Bluntnose Minnow	*Pimephales notatus*	X				X	
Black Crappie	*Pomoxis nigromaculatus*	X		X	X		
Flathead Catfish	*Pylodictis olivaris*	X	X	X	X	X	
Walleye	*Sander vitreus*			X	X		
Total Number of Exclusive Taxa		**9**	**7**	**1**	**5**	**7**	**2**

1) Electrofishing (EF) methods (boat or backpack).
2) Upstream (US) of Byllesby Dam (the Byllesby Pool).
3) Between dams includes the Byllesby bypass and tailwaters, transition zone, and Buck Pool.
4) Downstream (DS) of Buck Dam (Buck bypass and tailwater).

These data were used to determine the target species for inclusion in this Desktop study and included those species of management (i.e., state/federal protection), economic, and ecological importance (Table 5-4). Where appropriate, representative or surrogate species were used when evaluating other factors, such as swim burst speed and impingement potential.

Table 5-4. Target Fish Species and Species Groups Included in the Impingement and Entrainment Study for Byllesby-Buck Hydroelectric Project

Common Name	Scientific Name
Black Crappie	*Pomoxis nigromaculatus*
Bullheads and Madtoms	*Ameiurus* spp. and *Noturus* spp.
Catfishes	*Ictalurus* spp.
Common Carp	*Cyprinus carpio*
Darters and Logperch	*Etheostoma* and *Percina* spp.

Common Name	Scientific Name
Largemouth Bass	*Micropterus salmoides*
Lepomis Sunfishes	*Lepomis* spp.
Muskellunge	*Esox masquinongy*
Rock Bass	*Ambloplites rupestris*
Shiners, Chubs, and Minnows	Leuciscinae
Smallmouth Bass	*Micropterus dolomieu*
Spotted Bass	*Micropterus punctulatus*
Suckers and Redhorse	Catostomidae and *Moxostoma* spp.
Walleye	*Sander vitreus*
White Bass	*Morone chrysops*

5.2.2 Intake Avoidance and Impingement Risk

5.2.2.1 Intake Avoidance

Burst swim speeds for target or representative species were compared to the estimated intake velocity to evaluate whether fish may be susceptible to intake flows at the Project. Burst swim speed is the swim speed used to escape predation, maneuver through high flows, or in this case, escape intake velocities and avoid entrainment. Burst swim speed data were compiled from the literature, however if data for a specific species or group was not available, it was calculated as two times the critical or sustained swim speed based on Bell (1991).

As described in Section 5.1 of this study report, the assessment of impingement and entrainment susceptibility at the Project developments assumed velocities calculated under maximum discharge based on the design capacity of the existing turbines (5,868 cfs at Byllesby and 3,540 cfs at Buck), corresponding to maximum approach velocities of 2.0 fps and 1.6 fps at Byllesby and Buck developments, respectively. Burst swim speeds found in literature suggest that most fish species and life stages that may be in the vicinity of the intake would be able to avoid entrainment based on approach velocities at the Project (Table 5-5). The life stages most likely to be entrained are larvae, however the larvae of most species in the Project area are unlikely to occur near the intake based on their life history characteristics (i.e., appropriate spawning habitat requirements of adults such as low velocity, riffles, cover, substrate, vegetation, etc.). Additional analyses were performed to assess potential intake avoidance under the proposed turbine upgrades, which would result in a slight increase in approach velocity at Buck and 0.4 fps reduction at Byllesby. Given the overall swimming performance of the target species in the Project vicinity, that the small changes anticipated with the turbine unit upgrades would not result in a measurable change in fish susceptibility to impingement or entrainment at the Project intake structures.

Table 5-5. Summary of Fish Burst Swim Speeds by Species

Target Species/Group	Surrogate Species	Age	Length[1]	Burst Swim Speed (fps)[2]	Reference
Black Crappie	White Crappie	Juvenile	3.03	**1.04**	Smiley and Parsons 1997
	White Crappie	Juvenile/ Adult	6.7	**1.19**	Katopodis and Gervais 2016
Catfishes	Channel Catfish x Blue Catfish	Juvenile	6.30-9.06	7.88	Beecham et al. 2009
	Blue Catfish	Juvenile	2.05	**1.97**	Katopodis and Gervais 2016
Common Carp	Common Carp	Juvenile	6.02	2.76-4.59	Tsukamoto et al. 1975
Darters & Logperch	Darters (*Etheostoma* spp.)	Adult	1.42	2.62	Katopodis and Gervais 2016
	Greenside Darter	Adult	1.57-2.68	**1.02**-2.64	Layher 1993
Largemouth Bass	Largemouth Bass	Juvenile	3.5-4.72 (FL)	2.32-3.28	Farlinger and Beamish 1977
		Juvenile	5.04	2.46	Katopodis and Gervais 2016
Lepomis Sunfishes	Sunfish Species	Adult	3.19	4.35	Katopodis and Gervais 2016
	Bluegill	Adult	3.94-5.91	2.44	Gardner et al. 2006
		Juvenile	1.97	2.66	Katopodis and Gervais 2016
	Longear Sunfish	Juvenile/ Adult	2.20-5.35	**1.24**-2.56	Layher 1993
	Pumpkinseed	Adult	5.000	2.44	Brett and Sutherland 1965
	Redbreast Sunfish	Juvenile	1.890	2.32	Katopodis and Gervais 2016
Shiners, Chubs, and Minnows	Emerald Shiner	Adult	2.5	4	Bell 1991
	Golden Shiner	Adult	1.54-4.33	2.02-2.64	Layher 1993
	Blacknose Dace	Adult	1.60-1.74 (SL)	2.54	Nelson et al. 2003
		Juvenile	1.69	2.02-3.02	Katopodis and Gervais 2016
	Central Stoneroller	Juvenile	1.81	4.13	Katopodis and Gervais 2016

Target Species/Group	Surrogate Species	Age	Length[1]	Burst Swim Speed (fps)[2]	Reference
Smallmouth Bass, Spotted Bass	Smallmouth Bass	Larvae	0.55-0.98	**1.2**-1.74	Larimore and Deuver 1968
		Juvenile	3.58-3.66	2.6-3.6	Webb 1998
		Adult	10.3-14.9	3.2-7.8	Bunt et al. 1999
		Adult	11.81	5.77	Katopodis and Gervais 2016
Suckers and Redhorse	Longnose Sucker	Juvenile/ Adult	3.9-16.0	4.0-8.0	Bell 1991
	White Sucker	Adult	6.69-14.57 (FL	4.96	Hunter and Mayor 1986
	Robust Redhorse	Larvae	0.51-0.8	**0.46-0.76**	Reutz and Jennings 2000
	Suckers	Adult	7.05	8.33	Katopodis and Gervais 2016
Walleye	Walleye	Juvenile	6.3 (FL)	6.02 (S)	Peake et al. 2000
		Adult	13.78 (FL)	7.2 (S)	Peake et al. 2000
		Adult	22.44 (FL)	8.57 (S)	Peake et al. 2000
White Bass	Striped Bass	Larvae	0.51	**0.36-0.60**	Bell 1991
		Larvae	0.98	**0.52-1.00**	Bell 1991
		Juvenile	2.01	**1.10-2.00**	Bell 1991
		Juvenile	5.0	2.10-5.00	Bell 1991

[1] Lengths are Total Length (TL) unless otherwise noted (SL: standard length; FL: fork length)
[2] Burst swim speeds were calculated as 2x critical speed (Bell 1991), unless burst speed was provided in the literature. (S): startle speed.
Bold text indicates speeds at or below approach velocity at Byllesby (1.0 fps) or Buck (1.6 fps) developments.

5.2.2.2 Impingement Risk

Proportional estimates of body width to length (scaling factor) were compiled by Smith (1985) for all the target and representative species in this study. The scaling factor multiplied by the maximum recorded length for the species (Jenkins and Burkhead 1993), or maximum recorded length from field data collected during the 2020-2021 Fish Community Study (Appalachian 2021), resulted in a corresponding width which was then compared to the trash rack spacing at the Project (2.28 inches) (Table 5-6).

Most of the smaller-sized species, such as shiners, darters, minnows, and sunfishes would be able to pass through the trash racks and become entrained at the Project. However, some larger-bodied fishes, including recreationally important species, may be excluded once they reach the minimum size depending on species-specific length-to-width ratios (Table 5-6). Channel Catfish (*Ictalurus punctatus*), Common Carp, Largemouth Bass (*Micropterus salmoides*), Walleye (*Sander vitreus*), and White Sucker (*Catostomus commersonii*) may all be excluded once they reach minimum size, which ranges from 14.5 inches up to 18.5 inches.

Table 5-6. Estimated Minimum Lengths (inches) of Target and Representative Species Excluded by Trash Racks at Byllesby-Buck Hydroelectric Project

Common Name	Scaling Factor for Body Width[1]	Maximum Reported Length (inches)[2]	Corresponding Body Width (inches)	Minimum Size (inches) Excluded by Trash Rack at the Project (2.28 inches)
River Chub	0.127	8.9	1.1	Not Excluded
Black Crappie	0.099	15.6	1.5	Not Excluded
Blacknose Dace	0.132	2.8	0.4	Not Excluded
Bluegill*	0.132	6.7	0.9	Not Excluded
Bluegill	0.132	8.7	1.1	Not Excluded
Bluntnose Minnow	0.119	4.2	0.5	Not Excluded
Central Stoneroller	0.126	5.9	0.7	Not Excluded
Channel Catfish	0.156	27.6	4.3	14.5
Channel Catfish*	0.156	18.1	2.8	14.5
Common Carp	0.162	27.0	4.4	14.5
Common Carp*	0.162	30.5	4.9	14.5
Common Logperch	0.104	4.7	0.5	Not Excluded
Golden Redhorse	0.127	14.8	1.9	Not Excluded
Golden Shiner	0.105	7.9	0.8	Not Excluded
Green Sunfish*	0.154	5.3	0.8	Not Excluded
Green Sunfish	0.154	7.1	1.1	Not Excluded
Greenside Darter	0.122	3.5	0.4	Not Excluded
Johnny Darter	0.118	1.6	0.2	Not Excluded
Largemouth Bass*	0.134	17.5	2.3	17.0
Largemouth Bass	0.134	25.6	3.4	17.0
Longear Sunfish	0.153	5.9	0.9	Not Excluded
Longnose Dace	0.139	3.3	0.5	Not Excluded
Mimic Shiner	0.101	2.2	0.2	Not Excluded
Northern Hog Sucker*	0.146	4.4	0.6	Not Excluded
Northern Hog Sucker	0.146	11.8	1.7	Not Excluded
Pumpkinseed	0.124	6.3	0.8	Not Excluded
Rainbow Darter	0.134	2.0	0.3	Not Excluded

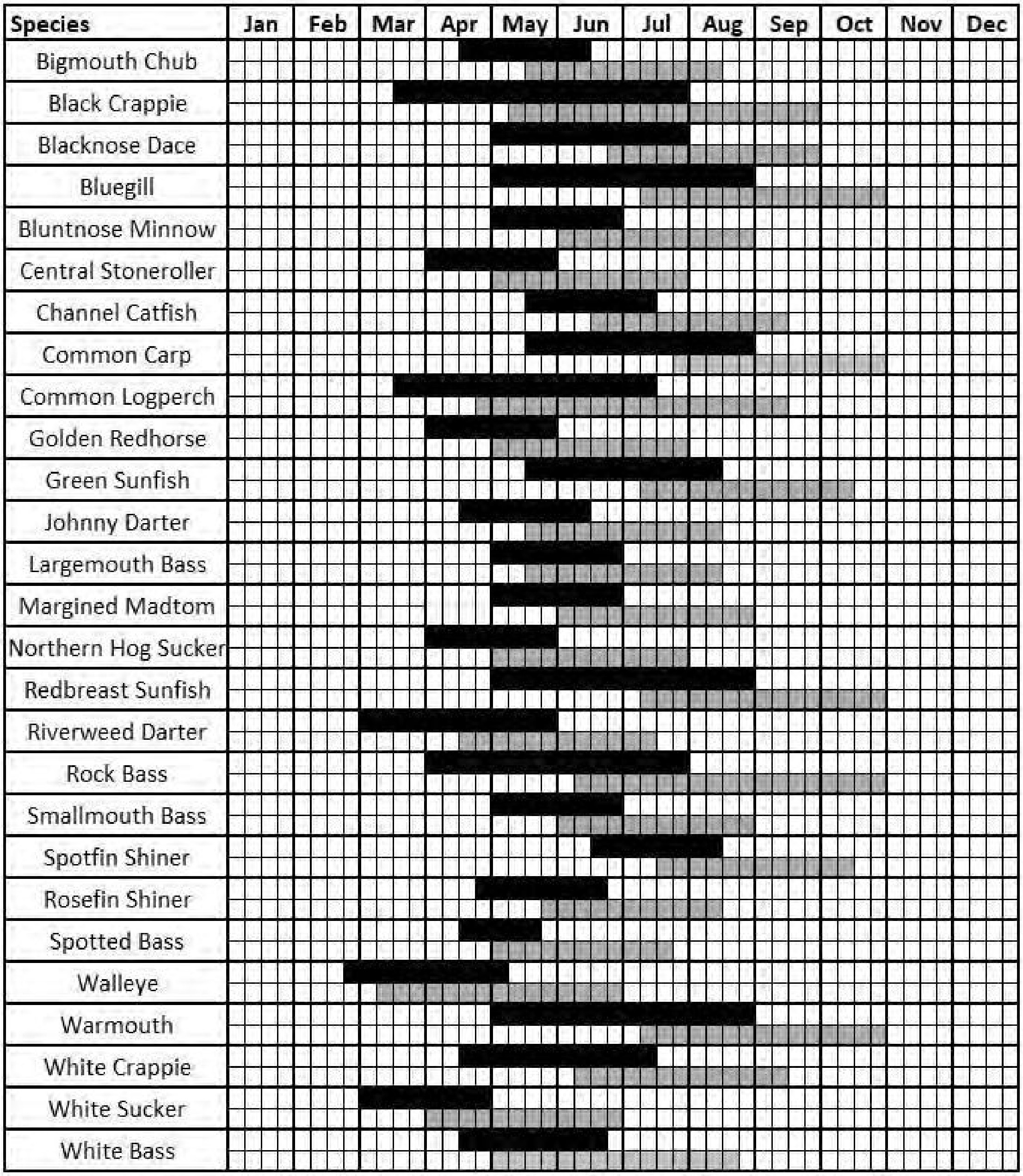
Common Name	Scaling Factor for Body Width[1]	Maximum Reported Length (inches)[2]	Corresponding Body Width (inches)	Minimum Size (inches) Excluded by Trash Rack at the Project (2.28 inches)
Redbreast Sunfish*	0.150	7.4	1.1	Not Excluded
Redbreast Sunfish	0.150	7.3	1.1	Not Excluded
Rock Bass*	0.155	4.4	0.7	Not Excluded
Rock Bass	0.155	7.9	1.2	Not Excluded
Smallmouth Bass*	0.128	13.0	1.7	Not Excluded
Smallmouth Bass	0.128	16.9	2.2	Not Excluded
Spotfin Shiner*	0.110	2.7	0.3	Not Excluded
Spotfin Shiner	0.110	2.8	0.3	Not Excluded
Spottail Shiner*	0.140	3.3	0.5	Not Excluded
Spottail Shiner	0.140	3.5	0.5	Not Excluded
Spotted Bass*	0.128	2.7	0.3	Not Excluded
Spotted Bass	0.128	15.0	1.9	Not Excluded
Walleye**	0.125	21.8	2.7	18.5
Walleye*	0.125	15.4	1.9	Not Excluded
Warmouth	0.140	7.9	1.1	Not Excluded
White Crappie*	0.085	4.5	0.4	Not Excluded
White Crappie	0.085	15.7	1.3	Not Excluded
White Sucker	0.146	15.7	2.3	16.0
Yellow Bullhead	0.172	11.8	2.0	Not Excluded

[1] Scaling factor (Smith 1985) expresses body width as a function of length based on proportional measurements.
[2] Maximum length reported by Jenkins and Burkhead (1993).
*Species and length collected in the 2020-2021 Fish Community Survey (Appalachian 2021).
** Maximum length reported by USFWS in comments received by the USFWS on the Draft License Applications.

5.2.3 Fish Entrainment Potential

The early life stages of fish (eggs and larvae) are unable to move independently (eggs) or have limited swimming ability (larvae), and therefore are at the mercy of the current and susceptible to entrainment at the Project. An assessment of target and representative species shows that the majority of species have spawning periods from late April through June, with subsequent egg and larvae development from late May through August (Table 5-7).

Table 5-7. Spawning and Early Life Stage Periodicities for Target and Representative Fish Species in the Vicinity of Byllesby-Buck Hydroelectric Project



Spawning Period (Stauffer et al. 1995; Jenkins and Burkhead 1993)

Eggs and larvae (estimated to begin two-thirds of the way through the spawning period and lasting 60 days post spawn)

Some species or groups, such as *Lepomis* sunfish, have long spawning periods with corresponding prolonged windows of egg and larvae development, increasing their risk of entrainment. However, this group, like others in the Centrarchidae family, guard nests constructed in shallow areas with cover (i.e., vegetation, woody debris, etc.) and newly hatch larvae use the cover for protection from predation, which also helps reduce the risk of entrainment to early life stages. Additionally, most freshwater fish species have demersal and/or adhesive eggs and larvae that remain close to areas with protective cover, which also lowers risk of entrainment (Cada 1991). A summary of life history information for target and representative species is included in Appendix B.

Although some early life stage organisms may be swept from nesting areas during high flow events or from reservoir level fluctuations (which does not exceed more than 1 ft at each development), it is expected that ichthyoplankton mortality resulting from turbine passage is low, at two to five percent (Cada 1991). Other sources of injury or mortality to early life stages, such as pressure changes, cavitation, turbulence, and shear stress are limited at the facility based on the prior entrainment study (Appalachian 1991). As no significant changes have occurred at the facility since the last relicensing, impacts from these factors are also considered minimal. Further, the proposed unit upgrades from Francis to Kaplan turbines will further reduce the risk of impacts to fish entrained through the turbines.

5.2.3.1 Fish Entrainment Estimates

Findings from FERC (1995) and Winchell et al. (2000) suggest that the majority of fish size classes entrained at hydroelectric projects is substantially smaller than the minimum length of fish physically excluded by a certain clear spacing, and that length frequencies of entrainment compositions are similar among sites with differing trash rack spacing. This indicates that the lack of larger fish may be related to their increased swimming performance and ability to avoid intake velocities as they approach the intake.

According to the EPRI (1997) database selections used for this study, fish less than eight inches in length exhibited the highest entrainment rates throughout the year (Table 5-8), of those, most (88 percent) consisted of fish measuring six inches in length or smaller (Figure 5-3) overall, and. Of the fish less than eight inches in length, entrainment rates in summer and fall were greatest, suggesting these are the species likely spawned the prior spring and recently recruited to sizes large enough to be captured in the sampling nets.

Table 5-8. Annual and Seasonal Entrainment Rates of Target Species and Species Groups by Fish Size Class

Fish Size (total length)	Average Monthly Entrainment Rate by Season (fish/hr)				
	Winter	Spring	Summer	Fall	Annual
Entrainment Rate (fish/hr) at Byllesby Development (5,868 cfs)					
<4 inch	0.35	0.85	0.98	0.58	**0.69**
4-8 inch	0.47	0.28	0.50	1.48	**0.68**
8-15 inch	0.07	0.06	0.06	0.08	**0.07**
>15 inch	0.00	0.00	0.00	0.00	**0.00**

Fish Size (total length)	Average Monthly Entrainment Rate by Season (fish/hr)				
	Winter	Spring	Summer	Fall	Annual
Total	**0.88**	**1.21**	**1.54**	**2.14**	**1.44**
Entrainment Rate (fish/hr) at Buck Development (3,540 cfs)					
<4 inch	0.21	0.51	0.59	0.35	**0.42**
4-8 inch	0.28	0.17	0.30	0.89	**0.41**
8-15 inch	0.04	0.04	0.04	0.05	**0.04**
>15 inch	0.00	0.00	0.00	0.00	**0.00**
Total	**0.53**	**0.73**	**0.93**	**1.29**	**0.87**
Note: Values represent average fish/hr entrainment from 33 sites selected from the EPRI database and adjusted for maximum turbine discharge (cfs) at each Project development.					

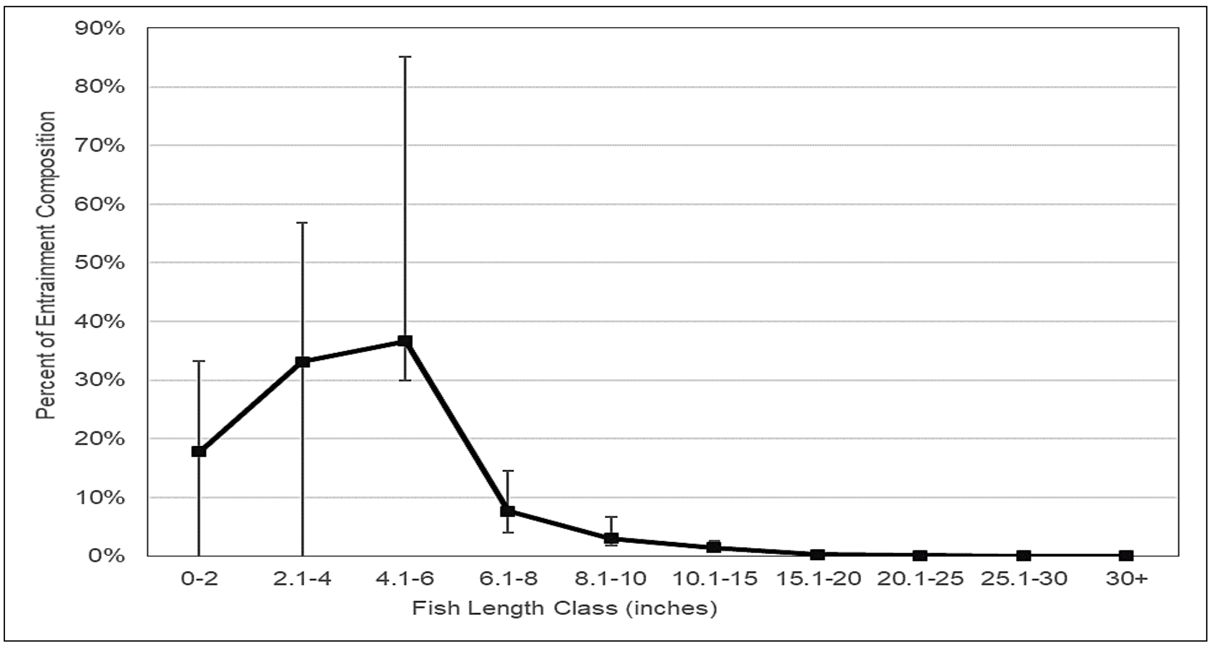


Figure 5-3. Mean Percent (standard deviation) of Entrainment Composition by Fish Size Class According to Target Species from 33 Hydroelectric Developments (EPRI 1997)

Seasonal entrainment rates from the EPRI (1997) database by target species and species group is presented in Table 5-9 for Byllesby Development and Table 5-10 for Buck Development. These include average entrainment rates by fish species and size class, combined by month and averaged by season. Mean monthly seasonal entrainment rates by target species/group and size is provided in Appendix C for Byllesby Development and Appendix D for Buck Development.

Table 5-9. Seasonal and Annual Entrainment Rates for Target Species and Species Groups at Byllesby Development (5,868 cfs)

Target Species/Group	Average Monthly Entrainment Rate (fish/hr) by Season				
	Winter	Spring	Summer	Fall	Annual
Rock Bass	4.69	6.09	4.49	12.70	6.99
Catfishes	0.59	10.07	15.72	1.05	6.86
Suckers and Redhorse	3.93	2.06	2.52	8.78	4.32
Lepomis Sunfishes	0.40	4.24	3.90	7.55	4.02
Black Crappie	1.03	1.06	6.73	4.35	3.29
Largemouth Bass	0.32	0.37	4.27	1.71	1.67
Darters and Logperch	0.29	4.53	1.03	0.24	1.52
Shiners, Chubs, and Minnows	1.02	1.35	1.38	1.50	1.31
Walleye	0.71	0.37	3.03	0.63	1.19
Bullheads and Madtoms	0.15	1.01	1.98	0.44	0.89
Smallmouth Bass	0.12	0.15	1.47	1.13	0.72
White Bass	0.09	1.20	0.09	0.13	0.38
Muskellunge	0.11	0.55	0.53	0.22	0.35
Common Carp	0.03	0.04	0.10	0.04	0.05
Total	**13.48**	**33.09**	**47.24**	**40.47**	**33.56**

Top 90 percent of species by relative abundance on annual basis.

Table 5-10. Seasonal and Annual Entrainment Rates for Target Species and Species Groups at Buck Development (3,540 cfs)

Target Species/Group	Average Monthly Entrainment Rate (fish/hr) by Season				
	Winter	Spring	Summer	Fall	Annual
Rock Bass	2.83	3.67	2.71	7.66	4.22
Catfishes	0.36	6.08	9.48	0.64	4.14
Suckers and Redhorse	2.37	1.24	1.52	5.30	2.61
Lepomis Sunfishes	0.24	2.56	2.35	4.56	2.43
Black Crappie	0.62	0.64	4.06	2.63	1.99
Largemouth Bass	0.19	0.22	2.57	1.03	1.01

Target Species/Group	Average Monthly Entrainment Rate (fish/hr) by Season				
	Winter	Spring	Summer	Fall	Annual
Darters and Logperch	0.17	2.73	0.62	0.15	0.92
Shiners, Chubs, and Minnows	0.62	0.81	0.84	0.91	0.79
Walleye	0.43	0.23	1.83	0.38	0.72
Bullheads and Madtoms	0.09	0.61	1.19	0.27	0.54
Smallmouth Bass	0.07	0.09	0.88	0.68	0.43
White Bass	0.06	0.72	0.05	0.08	0.23
Muskellunge	0.07	0.33	0.32	0.13	0.21
Common Carp	0.02	0.02	0.06	0.03	0.03
Total	**8.14**	**19.95**	**28.48**	**24.45**	**20.27**

Top 90 percent of species by relative abundance on annual basis.

Rock Bass (*Ambloplites rupestris*), catfishes, suckers and redhorses, *Lepomis* sunfishes, and Black Crappie, Largemouth Bass, darters and logperch, and shiners, chubs, and minnows represent the top 90 percent of target species and species groups entrained at the Byllesby and Buck developments based on the EPRI (1997) database (Table 5-9 and Table 5-10). Peaking months of entrainment for these species and species groups varied: Rock Bass, suckers and redhorse, and *Lepomis* sunfishes showed highest entrainment rates in fall; catfishes, Black Crappie, and Largemouth Bass entrainment rates were greatest during the summer season; darters and logperch peaked during spring months, and shiners, chubs, and minnows had relatively even entrainment rates throughout the year.

Entrainment rates were highest from April to October, with peaks in April, July, and October (Figure 5-4). Peaking months may correspond to spawning movements (April), recruitment to catchable size (July or October), or large storm/flow events.

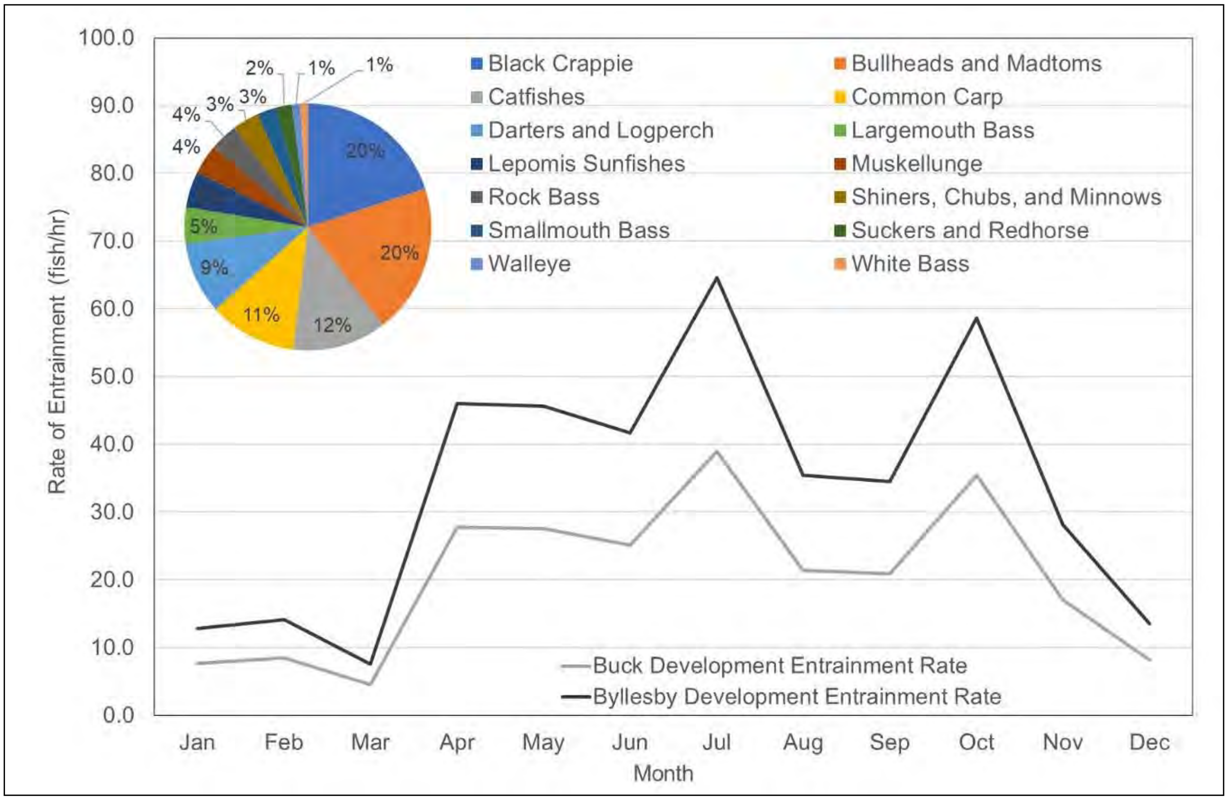


Figure 5-4. Average Monthly Entrainment Rate and Species Composition based on EPRI (1997) Entrainment Database Selections for the Byllesby-Buck Hydroelectric Project

5.2.3.2 Qualitative Turbine Entrainment Risk

Several factors were considered for qualitative entrainment risk ratings for target species at each of the Project developments, including:

- Entrainment rates for each species and species group based on the EPRI (1997) database and site-specific information (see Section 5.2.3.2);
- Maximum turbine discharge frequency (see Section 5.1);
- Comparison of burst swim speed versus intake velocity for likelihood of intake avoidance (see Section 5.2.2.1;
- Size exclusion (see Section 5.2.2.2); and
- Life history characteristics, such as migratory behavior, habitat preferences, spawning behavior/requirements, and early life stage periodicity (see Section 5.2.3).

Although few fish species in the vicinity of the Project developments would be excluded by the trash racks, almost all juvenile and adult fish species could avoid the intake entirely based on approach velocity and associated swim burst speeds. Therefore, most target species with elevated qualitative rankings were driven by increased entrainment rates based on the EPRI (1997) database, which has limited velocity data for comparison.

Some species have higher entrainment rates in the spring period, which may reflect increased activity associated with spawning (e.g., dispersal for nest site selection, increased feeding); none of the species evaluated for this study exhibit fall spawning behavior (see Section 5.2.3 and Appendix B). Although spring spawning is common for many species, some species migrate upstream and away from the intake (e.g., suckers and redhorse), create nests in protected areas (e.g., Central Stoneroller, crevice-spawning shiners), and/or require habitat not found in the vicinity of the intake (see Appendix B); therefore most species were given a low (L) ranking unless elevated entrainment rates were noted (Table 5-11 and Table 5-12).

Increased entrainment for certain species during the fall months (such as Rock Bass or suckers and redhorse group) may indicate increased activity in response to cooling summer water temperatures, triggering the need for increased foraging in preparation for the winter season, or possibly increased activity following late-summer egg hatch and swim up stage. Since most species are not expected to spawn in the vicinity of the intake or where eggs and larvae would be susceptible to intake flows, rankings for potential entrainment of early life stages were not elevated.

Since the same selection of data from the EPRI (1997) database was applied to both facilities, trends across species are similar, and therefore the considerations given below apply to both Byllesby and Buck developments (Table 5-11 and Table 5-12). However, slight differences in qualitative ratings may also be due to differences in total plant capacity.

The majority (59 percent) of catfishes entrained from May to July, based on the EPRI (1997) database, were of the 2-4-inch size class. Since swim burst speed data suggests that catfish of this size are able to swim faster than the intake velocity (1.97 fps [Katopodis and Gervais 2016] versus 1.0 fps; see Table 5-5), the qualitative rating for this species group was designated as moderate (M) for these months despite the relatively high entrainment rate in the EPRI (1997) database.

Similarly, the analysis indicated that Rock Bass have increased entrainment rates during the months of April, October, and November. Most fish estimated to be entrained in April were of the 2 to 4-inch size class, therefore this month was given an elevated entrainment potential rating. However, the majority of Rock Bass estimated to be entrained in October and November were larger in size (4-6 inches). Based on similar body size and shape as *Lepomis* species, swim burst speeds are likely similar and sufficient to also exclude them from susceptibility to entrainment at the Project. Therefore, the entrainment potential rating for Rock Bass was determined to be low-moderate (L-M).

Black Crappie exhibited higher entrainment rates in July and August based on the EPRI (1997) database; these fish were mostly 0-2 inches (60 percent) or 2-4 inches (39 percent) total length, and therefore likely juvenile fish. Black Crappie of this size (using White Crappie as a surrogate) do not have a swim burst speed substantially greater than the intake velocity, therefore the entrainment potential rating for Black Crappie was elevated to moderate-high (M-H).

Results of the entrainment modeling effort indicate that Walleye exhibit elevated entrainment rates at Byllesby during the summer and winter months (Table 5-9), and thus entrainment risk was elevated to moderate (M) during summer months and to low-moderate (L-M) during winter months (Table 5-11). The model results also show that Walleye are expected to have elevated entrainment rates (Table 5-10) at Buck during summer and winter months, although to a lesser extent that Byllesby based on the magnitude of flows passed at Buck compared to Byllesby. As such, the entrainment risk for Walleye at Buck was elevated to low-moderate (L-M) during summer and winter months (Table 5-12).

Table 5-11. Range of Monthly Turbine Entrainment Potential for the Target Species at the Byllesby Development

Target Species/Group	Qualitative Rating of Monthly Entrainment Potential*											
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Black Crappie	L	L	L	L	L	L	M-H	M	L-M	L-M	L-M	L
Bullheads and Madtoms	L	L	L	L	L	L	L-M	L	L	L	L	L
Catfishes	L	L	L	L	M	M	M	M	L	L	L	L
Common Carp	L	L	L	L	L	L	L	L	L	L	L	L
Darters and Logperch	L	L	L	L-M	L-M	L	L	L	L	L	L	L
Largemouth Bass	L	L	L	L	L	L-M	M	L-M	L-M	L	L	L
Lepomis Sunfishes	L	L	L	M-H	L-M	L	L-M	L-M	L-M	L-M	L	L
Muskellunge	L	L	L	L	L	L	L	L	L	L	L	L
Rock Bass	L	L-M	L	M	L	L-M	L-M	L-M	L-M	L-M	L-M	L-M
Shiners, Chubs, and Minnows	L	L	L	L	L	L	L	L	L	L	L	L
Smallmouth Bass	L	L	L	L	L	L	L	L	L	L	L	L
Suckers and Redhorse	L-M	L-M	L	L	L	L	L-M	L	L	M	M	L-M
Walleye	L-M	L-M	L	L	L	M	M	M	L	L	L	L-M
White Bass	L	L	L	L	L	L	L	L	L	L	L	L

*L (low), L-M (low-moderate), M (moderate), M-H (moderate-high), H (high)

Table 5-12. Range of Monthly Turbine Entrainment Potential for the Target Species at the Buck Development

Target Species/Group	Qualitative Rating of Monthly Entrainment Potential*											
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Black Crappie	L	L	L	L	L	L	M-H	L-M	L	L	L	L
Bullheads and Madtoms	L	L	L	L	L	L	L	L	L	L	L	L
Catfishes	L	L	L	L	M	M	M	L-M	L	L	L	L
Common Carp	L	L	L	L	L	L	L	L	L	L	L	L
Darters and Logperch	L	L	L	L	L	L	L	L	L	L	L	L
Largemouth Bass	L	L	L	L	L	L	L-M	L	L	L	L	L
Lepomis Sunfishes	L	L	L	M	L	L	L	L-M	M	L-M	L	L
Muskellunge	L	L	L	L	L	L	L	L	L	L	L	L
Rock Bass	L	L-M	L	L-M	L	L	L	L-M	L-M	L-M	L-M	L-M
Shiners, Chubs, and Minnows	L	L	L	L	L	L	L	L	L	L	L	L
Smallmouth Bass	L	L	L	L	L	L	L	L	L	L	L	L
Suckers and Redhorse	L	L	L	L	L	L	L	L	L	M	L-M	L
Walleye	L-M	L-M	L	L	L	L-M	L-M	L-M	L	L	L	L-M
White Bass	L	L	L	L	L	L	L	L	L	L	L	L

*L (low), L-M (low-moderate), M (moderate), M-H (moderate-high), H (high)

Lepomis sunfish had higher entrainment rates for the months of April and September. In April, most of the fish were of the 2-4 and 4-6-inch size classes (45 and 52 percent, respectively). In October, 91 percent of *Lepomis* sunfish entrained were within the 4-6-inch size class. Since almost half of the sunfish collected in April were relatively small, and with consideration of swim burst speeds for juvenile fishes, the rating for April was elevated. However, since the sunfishes estimated for October are larger and likely able to navigate intake flows adequately to avoid entrainment, the entrainment potential rating was determined to be low-moderate.

While entrainment rates of darters and logperch were low throughout the year, rates were slightly elevated in April and May. However, based on the required habitat of most species in the *Etheostoma* and *Percina* genera, these taxa are not expected to be found in the vicinity of the intake and at risk of entrainment. Therefore, ratings for these months were determined to be low-medium or low.

Suckers and redhorse were another group with elevated entrainment rates, which peaked in October and November. The November data shows elevated entrainment rates reported from several facilities, however entrainment in October was primarily driven by fish within the 4 to 6-inch size class from one facility. This single report accounted for 98 percent of the estimated entrainment of 4 to 6-inch fish for that month. With this consideration and the high burst swim speeds exhibited by suckers and redhorse (Section 5.2.2), the qualitative entrainment potential rating was determined to be moderate (M).

5.2.3.3 Turbine Blade Strike Analysis

As stated previously, the historical entrainment study completed for the prior license (Appalachian 1991a) concluded that impacts due to turbine passage on the fish population in the vicinity of the Project was negligible. A new turbine blade strike analysis was performed for the Project in 2021 based on the final results of the 2020-2021 Fish Community Survey. The evaluation was performed using the most recent version available of the Turbine Blade Strike model, mean and standard deviation of fish lengths based on fish data collected during the 2020-2021 Fish Community Study, and site-specific inputs for required model parameters, as summarized in Table 5-1and Table 5-2. All outputs for turbine blade strike analyses are provided in Appendix E through H.

Turbine blade strike probabilities for entrained fish of varying sizes were estimated for each Project under the existing and proposed conditions presented in Table 5-1and Table 5-2. For the size classes evaluated, blade strike probabilities at the Buck Project ranged from 4.5 - 65.9 percent under existing conditions and 2.9 - 42.2 percent under the proposed conditions (Table 5-13). For the size classes evaluated, blade strike probabilities at the Byllesby Dam ranged from 4.5 - 66.6 percent under existing conditions and 2.8 - 41.0 percent under the proposed conditions (Table 5-13). The probability of blade strike increased with increasing fish length. The existing Francis units have estimated blade strike probability that are more than double those of the proposed Kaplan units. During the 2020-2021 Fish Community Survey, a total of 1,119 fish were collected in the Project area. The average length was 4.65 inches and 72.5 percent of fish collected were smaller than 6 inches. While larger fish theoretically have a greater potential for blade strike, they are more likely to be excluded by the trash racks. Table 5-6 summarizes fish body length to width ratios and determines the minimum length at which fish species would be excluded by the trash racks. For the larger bodied fish species such as Largemouth Bass, Walleye, White Sucker, Channel Catfish, and Common Carp that attain sizes that could be excluded by the trash racks, the minimum size of exclusion ranged from 14.5 to 18.5 inches.

Table 5-13. Turbine Blade Strike Probability by Project Configuration and Fish Length Under No Spill Operations[1]

Project Dam	Turbine Type	Fish Length Class (inches)								
		2	4	6	8	10	15	20	25	30
Existing Conditions – Francis Turbines Under No Spill Operations										
Byllesby	Existing (4 Francis Turbines)	4.5%	8.8%	13.3%	17.8%	22.1%	33.3%	44.5%	55.4%	66.6%
Buck	Existing (3 Francis Turbines)	4.5%	8.7%	13.2%	17.7%	21.9%	32.9%	44.0%	54.8%	65.9%
Proposed Conditions – Upgraded Turbines Under No Spill Operations										
Byllesby Proposed Condition	New Kaplan (Units 1, 2 & 3)	2.2%	4.3%	6.5%	8.7%	10.8%	16.3%	21.7%	27.1%	32.5%
	Existing Francis	4.5%	8.8%	13.3%	17.8%	22.1%	33.3%	44.5%	55.4%	66.6%
	Average Strike Probability[2]	2.8%	5.4%	8.2%	11.0%	13.6%	20.5%	27.4%	34.2%	41.0%
Buck Proposed Condition	New Kaplan (Units 1 & 2)	2.1%	4.0%	6.1%	8.1%	10.1%	15.2%	20.3%	25.3%	30.4%
	Existing Francis	4.5%	8.7%	13.2%	17.7%	21.9%	32.9%	44.0%	54.8%	65.9%
	Average Strike Probability[2]	2.9%	5.6%	8.4%	11.3%	14.0%	21.1%	28.2%	35.1%	42.2%

1) Assumes all flows directed to turbine units and with only minimum required bypass flows or spillage.
2) Reflects blended average strike probability for the 1 remaining Francis turbine and the 2(Buck), 3(Byllesby) proposed Kaplan turbines.

The TBSA model was also used to estimate the downstream passage survival of Walleye under a variety of spill conditions. This approach allows for the inclusion of alternate routes such as the spillway and individual turbines to be combined into an overall passage survival estimate. The percentage of Walleye that would experience blade strike, spillway mortality, or pass downstream successfully was estimated for the range of flow conditions summarized in Table 5-14 below. The TBSA tool run outputs were exported and are available for review in Appendices E through H. It is important to note, that the results of this analysis only reflect the potential outcomes for fish that pass downstream of the project and does not include fish that remain in the Project impoundments. Due to the assumed survival rate of 97 percent for spillway passage, the overall downstream passage survival rate increased with the increasing volume of spill for the range of flow percentiles evaluated. For the Byllesby project spillage first occurred at annual 4 percent exceedance and Buck at a 12 percent exceedance flow.

For Walleye the percentage of fish that would survive downstream passage ranged from 60.1 to 77.3 percent under existing conditions at the Byllesby project and 75.7 to 84.6 percent under proposed conditions For the Buck Project the percentage of walleye that would survive downstream passage ranged from 58.9 to 85.1 percent under existing conditions and 72.2 to 89.8 percent under proposed conditions.

Table 5-14. Walleye Downstream Passage Survival Estimates for Existing and Proposed Project Configurations Under Four Spill Scenarios.

Project	Turbine Configuration	Flow Exceedance %	Volume Spill (CFS)	Spill Route Selection Probability	Turbine Strike Mortalities	Spillway Mortalities	Cumulative Downstream Passage Survival
Byllesby	Existing	4	230	0.0389	39.8%	0.0%	60.1%
Byllesby	Existing	3	1128	0.1657	34.6%	0.2%	65.2%
Byllesby	Existing	2	2355	0.2931	29.2%	0.7%	70.1%
Byllesby	Existing	1	5094	0.4728	21.2%	1.6%	77.3%
Byllesby	Proposed	4	425.6	0.0720	24.2%	0.2%	75.7%
Byllesby	Proposed	3	1324.3	0.1945	21.1%	0.8%	78.1%
Byllesby	Proposed	2	2551.2	0.3175	17.6%	1.1%	81.3%
Byllesby	Proposed	1	5290.3	0.491	14.0%	1.4%	84.6%
Buck	Existing	12	123	0.0336	41.0%	0.1%	58.9%
Buck	Existing	10	421	0.1063	38.3%	0.4%	61.3%
Buck	Existing	8	816	0.1874	29.9%	0.7%	69.5%
Buck	Existing	6	1427	0.2872	30.2%	1.0%	68.8%
Buck	Existing	4	2370	0.4010	27.3%	1.2%	71.5%
Buck	Existing	2	4495	0.5594	17.0%	1.5%	81.5%
Buck	Existing	1	7234	0.6714	12.6%	2.3%	85.1%
Buck	Proposed	12	92	0.0253	27.7%	0.0%	72.2%
Buck	Proposed	10	391	0.0987	22.8%	0.4%	76.8%
Buck	Proposed	8	786	0.1805	17.9%	1.0%	81.2%
Buck	Proposed	6	1397	0.2812	20.2%	0.6%	79.1%
Buck	Proposed	4	2340	0.3959	14.5%	1.0%	84.4%
Buck	Proposed	2	4465	0.5557	10.3%	1.6%	88.2%
Buck	Proposed	1	7204	0.6687	8.3%	1.9%	89.8%

6 Summary

In summary, the primary findings of the Desktop Fish Impingement and Entrainment Study include:

The Project is in a rural area within a relatively large watershed that which has the potential to influence habitat and water quality in this portion of the New River in ways that are independent of the Project. Byllesby and Buck dams influence habitat availability in the Project area, which determines species diversity and distribution, by impounding the existing riffle and run habitats and creating the pool habitats now present in the Project reservoirs. However, results of 2020-2021 Fish Community Survey were comparable to results of historical fish community assessments performed at the Project. Further, the data demonstrate that the habitats available in the New River within the Project boundary support a relatively healthy and diverse fish community.

Based on species-specific size distributions documented in the 2020-2021 Fish Community Survey, most fish in the New River would not be impinged on the intake trash racks. However, a comparison of calculated intake approach velocities to known fish swim speeds from existing literature indicates that most juvenile and adult fish are able to avoid impingement or entrainment at the Project intakes. Intake drawings are provided in Appendix I.

Entrainment of early life stage fishes (eggs and larvae) is likely minimal given the life history characteristics of species in the vicinity of the Project and the lack of suitable habitats near the Project intakes. Susceptibility to entrainment is expected to vary depending on species and time of year; however, most target species and species groups have low entrainment potential for most of the year.

A turbine blade strike and spillway survival assessment were performed to estimate the potential survival of those few life stages of fish that would be at risk of entrainment at the Project intakes. The assessment determined that:

- Blade strike mortality is expected to increase with increasing fish size regardless of spill or no spill operations; however, most larger fish are able to avoid the intake structures and are less likely to become entrained.
- The turbine upgrades planned for completion during the next license period will result in a substantial reduction in blade strike risk (up to 25 percent at Byllesby and 23 percent at Buck) to fish that are entrained at the Project intake structures under no spill operations.
- The low head Project dams and design of the Project spillways result in high spillway survival; as such, increasing spill events reduces turbine entrainment strike mortalities. However, spill events occur infrequently at the Project developments.
- Depending on the percent flow exceedance during spill operations, the cumulative downstream passage survival (turbine and spillway passage) under the proposed conditions is expected to increase by as much as 15 percent at the Byllesby Development and 10 percent at the Buck Development.
- The cumulative downstream fish passage survival estimated to occur at the Byllesby Development after the turbine upgrades is between 82.8 and 88.8 percent of all fish, and between 82.7 and 92.4 percent of all fish at the Buck Development.

- Therefore, the findings of this study concur with the historical entrainment study completed for the prior relicensing in that impingement or entrainment effects to the fish community in the Project vicinity are expected to be minimal; and further, are expected to be even less once the proposed turbine upgrades are installed and operational.

7 Variances from FERC-approved Study Plan

The Fish Impingement and Entrainment Study was conducted in full accordance with the methods described in the RSP. As detailed in Section 4.1, per the RSP and Commission's SPD, intake velocities were to be measured using an ADCP along the upstream face of the angled trash racks to determine the approximate approach velocity immediately upstream of the intake structure. During the 2020 field season, a combination of high flow events and inoperable units prevented field data collection efforts. As a result, approach velocity was calculated using the intake structure and trash rack dimensions along with the design maximum flow capacity of the two generating units.

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Appendix A

Appendix A – Site Characteristics of Hydropower Facilities from the EPRI (1997) Database

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Table 1. Electric Power Research Institute Entrainment Database[1] Sites Used for the Byllesby-Buck Hydroelectric Project Fish Impingement and Entrainment Study

No.	Site Name	State	River	Reservoir Area (ac)	Reservoir Volume (ac-ft)	Usable Storage (ac-ft)	Fluctuation Limits (ft)	Length (mi)	Width (ft)	Total Plant Capacity (cfs)	No. Units	Operating Mode[2]	Average Velocity at Trash Rack (ft/sec)	Trash Rack Spacing (inch)
1	Belding	MI	Flat	-	-	-	-	-	-	416	2	-	-	2
2	Bond Falls	MI	W.B. Ontonagon	-	-	-	-	-	-	900	2	PK	-	3
3	Brule	WI	Brule	545	8880	530	1	5.2	340	1,377	3	PK-partial	1	1.62
4	Caldron Falls	WI	Peshtigo	1,180	-	-	-	-	-	1,300	2	PK	-	2
5	Centralia	WI	Wisconsin	250	-	-	0	2	1400	3,640	6	ROR	2.3	3.5
6	Colton	NY	Raquette	195	620	103	0.5	-	-	1,503	3	PK	-	2
7	Crowley	WI	N.F. Flambeau	422	3,539	-	1	-	-	2,400	2	ROR	1.4	2.375
8	Feeder Dam	NY	Hudson	-	-	-	-	-	-	5,000	5	PK	-	2.75
9	Four Mile Dam	MI	Thunder Bay	1,112	2,500		0.5	-	-	1,500	3	ROR	-	2
10	Grand Rapids	MI/ WI	Menominee	250	-	-	0.5	-	-	3,870	5	ROR	-	1.75
11	Herrings	NY	Black	140	-	-	-	-	-	3,610	3	ROR	-	4.125
12	High Falls - Beaver River	NY	Beaver	145	1,058	290	-	-	-	900	3	-	0.7	1.81
13	Higley	NY	Raquette	742	4,446	-	1.5	-	-	2,045	3	PK	-	3.63
14	Hillman Dam	MI	Thunder Bay	988	1,600	-	-	-	-	270	1	ROR	-	3.25
15	Johnsonville	NY	Hoosic	450	6,430	540	6.5	-	-	1,288	2	PK	-	2
16	Kleber	MI	Black	270	3,000	-	0	0.9	-	400	2	ROR	1.41	3
17	Lake Algonquin	NY	Sacandaga	-	-	-	-	-	-	750	1	-	-	1
18	Luray	VA	S.F. Shenandoah	-	-	-	-	-	-	1,477	3	ROR	-	2.75

No.	Site Name	State	River	Reservoir Area (ac)	Reservoir Volume (ac-ft)	Usable Storage (ac-ft)	Fluctuation Limits (ft)	Length (mi)	Width (ft)	Total Plant Capacity (cfs)	No. Units	Operating Mode[2]	Average Velocity at Trash Rack (ft/sec)	Trash Rack Spacing (inch)
19	Minetto	NY	Oswego	350	4,730	290	1.8	-	-	7,500	5	PULSE	2.4	2.5
20	Moshier	NY	Beaver	365	7,339	680	3	-	-	660	2	PK	-	1.5
21	Ninth Street Dam	MI	Thunder Bay	9,884	2,600	-	0.5	-	-	1,650	3	ROR	-	1
22	Norway Point Dam	MI	Thunder Bay	10,502	3,800	-	0.5	-	-	1,775	2	ROR	-	1.69
23	Potato Rapids	WI	Peshtigo	288	-	-	-	-	-	1,380	3	ROR	-	1.75
24	Raymondville	NY	Raquette	50	264	-	1	-	-	1,640	1	PK	-	2.25
25	Sandstone Rapids	WI	Peshtigo	150	-	-	-	-	-	1,300	2	PK	-	1.75
26	Schaghticoke	NY	Hoosic	164	1,150	120	6.5	-	-	1,640	4	ROR	-	2.125
27	Sherman Island	NY	Hudson	305	6,960	1,060	3.7	-	-	6,600	4	PK	-	3.125
28	Thornapple	WI	Flambeau	295	1,000	295	1.5	4	600	1,400	2	ROR-mod	1.22	1.69
29	Tower	MI	Black	102	620	-	0	0.9	-	404	2	ROR	0.82	1
30	Twin Branch	IN	St. Joseph	1,065	-	-	-	8.75	-	3,200	-	ROR	-	3
31	Warrensburg	NY	Schroon	-	-	-	-	-	-	1,350	1	-	-	-
32	White Rapids	MI/ WI	Menominee	435	5,155	415	1	2.3	580	3,994	3	PK-partial	1.9	2.5
33	Wisconsin River Division	WI	Wisconsin	240	1,120	-	0	2.5	1,000	5,150	10	ROR	1.4	2.19

[1] Electric Power Research Institute. 1997. Turbine Entrainment and Survival Database. TR-108630. Palo Alto, CA.
[2]Operating Mode: peaking (PK), pulse, or run-of-river (ROR)
Notes: ac=acre; ac-ft=acre-feet; mi=mile; cfs=cubic feet per second; ft/sec=feet per second

Appendix B

Appendix B – Life History Information for Target Fish Species and Species Groups

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Black Crappie - *Pomoxis nigromaculatus*

Black Crappie is native throughout the Great Lakes-St. Lawrence and Mississippi basins, Gulf slope, and Atlantic slope, and widely transplanted to other regions (Jenkins and Burkhead 1993). They are found in swamps, ponds, lakes, reservoirs, and slack water of low-to-moderate gradient, usually associated with vegetation or other structure such as woody debris and stumps. Young Black Crappie feed on microcrustaceans, insects, and larval fish; adults feed on fish, crustaceans, and insects.

Spawning occurs early, with nest construction beginning in March and continuing through July; however, most spawning occurs in April in Virginia (Jenkins and Burkhead 1993). Nests are excavated in shallow to moderately deep water associated with vegetation and may be crowded.

Channel Catfish - *Ictalurus punctatus*

Channel Catfish are found in lakes and larger rivers with relatively clean sand, gravel, or stone substrate, over mud flats, and seldom in dense weedy areas (VDWR 2017b). They live in deep, slow pools of swift, clear-running streams. They are often found below dams in large reservoirs.

Spawning occurs from late May through July when water temperatures reach the mid-70s (VDGIF 2017b). Channel Catfish often deposit their eggs on rocky ledges, undercut banks, hollow logs, and other underwater structures. Males guard the nest and the eggs hatch in 7 to 10 days. The fry travel in schools, which are often herded and guarded by the male.

Common Carp – *Cyprinus carpio*

Common Carp are indigenous to Asia and was first introduced to Virginia in the 1870s (Jenkins and Burkhead 1993). It is an adaptable species found in a range of habitats except for high-gradient, small coldwater streams or habitats with extreme conditions, such as hot springs or very-low pH waters. It prefers sluggish pools with vegetation and soft bottoms. It is an omnivore and will feed on aquatic and terrestrial insects, small fish, plants, and organic matter.

Spawning occurs from late March to August, and possible into September (Jenkins and Burkhead). Common Carp spawn in backwaters and sloughs, and along shorelines of impoundments over vegetation or tree roots. Eggs are adhesive and demersal.

Common Logperch – *Percina caprodes*

Common Logperch are found throughout the Ohio basin and in several drainages of the southwestern Mississippi basin (Jenkins and Burkhead 1993). In Virginia, they are in the upper Tennessee drainage in the Valley and Ridge Province, but generally not found in the Blue Ridge. This species inhabits warm streams to large rivers with moderate gradient; it can also be found in lakes and reservoirs; however, it is associated with gravels and cobble in riffles, runs, and pools. Common Logperch feed on a variety of insects and invertebrates, often by turning over stones.

Spawning occurs on sand or gravel in swift current of streams or near shores of lakes, from mid-March to mid-July (Jenkins and Burkhead 1993). It is not a territorial spawner and often forms spawning groups. Eggs are buried by the spawning act or otherwise eaten by logperches and suckers.

Johnny Darter – *Etheostoma nigrum*

The Johnny Darter is found throughout Hudson Bay, Great Lakes, Mississippi, and Mobile basins (Jenkins and Burkhead 1993). It inhabits warm, moderate-gradient creeks, streams, and rivers, and rarely in lacustrine habitats. It prefers pools and slow runs with rubble, gravel, sand, silt, or detritus substrates.

Johnny Darter spawn from mid-March to mid-May in shallow parts of streams in slow to moderate current (Jenkins and Burkhead 1993). Nests have cover consisting of shelving stones, wood, tiles and cans, or other shelf-like materials and cover. Eggs are attached in a single layer to the underside of the nesting cover and the nest is territorially defended by the male.

Largemouth Bass – *Micropterus salmoides*

Largemouth Bass are native to the Great Lakes-St. Lawrence and Mississippi basins and the Gulf and south Atlantic slopes but has been widely introduced elsewhere in North America (Jenkins and Burkhead 1993). They are found in marshes, swamps, ponds, lakes, reservoirs, creeks, and large rivers. They feed on a wide array of aquatic animals.

Largemouth Bass spawn in May and June (Jenkins and Burkhead 1993). Males fan a nest area over a variety of substrates, and guards it against intruders. They may be found in open areas or associated with various cover, such as vegetation, ledges, or woody debris.

***Lepomis* Sunfishes - *Lepomis* spp.**

Lepomis are the largest genus of the Centrarchidae. All *Lepomis* in Virginia are found in pools and backwater areas of warm, clear creeks, streams, and rivers of low to moderate gradient, as well as lakes and ponds (Jenkins and Burkhead 1993). They feed on small prey such as aquatic insects, small fish and crustaceans, and incidentally, plant material.

Spawning begins in May with nests constructed in colonially in open, shallow areas on sand and small gravel (Jenkins and Burkhead 1993). Nests are constructed in water 2 meters deep or shallower and are defended by males.

Margined Madtom – *Noturus insignis.*

Margined Madtom are indigenous to the Atlantic slope drainages, and introduced to northern drainages in New York, New Hampshire, Maryland, and Pennsylvania (Jenkins and Burkhead 1993). It is found in low and moderate-gradient areas of large creeks to large rivers, over soft and hard bottoms of pools, runs, and riffles. It feeds on a variety of aquatic invertebrates, fish and terrestrial insects. Margined Madtom spawn in May and June. They create nests underneath flat rocks in gentle runs and slow water above and below riffles.

Muskellunge – *Esox masquinongy*

Muskellunge are native from the St. Lawrence to the Great Lakes, the upper Mississippi basin and Ohio basin (Jenkins and Burkhead 1993). It is unclear as to whether Muskellunge are native to Virginia. Muskellunge are found in lakes, reservoirs, and slow-moving parts of rivers. It prefers vegetative cover and structure such as brush piles, logs, bars, and rock outcrops. It is a voracious piscivore.

Spawning begins when water is between 49 and 60°F (Jenkins and Burkhead 1993). Muskellunge move to the shallows of streams and in lakes in northern areas, usually over detritus or living vegetation.

Northern Hogsucker – *Hypentelium nigricans*

Northern Hogsucker are widespread through the Great Lakes, upper Mississippi and Ohio basins, and present in certain drainages of the Gulf and south Atlantic slopes (Jenkins and Burkhead 1993). In Virginia, it is found in many of the major drainages. It is found in a range of habitats from large creeks to small rivers in upland and montane areas with cool or warm waters and gravelly or rocky bottoms. They feed on immature aquatic insects and microcrustaceans, small mollusks, and rarely, fish eggs. Spawning occurs in April and May, when they may or may not move into streams to reproduce. Northern Hogsucker prefers to spawn in gravelly tails of pools, riffles, or runs.

Rock Bass - *Ambloplites rupestris*

Rock Bass are native only to the Tennessee and Big Sandy drainages, but has been introduced to the New and all other major Atlantic slope drainages (Jenkins and Burkhead 1993). They are found in clear, cool and warm creeks, streams, and rivers with moderate gradient, as well as pools and backwater areas. They are strongly associated with shelter and avoid areas with heavy siltation and turbidity. Rock bass are generalist feeders and will eat a variety of microcrustaceans, insects, and other invertebrates when young, shifting to larger prey as adults such as fish and crayfish.

Spawning occurs from April to July (Jenkins and Burkhead 1993). Males fan out circular nests in shallow areas with coarse sand and large gravel substrates and defend them against other males.

Smallmouth Bass/Spotted Bass - *Micropterus dolomieu/M. punctulatus*

Smallmouth Bass are native to Virginia (VDWR 2017a) and they are now abundant in most large rivers and lakes throughout the State. Smallmouth Bass prefer slow-to-moderate current and select areas of rocky shorelines. They are most active in 19°C to 22°C water and are intolerant of silty, warm, polluted water.

Spawning usually occurs from late April to early June as temperatures exceed 16°C, in water depths of 2 to 4 feet. Males build a nest in sand, gravel, or rubble where they will guard the nest and fry (VDWR 2017b). Eggs hatch between 7 and 21 days after fertilization, depending on the water temperature (Smith 1985).

Walleye – *Sander vitreus*

Walleye are native from Canada to the Great Lakes and Mississippi basin, and widely introduced outside of its indigenous range (likely including those on the Atlantic slope south of the St. Lawrence) (Jenkins and Burkhead 1993). Walleye are found in a wide variety of habitats, including rivers with low to moderate gradient, lakes and impoundments greater than 400 acres in size. Bottom types include detritus, sand, gravel, rubble, and boulder. Walleye, like Muskellunge, are voracious predators, and are known to be cannibalistic.

Walleye spawning occurs within a three-week window from March to June, soon after ice-out (Jenkins and Burkhead 1993). They congregate and migrate short distances to spawning grounds. Spawning usually occurs at night over gravel or rock substrate in shallow areas of lakes and rivers.

They rarely spawn in vegetation or flooded areas. In rivers, spawning will take place in runs and reservoir tailwaters, but also in riffles. Eggs are broadcast over the bottom where they drop into crevices.

White Bass – *Morone saxatilis*

White Bass are native to the Atlantic Slope and was introduced across the U.S. (Jenkins and Burkhead 1993). It is an anadromous schooling fish that lives in large freshwater rivers, small and large estuaries, and the ocean. While many inland reservoirs support White Bass fisheries, these populations are generally stocked as they are not able to spawn naturally. They are predatory generalists and feed on open water species such as clupeids, and to a lesser extent littoral species such as black basses or crappies.

Whitetail Shiner – *Cyprinella galactura*

Whitetail Shiner was the most common shiner collected in the 2020 Fish Community Study. Whitetail Shiner is native to Tennessee and Cumberland drainages and part of the southern Ozarks (Jenkins and Burkhead 1993). It is considered native, though possibly introduced, to other drainages on the Atlantic slope. It feeds on a diverse array of allochthonous and benthic organisms such as worms, mites, insects, larval fish, and plant material.

Whitetail Shiners spawn from late May to August in Virginia (Jenkins and Burkhead 1993). Spawning occurs in shallow moderate-current runs and adjacent pools, where eggs are typically deposited above the bottom in crevices or underside of boulders, sticks, or trash. Males are territorial.

Yellow Bullhead – *Ameiurus natalis*

The Yellow Bullhead is commonly found in in shallow, soft-bottomed warm lakes, ponds, and reservoirs or slow-moving streams with emergent vegetation. This species lays eggs in saucer-shaped depressions beside or beneath banks, tree roots, logs, in burrows or along the bottom under debris (Becker 1983). Spawning occurs in spring and early summer, with eggs hatching out in 5-10 days. Nests and compact schools of young are guarded by parents until they reach approximately 50 mm in length. Sexual maturity for this species is believed to occur at age of 2-3 years.

Appendix C

Appendix C – Mean Monthly Entrainment Rates (Fish/Hour) for Target Species/Groups at Byllesby Development

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Target Species/Group: Black Crappie

Month	0-2 in	2-4 in	4-6 in	6-8 in	8-10 in	10-15 in	15-20 in	20-25 in	25-30 in	30+ in
Jan	0.17	0.08	0.02	0.02	0.00	0.00	0.00	0.00	0.00	0.00
Feb	0.06	0.38	0.03	0.03	0.00	0.00	0.00	0.00	0.00	0.00
Mar	0.01	0.08	0.03	0.15	0.03	0.01	0.00	0.00	0.00	0.00
Apr	0.07	1.06	0.19	0.92	0.10	0.05	0.00	0.00	0.00	0.00
May	0.01	0.32	0.04	0.10	0.02	0.00	0.00	0.00	0.00	0.00
Jun	0.09	0.22	0.04	0.08	0.02	0.00	0.00	0.00	0.00	0.00
Jul	10.31	0.47	0.04	0.05	0.00	0.00	0.00	0.00	0.00	0.00
Aug	1.50	7.13	0.04	0.10	0.06	0.01	0.00	0.00	0.00	0.00
Sep	0.47	4.27	0.11	0.06	0.03	0.01	0.00	0.00	0.00	0.00
Oct	0.47	3.79	0.15	0.03	0.02	0.01	0.00	0.00	0.00	0.00
Nov	0.13	3.31	0.17	0.03	0.01	0.00	0.00	0.00	0.00	0.00
Dec	0.03	2.24	0.02	0.00	0.01	0.00	0.00	0.00	0.00	0.00
Grand Total	**13.32**	**23.33**	**0.88**	**1.57**	**0.30**	**0.10**	**0.00**	**0.00**	**0.00**	**0.00**

Target Species/Group: Bullheads and Madtoms

Month	0-2 in	2-4 in	4-6 in	6-8 in	8-10 in	10-15 in	15-20 in	20-25 in	25-30 in	30+ in
Jan	0.00	0.04	0.04	0.00	0.02	0.00	0.00	0.00	0.00	0.00
Feb	0.04	0.10	0.00	0.02	0.06	0.00	0.00	0.00	0.00	0.00
Mar	0.03	0.08	0.04	0.05	0.05	0.00	0.00	0.00	0.00	0.00
Apr	0.09	0.39	0.13	1.25	0.35	0.11	0.00	0.00	0.00	0.00
May	0.03	0.25	0.08	0.05	0.04	0.03	0.00	0.00	0.00	0.00
Jun	0.01	0.21	0.14	0.39	0.36	0.11	0.00	0.00	0.00	0.00
Jul	0.67	0.10	0.28	1.91	0.21	0.06	0.00	0.00	0.00	0.00
Aug	0.07	0.20	0.47	0.66	0.07	0.02	0.00	0.00	0.00	0.00
Sep	0.04	0.16	0.20	0.24	0.09	0.01	0.00	0.00	0.00	0.00
Oct	0.01	0.18	0.03	0.06	0.06	0.01	0.00	0.00	0.00	0.00
Nov	0.02	0.10	0.04	0.04	0.03	0.00	0.00	0.00	0.00	0.00
Dec	0.02	0.09	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.00
Grand Total	**1.04**	**1.89**	**1.46**	**4.66**	**1.33**	**0.35**	**0.01**	**0.00**	**0.00**	**0.00**

Target Species/Group: Catfishes

Month	0-2 in	2-4 in	4-6 in	6-8 in	8-10 in	10-15 in	15-20 in	20-25 in	25-30 in	30+ in
Jan	0.19	0.23	0.05	0.00	0.00	0.03	0.00	0.00	0.00	0.00
Feb	0.57	0.41	0.14	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Mar	0.20	0.26	0.04	0.23	0.01	0.00	0.00	0.00	0.00	0.00
Apr	0.05	0.57	0.31	0.07	0.04	0.02	0.00	0.00	0.00	0.00
May	0.06	23.50	1.19	0.72	2.40	0.57	0.00	0.00	0.00	0.00
Jun	0.18	10.23	1.16	2.66	4.35	0.39	0.01	0.01	0.00	0.00
Jul	12.77	6.63	0.34	0.66	0.48	0.05	0.00	0.00	0.01	0.01
Aug	4.56	1.35	0.52	0.26	0.33	0.25	0.00	0.00	0.00	0.00
Sep	0.68	0.66	0.14	0.16	0.30	0.08	0.00	0.00	0.00	0.00
Oct	0.23	0.25	0.03	0.00	0.02	0.00	0.00	0.00	0.00	0.00
Nov	0.08	0.48	0.05	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Dec	0.00	0.10	0.04	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Grand Total	**19.55**	**44.68**	**4.01**	**4.75**	**7.91**	**1.39**	**0.01**	**0.01**	**0.01**	**0.01**

Target Species/Group: Common Carp

Month	0-2 in	2-4 in	4-6 in	6-8 in	8-10 in	10-15 in	15-20 in	20-25 in	25-30 in	30+ in
Jan	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.08	0.00	0.00
Feb	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Mar	0.00	0.02	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Apr	0.00	0.02	0.05	0.00	0.00	0.00	0.00	0.00	0.00	0.00
May	0.00	0.01	0.00	0.00	0.00	0.01	0.01	0.00	0.00	0.00
Jun	0.06	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.00
Jul	0.05	0.07	0.00	0.00	0.00	0.00	0.02	0.00	0.00	0.00
Aug	0.00	0.06	0.02	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Sep	0.00	0.02	0.01	0.01	0.01	0.00	0.00	0.00	0.00	0.00
Oct	0.01	0.01	0.01	0.01	0.00	0.00	0.00	0.00	0.00	0.00
Nov	0.00	0.02	0.02	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Dec	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Grand Total	**0.12**	**0.23**	**0.11**	**0.02**	**0.01**	**0.01**	**0.03**	**0.10**	**0.00**	**0.00**

Target Species/Group: Darters and Logperch

Month	0-2 in	2-4 in	4-6 in	6-8 in	8-10 in	10-15 in	15-20 in	20-25 in	25-30 in	30+ in
Jan	0.00	0.31	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Feb	0.18	0.25	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Mar	0.09	0.24	0.03	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Apr	1.02	6.45	0.06	0.00	0.00	0.00	0.00	0.00	0.00	0.00
May	4.61	1.06	0.03	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Jun	0.49	0.69	0.02	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Jul	1.32	0.39	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Aug	0.08	0.09	0.02	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Sep	0.03	0.13	0.14	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Oct	0.02	0.20	0.07	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Nov	0.01	0.10	0.02	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Dec	0.07	0.06	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Grand Total	**7.92**	**9.96**	**0.40**	**0.00**	**0.00**	**0.01**	**0.00**	**0.00**	**0.00**	**0.00**

Target Species/Group: Largemouth Bass

Month	0-2 in	2-4 in	4-6 in	6-8 in	8-10 in	10-15 in	15-20 in	20-25 in	25-30 in	30+ in
Jan	0.00	0.33	0.09	0.00	0.00	0.00	0.02	0.00	0.00	0.00
Feb	0.00	0.18	0.06	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Mar	0.02	0.09	0.02	0.01	0.01	0.01	0.00	0.00	0.00	0.00
Apr	0.04	0.27	0.00	0.03	0.00	0.34	0.00	0.00	0.00	0.00
May	0.00	0.01	0.00	0.06	0.03	0.17	0.00	0.00	0.00	0.00
Jun	3.57	0.06	0.02	0.17	0.14	0.17	0.00	0.00	0.00	0.00
Jul	4.34	1.59	0.03	0.17	0.08	0.05	0.00	0.00	0.00	0.00
Aug	0.07	1.43	0.40	0.40	0.08	0.05	0.00	0.00	0.00	0.00
Sep	0.01	0.96	0.63	0.40	0.14	0.03	0.00	0.00	0.00	0.00
Oct	0.01	0.97	0.33	0.04	0.03	0.03	0.00	0.00	0.00	0.00
Nov	0.00	0.83	0.46	0.11	0.02	0.16	0.00	0.00	0.00	0.00
Dec	0.01	0.25	0.02	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Grand Total	**8.07**	**6.97**	**2.04**	**1.39**	**0.53**	**1.00**	**0.02**	**0.00**	**0.00**	**0.00**

Target Species/Group: *Lepomis* Sunfishes

Month	0-2 in	2-4 in	4-6 in	6-8 in	8-10 in	10-15 in	15-20 in	20-25 in	25-30 in	30+ in
Jan	0.31	0.11	0.03	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Feb	0.12	0.05	0.05	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Mar	0.06	0.05	0.44	0.05	0.00	0.00	0.00	0.00	0.00	0.00
Apr	0.23	4.06	4.65	0.06	0.00	0.00	0.00	0.00	0.00	0.00
May	0.11	2.21	0.70	0.11	0.00	0.00	0.00	0.00	0.00	0.00
Jun	0.54	0.75	1.26	0.24	0.01	0.00	0.00	0.00	0.00	0.00
Jul	0.99	0.32	1.88	0.14	0.00	0.00	0.00	0.00	0.00	0.00
Aug	0.22	0.28	4.83	0.22	0.01	0.00	0.00	0.00	0.00	0.00
Sep	0.51	0.39	11.74	0.20	0.00	0.00	0.00	0.00	0.00	0.00
Oct	0.76	1.00	6.23	0.01	0.00	0.04	0.00	0.00	0.00	0.00
Nov	0.83	0.71	0.23	0.01	0.00	0.00	0.00	0.00	0.00	0.00
Dec	0.03	0.46	0.01	0.01	0.00	0.00	0.00	0.00	0.00	0.00
Grand Total	**4.71**	**10.37**	**32.07**	**1.05**	**0.03**	**0.04**	**0.00**	**0.00**	**0.00**	**0.00**

Target Species/Group: Muskellunge

Month	0-2 in	2-4 in	4-6 in	6-8 in	8-10 in	10-15 in	15-20 in	20-25 in	25-30 in	30+ in
Jan	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Feb	0.00	0.00	0.00	0.00	0.00	0.00	0.20	0.00	0.00	0.00
Mar	0.00	0.00	0.00	0.11	0.13	0.15	0.00	0.00	0.00	0.00
Apr	0.00	0.00	0.02	0.03	0.11	0.37	0.23	0.36	0.00	0.00
May	0.00	0.02	0.01	0.02	0.04	0.02	0.00	0.00	0.00	0.00
Jun	0.03	0.14	0.07	0.01	0.07	0.01	0.01	0.00	0.00	0.00
Jul	0.01	0.13	0.45	0.28	0.03	0.03	0.00	0.00	0.00	0.00
Aug	0.00	0.00	0.11	0.16	0.03	0.01	0.00	0.00	0.00	0.00
Sep	0.00	0.00	0.01	0.01	0.00	0.06	0.15	0.00	0.00	0.00
Oct	0.00	0.00	0.01	0.01	0.01	0.06	0.15	0.00	0.00	0.00
Nov	0.00	0.00	0.01	0.03	0.00	0.13	0.00	0.00	0.00	0.00
Dec	0.00	0.00	0.00	0.00	0.00	0.07	0.00	0.07	0.00	0.00
Grand Total	**0.04**	**0.29**	**0.68**	**0.68**	**0.42**	**0.91**	**0.75**	**0.44**	**0.00**	**0.00**

Target Species/Group: Rock Bass

Month	0-2 in	2-4 in	4-6 in	6-8 in	8-10 in	10-15 in	15-20 in	20-25 in	25-30 in	30+ in
Jan	1.93	0.65	0.25	0.01	0.01	0.00	0.00	0.00	0.00	0.00
Feb	3.46	1.41	0.81	0.10	0.00	0.00	0.00	0.00	0.00	0.00
Mar	0.37	0.04	0.41	0.03	0.00	0.00	0.00	0.00	0.00	0.00
Apr	0.61	9.76	4.75	0.12	0.06	0.00	0.00	0.00	0.00	0.00
May	0.16	0.55	0.72	0.59	0.11	0.00	0.00	0.00	0.00	0.00
Jun	0.15	1.14	2.15	0.92	0.06	0.00	0.00	0.00	0.00	0.00
Jul	1.00	0.29	1.55	0.39	0.05	0.00	0.00	0.00	0.00	0.00
Aug	0.17	0.29	4.01	1.20	0.12	0.00	0.00	0.00	0.00	0.00
Sep	0.36	0.23	2.46	2.73	0.03	0.00	0.00	0.00	0.00	0.00
Oct	0.34	0.87	19.70	0.29	0.01	0.00	0.00	0.00	0.00	0.00
Nov	0.18	0.33	10.10	0.48	0.01	0.00	0.00	0.00	0.00	0.00
Dec	0.40	1.17	3.54	0.32	0.00	0.00	0.00	0.00	0.00	0.00
Grand Total	**9.13**	**16.72**	**50.44**	**7.18**	**0.45**	**0.01**	**0.00**	**0.00**	**0.00**	**0.00**

Target Species/Group: Shiners, Chubs, and Minnows

Month	0-2 in	2-4 in	4-6 in	6-8 in	8-10 in	10-15 in	15-20 in	20-25 in	25-30 in	30+ in
Jan	0.02	0.61	0.15	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Feb	0.05	1.37	0.36	0.08	0.07	0.00	0.00	0.00	0.00	0.00
Mar	0.04	0.83	0.03	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Apr	0.56	1.09	0.23	0.02	0.00	0.00	0.00	0.00	0.00	0.00
May	0.34	0.79	0.08	0.01	0.00	0.01	0.00	0.00	0.00	0.00
Jun	0.28	0.59	0.06	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Jul	0.84	1.25	0.06	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Aug	0.23	0.81	0.02	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Sep	0.22	1.46	0.04	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Oct	0.08	1.11	0.09	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Nov	0.06	1.35	0.06	0.02	0.00	0.00	0.00	0.00	0.00	0.00
Dec	0.02	0.30	0.04	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Grand Total	**2.76**	**11.56**	**1.23**	**0.14**	**0.07**	**0.01**	**0.00**	**0.00**	**0.00**	**0.00**

Target Species/Group: Smallmouth Bass

Month	0-2 in	2-4 in	4-6 in	6-8 in	8-10 in	10-15 in	15-20 in	20-25 in	25-30 in	30+ in
Jan	0.11	0.01	0.00	0.06	0.00	0.00	0.00	0.00	0.00	0.00
Feb	0.00	0.05	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Mar	0.00	0.07	0.03	0.01	0.00	0.00	0.00	0.00	0.00	0.00
Apr	0.00	0.04	0.00	0.00	0.00	0.07	0.01	0.00	0.00	0.00
May	0.00	0.01	0.00	0.01	0.03	0.13	0.03	0.00	0.00	0.00
Jun	0.40	0.23	0.01	0.03	0.04	0.07	0.01	0.00	0.00	0.00
Jul	2.31	0.24	0.04	0.03	0.02	0.02	0.00	0.00	0.00	0.00
Aug	0.24	0.34	0.14	0.09	0.05	0.07	0.00	0.00	0.00	0.00
Sep	0.04	1.19	0.72	0.28	0.07	0.03	0.00	0.00	0.00	0.00
Oct	0.05	0.55	0.18	0.04	0.02	0.04	0.00	0.00	0.00	0.00
Nov	0.00	0.10	0.07	0.01	0.00	0.01	0.00	0.00	0.00	0.00
Dec	0.04	0.06	0.04	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Grand Total	**3.20**	**2.90**	**1.24**	**0.57**	**0.22**	**0.44**	**0.04**	**0.00**	**0.00**	**0.00**

Target Species/Group: Suckers and Redhorse

Month	0-2 in	2-4 in	4-6 in	6-8 in	8-10 in	10-15 in	15-20 in	20-25 in	25-30 in	30+ in
Jan	0.04	0.87	1.55	1.18	0.74	0.52	0.00	0.00	0.00	0.00
Feb	0.05	0.55	1.39	0.98	0.11	0.00	0.02	0.00	0.00	0.00
Mar	0.05	0.21	0.75	0.64	0.06	0.06	0.00	0.00	0.00	0.00
Apr	0.19	1.02	0.45	0.31	0.40	1.22	0.36	0.00	0.00	0.00
May	0.02	0.15	0.04	0.03	0.06	0.14	0.02	0.00	0.00	0.00
Jun	2.37	0.35	0.05	0.02	0.01	0.05	0.01	0.00	0.00	0.00
Jul	3.69	0.43	0.07	0.02	0.01	0.04	0.01	0.00	0.00	0.00
Aug	0.28	0.09	0.02	0.01	0.02	0.01	0.01	0.00	0.00	0.00
Sep	0.03	0.16	0.05	0.06	0.03	0.08	0.00	0.00	0.00	0.00
Oct	0.02	0.30	16.45	0.82	1.06	0.25	0.08	0.00	0.00	0.00
Nov	0.01	0.23	0.43	3.71	2.37	0.22	0.00	0.00	0.00	0.00
Dec	0.05	0.09	0.48	2.47	0.67	0.01	0.00	0.00	0.00	0.00
Grand Total	**6.79**	**4.43**	**21.75**	**10.23**	**5.54**	**2.60**	**0.51**	**0.00**	**0.00**	**0.00**

Target Species/Group: Walleye

Month	0-2 in	2-4 in	4-6 in	6-8 in	8-10 in	10-15 in	15-20 in	20-25 in	25-30 in	30+ in
Jan	0.11	0.01	0.03	0.11	1.13	0.39	0.00	0.00	0.00	0.00
Feb	0.00	0.05	0.15	0.03	0.00	0.00	0.00	0.00	0.00	0.00
Mar	0.00	0.00	0.02	0.00	0.00	0.01	0.00	0.00	0.00	0.00
Apr	0.00	0.00	0.04	0.04	0.05	0.12	0.01	0.00	0.00	0.00
May	0.00	0.01	0.07	0.27	0.17	0.31	0.01	0.00	0.00	0.00
Jun	2.14	0.61	0.02	0.15	0.11	0.19	0.01	0.00	0.00	0.00
Jul	0.39	3.92	0.27	0.06	0.06	0.08	0.06	0.00	0.00	0.00
Aug	0.01	0.28	0.48	0.07	0.06	0.13	0.00	0.00	0.00	0.00
Sep	0.01	0.15	0.41	0.16	0.08	0.05	0.02	0.01	0.00	0.00
Oct	0.00	0.02	0.19	0.29	0.12	0.16	0.01	0.00	0.00	0.00
Nov	0.00	0.03	0.05	0.05	0.02	0.04	0.02	0.00	0.00	0.00
Dec	0.00	0.00	0.07	0.03	0.00	0.00	0.00	0.00	0.00	0.00
Grand Total	**2.67**	**5.10**	**1.79**	**1.26**	**1.80**	**1.47**	**0.13**	**0.01**	**0.00**	**0.00**

Target Species/Group: White Bass

Month	0-2 in	2-4 in	4-6 in	6-8 in	8-10 in	10-15 in	15-20 in	20-25 in	25-30 in	30+ in
Jan	0.00	0.10	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Feb	0.00	0.09	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Mar	0.01	0.81	0.08	0.15	0.03	0.01	0.00	0.00	0.00	0.00
Apr	0.01	0.22	0.02	0.07	0.02	0.00	0.00	0.00	0.00	0.00
May	0.00	1.55	0.09	0.25	0.23	0.05	0.00	0.00	0.00	0.00
Jun	0.00	0.01	0.01	0.13	0.05	0.01	0.00	0.00	0.00	0.00
Jul	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.00
Aug	0.00	0.04	0.00	0.01	0.01	0.00	0.00	0.00	0.00	0.00
Sep	0.00	0.01	0.11	0.02	0.00	0.00	0.00	0.00	0.00	0.00
Oct	0.00	0.04	0.11	0.01	0.00	0.00	0.00	0.00	0.00	0.00
Nov	0.00	0.08	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Dec	0.00	0.09	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Grand Total	**0.02**	**3.04**	**0.43**	**0.62**	**0.35**	**0.07**	**0.00**	**0.00**	**0.00**	**0.00**

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Appendix D

Appendix D – Mean Monthly Entrainment Rates (Fish/Hour) for Target Species/Groups at Buck Development

Target Species/Group: Black Crappie

Month	0-2 in	2-4 in	4-6 in	6-8 in	8-10 in	10-15 in	15-20 in	20-25 in	25-30 in	30+ in
Jan	0.10	0.05	0.01	0.01	0.00	0.00	0.00	0.00	0.00	0.00
Feb	0.04	0.23	0.02	0.02	0.00	0.00	0.00	0.00	0.00	0.00
Mar	0.01	0.05	0.02	0.09	0.02	0.01	0.00	0.00	0.00	0.00
Apr	0.04	0.64	0.11	0.55	0.06	0.03	0.00	0.00	0.00	0.00
May	0.01	0.19	0.02	0.06	0.01	0.00	0.00	0.00	0.00	0.00
Jun	0.06	0.13	0.02	0.05	0.01	0.00	0.00	0.00	0.00	0.00
Jul	6.22	0.29	0.02	0.03	0.00	0.00	0.00	0.00	0.00	0.00
Aug	0.91	4.30	0.02	0.06	0.04	0.00	0.00	0.00	0.00	0.00
Sep	0.28	2.57	0.07	0.04	0.02	0.01	0.00	0.00	0.00	0.00
Oct	0.28	2.29	0.09	0.02	0.01	0.00	0.00	0.00	0.00	0.00
Nov	0.08	2.00	0.10	0.02	0.01	0.00	0.00	0.00	0.00	0.00
Dec	0.02	1.35	0.01	0.00	0.01	0.00	0.00	0.00	0.00	0.00
Grand Total	**8.04**	**14.08**	**0.53**	**0.95**	**0.18**	**0.06**	**0.00**	**0.00**	**0.00**	**0.00**

Target Species/Group: Bullheads and Madtoms

Month	0-2 in	2-4 in	4-6 in	6-8 in	8-10 in	10-15 in	15-20 in	20-25 in	25-30 in	30+ in
Jan	0.00	0.02	0.03	0.00	0.01	0.00	0.00	0.00	0.00	0.00
Feb	0.02	0.06	0.00	0.01	0.04	0.00	0.00	0.00	0.00	0.00
Mar	0.02	0.05	0.02	0.03	0.03	0.00	0.00	0.00	0.00	0.00
Apr	0.06	0.24	0.08	0.75	0.21	0.07	0.00	0.00	0.00	0.00
May	0.02	0.15	0.05	0.03	0.02	0.02	0.00	0.00	0.00	0.00
Jun	0.01	0.13	0.08	0.23	0.22	0.07	0.00	0.00	0.00	0.00
Jul	0.40	0.06	0.17	1.15	0.13	0.04	0.00	0.00	0.00	0.00
Aug	0.04	0.12	0.29	0.40	0.04	0.01	0.00	0.00	0.00	0.00
Sep	0.03	0.10	0.12	0.14	0.05	0.00	0.00	0.00	0.00	0.00
Oct	0.01	0.11	0.02	0.04	0.04	0.01	0.00	0.00	0.00	0.00
Nov	0.01	0.06	0.03	0.03	0.02	0.00	0.00	0.00	0.00	0.00
Dec	0.01	0.05	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.00
Grand Total	**0.63**	**1.14**	**0.88**	**2.81**	**0.80**	**0.21**	**0.01**	**0.00**	**0.00**	**0.00**

Target Species/Group: Catfishes

Month	0-2 in	2-4 in	4-6 in	6-8 in	8-10 in	10-15 in	15-20 in	20-25 in	25-30 in	30+ in
Jan	0.11	0.14	0.03	0.00	0.00	0.02	0.00	0.00	0.00	0.00
Feb	0.34	0.25	0.08	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Mar	0.12	0.16	0.02	0.14	0.01	0.00	0.00	0.00	0.00	0.00
Apr	0.03	0.34	0.19	0.04	0.02	0.01	0.00	0.00	0.00	0.00
May	0.04	14.17	0.72	0.44	1.45	0.34	0.00	0.00	0.00	0.00
Jun	0.11	6.17	0.70	1.60	2.62	0.23	0.00	0.00	0.00	0.00
Jul	7.70	4.00	0.20	0.40	0.29	0.03	0.00	0.00	0.00	0.00
Aug	2.75	0.82	0.31	0.15	0.20	0.15	0.00	0.00	0.00	0.00
Sep	0.41	0.40	0.08	0.09	0.18	0.05	0.00	0.00	0.00	0.00
Oct	0.14	0.15	0.02	0.00	0.01	0.00	0.00	0.00	0.00	0.00
Nov	0.05	0.29	0.03	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Dec	0.00	0.06	0.03	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Grand Total	**11.79**	**26.95**	**2.42**	**2.87**	**4.77**	**0.84**	**0.01**	**0.00**	**0.00**	**0.00**

Target Species/Group: Common Carp

Month	0-2 in	2-4 in	4-6 in	6-8 in	8-10 in	10-15 in	15-20 in	20-25 in	25-30 in	30+ in
Jan	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.05	0.00	0.00
Feb	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Mar	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Apr	0.00	0.01	0.03	0.00	0.00	0.00	0.00	0.00	0.00	0.00
May	0.00	0.01	0.00	0.00	0.00	0.01	0.01	0.00	0.00	0.00
Jun	0.04	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.00
Jul	0.03	0.05	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.00
Aug	0.00	0.04	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Sep	0.00	0.01	0.01	0.01	0.00	0.00	0.00	0.00	0.00	0.00
Oct	0.00	0.01	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Nov	0.00	0.01	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Dec	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Grand Total	**0.07**	**0.14**	**0.07**	**0.01**	**0.01**	**0.01**	**0.02**	**0.06**	**0.00**	**0.00**

Target Species/Group: Darters and Logperch

Month	0-2 in	2-4 in	4-6 in	6-8 in	8-10 in	10-15 in	15-20 in	20-25 in	25-30 in	30+ in
Jan	0.00	0.18	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Feb	0.11	0.15	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Mar	0.05	0.14	0.02	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Apr	0.62	3.89	0.04	0.00	0.00	0.00	0.00	0.00	0.00	0.00
May	2.78	0.64	0.02	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Jun	0.29	0.42	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Jul	0.80	0.24	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Aug	0.05	0.05	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Sep	0.02	0.08	0.09	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Oct	0.01	0.12	0.04	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Nov	0.00	0.06	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Dec	0.04	0.03	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Grand Total	**4.78**	**6.01**	**0.24**	**0.00**	**0.00**	**0.01**	**0.00**	**0.00**	**0.00**	**0.00**

Target Species/Group: Largemouth Bass

Month	0-2 in	2-4 in	4-6 in	6-8 in	8-10 in	10-15 in	15-20 in	20-25 in	25-30 in	30+ in
Jan	0.00	0.20	0.05	0.00	0.00	0.00	0.01	0.00	0.00	0.00
Feb	0.00	0.11	0.03	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Mar	0.01	0.06	0.01	0.01	0.00	0.00	0.00	0.00	0.00	0.00
Apr	0.02	0.16	0.00	0.02	0.00	0.21	0.00	0.00	0.00	0.00
May	0.00	0.00	0.00	0.04	0.02	0.10	0.00	0.00	0.00	0.00
Jun	2.15	0.04	0.01	0.10	0.09	0.10	0.00	0.00	0.00	0.00
Jul	2.62	0.96	0.02	0.10	0.05	0.03	0.00	0.00	0.00	0.00
Aug	0.04	0.86	0.24	0.24	0.05	0.03	0.00	0.00	0.00	0.00
Sep	0.01	0.58	0.38	0.24	0.09	0.02	0.00	0.00	0.00	0.00
Oct	0.01	0.58	0.20	0.02	0.02	0.02	0.00	0.00	0.00	0.00
Nov	0.00	0.50	0.27	0.07	0.01	0.09	0.00	0.00	0.00	0.00
Dec	0.01	0.15	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Grand Total	**4.87**	**4.20**	**1.23**	**0.84**	**0.32**	**0.60**	**0.01**	**0.00**	**0.00**	**0.00**

Target Species/Group: *Lepomis* Sunfishes

Month	0-2 in	2-4 in	4-6 in	6-8 in	8-10 in	10-15 in	15-20 in	20-25 in	25-30 in	30+ in
Jan	0.19	0.07	0.02	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Feb	0.07	0.03	0.03	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Mar	0.04	0.03	0.27	0.03	0.00	0.00	0.00	0.00	0.00	0.00
Apr	0.14	2.45	2.81	0.04	0.00	0.00	0.00	0.00	0.00	0.00
May	0.07	1.33	0.42	0.06	0.00	0.00	0.00	0.00	0.00	0.00
Jun	0.33	0.45	0.76	0.15	0.01	0.00	0.00	0.00	0.00	0.00
Jul	0.60	0.20	1.13	0.09	0.00	0.00	0.00	0.00	0.00	0.00
Aug	0.14	0.17	2.92	0.13	0.00	0.00	0.00	0.00	0.00	0.00
Sep	0.31	0.23	7.09	0.12	0.00	0.00	0.00	0.00	0.00	0.00
Oct	0.46	0.60	3.76	0.01	0.00	0.02	0.00	0.00	0.00	0.00
Nov	0.50	0.43	0.14	0.01	0.00	0.00	0.00	0.00	0.00	0.00
Dec	0.02	0.28	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Grand Total	**2.84**	**6.25**	**19.34**	**0.63**	**0.02**	**0.02**	**0.00**	**0.00**	**0.00**	**0.00**

Target Species/Group: Logperch

Month	0-2 in	2-4 in	4-6 in	6-8 in	8-10 in	10-15 in	15-20 in	20-25 in	25-30 in	30+ in
Jan	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Feb	0.00	0.48	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Mar	0.00	0.66	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Apr	0.00	4.45	0.08	0.00	0.00	0.01	0.00	0.00	0.00	0.00
May	0.09	0.61	0.04	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Jun	0.05	0.70	0.03	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Jul	1.42	0.40	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Aug	0.04	0.06	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Sep	0.01	0.12	0.16	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Oct	0.00	0.11	0.06	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Nov	0.01	0.04	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Dec	0.17	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Grand Total	**1.79**	**7.63**	**0.40**	**0.00**	**0.00**	**0.01**	**0.00**	**0.00**	**0.00**	**0.00**

Target Species/Group: Muskellunge

Month	0-2 in	2-4 in	4-6 in	6-8 in	8-10 in	10-15 in	15-20 in	20-25 in	25-30 in	30+ in
Jan	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Feb	0.00	0.00	0.00	0.00	0.00	0.00	0.12	0.00	0.00	0.00
Mar	0.00	0.00	0.00	0.07	0.08	0.09	0.00	0.00	0.00	0.00
Apr	0.00	0.00	0.01	0.02	0.07	0.22	0.14	0.22	0.00	0.00
May	0.00	0.01	0.00	0.01	0.03	0.01	0.00	0.00	0.00	0.00
Jun	0.02	0.08	0.04	0.01	0.04	0.01	0.00	0.00	0.00	0.00
Jul	0.01	0.08	0.27	0.17	0.02	0.02	0.00	0.00	0.00	0.00
Aug	0.00	0.00	0.07	0.10	0.02	0.01	0.00	0.00	0.00	0.00
Sep	0.00	0.00	0.00	0.01	0.00	0.03	0.09	0.00	0.00	0.00
Oct	0.00	0.00	0.00	0.01	0.01	0.04	0.09	0.00	0.00	0.00
Nov	0.00	0.00	0.01	0.02	0.00	0.08	0.00	0.00	0.00	0.00
Dec	0.00	0.00	0.00	0.00	0.00	0.04	0.00	0.04	0.00	0.00
Grand Total	**0.02**	**0.18**	**0.41**	**0.41**	**0.25**	**0.55**	**0.45**	**0.27**	**0.00**	**0.00**

Target Species/Group: Rock Bass

Month	0-2 in	2-4 in	4-6 in	6-8 in	8-10 in	10-15 in	15-20 in	20-25 in	25-30 in	30+ in
Jan	1.17	0.39	0.15	0.01	0.01	0.00	0.00	0.00	0.00	0.00
Feb	2.09	0.85	0.49	0.06	0.00	0.00	0.00	0.00	0.00	0.00
Mar	0.22	0.02	0.25	0.02	0.00	0.00	0.00	0.00	0.00	0.00
Apr	0.37	5.89	2.86	0.07	0.04	0.00	0.00	0.00	0.00	0.00
May	0.10	0.33	0.43	0.36	0.06	0.00	0.00	0.00	0.00	0.00
Jun	0.09	0.69	1.30	0.55	0.04	0.00	0.00	0.00	0.00	0.00
Jul	0.60	0.17	0.93	0.24	0.03	0.00	0.00	0.00	0.00	0.00
Aug	0.10	0.18	2.42	0.72	0.07	0.00	0.00	0.00	0.00	0.00
Sep	0.21	0.14	1.48	1.64	0.02	0.00	0.00	0.00	0.00	0.00
Oct	0.20	0.53	11.88	0.18	0.01	0.00	0.00	0.00	0.00	0.00
Nov	0.11	0.20	6.09	0.29	0.00	0.00	0.00	0.00	0.00	0.00
Dec	0.24	0.71	2.14	0.19	0.00	0.00	0.00	0.00	0.00	0.00
Grand Total	**5.51**	**10.09**	**30.43**	**4.33**	**0.27**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**

Target Species/Group: Shiners, Chubs, and Minnows

Month	0-2 in	2-4 in	4-6 in	6-8 in	8-10 in	10-15 in	15-20 in	20-25 in	25-30 in	30+ in
Jan	0.01	0.37	0.09	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Feb	0.03	0.83	0.21	0.05	0.04	0.00	0.00	0.00	0.00	0.00
Mar	0.03	0.50	0.02	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Apr	0.34	0.65	0.14	0.01	0.00	0.00	0.00	0.00	0.00	0.00
May	0.21	0.48	0.05	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Jun	0.17	0.36	0.04	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Jul	0.51	0.75	0.04	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Aug	0.14	0.49	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Sep	0.13	0.88	0.02	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Oct	0.05	0.67	0.06	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Nov	0.04	0.81	0.04	0.01	0.00	0.00	0.00	0.00	0.00	0.00
Dec	0.01	0.18	0.03	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Grand Total	**1.66**	**6.97**	**0.74**	**0.09**	**0.04**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**

Target Species/Group: Smallmouth Bass

Month	0-2 in	2-4 in	4-6 in	6-8 in	8-10 in	10-15 in	15-20 in	20-25 in	25-30 in	30+ in
Jan	0.06	0.00	0.00	0.04	0.00	0.00	0.00	0.00	0.00	0.00
Feb	0.00	0.03	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Mar	0.00	0.05	0.02	0.01	0.00	0.00	0.00	0.00	0.00	0.00
Apr	0.00	0.03	0.00	0.00	0.00	0.04	0.00	0.00	0.00	0.00
May	0.00	0.01	0.00	0.00	0.02	0.08	0.02	0.00	0.00	0.00
Jun	0.24	0.14	0.01	0.02	0.02	0.04	0.00	0.00	0.00	0.00
Jul	1.40	0.14	0.03	0.02	0.01	0.01	0.00	0.00	0.00	0.00
Aug	0.15	0.21	0.08	0.05	0.03	0.04	0.00	0.00	0.00	0.00
Sep	0.02	0.72	0.43	0.17	0.04	0.02	0.00	0.00	0.00	0.00
Oct	0.03	0.33	0.11	0.03	0.01	0.02	0.00	0.00	0.00	0.00
Nov	0.00	0.06	0.04	0.01	0.00	0.01	0.00	0.00	0.00	0.00
Dec	0.03	0.03	0.03	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Grand Total	**1.93**	**1.75**	**0.75**	**0.34**	**0.13**	**0.27**	**0.03**	**0.00**	**0.00**	**0.00**

Target Species/Group: Suckers and Redhorse

Month	0-2 in	2-4 in	4-6 in	6-8 in	8-10 in	10-15 in	15-20 in	20-25 in	25-30 in	30+ in
Jan	0.02	0.53	0.94	0.71	0.45	0.31	0.00	0.00	0.00	0.00
Feb	0.03	0.33	0.84	0.59	0.07	0.00	0.01	0.00	0.00	0.00
Mar	0.03	0.13	0.45	0.38	0.03	0.04	0.00	0.00	0.00	0.00
Apr	0.11	0.61	0.27	0.19	0.24	0.73	0.22	0.00	0.00	0.00
May	0.01	0.09	0.03	0.02	0.04	0.08	0.02	0.00	0.00	0.00
Jun	1.43	0.21	0.03	0.01	0.01	0.03	0.01	0.00	0.00	0.00
Jul	2.23	0.26	0.04	0.01	0.01	0.03	0.00	0.00	0.00	0.00
Aug	0.17	0.05	0.01	0.00	0.01	0.00	0.00	0.00	0.00	0.00
Sep	0.02	0.09	0.03	0.03	0.02	0.05	0.00	0.00	0.00	0.00
Oct	0.01	0.18	9.92	0.50	0.64	0.15	0.05	0.00	0.00	0.00
Nov	0.01	0.14	0.26	2.24	1.43	0.13	0.00	0.00	0.00	0.00
Dec	0.03	0.05	0.29	1.49	0.40	0.01	0.00	0.00	0.00	0.00
Grand Total	**4.10**	**2.67**	**13.12**	**6.17**	**3.34**	**1.57**	**0.31**	**0.00**	**0.00**	**0.00**

Target Species/Group: Walleye

Month	0-2 in	2-4 in	4-6 in	6-8 in	8-10 in	10-15 in	15-20 in	20-25 in	25-30 in	30+ in
Jan	0.07	0.01	0.02	0.07	0.68	0.23	0.00	0.00	0.00	0.00
Feb	0.00	0.03	0.09	0.02	0.00	0.00	0.00	0.00	0.00	0.00
Mar	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Apr	0.00	0.00	0.02	0.03	0.03	0.07	0.01	0.00	0.00	0.00
May	0.00	0.01	0.04	0.16	0.10	0.19	0.00	0.00	0.00	0.00
Jun	1.29	0.37	0.01	0.09	0.07	0.12	0.01	0.00	0.00	0.00
Jul	0.23	2.37	0.16	0.03	0.03	0.05	0.04	0.00	0.00	0.00
Aug	0.01	0.17	0.29	0.04	0.04	0.08	0.00	0.00	0.00	0.00
Sep	0.01	0.09	0.25	0.10	0.05	0.03	0.01	0.01	0.00	0.00
Oct	0.00	0.01	0.12	0.18	0.08	0.09	0.00	0.00	0.00	0.00
Nov	0.00	0.02	0.03	0.03	0.01	0.02	0.01	0.00	0.00	0.00
Dec	0.00	0.00	0.04	0.02	0.00	0.00	0.00	0.00	0.00	0.00
Grand Total	**1.61**	**3.08**	**1.08**	**0.76**	**1.09**	**0.89**	**0.08**	**0.01**	**0.00**	**0.00**

Target Species/Group: White Bass

Month	0-2 in	2-4 in	4-6 in	6-8 in	8-10 in	10-15 in	15-20 in	20-25 in	25-30 in	30+ in
Jan	0.00	0.06	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Feb	0.00	0.06	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Mar	0.00	0.49	0.05	0.09	0.02	0.00	0.00	0.00	0.00	0.00
Apr	0.01	0.14	0.01	0.04	0.01	0.00	0.00	0.00	0.00	0.00
May	0.00	0.93	0.05	0.15	0.14	0.03	0.00	0.00	0.00	0.00
Jun	0.00	0.00	0.01	0.08	0.03	0.01	0.00	0.00	0.00	0.00
Jul	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Aug	0.00	0.02	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.00
Sep	0.00	0.00	0.07	0.01	0.00	0.00	0.00	0.00	0.00	0.00
Oct	0.00	0.02	0.06	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Nov	0.00	0.05	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Dec	0.00	0.05	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Grand Total	**0.01**	**1.83**	**0.26**	**0.38**	**0.21**	**0.04**	**0.00**	**0.00**	**0.00**	**0.00**

Appendix E

Appendix E – USFWS Turbine Blade Strike Analysis Model Outputs for Byllesby Development – Existing Operations without Spill and with Varying Amounts of Spill for Walleye

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Byllesby-Buck Hydroelectric Project, FERC Project No. 2514 ARCHIVED RUN .N5000-L2-S96 10/28/2021
Byllesby Development Existing , New River, Galax, Virginia KESTLER
Release 201209

ROUTE SELECTION				TURBINE DATA													BYPASS
					D	N	B	Q	Q_{OPT}/Q	H	ω	ζ	λ	D_1	D_2	η	P_B
Route Name	Route Selection Prob.	Prob. Lower Bound	Calc. Type	Route Type	Runner Dia. (ft)	Blades (#)	Runner Height (ft)	Turbine Discharge (cfs)	Discharge at Opt. Eff. (%)	Net. Head (ft)	Speed (rpm)	Swirl Coeff. (-)	Correlation Coeff. (-)	Runner Dia. at Inlet (ft)	Runner Dia. at Disch. (ft)	Turbine Eff. (-)	Estimated Mortality (-)
Unit 1	0.250	0.000	1	Francis	7.52	16	3.06	1,467	79.0%	56.0	116.0	1.10	0.20	8.8	9.8	0.89	
Unit 2	0.250	0.250	1	Francis	7.52	16	3.06	1,467	79.0%	56.0	116.0	1.10	0.20	8.8	9.8	0.89	
Unit 3	0.250	0.500	1	Francis	7.52	16	3.06	1,467	79.0%	56.0	116.0	1.10	0.20	8.8	9.8	0.89	
Unit 4	0.250	0.750	1	Francis	7.52	16	3.06	1,467	79.0%	56.0	116.0	1.10	0.20	8.8	9.8	0.89	

MODEL SIMULATION INPUT PARAMETERS		
n_f	5,000	Number of fish
μ	2.0	Mean length (inches)
σ	0.0	SD in length (inches)

BLADE STRIKE SIMULATION RESULTS		
Turbine Strikes:	224 of 5000 fish	4.5%
Bypass Failures:	0 of 5000 fish	0.0%
Passed:	4776 of 5000 fish	95.5%

Byllesby-Buck Hydroelectric Project, FERC Project No. 2514 ARCHIVED RUN .N5000-L4-S92 10/28/2021
Byllesby Development Existing , New River, Galax, Virginia KESTLER
Release 201209

ROUTE SELECTION				TURBINE DATA													BYPASS
					D	N	B	Q	Q_{OPT}/Q	H	ω	ζ	λ	D_1	D_2	η	P_B
Route Name	Route Selection Prob.	Prob. Lower Bound	Calc. Type	Route Type	Runner Dia. (ft)	Blades (#)	Runner Height (ft)	Turbine Discharge (cfs)	Discharge at Opt. Eff. (%)	Net. Head (ft)	Speed (rpm)	Swirl Coeff. (-)	Correlation Coeff. (-)	Runner Dia. at Inlet (ft)	Runner Dia. at Disch. (ft)	Turbine Eff. (-)	Estimated Mortality (-)
Unit 1	0.250	0.000	1	Francis	7.52	16	3.06	1,467	79.0%	56.0	116.0	1.10	0.20	8.8	9.8	0.89	
Unit 2	0.250	0.250	1	Francis	7.52	16	3.06	1,467	79.0%	56.0	116.0	1.10	0.20	8.8	9.8	0.89	
Unit 3	0.250	0.500	1	Francis	7.52	16	3.06	1,467	79.0%	56.0	116.0	1.10	0.20	8.8	9.8	0.89	
Unit 4	0.250	0.750	1	Francis	7.52	16	3.06	1,467	79.0%	56.0	116.0	1.10	0.20	8.8	9.8	0.89	

MODEL SIMULATION INPUT PARAMETERS		
n_f	5,000	Number of fish
μ	4.0	Mean length (inches)
σ	0.0	SD in length (inches)

BLADE STRIKE SIMULATION RESULTS		
Turbine Strikes:	401 of 5000 fish	8.0%
Bypass Failures:	0 of 5000 fish	0.0%
Passed:	4599 of 5000 fish	92.0%

Byllesby-Buck Hydroelectric Project, FERC Project No. 2514 ARCHIVED RUN .N5000-L6-S86 10/28/2021
Byllesby Development Existing , New River, Galax, Virginia KESTLER
Release 201209

ROUTE SELECTION				TURBINE DATA													BYPASS
					D	N	B	Q	Q_{OPT}/Q	H	ω	ζ	λ	D_1	D_2	η	P_B
Route Name	Route Selection Prob.	Prob. Lower Bound	Calc. Type	Route Type	Runner Dia. (ft)	Blades (#)	Runner Height (ft)	Turbine Discharge (cfs)	Discharge at Opt. Eff. (%)	Net. Head (ft)	Speed (rpm)	Swirl Coeff. (-)	Correlation Coeff. (-)	Runner Dia. at Inlet (ft)	Runner Dia. at Disch. (ft)	Turbine Eff. (-)	Estimated Mortality (-)
Unit 1	0.250	0.000	1	Francis	7.52	16	3.06	1,467	79.0%	56.0	116.0	1.10	0.20	8.8	9.8	0.89	
Unit 2	0.250	0.250	1	Francis	7.52	16	3.06	1,467	79.0%	56.0	116.0	1.10	0.20	8.8	9.8	0.89	
Unit 3	0.250	0.500	1	Francis	7.52	16	3.06	1,467	79.0%	56.0	116.0	1.10	0.20	8.8	9.8	0.89	
Unit 4	0.250	0.750	1	Francis	7.52	16	3.06	1,467	79.0%	56.0	116.0	1.10	0.20	8.8	9.8	0.89	

MODEL SIMULATION INPUT PARAMETERS		
n_f	5,000	Number of fish
μ	6.0	Mean length (inches)
σ	0.0	SD in length (inches)

BLADE STRIKE SIMULATION RESULTS		
Turbine Strikes:	694 of 5000 fish	13.9%
Bypass Failures:	0 of 5000 fish	0.0%
Passed:	4306 of 5000 fish	86.1%

Byllesby-Buck Hydroelectric Project, FERC Project No. 2514 ARCHIVED RUN .N5000-L8-S83 10/28/2021
Byllesby Development Existing , New River, Galax, Virginia KESTLER
Release 201209

ROUTE SELECTION				TURBINE DATA													BYPASS
Route Name	Route Selection Prob.	Prob. Lower Bound	Calc. Type	Route Type	D Runner Dia. (ft)	N Blades (#)	B Runner Height (ft)	Q Turbine Discharge (cfs)	Q_{OPT}/Q Discharge at Opt. Eff. (%)	H Net. Head (ft)	ω Speed (rpm)	ζ Swirl Coeff. (-)	λ Correlation Coeff. (-)	D_1 Runner Dia. at Inlet (ft)	D_2 Runner Dia. at Disch. (ft)	η Turbine Eff. (-)	P_B Estimated Mortality (-)
Unit 1	0.250	0.000	1	Francis	7.52	16	3.06	1,467	79.0%	56.0	116.0	1.10	0.20	8.8	9.8	0.89	
Unit 2	0.250	0.250	1	Francis	7.52	16	3.06	1,467	79.0%	56.0	116.0	1.10	0.20	8.8	9.8	0.89	
Unit 3	0.250	0.500	1	Francis	7.52	16	3.06	1,467	79.0%	56.0	116.0	1.10	0.20	8.8	9.8	0.89	
Unit 4	0.250	0.750	1	Francis	7.52	16	3.06	1,467	79.0%	56.0	116.0	1.10	0.20	8.8	9.8	0.89	

	MODEL SIMULATION INPUT PARAMETERS	
n_f	5,000	Number of fish
μ	8.0	Mean length (inches)
σ	0.0	SD in length (inches)

	BLADE STRIKE SIMULATION RESULTS	
Turbine Strikes:	853 of 5000 fish	17.1%
Bypass Failures:	0 of 5000 fish	0.0%
Passed:	4147 of 5000 fish	82.9%

Byllesby-Buck Hydroelectric Project, FERC Project No. 2514 ARCHIVED RUN .N5000-L10-S79 10/28/2021
Byllesby Development Existing , New River, Galax, Virginia KESTLER
Release 201209

ROUTE SELECTION				TURBINE DATA													BYPASS
Route Name	Route Selection Prob.	Prob. Lower Bound	Calc. Type	Route Type	D Runner Dia. (ft)	N Blades (#)	B Runner Height (ft)	Q Turbine Discharge (cfs)	Q_{OPT}/Q Discharge at Opt. Eff. (%)	H Net. Head (ft)	ω Speed (rpm)	ζ Swirl Coeff. (-)	λ Correlation Coeff. (-)	D_1 Runner Dia. at Inlet (ft)	D_2 Runner Dia. at Disch. (ft)	η Turbine Eff. (-)	P_B Estimated Mortality (-)
Unit 1	0.250	0.000	1	Francis	7.52	16	3.06	1,467	79.0%	56.0	116.0	1.10	0.20	8.8	9.8	0.89	
Unit 2	0.250	0.250	1	Francis	7.52	16	3.06	1,467	79.0%	56.0	116.0	1.10	0.20	8.8	9.8	0.89	
Unit 3	0.250	0.500	1	Francis	7.52	16	3.06	1,467	79.0%	56.0	116.0	1.10	0.20	8.8	9.8	0.89	
Unit 4	0.250	0.750	1	Francis	7.52	16	3.06	1,467	79.0%	56.0	116.0	1.10	0.20	8.8	9.8	0.89	

	MODEL SIMULATION INPUT PARAMETERS	
n_f	5,000	Number of fish
μ	10.0	Mean length (inches)
σ	0.0	SD in length (inches)

	BLADE STRIKE SIMULATION RESULTS	
Turbine Strikes:	1026 of 5000 fish	20.5%
Bypass Failures:	0 of 5000 fish	0.0%
Passed:	3974 of 5000 fish	79.5%

Byllesby-Buck Hydroelectric Project, FERC Project No. 2514 ARCHIVED RUN .N5000-L15-S67 10/28/2021
Byllesby Development Existing , New River, Galax, Virginia KESTLER
Release 201209

ROUTE SELECTION				TURBINE DATA													BYPASS
Route Name	Route Selection Prob.	Prob. Lower Bound	Calc. Type	Route Type	D Runner Dia. (ft)	N Blades (#)	B Runner Height (ft)	Q Turbine Discharge (cfs)	Q_{OPT}/Q Discharge at Opt. Eff. (%)	H Net. Head (ft)	ω Speed (rpm)	ζ Swirl Coeff. (-)	λ Correlation Coeff. (-)	D_1 Runner Dia. at Inlet (ft)	D_2 Runner Dia. at Disch. (ft)	η Turbine Eff. (-)	P_B Estimated Mortality (-)
Unit 1	0.250	0.000	1	Francis	7.52	16	3.06	1,467	79.0%	56.0	116.0	1.10	0.20	8.8	9.8	0.89	
Unit 2	0.250	0.250	1	Francis	7.52	16	3.06	1,467	79.0%	56.0	116.0	1.10	0.20	8.8	9.8	0.89	
Unit 3	0.250	0.500	1	Francis	7.52	16	3.06	1,467	79.0%	56.0	116.0	1.10	0.20	8.8	9.8	0.89	
Unit 4	0.250	0.750	1	Francis	7.52	16	3.06	1,467	79.0%	56.0	116.0	1.10	0.20	8.8	9.8	0.89	

	MODEL SIMULATION INPUT PARAMETERS	
n_f	5,000	Number of fish
μ	15.0	Mean length (inches)
σ	0.0	SD in length (inches)

	BLADE STRIKE SIMULATION RESULTS	
Turbine Strikes:	1634 of 5000 fish	32.7%
Bypass Failures:	0 of 5000 fish	0.0%
Passed:	3366 of 5000 fish	67.3%

Byllesby-Buck Hydroelectric Project, FERC Project No. 2514 ARCHIVED RUN .N5000-L20-S55 10/28/2021
Byllesby Development Existing , New River, Galax, Virginia KESTLER
Release 201209

	ROUTE SELECTION			TURBINE DATA													BYPASS
					D	N	B	Q	Q_{OPT}/Q	H	ω	ζ	λ	D_1	D_2	η	P_B
Route Name	Route Selection Prob.	Prob. Lower Bound	Calc. Type	Route Type	Runner Dia. (ft)	Blades (#)	Runner Height (ft)	Turbine Discharge (cfs)	Discharge at Opt. Eff. (%)	Net. Head (ft)	Speed (rpm)	Swirl Coeff. (-)	Correlation Coeff. (-)	Runner Dia. at Inlet (ft)	Runner Dia. at Disch. (ft)	Turbine Eff. (-)	Estimated Mortality (-)
Unit 1	0.250	0.000	1	Francis	7.52	16	3.06	1,467	79.0%	56.0	116.0	1.10	0.20	8.8	9.8	0.89	
Unit 2	0.250	0.250	1	Francis	7.52	16	3.06	1,467	79.0%	56.0	116.0	1.10	0.20	8.8	9.8	0.89	
Unit 3	0.250	0.500	1	Francis	7.52	16	3.06	1,467	79.0%	56.0	116.0	1.10	0.20	8.8	9.8	0.89	
Unit 4	0.250	0.750	1	Francis	7.52	16	3.06	1,467	79.0%	56.0	116.0	1.10	0.20	8.8	9.8	0.89	

MODEL SIMULATION INPUT PARAMETERS		
n_f	5,000	Number of fish
μ	20.0	Mean length (inches)
σ	0.0	SD in length (inches)

BLADE STRIKE SIMULATION RESULTS		
Turbine Strikes:	2229 of 5000 fish	44.6%
Bypass Failures:	0 of 5000 fish	0.0%
Passed:	2771 of 5000 fish	55.4%

Byllesby-Buck Hydroelectric Project, FERC Project No. 2514 ARCHIVED RUN .N5000-L25-S44 10/28/2021
Byllesby Development Existing , New River, Galax, Virginia KESTLER
Release 201209

	ROUTE SELECTION			TURBINE DATA													BYPASS
					D	N	B	Q	Q_{OPT}/Q	H	ω	ζ	λ	D_1	D_2	η	P_B
Route Name	Route Selection Prob.	Prob. Lower Bound	Calc. Type	Route Type	Runner Dia. (ft)	Blades (#)	Runner Height (ft)	Turbine Discharge (cfs)	Discharge at Opt. Eff. (%)	Net. Head (ft)	Speed (rpm)	Swirl Coeff. (-)	Correlation Coeff. (-)	Runner Dia. at Inlet (ft)	Runner Dia. at Disch. (ft)	Turbine Eff. (-)	Estimated Mortality (-)
Unit 1	0.250	0.000	1	Francis	7.52	16	3.06	1,467	79.0%	56.0	116.0	1.10	0.20	8.8	9.8	0.89	
Unit 2	0.250	0.250	1	Francis	7.52	16	3.06	1,467	79.0%	56.0	116.0	1.10	0.20	8.8	9.8	0.89	
Unit 3	0.250	0.500	1	Francis	7.52	16	3.06	1,467	79.0%	56.0	116.0	1.10	0.20	8.8	9.8	0.89	
Unit 4	0.250	0.750	1	Francis	7.52	16	3.06	1,467	79.0%	56.0	116.0	1.10	0.20	8.8	9.8	0.89	

MODEL SIMULATION INPUT PARAMETERS		
n_f	5,000	Number of fish
μ	25.0	Mean length (inches)
σ	0.0	SD in length (inches)

BLADE STRIKE SIMULATION RESULTS		
Turbine Strikes:	2811 of 5000 fish	56.2%
Bypass Failures:	0 of 5000 fish	0.0%
Passed:	2189 of 5000 fish	43.8%

Byllesby-Buck Hydroelectric Project, FERC Project No. 2514 ARCHIVED RUN .N5000-L30-S32 10/28/2021
Byllesby Development Existing , New River, Galax, Virginia KESTLER
Release 201209

	ROUTE SELECTION			TURBINE DATA													BYPASS
					D	N	B	Q	Q_{OPT}/Q	H	ω	ζ	λ	D_1	D_2	η	P_B
Route Name	Route Selection Prob.	Prob. Lower Bound	Calc. Type	Route Type	Runner Dia. (ft)	Blades (#)	Runner Height (ft)	Turbine Discharge (cfs)	Discharge at Opt. Eff. (%)	Net. Head (ft)	Speed (rpm)	Swirl Coeff. (-)	Correlation Coeff. (-)	Runner Dia. at Inlet (ft)	Runner Dia. at Disch. (ft)	Turbine Eff. (-)	Estimated Mortality (-)
Unit 1	0.250	0.000	1	Francis	7.52	16	3.06	1,467	79.0%	56.0	116.0	1.10	0.20	8.8	9.8	0.89	
Unit 2	0.250	0.250	1	Francis	7.52	16	3.06	1,467	79.0%	56.0	116.0	1.10	0.20	8.8	9.8	0.89	
Unit 3	0.250	0.500	1	Francis	7.52	16	3.06	1,467	79.0%	56.0	116.0	1.10	0.20	8.8	9.8	0.89	
Unit 4	0.250	0.750	1	Francis	7.52	16	3.06	1,467	79.0%	56.0	116.0	1.10	0.20	8.8	9.8	0.89	

MODEL SIMULATION INPUT PARAMETERS		
n_f	5,000	Number of fish
μ	30.0	Mean length (inches)
σ	0.0	SD in length (inches)

BLADE STRIKE SIMULATION RESULTS		
Turbine Strikes:	3389 of 5000 fish	67.8%
Bypass Failures:	0 of 5000 fish	0.0%
Passed:	1611 of 5000 fish	32.2%

Byllesby-Buck Hydroelectric Project, FERC Project No. 2514 ARCHIVED RUN .N5000-L18-S60 2/2/2022

Byllesby Existing: 4% Exceedance Flow (230 CFS spill). Walleye KESTLER

Release 201209

ROUTE SELECTION				TURBINE DATA													BYPASS
					D	N	B	Q	Q_{OPT}/Q	H	ω	ζ	λ	D_1	D_2	η	P_B
Route Name	Route Selection Prob.	Prob. Lower Bound	Calc. Type	Route Type	Runner Dia. (ft)	Blades (#)	Runner Height (ft)	Turbine Discharge (cfs)	Discharge at Opt. Eff. (%)	Net. Head (ft)	Speed (rpm)	Swirl Coeff. (-)	Correlation Coeff. (-)	Runner Dia. at Inlet (ft)	Runner Dia. at Disch. (ft)	Turbine Eff. (-)	Estimated Mortality (-)
Unit 1	0.240	0.000	1	Francis	7.52	16	3.06	1,467	79.0%	56.0	116.0	1.10	0.20	8.8	9.8	0.89	
Unit 2	0.240	0.240	1	Francis	7.52	16	3.06	1,467	79.0%	56.0	116.0	1.10	0.20	8.8	9.8	0.89	
Unit 3	0.240	0.480	1	Francis	7.52	16	3.06	1,467	79.0%	56.0	116.0	1.10	0.20	8.8	9.8	0.89	
Unit 4	0.240	0.720	1	Francis	7.52	16	3.06	1,467	79.0%	56.0	116.0	1.10	0.20	8.8	9.8	0.89	
Spill	0.039	0.960	0	bypass													0.03

MODEL SIMULATION INPUT PARAMETERS		
n_f	5,000	Number of fish
μ	18.5	Mean length (inches)
σ	1.5	SD in length (inches)

BLADE STRIKE SIMULATION RESULTS		
Turbine Strikes:	1992 of 5000 fish	39.8%
Bypass Failures:	2 of 5000 fish	0.0%
Passed:	3006 of 5000 fish	60.1%

Byllesby-Buck Hydroelectric Project, FERC Project No. 2514 ARCHIVED RUN .N5000-L18-S65 2/2/2022

Byllesby Existing: 3% Exceedance Flow (1128 CFS spill). Walleye KESTLER

Release 201209

ROUTE SELECTION				TURBINE DATA													BYPASS
					D	N	B	Q	Q_{OPT}/Q	H	ω	ζ	λ	D_1	D_2	η	P_B
Route Name	Route Selection Prob.	Prob. Lower Bound	Calc. Type	Route Type	Runner Dia. (ft)	Blades (#)	Runner Height (ft)	Turbine Discharge (cfs)	Discharge at Opt. Eff. (%)	Net. Head (ft)	Speed (rpm)	Swirl Coeff. (-)	Correlation Coeff. (-)	Runner Dia. at Inlet (ft)	Runner Dia. at Disch. (ft)	Turbine Eff. (-)	Estimated Mortality (-)
Unit 1	0.209	0.000	1	Francis	7.52	16	3.06	1,467	79.0%	56.0	116.0	1.10	0.20	8.8	9.8	0.89	
Unit 2	0.209	0.209	1	Francis	7.52	16	3.06	1,467	79.0%	56.0	116.0	1.10	0.20	8.8	9.8	0.89	
Unit 3	0.209	0.418	1	Francis	7.52	16	3.06	1,467	79.0%	56.0	116.0	1.10	0.20	8.8	9.8	0.89	
Unit 4	0.209	0.627	1	Francis	7.52	16	3.06	1,467	79.0%	56.0	116.0	1.10	0.20	8.8	9.8	0.89	
Spill	0.167	0.836	0	bypass													0.03

MODEL SIMULATION INPUT PARAMETERS		
n_f	5,000	Number of fish
μ	18.5	Mean length (inches)
σ	1.5	SD in length (inches)

BLADE STRIKE SIMULATION RESULTS		
Turbine Strikes:	1729 of 5000 fish	34.6%
Bypass Failures:	12 of 5000 fish	0.2%
Passed:	3259 of 5000 fish	65.2%

Byllesby-Buck Hydroelectric Project, FERC Project No. 2514 ARCHIVED RUN .N5000-L18-S70 2/2/2022

Byllesby Existing: 2% Exceedance Flow (2355 CFS spill). Walleye KESTLER

Release 201209

Route Name	ROUTE SELECTION: Route Selection Prob.	Prob. Lower Bound	Calc. Type	TURBINE DATA: Route Type	D Runner Dia. (ft)	N Blades (#)	B Runner Height (ft)	Q Turbine Discharge (cfs)	Q_{OPT}/Q Discharge at Opt. Eff. (%)	H Net. Head (ft)	ω Speed (rpm)	ζ Swirl Coeff. (-)	λ Correlation Coeff. (-)	D_1 Runner Dia. at Inlet (ft)	D_2 Runner Dia. at Disch. (ft)	η Turbine Eff. (-)	BYPASS P_B Estimated Mortality (-)
Unit 1	0.177	0.000	1	Francis	7.52	16	3.06	1,467	79.0%	56.0	116.0	1.10	0.20	8.8	9.8	0.89	
Unit 2	0.177	0.177	1	Francis	7.52	16	3.06	1,467	79.0%	56.0	116.0	1.10	0.20	8.8	9.8	0.89	
Unit 3	0.177	0.354	1	Francis	7.52	16	3.06	1,467	79.0%	56.0	116.0	1.10	0.20	8.8	9.8	0.89	
Unit 4	0.177	0.531	1	Francis	7.52	16	3.06	1,467	79.0%	56.0	116.0	1.10	0.20	8.8	9.8	0.89	
Spill	0.293	0.708	0	bypass													0.03

MODEL SIMULATION INPUT PARAMETERS		
n_f	5,000	Number of fish
μ	18.5	Mean length (inches)
σ	1.5	SD in length (inches)

BLADE STRIKE SIMULATION RESULTS		
Turbine Strikes:	1458 of 5000 fish	29.2%
Bypass Failures:	37 of 5000 fish	0.7%
Passed:	3505 of 5000 fish	70.1%

Byllesby-Buck Hydroelectric Project, FERC Project No. 2514 ARCHIVED RUN .N5000-L18-S77 2/2/2022

Byllesby Existing: 1% Exceedance Flow (5094 CFS spill). Walleye KESTLER

Release 201209

Route Name	ROUTE SELECTION: Route Selection Prob.	Prob. Lower Bound	Calc. Type	TURBINE DATA: Route Type	D Runner Dia. (ft)	N Blades (#)	B Runner Height (ft)	Q Turbine Discharge (cfs)	Q_{OPT}/Q Discharge at Opt. Eff. (%)	H Net. Head (ft)	ω Speed (rpm)	ζ Swirl Coeff. (-)	λ Correlation Coeff. (-)	D_1 Runner Dia. at Inlet (ft)	D_2 Runner Dia. at Disch. (ft)	η Turbine Eff. (-)	BYPASS P_B Estimated Mortality (-)
Unit 1	0.132	0.000	1	Francis	7.52	16	3.06	1,467	79.0%	56.0	116.0	1.10	0.20	8.8	9.8	0.89	
Unit 2	0.132	0.132	1	Francis	7.52	16	3.06	1,467	79.0%	56.0	116.0	1.10	0.20	8.8	9.8	0.89	
Unit 3	0.132	0.264	1	Francis	7.52	16	3.06	1,467	79.0%	56.0	116.0	1.10	0.20	8.8	9.8	0.89	
Unit 4	0.132	0.395	1	Francis	7.52	16	3.06	1,467	79.0%	56.0	116.0	1.10	0.20	8.8	9.8	0.89	
Spill	0.473	0.527	0	bypass													0.03

MODEL SIMULATION INPUT PARAMETERS		
n_f	5,000	Number of fish
μ	18.5	Mean length (inches)
σ	1.5	SD in length (inches)

BLADE STRIKE SIMULATION RESULTS		
Turbine Strikes:	1058 of 5000 fish	21.2%
Bypass Failures:	78 of 5000 fish	1.6%
Passed:	3864 of 5000 fish	77.3%

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Appendix F

Appendix F – USFWS Turbine Blade Strike Analysis Model Outputs for Byllesby Development – Proposed Operations without Spill and with Varying Amounts of Spill for Walleye

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Byllesby-Buck Hydroelectric Project, FERC Project No. 2514 ARCHIVED RUN .N5000-L2-S97 10/28/2021
Byllesby Development Propsed , New River, Galax, Virginia KESTLER
Release 201209

Route Name	Route Selection Prob.	Prob. Lower Bound	Calc. Type	Route Type	D Runner Dia. (ft)	N Blades (#)	B Runner Height (ft)	Q Turbine Discharge (cfs)	Q_{OPT}/Q Discharge at Opt. Eff. (%)	H Net. Head (ft)	ω Speed (rpm)	ζ Swirl Coeff. (-)	λ Correlation Coeff. (-)	D_1 Runner Dia. at Inlet (ft)	D_2 Runner Dia. at Disch. (ft)	η Turbine Eff. (-)	BYPASS P_B Estimated Mortality (-)
Unit 1	0.247	0.000	2	Kaplan	8.70	5		1,348	92.0%	54.0	189.5		0.20			0.92	
Unit 2	0.247	0.247	2	Kaplan	8.70	5		1,348	92.0%	54.0	189.5		0.20			0.92	
Unit 3	0.247	0.493	2	Kaplan	8.70	5		1,348	92.0%	54.0	189.5		0.20			0.92	
Unit 4	0.260	0.740	1	Francis	7.52	16	3.06	1,467	79.0%	56.0	116.0	1.10	0.20	8.8	9.8	0.89	

MODEL SIMULATION INPUT PARAMETERS		
n_f	5,000	Number of fish
μ	2.0	Mean length (inches)
σ	0.0	SD in length (inches)

BLADE STRIKE SIMULATION RESULTS		
Turbine Strikes:	158 of 5000 fish	3.2%
Bypass Failures:	0 of 5000 fish	0.0%
Passed:	4842 of 5000 fish	96.8%

Byllesby-Buck Hydroelectric Project, FERC Project No. 2514 ARCHIVED RUN .N5000-L4-S94 10/28/2021
Byllesby Development Propsed , New River, Galax, Virginia KESTLER
Release 201209

Route Name	Route Selection Prob.	Prob. Lower Bound	Calc. Type	Route Type	D Runner Dia. (ft)	N Blades (#)	B Runner Height (ft)	Q Turbine Discharge (cfs)	Q_{OPT}/Q Discharge at Opt. Eff. (%)	H Net. Head (ft)	ω Speed (rpm)	ζ Swirl Coeff. (-)	λ Correlation Coeff. (-)	D_1 Runner Dia. at Inlet (ft)	D_2 Runner Dia. at Disch. (ft)	η Turbine Eff. (-)	BYPASS P_B Estimated Mortality (-)
Unit 1	0.247	0.000	2	Kaplan	8.70	5		1,348	92.0%	54.0	189.5		0.20			0.92	
Unit 2	0.247	0.247	2	Kaplan	8.70	5		1,348	92.0%	54.0	189.5		0.20			0.92	
Unit 3	0.247	0.493	2	Kaplan	8.70	5		1,348	92.0%	54.0	189.5		0.20			0.92	
Unit 4	0.260	0.740	1	Francis	7.52	16	3.06	1,467	79.0%	56.0	116.0	1.10	0.20	8.8	9.8	0.89	

MODEL SIMULATION INPUT PARAMETERS		
n_f	5,000	Number of fish
μ	4.0	Mean length (inches)
σ	0.0	SD in length (inches)

BLADE STRIKE SIMULATION RESULTS		
Turbine Strikes:	285 of 5000 fish	5.7%
Bypass Failures:	0 of 5000 fish	0.0%
Passed:	4715 of 5000 fish	94.3%

Byllesby-Buck Hydroelectric Project, FERC Project No. 2514 ARCHIVED RUN .N5000-L6-S92 10/28/2021
Byllesby Development Propsed , New River, Galax, Virginia KESTLER
Release 201209

Route Name	Route Selection Prob.	Prob. Lower Bound	Calc. Type	Route Type	D Runner Dia. (ft)	N Blades (#)	B Runner Height (ft)	Q Turbine Discharge (cfs)	Q_{OPT}/Q Discharge at Opt. Eff. (%)	H Net. Head (ft)	ω Speed (rpm)	ζ Swirl Coeff. (-)	λ Correlation Coeff. (-)	D_1 Runner Dia. at Inlet (ft)	D_2 Runner Dia. at Disch. (ft)	η Turbine Eff. (-)	BYPASS P_B Estimated Mortality (-)
Unit 1	0.247	0.000	2	Kaplan	8.70	5		1,348	92.0%	54.0	189.5		0.20			0.92	
Unit 2	0.247	0.247	2	Kaplan	8.70	5		1,348	92.0%	54.0	189.5		0.20			0.92	
Unit 3	0.247	0.493	2	Kaplan	8.70	5		1,348	92.0%	54.0	189.5		0.20			0.92	
Unit 4	0.260	0.740	1	Francis	7.52	16	3.06	1,467	79.0%	56.0	116.0	1.10	0.20	8.8	9.8	0.89	

MODEL SIMULATION INPUT PARAMETERS		
n_f	5,000	Number of fish
μ	6.0	Mean length (inches)
σ	0.0	SD in length (inches)

BLADE STRIKE SIMULATION RESULTS		
Turbine Strikes:	396 of 5000 fish	7.9%
Bypass Failures:	0 of 5000 fish	0.0%
Passed:	4604 of 5000 fish	92.1%

Byllesby-Buck Hydroelectric Project, FERC Project No. 2514 ARCHIVED RUN .N5000-L8-S89 10/28/2021
Byllesby Development Propsed , New River, Galax, Virginia KESTLER
Release 201209

ROUTE SELECTION				TURBINE DATA													BYPASS
					D	N	B	Q	Q_{OPT}/Q	H	ω	ζ	λ	D_1	D_2	η	P_B
Route Name	Route Selection Prob.	Prob. Lower Bound	Calc. Type	Route Type	Runner Dia. (ft)	Blades (#)	Runner Height (ft)	Turbine Discharge (cfs)	Discharge at Opt. Eff. (%)	Net. Head (ft)	Speed (rpm)	Swirl Coeff. (-)	Correlation Coeff. (-)	Runner Dia. at Inlet (ft)	Runner Dia. at Disch. (ft)	Turbine Eff. (-)	Estimated Mortality (-)
Unit 1	0.247	0.000	2	Kaplan	8.70	5		1,348	92.0%	54.0	189.5		0.20			0.92	
Unit 2	0.247	0.247	2	Kaplan	8.70	5		1,348	92.0%	54.0	189.5		0.20			0.92	
Unit 3	0.247	0.493	2	Kaplan	8.70	5		1,348	92.0%	54.0	189.5		0.20			0.92	
Unit 4	0.260	0.740	1	Francis	7.52	16	3.06	1,467	79.0%	56.0	116.0	1.10	0.20	8.8	9.8	0.89	

MODEL SIMULATION INPUT PARAMETERS		
n_f	5,000	Number of fish
μ	8.0	Mean length (inches)
σ	0.0	SD in length (inches)

BLADE STRIKE SIMULATION RESULTS		
Turbine Strikes:	565 of 5000 fish	11.3%
Bypass Failures:	0 of 5000 fish	0.0%
Passed:	4435 of 5000 fish	88.7%

Byllesby-Buck Hydroelectric Project, FERC Project No. 2514 ARCHIVED RUN .N5000-L10-S86 10/28/2021
Byllesby Development Propsed , New River, Galax, Virginia KESTLER
Release 201209

ROUTE SELECTION				TURBINE DATA													BYPASS
					D	N	B	Q	Q_{OPT}/Q	H	ω	ζ	λ	D_1	D_2	η	P_B
Route Name	Route Selection Prob.	Prob. Lower Bound	Calc. Type	Route Type	Runner Dia. (ft)	Blades (#)	Runner Height (ft)	Turbine Discharge (cfs)	Discharge at Opt. Eff. (%)	Net. Head (ft)	Speed (rpm)	Swirl Coeff. (-)	Correlation Coeff. (-)	Runner Dia. at Inlet (ft)	Runner Dia. at Disch. (ft)	Turbine Eff. (-)	Estimated Mortality (-)
Unit 1	0.247	0.000	2	Kaplan	8.70	5		1,348	92.0%	54.0	189.5		0.20			0.92	
Unit 2	0.247	0.247	2	Kaplan	8.70	5		1,348	92.0%	54.0	189.5		0.20			0.92	
Unit 3	0.247	0.493	2	Kaplan	8.70	5		1,348	92.0%	54.0	189.5		0.20			0.92	
Unit 4	0.260	0.740	1	Francis	7.52	16	3.06	1,467	79.0%	56.0	116.0	1.10	0.20	8.8	9.8	0.89	

MODEL SIMULATION INPUT PARAMETERS		
n_f	5,000	Number of fish
μ	10.0	Mean length (inches)
σ	0.0	SD in length (inches)

BLADE STRIKE SIMULATION RESULTS		
Turbine Strikes:	679 of 5000 fish	13.6%
Bypass Failures:	0 of 5000 fish	0.0%
Passed:	4321 of 5000 fish	86.4%

Byllesby-Buck Hydroelectric Project, FERC Project No. 2514 ARCHIVED RUN .N5000-L15-S79 10/28/2021
Byllesby Development Propsed , New River, Galax, Virginia KESTLER
Release 201209

ROUTE SELECTION				TURBINE DATA													BYPASS
					D	N	B	Q	Q_{OPT}/Q	H	ω	ζ	λ	D_1	D_2	η	P_B
Route Name	Route Selection Prob.	Prob. Lower Bound	Calc. Type	Route Type	Runner Dia. (ft)	Blades (#)	Runner Height (ft)	Turbine Discharge (cfs)	Discharge at Opt. Eff. (%)	Net. Head (ft)	Speed (rpm)	Swirl Coeff. (-)	Correlation Coeff. (-)	Runner Dia. at Inlet (ft)	Runner Dia. at Disch. (ft)	Turbine Eff. (-)	Estimated Mortality (-)
Unit 1	0.247	0.000	2	Kaplan	8.70	5		1,348	92.0%	54.0	189.5		0.20			0.92	
Unit 2	0.247	0.247	2	Kaplan	8.70	5		1,348	92.0%	54.0	189.5		0.20			0.92	
Unit 3	0.247	0.493	2	Kaplan	8.70	5		1,348	92.0%	54.0	189.5		0.20			0.92	
Unit 4	0.260	0.740	1	Francis	7.52	16	3.06	1,467	79.0%	56.0	116.0	1.10	0.20	8.8	9.8	0.89	

MODEL SIMULATION INPUT PARAMETERS		
n_f	5,000	Number of fish
μ	15.0	Mean length (inches)
σ	0.0	SD in length (inches)

BLADE STRIKE SIMULATION RESULTS		
Turbine Strikes:	1070 of 5000 fish	21.4%
Bypass Failures:	0 of 5000 fish	0.0%
Passed:	3930 of 5000 fish	78.6%

Byllesby-Buck Hydroelectric Project, FERC Project No. 2514 ARCHIVED RUN .N5000-L20-S73 10/28/2021

Byllesby Development Propsed , New River, Galax, Virginia KESTLER

Release 201209

ROUTE SELECTION				TURBINE DATA													BYPASS
					D	N	B	Q	Q_{OPT}/Q	H	ω	ζ	λ	D_1	D_2	η	P_B
Route Name	Route Selection Prob.	Prob. Lower Bound	Calc. Type	Route Type	Runner Dia. (ft)	Blades (#)	Runner Height (ft)	Turbine Discharge (cfs)	Discharge at Opt. Eff. (%)	Net. Head (ft)	Speed (rpm)	Swirl Coeff. (-)	Correlation Coeff. (-)	Runner Dia. at Inlet (ft)	Runner Dia. at Disch. (ft)	Turbine Eff. (-)	Estimated Mortality (-)
Unit 1	0.247	0.000	2	Kaplan	8.70	5		1,348	92.0%	54.0	189.5		0.20			0.92	
Unit 2	0.247	0.247	2	Kaplan	8.70	5		1,348	92.0%	54.0	189.5		0.20			0.92	
Unit 3	0.247	0.493	2	Kaplan	8.70	5		1,348	92.0%	54.0	189.5		0.20			0.92	
Unit 4	0.260	0.740	1	Francis	7.52	16	3.06	1,467	79.0%	56.0	116.0	1.10	0.20	8.8	9.8	0.89	

MODEL SIMULATION INPUT PARAMETERS		
n_f	5,000	Number of fish
μ	20.0	Mean length (inches)
σ	0.0	SD in length (inches)

BLADE STRIKE SIMULATION RESULTS		
Turbine Strikes:	1354 of 5000 fish	27.1%
Bypass Failures:	0 of 5000 fish	0.0%
Passed:	3646 of 5000 fish	72.9%

Byllesby-Buck Hydroelectric Project, FERC Project No. 2514 ARCHIVED RUN .N5000-L25-S66 10/28/2021

Byllesby Development Propsed , New River, Galax, Virginia KESTLER

Release 201209

ROUTE SELECTION				TURBINE DATA													BYPASS
					D	N	B	Q	Q_{OPT}/Q	H	ω	ζ	λ	D_1	D_2	η	P_B
Route Name	Route Selection Prob.	Prob. Lower Bound	Calc. Type	Route Type	Runner Dia. (ft)	Blades (#)	Runner Height (ft)	Turbine Discharge (cfs)	Discharge at Opt. Eff. (%)	Net. Head (ft)	Speed (rpm)	Swirl Coeff. (-)	Correlation Coeff. (-)	Runner Dia. at Inlet (ft)	Runner Dia. at Disch. (ft)	Turbine Eff. (-)	Estimated Mortality (-)
Unit 1	0.247	0.000	2	Kaplan	8.70	5		1,348	92.0%	54.0	189.5		0.20			0.92	
Unit 2	0.247	0.247	2	Kaplan	8.70	5		1,348	92.0%	54.0	189.5		0.20			0.92	
Unit 3	0.247	0.493	2	Kaplan	8.70	5		1,348	92.0%	54.0	189.5		0.20			0.92	
Unit 4	0.260	0.740	1	Francis	7.52	16	3.06	1,467	79.0%	56.0	116.0	1.10	0.20	8.8	9.8	0.89	

MODEL SIMULATION INPUT PARAMETERS		
n_f	5,000	Number of fish
μ	25.0	Mean length (inches)
σ	0.0	SD in length (inches)

BLADE STRIKE SIMULATION RESULTS		
Turbine Strikes:	1725 of 5000 fish	34.5%
Bypass Failures:	0 of 5000 fish	0.0%
Passed:	3275 of 5000 fish	65.5%

Byllesby-Buck Hydroelectric Project, FERC Project No. 2514 ARCHIVED RUN .N5000-L30-S58 10/28/2021

Byllesby Development Propsed , New River, Galax, Virginia KESTLER

Release 201209

ROUTE SELECTION				TURBINE DATA													BYPASS
					D	N	B	Q	Q_{OPT}/Q	H	ω	ζ	λ	D_1	D_2	η	P_B
Route Name	Route Selection Prob.	Prob. Lower Bound	Calc. Type	Route Type	Runner Dia. (ft)	Blades (#)	Runner Height (ft)	Turbine Discharge (cfs)	Discharge at Opt. Eff. (%)	Net. Head (ft)	Speed (rpm)	Swirl Coeff. (-)	Correlation Coeff. (-)	Runner Dia. at Inlet (ft)	Runner Dia. at Disch. (ft)	Turbine Eff. (-)	Estimated Mortality (-)
Unit 1	0.247	0.000	2	Kaplan	8.70	5		1,348	92.0%	54.0	189.5		0.20			0.92	
Unit 2	0.247	0.247	2	Kaplan	8.70	5		1,348	92.0%	54.0	189.5		0.20			0.92	
Unit 3	0.247	0.493	2	Kaplan	8.70	5		1,348	92.0%	54.0	189.5		0.20			0.92	
Unit 4	0.260	0.740	1	Francis	7.52	16	3.06	1,467	79.0%	56.0	116.0	1.10	0.20	8.8	9.8	0.89	

MODEL SIMULATION INPUT PARAMETERS		
n_f	5,000	Number of fish
μ	30.0	Mean length (inches)
σ	0.0	SD in length (inches)

BLADE STRIKE SIMULATION RESULTS		
Turbine Strikes:	2084 of 5000 fish	41.7%
Bypass Failures:	0 of 5000 fish	0.0%
Passed:	2916 of 5000 fish	58.3%

Byllesby-Buck Hydroelectric Project, FERC Project No. 2514 ARCHIVED RUN .N5000-L18-S76 2/2/2022

Byllesby Proposed, 4% Exceedance Flow (426 CFS) Walleye KESTLER

Release 201209

	ROUTE SELECTION			TURBINE DATA													BYPASS
					D	N	B	Q	Q_{OPT}/Q	H	ω	ζ	λ	D_1	D_2	η	P_B
Route Name	Route Selection Prob.	Prob. Lower Bound	Calc. Type	Route Type	Runner Dia. (ft)	Blades (#)	Runner Height (ft)	Turbine Discharge (cfs)	Discharge at Opt. Eff. (%)	Net. Head (ft)	Speed (rpm)	Swirl Coeff. (-)	Correlation Coeff. (-)	Runner Dia. at Inlet (ft)	Runner Dia. at Disch. (ft)	Turbine Eff. (-)	Estimated Mortality (-)
Unit 1	0.228	0.000	2	Kaplan	8.70	5		1,348	92.0%	54.0	189.5		0.20			0.92	
Unit 2	0.228	0.228	2	Kaplan	8.70	5		1,348	92.0%	54.0	189.5		0.20			0.92	
Unit 3	0.228	0.456	2	Kaplan	8.70	5		1,348	92.0%	54.0	189.5		0.20			0.92	
Unit 4	0.244	0.684	1	Francis	7.52	16	3.06	1,467	79.0%	56.0	116.0	1.10	0.20	8.8	9.8	0.89	
Spill	0.072	0.928	0	bypass													0.03

	MODEL SIMULATION INPUT PARAMETERS	
n_f	5,000	Number of fish
μ	18.5	Mean length (inches)
σ	1.5	SD in length (inches)

	BLADE STRIKE SIMULATION RESULTS	
Turbine Strikes:	1208 of 5000 fish	24.2%
Bypass Failures:	8 of 5000 fish	0.2%
Passed:	3784 of 5000 fish	75.7%

Byllesby-Buck Hydroelectric Project, FERC Project No. 2514 ARCHIVED RUN .N5000-L18-S78 2/2/2022

Byllesby Proposed, 3% Exceedance Flow (1324 CFS) Walleye KESTLER

Release 201209

	ROUTE SELECTION			TURBINE DATA													BYPASS
					D	N	B	Q	Q_{OPT}/Q	H	ω	ζ	λ	D_1	D_2	η	P_B
Route Name	Route Selection Prob.	Prob. Lower Bound	Calc. Type	Route Type	Runner Dia. (ft)	Blades (#)	Runner Height (ft)	Turbine Discharge (cfs)	Discharge at Opt. Eff. (%)	Net. Head (ft)	Speed (rpm)	Swirl Coeff. (-)	Correlation Coeff. (-)	Runner Dia. at Inlet (ft)	Runner Dia. at Disch. (ft)	Turbine Eff. (-)	Estimated Mortality (-)
Unit 1	0.198	0.000	2	Kaplan	8.70	5		1,348	92.0%	54.0	189.5		0.20			0.92	
Unit 2	0.198	0.198	2	Kaplan	8.70	5		1,348	92.0%	54.0	189.5		0.20			0.92	
Unit 3	0.198	0.396	2	Kaplan	8.70	5		1,348	92.0%	54.0	189.5		0.20			0.92	
Unit 4	0.212	0.594	1	Francis	7.52	16	3.06	1,467	79.0%	56.0	116.0	1.10	0.20	8.8	9.8	0.89	
Spill	0.195	0.806	0	bypass													0.03

	MODEL SIMULATION INPUT PARAMETERS	
n_f	5,000	Number of fish
μ	18.5	Mean length (inches)
σ	1.5	SD in length (inches)

	BLADE STRIKE SIMULATION RESULTS	
Turbine Strikes:	1053 of 5000 fish	21.1%
Bypass Failures:	42 of 5000 fish	0.8%
Passed:	3905 of 5000 fish	78.1%

Byllesby-Buck Hydroelectric Project, FERC Project No. 2514 ARCHIVED RUN .N5000-L18-S81 2/2/2022
Byllesby Proposed, 2% Exceedance Flow (2551 CFS) Walleye KESTLER
Release 201209

ROUTE SELECTION				TURBINE DATA													BYPASS
					D	N	B	Q	Q_{OPT}/Q	H	ω	ζ	λ	D_1	D_2	η	P_B
Route Name	Route Selection Prob.	Prob. Lower Bound	Calc. Type	Route Type	Runner Dia. (ft)	Blades (#)	Runner Height (ft)	Turbine Discharge (cfs)	Discharge at Opt. Eff. (%)	Net. Head (ft)	Speed (rpm)	Swirl Coeff. (-)	Correlation Coeff. (-)	Runner Dia. at Inlet (ft)	Runner Dia. at Disch. (ft)	Turbine Eff. (-)	Estimated Mortality (-)
Unit 1	0.168	0.000	2	Kaplan	8.70	5		1,348	92.0%	54.0	189.5		0.20			0.92	
Unit 2	0.168	0.168	2	Kaplan	8.70	5		1,348	92.0%	54.0	189.5		0.20			0.92	
Unit 3	0.168	0.336	2	Kaplan	8.70	5		1,348	92.0%	54.0	189.5		0.20			0.92	
Unit 4	0.179	0.504	1	Francis	7.52	16	3.06	1,467	79.0%	56.0	116.0	1.10	0.20	8.8	9.8	0.89	
Spill	0.318	0.683	0	bypass													0.03

MODEL SIMULATION INPUT PARAMETERS		
n_f	5,000	Number of fish
μ	18.5	Mean length (inches)
σ	1.5	SD in length (inches)

BLADE STRIKE SIMULATION RESULTS		
Turbine Strikes:	881 of 5000 fish	17.6%
Bypass Failures:	55 of 5000 fish	1.1%
Passed:	4064 of 5000 fish	81.3%

Byllesby-Buck Hydroelectric Project, FERC Project No. 2514 ARCHIVED RUN .N5000-L18-S85 2/2/2022
Byllesby Proposed, 1% Exceedance Flow (5290 CFS) Walleye KESTLER
Release 201209

ROUTE SELECTION				TURBINE DATA													BYPASS
					D	N	B	Q	Q_{OPT}/Q	H	ω	ζ	λ	D_1	D_2	η	P_B
Route Name	Route Selection Prob.	Prob. Lower Bound	Calc. Type	Route Type	Runner Dia. (ft)	Blades (#)	Runner Height (ft)	Turbine Discharge (cfs)	Discharge at Opt. Eff. (%)	Net. Head (ft)	Speed (rpm)	Swirl Coeff. (-)	Correlation Coeff. (-)	Runner Dia. at Inlet (ft)	Runner Dia. at Disch. (ft)	Turbine Eff. (-)	Estimated Mortality (-)
Unit 1	0.127	0.000	2	Kaplan	8.70	5		1,348	92.0%	54.0	189.5		0.20			0.92	
Unit 2	0.127	0.127	2	Kaplan	8.70	5		1,348	92.0%	54.0	189.5		0.20			0.92	
Unit 3	0.127	0.254	2	Kaplan	8.70	5		1,348	92.0%	54.0	189.5		0.20			0.92	
Unit 4	0.128	0.381	1	Francis	7.52	16	3.06	1,467	79.0%	56.0	116.0	1.10	0.20	8.8	9.8	0.89	
Spill	0.491	0.509	0	bypass													0.03

MODEL SIMULATION INPUT PARAMETERS		
n_f	5,000	Number of fish
μ	18.5	Mean length (inches)
σ	1.5	SD in length (inches)

BLADE STRIKE SIMULATION RESULTS		
Turbine Strikes:	701 of 5000 fish	14.0%
Bypass Failures:	68 of 5000 fish	1.4%
Passed:	4231 of 5000 fish	84.6%

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Appendix G

Appendix G – USFWS Turbine Blade Strike Analysis Model Outputs for Buck Development – Existing Operations without Spill and with Varying Amounts of Spill for Walleye

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Byllesby-Buck Hydroelectric Project, FERC Project No. 2514 ARCHIVED RUN .N5000-L2-S95 10/28/2021

Buck Development Existing , New River, Galax, Virginia KESTLER

Release 201209

ROUTE SELECTION				TURBINE DATA													BYPASS
					D	N	B	Q	Q_{OPT}/Q	H	ω	ζ	λ	D_1	D_2	η	P_B
Route Name	Route Selection Prob.	Prob. Lower Bound	Calc. Type	Route Type	Runner Dia. (ft)	Blades (#)	Runner Height (ft)	Turbine Discharge (cfs)	Discharge at Opt. Eff. (%)	Net. Head (ft)	Speed (rpm)	Swirl Coeff. (-)	Correlation Coeff. (-)	Runner Dia. at Inlet (ft)	Runner Dia. at Disch. (ft)	Turbine Eff. (-)	Estimated Mortality (-)
Unit 1	0.333	0.000	1	Francis	7.52	16	3.06	1,180	90.0%	40.0	97.0	1.10	0.20	8.8	9.8	0.85	
Unit 2	0.333	0.333	1	Francis	7.52	16	3.06	1,180	90.0%	40.0	97.0	1.10	0.20	8.8	9.8	0.85	
Unit 3	0.334	0.666	1	Francis	7.52	16	3.06	1,180	90.0%	40.0	97.0	1.10	0.20	8.8	9.8	0.85	

	MODEL SIMULATION INPUT PARAMETERS	
n_f	5,000	Number of fish
μ	2.0	Mean length (inches)
σ	0.0	SD in length (inches)

	BLADE STRIKE SIMULATION RESULTS	
Turbine Strikes:	229 of 5000 fish	4.6%
Bypass Failures:	0 of 5000 fish	0.0%
Passed:	4771 of 5000 fish	95.4%

Byllesby-Buck Hydroelectric Project, FERC Project No. 2514 ARCHIVED RUN .N5000-L4-S91 10/28/2021

Buck Development Existing , New River, Galax, Virginia KESTLER

Release 201209

ROUTE SELECTION				TURBINE DATA													BYPASS
					D	N	B	Q	Q_{OPT}/Q	H	ω	ζ	λ	D_1	D_2	η	P_B
Route Name	Route Selection Prob.	Prob. Lower Bound	Calc. Type	Route Type	Runner Dia. (ft)	Blades (#)	Runner Height (ft)	Turbine Discharge (cfs)	Discharge at Opt. Eff. (%)	Net. Head (ft)	Speed (rpm)	Swirl Coeff. (-)	Correlation Coeff. (-)	Runner Dia. at Inlet (ft)	Runner Dia. at Disch. (ft)	Turbine Eff. (-)	Estimated Mortality (-)
Unit 1	0.333	0.000	1	Francis	7.52	16	3.06	1,180	90.0%	40.0	97.0	1.10	0.20	8.8	9.8	0.85	
Unit 2	0.333	0.333	1	Francis	7.52	16	3.06	1,180	90.0%	40.0	97.0	1.10	0.20	8.8	9.8	0.85	
Unit 3	0.334	0.666	1	Francis	7.52	16	3.06	1,180	90.0%	40.0	97.0	1.10	0.20	8.8	9.8	0.85	

	MODEL SIMULATION INPUT PARAMETERS	
n_f	5,000	Number of fish
μ	4.0	Mean length (inches)
σ	0.0	SD in length (inches)

	BLADE STRIKE SIMULATION RESULTS	
Turbine Strikes:	437 of 5000 fish	8.7%
Bypass Failures:	0 of 5000 fish	0.0%
Passed:	4563 of 5000 fish	91.3%

Byllesby-Buck Hydroelectric Project, FERC Project No. 2514 ARCHIVED RUN .N5000-L6-S87 10/28/2021

Buck Development Existing , New River, Galax, Virginia KESTLER

Release 201209

ROUTE SELECTION				TURBINE DATA													BYPASS
					D	N	B	Q	Q_{OPT}/Q	H	ω	ζ	λ	D_1	D_2	η	P_B
Route Name	Route Selection Prob.	Prob. Lower Bound	Calc. Type	Route Type	Runner Dia. (ft)	Blades (#)	Runner Height (ft)	Turbine Discharge (cfs)	Discharge at Opt. Eff. (%)	Net. Head (ft)	Speed (rpm)	Swirl Coeff. (-)	Correlation Coeff. (-)	Runner Dia. at Inlet (ft)	Runner Dia. at Disch. (ft)	Turbine Eff. (-)	Estimated Mortality (-)
Unit 1	0.333	0.000	1	Francis	7.52	16	3.06	1,180	90.0%	40.0	97.0	1.10	0.20	8.8	9.8	0.85	
Unit 2	0.333	0.333	1	Francis	7.52	16	3.06	1,180	90.0%	40.0	97.0	1.10	0.20	8.8	9.8	0.85	
Unit 3	0.334	0.666	1	Francis	7.52	16	3.06	1,180	90.0%	40.0	97.0	1.10	0.20	8.8	9.8	0.85	

	MODEL SIMULATION INPUT PARAMETERS	
n_f	5,000	Number of fish
μ	6.0	Mean length (inches)
σ	0.0	SD in length (inches)

	BLADE STRIKE SIMULATION RESULTS	
Turbine Strikes:	667 of 5000 fish	13.3%
Bypass Failures:	0 of 5000 fish	0.0%
Passed:	4333 of 5000 fish	86.7%

Byllesby-Buck Hydroelectric Project, FERC Project No. 2514 ARCHIVED RUN .N5000-L8-S83 10/28/2021
Buck Development Existing , New River, Galax, Virginia KESTLER
Release 201209

ROUTE SELECTION				TURBINE DATA													BYPASS
					D	N	B	Q	Q_{OPT}/Q	H	ω	ζ	λ	D_1	D_2	η	P_B
Route Name	Route Selection Prob.	Prob. Lower Bound	Calc. Type	Route Type	Runner Dia. (ft)	Blades (#)	Runner Height (ft)	Turbine Discharge (cfs)	Discharge at Opt. Eff. (%)	Net. Head (ft)	Speed (rpm)	Swirl Coeff. (-)	Correlation Coeff. (-)	Runner Dia. at Inlet (ft)	Runner Dia. at Disch. (ft)	Turbine Eff. (-)	Estimated Mortality (-)
Unit 1	0.333	0.000	1	Francis	7.52	16	3.06	1,180	90.0%	40.0	97.0	1.10	0.20	8.8	9.8	0.85	
Unit 2	0.333	0.333	1	Francis	7.52	16	3.06	1,180	90.0%	40.0	97.0	1.10	0.20	8.8	9.8	0.85	
Unit 3	0.334	0.666	1	Francis	7.52	16	3.06	1,180	90.0%	40.0	97.0	1.10	0.20	8.8	9.8	0.85	

	MODEL SIMULATION INPUT PARAMETERS	
n_f	5,000	Number of fish
μ	8.0	Mean length (inches)
σ	0.0	SD in length (inches)

	BLADE STRIKE SIMULATION RESULTS	
Turbine Strikes:	830 of 5000 fish	16.6%
Bypass Failures:	0 of 5000 fish	0.0%
Passed:	4170 of 5000 fish	83.4%

Byllesby-Buck Hydroelectric Project, FERC Project No. 2514 ARCHIVED RUN .N5000-L10-S79 10/28/2021
Buck Development Existing , New River, Galax, Virginia KESTLER
Release 201209

ROUTE SELECTION				TURBINE DATA													BYPASS
					D	N	B	Q	Q_{OPT}/Q	H	ω	ζ	λ	D_1	D_2	η	P_B
Route Name	Route Selection Prob.	Prob. Lower Bound	Calc. Type	Route Type	Runner Dia. (ft)	Blades (#)	Runner Height (ft)	Turbine Discharge (cfs)	Discharge at Opt. Eff. (%)	Net. Head (ft)	Speed (rpm)	Swirl Coeff. (-)	Correlation Coeff. (-)	Runner Dia. at Inlet (ft)	Runner Dia. at Disch. (ft)	Turbine Eff. (-)	Estimated Mortality (-)
Unit 1	0.333	0.000	1	Francis	7.52	16	3.06	1,180	90.0%	40.0	97.0	1.10	0.20	8.8	9.8	0.85	
Unit 2	0.333	0.333	1	Francis	7.52	16	3.06	1,180	90.0%	40.0	97.0	1.10	0.20	8.8	9.8	0.85	
Unit 3	0.334	0.666	1	Francis	7.52	16	3.06	1,180	90.0%	40.0	97.0	1.10	0.20	8.8	9.8	0.85	

	MODEL SIMULATION INPUT PARAMETERS	
n_f	5,000	Number of fish
μ	10.0	Mean length (inches)
σ	0.0	SD in length (inches)

	BLADE STRIKE SIMULATION RESULTS	
Turbine Strikes:	1064 of 5000 fish	21.3%
Bypass Failures:	0 of 5000 fish	0.0%
Passed:	3936 of 5000 fish	78.7%

Byllesby-Buck Hydroelectric Project, FERC Project No. 2514 ARCHIVED RUN .N5000-L15-S65 10/28/2021
Buck Development Existing , New River, Galax, Virginia KESTLER
Release 201209

ROUTE SELECTION				TURBINE DATA													BYPASS
					D	N	B	Q	Q_{OPT}/Q	H	ω	ζ	λ	D_1	D_2	η	P_B
Route Name	Route Selection Prob.	Prob. Lower Bound	Calc. Type	Route Type	Runner Dia. (ft)	Blades (#)	Runner Height (ft)	Turbine Discharge (cfs)	Discharge at Opt. Eff. (%)	Net. Head (ft)	Speed (rpm)	Swirl Coeff. (-)	Correlation Coeff. (-)	Runner Dia. at Inlet (ft)	Runner Dia. at Disch. (ft)	Turbine Eff. (-)	Estimated Mortality (-)
Unit 1	0.333	0.000	1	Francis	7.52	16	3.06	1,180	90.0%	40.0	97.0	1.10	0.20	8.8	9.8	0.85	
Unit 2	0.333	0.333	1	Francis	7.52	16	3.06	1,180	90.0%	40.0	97.0	1.10	0.20	8.8	9.8	0.85	
Unit 3	0.334	0.666	1	Francis	7.52	16	3.06	1,180	90.0%	40.0	97.0	1.10	0.20	8.8	9.8	0.85	

	MODEL SIMULATION INPUT PARAMETERS	
n_f	5,000	Number of fish
μ	15.0	Mean length (inches)
σ	0.0	SD in length (inches)

	BLADE STRIKE SIMULATION RESULTS	
Turbine Strikes:	1768 of 5000 fish	35.4%
Bypass Failures:	0 of 5000 fish	0.0%
Passed:	3232 of 5000 fish	64.6%

Byllesby-Buck Hydroelectric Project, FERC Project No. 2514 ARCHIVED RUN .N5000-L20-S56 10/28/2021
Buck Development Existing , New River, Galax, Virginia KESTLER
Release 201209

ROUTE SELECTION				TURBINE DATA													BYPASS
					D	N	B	Q	Q_{OPT}/Q	H	ω	ζ	λ	D_1	D_2	η	P_B
Route Name	Route Selection Prob.	Prob. Lower Bound	Calc. Type	Route Type	Runner Dia. (ft)	Blades (#)	Runner Height (ft)	Turbine Discharge (cfs)	Discharge at Opt. Eff. (%)	Net. Head (ft)	Speed (rpm)	Swirl Coeff. (-)	Correlation Coeff. (-)	Runner Dia. at Inlet (ft)	Runner Dia. at Disch. (ft)	Turbine Eff. (-)	Estimated Mortality (-)
Unit 1	0.333	0.000	1	Francis	7.52	16	3.06	1,180	90.0%	40.0	97.0	1.10	0.20	8.8	9.8	0.85	
Unit 2	0.333	0.333	1	Francis	7.52	16	3.06	1,180	90.0%	40.0	97.0	1.10	0.20	8.8	9.8	0.85	
Unit 3	0.334	0.666	1	Francis	7.52	16	3.06	1,180	90.0%	40.0	97.0	1.10	0.20	8.8	9.8	0.85	

MODEL SIMULATION INPUT PARAMETERS		
n_f	5,000	Number of fish
μ	20.0	Mean length (inches)
σ	0.0	SD in length (inches)

BLADE STRIKE SIMULATION RESULTS		
Turbine Strikes:	2221 of 5000 fish	44.4%
Bypass Failures:	0 of 5000 fish	0.0%
Passed:	2779 of 5000 fish	55.6%

Byllesby-Buck Hydroelectric Project, FERC Project No. 2514 ARCHIVED RUN .N5000-L25-S45 10/28/2021
Buck Development Existing , New River, Galax, Virginia KESTLER
Release 201209

ROUTE SELECTION				TURBINE DATA													BYPASS
					D	N	B	Q	Q_{OPT}/Q	H	ω	ζ	λ	D_1	D_2	η	P_B
Route Name	Route Selection Prob.	Prob. Lower Bound	Calc. Type	Route Type	Runner Dia. (ft)	Blades (#)	Runner Height (ft)	Turbine Discharge (cfs)	Discharge at Opt. Eff. (%)	Net. Head (ft)	Speed (rpm)	Swirl Coeff. (-)	Correlation Coeff. (-)	Runner Dia. at Inlet (ft)	Runner Dia. at Disch. (ft)	Turbine Eff. (-)	Estimated Mortality (-)
Unit 1	0.333	0.000	1	Francis	7.52	16	3.06	1,180	90.0%	40.0	97.0	1.10	0.20	8.8	9.8	0.85	
Unit 2	0.333	0.333	1	Francis	7.52	16	3.06	1,180	90.0%	40.0	97.0	1.10	0.20	8.8	9.8	0.85	
Unit 3	0.334	0.666	1	Francis	7.52	16	3.06	1,180	90.0%	40.0	97.0	1.10	0.20	8.8	9.8	0.85	

MODEL SIMULATION INPUT PARAMETERS		
n_f	5,000	Number of fish
μ	25.0	Mean length (inches)
σ	0.0	SD in length (inches)

BLADE STRIKE SIMULATION RESULTS		
Turbine Strikes:	2753 of 5000 fish	55.1%
Bypass Failures:	0 of 5000 fish	0.0%
Passed:	2247 of 5000 fish	44.9%

Byllesby-Buck Hydroelectric Project, FERC Project No. 2514 ARCHIVED RUN .N5000-L30-S35 10/28/2021
Buck Development Existing , New River, Galax, Virginia KESTLER
Release 201209

ROUTE SELECTION				TURBINE DATA													BYPASS
					D	N	B	Q	Q_{OPT}/Q	H	ω	ζ	λ	D_1	D_2	η	P_B
Route Name	Route Selection Prob.	Prob. Lower Bound	Calc. Type	Route Type	Runner Dia. (ft)	Blades (#)	Runner Height (ft)	Turbine Discharge (cfs)	Discharge at Opt. Eff. (%)	Net. Head (ft)	Speed (rpm)	Swirl Coeff. (-)	Correlation Coeff. (-)	Runner Dia. at Inlet (ft)	Runner Dia. at Disch. (ft)	Turbine Eff. (-)	Estimated Mortality (-)
Unit 1	0.333	0.000	1	Francis	7.52	16	3.06	1,180	90.0%	40.0	97.0	1.10	0.20	8.8	9.8	0.85	
Unit 2	0.333	0.333	1	Francis	7.52	16	3.06	1,180	90.0%	40.0	97.0	1.10	0.20	8.8	9.8	0.85	
Unit 3	0.334	0.666	1	Francis	7.52	16	3.06	1,180	90.0%	40.0	97.0	1.10	0.20	8.8	9.8	0.85	

MODEL SIMULATION INPUT PARAMETERS		
n_f	5,000	Number of fish
μ	30.0	Mean length (inches)
σ	0.0	SD in length (inches)

BLADE STRIKE SIMULATION RESULTS		
Turbine Strikes:	3254 of 5000 fish	65.1%
Bypass Failures:	0 of 5000 fish	0.0%
Passed:	1746 of 5000 fish	34.9%

Byllesby-Buck Hydroelectric Project, FERC Project No. 2514 ARCHIVED RUN .N5000-L18-S59 2/1/2022

Buck Development, 12% Exceedance Flow (123 CFS Spill) Walleye KESTLER

Release 201209

ROUTE SELECTION				TURBINE DATA													BYPASS
					D	N	B	Q	Q_{OPT}/Q	H	ω	ζ	λ	D_1	D_2	η	P_B
Route Name	Route Selection Prob.	Prob. Lower Bound	Calc. Type	Route Type	Runner Dia. (ft)	Blades (#)	Runner Height (ft)	Turbine Discharge (cfs)	Discharge at Opt. Eff. (%)	Net. Head (ft)	Speed (rpm)	Swirl Coeff. (-)	Correlation Coeff. (-)	Runner Dia. at Inlet (ft)	Runner Dia. at Disch. (ft)	Turbine Eff. (-)	Estimated Mortality (-)
Unit 1	0.322	0.000	1	Francis	7.52	16	3.06	1,180	90.0%	40.0	97.0	1.10	0.20	8.8	9.8	0.85	
Unit 2	0.322	0.322	1	Francis	7.52	16	3.06	1,180	90.0%	40.0	97.0	1.10	0.20	8.8	9.8	0.85	
Unit 3	0.322	0.644	1	Francis	7.52	16	3.06	1,180	90.0%	40.0	97.0	1.10	0.20	8.8	9.8	0.85	
Spill	0.033	0.966	0	bypass													0.03

MODEL SIMULATION INPUT PARAMETERS		
n_f	5,000	Number of fish
μ	18.5	Mean length (inches)
σ	1.5	SD in length (inches)

BLADE STRIKE SIMULATION RESULTS		
Turbine Strikes:	2050 of 5000 fish	41.0%
Bypass Failures:	7 of 5000 fish	0.1%
Passed:	2943 of 5000 fish	58.9%

Byllesby-Buck Hydroelectric Project, FERC Project No. 2514 ARCHIVED RUN .N5000-L18-S61 2/1/2022

Buck Development, 10% Exceedance Flow (421 CFS Spill) Walleye KESTLER

Release 201209

ROUTE SELECTION				TURBINE DATA													BYPASS
					D	N	B	Q	Q_{OPT}/Q	H	ω	ζ	λ	D_1	D_2	η	P_B
Route Name	Route Selection Prob.	Prob. Lower Bound	Calc. Type	Route Type	Runner Dia. (ft)	Blades (#)	Runner Height (ft)	Turbine Discharge (cfs)	Discharge at Opt. Eff. (%)	Net. Head (ft)	Speed (rpm)	Swirl Coeff. (-)	Correlation Coeff. (-)	Runner Dia. at Inlet (ft)	Runner Dia. at Disch. (ft)	Turbine Eff. (-)	Estimated Mortality (-)
Unit 1	0.298	0.000	1	Francis	7.52	16	3.06	1,180	90.0%	40.0	97.0	1.10	0.20	8.8	9.8	0.85	
Unit 2	0.298	0.298	1	Francis	7.52	16	3.06	1,180	90.0%	40.0	97.0	1.10	0.20	8.8	9.8	0.85	
Unit 3	0.298	0.596	1	Francis	7.52	16	3.06	1,180	90.0%	40.0	97.0	1.10	0.20	8.8	9.8	0.85	
Spill	0.106	0.894	0	bypass													0.03

MODEL SIMULATION INPUT PARAMETERS		
n_f	5,000	Number of fish
μ	18.5	Mean length (inches)
σ	1.5	SD in length (inches)

BLADE STRIKE SIMULATION RESULTS		
Turbine Strikes:	1914 of 5000 fish	38.3%
Bypass Failures:	21 of 5000 fish	0.4%
Passed:	3065 of 5000 fish	61.3%

Byllesby-Buck Hydroelectric Project, FERC Project No. 2514 ARCHIVED RUN .N5000-L18-S69 2/1/2022

Buck Development, 8% Exceedance Flow (816 CFS Spill) Walleye KESTLER

Release 201209

ROUTE SELECTION				TURBINE DATA													BYPASS
					D	N	B	Q	Q_{OPT}/Q	H	ω	ζ	λ	D_1	D_2	η	P_B
Route Name	Route Selection Prob.	Prob. Lower Bound	Calc. Type	Route Type	Runner Dia. (ft)	Blades (#)	Runner Height (ft)	Turbine Discharge (cfs)	Discharge at Opt. Eff. (%)	Net. Head (ft)	Speed (rpm)	Swirl Coeff. (-)	Correlation Coeff. (-)	Runner Dia. at Inlet (ft)	Runner Dia. at Disch. (ft)	Turbine Eff. (-)	Estimated Mortality (-)
Unit 1	0.271	0.000	1	Francis	7.52	16	3.06	1,180	90.0%	40.0	97.0	1.10	0.20	8.8	9.8	0.85	
Unit 2	0.271	0.271	1	Francis	7.52	16	3.06	1,180	90.0%	40.0	97.0	1.10	0.20	8.8	9.8	0.85	
Unit 3	0.271	0.542	1	Francis	7.52	16	3.06	1,180	90.0%	40.0	97.0	1.10	0.20	8.8	9.8	0.85	
Spill	0.187	0.813	0	bypass													0.03

MODEL SIMULATION INPUT PARAMETERS		
n_f	5,000	Number of fish
μ	18.5	Mean length (inches)
σ	1.5	SD in length (inches)

BLADE STRIKE SIMULATION RESULTS		
Turbine Strikes:	1493 of 5000 fish	29.9%
Bypass Failures:	33 of 5000 fish	0.7%
Passed:	3474 of 5000 fish	69.5%

Byllesby-Buck Hydroelectric Project, FERC Project No. 2514 ARCHIVED RUN .N5000-L18-S69(2) 2/1/2022

Buck Development, 6% Exceedance Flow (1427 CFS Spill) Walleye KESTLER

Release 201209

ROUTE SELECTION				TURBINE DATA													BYPASS
					D	N	B	Q	Q_{OPT}/Q	H	ω	ζ	λ	D_1	D_2	η	P_B
Route Name	Route Selection Prob.	Prob. Lower Bound	Calc. Type	Route Type	Runner Dia. (ft)	Blades (#)	Runner Height (ft)	Turbine Discharge (cfs)	Discharge at Opt. Eff. (%)	Net. Head (ft)	Speed (rpm)	Swirl Coeff. (-)	Correlation Coeff. (-)	Runner Dia. at Inlet (ft)	Runner Dia. at Disch. (ft)	Turbine Eff. (-)	Estimated Mortality (-)
Unit 1	0.238	0.000	1	Francis	7.52	16	3.06	1,180	90.0%	40.0	97.0	1.10	0.20	8.8	9.8	0.85	
Unit 2	0.238	0.238	1	Francis	7.52	16	3.06	1,180	90.0%	40.0	97.0	1.10	0.20	8.8	9.8	0.85	
Unit 3	0.238	0.476	1	Francis	7.52	16	3.06	1,180	90.0%	40.0	97.0	1.10	0.20	8.8	9.8	0.85	
Spill	0.287	0.714	0	bypass													0.03

MODEL SIMULATION INPUT PARAMETERS		
n_f	5,000	Number of fish
μ	18.5	Mean length (inches)
σ	1.5	SD in length (inches)

BLADE STRIKE SIMULATION RESULTS		
Turbine Strikes:	1512 of 5000 fish	30.2%
Bypass Failures:	49 of 5000 fish	1.0%
Passed:	3439 of 5000 fish	68.8%

Byllesby-Buck Hydroelectric Project, FERC Project No. 2514 ARCHIVED RUN .N5000-L18-S71(2) 2/1/2022

Buck Development, 4% Exceedance Flow (2370 CFS Spill) Walleye KESTLER

Release 201209

	ROUTE SELECTION			TURBINE DATA													BYPASS
					D	N	B	Q	Q_{OPT}/Q	H	ω	ζ	λ	D_1	D_2	η	P_B
Route Name	Route Selection Prob.	Prob. Lower Bound	Calc. Type	Route Type	Runner Dia. (ft)	Blades (#)	Runner Height (ft)	Turbine Discharge (cfs)	Discharge at Opt. Eff. (%)	Net. Head (ft)	Speed (rpm)	Swirl Coeff. (-)	Correlation Coeff. (-)	Runner Dia. at Inlet (ft)	Runner Dia. at Disch. (ft)	Turbine Eff. (-)	Estimated Mortality (-)
Unit 1	0.200	0.000	1	Francis	7.52	16	3.06	1,180	90.0%	40.0	97.0	1.10	0.20	8.8	9.8	0.85	
Unit 2	0.200	0.200	1	Francis	7.52	16	3.06	1,180	90.0%	40.0	97.0	1.10	0.20	8.8	9.8	0.85	
Unit 3	0.200	0.400	1	Francis	7.52	16	3.06	1,180	90.0%	40.0	97.0	1.10	0.20	8.8	9.8	0.85	
Spill	0.401	0.600	0	bypass													0.03

	MODEL SIMULATION INPUT PARAMETERS	
n_f	5,000	Number of fish
μ	18.5	Mean length (inches)
σ	1.5	SD in length (inches)

	BLADE STRIKE SIMULATION RESULTS	
Turbine Strikes:	1367 of 5000 fish	27.3%
Bypass Failures:	60 of 5000 fish	1.2%
Passed:	3573 of 5000 fish	71.5%

Byllesby-Buck Hydroelectric Project, FERC Project No. 2514 ARCHIVED RUN .N5000-L18-S81 2/1/2022

Buck Development, 2% Exceedance Flow (4495 CFS Spill) Walleye KESTLER

Release 201209

	ROUTE SELECTION			TURBINE DATA													BYPASS
					D	N	B	Q	Q_{OPT}/Q	H	ω	ζ	λ	D_1	D_2	η	P_B
Route Name	Route Selection Prob.	Prob. Lower Bound	Calc. Type	Route Type	Runner Dia. (ft)	Blades (#)	Runner Height (ft)	Turbine Discharge (cfs)	Discharge at Opt. Eff. (%)	Net. Head (ft)	Speed (rpm)	Swirl Coeff. (-)	Correlation Coeff. (-)	Runner Dia. at Inlet (ft)	Runner Dia. at Disch. (ft)	Turbine Eff. (-)	Estimated Mortality (-)
Unit 1	0.147	0.000	1	Francis	7.52	16	3.06	1,180	90.0%	40.0	97.0	1.10	0.20	8.8	9.8	0.85	
Unit 2	0.147	0.147	1	Francis	7.52	16	3.06	1,180	90.0%	40.0	97.0	1.10	0.20	8.8	9.8	0.85	
Unit 3	0.147	0.294	1	Francis	7.52	16	3.06	1,180	90.0%	40.0	97.0	1.10	0.20	8.8	9.8	0.85	
Spill	0.559	0.441	0	bypass													0.03

	MODEL SIMULATION INPUT PARAMETERS	
n_f	5,000	Number of fish
μ	18.5	Mean length (inches)
σ	1.5	SD in length (inches)

	BLADE STRIKE SIMULATION RESULTS	
Turbine Strikes:	851 of 5000 fish	17.0%
Bypass Failures:	76 of 5000 fish	1.5%
Passed:	4073 of 5000 fish	81.5%

Byllesby-Buck Hydroelectric Project, FERC Project No. 2514 ARCHIVED RUN .N5000-L18-S85 2/1/2022

Buck Development, 1% Exceedance Flow (7234 CFS Spill) Walleye KESTLER

Release 201209

ROUTE SELECTION				TURBINE DATA													BYPASS
					D	N	B	Q	Q_{OPT}/Q	H	ω	ζ	λ	D_1	D_2	η	P_B
Route Name	Route Selection Prob.	Prob. Lower Bound	Calc. Type	Route Type	Runner Dia. (ft)	Blades (#)	Runner Height (ft)	Turbine Discharge (cfs)	Discharge at Opt. Eff. (%)	Net. Head (ft)	Speed (rpm)	Swirl Coeff. (-)	Correlation Coeff. (-)	Runner Dia. at Inlet (ft)	Runner Dia. at Disch. (ft)	Turbine Eff. (-)	Estimated Mortality (-)
Unit 1	0.110	0.000	1	Francis	7.52	16	3.06	1,180	90.0%	40.0	97.0	1.10	0.20	8.8	9.8	0.85	
Unit 2	0.110	0.110	1	Francis	7.52	16	3.06	1,180	90.0%	40.0	97.0	1.10	0.20	8.8	9.8	0.85	
Unit 3	0.110	0.220	1	Francis	7.52	16	3.06	1,180	90.0%	40.0	97.0	1.10	0.20	8.8	9.8	0.85	
Spill	0.671	0.330	0	bypass													0.03

	MODEL SIMULATION INPUT PARAMETERS	
n_f	5,000	Number of fish
μ	18.5	Mean length (inches)
σ	1.5	SD in length (inches)

	BLADE STRIKE SIMULATION RESULTS	
Turbine Strikes:	632 of 5000 fish	12.6%
Bypass Failures:	114 of 5000 fish	2.3%
Passed:	4254 of 5000 fish	85.1%

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Appendix H

Appendix H – USFWS Turbine Blade Strike Analysis Model Outputs for Buck Development – Proposed Operations without Spill and with Varying Amounts of Spill for Walleye

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Byllesby-Buck Hydroelectric Project, FERC Project No. 2514 ARCHIVED RUN .N5000-L2-S97 10/28/2021
Buck Development Proposed , New River, Galax, Virginia KESTLER
Release 201209

	ROUTE SELECTION			TURBINE DATA													BYPASS
					D	N	B	Q	Q_{OPT}/Q	H	ω	ζ	λ	D_1	D_2	η	P_B
Route Name	Route Selection Prob.	Prob. Lower Bound	Calc. Type	Route Type	Runner Dia. (ft)	Blades (#)	Runner Height (ft)	Turbine Discharge (cfs)	Discharge at Opt. Eff. (%)	Net. Head (ft)	Speed (rpm)	Swirl Coeff. (-)	Correlation Coeff. (-)	Runner Dia. at Inlet (ft)	Runner Dia. at Disch. (ft)	Turbine Eff. (-)	Estimated Mortality (-)
Unit 1	0.333	0.000	2	Kaplan	8.70	5		1,195	77.8%	42.4	156.5		0.20			0.92	
Unit 2	0.333	0.333	1	Francis	7.52	16	3.06	1,180	90.0%	40.0	97.0	1.10	0.20	8.8	9.8	0.85	
Unit 3	0.334	0.666	2	Kaplan	8.70	5		1,195	77.8%	42.4	156.5		0.20			0.92	

MODEL SIMULATION INPUT PARAMETERS		
n_f	5,000	Number of fish
μ	2.0	Mean length (inches)
σ	0.0	SD in length (inches)

BLADE STRIKE SIMULATION RESULTS		
Turbine Strikes:	144 of 5000 fish	2.9%
Bypass Failures:	0 of 5000 fish	0.0%
Passed:	4856 of 5000 fish	97.1%

Byllesby-Buck Hydroelectric Project, FERC Project No. 2514 ARCHIVED RUN .N5000-L4-S94 10/28/2021
Buck Development Proposed , New River, Galax, Virginia KESTLER
Release 201209

	ROUTE SELECTION			TURBINE DATA													BYPASS
					D	N	B	Q	Q_{OPT}/Q	H	ω	ζ	λ	D_1	D_2	η	P_B
Route Name	Route Selection Prob.	Prob. Lower Bound	Calc. Type	Route Type	Runner Dia. (ft)	Blades (#)	Runner Height (ft)	Turbine Discharge (cfs)	Discharge at Opt. Eff. (%)	Net. Head (ft)	Speed (rpm)	Swirl Coeff. (-)	Correlation Coeff. (-)	Runner Dia. at Inlet (ft)	Runner Dia. at Disch. (ft)	Turbine Eff. (-)	Estimated Mortality (-)
Unit 1	0.333	0.000	2	Kaplan	8.70	5		1,195	77.8%	42.4	156.5		0.20			0.92	
Unit 2	0.333	0.333	1	Francis	7.52	16	3.06	1,180	90.0%	40.0	97.0	1.10	0.20	8.8	9.8	0.85	
Unit 3	0.334	0.666	2	Kaplan	8.70	5		1,195	77.8%	42.4	156.5		0.20			0.92	

MODEL SIMULATION INPUT PARAMETERS		
n_f	5,000	Number of fish
μ	4.0	Mean length (inches)
σ	0.0	SD in length (inches)

BLADE STRIKE SIMULATION RESULTS		
Turbine Strikes:	310 of 5000 fish	6.2%
Bypass Failures:	0 of 5000 fish	0.0%
Passed:	4690 of 5000 fish	93.8%

Byllesby-Buck Hydroelectric Project, FERC Project No. 2514 ARCHIVED RUN .N5000-L6-S92 10/28/2021
Buck Development Proposed , New River, Galax, Virginia KESTLER
Release 201209

	ROUTE SELECTION			TURBINE DATA													BYPASS
					D	N	B	Q	Q_{OPT}/Q	H	ω	ζ	λ	D_1	D_2	η	P_B
Route Name	Route Selection Prob.	Prob. Lower Bound	Calc. Type	Route Type	Runner Dia. (ft)	Blades (#)	Runner Height (ft)	Turbine Discharge (cfs)	Discharge at Opt. Eff. (%)	Net. Head (ft)	Speed (rpm)	Swirl Coeff. (-)	Correlation Coeff. (-)	Runner Dia. at Inlet (ft)	Runner Dia. at Disch. (ft)	Turbine Eff. (-)	Estimated Mortality (-)
Unit 1	0.333	0.000	2	Kaplan	8.70	5		1,195	77.8%	42.4	156.5		0.20			0.92	
Unit 2	0.333	0.333	1	Francis	7.52	16	3.06	1,180	90.0%	40.0	97.0	1.10	0.20	8.8	9.8	0.85	
Unit 3	0.334	0.666	2	Kaplan	8.70	5		1,195	77.8%	42.4	156.5		0.20			0.92	

MODEL SIMULATION INPUT PARAMETERS		
n_f	5,000	Number of fish
μ	6.0	Mean length (inches)
σ	0.0	SD in length (inches)

BLADE STRIKE SIMULATION RESULTS		
Turbine Strikes:	387 of 5000 fish	7.7%
Bypass Failures:	0 of 5000 fish	0.0%
Passed:	4613 of 5000 fish	92.3%

Byllesby-Buck Hydroelectric Project, FERC Project No. 2514 ARCHIVED RUN .N5000-L8-S89 10/28/2021
Buck Development Proposed , New River, Galax, Virginia KESTLER
Release 201209

ROUTE SELECTION				TURBINE DATA													BYPASS
					D	N	B	Q	Q_{OPT}/Q	H	ω	ζ	λ	D_1	D_2	η	P_B
Route Name	Route Selection Prob.	Prob. Lower Bound	Calc. Type	Route Type	Runner Dia. (ft)	Blades (#)	Runner Height (ft)	Turbine Discharge (cfs)	Discharge at Opt. Eff. (%)	Net. Head (ft)	Speed (rpm)	Swirl Coeff. (-)	Correlation Coeff. (-)	Runner Dia. at Inlet (ft)	Runner Dia. at Disch. (ft)	Turbine Eff. (-)	Estimated Mortality (-)
Unit 1	0.333	0.000	2	Kaplan	8.70	5		1,195	77.8%	42.4	156.5		0.20			0.92	
Unit 2	0.333	0.333	1	Francis	7.52	16	3.06	1,180	90.0%	40.0	97.0	1.10	0.20	8.8	9.8	0.85	
Unit 3	0.334	0.666	2	Kaplan	8.70	5		1,195	77.8%	42.4	156.5		0.20			0.92	

MODEL SIMULATION INPUT PARAMETERS		
n_f	5,000	Number of fish
μ	8.0	Mean length (inches)
σ	0.0	SD in length (inches)

BLADE STRIKE SIMULATION RESULTS		
Turbine Strikes:	552 of 5000 fish	11.0%
Bypass Failures:	0 of 5000 fish	0.0%
Passed:	4448 of 5000 fish	89.0%

Byllesby-Buck Hydroelectric Project, FERC Project No. 2514 ARCHIVED RUN .N5000-L10-S85 10/28/2021
Buck Development Proposed , New River, Galax, Virginia KESTLER
Release 201209

ROUTE SELECTION				TURBINE DATA													BYPASS
					D	N	B	Q	Q_{OPT}/Q	H	ω	ζ	λ	D_1	D_2	η	P_B
Route Name	Route Selection Prob.	Prob. Lower Bound	Calc. Type	Route Type	Runner Dia. (ft)	Blades (#)	Runner Height (ft)	Turbine Discharge (cfs)	Discharge at Opt. Eff. (%)	Net. Head (ft)	Speed (rpm)	Swirl Coeff. (-)	Correlation Coeff. (-)	Runner Dia. at Inlet (ft)	Runner Dia. at Disch. (ft)	Turbine Eff. (-)	Estimated Mortality (-)
Unit 1	0.333	0.000	2	Kaplan	8.70	5		1,195	77.8%	42.4	156.5		0.20			0.92	
Unit 2	0.333	0.333	1	Francis	7.52	16	3.06	1,180	90.0%	40.0	97.0	1.10	0.20	8.8	9.8	0.85	
Unit 3	0.334	0.666	2	Kaplan	8.70	5		1,195	77.8%	42.4	156.5		0.20			0.92	

MODEL SIMULATION INPUT PARAMETERS		
n_f	5,000	Number of fish
μ	10.0	Mean length (inches)
σ	0.0	SD in length (inches)

BLADE STRIKE SIMULATION RESULTS		
Turbine Strikes:	742 of 5000 fish	14.8%
Bypass Failures:	0 of 5000 fish	0.0%
Passed:	4258 of 5000 fish	85.2%

Byllesby-Buck Hydroelectric Project, FERC Project No. 2514 ARCHIVED RUN .N5000-L15-S78 10/28/2021
Buck Development Proposed , New River, Galax, Virginia KESTLER
Release 201209

ROUTE SELECTION				TURBINE DATA													BYPASS
					D	N	B	Q	Q_{OPT}/Q	H	ω	ζ	λ	D_1	D_2	η	P_B
Route Name	Route Selection Prob.	Prob. Lower Bound	Calc. Type	Route Type	Runner Dia. (ft)	Blades (#)	Runner Height (ft)	Turbine Discharge (cfs)	Discharge at Opt. Eff. (%)	Net. Head (ft)	Speed (rpm)	Swirl Coeff. (-)	Correlation Coeff. (-)	Runner Dia. at Inlet (ft)	Runner Dia. at Disch. (ft)	Turbine Eff. (-)	Estimated Mortality (-)
Unit 1	0.333	0.000	2	Kaplan	8.70	5		1,195	77.8%	42.4	156.5		0.20			0.92	
Unit 2	0.333	0.333	1	Francis	7.52	16	3.06	1,180	90.0%	40.0	97.0	1.10	0.20	8.8	9.8	0.85	
Unit 3	0.334	0.666	2	Kaplan	8.70	5		1,195	77.8%	42.4	156.5		0.20			0.92	

MODEL SIMULATION INPUT PARAMETERS		
n_f	5,000	Number of fish
μ	15.0	Mean length (inches)
σ	0.0	SD in length (inches)

BLADE STRIKE SIMULATION RESULTS		
Turbine Strikes:	1088 of 5000 fish	21.8%
Bypass Failures:	0 of 5000 fish	0.0%
Passed:	3912 of 5000 fish	78.2%

Byllesby-Buck Hydroelectric Project, FERC Project No. 2514 ARCHIVED RUN .N5000-L20-S73 10/28/2021
Buck Development Proposed , New River, Galax, Virginia KESTLER
Release 201209

	ROUTE SELECTION			TURBINE DATA													BYPASS
					D	N	B	Q	Q_{OPT}/Q	H	ω	ζ	λ	D_1	D_2	η	P_B
Route Name	Route Selection Prob.	Prob. Lower Bound	Calc. Type	Route Type	Runner Dia. (ft)	Blades (#)	Runner Height (ft)	Turbine Discharge (cfs)	Discharge at Opt. Eff. (%)	Net. Head (ft)	Speed (rpm)	Swirl Coeff. (-)	Correlation Coeff. (-)	Runner Dia. at Inlet (ft)	Runner Dia. at Disch. (ft)	Turbine Eff. (-)	Estimated Mortality (-)
Unit 1	0.333	0.000	2	Kaplan	8.70	5		1,195	77.8%	42.4	156.5		0.20			0.92	
Unit 2	0.333	0.333	1	Francis	7.52	16	3.06	1,180	90.0%	40.0	97.0	1.10	0.20	8.8	9.8	0.85	
Unit 3	0.334	0.666	2	Kaplan	8.70	5		1,195	77.8%	42.4	156.5		0.20			0.92	

MODEL SIMULATION INPUT PARAMETERS		
n_f	5,000	Number of fish
μ	20.0	Mean length (inches)
σ	0.0	SD in length (inches)

BLADE STRIKE SIMULATION RESULTS		
Turbine Strikes:	1330 of 5000 fish	26.6%
Bypass Failures:	0 of 5000 fish	0.0%
Passed:	3670 of 5000 fish	73.4%

Byllesby-Buck Hydroelectric Project, FERC Project No. 2514 ARCHIVED RUN .N5000-L25-S65 10/28/2021
Buck Development Proposed , New River, Galax, Virginia KESTLER
Release 201209

	ROUTE SELECTION			TURBINE DATA													BYPASS
					D	N	B	Q	Q_{OPT}/Q	H	ω	ζ	λ	D_1	D_2	η	P_B
Route Name	Route Selection Prob.	Prob. Lower Bound	Calc. Type	Route Type	Runner Dia. (ft)	Blades (#)	Runner Height (ft)	Turbine Discharge (cfs)	Discharge at Opt. Eff. (%)	Net. Head (ft)	Speed (rpm)	Swirl Coeff. (-)	Correlation Coeff. (-)	Runner Dia. at Inlet (ft)	Runner Dia. at Disch. (ft)	Turbine Eff. (-)	Estimated Mortality (-)
Unit 1	0.333	0.000	2	Kaplan	8.70	5		1,195	77.8%	42.4	156.5		0.20			0.92	
Unit 2	0.333	0.333	1	Francis	7.52	16	3.06	1,180	90.0%	40.0	97.0	1.10	0.20	8.8	9.8	0.85	
Unit 3	0.334	0.666	2	Kaplan	8.70	5		1,195	77.8%	42.4	156.5		0.20			0.92	

MODEL SIMULATION INPUT PARAMETERS		
n_f	5,000	Number of fish
μ	25.0	Mean length (inches)
σ	0.0	SD in length (inches)

BLADE STRIKE SIMULATION RESULTS		
Turbine Strikes:	1771 of 5000 fish	35.4%
Bypass Failures:	0 of 5000 fish	0.0%
Passed:	3229 of 5000 fish	64.6%

Byllesby-Buck Hydroelectric Project, FERC Project No. 2514 ARCHIVED RUN .N5000-L30-S57 10/28/2021
Buck Development Proposed , New River, Galax, Virginia KESTLER
Release 201209

	ROUTE SELECTION			TURBINE DATA													BYPASS
					D	N	B	Q	Q_{OPT}/Q	H	ω	ζ	λ	D_1	D_2	η	P_B
Route Name	Route Selection Prob.	Prob. Lower Bound	Calc. Type	Route Type	Runner Dia. (ft)	Blades (#)	Runner Height (ft)	Turbine Discharge (cfs)	Discharge at Opt. Eff. (%)	Net. Head (ft)	Speed (rpm)	Swirl Coeff. (-)	Correlation Coeff. (-)	Runner Dia. at Inlet (ft)	Runner Dia. at Disch. (ft)	Turbine Eff. (-)	Estimated Mortality (-)
Unit 1	0.333	0.000	2	Kaplan	8.70	5		1,195	77.8%	42.4	156.5		0.20			0.92	
Unit 2	0.333	0.333	1	Francis	7.52	16	3.06	1,180	90.0%	40.0	97.0	1.10	0.20	8.8	9.8	0.85	
Unit 3	0.334	0.666	2	Kaplan	8.70	5		1,195	77.8%	42.4	156.5		0.20			0.92	

MODEL SIMULATION INPUT PARAMETERS		
n_f	5,000	Number of fish
μ	30.0	Mean length (inches)
σ	0.0	SD in length (inches)

BLADE STRIKE SIMULATION RESULTS		
Turbine Strikes:	2126 of 5000 fish	42.5%
Bypass Failures:	0 of 5000 fish	0.0%
Passed:	2874 of 5000 fish	57.5%

Byllesby-Buck Hydroelectric Project, FERC Project No. 2514 ARCHIVED RUN .N5000-L18-S72 2/1/2022
Buck Proposed, 12% Exceedance Flow (92 CFS Spill) Walleye Length KESTLER
Release 201209

	ROUTE SELECTION			TURBINE DATA													BYPASS
Route Name	Route Selection Prob.	Prob. Lower Bound	Calc. Type	Route Type	D Runner Dia. (ft)	N Blades (#)	B Runner Height (ft)	Q Turbine Discharge (cfs)	Q_{OPT}/Q Discharge at Opt. Eff. (%)	H Net. Head (ft)	ω Speed (rpm)	ζ Swirl Coeff. (-)	λ Correlation Coeff. (-)	D_1 Runner Dia. at Inlet (ft)	D_2 Runner Dia. at Disch. (ft)	η Turbine Eff. (-)	P_B Estimated Mortality (-)
Unit 1	0.326	0.000	2	Kaplan	8.70	5		1,195	77.8%	42.4	156.5		0.20			0.92	
Unit 2	0.322	0.326	1	Francis	7.52	16	3.06	1,180	90.0%	40.0	97.0	1.10	0.20	8.8	9.8	0.85	
Unit 3	0.326	0.648	2	Kaplan	8.70	5		1,195	77.8%	42.4	156.5		0.20			0.92	
Spill	0.025	0.974	0	bypass													0.03

	MODEL SIMULATION INPUT PARAMETERS	
n_f	5,000	Number of fish
μ	18.5	Mean length (inches)
σ	1.5	SD in length (inches)

	BLADE STRIKE SIMULATION RESULTS	
Turbine Strikes:	1387 of 5000 fish	27.7%
Bypass Failures:	1 of 5000 fish	0.0%
Passed:	3612 of 5000 fish	72.2%

Byllesby-Buck Hydroelectric Project, FERC Project No. 2514 ARCHIVED RUN .N5000-L18-S77 2/1/2022
Buck Proposed, 10% Exceedance Flow (391 CFS Spill) Walleye Length KESTLER
Release 201209

	ROUTE SELECTION			TURBINE DATA													BYPASS
Route Name	Route Selection Prob.	Prob. Lower Bound	Calc. Type	Route Type	D Runner Dia. (ft)	N Blades (#)	B Runner Height (ft)	Q Turbine Discharge (cfs)	Q_{OPT}/Q Discharge at Opt. Eff. (%)	H Net. Head (ft)	ω Speed (rpm)	ζ Swirl Coeff. (-)	λ Correlation Coeff. (-)	D_1 Runner Dia. at Inlet (ft)	D_2 Runner Dia. at Disch. (ft)	η Turbine Eff. (-)	P_B Estimated Mortality (-)
Unit 1	0.302	0.000	2	Kaplan	8.70	5		1,195	77.8%	42.4	156.5		0.20			0.92	
Unit 2	0.297	0.302	1	Francis	7.52	16	3.06	1,180	90.0%	40.0	97.0	1.10	0.20	8.8	9.8	0.85	
Unit 3	0.302	0.599	2	Kaplan	8.70	5		1,195	77.8%	42.4	156.5		0.20			0.92	
Spill	0.099	0.901	0	bypass													0.03

	MODEL SIMULATION INPUT PARAMETERS	
n_f	5,000	Number of fish
μ	18.5	Mean length (inches)
σ	1.5	SD in length (inches)

	BLADE STRIKE SIMULATION RESULTS	
Turbine Strikes:	1140 of 5000 fish	22.8%
Bypass Failures:	21 of 5000 fish	0.4%
Passed:	3839 of 5000 fish	76.8%

Byllesby-Buck Hydroelectric Project, FERC Project No. 2514 ARCHIVED RUN .N5000-L18-S81 2/1/2022

Buck Proposed, 8% Exceedance Flow (786 CFS Spill) Walleye Length KESTLER

Release 201209

ROUTE SELECTION				TURBINE DATA														BYPASS
					D	N	B	Q	Q_{OPT}/Q	H	ω	ζ	λ	D_1	D_2	η		P_B
Route Name	Route Selection Prob.	Prob. Lower Bound	Calc. Type	Route Type	Runner Dia. (ft)	Blades (#)	Runner Height (ft)	Turbine Discharge (cfs)	Discharge at Opt. Eff. (%)	Net. Head (ft)	Speed (rpm)	Swirl Coeff. (-)	Correlation Coeff. (-)	Runner Dia. at Inlet (ft)	Runner Dia. at Disch. (ft)	Turbine Eff. (-)		Estimated Mortality (-)
Unit 1	0.274	0.000	2	Kaplan	8.70	5		1,195	77.8%	42.4	156.5		0.20			0.92		
Unit 2	0.271	0.241	1	Francis	7.52	16	3.06	1,180	90.0%	40.0	97.0	1.10	0.20	8.8	9.8	0.85		
Unit 3	0.274	0.479	2	Kaplan	8.70	5		1,195	77.8%	42.4	156.5		0.20			0.92		
Spill	0.181	0.720	0	bypass														0.03

MODEL SIMULATION INPUT PARAMETERS		
n_f	5,000	Number of fish
μ	18.5	Mean length (inches)
σ	1.5	SD in length (inches)

BLADE STRIKE SIMULATION RESULTS		
Turbine Strikes:	893 of 5000 fish	17.9%
Bypass Failures:	49 of 5000 fish	1.0%
Passed:	4058 of 5000 fish	81.2%

Byllesby-Buck Hydroelectric Project, FERC Project No. 2514 ARCHIVED RUN .N5000-L18-S79 2/1/2022

Buck Proposed, 6% Exceedance Flow (1397 CFS Spill) Walleye Length KESTLER

Release 201209

ROUTE SELECTION				TURBINE DATA														BYPASS
					D	N	B	Q	Q_{OPT}/Q	H	ω	ζ	λ	D_1	D_2	η		P_B
Route Name	Route Selection Prob.	Prob. Lower Bound	Calc. Type	Route Type	Runner Dia. (ft)	Blades (#)	Runner Height (ft)	Turbine Discharge (cfs)	Discharge at Opt. Eff. (%)	Net. Head (ft)	Speed (rpm)	Swirl Coeff. (-)	Correlation Coeff. (-)	Runner Dia. at Inlet (ft)	Runner Dia. at Disch. (ft)	Turbine Eff. (-)		Estimated Mortality (-)
Unit 1	0.241	0.000	2	Kaplan	8.70	5		1,195	77.8%	42.4	156.5		0.20			0.92		
Unit 2	0.238	0.241	1	Francis	7.52	16	3.06	1,180	90.0%	40.0	97.0	1.10	0.20	8.8	9.8	0.85		
Unit 3	0.241	0.479	2	Kaplan	8.70	5		1,195	77.8%	42.4	156.5		0.20			0.92		
Spill	0.281	0.720	0	bypass														0.03

MODEL SIMULATION INPUT PARAMETERS		
n_f	5,000	Number of fish
μ	18.5	Mean length (inches)
σ	1.5	SD in length (inches)

BLADE STRIKE SIMULATION RESULTS		
Turbine Strikes:	1012 of 5000 fish	20.2%
Bypass Failures:	31 of 5000 fish	0.6%
Passed:	3957 of 5000 fish	79.1%

Byllesby-Buck Hydroelectric Project, FERC Project No. 2514 ARCHIVED RUN .N5000-L18-S84 2/1/2022

Buck Proposed, 4% Exceedance Flow (2340 CFS Spill) Walleye Length KESTLER

Release 201209

	ROUTE SELECTION			TURBINE DATA													BYPASS
					D	N	B	Q	Q_{OPT}/Q	H	ω	ζ	λ	D_1	D_2	η	P_B
Route Name	Route Selection Prob.	Prob. Lower Bound	Calc. Type	Route Type	Runner Dia. (ft)	Blades (#)	Runner Height (ft)	Turbine Discharge (cfs)	Discharge at Opt. Eff. (%)	Net. Head (ft)	Speed (rpm)	Swirl Coeff. (-)	Correlation Coeff. (-)	Runner Dia. at Inlet (ft)	Runner Dia. at Disch. (ft)	Turbine Eff. (-)	Estimated Mortality (-)
Unit 1	0.202	0.000	2	Kaplan	8.70	5		1,195	77.8%	42.4	156.5		0.20			0.92	
Unit 2	0.200	0.202	1	Francis	7.52	16	3.06	1,180	90.0%	40.0	97.0	1.10	0.20	8.8	9.8	0.85	
Unit 3	0.202	0.402	2	Kaplan	8.70	5		1,195	77.8%	42.4	156.5		0.20			0.92	
Spill	0.396	0.604	0	bypass													0.03

	MODEL SIMULATION INPUT PARAMETERS	
n_f	5,000	Number of fish
μ	18.5	Mean length (inches)
σ	1.5	SD in length (inches)

BLADE STRIKE SIMULATION RESULTS		
Turbine Strikes:	727 of 5000 fish	14.5%
Bypass Failures:	51 of 5000 fish	1.0%
Passed:	4222 of 5000 fish	84.4%

Byllesby-Buck Hydroelectric Project, FERC Project No. 2514 ARCHIVED RUN .N5000-L18-S88 2/1/2022

Buck Proposed, 2% Exceedance Flow (4465 CFS Spill) Walleye Length KESTLER

Release 201209

	ROUTE SELECTION			TURBINE DATA													BYPASS
					D	N	B	Q	Q_{OPT}/Q	H	ω	ζ	λ	D_1	D_2	η	P_B
Route Name	Route Selection Prob.	Prob. Lower Bound	Calc. Type	Route Type	Runner Dia. (ft)	Blades (#)	Runner Height (ft)	Turbine Discharge (cfs)	Discharge at Opt. Eff. (%)	Net. Head (ft)	Speed (rpm)	Swirl Coeff. (-)	Correlation Coeff. (-)	Runner Dia. at Inlet (ft)	Runner Dia. at Disch. (ft)	Turbine Eff. (-)	Estimated Mortality (-)
Unit 1	0.149	0.000	2	Kaplan	8.70	5		1,195	77.8%	42.4	156.5		0.20			0.92	
Unit 2	0.147	0.149	1	Francis	7.52	16	3.06	1,180	90.0%	40.0	97.0	1.10	0.20	8.8	9.8	0.85	
Unit 3	0.149	0.296	2	Kaplan	8.70	5		1,195	77.8%	42.4	156.5		0.20			0.92	
Spill	0.556	0.445	0	bypass													0.03

	MODEL SIMULATION INPUT PARAMETERS	
n_f	5,000	Number of fish
μ	18.5	Mean length (inches)
σ	1.5	SD in length (inches)

BLADE STRIKE SIMULATION RESULTS		
Turbine Strikes:	514 of 5000 fish	10.3%
Bypass Failures:	78 of 5000 fish	1.6%
Passed:	4408 of 5000 fish	88.2%

Byllesby-Buck Hydroelectric Project, FERC Project No. 2514 ARCHIVED RUN .N5000-L18-S90 2/1/2022

Buck Proposed, 1% Exceedance Flow (7204 CFS Spill) Walleye Length KESTLER

Release 201209

	ROUTE SELECTION			TURBINE DATA													BYPASS
					D	N	B	Q	Q_{OPT}/Q	H	ω	ζ	λ	D_1	D_2	η	P_B
Route Name	Route Selection Prob.	Prob. Lower Bound	Calc. Type	Route Type	Runner Dia. (ft)	Blades (#)	Runner Height (ft)	Turbine Discharge (cfs)	Discharge at Opt. Eff. (%)	Net. Head (ft)	Speed (rpm)	Swirl Coeff. (-)	Correlation Coeff. (-)	Runner Dia. at Inlet (ft)	Runner Dia. at Disch. (ft)	Turbine Eff. (-)	Estimated Mortality (-)
Unit 1	0.111	0.000	2	Kaplan	8.70	5		1,195	77.8%	42.4	156.5		0.20			0.92	
Unit 2	0.110	0.111	1	Francis	7.52	16	3.06	1,180	90.0%	40.0	97.0	1.10	0.20	8.8	9.8	0.85	
Unit 3	0.111	0.220	2	Kaplan	8.70	5		1,195	77.8%	42.4	156.5		0.20			0.92	
Spill	0.669	0.331	0	bypass													0.03

	MODEL SIMULATION INPUT PARAMETERS	
n_f	5,000	Number of fish
μ	18.5	Mean length (inches)
σ	1.5	SD in length (inches)

	BLADE STRIKE SIMULATION RESULTS	
Turbine Strikes:	414 of 5000 fish	8.3%
Bypass Failures:	97 of 5000 fish	1.9%
Passed:	4489 of 5000 fish	89.8%

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Appendix I

Appendix I – Additional Intake Drawings

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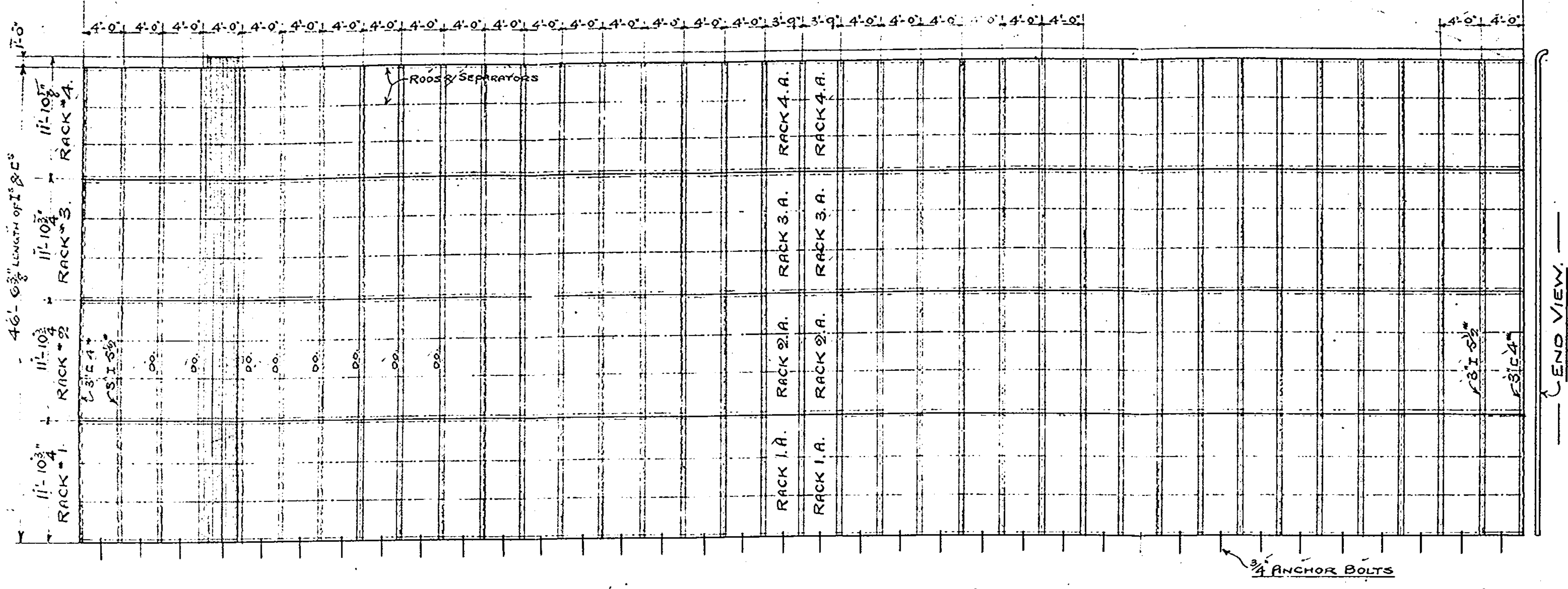
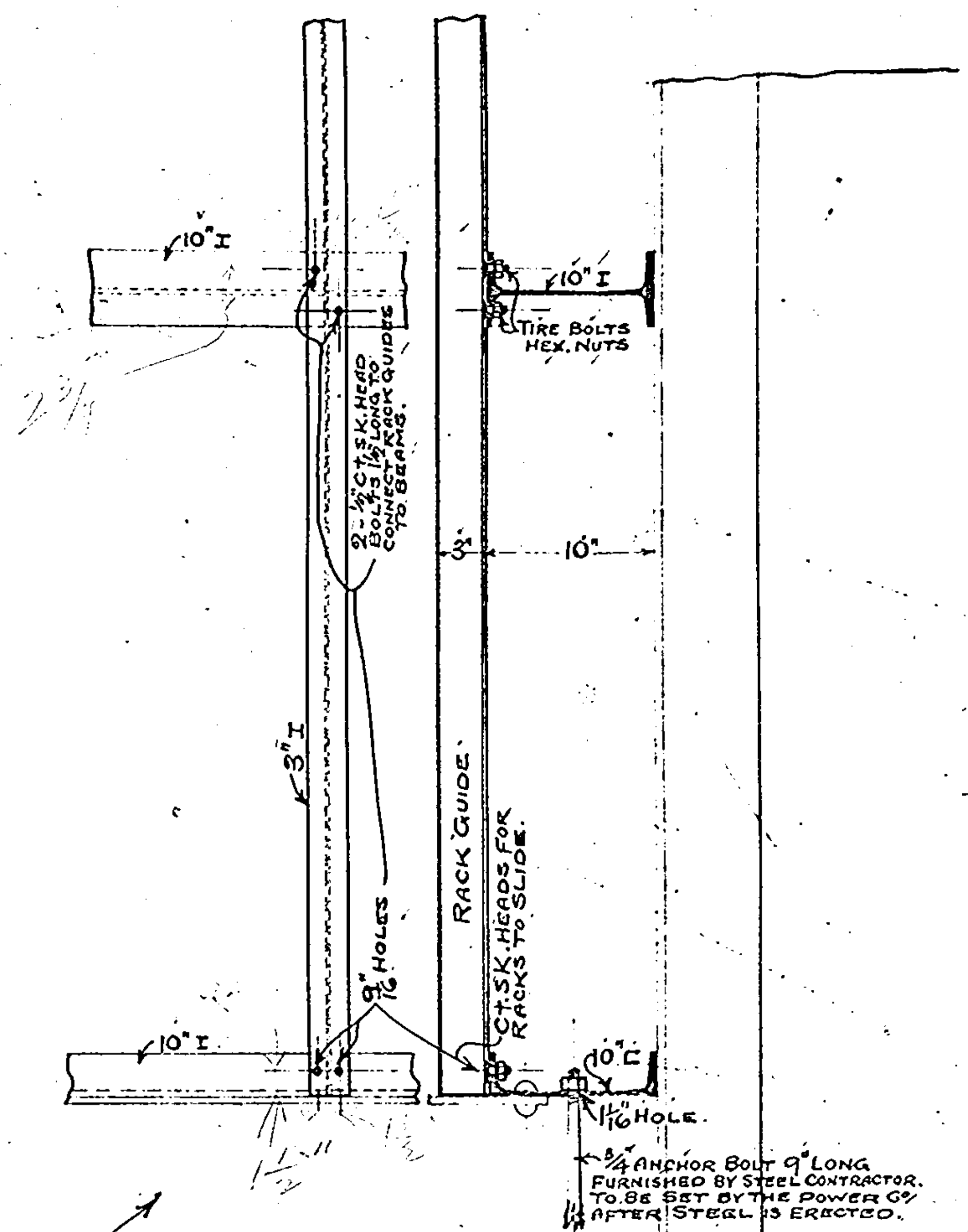
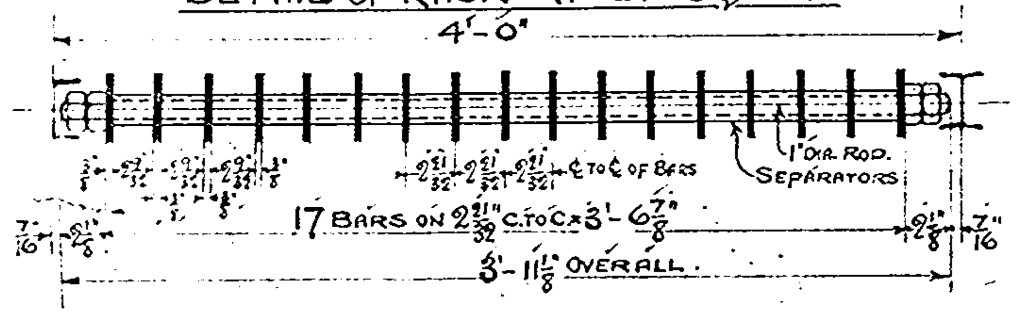


ASSEMBLY DIAGRAM OF RACKS & GUIDES.
SCALE 1/8" = 1 FOOT.

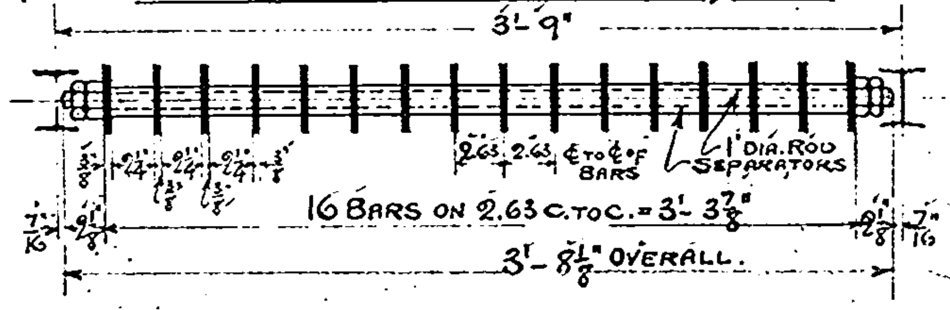


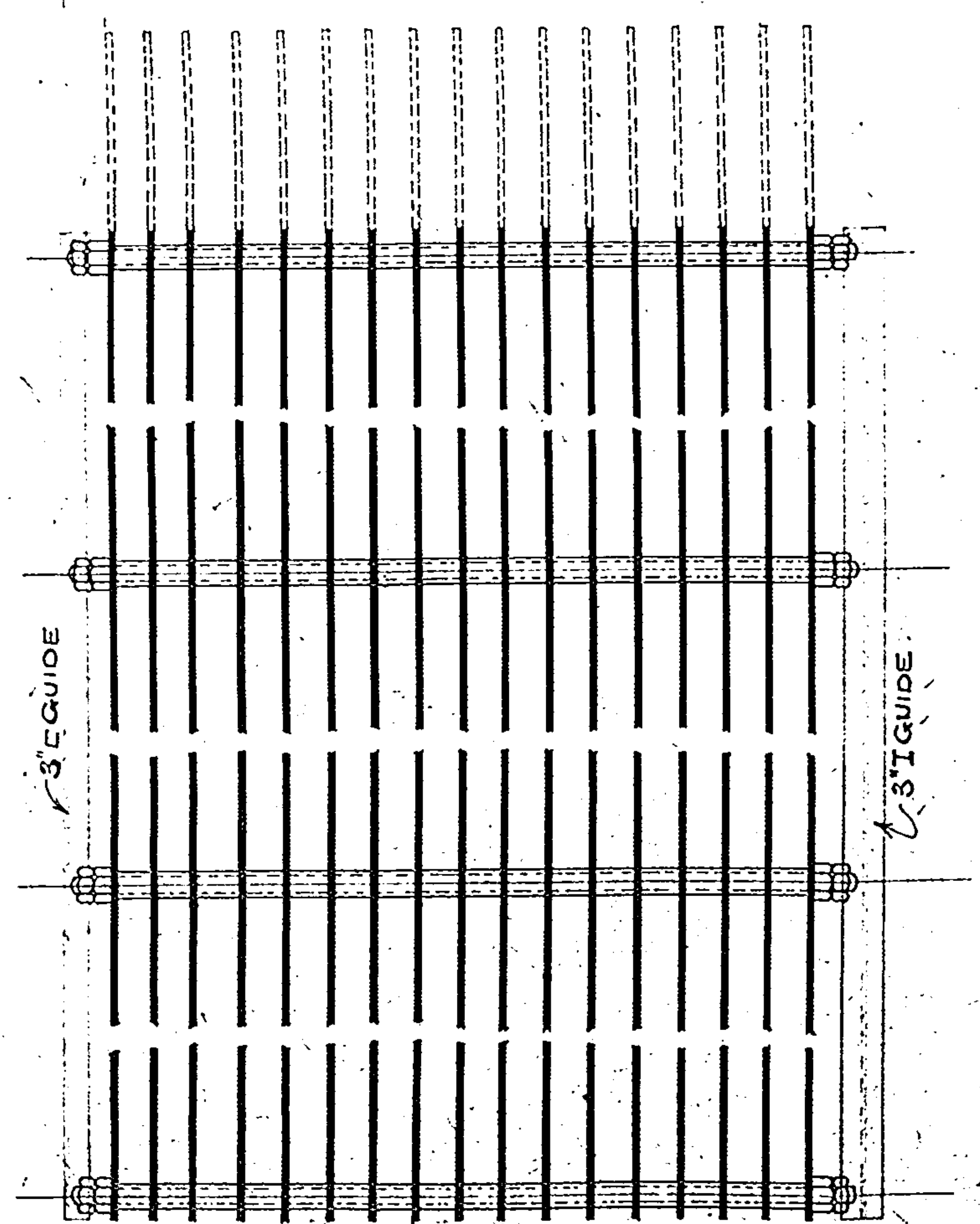
CONNECTIONS OF 3" I & 3" C RACK GUIDES TO 10" & 8" I's & C's.
SCALE 1 1/2" = 1 FOOT.

DETAIL OF RACK #1. #2. #3 & #4.

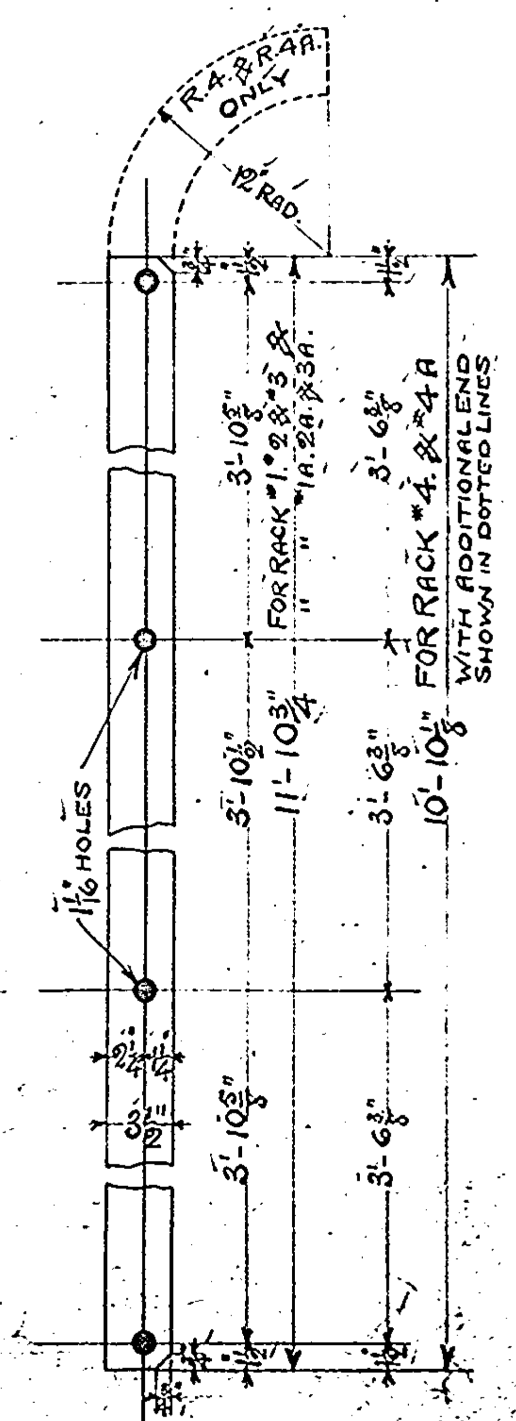


DETAIL OF RACK #1A. #2A. #3A & #4A.





DETAIL OF RACK.
SCALE 1 1/2" = 1 FOOT.



END VIEW GIVING LENGTHS FOR ALL RACKS.

4'-0" RACKS

BILL OF MATERIAL FOR RACKS #1. #2. & #3

DESCRIPTION	MARK	NO. REQ	SIZE	LENGTH	REMARKS.
BARS (STEEL)	R.1.	17	3 1/2" x 3/8"	11'-10 3/4"	SEE DETAIL
ROUND IRON RODS & 4 HEX. NUTS EACH	R.1.	4	1" DIA.	3'-11 1/8"	EXACT LENGTH. NUTS TO SUIT 3" C. SEE DETAIL
GAS PIPE SEPARATORS	R.1.	64	1 1/16" IN. DIA.	2 9/32" EXACT	STANDARD.

WANTED 34 RACKS COMPLETE #1.
" 34 " " #2.
" 34 " " #3.

BILL OF MATERIAL FOR RACK #4

DESCRIPTION	MARK	NO. REQ.	SIZE	LENGTH	REMARKS
BARS (STEEL)	R.4	17	3 1/2" x 3/8"		DEVELOPED LENGTH SEE DETAIL.
ROUND IRON RODS & 4 HEX. NUTS EACH	R.4	4	1" DIA.	3'-11 1/8"	EXACT LENGTH. NUTS TO SUIT 3" C. SEE DETAIL.
GAS PIPE SEPARATORS	R.4	64	1 1/16" IN. DIA.	2 9/32" EXACT	STANDARD

WANTED 34 RACKS COMPLETE #4

3'-9" RACKS

BILL OF MATERIAL FOR RACKS #1A. 2A. & 3A.

DESCRIPTION	MARK	NO. REQ	SIZE	LENGTH	REMARKS.
BARS (STEEL)	R.1A	16	3 1/2" x 3/8"	11'-10 3/4"	SEE DETAIL
ROUND IRON RODS & 4 HEX. NUTS EACH	R.1A.	4	1" DIA.	3'-8 1/8"	EXACT LENGTH. NUTS TO SUIT 3" C. SEE DETAIL
GAS PIPE SEPARATORS	R.1A	60	1 1/16" IN. DIA.	2 1/4" EXACT	STANDARD

WANTED 2 RACKS COMPLETE #1A.
" 2 " " #2A.
" 2 " " #3A.

BILL OF MATERIAL FOR RACK #4A.

DESCRIPTION	MARK	NO. REQ	SIZE	LENGTH	REMARKS
BARS (STEEL)	R.4A.	16	3 1/2" x 3/8"		DEVELOPED LENGTH SEE DETAIL
ROUND IRON RODS & 4 HEX. NUTS EACH	R.4A.	4	1" DIA.	3'-8 1/8"	EXACT LENGTH. NUTS TO SUIT 3" C. SEE DETAIL.
GAS PIPE SEPARATORS	R.4A.	60	1 1/16" IN. DIA.	2 1/4" EXACT	STANDARD.

WANTED 2 RACKS COMPLETE #4A.

GENERAL BILL OF MATERIAL

DESCRIPTION	MARK	NO. REQ	SIZE	LENGTH	REMARKS
TIRE BOLTS WITH HEX. NUTS		920	1/2" DIA.	1 1/2"	CT. SK. HEADS SEE DETAIL.
ANCHOR BOLTS WITH NUTS		36	3/4" DIA.	9"	FURNISHED BY STEEL CONTRACTOR
3" I 5 1/2#		35	3" I 5 1/2#	46'-6 3/8"	
3" C 4#		2	3" C 4#	46'-6 3/8"	

GENERAL NOTES:-
RACKS MUST BE STRAIGHT & TRUE SO THAT THEY CAN BE READILY PLACED IN POSITION. BUILD TO EXACT DIMENSIONS SHOWN SO THAT THEY WILL NOT SLIP OUT OF POSITION. NUTS ON RODS MUST BE OF DIMENSIONS SO AS TO ALLOW RACKS TO SLIDE IN THE 3" I's & 3" C's. MATERIAL, STEEL UNLESS NOTED. SHOP & FIELD CONNECTIONS BOLTED. SHOP PAINT #30 MARINE DETROIT GRAPHITE, FIELD COAT #106.

APPALACHIAN POWER CO.
DEVELOPMENT NO. 2.
DETAIL OF STEEL-WORK FOR INTAKE RACKS & GUIDES
SCALE 1/8" & 1 1/2" = 1 FOOT. DEC 21, 1911.
VIELE, BLACKWELL & BUCK. CONSULTING ENGINEERS. 49 WALL ST. NEW YORK
A-3976

CORREC. E. L. Broome APPROVED W. … Buck

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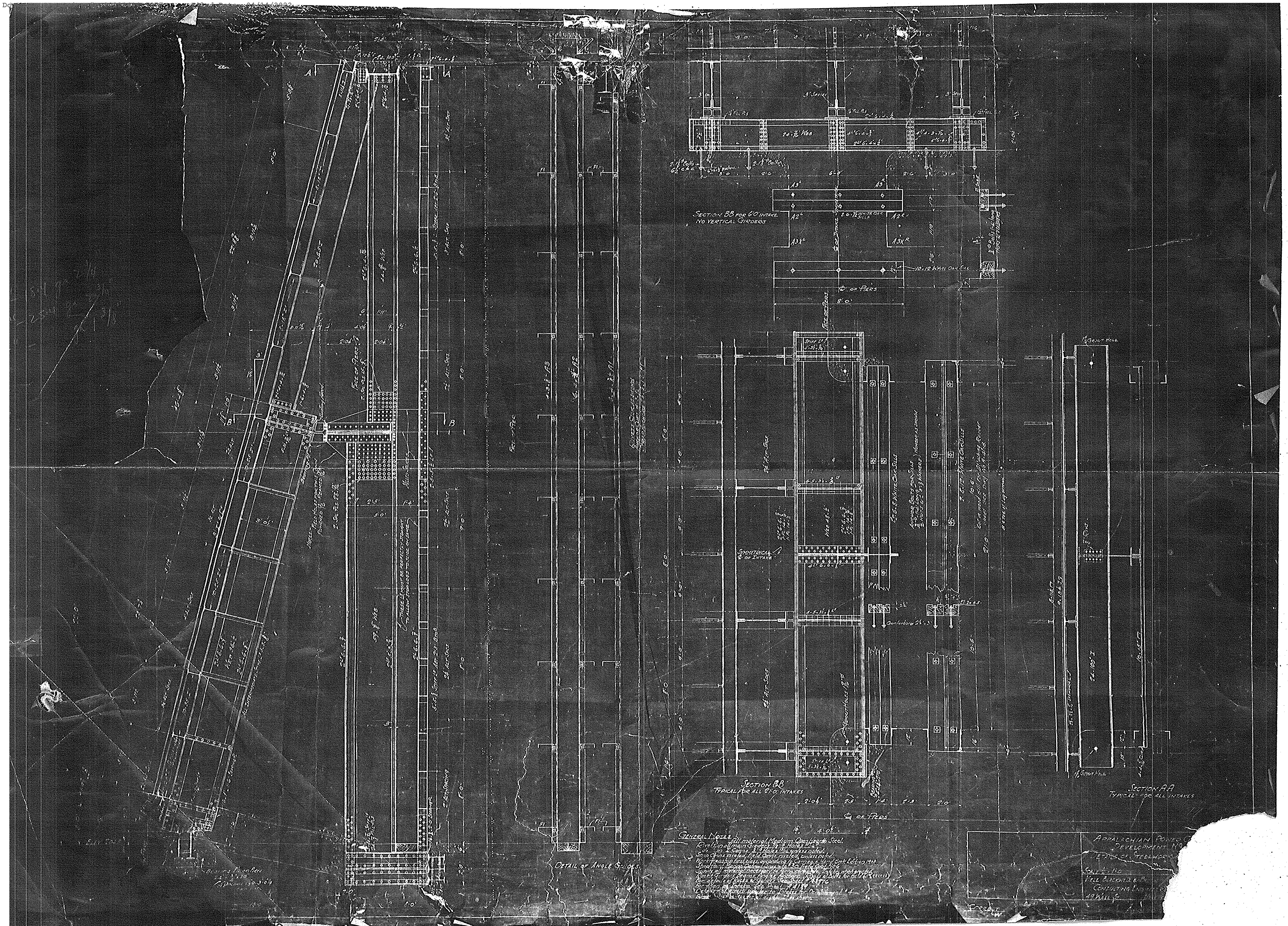

SECTION BB FOR 6'0" INTAKE
NO VERTICAL GIRDERS
SYMMETRICAL ℄ OF INTAKE
DETAIL OF ANGLE SPLICE
SECTION BB
TYPICAL FOR ALL 8'0" INTAKES
SECTION A-A
TYPICAL FOR ALL INTAKES
℄ OF PIERS
GENERAL NOTES
All material Medium Open Hearth Steel
Workmanship first class, according to Carnegie Handbook Edition 1903
For detail of Racks & Guides See Sheet A 3976
For Plan of Intake See Sheet A 4189
APPALACHIAN POWER
DEVELOPMENT No
Consulting Engineers
49 Wall St.

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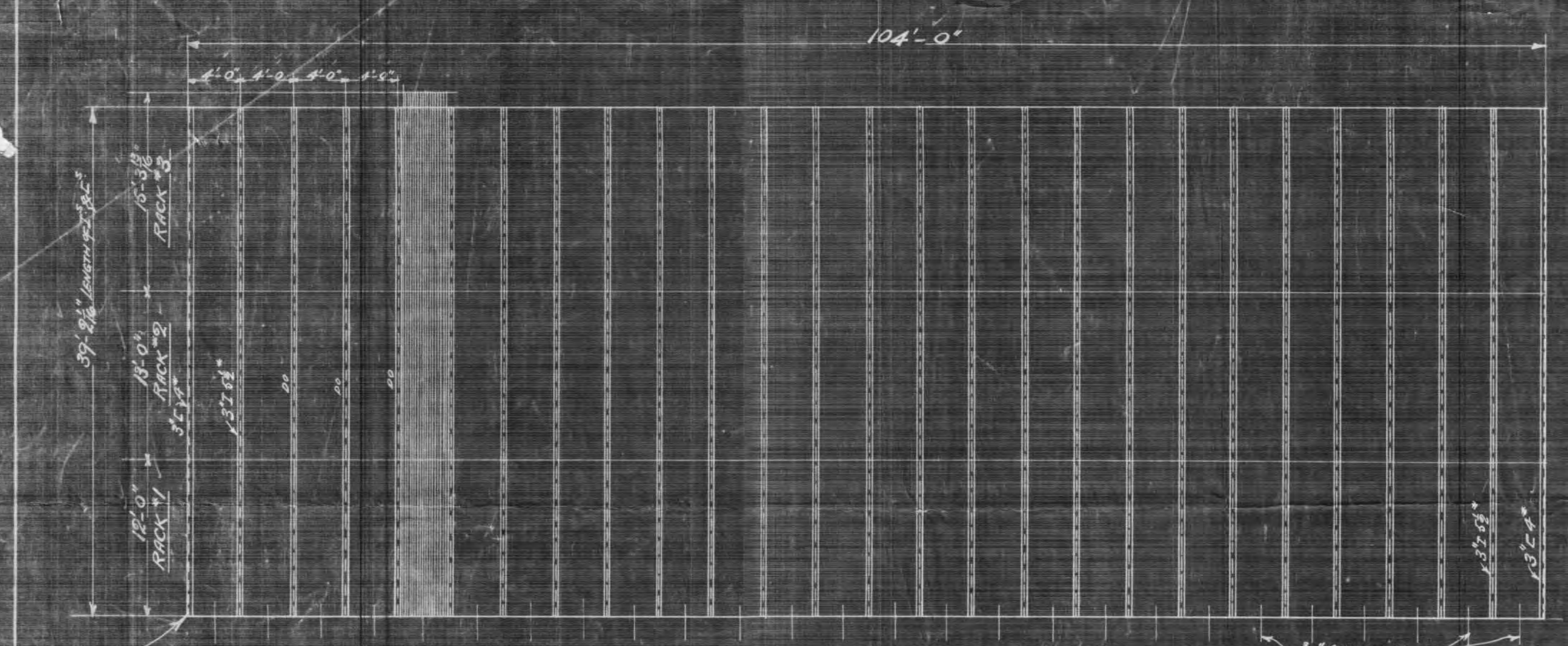
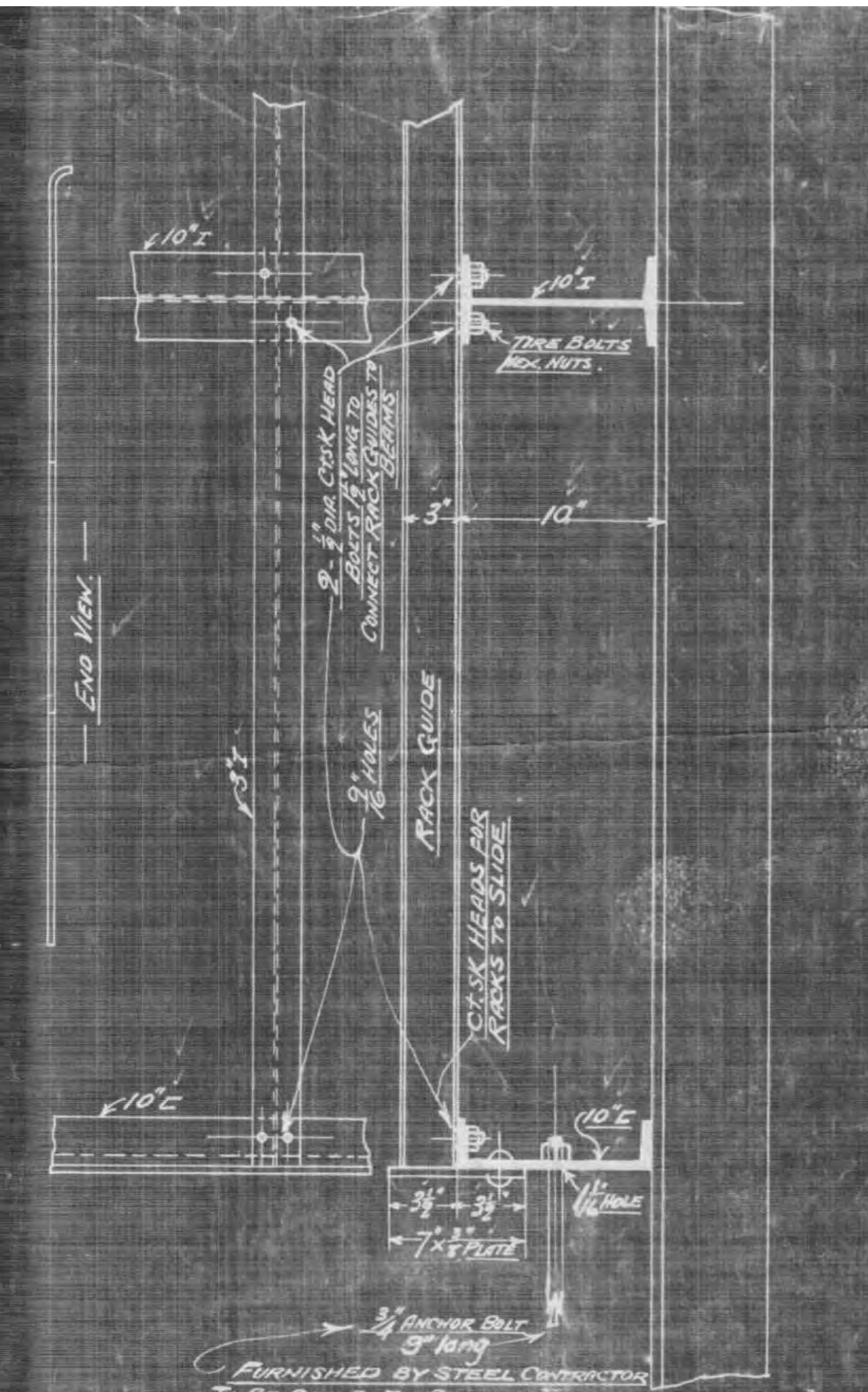
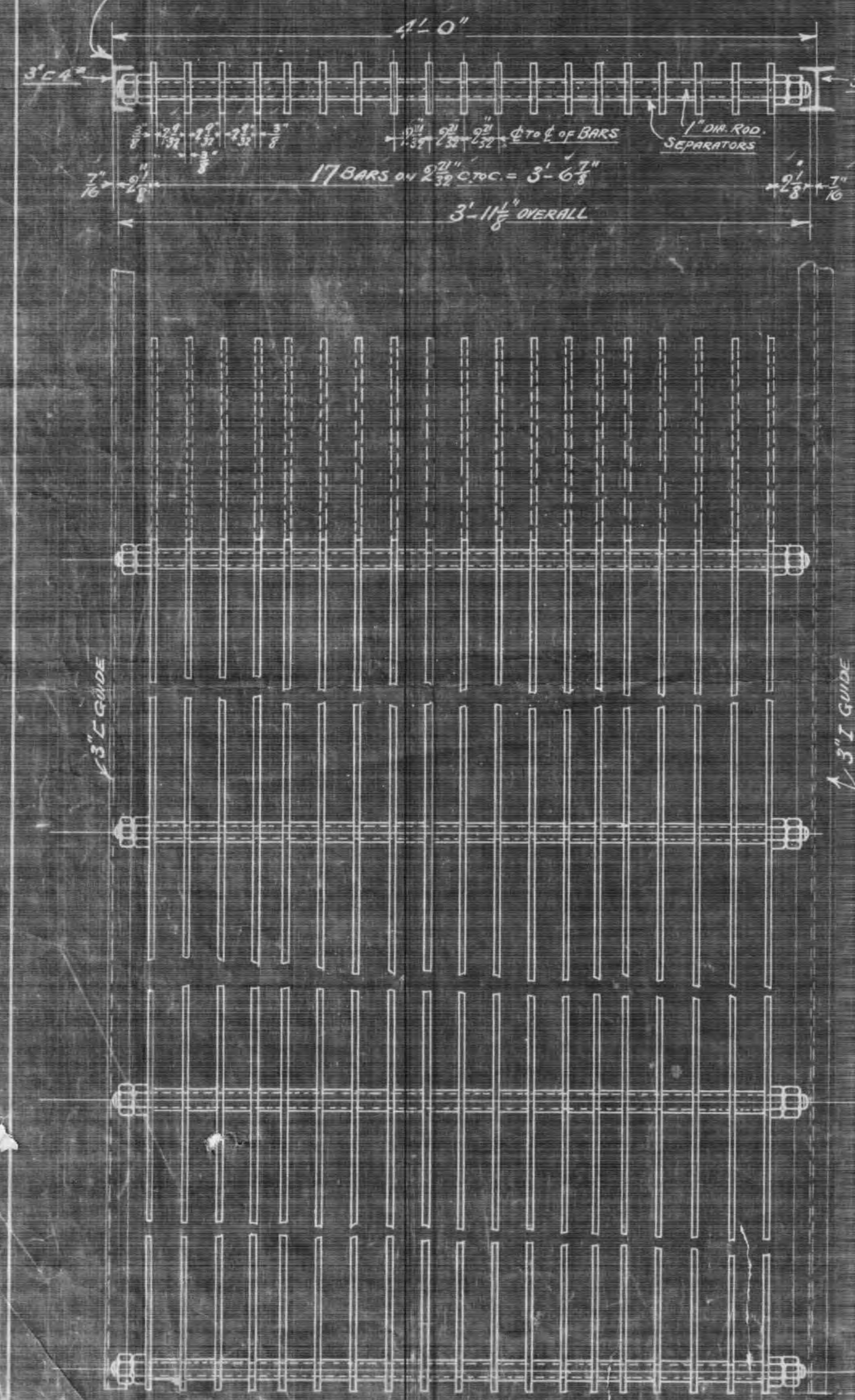


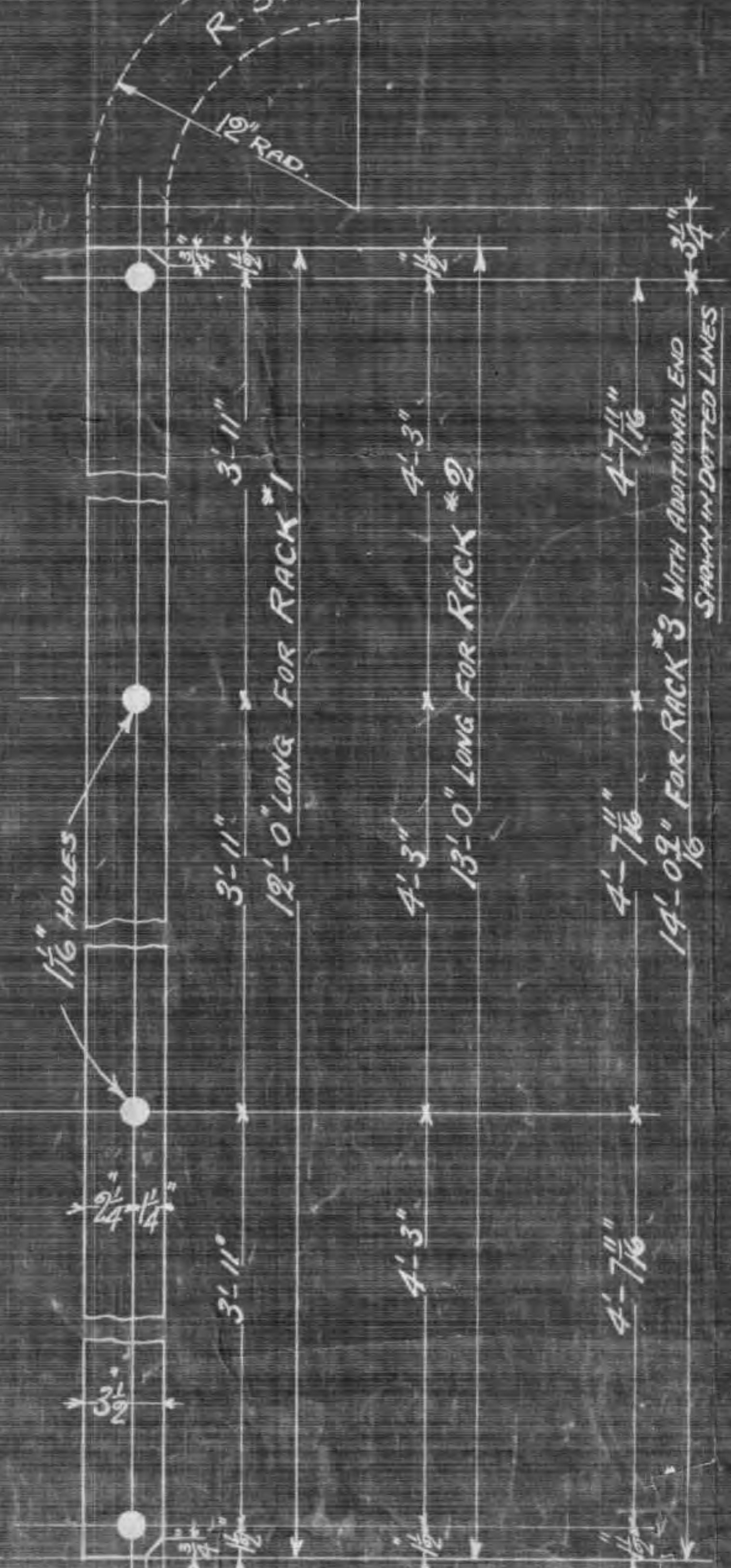
ASSEMBLY DIAGRAM OF RACKS & GUIDES
SCALE 1/8" = 1 FOOT



CONNECTIONS OF 3"I & 3"C RACK GUIDES TO 10" 9" & 7" I'S & C'S
SCALE 1 1/2" = 1 FOOT



DETAIL OF RACK
SCALE 1 1/2" = 1 FOOT



END VIEW GIVING LENGTHS
FOR RACK #1 RACK #2 & RACK #3

BILL OF MATERIAL FOR RACK #1. 26 REQ.					
DESCRIPTION	MARK	No. REQ.	SIZE	LENGTH	REMARKS
BARS (STEEL)	R.1.	17	3 1/2" x 3/8"	12'-0"	SEE DETAIL
ROUND IRON RODS & 4 HEX. NUTS EACH	R.1	4	1" DIA.	3'-11 1/8"	EXACT LENGTH. NUTS TO SUIT 3"C SEE DETAIL
GAS PIPE SEPARATORS	R.1	64	1 1/16" I. DIA.	2 9/32" (Exact)	STANDARD.

BILL OF MATERIAL FOR RACK #2 26 REQ.					
DESCRIPTION	MARK	No. REQ.	SIZE	LENGTH	REMARKS
BARS (STEEL)	R.2	17	3 1/2" x 3/8"	13'-0"	SEE DETAIL
ROUND IRON RODS & 4 HEX. NUTS EACH	R.2	4	1" DIA.	3'-11 1/8"	EXACT LENGTH. NUTS TO SUIT 3"C SEE DETAIL.
GAS PIPE SEPARATORS	R.2	64	1 1/16" I. DIA.	2 9/32" (Exact)	STANDARD.

BILL OF MATERIAL FOR RACK #3 26 REQ.					
DESCRIPTION	MARK	No. REQ	SIZE	LENGTH	REMARKS
BARS (STEEL)	R.3	17	3 1/2" x 3/8"		DEVELOPED LENGTH SEE DETAIL
ROUND IRON RODS & 4 HEX. NUTS EACH.	R.3	4	1" DIA.	3'-11 1/8"	EXACT LENGTH. NUTS TO SUIT 3"C SEE DETAIL.
GAS PIPE SEPARATORS	R.3	64	1 1/16" I. DIA.	2 9/32" (Exact)	STANDARD

GENERAL BILL OF MATERIAL					
DESCRIPTION	MARK	No. REQ	SIZE	LENGTH	REMARKS
TIRE BOLTS WITH HEX. NUTS		570	1/2" DIA.	1 1/2"	CT. SK. HEADS & SEE DETAIL
ANCHOR BOLT WITH NUT		26	3/4" DIA.	0'-9"	FURNISHED BY STEEL CONTRACTOR
3" I 5 1/2#		25	3" I 5 1/2#	39'-2 1/16"	
3" C 4#		2	3" C 4#	39'-2 1/16"	

GENERAL NOTES:-

RACKS MUST BE STRAIGHT & TRUE SO THAT THEY CAN BE READILY PLACED IN POSITION. BUILD TO EXACT DIMENSIONS SHOWN SO THAT THEY WILL NOT SLIP OUT OF POSITION. NUTS ON RODS MUST BE OF DIMENSIONS SO AS TO ALLOW RACKS TO SLIDE IN THE 3" I'S & C'S.

MATERIAL, STEEL UNLESS NOTED. SHOP & FIELD CONN'S BOLTED. SHOP PAINT #30 MARINE DETROIT GRAPHITE. FIELD COAT #106.

A-3836

Buck

APPALACHIAN POWER CO.
DEVELOPMENT #4
DETAIL OF STEELWORK FOR INTAKE RACKS & GUIDES
SCALE 1/8" & 1 1/2" - 1 FOOT
1911

VIELE, BLACKWELL & BUCK
CONSULTING ENGINEERS
49 WALL ST. NEW YORK

B. 3836

CORRECT E. C. Brooks APPROVED

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General Notes:-

All material Medium O.H. Steel.
Rivets 3/4" dia., holes 13/16" dia. unless otherwise noted
Shop connections riveted. - Field connections riveted unless otherwise noted.
Workmanship first class according to Carnegie Handbook, Edition-1903.
Shop Paint #30 Marine Detroit Graphite. Field coat #106
Supply all material necessary to form complete Intake when erected:-
Racks, Girders, Beams, Angles, Anchors, Rivets and Bolts for Field, (5% excess.)
For detail of Racks and Guides see Sheet- B3836.
For Plan of Intake see Sheet- B3851.

No.	DATE	REVISIONS
I	15/12/11	ADDED SKEW-BACK ANGLES ON 9" L
II	15/12/11	CUT 2' OFF ANGLE A-1 AT TOP

APPALACHIAN POWER CO.
DEVELOPMENT #4.
DETAILS OF STEELWORK FOR INTAKE

SCALE 1/2" & 1 1/2" = 1 FOOT. NOV. 1, 1911

VIELE, BLACKWELL & BUCK
CONSULTING ENGINEERS
49 WALL ST. NEW YORK.

A 3852

CORRECT: [signature] APPROVED: [signature]

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Attachment 3

Attachment 3 – 2020 – 2021 Macroinvertebrate and Crayfish Community Study Report

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Byllesby-Buck Hydroelectric Project
(FERC Project No. 2514)

2020-2021 Macroinvertebrate and Crayfish Community Survey Results, Virginia

Prepared for:

AMERICAN ELECTRIC POWER
BOUNDLESS ENERGY

Byllesby-Buck → HDR2020-0001

September 24, 2021

Prepared by:

EDGE ENGINEERING & SCIENCE
further insight.

Edge Engineering and Science, LLC
Cincinnati, Ohio

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LIST OF FIGURES

Figure 1: Overall Byllesby-Buck Project area including quantitative and qualitative macroinvertebrate survey sites on the New River in Carroll County, Virginia

Figure 2-6: Quantitative macroinvertebrate and crayfish 100-meter survey extents in riffle/run habitat in Carroll County, Virginia

Figure 7-13: Qualitative macroinvertebrate and crayfish 100-meter survey extents in mixed habitat in Carroll County, Virginia

APPENDICES

Appendix A. Scientific Collection Permits

Appendix B. Representative Photographs

Appendix C. Raw Data

LIST OF ACRONYMS

AEP	American Electric Power – Client
Appalachian	Appalachian Power Company
CFS	Cubic feet per second
CPUE	Catch per unit effort
DO	Dissolved oxygen
EDGE	Edge Engineering and Science, LLC
FERC	Federal Energy Regulatory Commission
HDR	HDR, Inc. – Client
ISR	Initial Study Report
LDB	Left descending bank
NRSA	National Rivers and Streams Assessment
Project	Byllesby-Buck Hydroelectric Project
RDB	Right descending bank
RSP	Revised Study Plan
SAV	Submerged aquatic vegetation
USFWS	U.S. Fish and Wildlife Service
USR	Updated Study Report
VAC	Virginia Administrative Code
VDCR	Virginia Department of Conservation and Recreation
VDEQ	Virginia Department of Environmental Quality
VDWR	Virginia Department of Wildlife Resources (formerly VDGIF)
VISAC	Virginia Invasive Species Advisory Committee

1.0 INTRODUCTION

The Byllesby and Buck Dams form the 30.1-megawatt Byllesby-Buck Hydroelectric Project (Project) located on the New River in Carroll County, Virginia. Appalachian Power Company (a unit of American Electric Power; AEP) is pursuing a new license for the Project as their existing license (FERC Project No. 2514) expires in 2024. Aquatic biological studies were completed to support existing FERC license and results of these studies are ultimately used as a record and reference for current relicensing efforts. The New River, along with the two contiguous impoundments resulting from the Byllesby Dam and the Buck Dam, harbors a diverse community of aquatic biota where aquatic biological studies are required to survey and document the contemporary community of organisms present within the Project area (Figure 1). The New River and lower reaches of tributary streams are included in the Project area. The information gained from these studies will document the current conditions of macroinvertebrate and crayfish abundance, diversity, and distribution in the vicinity of the Project.

Pre-licensing consultation with state and federal agencies resulted in the development and approval of a Project-specific Revised Study Plan (RSP) that identified two objectives for Project studies (AEP 2019) pertaining to the macroinvertebrate and crayfish community.

Goals and Objectives

1) Collect a baseline of existing macroinvertebrate and crayfish communities in the vicinity of the Project
2) Compare current aquatic resources data to historical data to determine any significant changes to species composition or abundance

In accordance with the RSP, field sampling efforts were necessary to satisfy each of the two objectives. Some of the objectives were not accomplished during the 2020 calendar year due to delays resulting from unforeseeable circumstances including the COVID-19 global pandemic; therefore, an Initial Study Report (ISR) was submitted on January 18, 2021. This report serves as the Update Study Report (USR) now that all field sampling efforts within the RSP have been completed.

2.0 METHODS

The RSP provided guidance on the biological sampling framework for the Project. Macroinvertebrate and crayfish sampling employ a variety of methods to target representative habitat at 16 sites throughout the Project area. The methods, number and location of sample sites, and seasonality were developed to document a comprehensive representation of the Project area and to correlate with previous sampling efforts for comparison. Replication of fall 2020 methods and sites occurred in spring 2021, both during the sample index period defined by Virginia Department of Environmental Quality (VDEQ) Biological Monitoring Program Quality Assurance Project Plan (VDEQ 2008).

2.1 Macroinvertebrate and Crayfish Community

The macroinvertebrate and crayfish study, detailed in the RSP, consists of two temporally independent efforts (one survey in fall and one survey in spring). Specific sampling dates within these timeframes are determined based on factors including (but not limited to) weather conditions, water temperatures, river flows and reservoir elevations, and safety of field staff and the public. Sampling methods were derived from National Rivers and Streams Assessment (NRSA) Field Operations Manual (USEPA 2019) and VDEQ (2008) and include quantitative and qualitative sampling methods that target different habitats. Within the constraints of the Project's objectives and geographic limits, quantitative sampling targets riffle/run habitats and qualitative sampling targets available microhabitats in pools. A variety of sampling techniques were used to sample macroinvertebrates using quantitative and qualitative methods as described in subsequent sections. Six sample sites were located upstream of the Byllesby Dam (two quantitative and four qualitative), eight sites were between Byllesby Dam and Buck Dam (four quantitative and four qualitative), and two sites were downstream of Buck Dam (both quantitative). Site naming conventions are as follows: Location-Seasonality-Method-Site Number. For example, BFQT1 = Byllesby-Buck Fall Quantitative Site 1, BFQL3 = Byllesby-Buck Fall Qualitative Site 3, and BSQL3 = Byllesby-Buck Spring Qualitative Site 3.

The sampling methods used to quantify macroinvertebrates only allows for the determination of presence of crayfish. To assess the crayfish community in the Project area, additional kick samples and seining efforts were performed following benthic macroinvertebrate sampling to ensure all crayfish habitat had been covered and that a broad representation of crayfish species available at each site was documented. The exact abundance of crayfish was not recorded because methods used are not crayfish specific and simply provide presence data.

2.1.1 Quantitative Sampling

Sampling for benthic macroinvertebrates and crayfish occurred at eight riffle/run sites (i.e., quantitative; BFQT and BSQT site names) along 100-meter transects following guidelines defined by USEPA (2019) and VDEQ (2008). Upon arrival at riffle/run sites (Figures 1-6), transects were delineated in riffle/run habitat and the start and endpoint coordinates were recorded. Site photos were taken in four directions (upstream, downstream, left descending bank [LDB], and right descending bank [RDB]; all 90 degrees to one another) and substrate, and field conditions were recorded (e.g., time, date, temperature, precipitation, cloudy/overcast, etc.). At each sample site, habitat characteristics (e.g., substrate, estimated water velocity, depth, and instream cover) and water quality parameters (e.g., pH, water temperature, dissolved oxygen [DO], and conductivity) were measured and recorded. Multiple points for habitat and water quality measurements were taken if there was large variation within a single site. Sampling effort (e.g., time, number of samples) was also recorded during each sampling event.

Starting at the downstream end of a transect and moving upstream, all riffle/run habitats were candidates for sampling throughout the reach. Sampling was conducted holding the D-frame net on the bottom of the stream perpendicular to flow and kicking substrate to agitate and dislodge organisms, allowing them to flow into the net. A single kick consists of disturbing the substrate upstream of the net by kicking with the feet and/or by using the hands to dislodge the cobble/boulder for 30-90 seconds. For example, a single sample was a composite of six kick sets, each disturbing approximately 0.33 m^2 above the dip net for a duration of 30-90 seconds and totaled an area comprising 2 m^2. The composited sample was washed by running clean stream water through the net 2-3 times and then transferred to a sieve (500 µm) if needed. For QA/QC measures, replicate sampling was conducted at one quantitative site within close proximity (not in the same locations as the first set of samples) of the initial sampling area. This replicate sample was completed between Byllesby Dam and Buck Dam (one from fall 2020 and one from spring 2021) and was included in data analysis.

2.1.2 Qualitative Sampling

Benthic macroinvertebrates and crayfish were also sampled at eight qualitative sites (i.e., multi-habitat; BFQL and BSQL site names) along 100-meter transects following guidelines defined by USEPA (2019) and VDEQ (2008). At pool sites (Figure 1 and Figures 7-13), transects were delineated in near-shore pool habitats and the start and endpoint coordinates were recorded. Site photos, field conditions, habitat characteristics, and water quality parameters were recorded in the same manner as quantitative sites (see Section 2.1.1). In addition, a Secchi disk reading was taken at each sample site at the time of sampling to assess water transparency. Multiple points for habitat and water quality measurements were taken if there was large variation within a single site.

A canoe was necessary to collect qualitative samples along each of the transects starting at the downstream end and moving upstream. Sampling was conducted by performing 20 jabs with a D-frame net into suitable, stable habitats (snags, vegetation, banks, and substrate). A single jab consists of forcefully thrusting the net into a microhabitat for a linear distance of 1.0 meter, followed by 2-3 sweeps of the same area to collect dislodged organisms for 20-90 seconds per jab, sweep, or kick. Multiple types of habitat were sampled in rough proportion to their frequency within the reach. Unique habitat types (i.e., those consisting of less than 5 percent of stable habitat within the sampling reach) were not sampled. Sampling effort was proportionally allocated (20 jabs/sweeps/kicks) to shore-zone and bottom-zone, 20-90 seconds per jab, sweep, or kick. Samples were cleaned and transferred to the sieve bucket at least every five jabs; or more often as necessary. At one qualitative site, replicate sampling was conducted within the initial sampling area in close proximity (not in the same locations as the first set of samples). This replicate sample was completed upstream of Byllesby Dam (one from fall 2020 and one from spring 2021) and was included in data analysis. All samples were preserved and processed in the same manner as quantitative methods (see Section 2.1.1).

2.1.3 Laboratory Processing

All field samples were preserved in 95% ethanol, placed in labeled jars, and sent to Civil & Environmental Consultants, Inc. (CEC) for processing and identification to the lowest practicable taxonomic level. Laboratory processing was performed in accordance with the VDEQ standard operating procedures "Methods for Laboratory Sorting and Subsampling of Benthic Macroinvertebrate Samples" (VDEQ 2008). Photo vouchers were taken of all unique or rare species collected. At the completion of the study, a summary of species and numbers collected will be provided to VDWR in compliance with the scientific collection permit specifications.

2.1.4 Data Analysis

The Virginia Stream Condition Index (VSCI) (Burton and Gerristen 2003) was employed to investigate the impairment of the New River within the Project area using eight metrics of the macroinvertebrate community. These metrics include (1) Total Taxa, (2) EPT Taxa (*Ephemeroptera* [mayflies], *Plecoptera* [stoneflies], and *Trichoptera* [caddisflies]), (3) Percent Ephemeroptera, (4) Percent Plecoptera plus Trichoptera less Hydropsychidae, (5) Percent Scrapers, (6) Percent Chironomidae, (7) Percent Top Two Dominant taxa, and (8) the Hilsenhoff Biotic Index (HBI). For the purposes of this study, and in agreement with VDEQ methods, all VSCI scores were calculated at family-level taxonomy. "Reference" conditions are a collection of aspects shared by streams deemed unimpaired within the region. The results of the VSCI scores determine the level of impairment at a specific site with scores over 80 indicating "reference" conditions, scores between 60 and 79 indicating "similar to reference" conditions, and scores below 60 indicating "impaired" conditions. VSCI scores were calculated by site and by season

(Appendix C). The site VSCI scores were also used to make qualitative comparisons of overall reach conditions between different Project areas (i.e., upstream of Byllesby Dam, between Byllesby and Buck Dam, and downstream of Buck Dam).

2.2 Deviations from Revised Study Plan

2.2.1 COVID-19 Delays

The initial field sampling plan called for spring and fall 2020 events; however, the COVID-19 pandemic, and subsequent restrictions on non-essential travel and safety considerations for field staff, prohibited spring 2020 field efforts. As a result, AEP requested and was granted an extension to accommodate the change in schedule as the VDEQ, U.S. Fish and Wildlife Service (USFWS), Virginia Department of Wildlife Resources (VDWR), and Virginia Department of Conservation and Recreation (VDCR) all concurred with adaptable schedule revisions. EDGE was contracted and given notice to proceed with fieldwork at the beginning of September 2020 and was able to complete the fall 2020 sampling event. Thus, spring macroinvertebrate and crayfish sampling was completed during spring 2021.

2.2.2 Weather Delays

Periodic delays associated with weather and stream conditions plagued the fall 2020 field study season. Average rainfall for Galax, Virginia (collected at this station since 1981) is approximately 26 centimeters between September 1 and December 1 (US Climate Data 2020); yet during the same three-month period in 2020, Galax accumulated over 37 centimeters of rain, a 42 percent increase (USGS 2020). Therefore, the fall 2020 sampling efforts were completed at the baseflows around 1,700 to 2,000 cubic feet per second (cfs), which at the time were the assumed baseflows for 2020. As a result of the 42 percent increase from average precipitation that occurred in 2020, the study area portion of the New River remained elevated well above the average annual baseflow conditions throughout the fall 2020 field study season. Spring 2021 flows more closely matched average flows during the sampling period.

3.0 RESULTS

Study samples were collected as closely as possible to the locations proposed in the RSP. Upon arrival at each proposed sample location, field biologists delineated the sample transect in the nearest location exhibiting the target habitat type (i.e., riffles, pools, etc.) using habitat-specific sampling methodologies. No notable or significant changes were made to proposed sampling locations for macroinvertebrate and crayfish survey efforts.

3.1 Macroinvertebrate and Crayfish Community

Macroinvertebrate samples were collected from 16 sites between October 6 and 8, 2020, during the fall sample index period (September 1 – November 30) and between April 20 and 23, 2021, during the spring sample index period (March 1 – May 31), as defined by VDEQ (2008). Sampling was performed by EDGE's state and federally permitted astacologist under Virginia Scientific Collecting Permit No. 070705 (see Appendix A). Visible differences in habitat and substrate types between sites were documented (Appendix B); however, differences in sampling dates, time of day, and low number of intra- and inter-site samples prevented a statistical comparison of physiochemical properties between sites. The resulting physiochemical data from each of the sample sites met the state water quality standards established for the New River (Virginia Administrative Code [VAC] Chapter 260), indicating that water quality conditions within the Project area are capable of supporting macroinvertebrate communities. Additional water quality data are provided in the Water Quality Study Report provided in the Project USR.

3.1.1 Upstream of Byllesby Dam

The substrate at quantitative macroinvertebrate sites upstream of Byllesby Dam consisted primarily of bedrock (25%), boulder (25%), cobble (20%), gravel (15%), and sand (15%) (Figure 1). Although instream habitat at these sites was relatively complex and conducive to macroinvertebrate and crayfish colonization, no crayfish were collected from these sites during the fall 2020 or spring 2021 sampling events. The substrate at qualitative macroinvertebrate sites upstream of Byllesby Dam generally consisted of sand (70%), silt (20%), gravel (5%), and boulder (5%). The impoundment upstream of Byllesby Dam exhibits predominantly steep sloped shorelines that converge toward the center of the channel. Along the LDB, many of the sample sites were located in lower gradient sections adjacent to vegetated floodplains; while sites located along the RDB were located in higher gradient habitats adjacent to rocky outcrops or steep rock face (Appendix B). The habitat structure at most sample sites within the Byllesby Pool generally consisted of sparse woody debris, submerged aquatic vegetation (SAV), and scattered boulders. Water quality parameters (temperature, pH, DO, and conductivity) remained relatively consistent throughout the Byllesby Pool, with the exception of velocity, which was slightly higher in the two upstream most sites near the head of the impoundment (Appendix C).

A total of 49 macroinvertebrate taxa were collected upstream of Byllesby Dam from two quantitative sites and four qualitative sites, along with the Spiny Stream Crayfish (*Faxonius cristavarius*), which was collected from a qualitative site near the dam. The average VSCI score for riffle/run sites and pool sites sampled upstream of Byllesby Dam in fall 2020 were 57.3 and 35.8, respectively, and only a single site (BFQT1) resulted in a “similar to reference” score above 60 (62.7) (Appendix C). The average VSCI score for riffle/run sites and pool sites sampled upstream of Byllesby Dam in spring 2021 were 65.9 and 26.9, respectively, and the same site (BSQT1) was the only site resulting in a “similar to reference” score above 60 (75.1). However, four sites in this Project area had HBI values indicating “Good” to “Excellent” water quality during the fall and spring sampling events based on the tolerance of the macroinvertebrate community. Two of these four sites were in riffle/run habitat and two were in pool habitat.

3.1.2 Between Byllesby Dam and Buck Dam

The substrate at quantitative macroinvertebrate sites between the Byllesby Dam and Buck Dam was comparable to that in the first two sites above Byllesby Dam, except higher percent bedrock at site BFQT7 (Bypass Reach), higher percent cobble at site BFQT8 (Figure 3), and higher percent gravel at site BFQT11 (Figure 4). All types of riffle/run habitat present between the dams was surveyed, from low-gradient riffles with relatively small substrate and no instream cover to high-gradient riffles with relatively large substrate and substantial instream cover. Conhoway Crayfish (*Cambarus appalachiensis*) and Spiny Stream Crayfish were both collected at quantitative sites within this Project area, with both species occurring at site BFQT7, the former also occurring at site BFQT10, and the latter also occurring at site BFQT11. Water quality parameters (temperature, pH, DO, velocity, and conductivity) remained relatively consistent throughout all quantitative sites except velocity (Appendix C), which often changed drastically within a single transect.

The substrate at qualitative macroinvertebrate sites between the Byllesby Dam and Buck Dam generally consisted of sand (60%), silt (20%), boulder (15%), and gravel (5%). Many of the sites along the LDB exhibited a low-gradient and were adjacent to a vegetated floodplain, whereas many of the sites along the RDB were located in a high-gradient area, adjacent to a rock face (Appendix B). The upstream portion of the Buck Pool was relatively shallow with a consistent depth across the width of the stream, whereas the downstream portion of the pool had shallow banks that rapidly descended towards the center of the channel. The habitat structure at most sites within the Buck Pool generally consisted of sparse woody debris, submerged aquatic vegetation (SAV), and scattered boulders. Spiny Stream Crayfish were collected at two qualitative sites within this Project area. Water quality parameters (temperature, pH, and conductivity) remained relatively consistent throughout the Buck Pool, except DO and velocity, which were higher toward the upstream end of the impoundment, just below a section of high-gradient riffles (Appendix C).

A total of 53 macroinvertebrate taxa were collected between the Byllesby Dam and Buck Dam from four quantitative sites and four qualitative sites. The average VSCI score for riffle/run sites and pool sites sampled between Byllesby Dam and Buck Dam in fall 2020 were 62.9 and 39.5, respectively, and four sites (three riffle/run and one pool) resulted in a “similar to reference” score above 60 (Appendix C). The average VSCI score for riffle/run sites and pool sites sampled between Byllesby Dam and Buck Dam in spring 2021 were 54.9 and 36.0, respectively, but only three sites (all riffle/run) resulted in a “similar to reference” score above 60. Four sites in this Project area had HBI values indicating “Good” to “Very Good” water quality during the fall sampling events and seven sites indicating “Good” to “Excellent” water quality during the spring based on the tolerance of the macroinvertebrate community.

3.1.3 Downstream of Buck Dam

The substrate at quantitative macroinvertebrate sites downstream of the Buck Dam generally consisted of bedrock (35%), boulder (25%), cobble (20%), gravel (15%), and sand (5%) in the Bypass Reach site (Figure 5) where the primary habitat is well-developed riffle. Bedrock (25%), boulder (25%), cobble (20%), gravel (15%), and sand (15%) were dominant substrates in the site downstream of the Bypass Reach (Figure 6) where the primary habitat structure is more typical of run habitats than riffles, with sporadic undercut banks and overhanging vegetation. Conhoway Crayfish and Spiny Stream Crayfish were collected at both quantitative sites within this Project area. Water quality parameters (temperature, pH, DO, and conductivity) remained relatively consistent throughout all quantitative sites except velocity (Appendix C), which often changed drastically within a single transect.

A total of 30 macroinvertebrate taxa were collected from two quantitative sites located downstream of the Buck Dam. The average VSCI score for riffle/run sites sampled below Buck Dam in fall 2020 and spring 2021 were 58.8 and 59.0, respectively, and one of two sites (BF/BSQT15) resulted in a “similar to reference” score above 60 during both sampling events (Appendix C). One of two sites in the fall and both sites in the spring had HBI values indicating “Good” to “Very Good” water quality based on the tolerance of the macroinvertebrate community.

4.0 DISCUSSION

4.1 Macroinvertebrate and Crayfish Community

Benthic macroinvertebrate and crayfish community metrics can be used as indicators of water quality, as these organisms often exhibit sensitivity to changing water quality conditions, and because they serve as a food resource for fish and other fauna in the riverine community. A healthy stream generally includes habitat diversity and limited pollution, often indicated by a high VSCI and HBI score (standard biological metrics). The Mustached Clubtail (*Gomphus adelphus*) and the Pygmy Snaketail (*Ophiogomphus howei*) were identified as species with potential to occur in the Project vicinity by VDCR in a letter dated September 23, 2017. The presence of these "species of greatest conservation need" would indicate relatively high water quality. The Pygmy Snaketail was collected from the New River near the Fries Project (Carey et al. 2017), which is located approximately 13 river kilometers upstream of the Byllesby-Buck Project. Prior to the present study, no macroinvertebrate data were available for the Project and the presence of the Mustached Clubtail and Pygmy Snaketail were unknown for the Project reach of the New River. Although *Gomphus* sp. were collected during both the fall and spring sampling events, none were identified as the Mustached Clubtail.

VSCI scores recorded at each site were relatively similar between the fall and spring, but substantially greater at riffle/run sites (quantitative) than pool sites (qualitative). VSCI scores at riffle/run sites were the lowest of the three Project areas in fall 2020 but the highest in spring 2021, although they were relatively consistent throughout the entire Project area. VSCI scores show at least one site upstream of the Byllesby Dam, between Byllesby Dam and Buck Dam, and downstream of Buck Dam was characterized as "similar to reference" conditions in fall 2020 and spring 2021. HBI scores at two riffle/run sites above the Byllesby Dam and two riffle/run sites below Buck Dam indicate better water quality at the upstream extent of the Project area as opposed to the downstream extent.

Crayfish surveys were also completed as part of the Fries Project, where Spiny Stream Crayfish were the only species collected (Carey et al. 2017); however, prior to the current study, no site-specific information on crayfish populations in the Project reach of the New River were available. Approximately 33 species of crayfish, including non-indigenous and/or invasive species such as Virile Crayfish (*Orconectes virilis*), have been documented in waterbodies throughout Virginia (VDGIF 2018; VISAC 2018). The Virile Crayfish was collected at the Claytor Project (DTA 2008) located 70 river kilometers downstream of the Byllesby-Buck Project.

One of two species of crayfish was collected upstream of Byllesby Dam, but both species were collected between Byllesby and Buck dam, and downstream of Buck Dam. There were zero crayfish captured at the two quantitative sites upstream of Byllesby Dam and both species of crayfish were captured at both quantitative sites below Buck Dam. These sites had similar substrate and habitat composition and relatively similar physiochemical parameters. Conhoway Crayfish were observed under large boulders both near the bank and further channelward, while the Spiny Stream Crayfish were concentrated in cobble and near shore cover. Overall, the presence of two relatively abundant native crayfish species and zero invasive crayfish species in the Project vicinity may indicate a healthy community.

5.0 LITERATURE CITED

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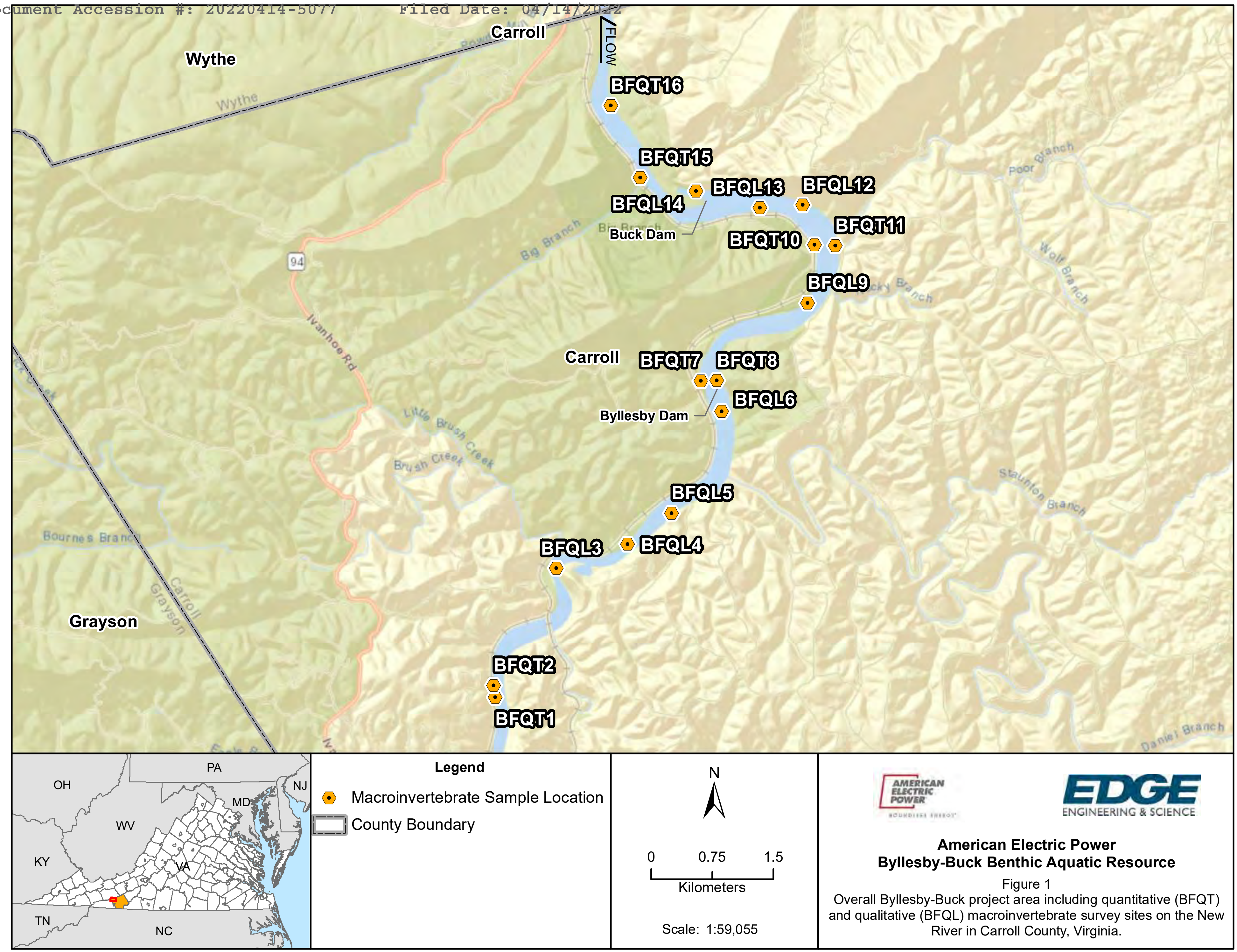
Figures



Legend

Macroinvertebrate Sample Location

County Boundary

N

0 0.75 1.5

Kilometers

Scale: 1:59,055

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Figure 1
Overall Byllesby-Buck project area including quantitative (BFQT) and qualitative (BFQL) macroinvertebrate survey sites on the New River in Carroll County, Virginia.

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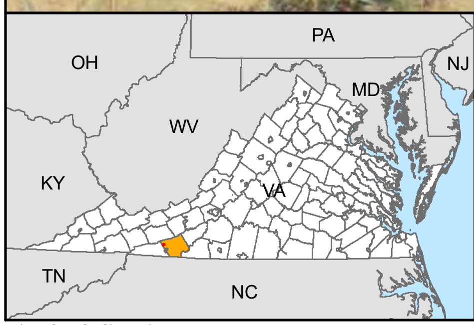

Legend

- Macroinvertebrate Sample Location
- Macroinvertabrate Sampling Transect

N

0 50 100
Meters

Scale: 1:3,937

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Figure 2
Quantitative macroinvertebrate and crayfish 100-meter survey extent in riffle/run habitat in Carroll County, Virginia.

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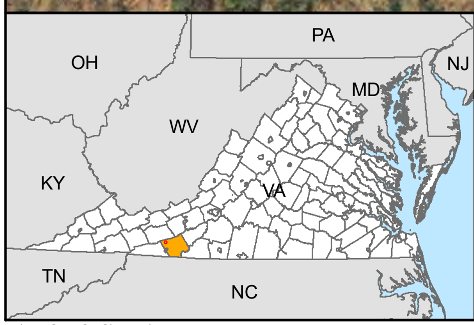

Legend

- Macroinvertebrate Sample Location
- Macroinvertabrate Sampling Transect

N

0 50 100
Meters

Scale: 1:3,937

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Byllesby-Buck Benthic Aquatic Resource

Figure 3
Quantitative macroinvertebrate and crayfish 100-meter survey extent in riffle/run habitat in Carroll County, Virginia.

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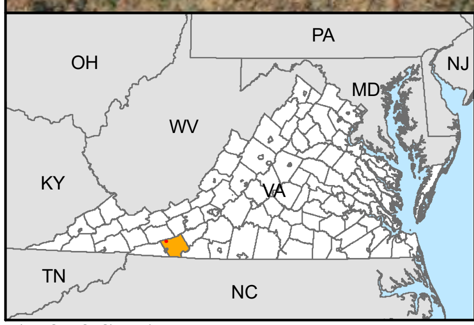

Legend

- Macroinvertebrate Sample Location
- Macroinvertabrate Sampling Transect

N

0 50 100
Meters

Scale: 1:3,937

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Byllesby-Buck Benthic Aquatic Resource

Figure 4
Quantitative macroinvertebrate and crayfish 100-meter survey extent in riffle/run habitat in Carroll County, Virginia.

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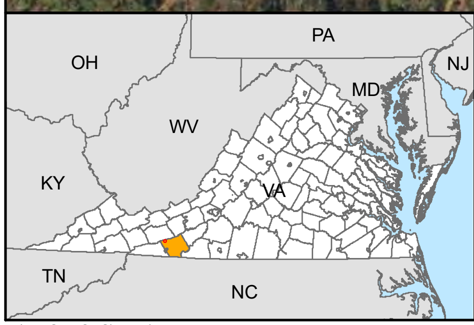

Legend

- Macroinvertebrate Sample Location
- Macroinvertabrate Sampling Transect

N

0 50 100
Meters

Scale: 1:3,937

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Byllesby-Buck Benthic Aquatic Resource

Figure 5
Quantitative macroinvertebrate and crayfish 100-meter survey extent in riffle/run habitat in Carroll County, Virginia.

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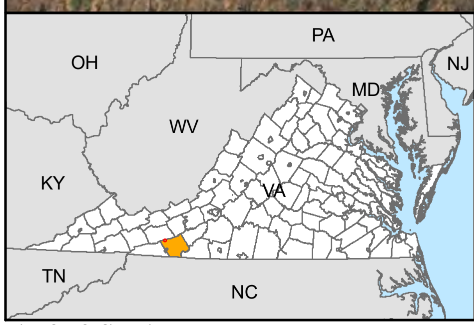

Legend

- Macroinvertebrate Sample Location
- Macroinvertabrate Sampling Transect

N

0 50 100
Meters

Scale: 1:3,937

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Byllesby-Buck Benthic Aquatic Resource

Figure 6
Quantitative macroinvertebrate and crayfish 100-meter survey extent in riffle/run habitat in Carroll County, Virginia.

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Legend

- Macroinvertebrate Sample Location
- Macroinvertabrate Sampling Transect

N

0 50 100
Meters

Scale: 1:3,937

AMERICAN ELECTRIC POWER

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Byllesby-Buck Benthic Aquatic Resource

Figure 7
Qualitative macroinvertebrate and crayfish 100-meter survey extent in mixed habitat in Carroll County, Virginia.

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Legend

- Macroinvertebrate Sample Location
- Macroinvertabrate Sampling Transect

N

0 50 100

Meters

Scale: 1:3,937

AMERICAN ELECTRIC POWER

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American Electric Power
Byllesby-Buck Benthic Aquatic Resource

Figure 8
Qualitative macroinvertebrate and crayfish 100-meter survey extent in mixed habitat in Carroll County, Virginia.

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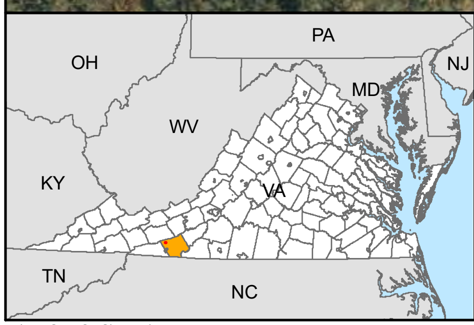

Legend

- Macroinvertebrate Sample Location
- Macroinvertabrate Sampling Transect

N

0 50 100
Meters

Scale: 1:3,937

American Electric Power
Byllesby-Buck Benthic Aquatic Resource

Figure 9
Qualitative macroinvertebrate and crayfish 100-meter survey extent in mixed habitat in Carroll County, Virginia.

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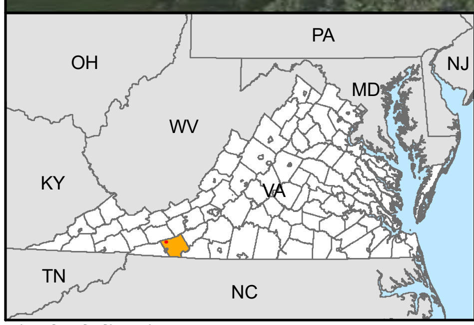

Legend

- Macroinvertebrate Sample Location
- Macroinvertabrate Sampling Transect

N

0 50 100
Meters

Scale: 1:3,937

AMERICAN ELECTRIC POWER

EDGE ENGINEERING & SCIENCE

American Electric Power
Byllesby-Buck Benthic Aquatic Resource

Figure 10
Qualitative macroinvertebrate and crayfish 100-meter survey extent in mixed habitat in Carroll County, Virginia.

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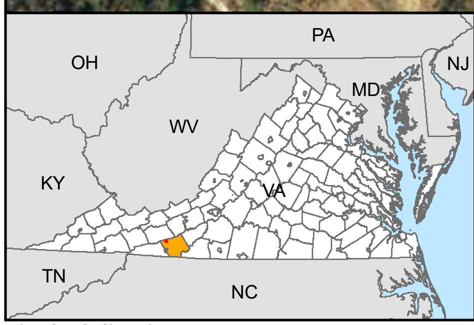

Legend

- Macroinvertebrate Sample Location
- Macroinvertabrate Sampling Transect

N

0 50 100

Meters

Scale: 1:3,937

American Electric Power
Byllesby-Buck Benthic Aquatic Resource

Figure 11
Qualitative macroinvertebrate and crayfish 100-meter survey extent in mixed habitat in Carroll County, Virginia.

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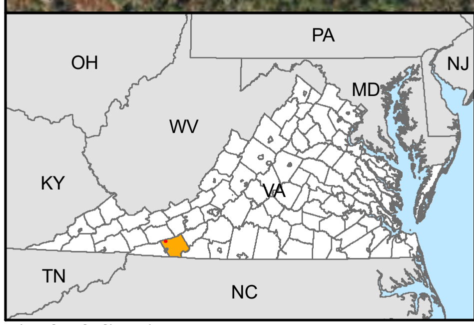

Legend

- Macroinvertebrate Sample Location
- Macroinvertabrate Sampling Transect

N

0 50 100

Meters

Scale: 1:3,937

AMERICAN ELECTRIC POWER

EDGE ENGINEERING & SCIENCE

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Byllesby-Buck Benthic Aquatic Resource

Figure 12
Qualitative macroinvertebrate and crayfish 100-meter survey extent in mixed habitat in Carroll County, Virginia.

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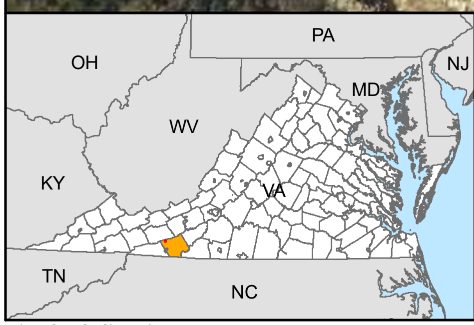


Legend

- Macroinvertebrate Sample Location
- Macroinvertabrate Sampling Transect

N

0 50 100
Meters

Scale: 1:3,937

AMERICAN ELECTRIC POWER

EDGE ENGINEERING & SCIENCE

American Electric Power
Byllesby-Buck Benthic Aquatic Resource

Figure 13
Qualitative macroinvertebrate and crayfish 100-meter survey extent in mixed habitat in Carroll County, Virginia.

D:\PROJECTS\HDR\HDR2020-0001 Byllesby-Buck Dam Relicensing\GIS\MXD\Macro_Surveys\Report_Figs\20201215\HDR2020-0001_Macro_Fig2_13_20201215.mxd

Appendix A

SCIENTIFIC COLLECTION PERMITS

Virginia Department of Game and Inland Fisheries
7870 Villa Park Drive, P.O. Box 90778, Henrico, VA 23228-0778
(804) 367-1000 (V/TDD)
Under Authority of § 29.1-412, § 29.1-417, & § 29.1-418 of the Code of Virginia

Scientific Collection Permit

Permit Type: **New** | Fee Paid: **$40.00** | VADGIF Permit No. **070705**

Permittee: **Jonathan Studio**
Address: **36550 Chester Road, Apt. 4801**
Avon, OH 44011
Email: **jastudio@edge-es.com**

Home:
Office: **(440) 413-4609**
City/County:

Business: **Edge Engineering & Science, LLC**
4005 Ponder Drive
Cincinnati, OH 45245

Niagara Hydroelectric Project/Byllesby-Buck Hydroelectric Project

Authorized Collection Methods: By Hand/Dip Nets/Electrofishing/Gill Nets/Trawl Nets/Nets-Traps (Fyke/Hoop/D-Frame)/Seine Nets/Drift Nets
Authorized Waterbodies: Roanoke River/Tinker Creek/New River
Authorized Marking Techniques: N/A

SPECIAL CONDITIONS: No electrofishing in Roanoke Logperch TOYR unless requested and approved by both USFWS and DWR. Mussels may not be targeted and any inadvertently collected must be returned to the point-of-capture after the individual is identified (if ID is possible).

Permittee MUST notify DWR within the 7 day period prior to each sampling event. Notification must be made via email to: collectionpermits@dwr.virginia.gov

Report Due: 31 January 2022, 31 January 2023

ANNUAL REPORTS MUST BE SUBMITTED VIA: https://vafwis.dgif.virginia.gov/collection_permits/

STANDARD CONDITIONS ATTACHED APPLY TO THIS PERMIT.

Authorized Counties / Cities:
Carroll
Roanoke

Authorized Species:

Description	ID Number	Scientific Name
Aquatic Insects		
Crayfish		
Freshwater Fish		
Other Aquatic Invertebrates		

Annual Report Due End of Each Year

Authorized Sub-Permittees:
See Attached Sheet

Approved by: [signature]

Title: **Randall T. Francis - Permits Manager**

Date: 3/2/2021

Applicants may appeal permit decisions within 30 days of issuance. The appeal must be in writing to the Director, Department of Game and Inland Fisheries.

Virginia Department of Game and Inland Fisheries
7870 Villa Park Drive, P.O. Box 90778, Henrico, VA 23228-0778
(804) 367-1000 (V/TDD)
Under Authority of § 29.1-412, § 29.1-417, & § 29.1-418 of the Code of Virginia

Scientific Collection Permit

Permit Type: **New** Fee Paid: **$40.00** VADGIF Permit No. **070705**

20 Permit Effective **3/2/2021** through **12/31/2022** **22**

Virginia Department of Game and Inland Fisheries
7870 Villa Park Drive, P.O. Box 90778, Henrico, VA 23228-0778
(804) 367-1000 (V/TDD)

Under Authority of § 29.1-412, § 29.1-417, & § 29.1-418 of the Code of Virginia

Scientific Collection Permit

Permit Type: **New** FeePaid: **$40.00** VADGIF Permit No. **070705**

Authorized Sub-Permittees:

Sarah Messer, Edge Engineering & Science, LLC
John Spaeth, Edge Engineering & Science, LLC
Aaron Prewitt, Edge Engineering & Science, LLC
Adam Benshoff, Edge Engineering & Science, LLC
David Foltz, Edge Engineering & Science, LLC
Mitchell Kriege, Edge Engineering & Science, LLC
Alyssa Jones, Edge Engineering & Science, LLC
David Ford, Edge Engineering & Science, LLC
Tim Brust, Edge Engineering & Science, LLC

Virginia Department of Wildlife Resources
P O Box 3337 Henrico, VA 23228-3337
(804) 367-6913

Under Authority of § 29.1-412, § 29.1-417, & § 29.1-418 of the Code of Virginia

SCIENTIFIC COLLECTION PERMIT – STANDARD CONDITIONS

1. Permits are issued to permittees with the understanding that if the principal permittee leaves the project the permit will be null and void and anyone desiring to continue the activities must apply for a new permit.

2. This permit, or a copy, must be carried by the permittee(s) during collection activities.

3. Permittee MUST notify the Virginia Department of Wildlife Resources (VDWR) within the seven (7) day period prior to EACH sampling event. Notification must be made via email to: collectionpermits@DWR.virginia.gov.)

4. The permittee is required to submit to this Department a report of all specimens collected under this permit by the report due date. Report form may be found at https://vafwis.DWR.virginia.gov/collection_permits/. FAILURE TO RETURN THIS REPORT WILL RESULT IN NON-ISSUANCE OF FUTURE PERMITS. If no activity occurs under this permit, an email should be sent to collectionpermits@DWR.virginia.gov containing the following statement: No activity occurred under Permit #*insert permit ID* during insert year (i.e. 2017). Permit reports are due by January 31.

5. Permittees shall give any and all changes of name, address, and/or phone number to the VDWR Permits Section within no more than seven (7) days of those changes. All permittees (to include sub-permittees) shall provide DWR with a complete home address, contact telephone number (home or cellular), and a valid e-mail address.

6. This permit does not support any activities outside of those associated with the application and proposal submitted to and approved by DWR.

7. No species currently listed by the U.S. Fish and Wildlife Service or VDWR as threatened or endangered may be intentionally collected under this permit. If incidental d*eath or injury* of threatened or endangered species does occur, the permittee is required to notify VDWR at collectionpermits@DWR.virginia.gov within twenty-four (24) hours of occurrence. The following information must be reported: collector, date, species, location (county, quad, waterbody, and latitude and longitude to nearest second), and number collected.

8. If incidental *observation or collection and live release* of threatened or endangered species occurs, the permittee is required to notify VDWR at collectionpermits@DWR.virginia.gov within four (4) working days, providing the same information as the Condition No. 7.

9. If incidental *mortality or injury of specimens intended to be taken live* occurs, the permittee is required to notify VDWR at collectionpermits@DWR.virginia.gov within 48 hours, providing the same information as the above conditions. In addition, the permittee must provide the cause of mortality or injury and steps that are being taken to address the problem.

10. No species may be retained unless specifically authorized by this permit.

11. Game birds/game mammals/game fish protected by State and/or Federal laws must be taken during authorized hunting and trapping seasons and under applicable daily and seasonal bag/number limits by properly licensed persons unless otherwise specifically authorized. A valid Virginia fishing license is required for each person collecting samples by hook-and-line.

12. All traps must be marked with the name and address of the trapper or an identification number issued by VDWR (Code of Virginia §29.1-521.7). Steel foothold traps, Conibear-style body gripping traps, and snares must be marked with a nonferrous metal tag bearing this information (Virginia Administrative Code 4 VAC 15-40-170).

13. All traps must be checked at least once a day and all captured animals removed, except completely submerged body-gripping traps which must be checked at least once every 72 hours (Code of Virginia §29.1-521.9).

14. The permittee is required to report any incidences of wildlife deaths or diseases observed during the course of collection activities. Reports should be made to: collectionpermits@DWR.virginia.gov within four (4) working days.

15. This permit satisfies only VDWR's requirement for collection permits and is issued with the understanding that no collections will be made on Federal, state, or private property without the prior approval and necessary permits from the landowners involved. The permittee is responsible for obtaining any additional permits required for collection.

16. Sampling gear, boats, or trailers which have been used in states harboring zebra mussels must be cleaned and prepared following accepted guidelines for removal of zebra mussels, prior to being used in Virginia.

17. For safety reasons, it is recommended that all permittees display at least 100 square inches of solid blaze orange material at shoulder level within body reach and visible from 360 degrees, especially during hunting season.

Appendix B

REPRESENTATIVE PHOTOGRAPHS

Appendix B: Representative Photographs

BFQT1 - Upstream
Quantitative Macroinvertebrate Sample Site

BFQT2 - Upstream
Quantitative Macroinvertebrate Sample Site

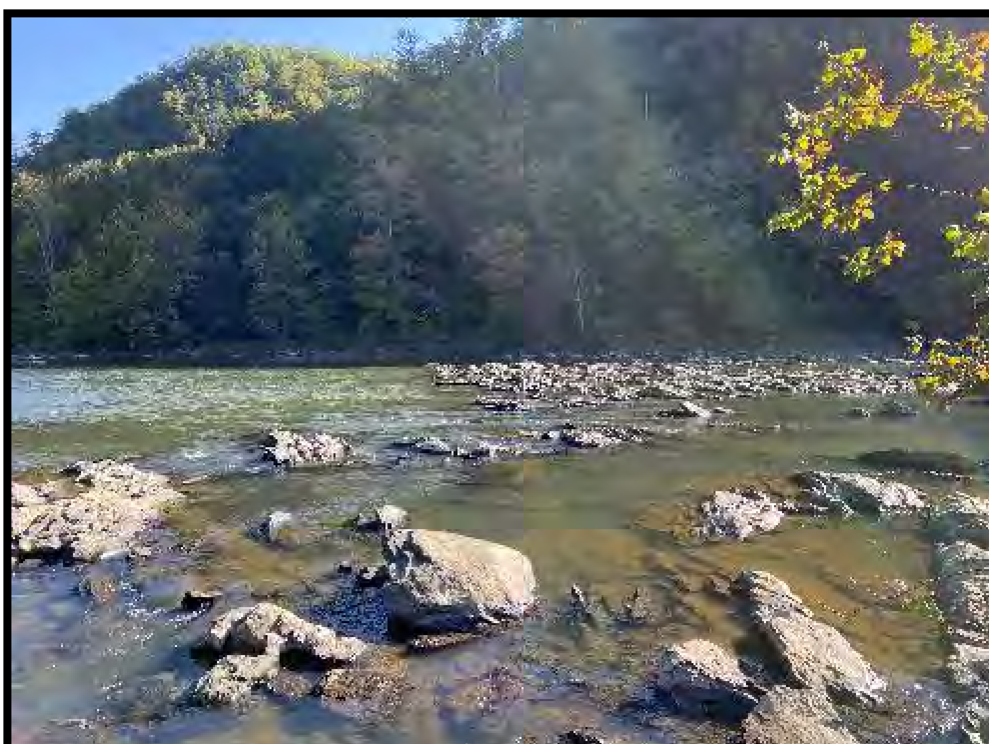
BFQL3 - Upstream
Qualitative Macroinvertebrate Sample Site

BFQL4 - Upstream
Qualitative Macroinvertebrate Sample Site

BFQL5 - Downstream
Qualitative Macroinvertebrate Sample Site

BFQL6 - Upstream
Qualitative Macroinvertebrate Sample Site

BFQT7 - Downstream
Quantitative Macroinvertebrate Sample Site



BFQT8 - Downstream
Quantitative Macroinvertebrate Sample Site

BFQL9 - Upstream
Qualitative Macroinvertebrate Sample Site

BFQT10 - Downstream
Quantitative Macroinvertebrate Sample Site

BFQT11 - Upstream
Quantitative Macroinvertebrate Sample Site

BFQL12 - Downstream
Qualitative Macroinvertebrate Sample Site

BFQL13 - Upstream
Qualitative Macroinvertebrate Sample Site

BFQL14 - Downstream
Qualitative Macroinvertebrate Sample Site

BFQT15 - Downstream
Quantitative Macroinvertebrate Sample Site

BFQT16 - Downstream
Quantitative Macroinvertebrate Sample Site

Conhaway Crayfish
(*Cambarus appalachiensis*)

Spiny Stream Crayfish
(*Faxonius cristavarius*)

Appendix C

RAW DATA

TAXON	Number of Organisms per Taxon per Subsample																	
	New River Samples and Collection Date																	
	BFQL1	**BFQL2 ORIGINAL**	**BFQL2 REPLICATE**	**BFQT3**	**BFQT4**	**BFQL5**	**BFQL6**	**BFQT7 ORIGINAL**	**BFQT7 REPLICATE**	**BFQT8**	**BFQL9**	**BFQL10**	**BFQL11**	**BFQT12**	**BFQL13**	**BFQT14**	**BFQT15**	**BFQT16**
	10/6/2020	**10/6/2020**	**10/6/2020**	**10/6/2020**	**10/6/2020**	**10/6/2020**	**10/6/2020**	**10/7/2020**	**10/7/2020**	**10/7/2020**	**10/7/2020**	**10/7/2020**	**10/7/2020**	**10/7/2020**	**10/7/2020**	**10/8/2020**	**10/8/2020**	**10/8/2020**
PLATYHELMINTHES (flatworms)																		
TURBELLARIA																		
Planariidae	16	5	3			3	9			1						1		
ANNELIDA (segmented worms)																		
OLIGOCHAETA (aquatic worms)	11	55	17	2		17	30	1	8	1	10	14	6		8	1		4
ARTHROPODA (arthropods)																		
HYDRACARINA (water mites)										1								1
CRUSTACEA (crayfish, scuds, aquatic sow bugs)																		
AMPHIPODA (scuds, sideswimmers)																		
Talitridae																		
Hyalella sp.	2						23											
DECAPODA (crayfish)																		
Cambaridae																		
Faxonius sp.								1	1									
INSECTA (insects)																		
EPHEMEROPTERA (mayflies)																		
Baetidae (small minnow mayflies)			2		2		1											
Acentrella sp.				3						7				9		5		7
Acerpenna sp.		1	1		3			1		1	1	1			8			
Baetis flavistriga				1	1				2	3				3		4		3
Baetis intercalaris				51	58	1		35	19	18				13		15	3	10
Baetis spp.				17	4			4	8	1							1	3
Labiobaetis sp.			5								38	3	5					
Neocloeon sp.	2	1	3			6					10	4	4		2			
Plauditus sp.					17									1		1	3	1
Procloeon sp.									1			1						
Baetiscidae (armored mayflies)																		
Baetisca sp.															1			
Ephemerellidae (spiny crawler mayflies)																		
Eurylophella sp.									1									
Teloganopsis deficiens [1]								3		1							1	
Heptageniidae (flatheaded mayflies)																		
Heptagenia marginata				1	4			1	2					1		3		2
Maccaffertium spp.				6	1			8	5	14			1	3		7	7	9
Stenacron sp.				1	2			1		1	3		2			1		
Isonychiidae (brushlegged mayflies)																		
Isonychia sp.				2				5	2	6				1		1	10	15
Leptohyphidae (little stout crawlers) [2]																		
Tricorythodes sp.															1	1		
PLECOPTERA (stoneflies)																		
Chloroperlidae (green stoneflies)																		
Sweltsa sp.								1										
Perlidae (common stoneflies)																		
Acroneuria sp.				1				1		1						1		
Agnetina sp.									1									
Attaneuria ruralis														1				

TAXON	Number of Organisms per Taxon per Subsample New River Samples and Collection Date																	
	BFQL1	**BFQL2 ORIGINAL**	**BFQL2 REPLICATE**	**BFQT3**	**BFQT4**	**BFQL5**	**BFQL6**	**BFQT7 ORIGINAL**	**BFQT7 REPLICATE**	**BFQT8**	**BFQL9**	**BFQL10**	**BFQL11**	**BFQT12**	**BFQL13**	**BFQT14**	**BFQT15**	**BFQT16**
	10/6/2020	**10/6/2020**	**10/6/2020**	**10/6/2020**	**10/6/2020**	**10/6/2020**	**10/6/2020**	**10/7/2020**	**10/7/2020**	**10/7/2020**	**10/7/2020**	**10/7/2020**	**10/7/2020**	**10/7/2020**	**10/7/2020**	**10/8/2020**	**10/8/2020**	**10/8/2020**
TRICHOPTERA (caddisflies)																		
Helicopsychidae (snail casemakers)																		
Helicopsyche borealis					1			1	1									
Hydropsychidae (common net-spinners)																		
Ceratopsyche morosa								1						1			1	3
Cheumatopsyche spp.								7	7	6				9		15	13	6
Hydropsyche spp.				2				1	1	4				5		4	28	6
Hydroptilidae (micro-caddisflies)											1							
Hydroptila sp.	1		1															
Lepidostomatidae (Lepidostomid caddisflies)																		
Lepidostoma sp.					1													
Leptoceridae (long-horned caddisflies)	1																	
Oecetis sp.									1									
Triaenodes spp.		1					2								9	1	1	
Molannidae (hood casemakers)																		
Molanna sp.						1												
Philopotamidae (fingernet caddisflies)																		
Chimarra sp.				4					2	2				1				1
Phryganeidae (giant casemakers)																		
Oligostomis sp.	1																	
Polycentropodidae (trumpetnet and tubemakers)																		
Neureclipsis sp.				1				6	1	1								
Nyctiophylax sp.									1									
Polycentropus sp.									1				1		26			
Psychomyiidae (tube-making caddisflies)																		
Psychomyia flavida									1									
COLEOPTERA (aquatic beetles)																		
Dryopidae (long-toed water beetle)																		
Helichus sp.															1			
Dytiscidae (predacious diving beetles)																		
Agabus sp.							1											
Elmidae (riffle beetles)																		
Ancyronyx sp.															1			
Dubiraphia sp.			1			1							1	1	1			
Gonielmis sp.	3				1							1					3	
Macronychus sp.			1	1						1					2			
Optioservus sp.				1										9		5	6	7
Oulimnius sp.														1				
Stenelmis sp.				1						3				13		5	4	18
Gyrinidae (whirligig beetles)																		
Dineutus sp.				2	7				1						7			

TAXON	Number of Organisms per Taxon per Subsample																	
	New River Samples and Collection Date																	
	BFQL1	BFQL2 ORIGINAL	BFQL2 REPLICATE	BFQT3	BFQT4	BFQL5	BFQL6	BFQT7 ORIGINAL	BFQT7 REPLICATE	BFQT8	BFQL9	BFQL10	BFQL11	BFQT12	BFQL13	BFQT14	BFQT15	BFQT16
	10/6/2020	10/6/2020	10/6/2020	10/6/2020	10/6/2020	10/6/2020	10/6/2020	10/7/2020	10/7/2020	10/7/2020	10/7/2020	10/7/2020	10/7/2020	10/7/2020	10/7/2020	10/8/2020	10/8/2020	10/8/2020
Hydrophilidae (water scavenger beetles)																		
Berosus sp.	1		2															
Psephenidae (water penny beetles)																		
Psephenus herricki														2		1		
MEGALOPTERA (alderflies, fishflies, dobsonflies)																		
Corydalidae (fishflies, dobsonflies)																		
Corydalus sp.								1	1	1						1		3
Nigronia sp.																1		
ODONATA (dragonflies, damselflies)																		
ANISOPTERA (dragonflies)																		
Aeshnidae (darners)																		
Basiaeschna sp.	1	1	3															
Cordulegastridae (biddies)																		
Cordulegaster sp.													1					
Corduliidae/ Libellulidae (skimmers)			1										1					
Libellulidae (skimmers)																		
Plathemis sp.							1											
Gomphidae (clubtails)																		
Gomphurus sp.								1										
Hylogomphus sp.[4]								1										
Stylurus spiniceps													1					
Macromiidae (cruisers)																		
Macromia sp.		1													1			
ZYGOPTERA (damselflies)																		
Coenagrionidae (narrow-winged damselflies)																		
Argia sp.				1	1			1	3	10			5	2	7	1	1	4
Enallagma sp.	38	15	33			1	13				1							
Ishnura sp.	2																	
DIPTERA (true flies)																		
Ceratopogonidae (biting midges)																		
Culicoides sp.							4											
Probezzia sp.							1											
Chironomidae (A)[3] - (midges)	34	22	33	3	2	87	22	16	26	21	24	93	74	5	15	15	9	11
Simuliidae (blackflies)																		
Simulium sp.				1					1	3				6		2	7	1
Tabanidae (deer and horse flies)																		
Chrysops sp.							1											
Tipulidae (crane flies)				1														
LEPIDOPTERA (aquatic moths)																		
Pyralidae (pyralid moths)																		
Petrophila sp.									1	1								

TAXON	Number of Organisms per Taxon per Subsample																	
	New River Samples and Collection Date																	
	BFQL1	BFQL2 ORIGINAL	BFQL2 REPLICATE	BFQT3	BFQT4	BFQL5	BFQL6	BFQT7 ORIGINAL	BFQT7 REPLICATE	BFQT8	BFQL9	BFQL10	BFQL11	BFQT12	BFQL13	BFQT14	BFQT15	BFQT16
	10/6/2020	10/6/2020	10/6/2020	10/6/2020	10/6/2020	10/6/2020	10/6/2020	10/7/2020	10/7/2020	10/7/2020	10/7/2020	10/7/2020	10/7/2020	10/7/2020	10/7/2020	10/8/2020	10/8/2020	10/8/2020
HEMIPTERA (water bugs)																		
Belostomatidae (giant water bugs)							1											
Corixidae (water boatmen)						3												
Nepidae (water scorpions)																		
Ranatra sp.															1			
MOLLUSCA																		
GASTROPODA (snails, limpets)																		
Ancylidae (limpets)					3			6	7	4				3		3	1	
Lymnaeidae (pond snails)							1				1							
Planorbidae (ram's horn snails)		1					1											
Pleuroceridae (pleurocerid snails)				4												3	3	
Physidae (bladder snails)	1	2	4				8				17	2	1		1			1
BIVALVIA (clams or bivalves)																		
Corbiculidae (Asian clam)				3	2		1	12	4	3			2	30	7	14	10	1
Sphaeriidae (fingernail clams)		1	1												1		1	
TOTAL NUMBER OF TAXA	**17**	**15**	**19**	**26**	**20**	**12**	**20**	**27**	**31**	**29**	**13**	**11**	**17**	**25**	**22**	**29**	**23**	**25**
TOTAL NUMBER OF ORGANISMS	**132444**	**132436**	**132441**	**132440**	**132440**	**132450**	**132450**	**132449**	**132443**	**132449**	**132439**	**132452**	**132438**	**132453**	**132433**	**132448**	**132449**	**132453**

[1] - *Teloganopsis deficiens* previously identified as *Serratella deficiens*

[2] - Family Leptohyphidae previously named Family Tricorythidae

[3] - Chironomidae Group (A) includes all chironomid taxa except those that are highly tolerant of organic pollution, which are placed in Group (B). All identified Chironomidae specimens in all subsamples were assigned to Group A.

[4] - Based on taxonomic characteristics, this specimen does not appear to be *Hylogomphus adelphus* (Mustached Clubtail), identified in Virginia as a "species of greatest conservation need

TAXON	Number of Organisms per Taxon per Subsample																	
	New River Samples and Collection Date																	
	BSQT1	BSQT2	BSQL3	BSQL4 ORIGINAL	BSQL4 REPLICATE[3]	BSQL5	BSQL6	BSQT7 ORIGINAL	BSQT7 REPLICATE	BSQT8	BSQL9	BSQT10	BSQT11	BSQL12	BSQL13	BSQL14	BSQT15	BSQT16
	4/20/2021	4/20/2021	4/20/2021	4/20/2021	4/20/2021	4/20/2021	4/20/2021	4/21/2021	4/21/2021	4/21/2021	4/21/2021	4/21/2021	4/23/2021	4/21/2021	4/22/2021	4/22/2021	4/22/2021	4/23/2021
PLATYHELMINTHES (flatworms)																		
TURBELLARIA																		
Planariidae					1	7	2			2		1		2				1
ANNELIDA (segmented worms)																		
OLIGOCHAETA (aquatic worms)	7	27	8	39	14	10	39	12	29	46	23	17	12	8	10	81	6	8
ARTHROPODA (arthropods)																		
HYDRACARINA (water mites)				1		1												
CRUSTACEA (crayfish, scuds, aquatic sow bugs)																		
AMPHIPODA (scuds, sideswimmers)																		
Talitridae																		
Hyalella sp.						2												
ISOPODA (aquatic sow bugs)																		
Asellidae																		
Caecidotea sp.																5		
DECAPODA (crayfish)																		
Cambaridae																		
Cambarus sp.												1						
Faxonius sp.						1												
INSECTA (insects)																		
EPHEMEROPTERA (mayflies)																		
Baetidae (small minnow mayflies)																		
Acentrella sp.	4							2		14		5	6				33	12
Acerpenna sp.		2										1						
Baetis flavistriga		1								1		1	4				6	1
Baetis spp.	3	2						1	1	4		3	2				3	2
Heterocloeon spp.												1					2	
Plauditus spp.	23	17		1	1			6	6	6		17	1				3	4
Ephemerellidae (spiny crawler mayflies)																		
Dannella sp.		1										1						1
Ephemerella sp.													1					
Teloganopsis deficiens[1]	2												2				2	1
Ephemeridae (burrowing mayflies)																		
Ephemera sp.									1					2				
Heptageniidae (flatheaded mayflies)																		
Heptagenia marginalis	1	7																
Leucrocuta sp.	1	1								1		1						
Maccaffertium spp.	13	17						4	2	8	2	11	13	1			5	2
Stenacron sp.									1					1				
Isonychiidae (brushlegged mayflies)																		
Isonychia sp.	1									1			4					1
Siphlonuridae (primitive minnow mayflies)																		
Siphlonurus sp.				1	5				2		1			1	7			

TAXON	Number of Organisms per Taxon per Subsample																	
	New River Samples and Collection Date																	
	BSQT1	BSQT2	BSQL3	BSQL4 ORIGINAL	BSQL4 REPLICATE[3]	BSQL5	BSQL6	BSQT7 ORIGINAL	BSQT7 REPLICATE	BSQT8	BSQL9	BSQT10	BSQT11	BSQL12	BSQL13	BSQL14	BSQT15	BSQT16
	4/20/2021	4/20/2021	4/20/2021	4/20/2021	4/20/2021	4/20/2021	4/20/2021	4/21/2021	4/21/2021	4/21/2021	4/21/2021	4/21/2021	4/23/2021	4/21/2021	4/22/2021	4/22/2021	4/22/2021	4/23/2021
PLECOPTERA (stoneflies)																		
Chloroperlidae (green stoneflies)																		
Haploperla sp.									1				2	4				
Leuctridae (rolled-wing stoneflies)																		
Leuctra sp.																		1
Nemouridae (spring stoneflies)																		
Amphinemura sp.																		2
Perlidae (common stoneflies)																		
Acroneuria sp.	3	1										1	1				1	
Agnetina sp.																	1	
Perlesta sp.	6							1		5		2	8				4	
Perlodidae (stripetails, springflies)																		
Cultus sp.												1						
Helopicus sp.	1																	
Isoperla sp.													1	4			1	
Taeniopterygidae (broadbacks, winter stoneflies)																		
Taeniopteryx sp.										1								
TRICHOPTERA (caddisflies)																		
Brachycentridae (humpless casemakers)																		
Brachycentrus sp.	1									1			1				1	20
Glossosomatidae (saddle- casemakers)													1					
Hydropsychidae (common net-spinners)																		
Cheumatopsyche spp.	3											3	5				3	
Diplectrona sp.														1				
Hydropsyche spp.													4				1	
Hydroptilidae (micro-caddisflies)																		
Hydroptila sp.	2	2		1				3	2	1	3	6	5	2	4		1	1
Lepidostomatidae (Lepidostomid caddisflies)																		
Lepidostoma sp.	3											4			1			1
Leptoceridae (long-horned caddisflies)																		
Ceraclea sp.																		1
Oecetis sp.												1						
Triaenodes sp.											1							
Limnephilidae (northern casemakers)																		
Pycnopsyche sp.															1			
Polycentropodidae (trumpetnet and tubemakers)																		
Neureclipsis sp.			1							1		1						
Polycentropus sp.											1							
COLEOPTERA (aquatic beetles)																		
Elmidae (riffle beetles)																		
Dubiraphia sp.					1													
Gonielmis sp.				9	3	11	4		1	1	3			22	4	3	1	
Macronychus sp.	5																	
Optioservus sp.			1	4	1	3		1				1		4		1	1	
Oulimnius sp.													1					
Stenelmis sp.	6									2		3		1			10	2

TAXON	Number of Organisms per Taxon per Subsample — New River Samples and Collection Date																	
	BSQT1	**BSQT2**	**BSQL3**	**BSQL4 ORIGINAL**	**BSQL4 REPLICATE[3]**	**BSQL5**	**BSQL6**	**BSQT7 ORIGINAL**	**BSQT7 REPLICATE**	**BSQT8**	**BSQL9**	**BSQT10**	**BSQT11**	**BSQL12**	**BSQL13**	**BSQL14**	**BSQT15**	**BSQT16**
	4/20/2021	**4/20/2021**	**4/20/2021**	**4/20/2021**	**4/20/2021**	**4/20/2021**	**4/20/2021**	**4/21/2021**	**4/21/2021**	**4/21/2021**	**4/21/2021**	**4/21/2021**	**4/23/2021**	**4/21/2021**	**4/22/2021**	**4/22/2021**	**4/22/2021**	**4/23/2021**
Gyrinidae (whirligig beetles)																		
Dineutus sp.		10			2	1		4	3		3							
Gyrinus sp.				3	4													
Haliplidae (crawling water beetles)																		
Peltodytes sp.					1	3												
Psephenidae (water penny beetles)																		
Psephenus herricki										2							2	
MEGALOPTERA (alderflies, fishflies, dobsonflies)																		
Corydalidae (fishflies, dobsonflies)																		
Corydalus sp.	4									1			1					
ODONATA (dragonflies, damselflies)																		
ANISOPTERA (dragonflies)																		
Gomphidae (clubtails)																		
Hylogomphus sp.[4]		1									1							
Macromiidae (cruisers)																		
Macromia sp.											2							
ZYGOPTERA (damselflies)																		
Calopterygidae (broad-winged damselflies)																		
Calopteryx sp.											1							
Coenagrionidae (narrow-winged damselflies)																		
Argia sp.										1	2	2						
Enallagma sp.						3												
DIPTERA (true flies)																		
Ceratopogonidae (biting midges)																		
Culicoides sp.							1											
Probezzia sp.							1							1				
Serromyia sp.						1												
Chironomidae (A)[2] - (midges)	17	29	105	52	54	65	54	81	56	16	65	16	32	52	72	21	21	36
Chironomidae (B)[2] - (midges)							11								3	1		
Empididae (dance flies)																		
Hemerodromia sp.													2					
Simuliidae (blackflies)																		
Simulium sp.	10				1			1	1	2		1					2	14
Tipulidae (crane flies)																		
Antocha sp.	1											5	1				1	1
Limonia sp.									1									
LEPIDOPTERA (aquatic moths)																		
Pyralidae (pyralid moths)																		
Petrophila sp.										1		1						

TAXON	Number of Organisms per Taxon per Subsample																	
	New River Samples and Collection Date																	
	BSQT1	BSQT2	BSQL3	BSQL4 ORIGINAL	BSQL4 REPLICATE[3]	BSQL5	BSQL6	BSQT7 ORIGINAL	BSQT7 REPLICATE	BSQT8	BSQL9	BSQT10	BSQT11	BSQL12	BSQL13	BSQL14	BSQT15	BSQT16
	4/20/2021	4/20/2021	4/20/2021	4/20/2021	4/20/2021	4/20/2021	4/20/2021	4/21/2021	4/21/2021	4/21/2021	4/21/2021	4/21/2021	4/23/2021	4/21/2021	4/22/2021	4/22/2021	4/22/2021	4/23/2021
HEMIPTERA (water bugs)																		
Corixidae (water boatmen)							1											
Sigara sp.						3												
MOLLUSCA																		
GASTROPODA (snails, limpets)																		
Ancylidae (limpets)												2						
Planorbidae (ram's horn snails)					2	1	2											
Pleuroceridae (pleurocerid snails)	1											1						
Physidae (bladder snails)	1						2								1	3		
BIVALVIA (clams or bivalves)																		
Corbiculidae	1				1						1	3	8					2
Sphaeriidae (fingernail clams)					3		1					1						
TOTAL NUMBER OF TAXA	**28**	**17**	**7**	**12**	**18**	**17**	**13**	**14**	**17**	**25**	**17**	**34**	**27**	**18**	**11**	**9**	**26**	**24**
TOTAL NUMBER OF ORGANISMS	**133038**	**133036**	**133033**	**133029**	**133012**	**133030**	**133036**	**133037**	**133028**	**133039**	**133030**	**133036**	**133045**	**133027**	**133027**	**133039**	**133035**	**133041**

[1] - *Teloganopsis deficiens* previously identified as *Serratella deficiens*

[2] - Chironomidae Group (A) includes all chironomid taxa except those that are highly tolerant of organic pollution, which are placed in Group (B). The family Chironomidae is counted as one taxon, despite the Group A and Group B designations.

[3] - Sample BSQL4-(Site 8)-Replicate was completely sorted (50 of 50 primary grids) and produced a total of 94 organisms, five less than the minimum subsample target number of 99 organisms.

[4] - Based on taxonomic characteristics, these specimens do not appear to be *Hylogomphus adelphus* (Mustached Clubtail), identified in Virginia as a "species of greatest conservation need"

Water quality parameters at quantitative and qualitative sites in fall 2020 (BFQT and BFQL site names, respectively) and spring 2021 (BSQT and BSQL site names). Sites above the first dashed line are upstream of Byllesby Dam, sites below the first dashed line are between Byllesby and Buck Dam, and sites below the second dashed line are downstream of Buck Dam.

Date	Site ID	Water Temp. (C)	pH	DO (%)	Conductivity (us/cm)	Habitat
10/6/2020	BFQT1	15.6	8.10	113.9	66.2	Riffle
10/6/2020	BFQT2	15.7	8.00	109.9	64.5	Riffle/Run
10/6/2020	BFQL3	15.3	8.40	101.6	64.4	Pool
10/6/2020	BFQL4	15.1	8.30	91.4	65.5	Pool
10/6/2020	BFQL5	14.8	8.40	92.1	64.4	Pool
10/6/2020	BFQL6	27.3	7.20	84.3	44.9	Pool
4/20/2021	BSQT1	12.6	7.73	100.4	58.8	Riffle
4/20/2021	BSQT2	13.4	7.90	99.7	55.6	Riffle/Run
4/20/2021	BSQL3	14.7	7.60	92.6	58.5	Pool
4/20/2021	BSQL4	13.9	7.47	97.4	58.4	Pool
4/20/2021	BSQL5	13.5	7.60	100.3	58.1	Pool
4/20/2021	BSQL6	15.1	7.12	88.7	58.2	Pool
10/7/2020	BFQT7	15.3	7.20	115.7	63.9	Riffle/Run
10/7/2020	BFQT8	15.7	7.20	114.9	64.0	Riffle
10/7/2020	BFQL9	17.3	7.30	101.8	63.8	Pool
10/7/2020	BFQT10	17.1	7.40	104.8	63.8	Riffle
10/8/2020	BFQT11	15.1	7.00	110.7	66.6	Riffle
10/7/2020	BFQL12	17.4	7.30	101.3	65.7	Pool
10/7/2020	BFQL13	16.7	7.50	92.7	65.1	Pool
10/7/2020	BFQL14	16.7	7.50	92.7	65.1	Pool
4/21/2021	BSQT7	13.4	7.40	88.2	57.3	Riffle/Run
4/21/2021	BSQT8	13.7	7.60	95.6	57.7	Riffle
4/21/2021	BSQL9	13.6	7.40	93.6	57.7	Pool
4/21/2021	BSQT10	13.7	7.60	97.0	57.8	Riffle
4/23/2021	BSQT11	6.9	7.62	102.8	58.8	Riffle
4/22/2021	BSQL12	11.2	7.60	100.2	58.4	Pool
4/22/2021	BSQL13	11.3	7.50	96.1	58.7	Pool
4/22/2021	BSQL14	11.6	7.50	92.2	58.7	Pool
10/8/2020	BFQT15	17.2	7.70	108.1	57.7	Riffle
10/8/2020	BFQT16	16.4	7.00	107.3	69.9	Riffle
4/22/2021	BSQT15	10.4	7.70	108.0	38.2	Riffle
4/23/2021	BSQT16	11.0	7.80	105.7	64.4	Riffle

Raw data used to calculate VSCI scores for fall 2020 macroinvertebrate data (family). Sites above the first dashed line are upstream of Byllesby Dam, sites below the first dashed line are between Byllesby and Buck Dam, and sites below the second dashed line are downstream of Buck Dam.

Site	Total	Total Taxa	EPT Taxa	% Eph.	% Plec. + Trich. - Hydropsych.	% Scrapers	% Top 2 Dominant	% Chironomidae	HBI
BFQT1	110	16	7	74.55	5.45	13.64	72.73	2.73	**4.08**
BFQT2	111	10	4	83.78	1.80	10.81	83.78	1.80	**4.23**
BFQL3	120	8	2	5.83	0.83	1.67	86.67	72.50	**5.07**
BFQL4 ORIGINAL	106	11	2	1.89	0.94	2.83	72.64	20.75	**3.36**
BFQL4 REPLICATE	111	12	2	9.91	0.90	6.31	59.46	29.73	**5.77**
BFQL5	114	13	4	1.75	2.63	4.39	64.91	29.82	**6.51**
BFQL6	120	16	2	0.83	1.67	8.33	44.17	18.33	**3.93**
BFQT7 ORIGINAL	117	17	9	50.43	7.69	13.68	48.72	13.68	**4.79**
BFQT7 REPLICATE	111	21	11	36.94	8.11	12.61	51.35	23.42	**4.68**
BFQT8	117	18	8	45.30	3.42	19.66	44.44	17.95	**4.98**
BFQL9	100	16	5	12.00	35.00	5.00	41.00	15.00	**5.31**
BFQT10	120	13	6	25.83	1.67	27.50	46.67	4.17	**5.50**
BFQT11	113	18	7	33.63	1.77	24.78	39.82	13.27	**5.20**
BFQL12	105	12	3	11.43	0.95	4.76	79.05	70.48	**5.52**
BFQL13	119	5	1	7.56	0.00	2.52	89.92	78.15	**5.16**
BFQL14	106	8	3	49.06	0.94	20.75	68.87	22.64	**4.81**
BFQT15	117	14	5	42.74	0.85	31.62	41.88	9.40	**4.08**
BFQT16	115	14	6	22.61	0.87	20.87	48.70	7.83	**5.12**

Site results of VSCI scores for fall 2020 macroinvertebrate data (family). Sites above the first dashed line are upstream of Byllesby Dam, sites below the first dashed line are between Byllesby and Buck Dam, and sites below the second dashed line are downstream of Buck Dam.

Site	Total	Total Taxa	EPT Taxa	% Eph.	% Plec. + Trich. - Hydropsych.	% Scrapers	% Top 2 Dominant	% Chironomidae	HBI	VSCI Score
BFQT1	110	72.73	63.64	100.00	15.31	26.43	39.41	97.27	87.03	**62.73**
BFQT2	111	45.45	36.36	100.00	5.06	20.95	23.43	98.20	84.79	**51.78**
BFQL3	120	36.36	18.18	9.51	2.33	3.24	19.27	27.50	72.55	**23.62**
BFQL4 ORIGINAL	106	50.00	18.18	3.08	2.64	5.48	39.54	79.25	97.67	**36.98**
BFQL4 REPLICATE	111	54.55	18.18	16.17	2.53	12.23	58.58	70.27	62.14	**36.83**
BFQL5	114	59.09	36.36	2.85	7.39	8.51	50.70	70.18	51.34	**35.80**
BFQL6	120	72.73	18.18	1.35	4.69	16.14	80.68	81.67	89.22	**45.58**
BFQT7 ORIGINAL	117	77.27	81.82	82.27	21.60	26.51	74.11	86.32	76.67	**65.82**
BFQT7 REPLICATE	111	95.45	100.00	60.26	22.78	24.44	70.30	76.58	78.30	**66.01**
BFQT8	117	81.82	72.73	73.90	9.61	38.10	80.28	82.05	73.78	**64.03**
BFQL9	100	72.73	45.45	19.58	98.31	9.69	85.26	85.00	68.97	**60.62**
BFQT10	120	59.09	54.55	42.14	4.69	53.29	77.07	95.83	66.18	**56.61**
BFQT11	113	81.82	63.64	54.86	4.97	48.02	86.96	86.73	70.54	**62.19**
BFQL12	105	54.55	27.27	18.65	2.67	9.22	30.28	29.52	65.83	**29.75**
BFQL13	119	22.73	9.09	12.33	0.00	4.88	14.57	21.85	71.18	**19.58**
BFQL14	106	36.36	27.27	80.03	2.64	40.21	44.99	77.36	76.30	**48.15**
BFQT15	117	63.64	45.45	69.72	2.39	61.28	83.99	90.60	87.10	**63.02**
BFQT16	115	63.64	54.55	36.88	2.44	40.45	74.14	92.17	71.74	**54.50**

EPT = Ephemeroptera, Trichoptera, and Plecoptera; HBI = Hilsenhoff Biotic Index; VSCI = Virginia stream condition index

Raw data used to calculate VSCI scores for spring 2021 macroinvertebrate data (family). Sites above the first dashed line are upstream of Byllesby Dam, sites below the first dashed line are between Byllesby and Buck Dam, and sites below the second dashed line are downstream of Buck Dam.

Site	Total	Total Taxa	EPT Taxa	% Eph.	% Plec. + Trich. - Hydropsych.	% Scrapers	% Top 2 Dominant	% Chironomidae	HBI
BFQT1	84	19	10	25.00	19.05	35.71	38.10	20.24	**3.81**
BFQT2	109	9	5	44.04	2.75	24.77	51.38	26.61	**3.53**
BFQL3	115	4	1	0.00	0.87	4.00	98.26	60.00	**5.57**
BFQL4 ORIGINAL	111	8	3	1.80	0.90	0.87	81.98	91.30	**3.61**
BFQL4 REPLICATE	94	12	2	6.38	0.00	7.45	72.34	57.45	**5.11**
BFQL5	103	13	0	0.00	0.00	14.56	76.70	63.11	**5.76**
BFQL6	118	10	0	0.00	0.00	6.78	49.47	55.08	**4.32**
BFQT7 ORIGINAL	116	9	4	11.21	3.45	6.90	80.17	69.83	**5.06**
BFQT7 REPLICATE	107	12	6	12.15	2.80	5.61	79.44	52.34	**4.07**
BFQT8	118	17	8	29.66	7.63	12.71	60.17	13.56	**2.70**
BFQL9	109	14	5	2.75	4.59	7.34	80.73	59.63	**4.57**
BFQT10	115	23	10	35.65	13.91	21.74	39.13	13.91	**3.95**
BFQT11	118	17	10	27.97	16.10	16.10	38.14	27.12	**4.19**
BFQL12	106	12	7	4.72	9.43	29.25	74.53	49.06	**4.67**
BFQL13	94	9	4	7.45	6.38	9.57	84.04	79.79	**5.97**
BFQL14	115	6	0	0.00	0.00	6.09	88.70	19.13	**1.52**
BFQT15	111	14	8	48.65	8.11	18.02	61.26	18.92	**4.07**
BFQT16	96	17	10	25.00	8.33	5.21	57.29	37.50	**4.63**

Site results of VSCI scores for spring 2021 macroinvertebrate data (family). Sites above the first dashed line are upstream of Byllesby Dam, sites below the first dashed line are between Byllesby and Buck Dam, and sites below the second dashed line are downstream of Buck Dam.

Site	Total	Total Taxa	EPT Taxa	% Eph.	% Plec. + Trich. - Hydropsych.	% Scrapers	% Top 2 Dominant	% Chironomidae	HBI	VSCI Score
BFQT1	84	86.36	90.91	40.78	53.50	69.21	89.46	79.76	91.04	**75.13**
BFQT2	109	40.91	45.45	71.84	7.73	48.01	70.27	73.39	95.12	**56.59**
BFQL3	115	18.18	9.09	0.00	2.44	7.75	2.51	40.00	65.22	**18.15**
BFQL4 ORIGINAL	111	36.36	27.27	2.94	2.53	1.69	26.04	8.70	93.93	**24.93**
BFQL4 REPLICATE	94	54.55	18.18	10.41	0.00	14.43	39.97	42.55	71.96	**31.51**
BFQL5	103	59.09	0.00	0.00	0.00	28.22	33.67	36.89	62.39	**27.53**
BFQL6	118	45.45	0.00	0.00	0.00	13.14	73.02	44.92	83.50	**32.50**
BFQT7 ORIGINAL	116	40.91	36.36	18.28	9.69	13.37	28.65	30.17	72.64	**31.26**
BFQT7 REPLICATE	107	54.55	54.55	19.82	7.88	10.87	29.71	47.66	87.27	**39.04**
BFQT8	118	77.27	72.73	48.39	21.42	24.64	57.56	86.44	107.30	**61.97**
BFQL9	109	63.64	45.45	4.49	12.89	14.22	27.84	40.37	79.87	**36.10**
BFQT10	115	104.55	90.91	58.16	39.08	42.13	87.96	86.09	89.00	**74.73**
BFQT11	118	77.27	90.91	45.62	45.23	31.20	89.40	72.88	85.37	**67.24**
BFQL12	106	54.55	63.64	7.69	26.50	56.68	36.81	50.94	78.39	**46.90**
BFQL13	94	40.91	36.36	12.15	17.93	18.56	23.06	20.21	59.29	**28.56**
BFQL14	115	27.27	0.00	0.00	0.00	11.80	16.34	80.87	124.68	**32.62**
BFQT15	111	63.64	72.73	79.36	22.78	34.92	55.98	81.08	87.18	**62.21**
BFQT16	96	77.27	90.91	40.78	23.41	10.09	61.72	62.50	79.04	**55.72**

EPT = Ephemeroptera, Trichoptera, and Plecoptera; HBI = Hilsenhoff Biotic Index; VSCI = Virginia stream condition index

Crayfish observations. Sites above the first dashed line are upstream of Byllesby Dam, sites below the first dashed line are between Byllesby and Buck Dam, and sites below the second dashed line are downstream of Buck Dam. Both species are native.

Date	Site	Conhoway Crayfish	Spiny Stream Crayfish
10/6/2020	BFQT1		
10/6/2020	BFQT2		
10/6/2020	BFQL3		
10/6/2020	BFQL4		
10/6/2020	BFQL5		present
10/6/2020	BFQL6		
10/7/2020	BFQT7	present	present
10/7/2020	BFQT8		
10/7/2020	BFQL9		present
10/7/2020	BFQT10	present	
10/8/2020	BFQT11		present
10/7/2020	BFQL12		present
10/7/2020	BFQL13		
10/7/2020	BFQL14		
10/8/2020	BFQT15	present	present
10/8/2020	BFQT16	present	present

Attachment 4

Attachment 4 – Mussel Community Study Report

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Prepared for Appalachian Power Company

Byllesby-Buck Hydroelectric Project Freshwater Mussel Survey (FERC No. 2514)

January 4, 2021

Prepared by:
Stantec Consulting Services Inc.
11687 Lebanon Road
Cincinnati, OH 45241

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Prepared by ______________________
Elizabeth Dilbone

____
Jane DeClerck

Reviewed by ______________________
Steve Bedross

Approved by ______________________
Cody Fleece

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Executive Summary

As part of the ongoing Aquatic Resources Study being conducted for relicensing of the Byllesby-Buck Hydroelectric Project (Project), current and historical mussel surveys within the Project area were assessed to evaluate the status of the mussel community effected by Project operations. This report is intended to present data from surveys conducted in 2020 as well as review and summarize existing information regarding mussel assemblages in the Project area.

During September and October 2020, mussel surveys were conducted to assess mussel assemblages in the reservoir reach of the New River between the Byllesby and Buck Dams, as well as the tailrace of Buck Dam. Prior to mussel surveys, a desktop assessment of hydraulic habitat types within the study area was conducted to identify ten potential habitat units for survey. Theses ten habitats were then examined via boat to identify specific areas to target during in-water surveys. Nine *Cyclonaias tuberculata* were found during survey of the ten habitat units. Live mussels were only found in two of the ten surveyed areas and overall mussel densities were lower than other sites within the Project area (e.g. downstream of Buck Dam). Quality habitat within the survey area was limited, with bedrock and overlying silt deposits being the most prominent substrate types. A reconnaissance level habitat assessment of the Buck Dam tailrace was also conducted. No evidence of spent valves or viable mussel habitat were observed within the Buck Dam tailrace, where high velocities resulting from a narrow, confined channel most likely preclude mussel occupancy.

Existing relevant and reasonably available studies of mussels within the Project area were reviewed and compared to results of summer 2020 field surveys. In total, data from six other mussel surveys conducted within the Project area between 1997 and 2018 were compiled to form a more comprehensive understanding of the mussel community in the vicinity of Project operations. Six species were observed within the Project area: *Cyclonaias tuberculata*, *Eurynia dilatata, Tritogonia verrucosa, Lampsilis fasciola, Lasmigona subviridis,* and *Lampsilis ovata.* Survey sites downstream of Buck Dam (downstream of the confluence of the tailrace and bypass channel) supported the highest density mussel habitats. *Cyclonaias tuberculata* and *Tritogonia verrucosa* were the most abundant species and mussel size data suggests that recent recruitment has occurred for these species. Results of 2020 field surveys are consistent with findings of historical surveys. High quality mussel habitat within the Project area is limited and does not support a diverse or abundant mussel community.

Abbreviations

AEP	American Electric Power
°C	Celsius
µS	Microsiemens
CFS	Cubic feet per second
CPUE	Catch per unit effort
DO	Dissolved Oxygen
EA	Environmental Assessment
FERC	Federal Energy Regulatory Commission
Ft	Feet
hr	Hour
ILP	Integrated Licensing Process
M	Meter
m^2	Square meter
mi^2	Square mile
mg/L	Milligrams per liter
mm	Millimeters
NOI	Notice of Intent
NTU	Nephelometric Turbidity Units
PAD	Pre-Application Document
PSP	Proposed Study Plan
RSP	Revised Study Plan
SCUBA	Self-Contained Underwater Breathing Apparatus
USFWS	U.S. Fish and Wildlife Service
VDWR	Virginia Department of Wildlife Resources

1.0 INTRODUCTION

1.1 PROJECT BACKGROUND

The existing Federal Energy Regulatory Commission (FERC or Commission) license for the Byllesby-Buck Hydroelectric Project (FERC No. 2514) (Project) located on the New River in Carroll County, Virginia expires on February 29, 2024. Accordingly, Appalachian Power Company (Appalachian), the Licensee, owner and operator of the Project, is pursuing a subsequent license for the Project pursuant to the Commission's Integrated Licensing Process (ILP). The Appalachian Power Company submitted a Pre-Application Document (PAD) and Notice of Intent (NOI) for the Project to initiate the ILP on January 7, 2019. At this time, the Commission stated its intent to prepare an Environmental Assessment (EA) that evaluates the potential effects of issuing a subsequent license.

In accordance with 18 CFR §5.11, Appalachian developed a Proposed Study Plan (PSP) for the Project that recommended studies and approaches to addressing agency and stakeholder requests. A Revised Study Plan (RSP) was submitted in response to the comments on the PSP from the Commission, U.S. Fish and Wildlife Service (USFWS), and Virginia Department of Wildlife Resources (VDWR) on October 18, 2019. This RSP included provisions for an Aquatic Resources Study to examine multiple taxa within the New River, including a Mussel Community Sub-study. Due to the lack of mussel abundance found in existing data summarized in the PAD, the proposed mussel community study involved a two-stage approach that included 1) field surveys of the Buck Dam Tailrace channel and the reach of the New River between Byllesby Dam and Buck Reservoir Islands and 2) A desktop literature review of available data on the mussel communities in the Project vicinity. The goals of this study are to:

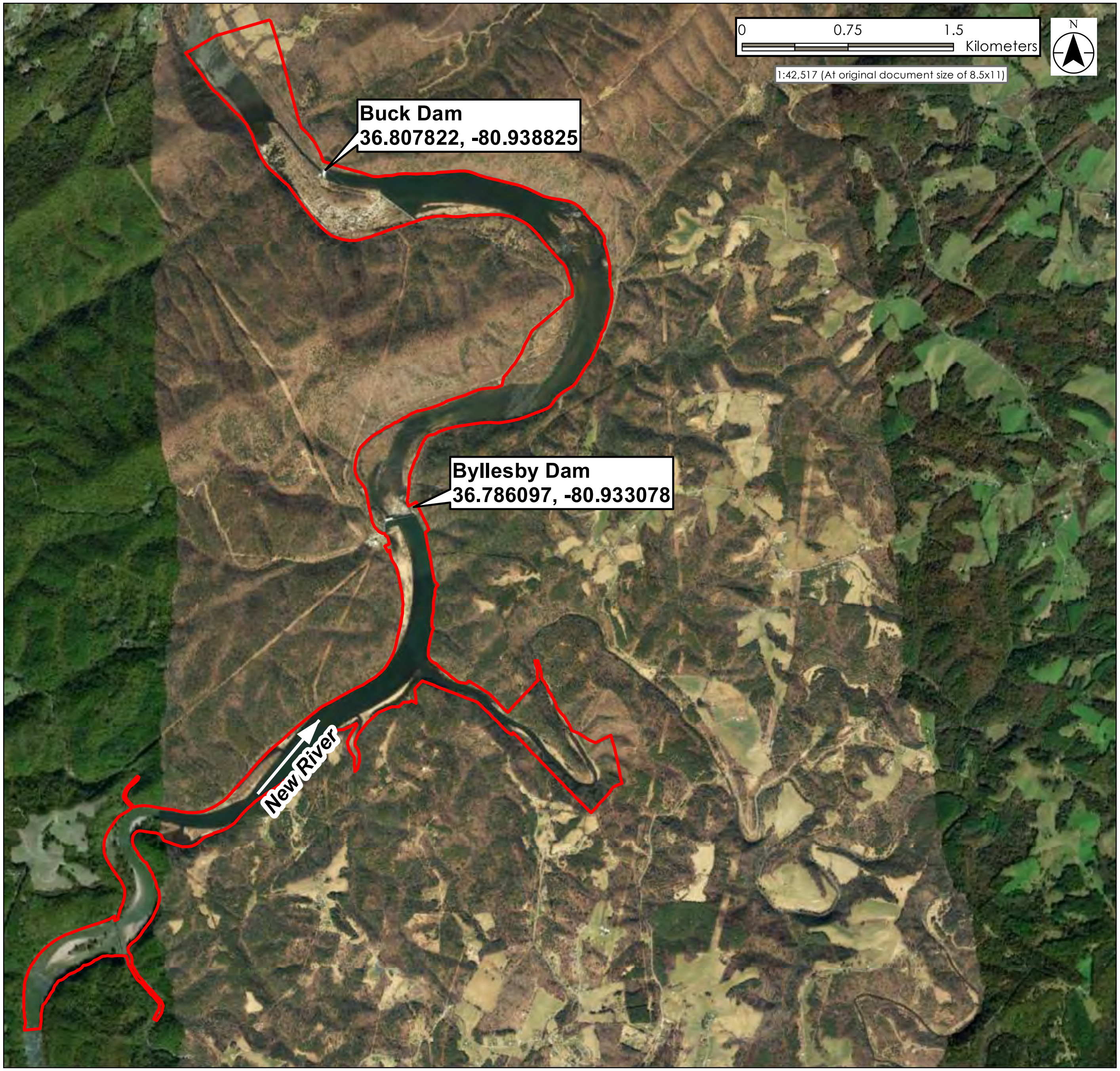
- Collect a more comprehensive baseline understanding of the mussel community within the Project area;
- Compare current mussel survey data to historical data to determine any significant changes in species composition or abundance; and
- Assess spatial distribution of mussel species within the Project area.

1.2 PROJECT AREA

The Project is located on the upper New River in Carroll County, Virginia. The Byllesby development is located about 9 mi north of the city of Galax, and the Buck development is located approximately 3 river miles (RM) downstream of Byllesby and 43.5 RM upstream of Claytor Dam (Figure 1). Each development consists of a reservoir, concrete gravity dam and spillway, and powerhouse. The Project area extends approximately 0.5 mi downstream of the Buck development. Figure 1 depicts the FERC project boundary and Project location.

1.3 STUDY OBJECTIVES

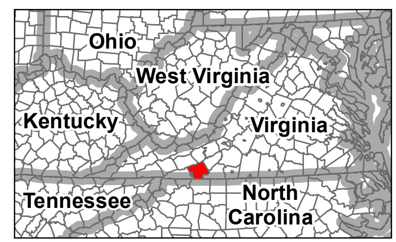
The Unionid fauna of the New River in the vicinity of the Project area has been studied at intervals beginning with Pinder et al. (2002) and most recently by Stantec (2020). Section 2.0 of this report presents the results of surveys completed in the un-impounded reach of the New River between Byllesby Dam and Buck Pool. Section 3.0 of the report presents a compilation and review of readily available studies of unionid mussels in the Project Area.



Legend

Study Area Boundary

Notes
1. Coordinate System: NAD 1983 StatePlane Ohio North FIPS 3401 Feet
2. Base Imagery: ESRI Map Services.



Project Location
Carroll County, Virginia
New River

Prepared by EKD on 2020-11-24

Client/Project
Byllesby & Buck Hydroelectric Project
(FERC No. 2514)

Figure No.
1

Title
Byllesby - Buck Project Study Area

2.0 2020 MUSSEL SURVEY

2.1 METHODS

Methods consisted of visually identifying potential mussel habitats within the approximately 3,000 meter (m) long reach between Byllesby Dam and the Buck Reservoir Islands as well as the tailrace of Buck Dam. These areas were chosen for searching due to historic information already existing for the majority of the surrounding habitats (Pinder et al. 2002, Alderman 2008, Stantec 2018a, Stantec 2018b), as seen in Figure 2. These studies will be detailed in section 3.0. This study did not examine the Buck or Byllesby impoundment pools due to the recent studies done during drawdown activities (Stantec 2018a & 2018b).

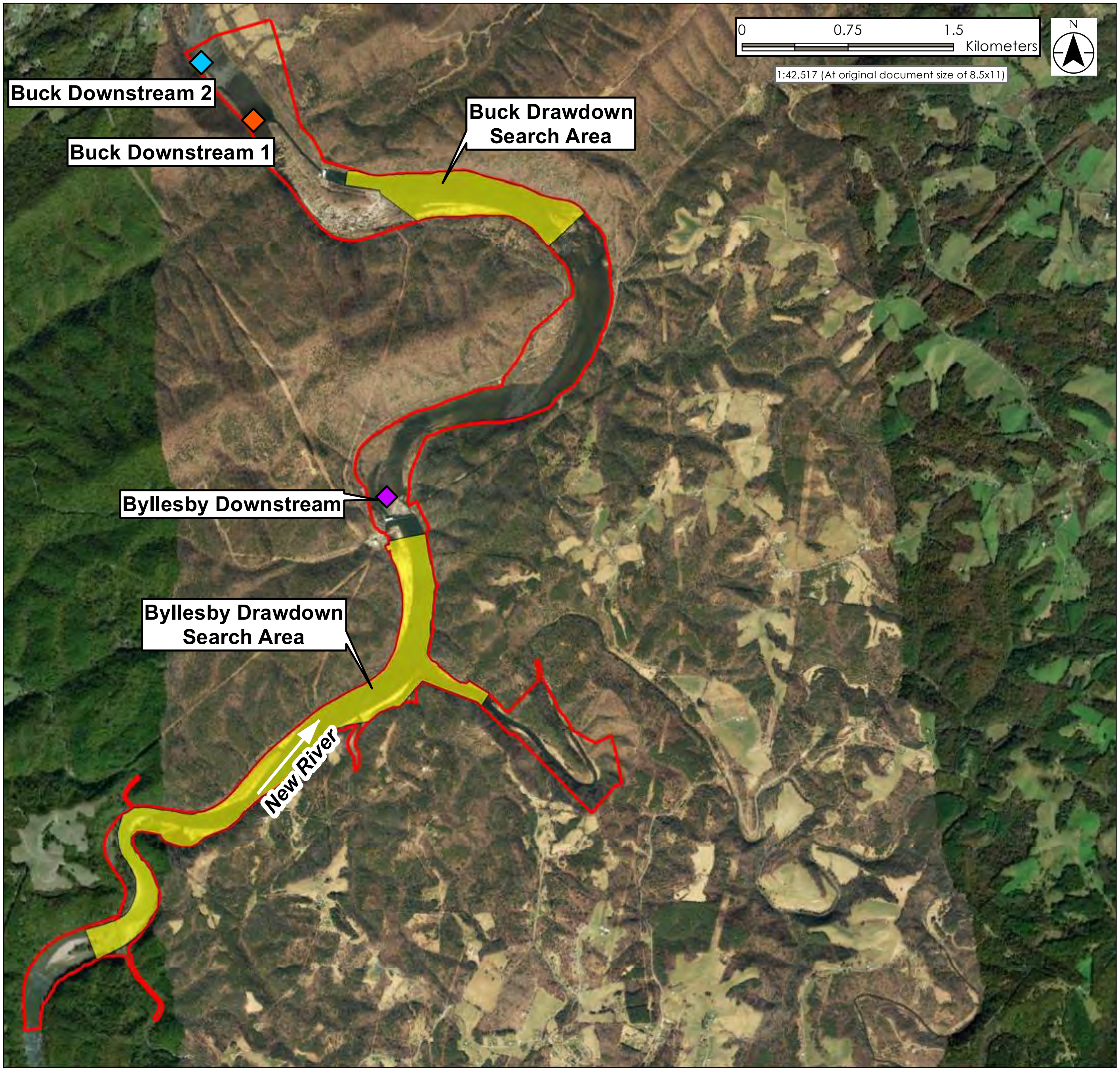
2.1.1 Agency Correspondence

A study plan outlining the proposed survey methodologies was submitted to Virginia Department of Wildlife Resources (VDWR) on September 8, 2020, with approval received from Mr. Brian Watson on September 21, 2020. Documentation of this approval can be found in Appendix A. Field surveys were led by Dan Symonds under Stantec's Scientific Collecting Permit (#605183) and Threatened and Endangered Species Permit (#067427) (Appendix B).

2.1.2 Unimpounded Reach Between Byllesby Dam and Buck Pool

Prior to field work, a desktop evaluation of hydraulic habitat types identified ten distinct habitats within the Project area. A boat-based habitat survey was performed to visually identify specific survey areas within the ten potential mussel habitats of varying hydraulic habitat types. The areas chosen for the wandering timed searches consisted of two shallow shoals, three deep shoals, three pools, and two side channels (Figure 3).

Qualitative surveys were conducted in the chosen survey areas when conditions were appropriate for detecting mussels as well as safe for divers to complete their work. Surveyors used SCUBA, surface supplied air diving, and snorkeling to conduct 200-minute wandering searches of the substrates in each area. Searching tactics included moving cobble and woody debris, hand sweeping away silt, sand, and/or small detritus, and disturbing/probing the upper five centimeters (two inches) of substrate where possible. Mussels were collected in mesh bags and brought to shore for identification and data collection. After data processing, mussels were hand placed on top of the substrate in the general area where they were found. Total search time was 33.3 hours. Turbidities rose higher than 21.6 NTU on the third day of surveying, inhibiting the visual searching techniques for the divers. Completion of the survey was postponed until October 21, 2020 when river conditions had improved. Photographs were taken of representative species (Appendix C).



Stantec

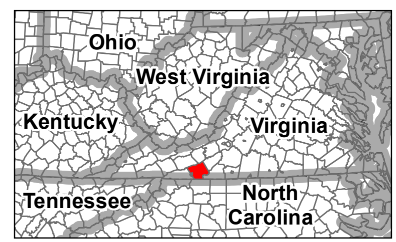
Legend

Study Area Boundary

Historical Survey Locations

- Stantec 2016, 2017, Alderman 2008, Pinder et al. 2002
- Stantec 2016, Alderman 2008
- Pinder et al. 2002
- Stantec 2018a, 2018b

Notes
1. Coordinate System: NAD 1983 StatePlane Ohio North FIPS 3401 Feet
2. Base Imagery: ESRI Map Services.



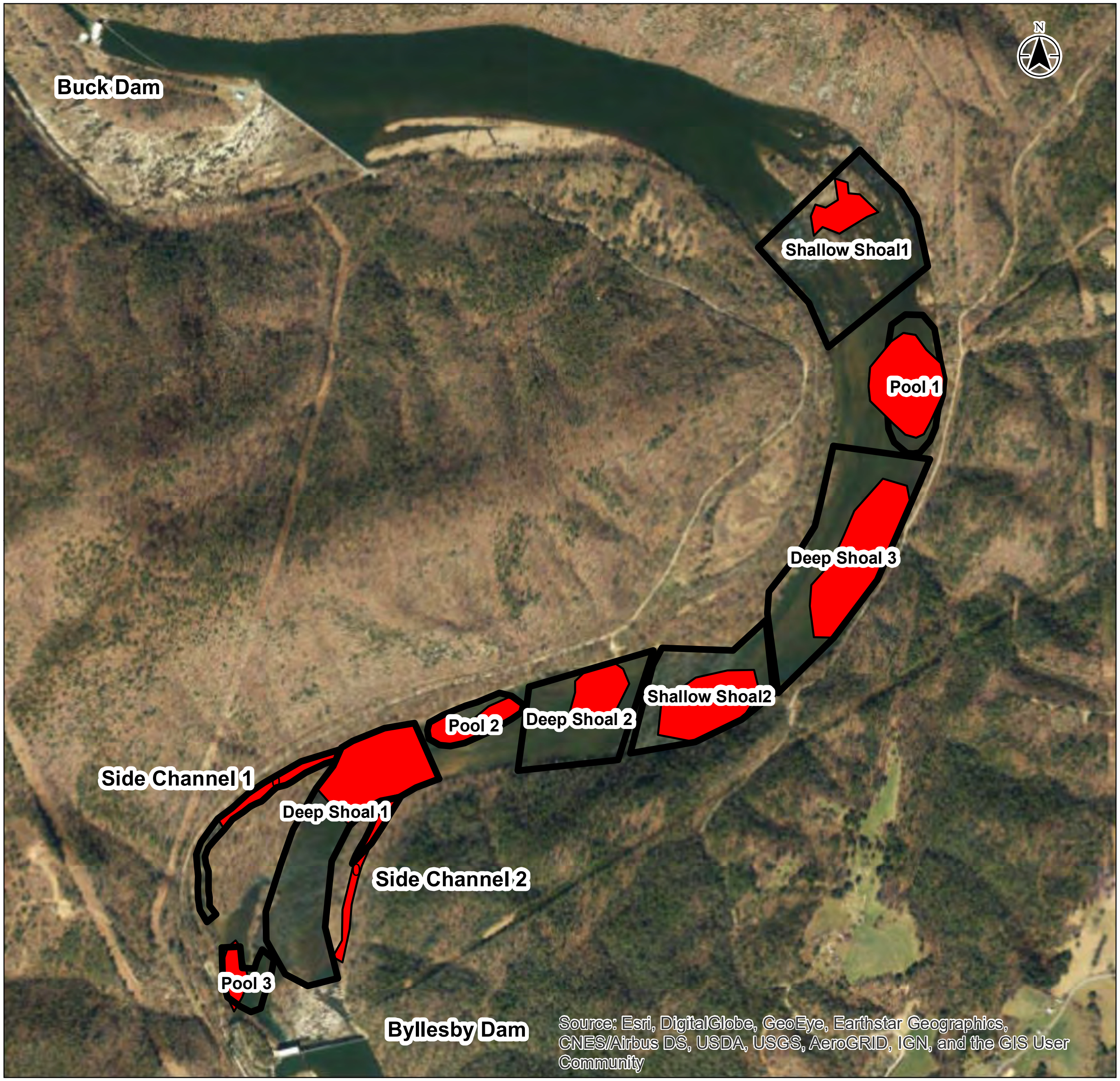
Project Location
Carroll County, Virginia
New River

Prepared by EKD on 2020-11-24

Client/Project
Byllesby & Buck Hydroelectric Project
(FERC No. 2514)

Figure No.
2

Title
Historical Survey Locations



Stantec

Legend

Survey Areas

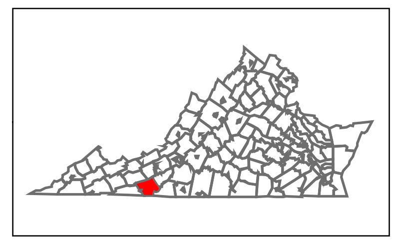
Hydraulic Habitat Units

0 720 1,440 Feet

1:14,557 (At original document size of 8.5x11)

Notes

1. Coordinate System: NAD 1983 StatePlane Ohio North FIPS 3401 Feet
2. Base features: layer sources
3. Base Imagery: ESRI Map Services.



Project Location
Carroll County, Virginia

Prepared by DES on 2020-11-12

Client/Project
American Electric Power

Figure No.
1

Title
Buck/Byllesby Dam Mussel Survey Areas

2.1.3 Buck Dam Tailrace

A reconnaissance level habitat assessment of the Buck Dam tailrace was conducted. Surveyors walked approximately 500m along the stream bank adjacent to the tailrace channel to the point where it converges with the bypass channel (Figure 4). Visual searches were conducted of the exposed riverbanks to discern any spent valves or evidence of suitable mussel habitat. The high velocities and unknown depths in the narrow channel were not conducive for safe in-water surveys such as wading, SCUBA, or snorkeling.

2.2 RESULTS

2.2.1 Site Conditions

Surveys were conducted September 24-26, 2020 and October 21, 2020. Water quality data in the New River was recorded daily at the survey site (Table 1). Visibility was approximately 3-5 ft prior to higher turbidity observed on September 26. A midchannel turbidity reading on the 26th read 50 NTU's and surveys were discontinued. Water quality metrics were generally indicative of a site suitable for mussel occupancy. Discharge was higher than that of the seasonal daily median and varied between 1200 CFS and 1400 CFS (Figure 5).

Table 1. Water Quality

Date	Temperature (C°)	Turbidity (NTU)	pH	Conductivity (µS)	DO (% Sat)	DO (mg/L)
24-Sep	16.8	7.62	8.25	62	97.5	9.70
25-Sep	16.2	8.67	8.31	62	98.7	9.64
26-Sep	15.4	21.60	8.24	61	97.5	9.80
21-Oct	12.9	4.91	8.70	62	105.0	11.03

Stantec

Legend

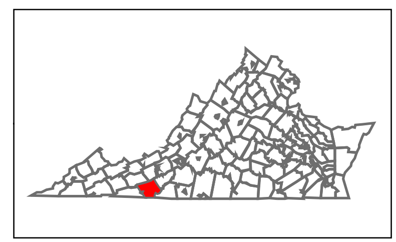
Tailrace

0 320 640 Feet

1:6,489 (At original document size of 8.5x11)

Notes

1. Coordinate System: NAD 1983 StatePlane Ohio North FIPS 3401 Feet
2. Base features: layer sources
3. Base Imagery: ESRI Map Services.



Project Location
Carroll County, Virginia

Prepared by DES on 2020-11-12

Client/Project
American Electric Power

Figure No.
2

Title
Buck Tailrace Survey Area

C:\Users\dsymonds\Documents\2020 Surveys\Byllesby-Buck_HDR_Mussels\GIS\Tailrace.mxd Revised: 2020-11-19 By: dsymonds

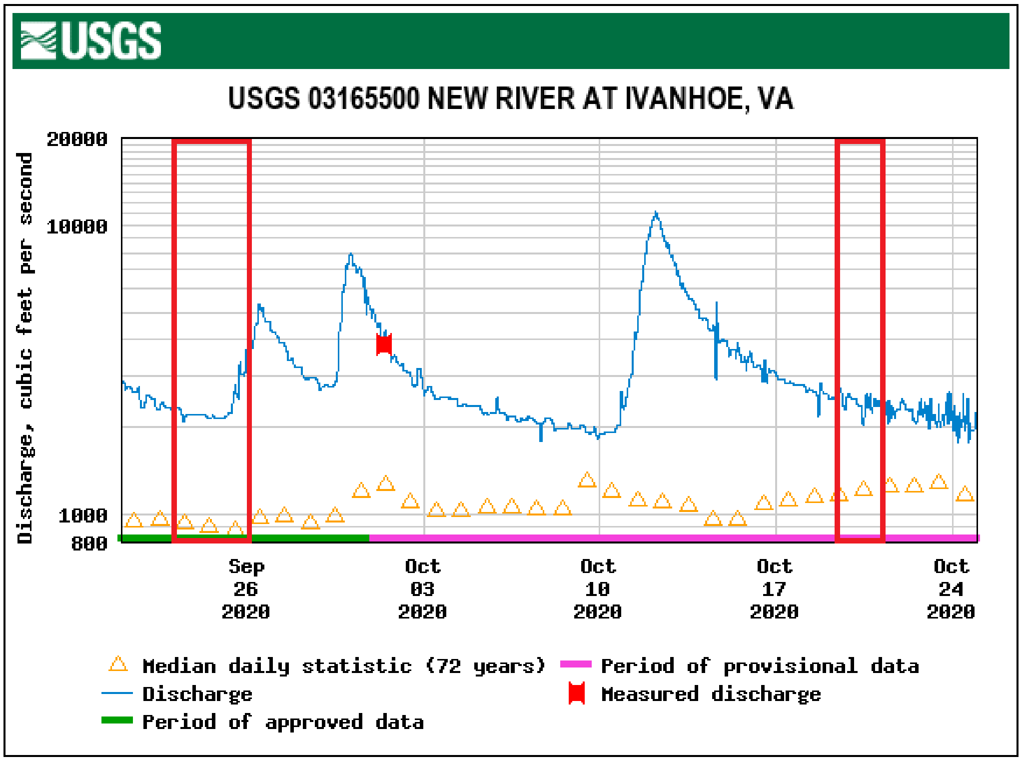


Figure 5. Discharge during time of site survey

Substrates in shallow shoals and deep shoals were predominantly bedrock and bedrock with silt on top. Bedrock and cobble were the dominant substrates in Pool 1, while Pool 2 and 3 were comprised primarily of sand. Substrates in the side channels were most suitable for mussel occupation with dominant substrates being gravel and cobble. Depths varied depending on the hydraulic habitat type with shallow shoals between 1 and 5 ft, deep shoals between 2 and 5 ft, and pools between 3 and 7ft with Pool 3 reaching a maximum depth of 24 ft (Table 2).

Table 2. Individual Site Characteristics

Survey Area	Effort (minutes)	Average Depth (feet)	Max Depth (feet)	Dominant Substrate
Shallow Shoal 1	200	1	3	Bedrock
Shallow Shoal 2	200	3	5	Bedrock
Pool 1	200	3	7	Bedrock/Cobble
Pool 2	200	5	7	Sand
Pool 3	200	10	24	Sand
Deep Shoal 1	200	2	4	Bedrock
Deep Shoal 2	200	3	4	Silt
Deep Shoal 3	200	3	5	Bedrock
Side Channel 1	200	1	2	Gravel
Side Channel 2	200	1	2	Cobble

2.2.2 Mussel Distribution and Abundance in Unimpounded Reach

Nine total live mussels were found all identified as *Cyclonaias tuberculata* (Purple Wartyback). The smallest of these was 48 mm and the largest was 95 mm in length. The mean length of live *Cyclonaias tuberculata* was 80 mm. One spent *Eurynia dilatata* (Spike) valve was found in weathered condition (Table 3).

Table 3. Mussels Found in Survey Area

Area	Species	Length (mm)	Condition
Shallow Shoal 1	*C. tuberculata*	48	Live
Shallow Shoal 1	*C. tuberculata*	87	Live
Shallow Shoal 1	*C. tuberculata*	-	Weathered
Deep Shoal 2	*C. tuberculata*	85	Live
Deep Shoal 2	*C. tuberculata*	84	Live
Deep Shoal 2	*C. tuberculata*	95	Live
Deep Shoal 2	*C. tuberculata*	85	Live
Deep Shoal 2	*C. tuberculata*	78	Live
Deep Shoal 2	*C. tuberculata*	91	Live
Deep Shoal 2	*C. tuberculata*	64	Live
Pool 1	*E. dilatata*	-	Weathered

2.2.3 Tailrace Findings

No evidence of freshwater mussels was found in the tailrace of Buck Dam. The exposed areas of the riverbanks were devoid of any spent valves. The velocity was high throughout the channel and visually estimated to be above 3.0 feet per second. Surveyors could not see or safely probe the bottom of the channel to gain information about substrate.

2.3 DISCUSSION

Overall mussel abundance and richness were low in the Project area. While the New River is not known as a productive mussel river, some reaches do support higher densities than observed in this study (See Section 3.0). 0.27 mussels per search hour is low relative to other freshwater mussel survey results, even within the New River Basin (See 3.2.6).

Most of the substrate was bedrock or a thin layer of sediment on top of bedrock. Impermeable bedrock can be inhabitable for burrowing invertebrates like freshwater mussels (Haag 2012). The West side channel contained the best substrate (Gravel/Cobble/Sand mixture). Combined with steady flow through a riffle/run complex, this was thought to be the best potential area for mussels. However, benthic macrofauna, unionid and non-unionid alike, were not encountered. While lack of quality habitat through the other survey areas is most likely dictating the lack of mussels, the absence in the side channel remains unexplained.

Similar findings were encountered during earlier studies by Stantec. In 2018 Stantec performed a mussel rescue during the Byllesby Dam drawdown necessary for scheduled repairs. This survey only collected 4 live mussels (3 *Cyclonaias tuberculata*, and 1 *Lasmigona subviridis* [Green floater]), and 20 spent valves (14 *Cyclonaias tuberculata*, 1 *Eurynia dilatata*, and 5 *Lasmigona subviridis*). That same year Stantec performed a mussel rescue during the Buck Dam drawdown necessary for scheduled repairs. This survey collected 2 live mussels (*Lampsilis fasciola* [Wavyrayed Lampmussel]) and 3 spent valves (2 *Lampsilis fasciola* and 1 *Cyclonaias tuberculata*).

The catch per unit of effort (CPUE) of the two 2018 studies and the current study were of similar low magnitude. The Byllesby Dam drawdown had 0.13 CPUE, the Buck Dam draw down had 0.15 CPUE, and this survey had 0.27 CPUE.

2.4 CONCLUSIONS

A total of nine live mussels were found during 33.3 diver-hours of surveying, representing one live species and one additional species solely by shell specimen. The total CPUE for this project was 0.27 mussels/hour. The mussels found did not represent any state or federal listed species. Overall, the Project area contains low numbers of mussels and shell specimens, which may be due to the overall lack of quality habitat through the riverine reach. The current results are consistent with results from recent survey efforts within the project area.

3.0 LITERATURE REVIEW

A literature review of available information regarding the freshwater mussel community in the Project area was performed to compile a baseline understanding of mussel resources within the Project area. All relevant and readily available studies regarding the mussel community in the Project vicinity were reviewed. This was combined with surveys conducted in 2020 to provide a complete picture of the status of freshwater mussel resources and their trends through time and across the Project area.

3.1 METHODS

For each study, survey methods, species composition, mussel abundance and density, and specimen length data (if available) was noted. CPUE was calculated as the number of mussels found per person-hour of searching using transect and timed search data. Mussel density was calculated for quantitative surveys as the number of mussels per m^2 of search area.

Survey methods, durations, and reported metrics differed substantially between studies (Table 4). However, qualitative comparison of reported data between survey sites and years allowed for assessment of potential spatial and temporal trends in species composition and abundance. Mussel locations relative to field-identified habitat types were also reviewed to help characterize the quality of mussel habitat within the Project area.

Table 4. Summary of Survey Methods

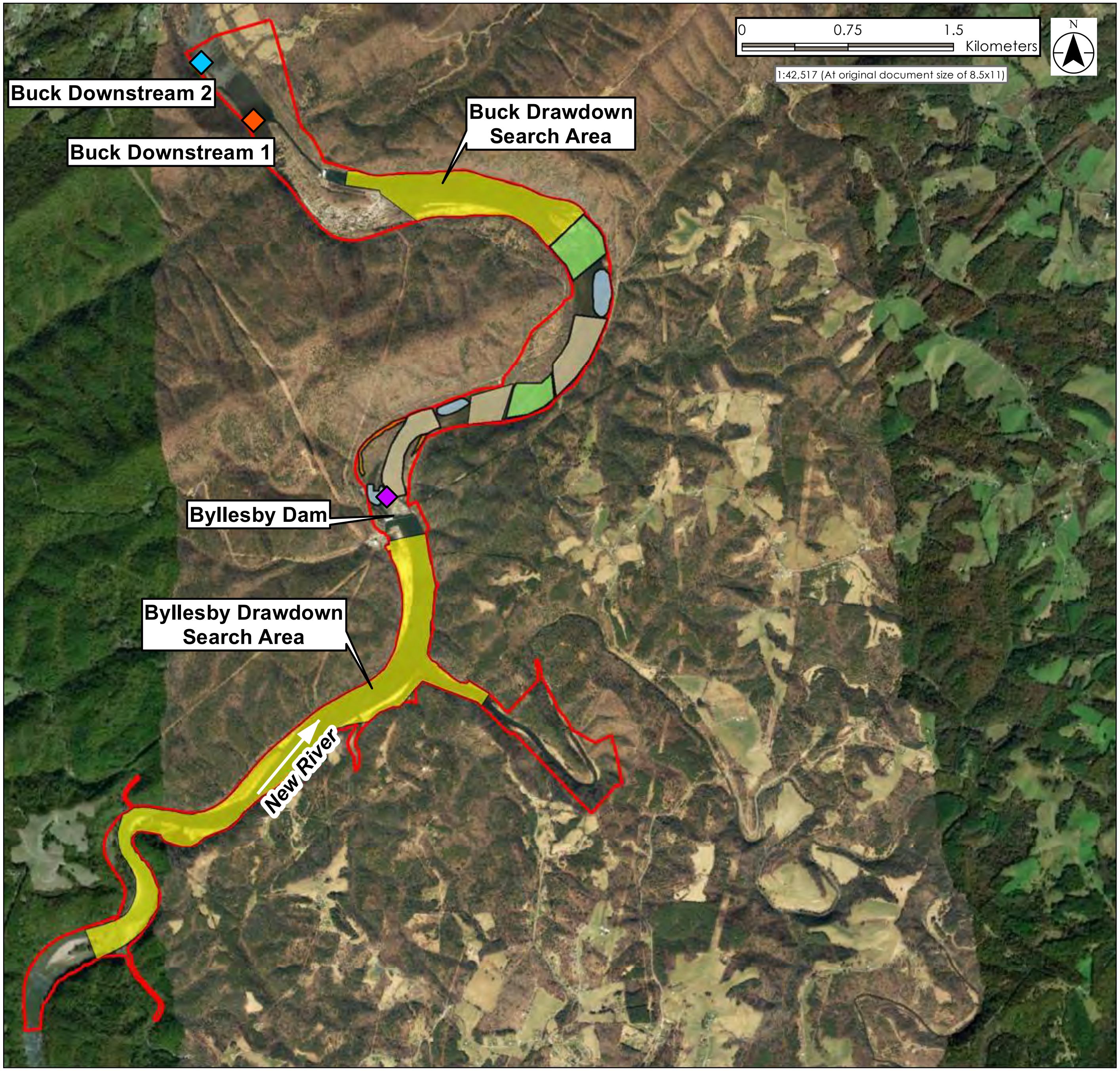
Study	Location	Methods	Site Search Time (Hours)	Total Search Time (hours)
Pinder et al. 2002	Buck 2 Bellow Byllesby	Wandering search - snorkel and/or viewscopes	1 - 4	5
Alderman 2008	Buck 2 Buck 1	Wandering search – snorkel, SCUBA and/or viewscopes	3.25 - 6	9.25
Stantec 2016	Buck 2 Buck 1	Transects – snorkel SCUBA Quadrat excavation	6.7	13.4
Stantec 2017	Buck 2	Transects – snorkel SCUBA Quadrat excavation	6.7	6.7
Stantec 2018a	Byllesby Drawdown Area	Wandering search – walking dewatered substrates	-	27.2
Stantec 2018b	Buck Drawdown Area	Wandering search – walking dewatered substrates	-	15.5
Stantec 2020	Un-impounded Reach	Wandering search – snorkel SCUBA	3.3	33.3

3.2 RESULTS

The following sections provide a summary of findings from freshwater mussel surveys identified by the RSP and Byllesby-Buck PAD as being located within the Project study area and relevant to Project operations (HDR 2019, Appalachian Power Company 2019). The GPS coordinates of each survey site assessed in this report are listed in Table 5. Survey site locations and their associated study are presented in Figure 6.

Table 5. Location of Historical Mussel Survey Sites

Site Name	Location
Buck Downstream 1	36.811950, -80.944339
Buck Downstream 2	36.815411, -80.948300
Buck Drawdown Area	0 - 2,700 m upstream of Buck Dam
Below Byllesby Dam	36.7875316, -80.934210
Byllesby Drawdown Area	0 - 5,000 m upstream of Byllesby Dam



Stantec

Legend

Study Area Boundary

Historical Survey Locations

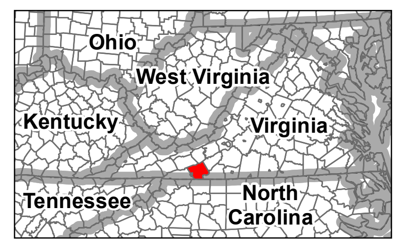
- Stantec 2016, 2017, Alderman 2008, Pinder et al. 2002
- Stantec 2016, Alderman 2008
- Pinder et al. 2002
- Stantec 2018a, 2018b

2020 Survey Locations

- Shallow Shoal
- Deep Shoal
- Pool
- Side Channel

Notes

1. Coordinate System: NAD 1983 StatePlane Ohio North FIPS 3401 Feet
2. Base Imagery: ESRI Map Services.



Project Location

Carroll County, Virginia
New River

Prepared by EKD on 2020-11-24

Client/Project

Byllesby & Buck Hydroelectric Project
(FERC No. 2514)

Figure No.
2

Title

Historical Survey Sites

3.2.1 Historical Studies

3.2.1.1 Pinder et al. 2002

Pinder et al. (2002) conducted a drainage wide survey of the New River to assess the status and distribution of freshwater mussels within the basin. Mussel surveys were conducted between 1997 and 1998 at 134 sites (Note the report was written in 2002 and is cited accordingly within), including mainstem and tributaries within the basin. Surveys were conducted using timed searches and snorkel or viewscope methods. Two of the 134 sites were located within the Project area; Site 20 corresponds with Buck Downstream 2 and Site 25 is directly below Byllesby Dam (Figure 6). Search effort was four person-hours at Buck Downstream 2 and one person-hour below Byllesby Dam. Table 6 presents a count of live mussels by species found for each survey site within the Project area. A total of 26 live mussels from four species were found between both sites. The two most widely distributed species both within the New River basin and Project area were *Cyclonaias tuberculata* and *Eurynia dilatata* (Table 6). Pinder et al. (2002) did not report mussel lengths.

Table 6. Live Mussels by Species Found by Pinder et al. (2002) Within the Project area

Species	Buck Downstream 2	Below Byllesby
Cyclonaias tuberculata	15	1
Eurynia dilatata	6	-
Lampsilis ovata	2	-
Tritogonia verrucosa	2	-
Total	25	1

3.2.1.2 Alderman 2008

Alderman (2008) conducted mussel surveys within the New River between 2007 and 2008 in support of the FERC relicensing of the Claytor Hydroelectric Project (FERC No. 739). Sites 20080724.1 and 20080724.2 were located within the Project area directly downstream of Buck Dam (corresponding to Buck Downstream 1 and Buck Downstream 2 in Figure 6). Surveys at these sites were conducted on July 24, 2008 and consisted of timed searches. Search effort was six person-hours at Buck Downstream 1 and 3.25 person-hours for Buck Downstream 2.

The number of mussels by species found at Buck Downstream 1 and 2 is presented in Table 7. A total of 275 mussels from four species were found between both survey sites. Abundance at Buck Downstream 2 (n = 180, CPUE = 55.4) was almost double that of Buck Downstream 1 (n = 95, CPUE = 15.8) and almost four times greater CPUE. *Cyclonaias tuberculata* (n = 134) and *Tritogonia verrucosa* (Pistolgrip, n = 125) were the most abundant species (Table 7). Alderman (2008) noted that most of the *Tritogonia verrucosa* at Buck Downstream 2 were found along the island near the upstream limit of the survey area. The study did not report size data for mussels at sites within the Project area but did state that only relatively mature specimens of each species were found as evidenced by the lack of observed smaller individuals (e.g. < 40 mm) (Alderman 2008).

Table 7. Live Mussels by Species Found by Alderman (2008) Within the Project area

Species	Buck Downstream 1	Buck Downstream 2
Cyclonaias tuberculata	11	123
Eurynia dilatata	1	6
Lampsilis ovata	4	5
Tritogonia verrucosa	79	46
Total	95	180

3.2.2 Stantec 2015 and 2017 Surveys

During the fall of 2015 and 2017, Stantec conducted mussel surveys at seven sites in the New River for aquatic studies related to the Claytor Hydroelectric Project (Stantec 2016, 2017). Two of the sites surveyed for these studies were within the Byllesby-Buck Project area, corresponding to sites Buck Downstream 1 and 2 (Figure 6).

3.2.2.1 Stantec 2016

During October 2015, Stantec (2016) surveyed Buck Downstream 1 and 2 using a two-staged approach to focus on higher quality habitats. During Stage 1, ten 40-meter-long transects were divided into 10 m segments and surveyed at a rate of 1 minute per meter (m). Total search effort at each site was a minimum of 6.7 person-hours. Stage 2 sampling consisted of quantitative surveys targeting the best mussel habitat identified during Stage 1. Quadrat samples were excavated near the four transect segments with the highest mussel densities during Stage 1, resulting in a total quantitative survey area of 25 m^2 for each site (Stantec 2016).

Table 8 presents the total number of live mussels found by species during Stage 1 and 2 surveys of Buck Downstream 1 and 2 during October 2015. A total of 65 live mussels from three species were found downstream of Buck Dam. No additional species were found that differed from those found by Pinder et al. (2002) and Alderman (2008). As was the case for Alderman (2008), abundance was greater at Buck Downstream 2 (n = 52) than Buck Downstream 1 (n = 13). *Cyclonaias tuberculata* (n = 40) and *Tritogonia verrucosa* (n=24) were the most abundant species, with only one *Eurynia dilatata* specimen found (Table 8).

Table 8. Mussels Found at Buck Downstream 1 and 2 by Stantec (2016)

Species	Buck Downstream 1	Buck Downstream 2	Total
Cyclonaias tuberculata	1	39	40
Eurynia dilatata	1	-	1
Tritogonia verrucosa	11	13	24
Total	13	52	65

3.2.2.2 Stantec 2017

During September 2016, Stantec (2017) conducted additional mussel surveys at Buck Downstream 2 (Buck Downstream 1 was discontinued as a survey site after 2015 surveys). Survey methods followed the same two-staged approach used by Stantec (2017). A total of 82 mussels were found during transect and quadrat surveys, consisting of 49 *Cyclonaias tuberculata*, three *Eurynia dilatata*, and 30 *Tritogonia verrucosa*.

3.2.3 Impoundment Drawdowns

3.2.3.1 Byllesby Drawdown 2018

Mussel salvage and relocation was conducted within the Byllesby Dam impoundment from April 30 – May 1, 2018 during a planned reservoir drawdown for installation of Obermeyer crest gates. The dam pool was lowered approximately nine feet over a 48-hour (hr) period. Stantec (2018a) relocated freshwater mussels stranded on habitat exposed by the impoundment drawdown to outside the disturbance limits. The total search effort was 27.2 person-hours and covered approximately 5,000 linear meters of stream, focusing on exposed channel margins and islands towards the upstream end of the dam pool (Figure 6). Four live mussels were collected, consisting of three *Cyclonaias tuberculata* and one *Lasmigona subviridis*. *Lasmigona subviridis* is listed as threatened in the state of Virginia (VDWR 2020) and was a new finding within the Project area. All collected mussels, both shells and living, were observed at the upstream end of the impoundment, above the New River Trail foot bridge. Higher quality mussel habitat (e.g. sand, gravel, and cobble) was observed more frequently along the upstream end of the search area and silt deposits were common closer to the dam (Stantec 2018a).

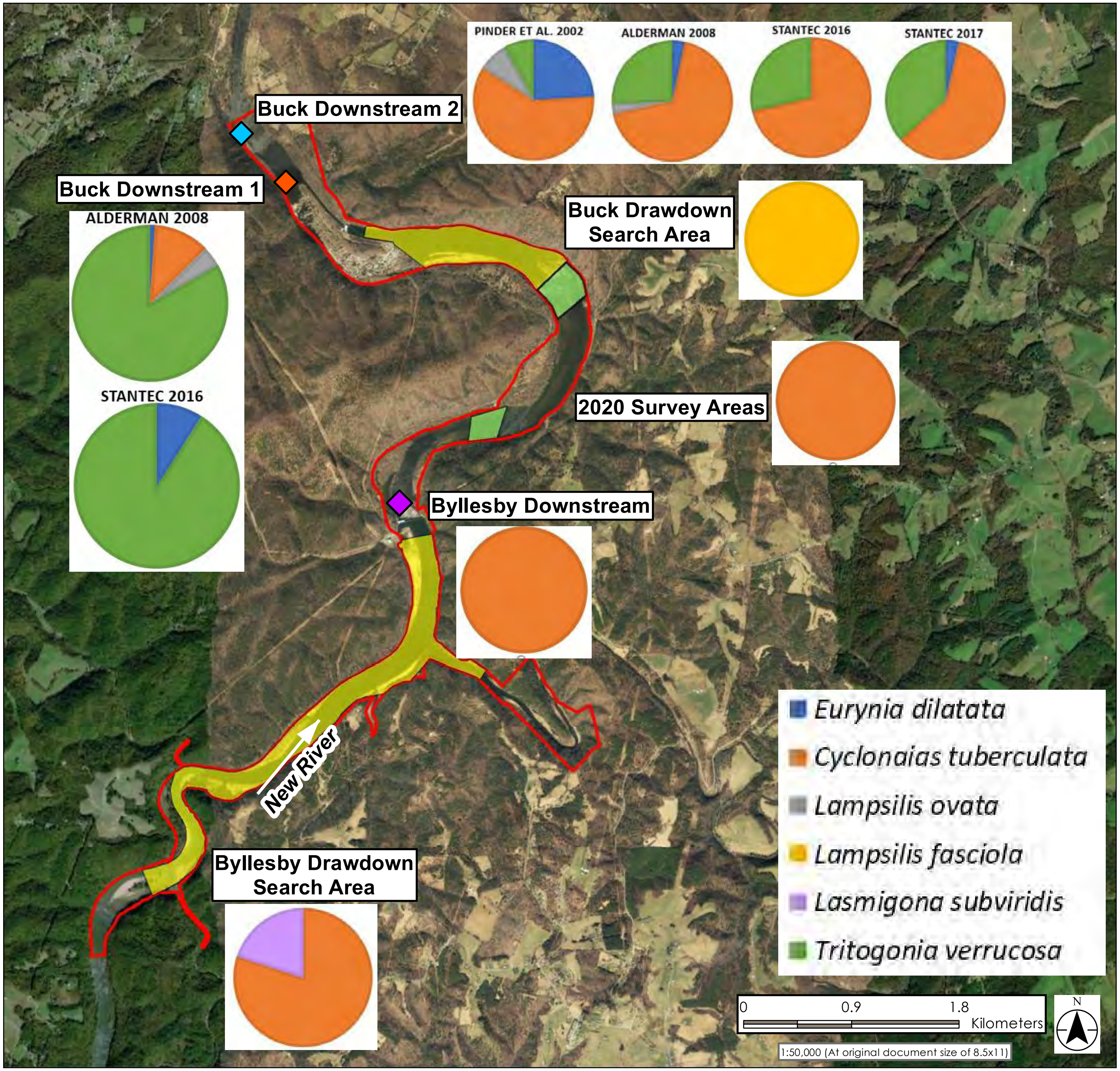
3.2.3.2 Buck Drawdown 2018

Between July 10 and July 11, 2018, Stantec (2018b) conducted a mussel salvage and relocation during a drawdown at the Buck Dam impoundment performed for installation of Obermeyer crest gates. The dam pool was lowered approximately nine feet over a 24-hr period. The search effort focused on potential mussel habitat along channel margins and islands above Buck Dam (Figure 6). The total search effort was 15.5 person-hours, covering approximately 2,700 linear meters of streambank upstream of Buck Dam. Two live mussels, both *Lampsilis fasciola*, were collected and relocated outside the dewatered area. Both specimens were found along the mid-channel island near the upstream limits of the impoundment. This area is slightly downstream of Shallow Shoal 1 from the Stantec 2020 survey (Section 2.0). The island contained pockets of flow refugia and gravel substrate which offered more suitable mussel habitat than the silt deposits that were dominate downstream of the island. *Cyclonaias tuberculata* was also found as a shell only (Stantec 2018b).

3.2.4 Mussel Abundance and Species Composition

A total of 452 live mussels from six species were found during mussel surveys within the Project area between 1997 and 2020 (Pinder et al. 2002, Alderman 2008, Stantec 2016, Stantec 2017, Stantec 2018a, Stantec 2018b, and Stantec 2020). The most widespread species across all survey years were *Cyclonaias tuberculata* (n = 242) and *Tritogonia verrucosa* (n = 179). These two species accounted for 421 of the 452 mussels found within the Project area. *Lampsilis ovata* (Pocketbook) was found in small numbers downstream of the Buck Dam during 1997 and 2008 surveys but was not found during more recent surveys between 2015 and 2020 (Pinder et al. 2002, Alderman 2008). The only *Lasmigona subviridis* found within the Project area was encountered along an island at the upstream limits of the Byllesby impoundment (Stantec 2018a). Likewise, *Lampsilis fasciola* was only found near an island upstream of Buck Dam (Stantec 2018b, Figure 7).

Overall, species richness and abundance were greater at sites downstream of Buck Dam than elsewhere in the Project area. Mussel densities within the dam impoundments were some of the lowest observed within the Project area. Mussel observations during drawdown surveys were limited to coarser habitats found along upstream islands. No federally listed threatened or endangered species were found within the Project area. *Tritogonia verrucosa* and *Lasmigona subviridis* are listed as threatened in Virginia (VDWR 2020).



Stantec

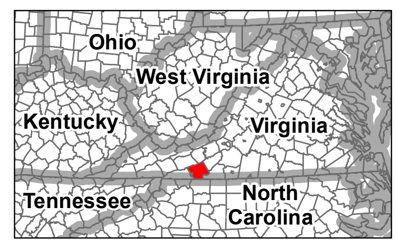
Legend

Study Area Boundary

Historical Survey Locations

- Stantec 2016, 2017, Alderman 2008, Pinder et al. 2002
- Stantec 2016, Alderman 2008
- Pinder et al. 2002
- Stantec 2018a, 2018b
- 2020 Survey Areas

Notes
1. Coordinate System: NAD 1983 StatePlane Ohio North FIPS 3401 Feet
2. Base Imagery: ESRI Map Services.



Project Location
Carroll County, Virginia
New River

Prepared by EKD on 2020-11-24

Client/Project
Byllesby & Buck Hydroelectric Project
(FERC No. 2514)

Figure No.
7

Title
Species Compostion by Survey Site

3.2.5 Mussel Lengths

Figures 8 and 9 show the distribution of mussel lengths for the two most abundant species within the Project area (*Cyclonaias tuberculata* and *Tritogonia verrucosa*) found during surveys at Buck Downstream 1 and 2 (Stantec 2016, 2017, and 2020). Pinder et al. (2002) and Alderman (2008) did not report mussel sizes, so data from these studies were not included in this length assessment. Both *Cyclonaias tuberculata* and *Tritogonia verrucosa* were collected across a wide range of size classes during 2015, 2017, and 2020 field surveys. Although the size distribution of *Cyclonaias tuberculata* is skewed towards larger individuals, the presence of smaller or younger individuals suggests recent recruitment has occurred downstream of Buck Dam (Figure 8). The three *Cyclonaias tuberculata* collected during the Byllesby drawdown were also a range of sizes (34 – 71 mm), further confirming the presence of a reproducing mussel population within the Project area (Stantec 2018a).

The four *Eurynia dilatata* specimens collected during 2015 and 2017 surveys were all larger individuals (85 – 95 mm) (Stantec 2016, 2017). The small sample size of *Lasmigona subviridis* (n = 1) and *Lampsilis fasciola* (n = 2) precluded a viable assessment of mussel size distribution and recruitment for these species within the Project area. The lone *L. subviridis* appeared to be approximately 8 years old based on growth rings, which would suggest recruitment in 2010. *Lampsilis ovata* was only found live during earlier studies that did not report length data (Pinder et al. 2002 and Alderman 2008).

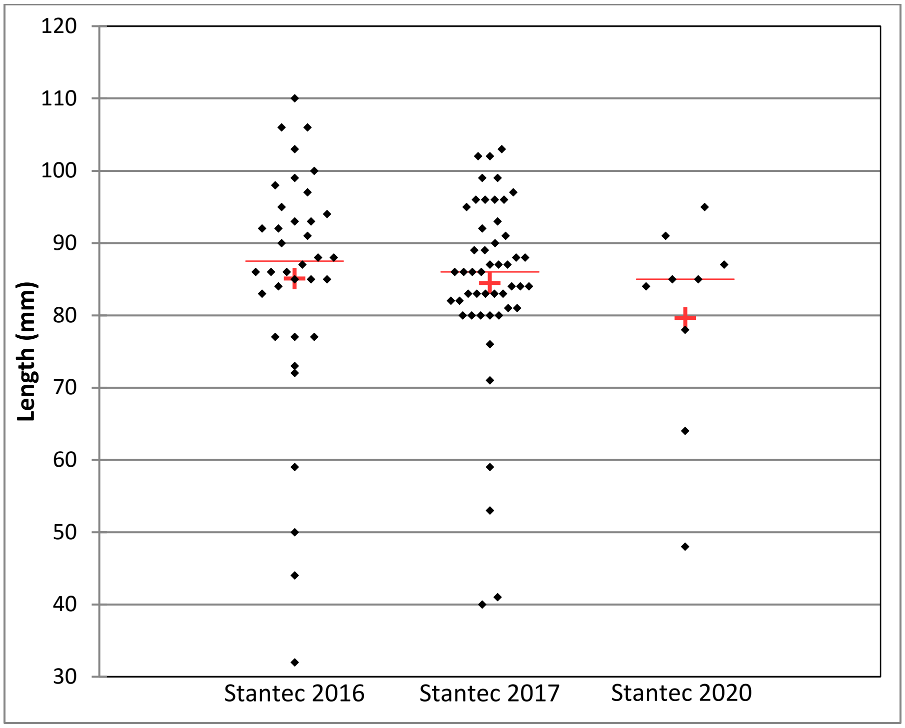


Figure 8. Shell lengths of *Cyclonaias tuberculata* Found Downstream of Buck Dam by Stantec (2016, 2017, 2020)

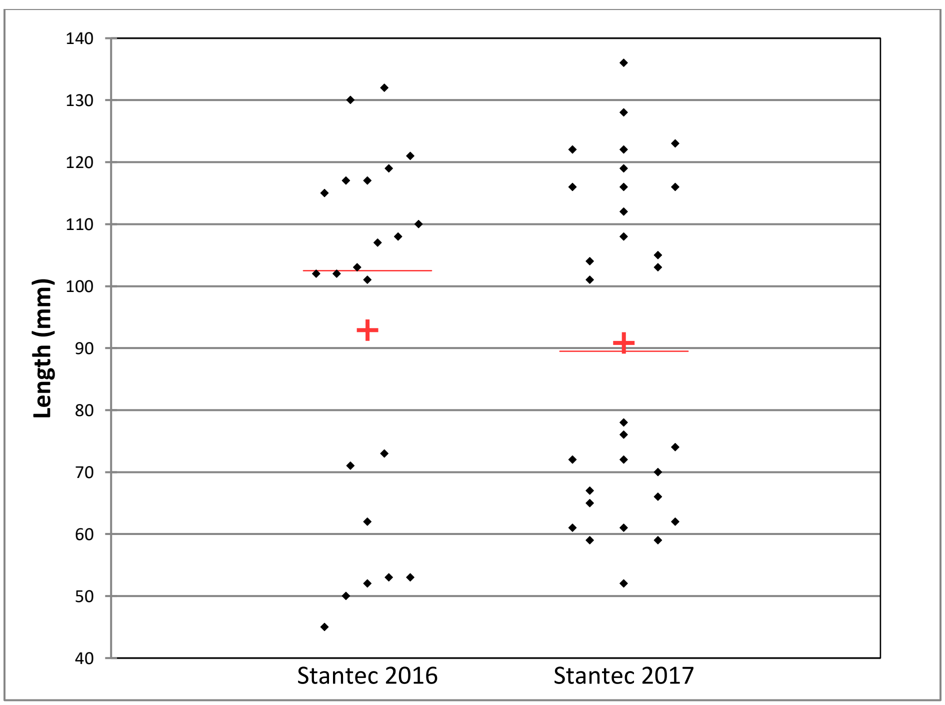


Figure 9. Shell lengths of *Tritogonia verrucosa* Found Downstream of Buck Dam by Stantec (2016, 2017)

3.2.6 Community Metrics

Table 9 presents a summary of mussel community metrics, including richness, abundance, Catch per Unit Effort (CPUE), and mussel density, for all studies assessed within the Project area. While direct comparison of mussel abundance and density between studies is difficult due to different survey methods, general observations about the quality of mussel habitat and composition of the mussel community can still be made.

Overall species richness within the Project area is low, with a maximum of four species found during any one survey. Richness was slightly higher for Pinder et al. 2002 and Alderman 2008 surveys than more recent surveys downstream of Buck Dam in 2015 and 2017 (Table 9). Abundance and CPUE was generally higher for survey sites directly downstream of Buck Dam, with the greatest abundance observed for Alderman (2008) (n = 275). For surveys within the dam pools (Stantec 2018a, 2018b), richness was limited to one or two species and CPUE was < 1.0 mussels/hr.

Table 9. Comparison of Mussel Community Metrics for Surveys within the Project area by Study Year Between 1997-2020

	Pinder et al. 2002	Alderman 2008	Stantec 2016	Stantec 2017	Stantec 2018a	Stantec 2018b	Stantec 2020
Species Richness	4	4	3	3	2	1	1
Abundance	26	275	53	82	5	1	9
Search effort (hours)	5	9.25	6.7	6.7	27.2	15.5	33.3
CPUE	5.2	29.7	3.9	11.0	0.18	0.13	0.27
Density (mussels/m^2)	-	-	0.24	0.32	-	-	-

Repeat surveys at Buck Downstream 1 and 2 allowed for assessment of potential temporal changes in the mussel community between survey dates. Table 10 compares species richness, CPUE, and mussel density for 2008 and 2015 surveys of Buck Downstream 1. While abundance was low for both survey years, both CPUE and richness were slightly higher in 2008 than 2015 (Table 10).

Table 10. Comparison of Mussel Community Metrics at Buck Downstream 1

Metric	Alderman 2008	Stantec 2016
Richness	4	2
CPUE	6.0	1.6
Density (mussels/m^2)	-	0.10

Buck Downstream 2 was surveyed during four different studies between 1997 and 2017. Table 11 compares richness, CPUE, and mussel density observed at Buck Downstream 2 for all four studies. CPUE ranged from 4.0 to 55 mussels per hour of searching among all survey dates. Species were limited for all survey years, with no more than four species observed during each survey (Table 11).

Table 11. Comparison of Mussel Community Metrics at Buck Downstream 2

Metric	Pinder et al. 2002	Alderman 2008	Stantec 2016	Stantec 2017
Richness	4	4	2	3
CPUE	4.0	55	6.3	11
Density (mussels/m^2)	-	-	0.4	0.32

Examining CPUE from downstream to upstream shows that the most mussels were found downstream of Buck Dam (Figure 10). Despite differences between the four surveys (some of which is due to different methods), the Buck Downstream 2 site has the greatest CPUE through time. Upstream of the Buck Dam and continuing to upstream of the Byllesby Dam shows low CPUE's throughout the Project area. Note that for display purposes this figure ignores the Buck Tailrace and eight hydraulic units that contained zero mussels.

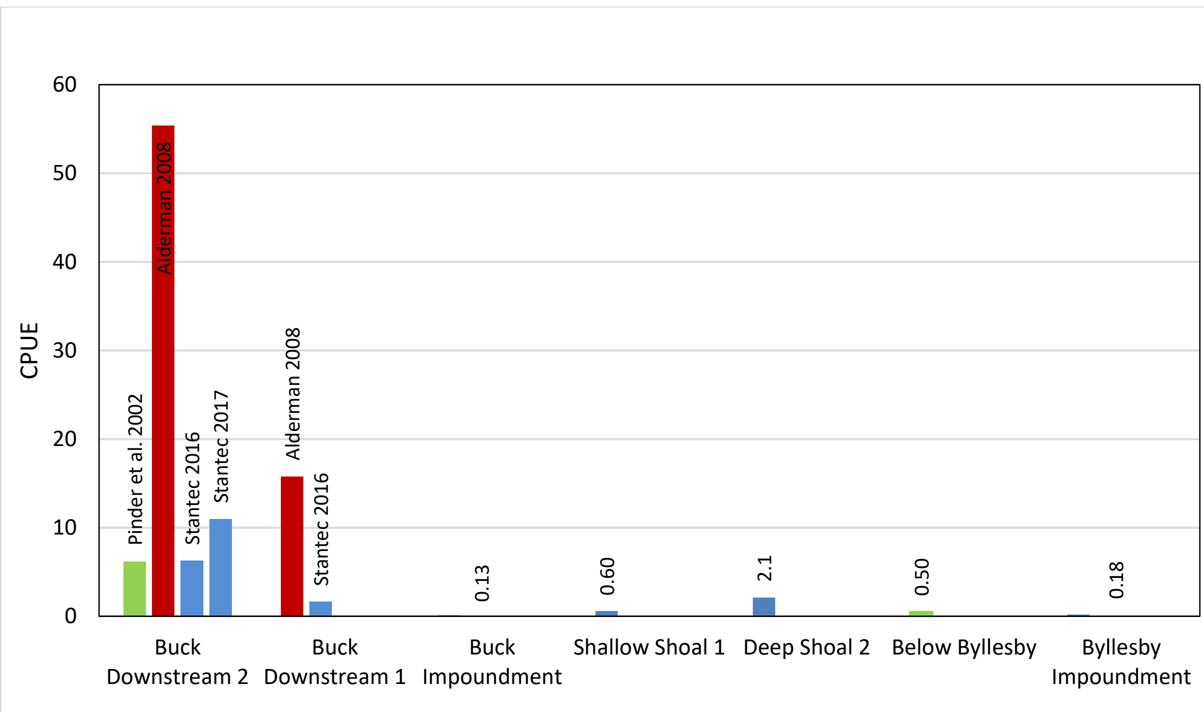


Figure 10. CPUE Across all Survey Sites from Downstream to Upstream.

Distinct differences in CPUE from downstream to upstream is further illustrated by averaging the CPUE's across all surveys (Figure 11). Downstream of Buck Dam is where mussel communities really become abundant enough for higher CPUE's.

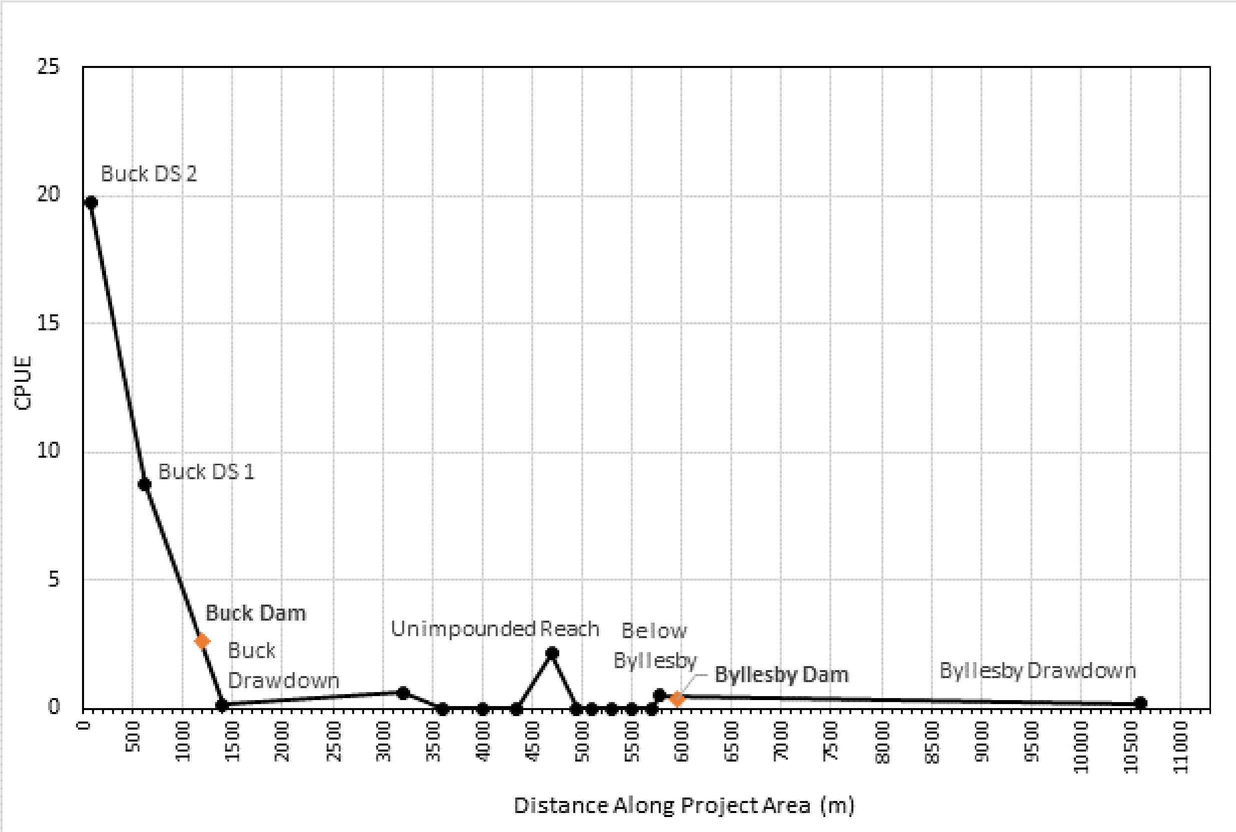


Figure 11. Average CPUE by Site from Downstream to Upstream Through the Project Area.

Four sampling periods at Buck Downstream 2 allows for temporal comparisons unavailable at other specific sites (Figure 12). CPUE's were similar between 1997 (4), 2015 (6.3), and 2017 (11) surveys, with the 2008 Alderman study being the outlier (55.4). Species richness varied between two and four species but may be tied to overall survey effort.

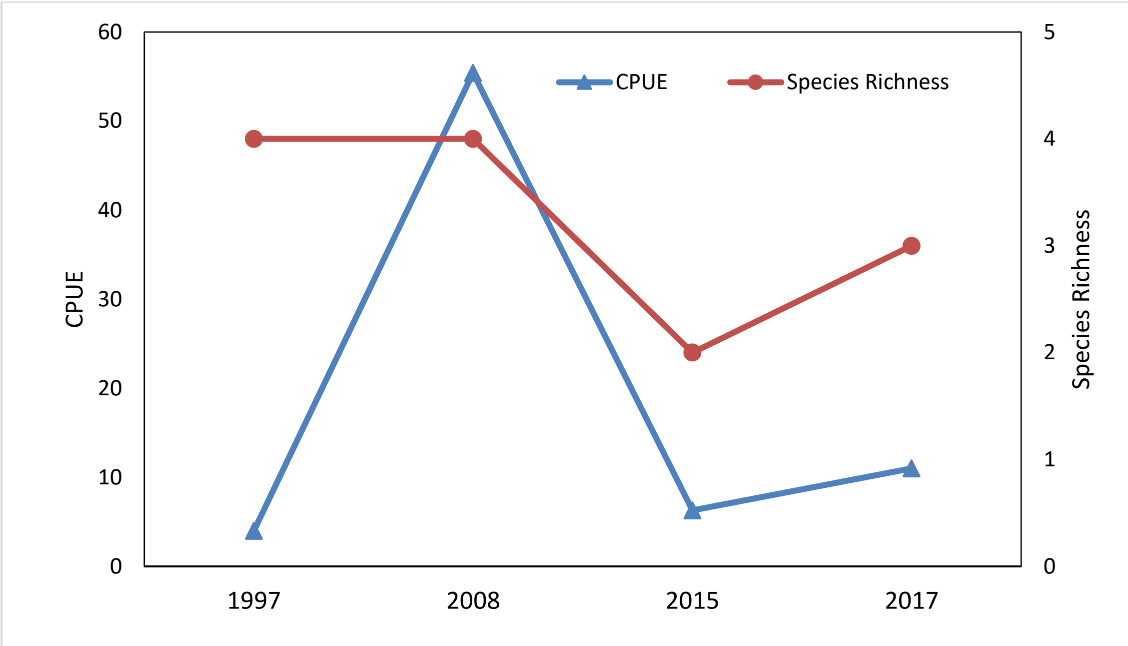


Figure 12. CPUE and Species Richness at Buck Downstream 2 (1997 – 2017)

3.3 DISCUSSION

Results of mussel surveys of the New River from 1997 to 2020 demonstrate that overall abundance and density of freshwater mussels within the Project area is low. Species rarity and the low number of collected mussels presents challenges for understanding population dynamics within the Project area. However, a broad assessment of the habitat quality and spatial distribution of aquatic resources within the Project area can still be made. Six species were observed in the Project area, with only *Cyclonaias tuberculata* and *Tritogonia verrucosa* found in large numbers. Quality mussel habitat within the Project area appears to be limited. Coarser substrates (e.g. cobble and boulder) were observed at Buck Downstream 2 where some of the highest densities of mussels were observed. Habitat at Buck Downstream 1 was not as productive as Buck Downstream 2 with large amounts of rubble noted at the site by Stantec (2016).

Some of the lowest observed mussel densities were encountered in the riverine reach between Buck and Byllesby facilities during surveys in 2020. Despite the targeted approach of surveying hydraulic habitat units, CPUE (0.27 mussels/hr) and abundance (n = 9) were still low and consistent with findings of historical studies. Much of the habitat in this reach consisted of silt deposits on top of bedrock. Pockets of more habitable substrate did not correspond to mussel abundance. The side channel near Byllesby Dam contained perceived high quality substrates of gravel/sand/cobble in a riffle/run sequence, however almost no invertebrate life was observed. This potentially could be due to these side channels being intermittent during summer but has not been directly observed by Stantec.

Within the dam impoundments, substrates were predominantly thick deposits of silt with some bedrock outcroppings. While such backwater habitat is often capable of supporting lentic species, such as *Pyganodon grandis* and *Utterbackia imbecillis*, none were observed and overall counts of both live animals and spent shells along the impoundments were low. The only mussels observed in the drawdown studies were found in flow refugia and coarser substrates along islands at the upper limits of the impoundments.

Different survey methods between studies make assessment of temporal trends in abundance and composition of the mussel community difficult. While slightly greater abundances were observed downstream of Buck Dam during earlier studies conducted in 1997 and 2008 than during more recent studies, this may be an artifact of survey methods and not necessarily an indication of mussel population declines. Surveys in 2015 and 2017 downstream of Buck Dam suggest that *Cyclonaias tuberculata* and *Tritogonia verrucosa* are still abundant and reproducing in these locations. *Eurynia dilatata, Lampsilis Fasciola,* and *Lasmigona subviridis* were not found in sufficient abundances to gain insights into population dynamics.

Spatial distribution of mussels appears to be concentrated downstream of Buck Dam (Figures 10 & 11). These figures suggest that the Byllesby-Buck Project may be influencing the mussel communities within the Project area, however the Buck Downstream 2 site is similar to those seen during the 2020 study between Buck and Byllesby Dams.

The decline in CPUE from 2008 to 2015-2017 at Buck Downstream 2 may be due to differences in survey methodologies, as Alderman's timed searches allow for locating and focusing on areas of high mussel concentrations, while Stantec (2016, 2017) used transects at fixed distances where all habitats were sampled regardless of quality. Species Richness was lower in 2015 (2) and 2017 (3) compared to 1997 and 2008 surveys, despite having higher effort than the 1997 survey. Surveys in 1997 (N = 2) and 2008 (N = 5) managed to locate *Lampsilis ovata*, which is uncommon throughout the basin and normally found in low numbers. Shifts in species richness over time may be due to the probability of detecting these rare species rather than shifts in the assemblage or local extirpation.

3.4 CONCLUSIONS

Since 1997, six species have been collected within the Project area: *Cyclonaias tuberculata*, *Eurynia dilatata, Tritogonia verrucosa, Lampsilis fasciola, Lasmigona subviridis,* and *Lampsilis ovata. Cyclonaias tuberculata* and *Tritogonia verrucosa* were observed most frequently within the Project area, particularly downstream of Buck Dam. The range of sizes recorded for these species demonstrates that juvenile recruitment is occurring for these species. Other species were observed in too low of abundances (e.g. < 10) to accurately depict assemblage status. *Lampsilis fasciola* and *Lasmigona subviridis* were the least abundant species and were only found along mid-channel islands upstream of the dams. As was demonstrated by 2020 field efforts and historical studies, quality mussel habitat is limited within the impounded portion of the Project area. Furthermore, areas with suitable habitat did not always support mussel inhabitance. Species composition and abundance were relatively consistent across survey years, with some rarer species not occurring during some surveys. However, low overall abundances throughout the Project area doesn’t mean these species are extirpated. The low number of shells observed within the Project area supports the conclusion that the mussel community has not undergone a significant die-off in recent years and abundances and species have always been low. Spatial trends within the Project area suggest that downstream of Buck Dam is the highest quality mussel community, having relatively high species richness and CPUE. Within the impoundments, reaches between the two dams, and upstream of Byllesby Dam are all seemingly lower quality mussel communities. The appearance of mussel declines at the Buck Downstream 2 site, which has been sampled four times over the past 23 years may simply be due to differences in survey methods, as project operations have not differed in this area during that time frame.

4.0 REFERENCES

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Appendix A - AGENCY CORRESPONDENCE

From: Symonds, Daniel
To: Symonds, Daniel
Subject: RE: Buck/Byllesby Dam Mussel Survey Study Plan
Date: Wednesday, December 2, 2020 4:41:36 PM

From: Watson, Brian <brian.watson@dwr.virginia.gov>
Sent: Monday, September 21, 2020 2:05 PM
To: Symonds, Daniel <Daniel.Symonds@stantec.com>
Cc: Fleece, Cody <Cody.Fleece@stantec.com>; Kiser, James <James.Kiser@stantec.com>; brian.watson@dgif.virginia.gov
Subject: Re: Buck/Byllesby Dam Mussel Survey Study Plan

Dan,

I'm fine with the mussel survey plan. Let me know when you guys get out and I might be able to help if you need an extra set of eyes.

Brian

On Tue, Sep 8, 2020 at 2:37 PM Symonds, Daniel <Daniel.Symonds@stantec.com> wrote:

> Hello Brian,
> I'm sending this study plan on behalf of Cody, who is stuck driving today. Attached is our plan to sample for mussels between Buck and Byllesby Dams, as part of Appalachian Power
>
> Company's Revised Study Plan from 2019. We plan on conducting this survey sometime in the next month or so, pending your approval.
>
> Please let us know if you have any questions or comments.
>
> Thanks,
> Dan
> **Daniel Symonds**
>
> Aquatic Ecologist
> Direct: (614) 282-3215
>
> Daniel.Symonds@stantec.com

--
Brian T. Watson
Aquatic Resources Biologist/State Malacologist
Office: 434.525.7522, x 114
Mobile: 434.941.5990
Fax: 434.525.7720

Virginia Department of Wildlife Resources

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Forest, VA 24551
www.VirginiaWildlife.gov

Stantec

Stantec Consulting Services Inc.
1500 Lake Shore Drive Suite 100, Columbus OH 43204-3800

September 8, 2020
File: 173430067

Attention: Brian Watson
Virginia State Malacologist
Virginia Department of Wildlife Resources
1132 Thomas Jefferson Road
Forest, VA 24551
(434) 941-5990

Dear Brian Watson,

Reference: Byllesby-Buck Hydroelectric Project – Mussel Survey Study Plan

Stantec Consulting Inc. has been contracted by HDR, Inc. to conduct freshwater mussel surveys in the vicinity of Buck Dam and Byllesby Dam, Wythe and Carroll Counties, Virginia. These surveys are a component of Appalachian Power Company's Revised Study Plan (RSP) filed with the Federal Energy Regulatory Commission (FERC) on October 18, 2019. The RSP included provisions for an Aquatic Resources Study, including the freshwater mussel surveys that will be detailed in this study plan. Per conditions outlined in Stantec's Scientific Collecting Permit (#065183) and Threatened and Endangered Species Permit (#067427) this letter seeks Virginia Division of Wildlife Resource (VDWR) approval to conduct the work outlined below, with the overall goal to determine the distribution and abundance of freshwater mussels in the area.

FIELD SAMPLING

Due to historic documentation of mussels in large portions of the project area, this study will focus on the tailrace and approximately 3,000 meter long reach between Byllesby Dam and the Buck Reservoir Islands. By examining these two reaches, it should provide a more complete picture of the overall mussel community in this area of the New River.

Stantec proposes a two-step approach for surveying the Byllesby-Buck Project Area. Initially, a boat-based habitat survey will be performed to visually identify potential mussel habitats in the transition area between Byllesby Dam and the Buck Dam Reservoir. This will facilitate surveying in the best habitats within the survey area. Review of aerial photography shows a number of different hydraulic habitat types (e.g. fast velocity/deep depth, slow/shallow, etc., See Attachment A) that may yield different mussel community compositions. Initial boat surveys will choose specific locations within each of these hydraulic habitat types. A total of ten sites will be selected, one from each distinct hydraulic habitat area. Each area will be searched using wandering timed searches, a total of 200 person-minutes per area. This will result in a total of 33.3 person-hours of searching in the area between the two dams. These searches will involve snorkeling, tactile searches, or diving (SCUBA or surface supplied) depending on conditions in each habitat. Substrates will be searched by moving cobble and woody debris; hand sweeping away silt, sand

and/or detritus; and disturbing/probing the upper two inches of substrate to better view resident mussels. All mussels (live and shell) will be placed in a mesh bag, taken to the streambank/boat, and identified to species and sized for data collection. Mussels will be returned to the approximate location they were found. Each species will be photographed as vouchers.

An additional search will take place in the tailrace of Buck Dam, which has not previously been surveyed. This stretch of river extends approximately 500m along a vegetated island from the Buck Dam powerhouse until it reaches a wider channel with a wetted width more typical of the New River. This narrow cross sectional area and large volume of discharge suggests that the reach does not provide suitable habitat for freshwater mussels. Surveyors will conduct a reconnaissance level habitat assessment of the channel to assess potential freshwater mussel habitat. Notes will be taken about substrate composition and habitat quality. Shell and any live mussels encountered will be recorded. Due to the high flow's normally encountered in this area, no diving is scheduled to take place during this search.

Upon completion of the survey a technical report will be prepared and submitted to FERC and VDWR. This project will be conducted under Senior Malacologist Cody Fleece's Scientific Collecting permit (#065183, Attachment B) and Threatened and Endangered species permit (#067427, Attachment B).

Regards,

Stantec Consulting Services Inc.

W. Cody Fleece
Senior Malacologist
Phone: (513) 262-3994
Cody.Fleece@stantec.com

Attachment: A – Survey Area Figure
B – Collecting Permits

Appendix B - COLLECTING PERMITS

Virginia Department of Game and Inland Fisheries

7870 Villa Park Drive, P.O. Box 90778, Henrico, VA 23228-0778
(804) 367-1000 (V/TDD)
Under Authority of § 29.1-412, § 29.1-417, & § 29.1-568 of the Code of Virginia & DGIF Policy E-1-90

Threatened/Endangered Species Permit

Permit Type: **Renewal** Fee Paid: **$20.00** VADGIF Permit No. **067427**

Permittee: **William Cody Fleece**
Address: **11687 Lebanon Road**
Sharonville, OH 45241
Email:

Office: **(513) 262-3994**
City/County:

Business: **Stantec Consulting Services, Inc.**
11687 Lebanon Road
Sharonville, OH 45241

Biomonitoring/Contract Environmental Impact/Contract Species Surveys

Authorized Collection Methods: By Hand/Scuba/Snorkel/View Scope
Authorized Waterbodies: New River
Authorized Marking Techniques: N/A

NO LIVE MUSSELS MAY BE PRESERVED

Permittee MUST notify VDGIF within the 7 day period prior to each sampling event. Notification must be made via email to: collectionpermits@dgif.virginia.gov

Report Due: 31 January 2021

ANNUAL REPORTS MUST BE SUBMITTED VIA: https://vafwis.dgif.virginia.gov/collection_permits/

STANDARD CONDITIONS ATTACHED APPLY TO THIS PERMIT.

Authorized Counties / Cities:
Carroll
Giles
Montgomery
Pulaski
Wythe
Radford

Authorized Species:

Description	ID Number	Scientific Name
Threatened & Endangered Aquatic Mollusk Species		
Threatened & Endangered Freshwater Mussels		

Authorized Sub-Permittees:
Aaron Kwolek, Stantec
Daniel Symonds, Stantec
James Kiser, Stantec

Approved by: [signature]

Title: **Randall T. Francis - Permits Manager** **Date:** **3/20/2020**

Applicants may appeal permit decisions within 30 days of issuance. The appeal must be in writing to the Director, Department of Game and Inland Fisheries.

Virginia Department of Game and Inland Fisheries

7870 Villa Park Drive, P.O. Box 90778, Henrico, VA 23228-0778
(804) 367-1000 (V/TDD)

Under Authority of § 29.1-412, § 29.1-417, & § 29.1-568 of the Code of Virginia & DGIF Policy E-1-90

Threatened/Endangered Species Permit

Permit Type: **Renewal**   Fee Paid: **$20.00**   VADGIF Permit No. **067427**

20   Permit Effective **3/20/2020** through **12/31/2020**   **20**

Virginia Department of Game and Inland Fisheries
P O Box 3337 Henrico, VA 23228-3337
(804) 367-6913

Under Authority of § 29.1-412, § 29.1-417, & § 29.1-568 of the Code of Virginia and Policy E-1-90

THREATENED/ENDANGERED SPECIES PERMIT -- STANDARD CONDITIONS

1. Permits are issued to permittees with the understanding that if the principal permittee leaves the project the permit will be null and void and anyone desiring to continue the activities must apply for a new permit.

2. This permit, or a copy, must be carried by the permittee(s) during collection activities.

3. Permittee MUST notify the Virginia Department of Game and Inland Fisheries (VDGIF) within the seven (7) day period prior to EACH sampling event. Notification must be made via email to: collectionpermits@dgif.virginia.gov.

4. The permittee is required to submit to VDGIF a report of all specimens collected under this permit by the report due date. Report form may be found https://vafwis.dgif.virginia.gov/collection_permits/.asp. FAILURE TO RETURN THIS REPORT WILL RESULT IN NON-ISSUANCE OF FUTURE PERMITS. If no activity occurs under this permit, an email should be sent to collectionpermits@dgif.virginia.gov containing the following statement: No activity occurred under Permit #*insert permitID* during insert year (i.e. 2017). Permit reports are due by January 31.

5. Permittees shall give any and all changes of name, address, and/or phone number to the VDGIF Permits Section within no more than seven (7) days of those changes. All permittees (to include sub-permittees) shall provide DGIF with a complete home address, contact telephone number (home or cellular), and a valid e-mail address.

6. This permit does not support any activities outside of those associated with the application and proposal submitted to and approved by DGIF.

7. If incidental death or injury of threatened or endangered species occurs, the permittee is required to notify VDGIF at collectionpermits@dgif.virginia.gov within twenty-four (24) hours of occurrence. The following information must be reported: collector, date, species, location (county, quad, waterbody, and latitude and longitude to nearest second), and number collected.

8. If incidental *collection and live release* of threatened or endangered species occurs *for species other than those authorized under this permit*, the permittee is required to notify VDGIF at collectionpermits@dgif.virginia.gov within four (4) working days. The following information must be reported: collector, date, species, location (county, quad, waterbody, and specific location, either in latitude and longitude to nearest second, or by way of a photocopied 7.5' topographic map), general habitat associations, and number collected.

9. No species may be retained unless specifically authorized by this permit.

10. All traps must be marked with the name and address of the trapper or an identification number issued by VDGIF (Code of Virginia §29.1-521.7). Steel foothold traps, Conibear-style body gripping traps, and snares must be marked with a nonferrous metal tag bearing this information (Virginia Administrative Code 4 VAC 15-40-170).

11. All traps must be checked at least once a day and all captured animals removed, except completely submerged body-gripping traps which must be checked at least once every 72 hours (Code of Virginia §29.1-521.9).

12. The permittee is required to report any incidences of wildlife deaths or diseases observed during the course of collection activities. Reports should be made to: collectionpermits@dgif.virginia.gov within four (4) working days.

13. This permit satisfies only VDGIF's requirement for collection permits and is issued with the understanding that no collections will be made on Federal, state, or private property without the prior approval and necessary permits from the landowners involved. The permittee is responsible for obtaining any additional permits required for collection.

14. Sampling gear, boats, or trailers which have been used in states harboring zebra mussels must be cleaned and prepared following the guidelines specified in the attached summary prior to use in waters in the Commonwealth.

15. For safety reasons, it is recommended that all permittees display at least 100 square inches of solid blaze orange material at shoulder level within body reach and visible from 360 degrees, especially during hunting season.

Virginia Department of Game and Inland Fisheries

7870 Villa Park Drive, P.O. Box 90778, Henrico, VA 23228-0778
(804) 367-1000 (V/TDD)
Under Authority of § 29.1-412, § 29.1-417, & § 29.1-418 of the Code of Virginia

Scientific Collection Permit

Permit Type: **Renewal**   Fee Paid: **$40.00**   VADGIF Permit No. **065183**

Permittee: **William Cody Fleece**
Address: **Stantec Consulting Services, Inc.**
11687 Lebanon Road
Sharonville, OH 45241
Email: **cody.fleece@stantec.com**

Home:
Office: **(513) 842-8238**

Appalachian Power Company - Biomonitoring/Contract Environmental Impact/Contract Species Surveys

Authorized Collection Methods: By Hand/Scuba/Snorkel/Hooka
Authorized Waterbodies: New River
Authorized Marking Techniques: N/A

NO LIVE MUSSELS MAY BE PRESERVED

Permittee MUST notify VDGIF within the 7 day period prior to each sampling event. Notification must be made via email to: collectionpermits@dgif.virginia.gov

Report Due: 31 January 2020, 31 January 2021

ANNUAL REPORTS MUST BE SUBMITTED VIA: https://vafwis.dgif.virginia.gov/collection_permits/

STANDARD CONDITIONS ATTACHED APPLY TO THIS PERMIT.

Authorized Counties / Cities:
Carroll
Giles
Montgomery
Pulaski
Wythe
Radford

Authorized Species:

Description	ID Number	Scientific Name
Freshwater Mussels		

Annual Report Due End of Each Year

Authorized Sub-Permittees:
James Kiser, Stantec
Dillon McNulty, Stantec
Aaron Kwolek, Stantec
Elizabeth Dilbone, Stantec
Daniel Symonds, Stantec

Approved by: Randall T. Francis (signature)

Title: Randall T. Francis - Permits Manager   **Date: 4/29/2019**

Applicants may appeal permit decisions within 30 days of issuance. The appeal must be in writing to the Director, Department of Game and Inland Fisheries.

20   Permit Effective **4/29/2019** through **12/31/2020**   **20**

Virginia Department of Game and Inland Fisheries
P O Box 3337 Henrico, VA 23228-3337
(804) 367-6913

Under Authority of § 29.1-412, § 29.1-417, & § 29.1-418 of the Code of Virginia

SCIENTIFIC COLLECTION PERMIT – STANDARD CONDITIONS

1. Permits are issued to permittees with the understanding that if the principal permittee leaves the project the permit will be null and void and anyone desiring to continue the activities must apply for a new permit.

2. This permit, or a copy, must be carried by the permittee(s) during collection activities.

3. Permittee MUST notify the Virginia Department of Game and Inland Fisheries (VDGIF) within the seven (7) day period prior to EACH sampling event. Notification must be made via email to: collectionpermits@dgif.virginia.gov.)

4. The permittee is required to submit to this Department a report of all specimens collected under this permit by the report due date. Report form may be found at https://vafwis.dgif.virginia.gov/collection_permits/. FAILURE TO RETURN THIS REPORT WILL RESULT IN NON-ISSUANCE OF FUTURE PERMITS. If no activity occurs under this permit, an email should be sent to collectionpermits@dgif.virginia.gov containing the following statement: No activity occurred under Permit #*insert permit ID* during insert year (i.e. 2017). Permit reports are due by January 31.

5. Permittees shall give any and all changes of name, address, and/or phone number to the VDGIF Permits Section within no more than seven (7) days of those changes. All permittees (to include sub-permittees) shall provide DGIF with a complete home address, contact telephone number (home or cellular), and a valid e-mail address.

6. This permit does not support any activities outside of those associated with the application and proposal submitted to and approved by DGIF.

7. No species currently listed by the U.S. Fish and Wildlife Service or VDGIF as threatened or endangered may be intentionally collected under this permit. If incidental d*eath or injury* of threatened or endangered species does occur, the permittee is required to notify VDGIF at collectionpermits@dgif.virginia.gov within twenty-four (24) hours of occurrence. The following information must be reported: collector, date, species, location (county, quad, waterbody, and latitude and longitude to nearest second), and number collected.

8. If incidental *observation or collection and live release* of threatened or endangered species occurs, the permittee is required to notify VDGIF at collectionpermits@dgif.virginia.gov within four (4) working days, providing the same information as the Condition No. 7.

9. If incidental *mortality or injury of specimens intended to be taken live* occurs, the permittee is required to notify VDGIF at collectionpermits@dgif.virginia.gov within 48 hours, providing the same information as the above conditions. In addition, the permittee must provide the cause of mortality or injury and steps that are being taken to address the problem.

10. No species may be retained unless specifically authorized by this permit.

11. Game birds/game mammals/game fish protected by State and/or Federal laws must be taken during authorized hunting and trapping seasons and under applicable daily and seasonal bag/number limits by properly licensed persons unless otherwise specifically authorized. A valid Virginia fishing license is required for each person collecting samples by hook-and-line.

12. All traps must be marked with the name and address of the trapper or an identification number issued by VDGIF (Code of Virginia §29.1-521.7). Steel foothold traps, Conibear-style body gripping traps, and snares must be marked with a nonferrous metal tag bearing this information (Virginia Administrative Code 4 VAC 15-40-170).

13. All traps must be checked at least once a day and all captured animals removed, except completely submerged body-gripping traps which must be checked at least once every 72 hours (Code of Virginia §29.1-521.9).

14. The permittee is required to report any incidences of wildlife deaths or diseases observed during the course of collection activities. Reports should be made to: collectionpermits@dgif.virginia.gov within four (4) working days.

15. This permit satisfies only VDGIF's requirement for collection permits and is issued with the understanding that no collections will be made on Federal, state, or private property without the prior approval and necessary permits from the landowners involved. The permittee is responsible for obtaining any additional permits required for collection.

16. Sampling gear, boats, or trailers which have been used in states harboring zebra mussels must be cleaned and prepared following accepted guidelines for removal of zebra mussels, prior to being used in Virginia.

17. For safety reasons, it is recommended that all permittees display at least 100 square inches of solid blaze orange material at shoulder level within body reach and visible from 360 degrees, especially during hunting season.

Appendix C - SITE AND SPECIES PHOTOS

Stantec **Photographic Log**

Client:	**Appalachian Power Company**	**Project:**	**Buck/Byllesby Dam Mussel Survey**
Site Name:	**New River**	**Site Location:**	**Carroll County, Virginia**

Photograph ID: 1

Photo Location: Shallow Shoal 1

Direction:

Survey Date: 9/24/2020

Comments: Cyclonaias tuberculata (Purple Wartyback)

Photograph ID: 2

Photo Location: Shallow Shoal 1

Direction: East

Survey Date: 9/24/2020

Comments: Both live and the shell specimen were found along the east bank of the river (left side of photo)

Client:	Appalachian Power Company	Project:	Buck/Byllesby Dam Mussel Survey
Site Name:	New River	Site Location:	Carroll County, Virginia

Photograph ID: 3

Photo Location:
Shallow Shoal 1

Direction:
South

Survey Date:
9/24/2020

Comments:

Photograph ID: 4

Photo Location:
Shallow Shoal 1

Direction:
North

Survey Date:
9/24/2020

Comments:

Stantec **Photographic Log**

Client:	**Appalachian Power Company**	**Project:**	**Buck/Byllesby Dam Mussel Survey**
Site Name:	**New River**	**Site Location:**	**Carroll County, Virginia**

Photograph ID: 5 **Photo Location:** Shallow Shoal 1 **Direction:** Southwest **Survey Date:** 9/24/2020 **Comments:**	
Photograph ID: 6 **Photo Location:** Shallow Shoal 2 **Direction:** North **Survey Date:** 9/25/2020 **Comments:**	

Client:	Appalachian Power Company	Project:	Buck/Byllesby Dam Mussel Survey
Site Name:	New River	Site Location:	Carroll County, Virginia

Photograph ID: 7

Photo Location:
Shallow Shoal 2

Direction:
South

Survey Date:
9/25/2020

Comments:

Photograph ID: 8

Photo Location:
Deep Shoal 2 & Shallow Shoal 2

Direction:
East

Survey Date:
9/24/2020

Comments:

Client:	Appalachian Power Company	Project:	Buck/Byllesby Dam Mussel Survey
Site Name:	New River	Site Location:	Carroll County, Virginia

Photograph ID: 9

Photo Location:
Deep Shoal 2

Direction:
East

Survey Date:
9/24/2020

Comments:

Photograph ID: 10

Photo Location:
Pool 2 & Deep Shoal 1

Direction:
Southwest

Survey Date:
9/24/2020

Comments:

Client:	Appalachian Power Company	Project:	Buck/Byllesby Dam Mussel Survey
Site Name:	New River	Site Location:	Carroll County, Virginia

Photograph ID: 11

Photo Location: Pool 2

Direction: North

Survey Date: 9/24/2020

Comments:

Photograph ID: 12

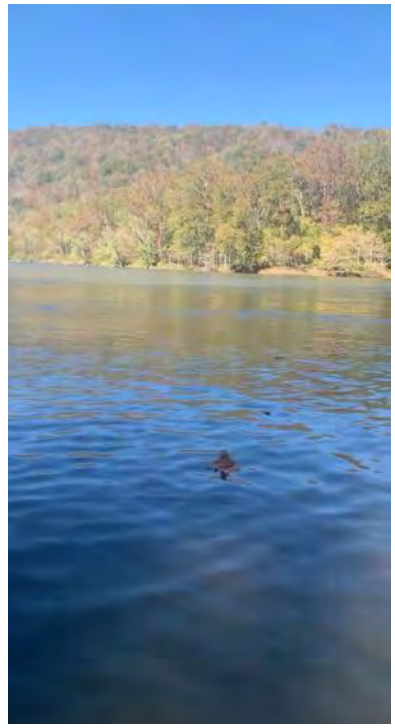
Photo Location: Pool 2

Direction: East

Survey Date: 9/24/2020

Comments:

Client:	Appalachian Power Company	Project:	Buck/Byllesby Dam Mussel Survey
Site Name:	New River	Site Location:	Carroll County, Virginia

Photograph ID: 13	
Photo Location: Deep Shoal 3	
Direction: East	
Survey Date: 10/21/2020	
Comments:	

Photograph ID: 14	
Photo Location: Shallow Shoal 3	
Direction: East	
Survey Date: 10/21/2020	
Comments:	

Stantec **Photographic Log**

Client:	**Appalachian Power Company**	**Project:**	**Buck/Byllesby Dam Mussel Survey**
Site Name:	**New River**	**Site Location:**	**Carroll County, Virginia**

Photograph ID: 15

Photo Location:
Deep Shoal 3

Direction:
South East

Survey Date:
10/21/2020

Comments:

Photograph ID: 16

Photo Location:
Deep Shoal 3

Direction:
North

Survey Date:
10/21/2020

Comments:

Client:	Appalachian Power Company	Project:	Buck/Byllesby Dam Mussel Survey
Site Name:	New River	Site Location:	Carroll County, Virginia

Photograph ID: 17 **Photo Location:** Pool 3 **Direction:** East **Survey Date:** 10/21/2020 **Comments:**	
Photograph ID: 18 **Photo Location:** West Side Channel **Direction:** South **Survey Date:** 9/25/2020 **Comments:**	

Client:	Appalachian Power Company	Project:	Buck/Byllesby Dam Mussel Survey
Site Name:	New River	Site Location:	Carroll County, Virginia

Photograph ID: 19

Photo Location: Downstream Extent of West Side Channel

Direction: Northwest

Survey Date: 9/25/2020

Comments:

Photograph ID: 20

Photo Location: Middle of West Side Channel

Direction: Southwest

Survey Date: 9/25/2020

Comments:

Stantec **Photographic Log**

Client:	**Appalachian Power Company**	**Project:**	**Buck/Byllesby Dam Mussel Survey**
Site Name:	**New River**	**Site Location:**	**Carroll County, Virginia**

Photograph ID: 21 **Photo Location:** East Side Channel **Direction:** South **Survey Date:** 9/25/2020 **Comments:**	
Photograph ID: 22 **Photo Location:** East Side Channel **Direction:** West **Survey Date:** 9/25/2020 **Comments:**	

Client:	Appalachian Power Company	Project:	Buck/Byllesby Dam Mussel Survey
Site Name:	New River	Site Location:	Carroll County, Virginia

Photograph ID: 23

Photo Location:
Downstream Extent of East Side Channel

Direction:
Northwest

Survey Date:
9/25/2020

Comments:

Photograph ID: 24

Photo Location:
Tailrace

Direction:
Southeast

Survey Date:
9/24/2020

Comments:

Client:	Appalachian Power Company	Project:	Buck/Byllesby Dam Mussel Survey
Site Name:	New River	Site Location:	Carroll County, Virginia

Photograph ID: 25

Photo Location:
Tailrace

Direction:
Northeast

Survey Date:
9/24/2020

Comments:

Photograph ID: 26

Photo Location:
Tailrace

Direction:

Survey Date:
9/24/2020

Comments:
Riprap lining edge of tailrace

Stantec

Photographic Log

Client:	**Appalachian Power Company**	**Project:**	**Buck/Byllesby Dam Mussel Survey**
Site Name:	**New River**	**Site Location:**	**Carroll County, Virginia**

Photograph ID: 27

Photo Location:
Tailrace

Direction:
Northwest

Survey Date:
9/24/2020

Comments:

Attachment 5

Attachment 5 – Germane Correspondence

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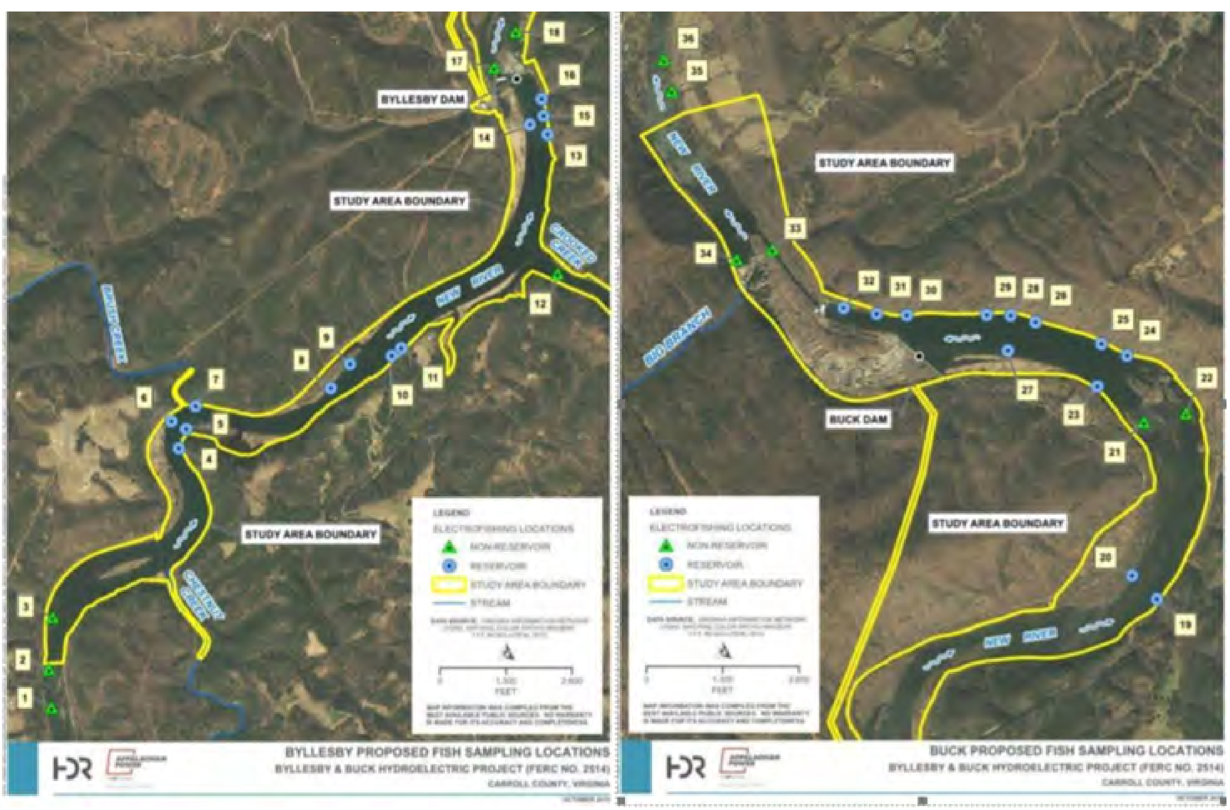
Yayac, Maggie

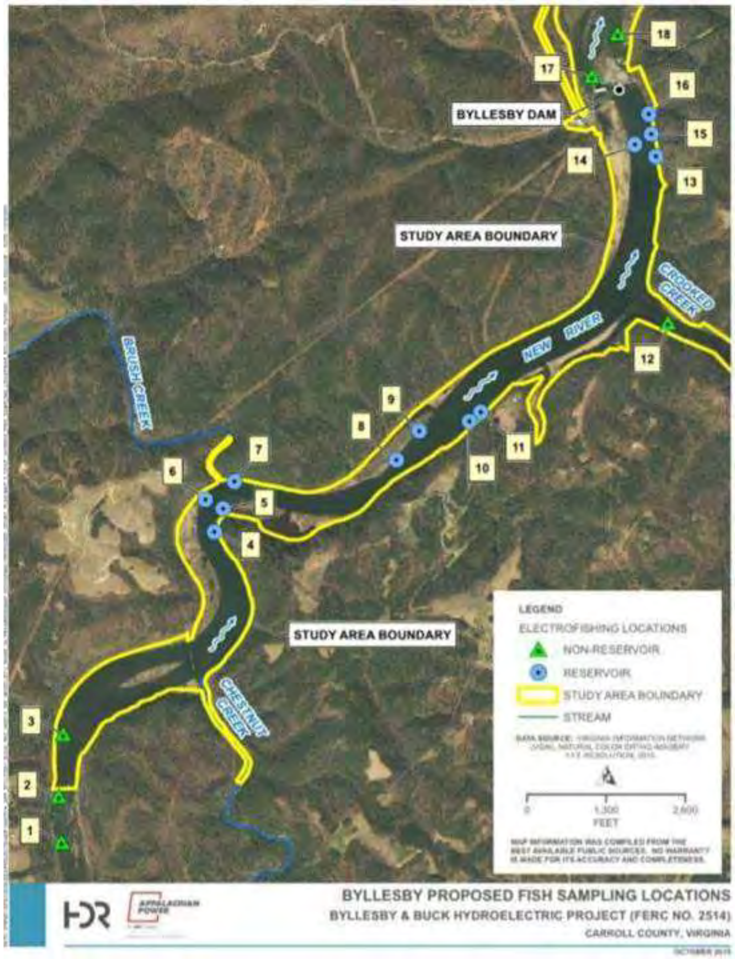
Subject: FW: Walleye gill net methods (Byllesby Reservoir)

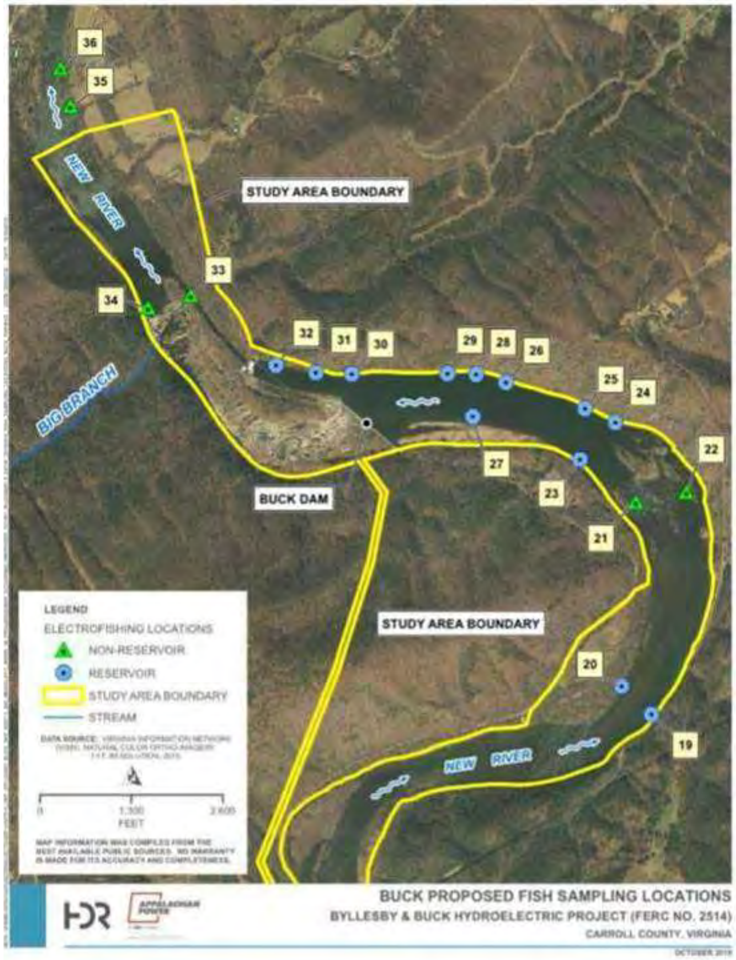
From: Jon Studio [mailto:JStudio@envsi.com]
Sent: Friday, April 3, 2020 2:23 PM
To: Copeland, John <john.copeland@dgif.virginia.gov>; Huddleston, Misty <Misty.Huddleston@hdrinc.com>
Cc: Bill.Kittrell@dgif.virginia.gov; John Spaeth <jspaeth@envsi.com>; Kulpa, Sarah <Sarah.Kulpa@hdrinc.com>; Jonathan M Magalski <jmmagalski@aep.com>; Elizabeth B Parcell <ebparcell@aep.com>
Subject: RE: Walleye gill net methods (Byllesby Reservoir)

John,

Below are the tentative field sampling sites. Non-reservoir (green; backpack electrofishing) and Reservoir (blue; boat electrofishing) sites are shown. Tentative gill net sites coincide with Figure 4 from the 1991 report. It was agreed upon during development of the Study Plan that hoop netting will not be used because hoop net methods did not yield novel information in the previous study. We will be in touch at the beginning of next week regarding gill net mesh sizes. Enjoy your weekend.




BYLLESBY DAM
STUDY AREA BOUNDARY
NEW RIVER
CROOKED CREEK
BRUSH CREEK
STUDY AREA BOUNDARY
CHESTNUT CREEK
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
LEGEND
ELECTROFISHING LOCATIONS
NON-RESERVOIR
RESERVOIR
STUDY AREA BOUNDARY
STREAM
0
1,300
2,600
FEET
BYLLESBY PROPOSED FISH SAMPLING LOCATIONS
BYLLESBY & BUCK HYDROELECTRIC PROJECT (FERC NO. 2514)
CARROLL COUNTY, VIRGINIA



Thank you,
Jon Studio

From: Copeland, John <john.copeland@dgif.virginia.gov>
Sent: Tuesday, March 31, 2020 1:00 PM
To: Huddleston, Misty <Misty.Huddleston@hdrinc.com>
Cc: Jon Studio <JStudio@envsi.com>; Bill.Kittrell@dgif.virginia.gov; John Spaeth <jspaeth@envsi.com>; Kulpa, Sarah <Sarah.Kulpa@hdrinc.com>; Jonathan M Magalski <jmmagalski@aep.com>; Elizabeth B Parcell <ebparcell@aep.com>; John Copeland <john.copeland@dgif.virginia.gov>
Subject: Re: Walleye gill net methods (Byllesby Reservoir)

I appreciate the summary Misty provided. In my earlier email I meant to say that **Walleye were NOT a factor** during the 1990 fisheries sampling. We did not start stocking New River strain Walleye intensively in the Upper New River area (including Byllesby Reservoir) until the early 2000's. I think Byllesby was experimentally stocked with Walleye from another source in the mid-late 1990's. Since we started our New River strain Walleye work, we have stocked Byllesby occasionally, but most of the Walleye using Byllesby are coming from stockings at the low water bridge downstream from Fries Dam, which we try to stock annually.

With this background in mind, take a look at the attached spreadsheet from Claytor Lake gill net surveys from 2010 to 2019. In order to collect the smaller size Walleye, the 3/4 in bar mesh net is important. As you can see, the 1.25 in bar mesh net is very important as well, so **I think adding these sizes (0.75 and 1.25 in bar mesh) to gill nets used in the current survey in addition to the ones proposed below by Misty Huddleston will provide better length data on Walleye in Byllesby Reservoir and not detract from collecting other species or comparisons to historic data.** At Claytor Lake, plenty of Walleye are collected in the 1.0, 1.5. 2.0, and 2.5 in bar mesh nets, but the smaller net sizes are important. We always get larger size Walleye in a variety of mesh sizes due to their propensity to get lip hung and roll in the nets, but collecting the smaller Walleye requires using smaller mesh sizes. I see you are planning for 120 foot nets with 6 panels, so adding panels will limit either the mesh sizes or the panel sizes. In the 1990 survey, each mesh size had 30 foot panels that were 6 feet deep (180 square feet of panel). Since you are planning 8 foot deep nets instead of the 6 foot deep nets used in the 1990 survey, if you employ 8 mesh sizes of 15 feet each (120 feet total length) it will still yield 120 square feet of each mesh panel, instead of what you propose with 6 mesh sizes of 20 feet each, which will yield 160 square feet of each mesh panel.

I would like to see the other planned methods for the 2020-2021 fisheries survey (electrofishing, hoop netting) and what sites will be sampled for each technique. I'm particularly interested in what reference sites will be sampled upstream and downstream from the Project. **If you are planning to replicate the 1990 fisheries study locations and techniques shown in Figure 4 of the 1991 report, then you can simply let me know that is your plan.**

If you think we need to resolve anything in a conference call, I am available tomorrow (Wednesday, April 1), but not Friday, April 3. We appreciate the coordination of this study in advance of sampling.

Thanks.

John R. Copeland
Fisheries Biologist III
P 540.961.8304
M 540.871.6064
Virginia Department of Game & Inland Fisheries
A **2206 South Main Street, Suite C, Blacksburg, VA 24060**
www.dgif.virginia.gov
CONSERVE. CONNECT. PROTECT.

On Tue, Mar 31, 2020 at 9:31 AM Huddleston, Misty <Misty.Huddleston@hdrinc.com> wrote:

Jon/John,

Following up on the email chain below.

The 1991 fisheries study at Byllesby/Buck used electrofishing, gillnet, and hoop net gear types. No Walleye were collected during the study.

For the upcoming fisheries work at Byllesby/Buck it is important that we have parity with previous collection methods. However, there is room for deviation as long as the gear changes are not expected to decrease the representativeness of the fish community.

The 1991 study report does not clarify if the gillnet mesh used was bar or stretch measurements; however, the measurements are consistent with typical bar mesh sizes used in experimental gill nets.

I have summarized the information from the 1991 study, provided by John from Claytor Lake surveys, and for reference purposes included gillnet specifications used by the USGS National Water Quality Assessment.

At the bottom of the table, I have provided my thoughts on gillnet specifications that could be used to meet the fish community study goals and target Walleye.

Summary of gillnet information:

Gillnet Source	Depth (feet)	Width (feet)	Number and Width (feet) of Panels	Bar Mesh Size (inches)	Notes
1991 study	6	120	4 – 30'	1 to 4	
Claytor Lake	8	100	4 – 25'	0.5 to 2.5	Walleye collected on 0.75 in, 1.0 in, 1.25 in, 1.5 in, 2.0 in, and 2.5 mesh
NAWQA (for reference)	6	120	6 – 20'	0.5 to 4	0.5-in, 1.0-in, 1.5-in, 2.0-in, 3.0-in, 4.0
Potential Specifications for 2020-2021 Byllesby/Buck Sampling	**8**	**120**	**6 – 20'**	**1 to 4**	**Mesh sizes of 1.0-in, 1.5-in, 2.0-in, 2.5-in, 3.0-in, 4.0-in**

*NAWQA: US Geological Survey, National Water Quality Assessment Methodology

If we need to have a call to discuss further, I am available anytime on Wednesday, April 1st or Friday, April 3rd.

I have quite a bit of availability next week if we need to push a discussion to sometime next week.

Thanks,

Misty

Misty Huddleston, PhD

Associate, SR. Environmental Scientist

HDR

440 S. Church Street, Suite 900
Charlotte, NC 28202-2075
D 704.248.3614 **M** 865.556.9153
Misty.Huddleston@hdrinc.com

hdrinc.com/follow-us

From: Jon Studio [mailto:JStudio@envsi.com]
Sent: Friday, March 27, 2020 2:46 PM
To: Copeland, John <john.copeland@dgif.virginia.gov>
Cc: Bill.Kittrell@dgif.virginia.gov; John Spaeth <jspaeth@envsi.com>; Huddleston, Misty <Misty.Huddleston@hdrinc.com>; Kulpa, Sarah <Sarah.Kulpa@hdrinc.com>; Jonathan M Magalski <jmmagalski@aep.com>; Elizabeth B Parcell <ebparcell@aep.com>
Subject: RE: Walleye gill net methods (Byllesby Reservoir)

CAUTION: [EXTERNAL] This email originated from outside of the organization. Do not click links or open attachments unless you recognize the sender and know the content is safe.

John,

I appreciate your timely response. One objective of the fish community study for this project is "*Compare current aquatic resources data to historical data to determine any significant changes to species composition or abundance*." Using similar methods may allow us to make more direct comparisons (e.g., CPUE); however, it is also important to use the best methodology to sample and quantify the current aquatic resources.

Sarah and Misty, can you speak to the importance of parity with previous collection methods?

Attached is the 1991 fisheries study from the Byllesby-Buck Project Area. After looking over the paper, please propose a few times that work for you and I will try to make myself available for a phone conversation.

Thank you,

Jon Studio

From: Copeland, John <john.copeland@dgif.virginia.gov>
Sent: Friday, March 27, 2020 2:23 PM
To: Jon Studio <JStudio@envsi.com>
Cc: Bill.Kittrell@dgif.virginia.gov; John Spaeth <jspaeth@envsi.com>; Huddleston, Misty <Misty.Huddleston@hdrinc.com>; Kulpa, Sarah <Sarah.Kulpa@hdrinc.com>; Jonathan M Magalski

<jmmagalski@aep.com>; Elizabeth B Parcell <ebparcell@aep.com>; John Copeland <john.copeland@dgif.virginia.gov>
Subject: Re: Walleye gill net methods (Byllesby Reservoir)

Jon:

I think parity with previous collection methods is one factor to consider, but, since walleye were a developed fishery during the last relicensing studies, that's less of a concern for me for walleye.

Were walleye collected during the previous relicensing studies?

Do you know if the mesh sizes described in the previous methodology were bar mesh sizes or stretch mesh sizes?

If your gill netting is targeting fish across the fish community, then parity with previous collection methods is a good idea.

In annual sampling at Claytor Lake, I use 100 ft by 8 ft experimental nets with varying bar mesh sizes in 25 ft panels from 0.5 inch (1 inch stretch mesh) up to 2.5 inch bar mesh (5 inch stretch mesh). The mesh sizes include the following bar mesh sizes in inches: 0.5, 0.625. 0.75, 1.0, 1.25, 1.5, 2.0, and 2.5. Not all of these mesh sizes are useful for collecting walleye. Most of the Walleye I catch in those nets are in the 0.75 in, 1.0 in, 1.25 in, 1.5 in, 2.0 in, and 2.5 in mesh sizes, since the smaller mesh sizes are primarily catching gizzard shad and alewife.

Walleye could also be collected using night electrofishing, which could be effective in Byllesby Reservoir in April. At Claytor Lake, we also collect some walleye during day electrofishing, but not frequently, since they tend to be deeper during the day.

I'm not sure where to find the previous fisheries study in my files.

If you send me the previous fisheries study, I can take a look early next week and we can talk about it by phone.

John R. Copeland

Fisheries Biologist III
P 540.961.8304

M 540.871.6064

Virginia Department of Game & Inland Fisheries
A 2206 South Main Street, Suite C, Blacksburg, VA 24060
www.dgif.virginia.gov

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On Thu, Mar 26, 2020 at 10:27 AM Jon Studio <JStudio@envsi.com> wrote:

Good morning Bill and John,

Environmental Solutions & Innovations, Inc. (ESI) anticipates conducting gill net surveys targeting walleye in the Byllesby Reservoir at the dam relicensing Project Area (New River) during the 2020 field season. ESI understands you participated in Study Plan review for this Project. To obtain representative information on the relative abundance and size structure of the walleye population (per VDGIF requests), sampling as early in April as possible is necessary. ESI also requests your recommendations for the following gill net methods at the Byllesby Reservoir Project Area: 1) gill net length, height, and float line height, 2) gill net mesh sizes, and 3) gill net duration.

The following gill net methods were used in the fish community study in 1991: "*Gill nets were 6 ft x 120 ft monofilament, with four 30-ft panels of mesh size ranging from 1-4 inches. Net sets were placed at two sites each on the upper, middle, and lower portions of the Byllesby Reservoir… Each net was checked after 24 hours, reset, and checked and removed after 48 hours*". ESI requests your advice regarding the most effective methods/techniques for sampling walleye in the Byllesby Reservoir. Please feel free to contact us if you have questions or additional information is required. Thank you.

Kind regards,

ESI
Jon Studio
Aquatic Scientist
Environmental Solutions & Innovations, Inc.

4300 Lynn Road | Ravenna, OH 44266 | USA
office: 513.591.6134 **direct:** 440.413.4609
jstudio@envsi.com | www.envsi.com

Yayac, Maggie

Subject: FW: New River Update

From: Brian Watson <brian.watson@dwr.virginia.gov>
Sent: Thursday, October 8, 2020 11:01 AM
To: Fleece, Cody <cody.fleece@stantec.com>; Brian Watson <brian.watson@dgif.virginia.gov>
Cc: Kulpa, Sarah <Sarah.Kulpa@hdrinc.com>; Huddleston, Misty <Misty.Huddleston@hdrinc.com>; Symonds, Daniel <Daniel.Symonds@stantec.com>; Elizabeth B Parcell <ebparcell@aep.com>; Yayac, Maggie <Maggie.Yayac@hdrinc.com>
Subject: RE: New River Update

Cody,

I can see the notes now that I am back at my computer and not viewing the PDF thru my phone. Since two of the areas include shoal habitat, DWR does recommend surveying the 3 areas that were not surveyed in September due to rain and poor river conditions. Despite a low number of mussels being founds so far, DWR would prefer to see those areas surveyed to get a more complete assessment. If you have any questions, let me know. And if you need any assistance, let me know when you guys do the surveys as I may be able to make it out.

Brian

Brian T. Watson
Aquatic Resources Biologist/State Malacologist
P 434.525.7522, x114 / M 434.941.5990 / F 434.525.7720

Virginia Department of Wildlife Resources
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A 1132 Thomas Jefferson Road, Forest, VA 24551
www.VirginiaWildlife.gov

From: Fleece, Cody <Cody.Fleece@stantec.com>
Sent: Tuesday, September 29, 2020 1:05 PM
To: Brian Watson <brian.watson@dgif.virginia.gov>
Cc: Kulpa, Sarah <Sarah.Kulpa@hdrinc.com>; Huddleston, Misty <Misty.Huddleston@hdrinc.com>; Symonds, Daniel <Daniel.Symonds@stantec.com>; Elizabeth B Parcell <ebparcell@aep.com>; Yayac, Maggie

<Maggie.Yayac@hdrinc.com>
Subject: FW: New River Update

Brian

As discussed on the phone we were able to complete surveys in 8 of the 11 planned areas. Heavy rainfall and reduced visibility caused us to abandon the last day of survey (we completed 3 of 4). I attached a map with notes of what we found and how much time was spent searching. Dan Symond's initial survey summary is also presented below.

Based on what we're finding so far we have been wondering about the necessity of re-mobilizing to assess the 3 missing areas. Let us know if you think we need to get back out to finish the work or if the information in hand will suffice to inform decisions in the relicensing process.

Thanks for your time and attention.

Cody

From: Symonds, Daniel <Daniel.Symonds@stantec.com>
Sent: Monday, September 28, 2020 11:09 AM
To: Fleece, Cody <Cody.Fleece@stantec.com>
Subject: New River Update

We completed 8 of the 11 target areas on the New River (That's including the Buck Tailrace). We have surveyed at least one area of each type (shallow/deep shoal, pool, side channel). Six of the areas yielded zero mussels, and zero shells. Habitat varied from very poor (80-100% drifting sand) to very good (gravel/sand/cobble riffles) in the areas with no evidence of mussels.

Two live and one shell C. tuberculata were found in the most downstream shallow shoal. They were found in the flow refuge behind boulders, where sand/gravel accumulates in small amounts.

Six live C. tuberculata were found in the middle deep shoal. Similar story to the shallow shoal, the mussels were found in the silt that accumulated behind larger cobble/boulders.

To summarize, 25.3 people-hours of searching has occurred, with a catch-per-unit-effort of 0.35 mussels/hr and species diversity of one.

Daniel Symonds
Aquatic Ecologist

Direct: (614) 282-3215
Daniel.Symonds@stantec.com

Stantec
1500 Lake Shore Drive Suite 100
Columbus OH 43204-3800

Yayac, Maggie

Subject: FW: Fish Community Study at Byllesby/Buck Project (FERC No. 2514)

From: Copeland, John <john.copeland@dwr.virginia.gov>
Sent: Monday, November 9, 2020 8:32 AM
To: Huddleston, Misty <Misty.Huddleston@hdrinc.com>
Cc: Jonathan M Magalski <jmmagalski@aep.com>; Elizabeth B Parcell <ebparcell@aep.com>; jon Studio (jastudio@edge-es.com) <jastudio@edge-es.com>; John Spaeth <jpspaeth@edge-es.com>; Kulpa, Sarah <Sarah.Kulpa@hdrinc.com>; Yayac, Maggie <Maggie.Yayac@hdrinc.com>; John Copeland <john.copeland@dwr.virginia.gov>; Kittrell, Bill (DGIF) <bill.kittrell@dwr.virginia.gov>; Pinder, Mike (DGIF) <mike.pinder@dwr.virginia.gov>
Subject: Re: Fish Community Study at Byllesby/Buck Project (FERC No. 2514)

I understand your planned course of action for gill net sampling. If that sampling cannot be completed this week, it is acceptable to target Walleye with your gill net sampling as late as early December. Walleye will continue to move around when the water temperatures drop into the 50 degree range. Catch of other species (Catfish and other species) will likely not be as high if you delay into early December.

Regarding backpack electrofishing, deciding to postpone that work until August/September of 2021 is acceptable to us. The boat electrofishing and gill net sampling are targeting the reservoir habitat so the lack of overlap in sampling periods with the lotic areas sampled by backpack electrofishing is acceptable.

John R. Copeland

Fisheries Biologist III

P 540.961.8397 / M 540.871.6064

Virginia Department of Wildlife Resources

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www.dwr.virginia.gov

Yayac, Maggie

Subject: FW: Notification of Collection of State Threatened Pistolgrip Mussel on AEP Byllesby-Buck project
Attachments: pistolgrips.jpg

From: David Foltz [mailto:dafoltz@edge-es.com]
Sent: Thursday, October 8, 2020 11:30 PM
To: Brian Watson <brian.watson@dwr.virginia.gov>; john_mccloskey@fws.gov; richard_mccorkle@fws.gov; janet_norman@fws.gov; collectionpermits@dgif.virginia.gov; scott.smith@dgif.virginia.gov
Cc: John Spaeth <jpspaeth@edge-es.com>; Jon Studio <jastudio@edge-es.com>; Casey Swecker <cdswecker@edge-es.com>; Huddleston, Misty <Misty.Huddleston@hdrinc.com>; Kay, Jenessa <Jenessa.Kay@hdrinc.com>
Subject: Notification of Collection of State Threatened Pistolgrip Mussel on AEP Byllesby-Buck project

All, Edge and HDR employees conducted benthic macroinvertebrate surveys approximately 1.35 kilometers downstream from the Buck Dam as part of the relicensing project today on 10/8/2020. During the survey efforts multiple freshwater mussels were discovered in the substrates sampled, including Virginia state listed Pistolgrip (*Tritogonia verrucosa*). Mussels were removed from the water briefly for photographic voucher (please see attachment) before being placed back in the substrates.

Please let us know if you need any further information on the animals or site.

Thank you.

DAVID A. FOLTZ II
Project Manager/ Senior Malacologist/ Astacologist
Weirton, West Virginia
D: 304.479.3268
edge-es.com

On Wed, Nov 4, 2020 at 12:49 PM Huddleston, Misty <Misty.Huddleston@hdrinc.com> wrote:

Good afternoon John,

I wanted to follow up with you regarding the status of the data collection efforts for the Byllesby/Buck (FERC No. 2514) Fish Community Study and to request your input on the path forward for completing the study.

As Jon Studio (Edge Engineering) has previously discussed with you, the boat shocking portion of the study has been completed, but weather and high flows have prevented the field crews from completing the gillnet or backpack electrofishing samples at the site. Based on your conversations with Jon Studio, I understand that you support the collection of gillnet data in November as the target organism (Walleye) will still be mobile at that time.

Can you confirm that this is still acceptable and provide any additional criteria or threshold where you believe the collected data would no longer be valid?

Regarding backpack electrofishing efforts, recent weather forecasts indicate additional precipitation and cooler temps are present or moving into the watershed this week. Based on the predicted flows and colder temperatures, we believe that it is appropriate to move this sampling effort to August/September 2021. As a result, we will have boat electrofishing and gillnet samples (likely) collected in fall 2020 and backpack electrofishing samples collected in August/September 2021.

Do you foresee any issues or concerns with the proposed revised approach and the use of these data to support the relicensing effort at Byllesby-Buck?

Let us know if you have any other recommendations or concerns or if you would prefer to have a call to discuss this issue in further detail.

Thanks,

Misty

Misty Huddleston, PhD

Associate, SR. Environmental Scientist

HDR

Salazar, Maggie

Subject: FW: Byllesby-Buck USR FERC Comment re Walleye Body Depth Data
Attachments: PICT0027.JPG; PICT0030.JPG; PICT0029.JPG; PICT0032.JPG; PICT0031.JPG; PICT0033.JPG; Staunton River WAE TL Body Depth Data 25 Jan 2022.pdf

---

From: Copeland, John <john.copeland@dwr.virginia.gov>
Sent: Friday, January 28, 2022 2:35 PM
To: Elizabeth B Parcell <ebparcell@aep.com>
Cc: Kulpa, Sarah <sarah.kulpa@hdrinc.com>; Jonathan M Magalski <jmmagalski@aep.com>; Salazar, Maggie <Maggie.Salazar@hdrinc.com>; Williams, Jeff (DGIF) <jeff.williams@dwr.virginia.gov>; John Copeland <john.copeland@dwr.virginia.gov>
Subject: Re: Byllesby-Buck USR FERC Comment re Walleye Body Depth Data

Liz et. al.:

Walleye Body Depth Data
I wanted to respond before the weekend, since our call is Tuesday afternoon. After reading what you referenced below in the FERC comment letter, I called our statewide Walleye Committee Chairperson, George Palmer, to ask about the existence of such data. He responded (as I had already done in my head) that it would be unusual for anyone to have that data, unless a university researcher was doing something like that.

Well, since we need it for this purpose, George initiated getting preliminary data (attached here, less 1 Walleye that is included below in the email I received from Dan Michaelson) from Walleye broodstock collections they started earlier this week on the Staunton River in Brookneal and Long Island, downstream from your Smith Mountain/Leesville Project. At this point, we only have 23 Walleye total lengths and body depths to share. The team will be out 2 days next week and will collect more data then. One difference between the Staunton River and New River Walleye populations may be the ultimate body size being bigger in the New River, so any use of this data should be done with that understanding. Given a few more days, I can provide some population level comparisons between the 2 river Walleye populations (like Stock Density Indices, Average Total Lengths, etc.), but it will require me soliciting that data from George Palmer or one of his colleagues, Dan Michaelson or Hunter Hatcher in Farmville, VA. I have those statistics or can easily generate them for the New River Walleye population.

We will have the opportunity to get similar data from the New River when we start our broodstock collections in mid-late February. Using that data will be more relevant in applying it to the Buck Bypass Reach. Let's discuss it further at our meeting on February 1, because I don't know enough about your timeline to know if it's possible to get the data in that timeframe.

Stranding in the Buck Bypass Reach
I suggest we have more discussion about this one in our meeting on Tuesday. I'm in the process of interviewing current and former employees of our agency about this one. In fact, at the time you sent this email yesterday, I was interviewing retired VDWR Marion Office Conservation Police Lt. Rex Hill, who is now a Carroll County Supervisor, about events he observed stretching back into the 1970's. Formal reports are simply not available, but I can connect you with people who can testify to these events. In fact, I've asked for the current Carroll County Conservation Police Officer, Ben Boyette, to be on the call Tuesday. He's very familiar with occurrences of this nature in the Buck Bypass Reach over his years in the county and is contacting the retired county officer as well. **If possible, it would be good to put this topic up**

front in Tuesday's agenda so Officer Boyette can share his knowledge with the group and not have to sit through all the biological discussions.

I was able to get pictures of a Buck Bypass fish stranding event in 2010 subsequent to the ice dam that broke loose that winter. If you look closely at some of the pictures, you will see pieces of flashboard risers scattered throughout the bypass reach. From the vegetation observed in this photo, with trees fully leafed out, it appears to be well into at least the spring season. George Palmer sent me those pictures. I also called Bill Kittrell, retired Marion aquatics manager, to ask his recollections about it. He remembered it well, but again, no record appears to exist other than these photos (attached below, including 1 dead Walleye), nor could Bill recall the month it happened. This Walleye looks to be at least 12 inches, based on the type of teardrop net we use. We're still using the same nets.

That's all I have to report at this point.

From: Michaelson, Daniel <dan.michaelson@dwr.virginia.gov>
Sent: Wednesday, January 26, 2022 8:45 AM
To: Copeland John fhg96061 <john.copeland@dwr.virginia.gov>
Subject: WAE & truck specs

Hello John,

Attached are WAE data from yesterday (1/25/2022) at the Staunton River. I did not get the back of the data sheet copied but it was only one fish:
WAE 478 mm 84 mm (depth) M

Staunton River - Long Island - 2:51 (these are in hours and minutes by-the-way)

Two boats at Brookneal, one at Long Island.

Give me a call today if this isn't the data you're looking for. Depth measure was just a max depth of belly to top of dorsal (pretty much in front of the dorsal fin).

Dan M.

On Thu, Jan 27, 2022 at 12:48 PM Elizabeth B Parcell <ebparcell@aep.com> wrote:

> John,
>
> You may have noticed that FERC had a USR comment on walleye body depth. Specifically, they stated:
>
> *As indicated at both the USR and Initial Study Report (ISR) meetings, the potential stranding of walleye in the Buck bypassed reach during spill events in the spring spawning season is a concern. While a two-dimensional (2-D) hydraulic model was developed to simulate water depths and flow patterns in the Buck bypassed reach under the currently required ramping rate, the USR contains no information on the body depths of walleye. Therefore, to aid staff in their interpretation of the additional modeling scenario requested below in item 4, please provide body depth data for the size range of walleye that would be expected to occur in this portion of the New River during the spring spawning season. This information will help staff determine whether the existing ramping rate provides adequate escape routes (of*

sufficient water depth) for any walleye that may be attracted to intermittent spill flows and enter the Buck bypassed reach during the spring spawning season.

Any chance that you might have relevant data for the New River strain of walleye that you could share with us to support our analyses? If so, we would welcome receipt as soon as possible. If not, do you have data from nearby river systems that could be used? In either case, please specify the sample sizes for all provided body depth data. Lastly, please provide copies of any stranding reports or incidents (for walleye or other species) that VDWR may have in its possession or be aware of, as this could provide information on the potential stranding locations in the Buck bypassed reach as well as the sizes of stranded fish.

Many thanks. We appreciate your help and insight, as always.

Liz

AMERICAN ELECTRIC POWER
BOUNDLESS ENERGY
ELIZABETH B PARCELL | **PROCESS SUPV**
EBPARCELL@AEP.COM | D:540.985.2441 | C:540.529.4191
40 FRANKLIN ROAD SW, ROANOKE, VA 24011

STAUNTON RIVER

Location: Brookneal Date: 1-25-22

Effort: 1:25 + 1:00 Gear: ______ Temp.: 2 °C

Comments: 1360 cfs WAE tagging

Species	Length	Depth ~~Length~~	Sex ~~Length~~	Tag ~~Length~~	BC	Species	Length	Weight
WAE	511	110	F	601				
	458	84	M	602				
	465	80	M	603				
	502	108	F	604				
	505	92	F	605				
	485	100	F	606				
	509	104	F	607				
	449	84	M	608				
	484	100	F	609				
	425	80	M	610				
	496	95	F	611				
	382	75	M	612				
	525	111	F	613				
	494	98	F	614				
	526	100	F	615				
	510	100	F	616				
	454	88	M	617				
	470	94	F	618				
	511	108	F	619				
	501	90	~~M~~ F	620				
	482	99	F	621				
	486	99	F	622				

Salazar, Maggie

Subject: FW: J. D. Kloepfer's Contact

From: Kleopfer, John <john.kleopfer@dwr.virginia.gov>
Sent: Thursday, February 3, 2022 7:58 AM
To: Copeland, John <john.copeland@dwr.virginia.gov>
Cc: Williams, Jeff (DGIF) <jeff.williams@dwr.virginia.gov>; Huddleston, Misty <Misty.Huddleston@hdrinc.com>; Salazar, Maggie <Maggie.Salazar@hdrinc.com>; Kulpa, Sarah <Sarah.Kulpa@hdrinc.com>; Martin, Amy <amy.martin@dwr.virginia.gov>; Hopkins, William <hopkinsw@vt.edu>
Subject: Re: J. D. Kloepfer's Contact

John,
Thank you for the background information and introduction. The effects of hydroelectric power on hellbenders is poorly studied and therefore poorly understood. As we all know, modification of stream flow for hydroelectric power can alter stream ecosystems. Changes to stream flow can alter invertebrate drift and species diversity. Stream flow alteration could therefore impact hellbenders by changing the abundance and diversity of vertebrate and invertebrate prey. Reduction in flow may also affect the respiratory ability of hellbenders because gas exchange is increased by flowing water. I looped in Dr. Bill Hopkins from VT, who has done a lot of work on hellbenders in Virginia. I also included Amy Martin (Environmental Services Manager) in this correspondence, since I'm assuming this project will go through the environmental review process.

Misty,
I'm available early next week to discuss.

On Thu, Feb 3, 2022 at 6:27 AM Copeland, John <john.copeland@dwr.virginia.gov> wrote:

J.D.

I did not try to call you again on Tuesday because I, like you, was slammed with other things before my conference call with the U.S. Fish and Wildlife Service, Appalachian Power Company, and Region 2 and 3 aquatics staff. You will be contacted by one of the consultants with HDR Inc, the consulting firm for the Byllesby Buck relicensing. So you are familiar with why they are contacting you, here's a brief overview.

The Byllesby Buck hydroelectric project on the New River is located in a remote section in Carroll County. This is an approximately 30MW hydro generation system, so it's nearly half the production capacity of Claytor Lake Dam. The mainstem New River dams are primarily owned and operated by Appalachian Power. Their consultant for the relicensing is HDR Inc. https://www.hdrinc.com/. Relicensing is a fast-moving process with tight timelines. **HDR is planning to file the Final License Application for the Project on February 28, 2022.**

In the current discussion of instream flow needs in the bypass reaches below these dams, our primary discussion right now is the Buck Bypass Reach, which is about 3/4 of a mile of formerly mainstem river. https://www.google.com/maps/place/Buck+Dam/@36.8065405,-80.940762,666m/data=!3m1!1e3!4m5!3m4!1s0x8851fa43359d82a1:0x7ba31982ad535ba2!8m2!3d36.8078216!4d-80.9388261 It does not get regular flows as a result.

The Byllesby Bypass Reach (the upstream dam) is shorter, with an approximately 400+ foot bypass reach. https://www.google.com/maps/place/Byllesby+Dam,+Ivanhoe,+VA+24350/@36.78683,-80.9353715,488m/data=!3m1!1e3!4m5!3m4!1s0x8851fa7a1fe04ca5:0xf8278eefaf7769ac!8m2!3d36.7851212!4d-80.9331397

During development of relicensing study plans to establish background biological and other information in 2020 and 2021, we discussed Eastern Hellbender. Appalachian Power Company agreed to assume the presence of this species without doing costly survey work. That decision leads to this email and the need for your input. HDR is using high resolution photography and a 2-D flow model to look at instream flow needs for the Project. In our meeting on Tuesday, I was amazed at the level of detail available to examine habitat in the Buck bypass reach.

As I understand it, Misty will contact you regarding having an online meeting for you to look at that information with HDR's team and provide an initial assessment of potential Eastern hellbender habitat.

Thanks J.D.!

John R. Copeland

Fisheries Biologist III

Cell 540.871.6064

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---------- Forwarded message ---------
From: **Huddleston, Misty** <Misty.Huddleston@hdrinc.com>
Date: Wed, Feb 2, 2022 at 11:15 AM
Subject: RE: J. D. Kloepfer's Contact
To: Copeland, John <john.copeland@dwr.virginia.gov>
Cc: Williams, Jeff (DGIF) <jeff.williams@dwr.virginia.gov>, Salazar, Maggie <Maggie.Salazar@hdrinc.com>, Kulpa, Sarah <sarah.kulpa@hdrinc.com>

John,

Thanks for passing along the contact information.

Misty

Misty Huddleston, PhD

Associate, SR. Environmental Scientist
D 704.248.3614 **M** 865.556.9153

hdrinc.com/follow-us

From: Copeland, John <john.copeland@dwr.virginia.gov>
Sent: Wednesday, February 2, 2022 6:03 AM
To: Huddleston, Misty <Misty.Huddleston@hdrinc.com>
Cc: John Copeland <john.copeland@dwr.virginia.gov>; Williams, Jeff (DGIF) <jeff.williams@dwr.virginia.gov>; Salazar, Maggie <Maggie.Salazar@hdrinc.com>; Kulpa, Sarah <Sarah.Kulpa@hdrinc.com>
Subject: J. D. Kloepfer's Contact

Misty:

I think you were the person on the call yesterday who asked for J.D. (John) Kloepfer's contact information regarding getting him on the phone to discuss Eastern Hellbender habitat in the Buck Bypass reach. With the photography you have and can display, he should be able to provide feedback. I was not able to get him on the phone prior to our call yesterday, but he may have a collections database as well.

Following is what you need to contact him.

John (goes by J.D.) Kloepfer

Contact details

john.kleopfer@dwr.virginia.gov

john.kleopfer@dgif.virginia.gov • Obsolete

Directory profile

john.kleopfer@dwr.virginia.gov

(804) 829-6703 • Work

Route 5 Williamsburg VA 23185 • Work

John R. Copeland

Fisheries Biologist III

Cell 540.871.6064

Virginia Department of Wildlife Resources

CONSERVE. CONNECT. PROTECT.

A 2206 South Main Street, Suite C, Blacksburg, VA 24060

www.dwr.virginia.gov

U.S. Fish and Wildlife Service Comment:

In a comment on the Byllesby-Buck Hydroelectric Project Aquatic Resources Study Report received on **January 18, 2022**, the U.S. Fish and Wildlife Service made the following request:

> *Water quality data and velocity data were collected at sampling sites which included the bypass reaches. What were the flows (cfs) to the bypass during the surveys? The Service did not see this information in the USR. If this information was not documented at the time of the surveys, it should be possible to look back to the dates and times of the surveys and provide this information.*

Appalachian's Response:

To allow field personnel to safely collect samples in the Byllesby and Buck bypass reach channels, field sampling for the Fish Community Study was performed on days when stream flows were as close to base flow as feasible and no flows beyond leakage flows were being passed over the Project spillways. Average daily flows in the New River recorded at the U.S. Geological Survey (USGS) stream gage (03165500 New River at Ivanhoe, Virginia) located just upstream of the Byllesby and Buck developments are provided in Table 1.

Table 1. Average Daily New River Flows (cfs) Recorded at the Nearest Upstream USGS Gage (03165500 New River at Ivanhoe, Virginia)

Fish Community Field Sampling Dates	New River Average Daily Flow (cfs)*
10/22/2020	2,270
10/24/2020	2,130
10/25/2020	2,480
11/9/2020	2,620
11/10/2020	2,550
11/11/2020	6,260
11/18/2020	4,030
11/19/2020	3,690
11/20/2020	3,430
4/20/2021	3,000
4/21/2021	2,800
4/22/2021	2,730
4/23/2021	2,640
4/24/2021	2,620
4/25/2021	3,070
4/26/2021	3,020
5/27/2021	2,190

*USGS Gage 03165500 New River at Ivanhoe, Virginia; cfs=cubic feet per second

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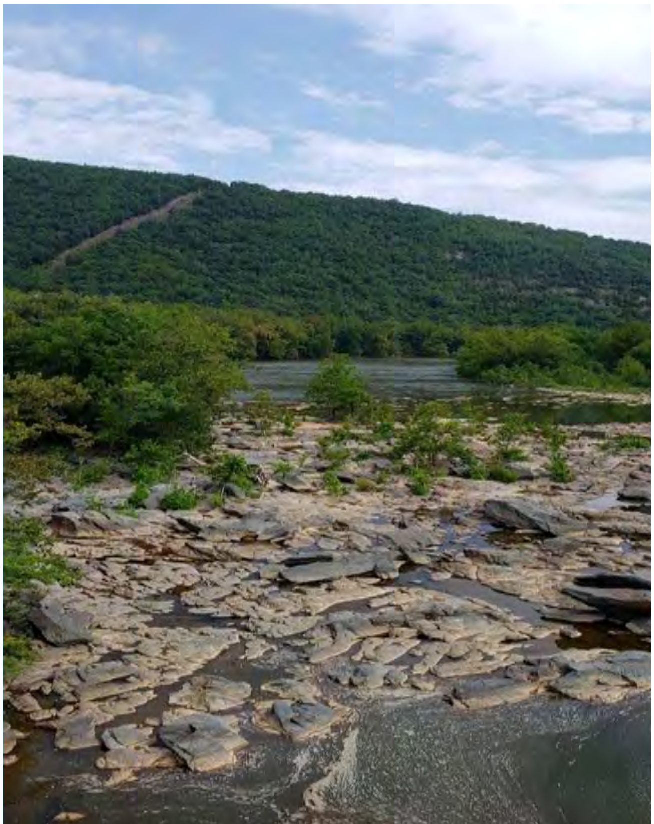

Bypass Reach Flow and Aquatic Habitat Study Report

Byllesby-Buck Hydroelectric Project (FERC No. 2514)

April 14, 2022

Prepared by:

HDR

Prepared for:

Appalachian Power Company

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Acronyms and Abbreviations

1-D	one-dimensional
2-D	two-dimensional
3-D	three-dimensional
°C	degrees Celsius
AEP	American Electric Power
Appalachian or Licensee	Appalachian Power Company
Buck	Buck Development
Byllesby	Byllesby Development
CFR	Code of Federal Regulations
cfs	cubic feet per second
FERC or Commission	Federal Energy Regulatory Commission
fps	ft per second
ft	feet/foot
HSC	habitat suitability criteria
HSI	habitat suitability index
LiDAR	light detection and ranging
mm	millimeter
NGVD	National Geodetic Vertical Datum of 1929
ICM	2-D Innovyze Infoworks Integrated Catchment Model
ILP	Integrated Licensing Process
PM&E	protection, mitigation, and enhancement
POR	period of record
Project	Byllesby-Buck Hydroelectric Project
PSP	Proposed Study Plan
RSP	Revised Study Plan
SPD	Study Plan Determination
USFWS	U.S. Fish and Wildlife Service
USGS	U.S. Geological Survey
VDWR	Virginia Department of Wildlife Resources

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1 Project Introduction and Background

Appalachian Power Company (Appalachian or Licensee), a unit of American Electric Power (AEP), is the Licensee, owner, and operator of the two-development Byllesby-Buck Hydroelectric Project (Project) (Project No. 2514), located on the upper New River in Carroll County, Virginia. The Byllesby Development (Byllesby) is located about 9 miles north of the city of Galax, and the Buck Development (Buck) is located approximately 3 river miles (RM) downstream of Byllesby and 43.5 river miles upstream of Claytor Dam.

The Project is currently licensed by the Federal Energy Regulatory Commission (FERC or Commission). The Project underwent relicensing in the early 1990s, including conversion to run-of-river operations and incorporating additional protection, mitigation, and enhancement (PM&E) measures (FERC 1994). The current operating license for the Project expires on February 29, 2024. Accordingly, Appalachian is pursuing a subsequent license for the Project pursuant to the Commission's Integrated Licensing Process (ILP), as described at 18 Code of Federal Regulations (CFR) Part 5. In accordance with FERC's regulations at 18 CFR §16.9(b), the Licensee filed it's final application for a new license with FERC on February 28, 2022.

In accordance with 18 CFR §5.11 of the Commission's regulations, Appalachian developed a Revised Study Plan (RSP) for the Project that was filed with the Commission and made available to stakeholders on October 18, 2019. On November 18, 2019 FERC issued the Study Plan Determination (SPD). On December 12, 2019, Appalachian filed a clarification letter on the SPD with the Commission. On December 18, 2019, Appalachian filed a request for rehearing of the SPD. The SPD was subsequently modified by FERC by an Order on Rehearing dated February 20, 2020.

On July 27, 2020, Appalachian filed an updated ILP study schedule and a request for extension of time to file the Initial Study Report (ISR) to account for Project delays resulting from the COVID-19 pandemic. The request was approved by FERC on August 10, 2020, and the filing deadline for the ISR for the Project was extended from November 17, 2020 to January 18, 2021. On December 23, 2020, FERC issued Scoping Document 3 (SD3) for the Project, to account for updates about how Commission staff intend to conduct their National Environmental Policy Act (NEPA) review in accordance with the Council on Environmental Quality's (CEQ) new NEPA regulations at 40 CFR Part 1500-1518.

Appalachian filed the ISR on January 18, 2021, conducted a virtual ISR Meeting on January 28, 2021, and filed the ISR Meeting summary with the Commission on February 12, 2021. Stakeholders provided written comments in response to Appalachian's filing of the ISR meeting summary, which were addressed in the Updated Study Report (USR). The USR was filed with the FERC on November 17, 2021 and the USR meeting was held on December 1, 2021; the meeting summary was filed on December 16, 2021. The following parties provided written comments in response to Appalachian's filing of the USR meeting summary: FERC staff (January 18, 2022), USFWS (January 18, 2022), and VDWR (January 18, 2022). On February 14, 2022, Appalachian filed with FERC a response to comments on the USR and a request for extension of time to file the revised Bypass Reach Flow and Aquatic Habitat Study Report, given the additional time and effort needed to address comments received on the USR.

This revised Bypass Reach Flow and Aquatic Habitat Study Report is being filed as supplemental information to the FLA and describes the methods and results of the Bypass Reach Flow and Aquatic Habitat Study conducted in support of preparing an application for new license for the Project.

2 Study Goals and Objectives

As described in the RSP and SPD, the objectives of this study are to conduct a flow and habitat assessment for each of the development's tailrace and bypass reaches (excluding the Byllesby auxiliary spillway channel) using a combination of desktop, field survey, and hydraulic modeling methodologies with the following goals:

- Delineate and quantify aquatic habitats and substrate types in the Byllesby and Buck bypass reaches.
- Identify and characterize locations of habitat management interest located within each bypass reach.
- Develop an understanding of surface water travel times and water surface elevation responses under variable base flow and spillway release flow combinations in the tailrace and bypass reach of each development to:
    - Demonstrate the efficacy of existing ramping rates required by the existing license[1].
    - Demonstrate the efficacy of the existing powerhouse minimum flow requirement (i.e., 360 cubic feet per second [cfs] minimum flow to maintain aquatic resources, including resident fish species, downstream of each development consisting of the tailrace areas below each powerhouse and the bypass reaches below the main spillways).
    - Evaluate the impacts of providing seasonal minimum flows to the bypass reaches.

3 Study Area

The Study Area for the Flow and Bypass Reach Aquatic Habitat Study includes the tailrace, bypass reach, and a short stream segment downstream of where the tailrace and bypass reach waters join (see Figure 3-1 for the Byllesby Study Area and Figure 3-2 for the Buck Study Area).

[1] In accordance with existing FERC spillway gate operating requirements for the Buck Development, Appalachian discharges flows through a 2.0-ft gate opening for at least three hours following any spills released through a gate opened 2.0 ft or more. Appalachian must then reduce the opening to 1.0 ft for at least an additional three hours, after which time the gate may be completely closed. The gradual reduction of flow allows time for fish to respond to the receding water levels, thus avoiding stranding that can occur with sudden flow discontinuation.

Figure 3-1. Byllesby Development Bypass Reach Study Area

Figure 3-2. Buck Development Bypass Study Area

4 Background and Existing Information

The Byllesby bypass reach is approximately 590 feet (ft) long, consisting primarily of exposed bedrock and rock outcroppings. The Buck bypass reach is approximately 4,100 ft long, with a steep gradient (approximately 24 ft per mile) and consisting primarily of exposed bedrock. Both bypass reaches normally receive seepage and leakage unless flows are being spilled at the dams or the flashboards are breached. Under Appalachian's normal operating conditions, the developments use available flows for powerhouse generation, maintaining the elevation of the Byllesby reservoir between 2,078.2 ft and 2,079.2 ft National Geodetic Vertical Datum (NGVD of 1929) and the Buck reservoir between 2,002.4 ft and 2,003.4 ft NGVD.

Under Article 403 of the current license, Appalachian is also required to maintain 360 cfs minimum flow release or inflow, whichever is less, downstream of the Project powerhouses. When inflow to either Project exceeds the powerhouse discharge capacity (5,868 cfs for Byllesby and 3,540 cfs for Buck), the Obermeyer and/or Tainter gates are opened to pass the excess flow into the respective bypass reaches (Figure 4-1 and Figure 4-2).[2]

Monthly flow data from the U.S. Geological Survey (USGS) 03165500 New River at Ivanhoe, VA flow gaging station from 1996-2020 is provided in Table 4-1. This gage is located approximately 2.8 miles downstream of Buck and reports daily average flow data starting in October 1929 through present, with a data gap from September 1978 to January 1996, providing a discontinuous 74-year period of record (POR). Monthly mean flow data, along with the 25th and 75th percentile flow data[3] is provided from January 1996 through December 2020 (a 25-year POR[4]) to put recent historic river flows in perspective with Byllesby and Buck maximum hydraulic capacities and current minimum downstream flow release requirements. For example, mean monthly flows recorded at the USGS 03165500 New River at Ivanhoe, VA gage are less than the hydraulic capacities of both the Byllesby and Buck developments. And while the monthly 75th percentile flows are less than the Byllesby powerhouse capacity, they exceed the smaller Buck powerhouse capacity. As a result, flow releases into the Buck bypass reach are more common than into the Byllesby bypass reach (see Table 4-2).

---

[2] During station generating unit outages, all Project inflows are passed through the spillway gates at Byllesby and Buck. During outages, emergency generators are started and all spillway gates can be operated normally. If Appalachian's network connection is lost, Tainter gates can be operated via individual gate motor starters and Obermeyer gates can be operated by manually manipulating the pneumatic system's bypass valves.

[3] A percentile is a value on a scale of one hundred that indicates the percent of a distribution that is equal to or below it. A flow percentile greater than 75 is considered to be wetter than normal; a flow percentile between 25 and 75 is considered normal; and a flow percentile less than 25 is considered to be drier than normal.

[4] The January 1996 – December 2020 POR is reflective of current land use and water use practices and uses more modern data collection and recording methods compared to the 1929 – 1978 POR. The more recent POR also contains a number of dry and wet periods that are sufficient for purposes of evaluating flow regimes relevant to the bypass reach flow and aquatic habitat study goals and objectives.

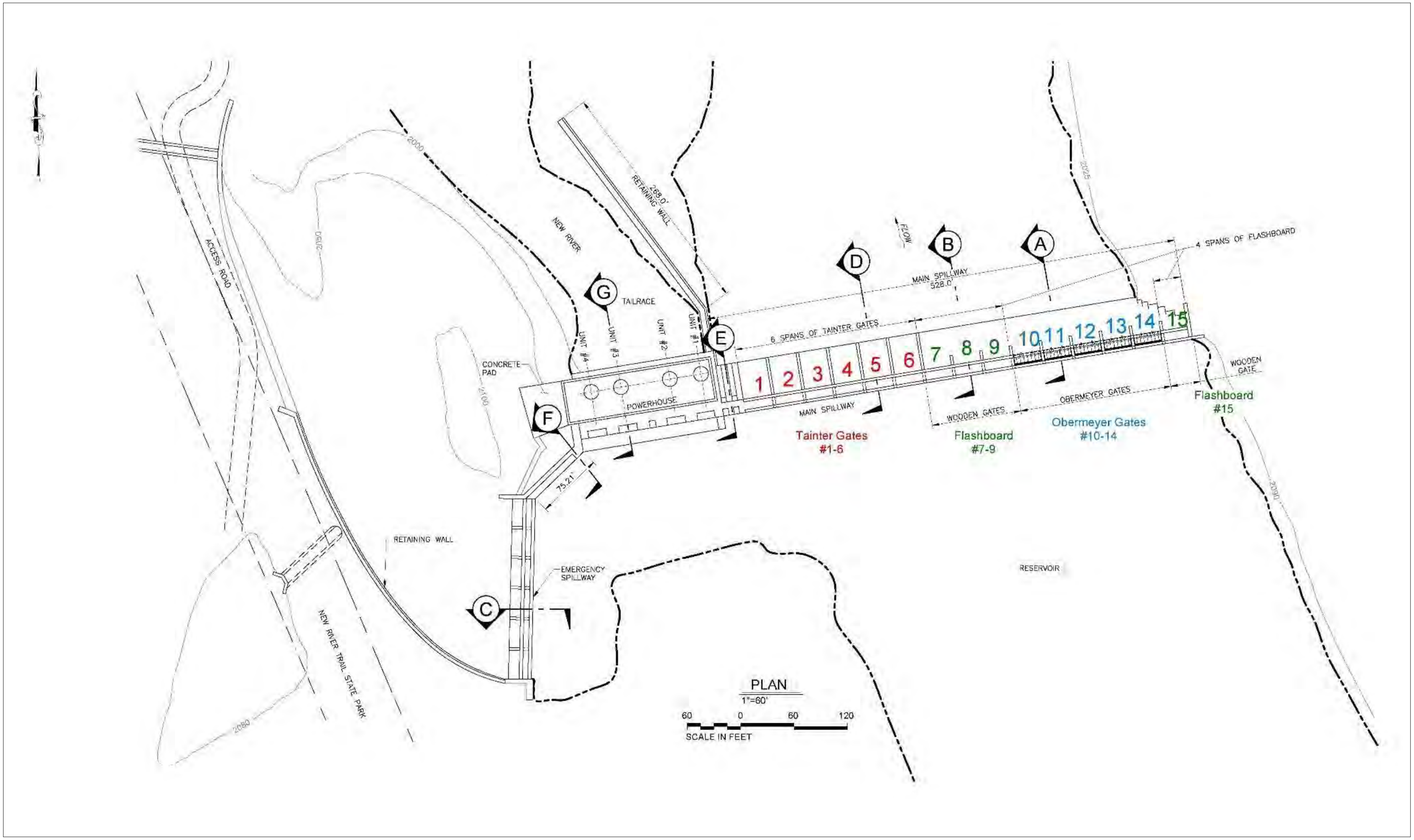


Figure 4-1. Byllesby Dam Spillway Gates

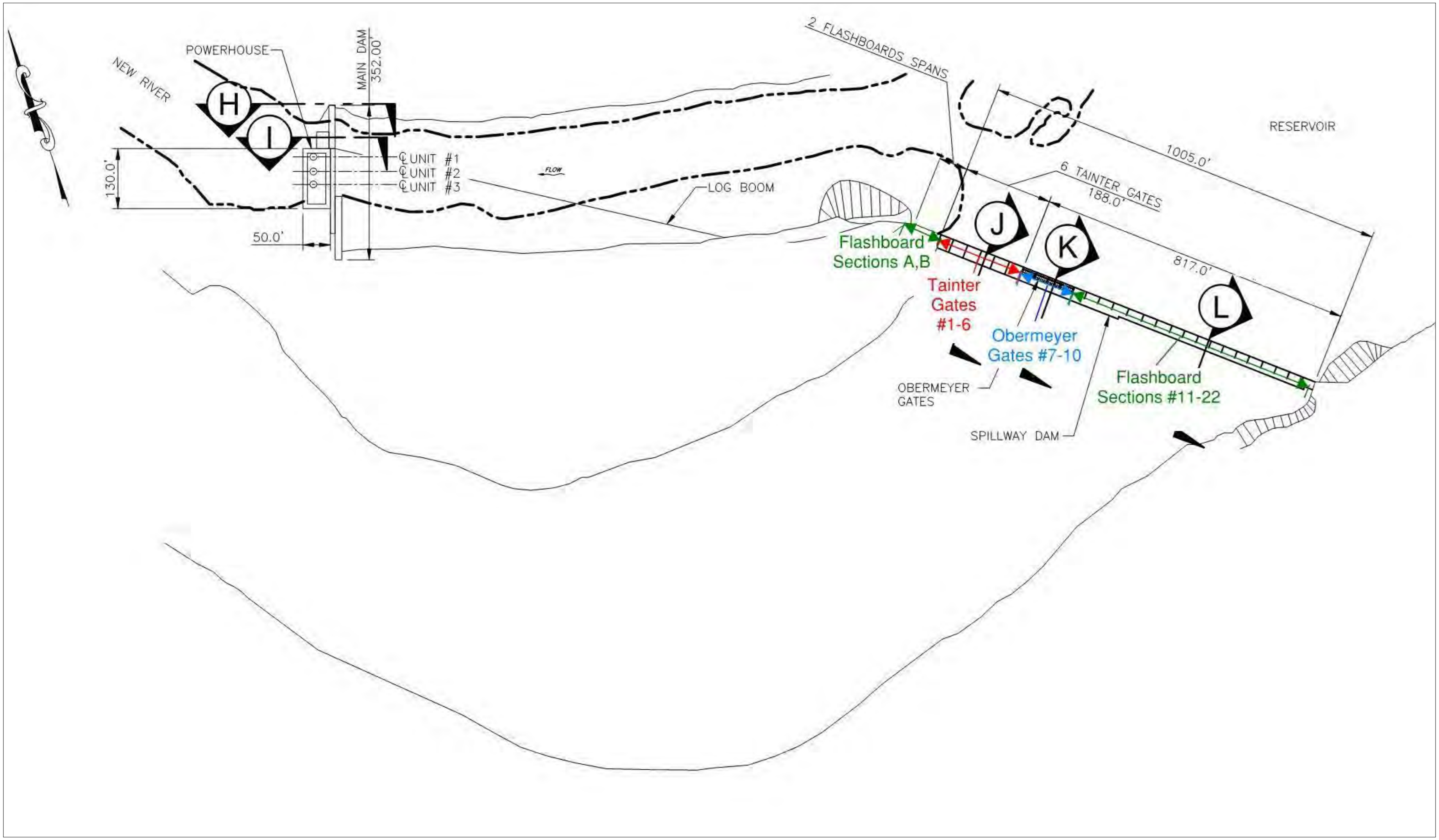


Figure 4-2. Buck Dam Spillway Gates

Table 4-1. USGS 03165500 New River at Ivanhoe, Virginia Monthly Flow Statistics, 1996 - 2020

Time Period	USGS 03165500 New River at Ivanhoe, VA		
	25th Percentile Flow (cfs)	Median Monthly Flow (cfs)	75th Percentile Flow (cfs)
Annual	**1,261**	**1,800**	**2,607**
Jan	1,440	2,090	2,950
Feb	1,595	2,350	3,385
Mar	1,945	2,600	3,340
Apr	1,980	2,590	3,448
May	1,710	2,270	3,170
Jun	1,190	1,790	2,760
Jul	1,020	1,290	1,775
Aug	838	1,100	1,660
Sep	720	984	1,710
Oct	744	1,140	1,805
Nov	816	1,300	2,418
Dec	1,135	1,990	2,860

Table 4-2. Percentage of Days with Spillage to the Bypass Reaches for Byllesby and Buck Developments

Facility	Byllesby (powerhouse capacity 5,868 cfs)			Buck (powerhouse capacity 3,540 cfs)		
Time Period	1996-2020	1999 (dry year)	2013 (wet year)	1996-2020	1999 (dry year)	2013 (wet year)
Annual	10.8	1.4	30.7	15.5	1.9	40.0
Jan	14.7	6.5	32.3	20.5	12.9	32.3
Feb	15.8	0.0	14.3	22.0	0.0	17.9
Mar	16.4	0.0	12.9	25.3	0.0	29.0
Apr	18.1	3.3	40.0	27.1	3.3	63.3
May	14.7	3.2	54.8	21.7	3.2	74.2
Jun	10.0	0.0	33.3	14.1	0.0	43.3
Jul	5.3	0.0	93.5	5.9	0.0	96.8
Aug	5.8	0.0	51.6	8.0	0.0	74.2
Sep	5.3	0.9	0.0	6.8	0.0	0.0
Oct	5.4	0.0	0.0	7.7	0.0	3.2
Nov	7.6	3.3	6.7	10.9	3.3	6.7
Dec	11.0	0.0	25.8	16.3	0.0	35.5

In addition to the minimum flow requirements, and to further protect fish communities, ramping rates are required for the Buck bypass reach. Appalachian is required to discharge flows through a 2-ft gate opening for at least three hours following any spills released through a gate opened 2 ft or more. Appalachian is then required to reduce the opening to 1 ft for at least an additional three hours, after which Appalachian may close the gate. The gradual reduction of flow allows time for fish to respond to the receding water levels, thus avoiding stranding that can occur with sudden flow discontinuation.

An assessment of the effectiveness of the ramping procedure for the protection of aquatic organisms in the Buck bypass was performed in 1997 (Appalachian 1997). Backpack electrofishing was conducted following the cessation of bypass releases in the range of 4,300 to 6,140 cfs. A total of 734 fish representing 24 species were collected. Several species, including Central Stoneroller (*Campostoma anomalum*), White Shiner (*Luxilus albeolus*), White Sucker (*Catostomus commersonii*), Northern Hogsucker (*Hypentelium nigricans*), darters, and Walleye (*Sander vitreus*) were collected in the flowing-water habitat immediately downstream of the spillway, whereas species such as Rock Bass (*Ambloplites rupestris*), Redbreast Sunfish (*Lepomis auritus*), Green Sunfish (*L. cyanellus*), and Bluegill (*L. macrochirus*) were collected in locations further downstream in habitat dominated by pools. The study concluded that fish stranding is not a substantial problem within the Buck bypass when ramping procedures are followed. On March 27, 1998, FERC approved Appalachian's ramping rate assessment report, which included recommendations for Appalachian to continue to retain the ramping rate protocol assessed in the 1997 study. The Virginia Department of Wildlife Resources (VDWR) (formerly the Virginia Department of Game and Inland Fisheries) noted in comments on the PSP that this historical assessment may not apply under current Walleye population conditions.

5 Methodology

The USFWS requested an instream flow study with the goal of determining the impacts of modifying the discharge location and configuration (gate operation) on the current velocity and direction, sediment transport and deposition patterns, aquatic species and habitats, and recreation in the tailrace area and bypass reach below the Project dams.

Appalachian's goal in selecting a process for evaluating flows at the Project is to develop a technical basis for systematically evaluating and balancing the needs and priorities of the various flow-related resources. Therefore, the goal of this study is to characterize changes in quantity of aquatic habitat over a range of flows and operational scenarios. There are several types or combinations of methodologies that could be used to meet the study objectives, ranging from very quantitative to relatively qualitative data. Appalachian believes that the approach used for this study (i.e., development of a two-dimensional [2-D] hydraulic and habitat model) provides the requested information at an appropriate level of effort. This approach also allows for an assessment of potential Project protection, mitigation, and enhancement measures for the benefit of the range of resources in the bypass reaches.

5.1 Literature Review and Desktop Assessment

A literature review of available information was performed to support the study goals, methodologies, and planning of field portions of the study. This task included a review of the hydrologic record for the Project reaches, existing spillway gate operating procedures maintained by Appalachian, existing topographic and geologic maps, and available recent and historical aerial imagery.

Several pieces of information were considered in the field study planning process. First, a desktop analysis of mesohabitat (i.e., pools, riffles, runs, bedrock, shoals) mapping of the bypass reaches was completed using high-resolution aerial imagery and topographic contour data collected as described in Section 5.2. Second, species of interest were determined based on stakeholder consultation and an evaluation of management objectives (e.g., Walleye spawning, minimizing fish stranding, habitat availability under different flow regimes using guild curves to represent fish species that are or may be present in the bypass reaches, etc.). The life history characteristics and habitat preferences of selected species, as well distribution of mesohabitat types, were considered in the selection of calibration flows and locations for field data collection. GIS figures delineating mesohabitat types are provided in Section 6.3.

5.2 Topography Mapping and Photogrammetry Data Collection

Light detection and ranging (LiDAR) data were collected during a period of no releases at the dams and minimal water levels in the bypass reaches to support development of comprehensive three-dimensional (3-D) elevation and visual surface layers of each bypass reach. These data were used for desktop mesohabitat mapping as well as to produce a digital terrain map of each bypass reach. The topographic information was then incorporated as a base layer for subsequent field data collection and hydraulic modeling efforts. LiDAR data collection and digital terrain models are discussed further in the Byllesby and Buck Bypass Reach ICM Model Development reports, which are included in Attachment 1.

5.3 Desktop Mesohabitat Mapping

Using the high-resolution photogrammetry data (see Section 5.2), polygons were drawn in GIS to encompass the study areas according to presence or type of cover (e.g., no cover, overhead vegetation, etc.) and substrate size (e.g., sand, gravel, cobble, etc.) (Table 5-1). If multiple types of cover were present, the most immediate cover type was selected assuming it would have greater influence over aquatic organism behavior (e.g., if instream cover and overhead vegetation both exist, instream cover was selected). While substrate could be composed of several types/sizes, the dominant size class was selected. Mesohabitats were delineated based on typical stream and river morphological, longitudinal sequences (i.e., riffle, run, pool, glide) (Wildland Hydrology 1996) and aerial signatures denoting flow and turbulence at leakage, low-flow, or moderate-flow conditions.

Table 5-1. Desktop Mesohabitat Delineation Codes Used for the Byllesby-Buck Flow and Aquatic Habitat Study

Substrate-Cover Classifications		
Code	**Cover**	**Substrate**
01	No Cover	and silt or terrestrial vegetation
02	No Cover	and sand
03	No Cover	and gravel
04	No Cover	and cobble
05	No Cover	and small boulder
06	No Cover	and boulder, angled bedrock, or woody debris

Substrate-Cover Classifications		
07	No Cover	and mud or flat bedrock[1] (unsuitable as cover)
08	Overhead vegetation	and terrestrial vegetation
09	Overhead vegetation	and gravel
10	Overhead vegetation	and cobble
11	Overhead vegetation	and small boulder, angled bedrock[3], or woody debris
12	Instream cover	and cobble
13	Instream cover	and small boulder, angled bedrock[3], or woody debris
14	Proximal[2]	and cobble
15	Proximal[2]	and small boulder, angled bedrock[3], or woody debris
16	Instream or proximal[2]	and gravel
17	Overhead, instream, or proximal[2]	and silt or sand
18	Aquatic vegetation	and aquatic macrophytes
Mesohabitat Classifications		
Code	**Mesohabitat Type**	
00	Upland[4]	
01	Pool	
02	Riffle	
03	Run	
04	Glide	
05	Shoal	
06	Backwater	

[1] Flat bedrock consists of bedrock that is smooth, with or without crater-like divots, or otherwise unsuitable as instream cover.
[2] ”Proximal” is defined as within four feet of suitable cover.
[3] Angled bedrock is angular, jutting or semi-vertical, slab-like bedrock. Angled bedrock was categorized as instream cover, regardless of presence of overhead vegetation.
[4.] Upland areas are areas that are inundated during spill events.

5.4 Field Data Collection

5.4.1 Flow and Water Level Assessment

In this task, field data was collected to support development of a 2-D hydraulic model of each development’s tailrace and bypass reach. Calibration flows were released into the tailrace and bypass reaches for purposes of collecting water surface elevation, depth, velocity, and wetted area data under four bypass reach and tailrace flow regimes. The model enables a comparison between powerhouse operations (i.e., flow releases into the tailrace areas) and dam operations (i.e., flow releases into the bypass reaches via spillway gates).

A proposed framework for model scenarios was developed and the opportunity for agencies to review and comment was provided (prior to collecting data) in late August of 2020. The objective of the proposed flow test scenario study was designed to capture existing (baseline) Project operations and also to support the development and calibration of hydraulic models that allowed for visualization and evaluation of flow releases from set Tainter gate openings.

For Byllesby, the calibration flow scenarios (Table 5-2) were designed to evaluate the effect of passing the entire minimum downstream flow requirement of 360 cfs through the bypass reach. Tainter Gate 6 was used to pass flows into the bypass reach as it is near the center of the spillway structure and under existing operating procedures is the first gate operated for releases into the bypass reach (see Figure 4-1).

For Buck, the calibration flow scenarios (Table 5-2) were designed to evaluate the effect of the existing ramping rate requirements. Appalachian is required to discharge flows through a 2-ft gate opening for at least three hours following any spills released through a gate opened 2 ft or more. Appalachian must then reduce the opening to 1 ft for at least an additional three hours, after which time the gate may be completely closed. This gradual reduction of flow allows adequate time for fish that may have traveled upstream into the bypass reach to respond to receding water levels, reducing instances of fish stranding that can potentially occur with sudden flow discontinuation.

Tainter Gate 1 (see Figure 4-2) was utilized at the Buck development to pass the calibration flows since this reflects current operations (i.e., Tainter Gate 1 is first to open and last to close during high flow events where flows are routed into the bypass reach). Gate openings of 2 ft and 1 ft were evaluated (as per existing ramping rate operating protocols) as well as a gate opening of 0.5 ft to represent flows that would occur between a 1-ft gate opening and leakage[5] conditions.

Water level data loggers (pressure transducers that measure water stage changes) were strategically deployed in the tailrace, bypass, and downstream study reaches prior to releasing the calibration flows. The instrumentation remained in place for several weeks afterwards to collect additional data during several rainfall runoff events, which captured depth and surface flow travel time information under a variety of flow regimes (i.e., powerhouse operations and spillway gate openings).

A level logger was also placed at the downstream end of the Buck study area to capture changes in water surface elevations created by Project operations. This downstream boundary was requested by the VDWR to help better understand the potential effect Project operations may have on mussel habitat in this area.

[5] Several factors control leakage flows into the bypass reach at both Byllesby and Buck dams including reservoir level (controlled by a combination of inflow and powerhouse operations), age and condition of flashboards and gate seals, and sediment build-up upstream of the flashboards. Leakage flows measured during the field studies at Byllesby and Buck are considered to be typical of past and potential future leakage flow conditions.

Table 5-2. Byllesby-Buck Bypass Reach Aquatic Habitat Study proposed Calibration Flow Scenarios

Byllesby Bypass Reach			
Pool Range: 2078.2 - 2079.2 NGVD 29; Assume starting Pool Elevation is 2078.7 NGVD 29)			
Powerhouse Discharge Capacity: 5,868 cfs			
Powerhouse Minimum Discharge Capacity: 85 cfs/unit			
Tainter Gate 6			
Opening* (ft)	Proposed Calibration Flows (cfs)	Flow Test Duration (hours)	Volume (acre-ft)
0.0	Leakage	NA	0
0.25	105	8	69
0.5	203	4	67
1.0	398	4	132
Buck Bypass Reach			
Pool Range: 2002.4 - 2003.4 NGVD 29; Assume starting Pool Elevation is 2002.9 NGVD 29			
Powerhouse Discharge Capacity: 3,540 cfs			
Powerhouse Minimum Discharge Capacity: 73 cfs/unit			
Tainter Gate 1			
Opening* (ft)	Proposed Calibration Flows (cfs)	Flow Test Duration (hours)	Volume (acre-ft)
0.0	Leakage	NA	0
0.5	224	8	148
1.0	448	8	296
2.0	897	8	593

5.4.2 Particle Size Distribution

A Wolman pebble count (Wolman 1954) was performed along three transects in the Byllesby bypass reach study area to characterize the existing grain size distribution of substrate. The transects were located in (1) the bypass reach, (2) the cross-over channel between the tailrace and main channel, and (3) the upper end of the side channel to evaluate differences in substrate between the three transect locations. Substrate particle sizes were plotted by size class and frequency to determine distributions within the bypass reach study area; plots are shown in Section 6.4.3.

A similar Wolman pebble count was also performed along three transects in the Buck bypass reach. The transects were located in (1) the upper, (2) middle, and (3) lower portions of the bypass reach to evaluate differences in substrate between the three locations. Substrate particle sizes were plotted by size class using the Wentworth grain size scale (Wentworth 1922) and frequency to determine distributions within the mesohabitats of each of the bypass reaches; plots are shown in Section 6.4.3.

5.5 Hydraulic Model Development

5.5.1 General Model Description

Development of a 2-D hydraulic model was carried out as part of the Bypass Reach Flow and Aquatic Habitat Study. A 2-D model incorporates detailed terrain data obtained by topographic mapping technologies and provides options for building one-dimensional (1-D) and 2-D geometries. It also utilizes a 1-D/2-D model development approach which optimizes the simulation of observed hydraulic behavior for specific project requirements. This study used the 2-D Innovyze Infoworks Integrated Catchment Model (ICM) software (version 7.0), which is capable of simulating depth and velocities in a 2-D triangular pattern over a wide range of flow conditions.

The advantage of implementing a 2-D model is that it provides more stable results over a wider range of flows than a 1-D model, thus reducing troubleshooting during model development; however, simulation speed is generally slower. The ICM software performs 2-D unsteady flow hydraulic calculations based on conservation of mass and momentum to dynamically route the spillway release flood wave downstream and uses a finite-volume solution algorithm to allow for 2-D cells to be wet or dry and handle a sudden rush of water, subcritical, supercritical, and mixed-flow regimes. For instance, a spillway release is a highly dynamic flood wave that rises and falls quickly; therefore, the 2-D unsteady flow calculation must use the full momentum form of the St. Venant equations (the full momentum equation accounts for the change in velocity both spatially and temporally).

The model geometry is defined by digital terrain model elevation values, user inputs based on Project drawings and survey information, and Manning's roughness coefficient inputs (used to establish terrain roughness) and calculates the flood wave hydrograph resulting from a spillway release based on input gate operation parameters. The model is also capable of simulating reservoir inflow and rate of reservoir rise, dynamic gate operations scenarios, release travel times, and rates of rise at locations within and downstream of the bypass reach.

5.5.2 Byllesby and Buck Bypass Reach ICM Model Development

The morphology of the approximately 590-ft long Byllesby bypass reach extending from the spillway to the vicinity of the powerhouse tailrace is variable and includes deep and shallow pools, runs, shoals, and steep cascades with large boulders. The Byllesby model domain extends approximately 1,800 ft downstream of the bypass reach/tailrace confluence and includes a cross-over channel with shallow pool/glide habitat with a mostly sandy bottom, a wide main channel consisting of mostly run habitat with undulating bedrock, and a narrow side channel with shallow pools, runs, and riffles with a mostly cobble and gravel substrate. This complex study area impacts flow travel times differently at varying flows and is most accurately represented by a 2-D model. Results of the modeling effort for the Byllesby Bypass study area are included in Attachment 1 (Byllesby Bypass Reach ICM Model Development); this report presents the final 2-D Byllesby bypass reach model developed using the ICM software, which was used to predict hydraulic regimes in the study area under varying flow conditions.

The morphology of the approximately 4,100-foot long Buck bypass reach extending from the spillway to the vicinity of the powerhouse tailrace is variable and includes deep and shallow pools, runs, shoals, steep cascades, and side channels with large boulders. This channel variability impacts flow travel times differently at varying flows and is most accurately represented by a 2-D model. Results of the modeling effort for the Buck Bypass are included in Attachment 1 (Buck Bypass Reach ICM Model Development); this report presents the final 2-D Buck bypass reach model developed using the ICM software, which was used to predict hydraulic regimes in the bypass reach under varying flows and from varying spill locations.

Flow and water surface elevation data collected at four calibration flows for each development were used to calibrate and validate the hydraulic models to allow simulation of flow conditions and gate operations other than those that were explicitly sampled during data collection. Recorded gate operations (provided by Appalachian), flow, survey, and level-logger data from each tailrace and bypass study reach were processed to provide operation sequences and flow and elevation hydrographs used for the calibration of gate and bypass reach model hydraulic parameters. Operational procedures for spilling and ramping rates that affect upstream-downstream connectivity were also assessed. Analyzing the results of varying spill events and spill configurations can provide insight to potential adverse effects on the fish and other aquatic species or recreational fishing opportunities in each bypass reach. Simulations were used to establish matrices of travel time, rise in water surface elevation, and velocities at locations of interest under the different flow regimes.

It is noted that any model is an approximation of actual physical processes and has inherent uncertainty. The level of model accuracy is influenced by the quality of data used to build the model, such as channel geometry, topographic data resolution, and hydraulic parameters of controlling structures (i.e. gates and spillways), the quality of data used to calibrate the model, and choice of model (e.g., uncertainty inherent in numerical methods, flow calculation equations).

5.6 Aquatic Habitat Evaluation

Activities described above (i.e., literature review and desktop assessment, topographic mapping and photogrammetry, field data collection, and hydraulic model development) were used to develop a flow and aquatic habitat assessment of each tailrace and bypass reach. Specifically, for each flow scenario evaluated, incremental changes in depth and wetted area were determined. The water level logger data in combination with the 2-D model results were used to determine rate of rise and fall of water elevation (i.e., water depth) in the tailrace and bypass reaches and evaluate flow patterns and hydraulic connectivity under each flow regime evaluated. In addition, substrate and mesohabitat mapping along with the 2-D model depth and velocity simulation results were used in combination with aquatic species habitat suitability criteria (HSC) (i.e., using depth, velocity, and substrate/cover preferences) to evaluate potential available habitat under each modeled flow scenario in the study areas.

5.6.1 Target Species and Habitat Suitability Criteria

Walleye was selected as the target species for this study along with a total of eight species-guild representatives including three shallow-slow, one shallow-fast, two deep-slow, and two deep-fast guilds. Guild representatives were selected from a variety of regionally representative sources, represent a wide range of habitat characteristics, and were selected to represent a wide range of species. In some cases, general non-species-specific criteria were used. In other cases specific species were used to represent a guild category; these include Redbreast Sunfish, Silver Redhorse (*Moxostoma anisurum*), and Shorthead Redhorse (*Moxostoma macrolepidotum*) (Table 5-3).

5.6.1.1 Target Species

Walleye is the largest member of the Percidae family and attains average adult sizes of 300-780 millimeters (mm) total length (Lee et al. 1980; Stauffer et al. 1995). The fish is native to most of North America, excluding the arid west where it has been widely introduced for its recreational importance (Lee et al. 1980). The species is a voracious predator that begins feeding solely on fish at the size of only 30 mm (Li and Mathias 1982). Walleye are yellow to green dorsally, slightly fade laterally, and become white ventrally. Dark bands across the dorsum can be present in some individuals. Fins are mostly clear with some spotting, but the posterior margin of the anterior dorsal fin has a dark blotch and the ventral tips of the caudal and anal fins are white (Stauffer et al. 1995).

Walleye are most commonly associated with large rivers in deep water habitat such as pools and runs. They only leave the protection of deep water at night when they feed in the shallows (Lee et. al. 1980; Stauffer et. al. 1995). Spawning takes place during early spring at temperatures ranging from 3-16 degrees Celsius (°C). Shallow gravel substrate is necessary for successful spawning (Lee et. al. 1980).

5.6.1.2 Guild Species

Redbreast Sunfish

The Redbreast Sunfish (a Centrarchid) is used as one of the representatives for the deep/slow guild. The redbreast is native along the Atlantic slope of the Appalachians from southern Canada to Florida west to the Apalachicola River (Lee et al. 1980). Like most sunfishes the Redbreast Sunfish is an opportunistic insectivore that incorporates smaller fish into its diet as it obtains larger sizes (Levine et al. 1986; Wallace 1984). Superficially, the Redbreast Sunfish resembles most other sunfish, particularly the bluegill (*Lepomis macrochirus*). However, unlike the bluegill, the redbreast lacks a black blotch on the dorsal fin and has shorter gill rakers. The redbreast can be distinguished from all other sunfish, except the bluegill, by black on the opercular flap that extends to the posterior margin. Adults range from 60-155 mm total length (Lee et. al. 1980).

More than any other sunfish, the Redbreast dwells almost entirely in lotic environments (Lee et al. 1980; Stauffer et al. 1995). Gravel spawning nests are constructed from spring through summer when water temperatures reach 23°C (Levine et al. 1986; Stauffer et al. 1995).

Redhorse

Representing both shallow/slow (i.e., young-of-year) and deep/fast (i.e., adults) guilds, Catostomidae are members of the genus *Moxostoma*, the redhorses. Specifically, Silver Redhorse and Shorthead Redhorse habitat suitability information is included in the guild habitat modeling.

The redhorses are indigenous to the Atlantic slope of the Appalachians, the Mississippi River Drainage, and the Great Lakes Basin. All the redhorses possess subterminal mouths used to forage the streambed for benthic macroinvertebrates. Like other catostomids, they are drab olive bronze dorsally and fade to white ventrally. They possess complete, well developed lateral lines and develop tubercles during breeding. These fish can attain lengths up to 600 mm standard length (Lee et al. 1980; Stauffer et al. 1995).

The redhorse can inhabit both lentic and lotic environments, but they prefer medium to large streams and rivers with clear water and assorted rock substrates. While they are usually associated with deep pools and backwaters, they spawn in spring and early summer on coarse gravel (Lee et al. 1980; Stauffer et al. 1995).

5.6.1.3 Habitat Suitability Criteria

HSC define the range of microhabitat variables that are suitable for a particular species and life stage of interest. Variables typically defined with HSC include depth, velocity, instream cover, and bottom substrate. HSC provide the biological criteria input to the ICM 2-D model, which combines the physical habitat data and the habitat suitability criteria into a site-wide habitat suitability index (i.e., usable) over a range of simulation flows. The habitat suitability index (HSI) is a numerical scale that represents habitat suitability with values ranging from 0.0 to 1.0 indicating habitat conditions that are unsuitable to optimal, respectively. Usable area is defined as the sum of stream surface area within a nodal area model domain or stream reach estimated by multiplying area by habitat suitability variables (most often velocity, depth, and substrate or cover), which range from 0.0 to 1.0 each.

HSC for target species and life stages were obtained from the Hawks Nest Hydroelectric Project Bypass Reach Aquatic Habitat Use/Instream Flow Study (HDR 2015). The Hawks Nest instream flow study was conducted on a bypass reach of the New River near Ansted, West Virginia, with similar stream channel characteristics to the Byllesby and Buck instream flow study areas. The Hawks Nest study relied in part on HSC from other previous instream flow investigations conducted on nearby streams in West Virginia and Virginia including: (1) Sutton Hydroelectric Project, Elk River, WV (HDR 2010); (2) Smith Mountain Hydroelectric Project, Roanoke River, VA (TRPA & Berger 2007); (3) Claytor Hydroelectric Project, New River, VA (TRPA & Berger 2008); and (4) Clover Power Station, Roanoke River, VA (Gore 2006). These four recent studies represent the best available sources for regionally applicable species information due to their close proximity to the study location, the similarity in river condition and species community modeled, and the collaborative HSC review process that each underwent.

Velocity, depth, and substrate HSC curves for Walleye, shallow water guilds, and fast water guilds are shown on Figure 5-1 through Figure 5-6. HSC data tables are included in Attachment 2.

Table 5-3. Target Species Habitat and Suitability Criteria Source and Code Table

Species / Life stage or Guild Category	HSC Code	Representative	Comments / References
Walleye Fry	WLEF	NA	Habitat suitability information from the USFWS (McMahon et al. 1984); Clover Power Station instream flow study, Roanoke River, VA (Gore 2006); Claytor Hydroelectric Project instream flow study, New River, VA (TRPA & Berger 2008); and Sutton Hydroelectric Project instream flow study, Elk River, WV (HDR 2010)
Walleye Juvenile	WLEJ	NA	
Walleye Adult	WLEA	NA	
Walleye Spawning	WLES	NA	
Shallow-Slow Guild (Depth < 2 ft, Velocity < 1 foot per second [fps])			
Fine substrate without cover	RBSFS	Redbreast Sunfish spawning	Representative of centrarchid spawning requirements; Smith Mountain Hydroelectric Project instream flow study, Roanoke River, VA (TRPA & Berger 2007)
Fine and small gravel substrate with aquatic vegetation	SRHAV	Silver Redhorse young-of-year	Representative of catostomid and cyprinid young-of-year requirements; Sutton Hydroelectric Project instream flow study, Elk River, WV (HDR 2010)

Species / Life stage or Guild Category	HSC Code	Representative	Comments / References
Coarse substrate	SHSLO	Generic Shallow-Slow	Representative of habitat requirements of adult cyprinids and young-of-year of species that may use the predominant substrate type found in the New River; Sutton Hydroelectric Project instream flow study, Elk River, WV (HDR 2010)
Shallow-Fast Guild (Depth < 2 ft, Velocity > 1 fps)			
Moderate velocity with coarse substrate	SHFST	Generic Shallow-Fast	Representative of all species inhabiting shallow-fast habitats that use coarse substrate types which are predominant in the New River study area; Hawks Nest Hydroelectric Project instream flow study, New River, WV (HDR 2015)
Deep-Slow Guild (Depth > 2 ft, Velocity < 1 fps)			
Cover	RBSFA	Redbreast Sunfish adult	Representative of many adult centrarchids and other cover dependent species that rely on boulder cover types which are predominant in the New River study area; Hawks Nest Hydroelectric Project instream flow study, New River, WV (HDR 2015)
No cover	DSLON	Generic Deep-Slow	Representative of many species inhabiting deep, slow moving habitats; Sutton Hydroelectric Project instream flow study, Elk River, WV (HDR 2010)
Deep-Fast Guild (Depth > 2 ft, Velocity > 1 fps)			
Fine substrate with cover	SRHAD	Silver Redhorse adult	Representative of many adult catostomids and cyprinids; Hawks Nest Hydroelectric Project instream flow study, New River, WV (HDR 2015)
Coarse-mixed substrate	SHRHA	Shorthead Redhorse adult	Representative of those species requiring deep-fast habitats for foraging on coarse-mixed substrate; Smith Mountain Hydroelectric Project instream flow study, Roanoke River, VA (TRPA & Berger 2007)

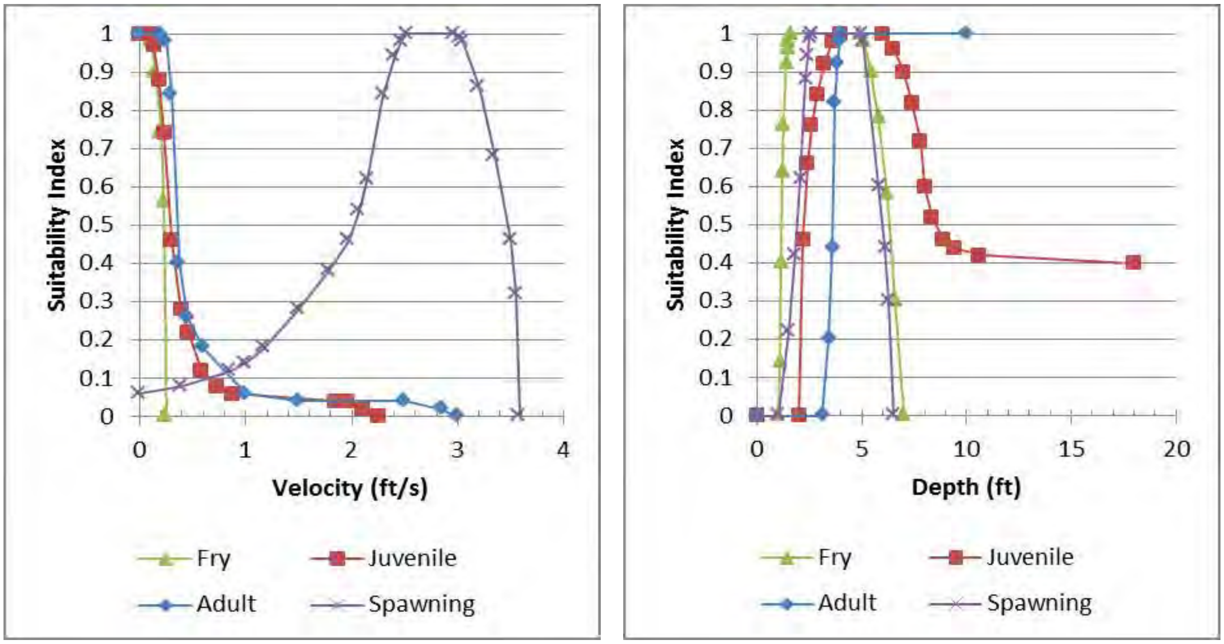


Figure 5-1. Velocity HSC (left) and Depth HSC (right) for Walleye

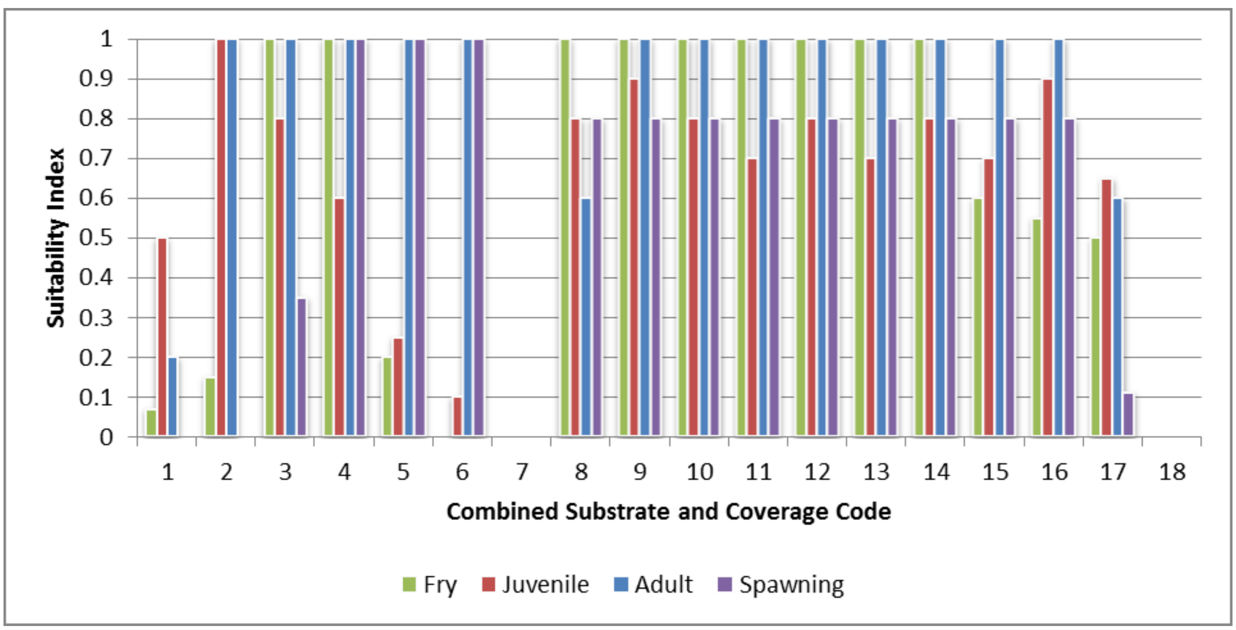


Figure 5-2. Substrate HSC for Walleye

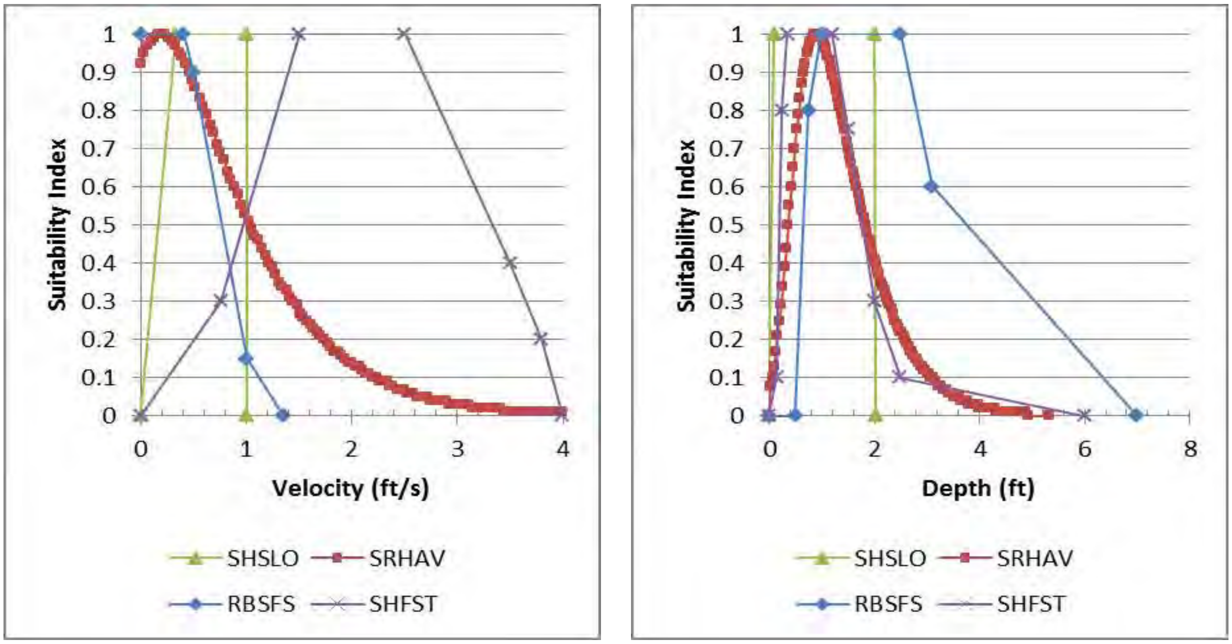


Figure 5-3. Velocity HSC (left) and Depth HSC (right) for Shallow Water Guilds

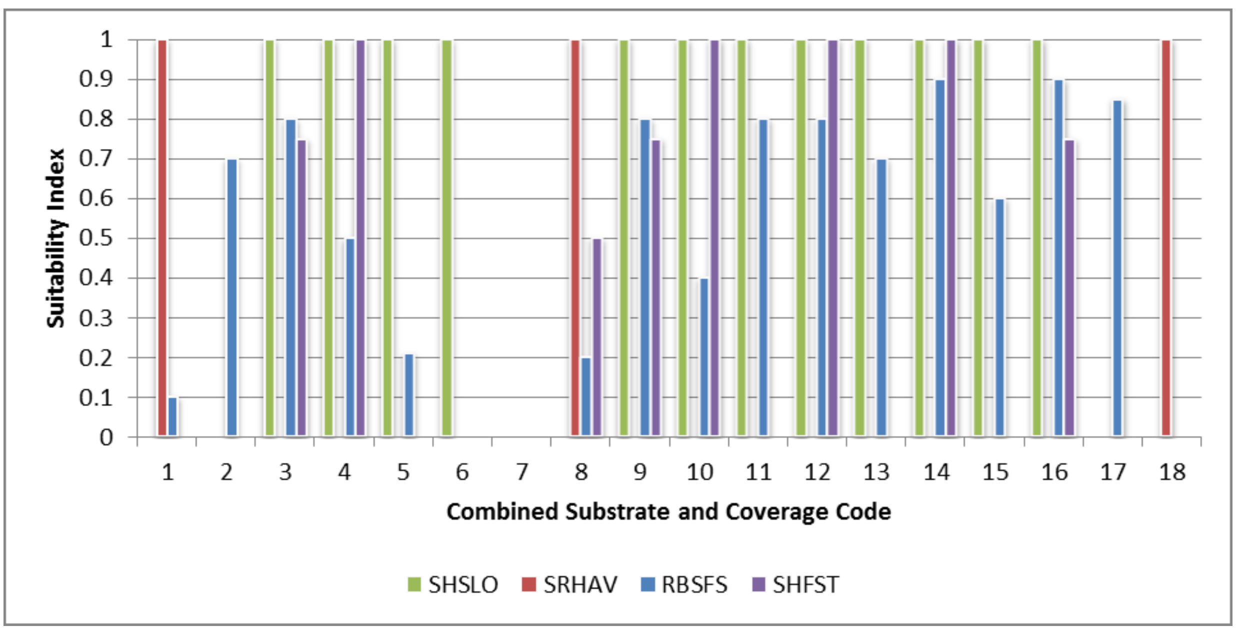
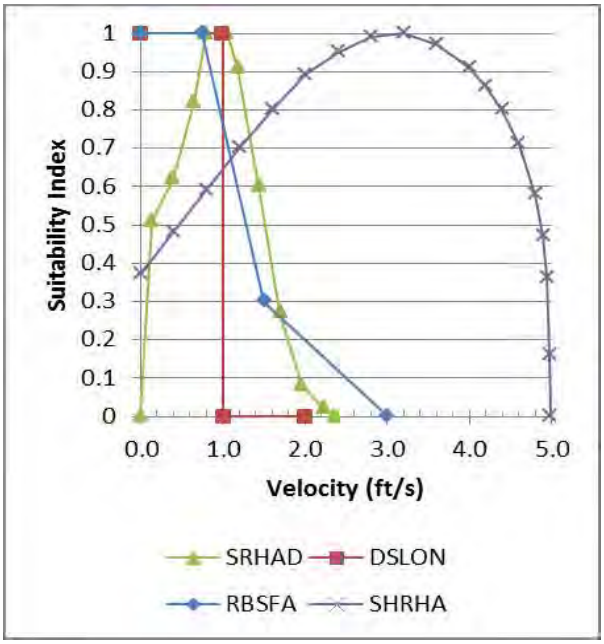


Figure 5-4. Substrate HSC for Shallow Water Guilds



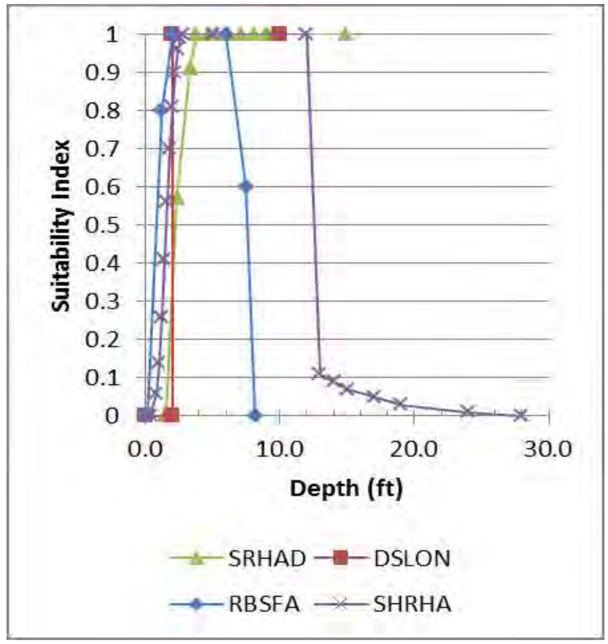


Figure 5-5. Velocity HSC (left) and Depth HSC (right) for Deep Water Guilds

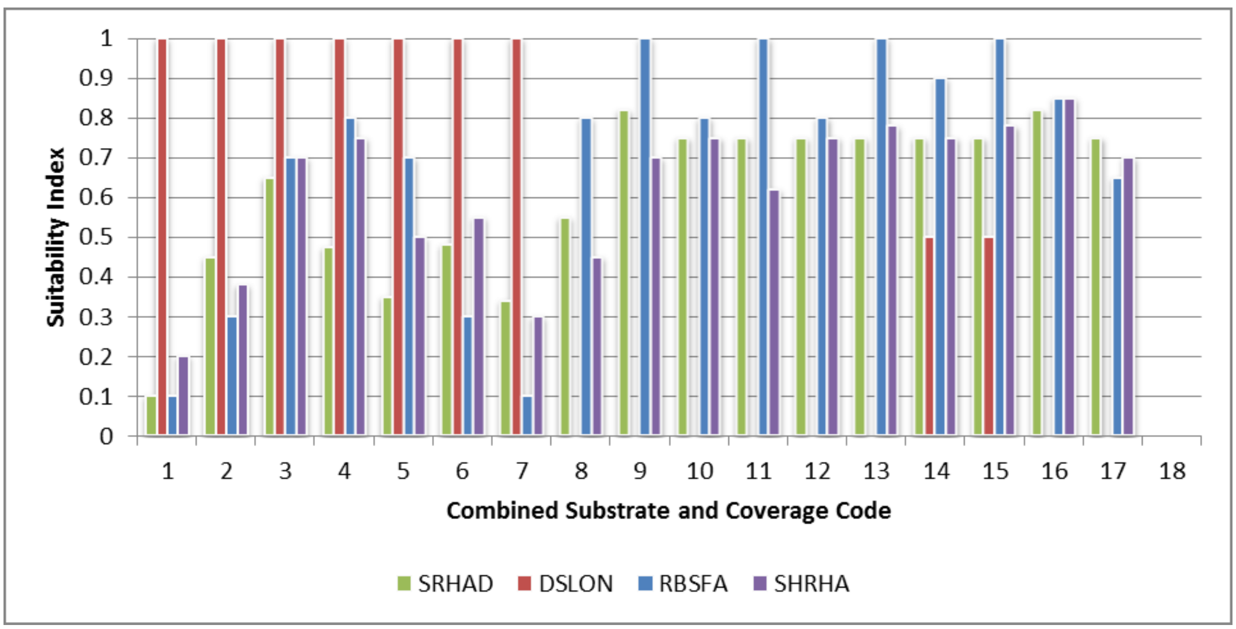


Figure 5-6. Substrate HSC for Deep Water Guilds

6 Study Results

6.1 Literature Review and Desktop Assessment Results

The literature review included several key reports and documents, which are included in the references section, as well as USGS and Project flow data as described in Section 5. The results of the desktop mesohabitat mapping of the bypass reaches, which was completed using high-resolution aerial imagery and topographic contour data, are included in Section 6.3. The 2-D hydraulic model results are included in Section 6.5 and Attachment 1. The aquatic habitat evaluation results including the life history characteristics and habitat preferences of selected species, as well distribution of mesohabitat types, are provided in Section 6.6.

6.2 Topography Mapping and Photogrammetry Data Collection Results

LiDAR data were collected during a period of no bypass flow releases at the dams and minimal water levels in the bypass reaches to support development of comprehensive 3-D elevation and visual surface layers of each bypass reach. These data were used for desktop mesohabitat mapping as well as to produce a topographic map of each bypass reach. The mesohabitat maps are provided in this section of the report and the digital terrain models are included in the ICM Model Development reports for Byllesby and Buck (Attachment 1).

6.3 Desktop Mesohabitat Mapping Results

The habitat mapping codes described in Section 5.3 were used to delineate the Byllesby and Buck bypass reaches. For areas where both overhead cover and instream cover are present, the latter was chosen as it is likely that instream cover has a greater influence on fish habitat selection and behavior because it is in the immediate in-water environment. The desktop habitat mapping effort was validated in the field throughout each study area (shown on Figure 6-2 for Byllesby and Figures 6-4 through 6-6 for Buck) during the hydraulic model calibration field data collection effort. Habitat types were then either verified and/or updated in GIS as necessary based on those field observations. Substrate-cover and mesohabitat classifications were reviewed by a senior scientist and polygons were processed using quality control procedures to ensure data integrity throughout the aquatic habitat modeling process.

6.3.1 Byllesby Bypass Reach

The total area evaluated for the Byllesby bypass reach was 40.1 acres. Cover and substrate characterization was reviewed, verified, and/or updated (as necessary) by a field investigation in July 2021. The majority of the Byllesby bypass reach had some kind of cover as either instream cover or overhead vegetation (46.5 and 22.7 percent, respectively) (Table 6-1). Concurrent with the pebble count (Section 6.4.3.1), boulder, bedrock, or woody debris was the most dominant substrate category (43.4 percent). Cobble (20.1 percent) and sand (15.9 percent) consisted of the next-two most prevalent substrate types in the desktop analysis. Run and riffle habitats were the most common within bypass the reach (44.2 and 41.0 percent, respectively), followed distantly by shoal, glide, upland, pool, and backwater mesohabitats. A photo of the Byllesby bypass reach is presented below (Figure 6-1) and a figure depicting the habitat desktop delineation is shown on Figure 6-2.

Table 6-1. Summary of Habitat Characteristics of the Byllesby Bypass Reach

Habitat Characteristic	Area (acres)	Percent (%)
Cover		
Instream Cover	18.7	46.5
No Cover	12.3	30.8
Overhead Vegetation	9.1	22.7
Total	40.1	100.0
Substrate		
Boulder, Bedrock, or Woody Debris	17.4	43.4
Cobble	8.0	20.1
Sand	6.4	15.9
Mud or Flat Bedrock	3.2	7.9
Silt or Sand	2.6	6.5
Small Boulder	1.5	3.7
Gravel	1.1	2.6
Total	40.1	100.0
Mesohabitat		
Run	17.7	44.2
Riffle	16.4	41.0
Shoal	2.9	7.2
Glide	1.3	3.3
Upland	0.9	2.2
Pool	0.6	1.4
Backwater	0.3	0.7
Total	40.1	100.0

Figure 6-1. Byllesby Bypass Reach at Byllesby-Buck Hydroelectric Project

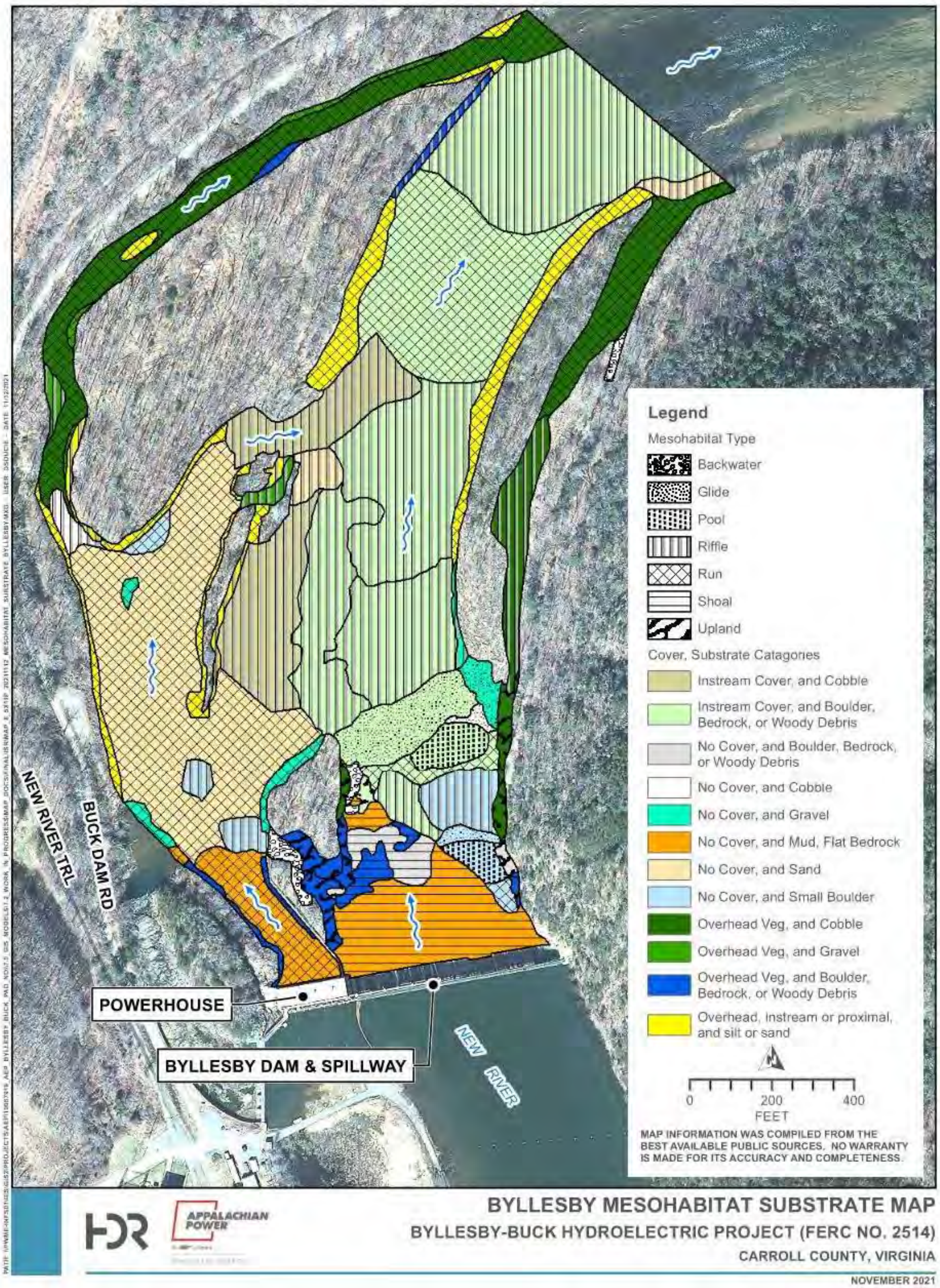


Figure 6-2. Byllesby Study Area Desktop Habitat Delineation at Byllesby-Buck Hydroelectric Project

6.3.2 Buck Bypass Reach

The total area evaluated for the Buck bypass area was 99.4 acres. Cover and substrate characterization was reviewed, verified, and/or updated (as necessary) by a field investigation in September 2020. The majority of the Buck bypass reach has some form of cover consisting of either instream cover (58.1 percent) or overhead vegetation (17.2 percent) (Table 6-2). Concurrent with Wolman pebble count data (see Section 6.4.3), most of the substrate identified through the desktop habitat analysis was designated as a cobble or larger (including bedrock) (84.9 percent).

The mesohabitat desktop mapping and field-verification showed that different shapes/sizes and orientation of bedrock exist at the Byllesby and Buck bypass reaches. At Byllesby, flat bedrock with or without divots provides little or no instream cover (Figure 6-1); conversely at Buck, the bedrock is angular and vertically slanted, resulting in microhabitats as instream cover available for aquatic organisms. The bedrock slabs in the upper portion of the bypass reach are oriented parallel to flow resulting in scour of smaller substrate sizes, whereas in the middle-to-lower portion of the bypass reach, the bedrock is angled perpendicular to flow, resulting in substrate buildup (i.e., deposition) on the downstream side of the bedrock slabs. The difference in bedrock types is captured in the substrate-cover classifications below and is depicted in Figure 6-3 (i.e., the upper photograph is representative of the upper portion of the bypass reach and the lower photograph is representative of the mid-to-lower portion of the bypass reach). The desktop delineation of habitat types is presented in Figure 6-4 (upper bypass), Figure 6-5 (middle bypass), and Figure 6-6 (downstream of bypass reach).

Table 6-2. Summary of Habitat Characteristics of the Buck Bypass Reach

Habitat Characteristic	Area (acres)	Percent (%)
Cover		
Instream Cover	57.8	58.1
No Cover	24.5	24.7
Overhead Vegetation	17.1	17.2
Total	99.4	100.0
Substrate		
Boulder, Bedrock, or Woody Debris	61.6	61.9
Cobble	15.0	15.1
Silt or Sand	8.0	8.1
Gravel	4.3	4.3
Small Boulder	3.8	3.8
Mud or Flat Bedrock	3.8	3.8
Sand	2.6	2.7
Boulder	0.4	0.4
Total	99.4	100.0
Mesohabitat		
Run	31.1	31.2
Shoal	20.6	20.7

Habitat Characteristic	Area (acres)	Percent (%)
Riffle	20.2	20.4
Upland	14.5	14.6
Pool	12.6	12.7
Glide	0.4	0.4
Backwater	0.0	0.0
Total	99.4	100.0

Figure 6-3. Buck Bypass Reach with Flow Arrows (upper photo = Upper transect, bottom photo = Lower and Middle transects)

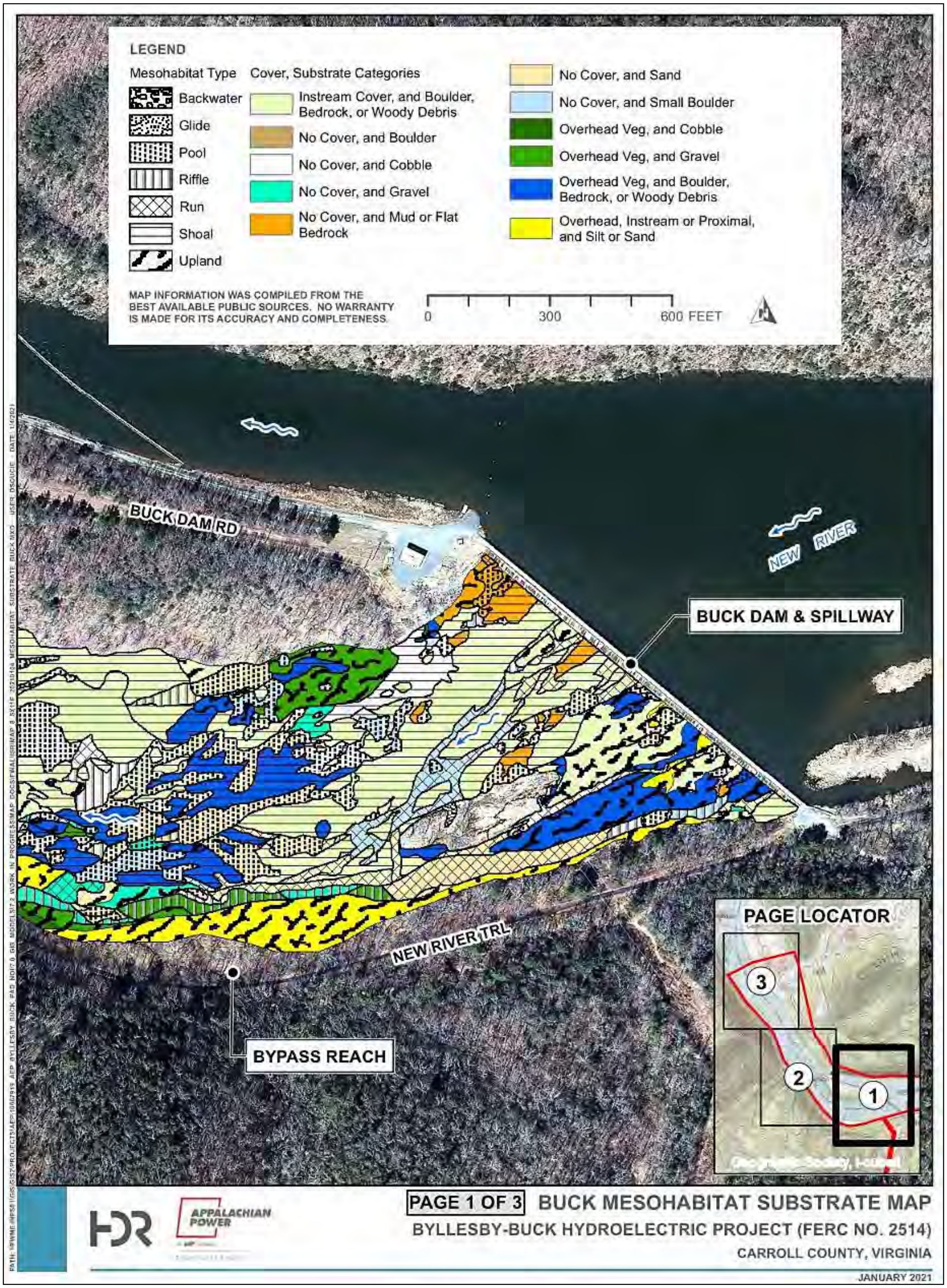


Figure 6-4. Desktop Habitat Delineation of the Upper Buck Bypass Reach

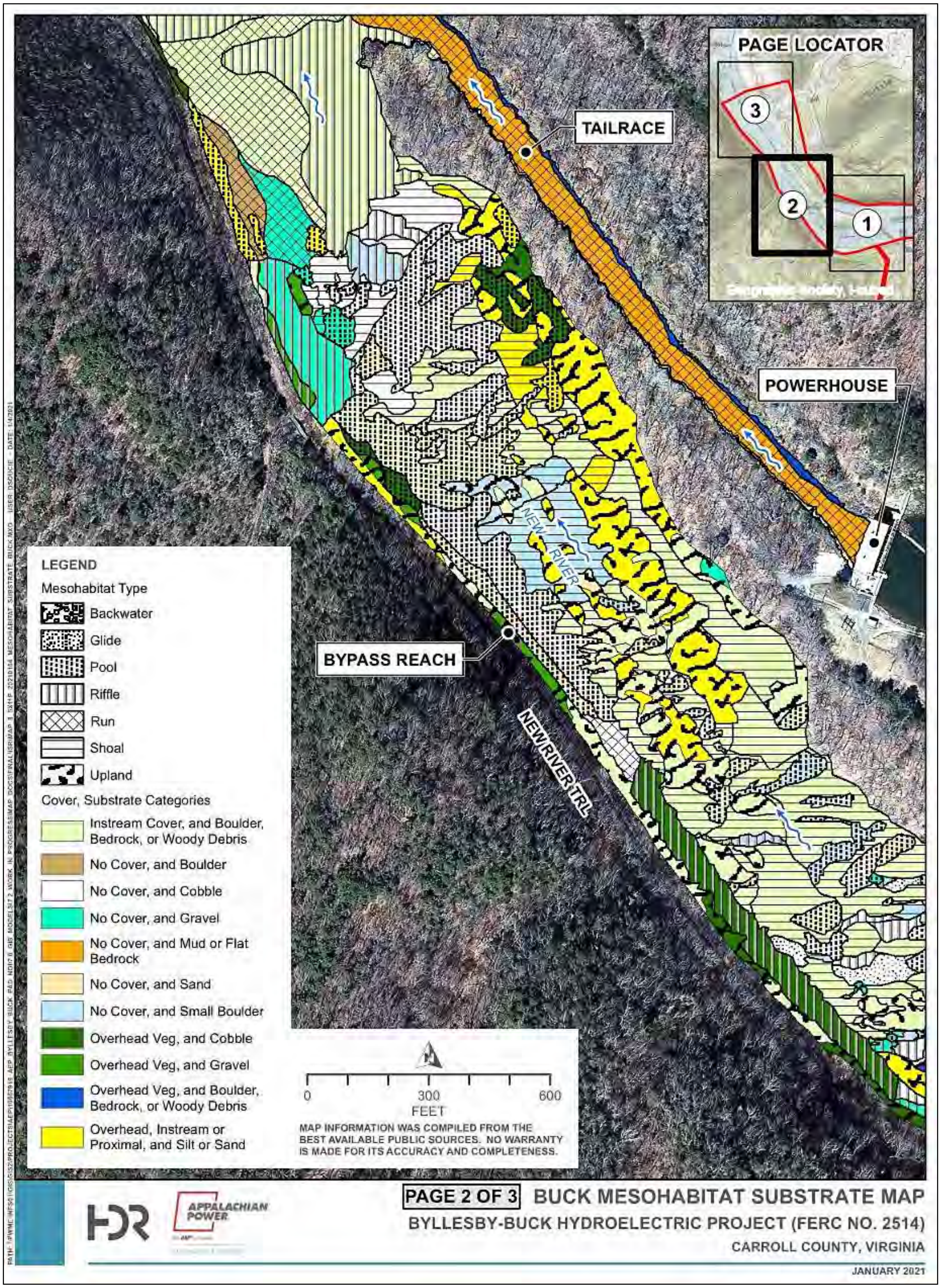


Figure 6-5. Desktop Habitat Delineation of the Middle Buck Bypass and Powerhouse Tailrace

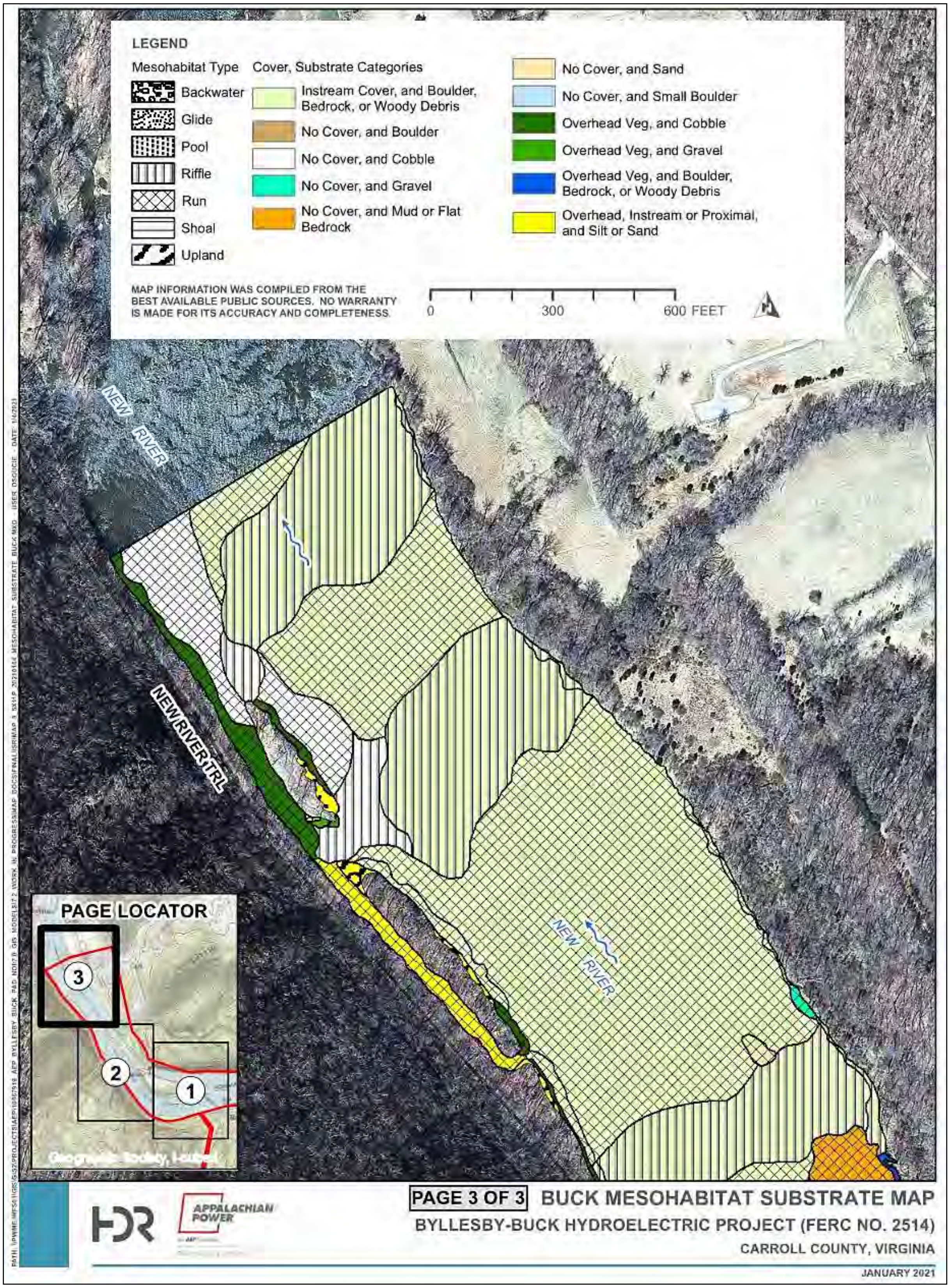


Figure 6-6. Desktop Habitat Delineation of the Lower Buck Reach (Downstream of Bypass Reach and Powerhouse Tailrace)

6.4 Field Data Collection Results

6.4.1 Byllesby Flow and Water Level Assessment Results

Four calibration flow releases (listed in Table 5-2) were performed over three days and two separate trips, July 28, 2021 and September 8–9, 2021. Each calibration flow was designed to capture a specific/stable flow in the bypass reach. Flow was delivered to the bypass reach via leakage through the closed spillway gates, flashboard bays, and/or Tainter Gate 6. Total flows in the bypass reach were recorded using an acoustic Doppler current profiler at a transect location near the downstream end of the bypass reach. Gate settings and resulting flows are provided in Table 6-3. Additional details on the calibration flow measurements (including location in the bypass reach) is provided in Attachment 1. The Proposed Flow Test Scenarios technical memo was emailed by Appalachian to key agency stakeholders on August 18, 2020. On August 25, 2020, VDWR requested a conference call with Appalachian and key agency stakeholders, which was held on August 28, 2020. The Proposed Flow Test Scenarios technical memo, the Bypass Flow Test Scenario meeting notes, and emails with agency concurrence are included in Attachment 5 (Germane Correspondence).

Table 6-3. Byllesby Tainter Gate 6 Settings and Measured Bypass Reach Flow

Tainter Gate 6 Opening (ft)	Bypass Reach Flow (cfs)
Day 1: Closed (Leakage Flow)	11
Day 2: Broken Flashboards (Low Flow)	88
Day 3: 0.5 (Mid Flow)	158
Day 4: 1.0 (High Flow)	194

To aid calibration and validation of the ICM 2-D model in the Byllesby bypass reach study area, water surface elevations were collected during the calibration flow releases described in Section 5.4.1 using Onset U-20 level loggers set to record data at 5-minute intervals. This data was also used to determine flow travel times during the calibration flow releases to determine the amount of time required for each calibration flow to stabilize within the study area and the amount of time it took for the calibration flow to recede once Tainter Gate 6 was closed. Locations of the deployed level loggers are shown in Figure 6-7 for the Byllesby bypass reach.

Level logger data during the bypass flow field data collection period (July 26 – September 13, 2021) is shown on Figure 6-8 for the bypass reach and main channel immediately downstream from the bypass reach and on Figure 6-9 for the tailrace, cross-over channel between the tailrace and main channel, and side channel. Summary results/observations pertinent to the Bypass Reach Flow and Aquatic Habitat Study include:

- Depths increased in the bypass reach approximately 0.8 ft from Leakage Flow to Low Flow range (11 cfs to 88 cfs), approximately 0.2 ft from Low Flow to Mid Flow (88 cfs to 158 cfs), and approximately 0.5 ft from Mid Flow to High Flow (158 cfs to 194 cfs). The overall depth increase was approximately 1.5 ft from Leakage Flow to High Flow (11 cfs to 194 cfs).

- Depth increases in the main channel immediately downstream from the bypass reach were much lower than the bypass reach increasing a maximum of only 0.25 ft between Leakage Flow and High Flow.

- Bypass flow releases did not influence water surface elevations in the tailrace, cross-over channel, or side channel areas. These areas are influenced by powerhouse flow releases and not bypass flow releases.
- Because the Byllesby bypass reach is relatively short (i.e., 590 ft long), travel times of flow releases from Tainter Gate 6 to the downstream end of the bypass reach are also relatively short. For example, the Mid Flow and High Flow releases reached the downstream end of the bypass reach in 6 minutes and 2 minutes, respectively.

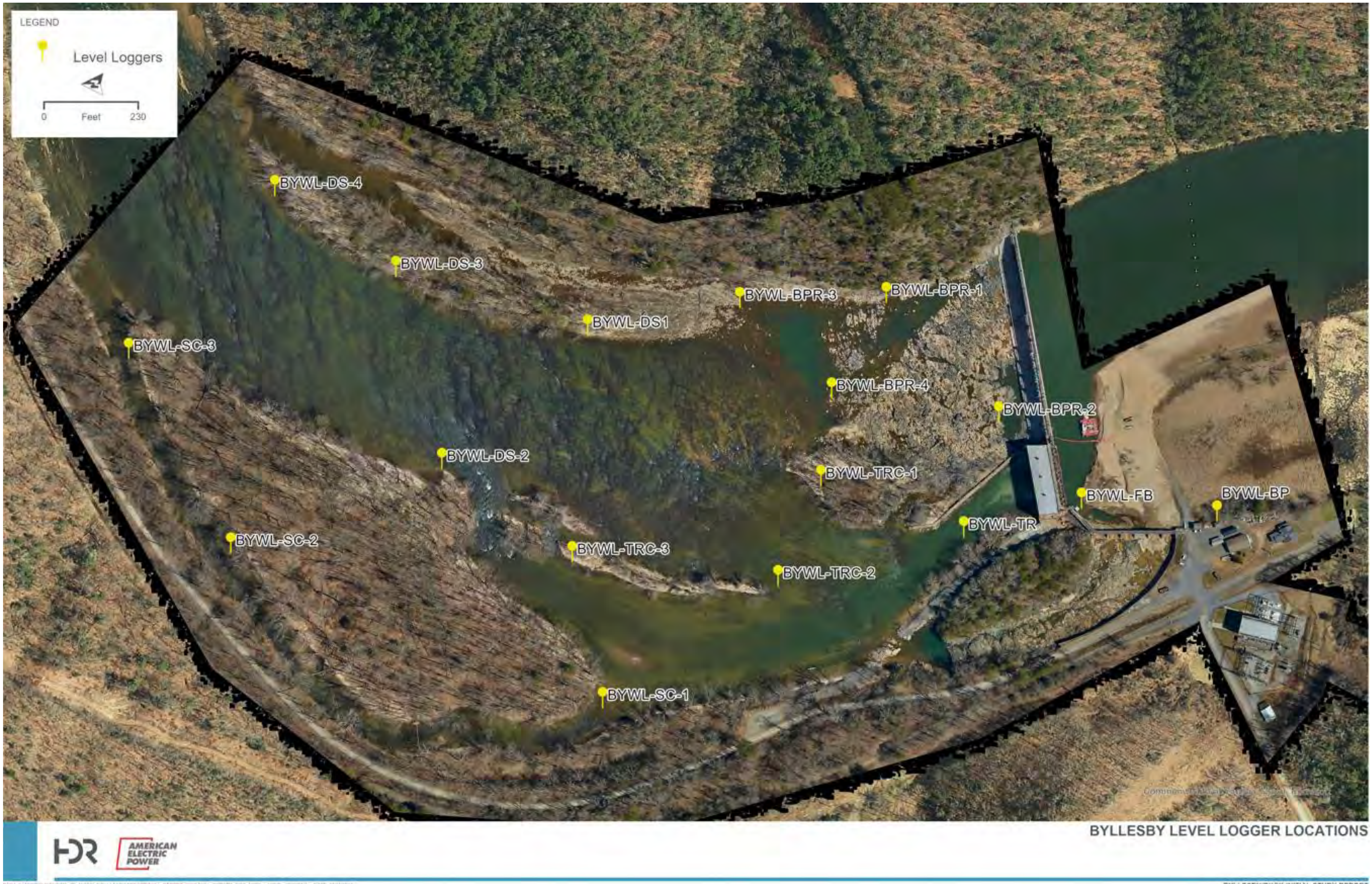


Figure 6-7. Byllesby Study Area Level Logger Locations

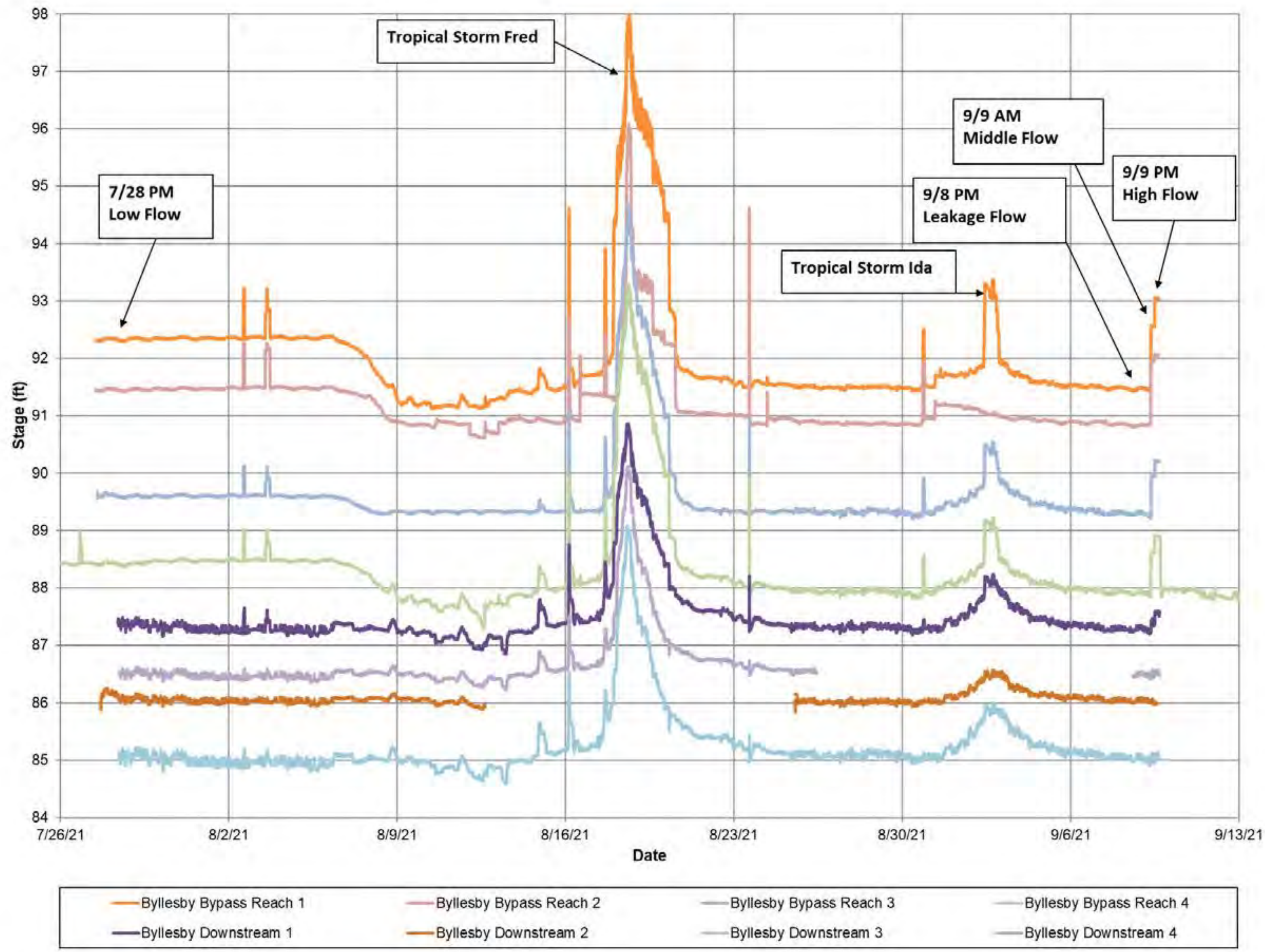


Figure 6-8. Byllesby Bypass Reach and Downstream Main Channel Level Logger Data during Study Period

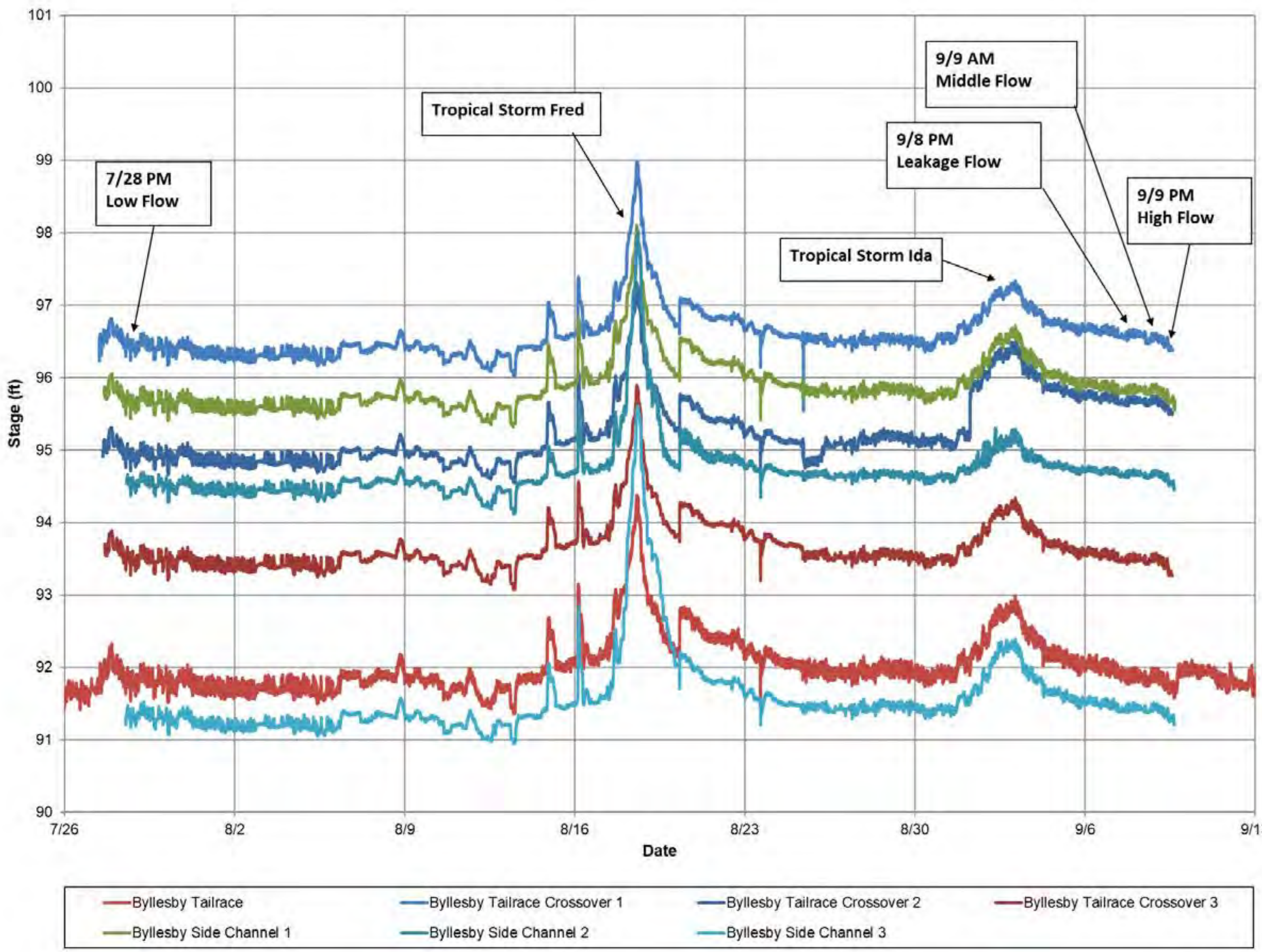


Figure 6-9. Byllesby Tailrace, Cross-over Channel, and Side Channel Level Logger Data during Study Period

6.4.2 Buck Flow and Water Level Assessment Results

Four calibration flow releases were performed over four days and two separate trips, September 8–10, 2020 and September 15–17, 2020. Each calibration flow was designed to capture a specific/stable flow in the bypass reach. Flow was delivered to the bypass reach via leakage through the closed spillway gates and flashboard bays and/or Tainter Gate 1. Total flows in the bypass reach were recorded using a handheld manual Swoffer® flow meter for the Day 1 (leakage) and Day 2 (0.5 ft gate opening) calibration flows and using an acoustic Doppler current profiler for the Day 3 and Day 4 (1 ft and 2 ft gate opening, respectively) calibration flows. Gate settings and resulting flows are provided in Table 6-4. Additional details on the calibration flow measurements (including location in the bypass reach) is provided in Attachment 1. The Proposed Flow Test Scenarios technical memo was emailed by Appalachian to key agency stakeholders on August 18, 2020. On August 25, 2020, VDWR requested a conference call with Appalachian and key agency stakeholders, which was held on August 28, 2020. The Proposed Flow Test Scenarios technical memo, the Bypass Flow Test Scenario meeting notes, and emails with agency concurrence are included in Attachment 5 (Germane Correspondence).

Table 6-4. Buck Tainter Gate 1 Settings and Measured Bypass Reach Flow

Tainter Gate 1 Opening (ft)	Bypass Reach Flow (cfs)
Day 1: Closed (Leakage Flow)	17
Day 2: 0.5 (Low Flow)	211
Day 3: 1.0 (Mid Flow)	354
Day 4: 2.0 (High Flow)	714

To aid calibration and validation of the ICM 2-D model in the Buck bypass reach, water surface elevations were collected during the calibration flow releases described in Section 5.4.1 using Onset U-20 level loggers set to record data at 5-minute intervals. This data was also used to determine flow travel times during the calibration flow releases to determine the amount of time required for each calibration flow to stabilize within the study area and the amount of time it took for the calibration flow to recede once Tainter Gate 1 was closed. Locations of the deployed level loggers are shown on Figure 6-10 for the Buck bypass reach.

Level logger data during the two-week calibration flow field data collection period is shown on Figure 6-11 and the full period of level logger deployment (i.e., August 20 – October 6, 2020) is shown on Figure 6-12. Summary results/observations pertinent to the Bypass Reach Flow and Aquatic Habitat Study include:

- From the Leakage Flow to Low Flow range (17 cfs to 211 cfs), depths increased approximately 1.0 to 1.5 ft along the main flow path (i.e., center of upper reach and along the left descending bank in the lower portion of the reach). As the calibration flows increased to the Mid (354 cfs) to High (714 cfs) flow range, corresponding depths along the main flow path were approximately 2.5 ft deeper than at leakage flow.

- Calibration flow releases up to the High Flow range (714 cfs) did not influence water depth along the upper portions of the left descending side channel (BK_LL2; Figure 6-10); and resu lted in a small depth increase (< 0.5 ft) relative to leakage flows at BK_LL4 (Figure 6-10) (which is just outside the main flow path).

- Depths along the left descending side channel were only impacted during rainfall runoff events that resulted in bypass reach flow releases that were much higher (i.e., at least 5,000 cfs) than the calibration flow scenarios (several flow events in this range are shown on Figure 6-12.

- Water depths at the downstream study area boundary were not influenced by the calibration flow releases as this location is downstream of the confluence of the tailrace and bypass reach. However, depths at this location are influenced by the overall magnitude of Project inflows. For example, as flows increased from approximately 2,000 cfs to 8,000 cfs, this resulted in a depth increase of approximately 2 ft at this location. As flows increased from approximately 2,500 cfs to 5,000 cfs resulted in a depth increase of approximately 0.75 ft (see Figure 6-12, location Buck Downstream).

- Water surface elevations in the lower portion of the bypass reach (i.e., near BK_LL10 and BK_LL11; Figure 6-10) are not influenced by flow releases from the spillway as the backwater effect from the New River extends upstream into this area.

- Flow travel time from the uppermost level logger (BK_LL1) to the most downstream level logger not influenced by the New River backwater effect (BK_LL8) (Figure 6-10) ranged from approximately 1 hour (Low Flow release) to approximately 15 minutes (High Flow release). Time for flow stabilization at each location typically took less than 15 minutes once the flow arrived.

- Calibration flow releases were stable during the entire data collection period each day as evidenced by a steady water surface elevation for at least 8–10 hours each day.

- Once the calibration flow release stopped each day, water surface elevations in the Buck bypass reach dropped almost immediately and returned to leakage levels within approximately 2 hours.

- The existing ramping rate effect on bypass reach water surface elevations is clearly shown at the end of the Day 4 (High Flow) calibration flow release as the Tainter Gate 1 2-ft opening paused at a 1-ft opening for 3 hours before closing (Figure 6-11). This allowed water surface elevations in the bypass reach main flow path to decrease approximately 0.5 ft before the gate was closed completely.

- Tainter gate operations are evident during a rainfall runoff event that occurred between the two calibration flow measurement weeks (see September 13 – 15, 2020 on Figure 6-11).

Figure 6-10. Buck Bypass Reach Level Logger Locations

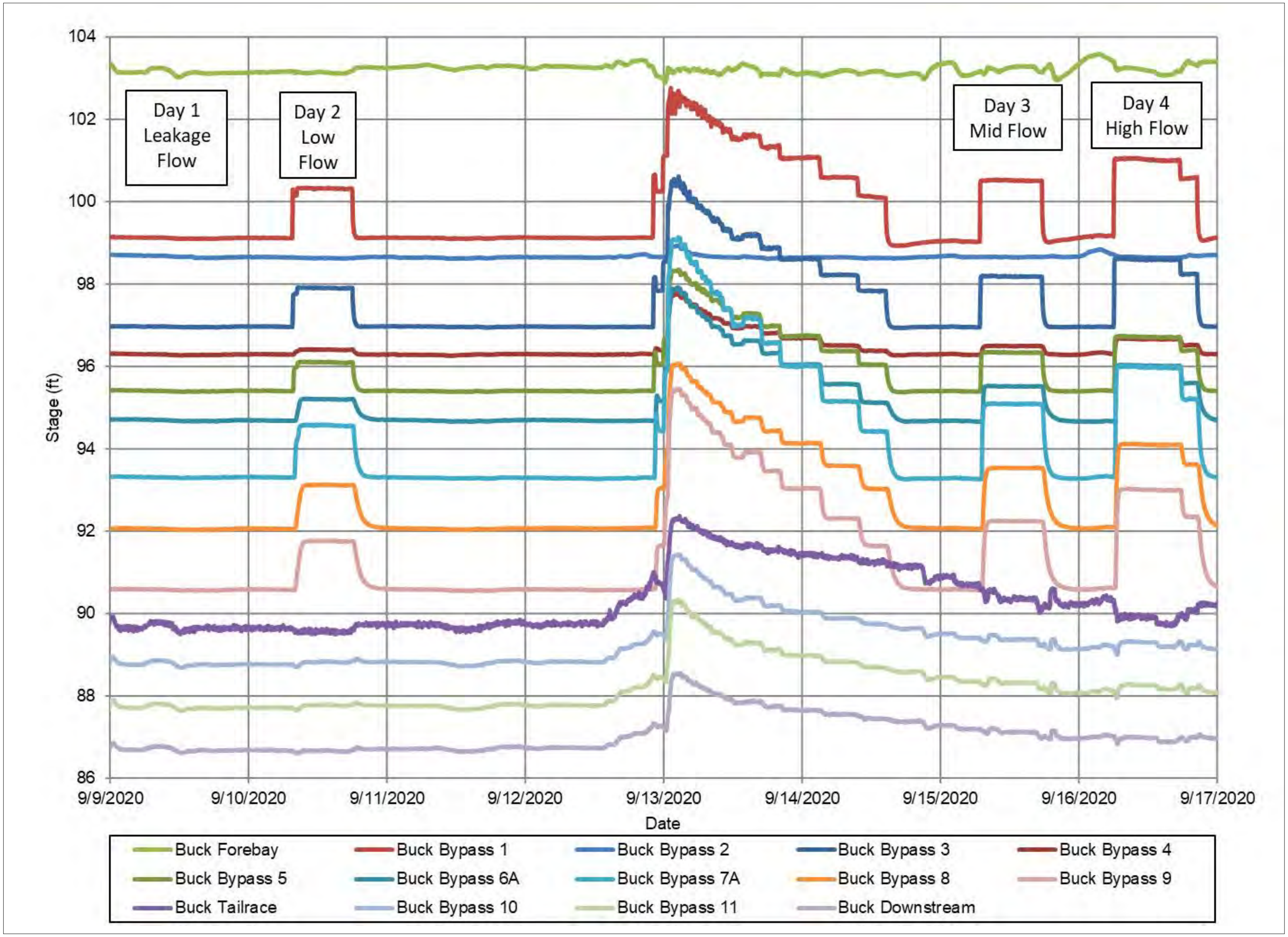


Figure 6-11. Buck Bypass Reach Level Logger Data during Calibration Flow Measurements

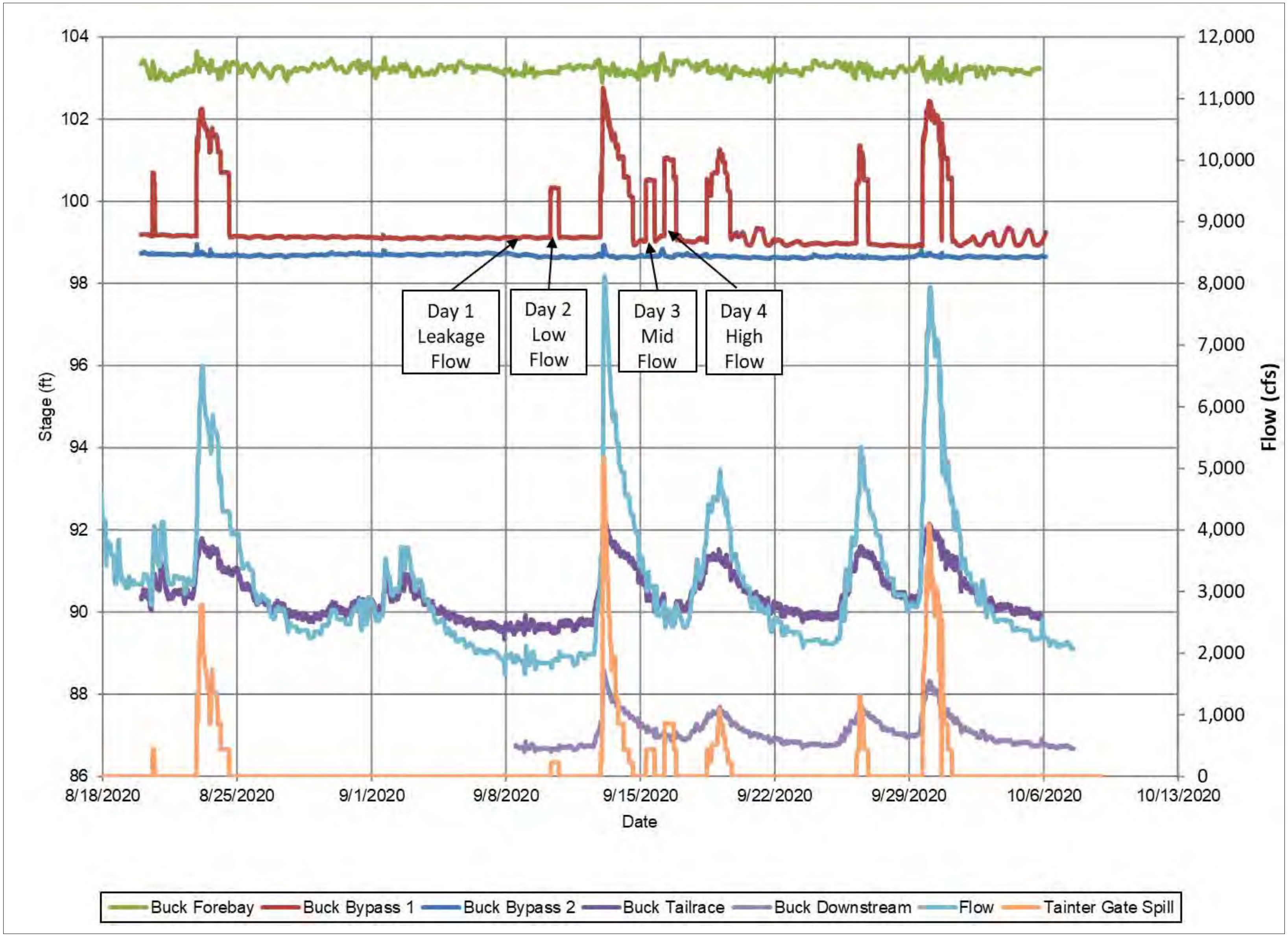


Figure 6-12. Buck Bypass Reach Level Logger Data during Study Period

6.4.3 Particle Size Distribution Results

6.4.3.1 Byllesby Bypass Reach

The locations of the three Wolman pebble count transects at the Byllesby bypass flow study area are shown on Figure 6-13. The transects were located at the bypass reach, the cross-over channel between the tailrace and main channel, and the upper end of the side channel to evaluate differences in substrate particle size distribution within the Study Area. Substrate particle sizes (Wentworth 1922) were plotted by size class and frequency for each transect in Figure 6-14 (bypass reach transect), Figure 6-15 (cross-over channel transect), and Figure 6-16 (side channel transect).

The bypass reach was dominated by bedrock, which covers approximately 66 percent of the width. Gravel (2-64 mm) was the second most abundant discrete size class along the upper transect (approximately 16 percent of the total), and particle sizes between 16.1 mm and 362 mm (i.e., coarse gravel to small boulders) were fairly evenly distributed, comprising the remaining 28.5 percent of the transect. There was a notable absence of sand and particle sizes ranging from 2.0 mm to 16 mm (clay/silt/sand/medium gravel), as those substrate sizes are likely swept downstream during high-flow events (or become wedged between the dominant angular bedrock slabs).

Gravel was the dominant substrate for both the cross-over and side channels, comprising 69.5 percent and 55 percent of the transects, respectively. Cobble was the second-most abundant particle size in these channels as well, comprising 14.5 to 31.5 percent of the reach. Distribution of particle sizes between 11.3 mm and 180 mm (i.e., medium gravel to medium boulders) was similar between the cross-over and side channel transects, with particles between 22.6 and 32 mm being the most abundant (coarse to very coarse gravel).

As described in Section 6.3.1, the dominant instream cover type in the Byllesby bypass reach is bedrock, boulder, and woody debris. However, both the cross-over and side channel had very little bedrock and an increased abundance of sand and fine gravel within each transect compared to the bypass reach. As powerhouse flows travel downstream from the tailrace, the channel widens significantly which results in slower velocities in cross-over channel and side channel (compared to much higher scouring velocities in the bypass reach during large rainfall runoff events), reducing sediment transport.

Figure 6-13. Byllesby Study Area Pebble Count Transect Locations

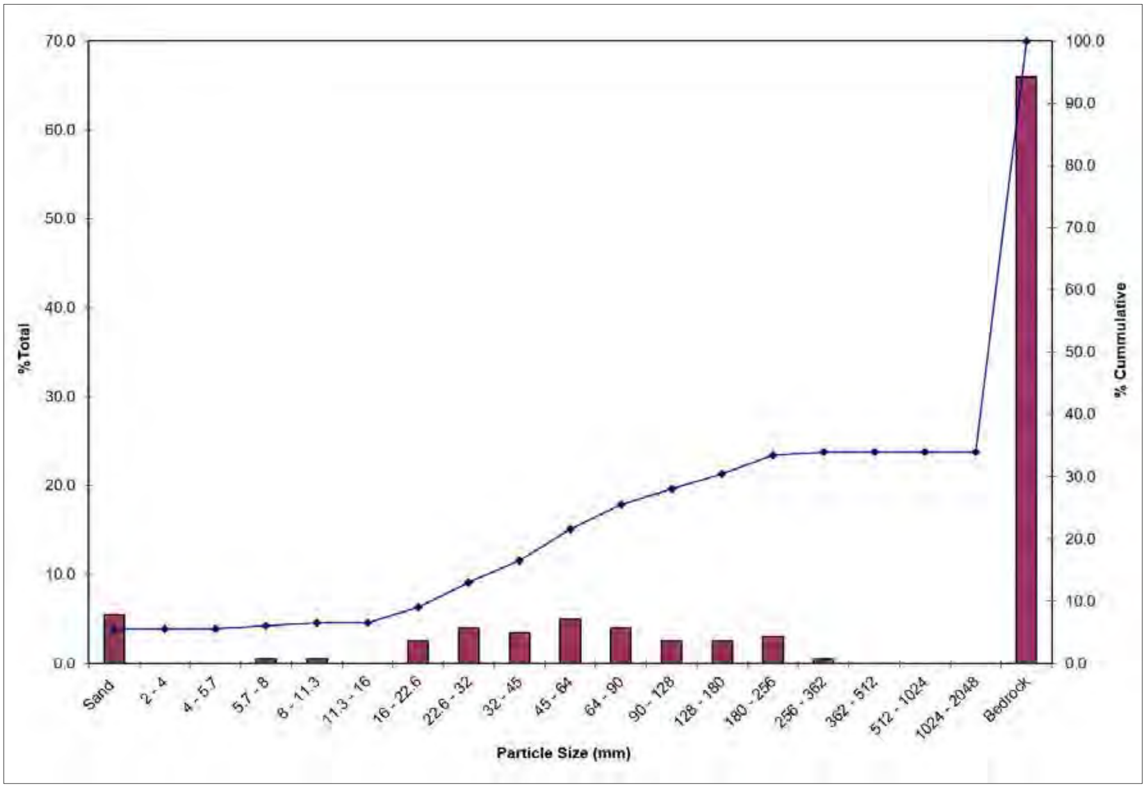


Figure 6-14. Pebble Count Particle Size Data at Byllesby Bypass Reach Transect

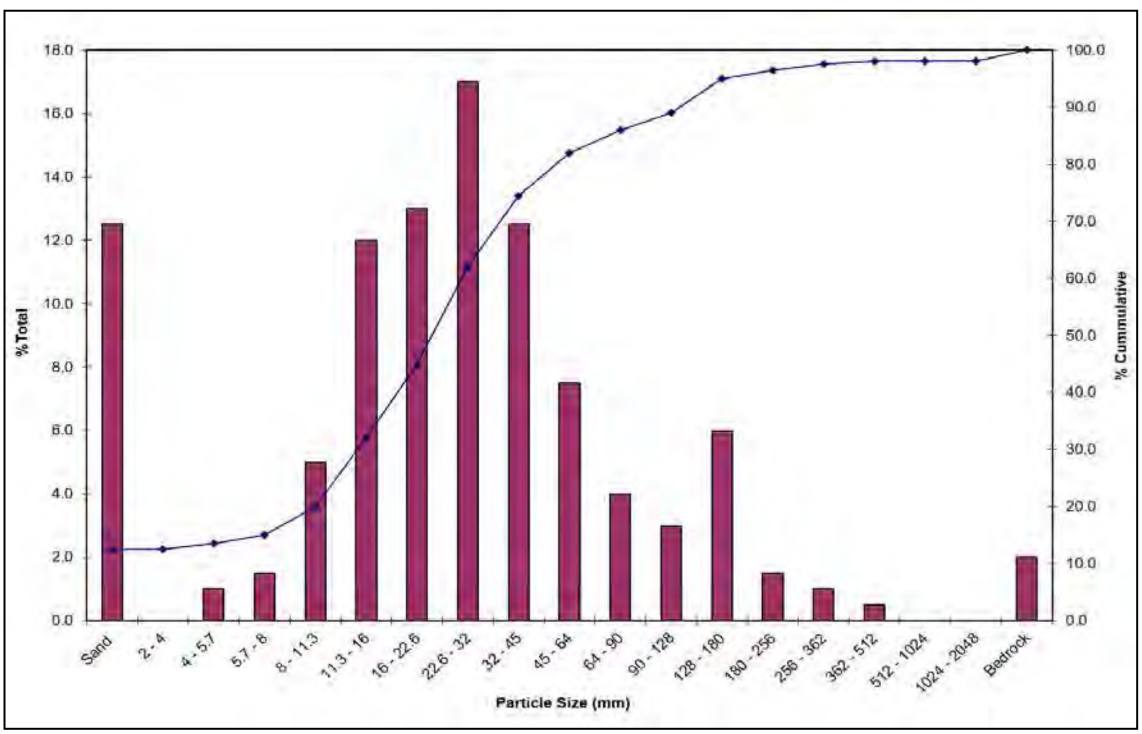


Figure 6-15. Pebble Count Particle Size Data at Byllesby Cross-over Channel Transect

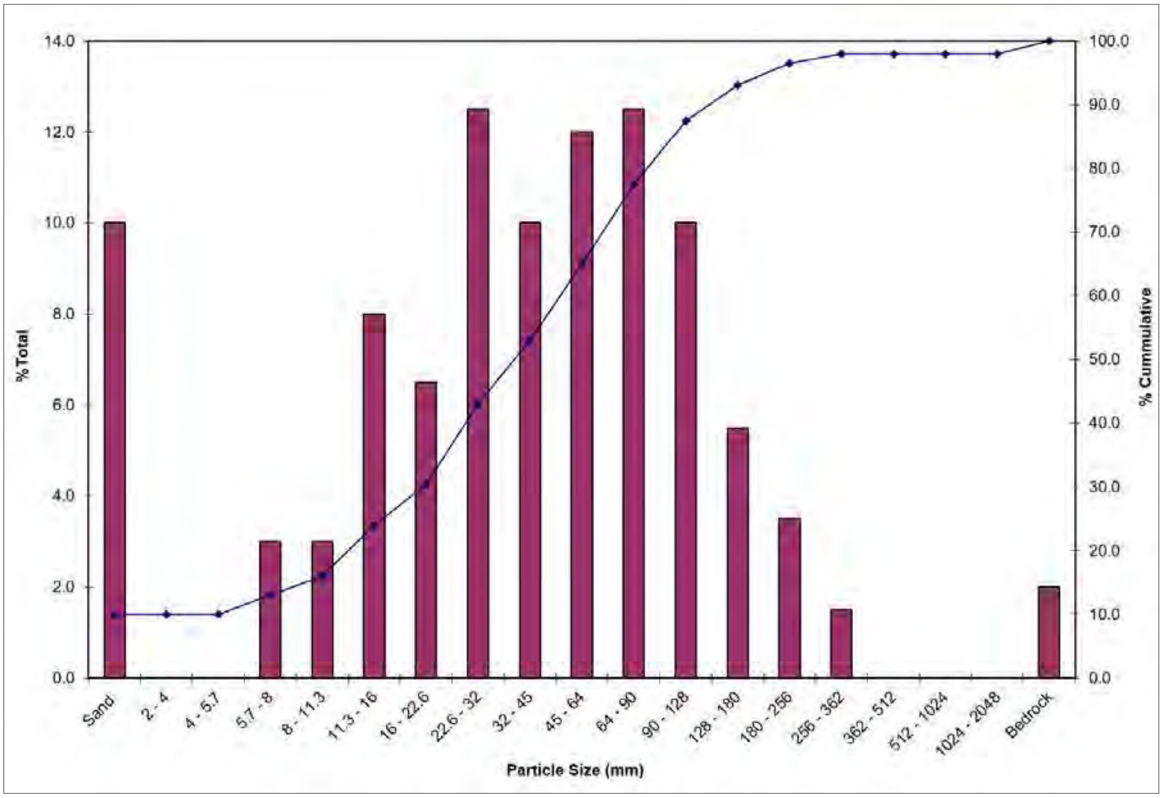


Figure 6-16. Pebble Count Particle Size Data at Byllesby Side Channel Transect

6.4.3.2 Buck Bypass Reach

The locations of the three Wolman pebble count transects are shown on Figure 6-17. The transects were located in the upper, middle, and lower portions of the bypass reach to evaluate differences in substrate particle size distribution along the bypass reach. Substrate particle sizes are plotted by size class and frequency for each transect in Figure 6-18 (upper transect), Figure 6-19 (middle transect), and Figure 6-20. (lower transect).

The upper transect is dominated by bedrock, which covers approximately 50 percent of the width. Sand (<2 mm) is the second most abundant discrete size class along the upper transect (approximately 8 percent of the total) and particle sizes between 11.3 mm and 1,024 mm (i.e., medium gravel to medium boulders) are fairly evenly distributed, comprising the remaining 42 percent of the transect. There is a notable absence of particle sizes in the 0.5-mm to 11.3-mm range (clay/silt/sand/medium gravel) as those substrate sizes are likely scoured out during frequent high flow events. Most sediment of smaller particle size classes was wedged between the dominant angular bedrock slabs.

Bedrock was also the dominant substrate for the middle and lower reaches but comprised only 21 – 26 percent of the reach (compared to double that for the upper transect). Distribution of particle sizes between 11.3-mm and 1,024-mm was similar between the middle and lower transects. Similar to the upper transect, the overall substrate lacked particle sizes between 0.5-mm and 11.3-mm, which is likely due to scouring during high flow events; however, sand deposits (some large in surface area) were identified in velocity shelters downstream of bedrock slabs in the lower half of the bypass reach.

As described in Section 6.3.2, one of the major differences between the upper and middle-to-lower portions of the Buck bypass reach is the orientation of the angled bedrock. In the upper portion of the bypass reach, the bedrock is oriented parallel to flow resulting in scour of smaller substrate sizes, whereas in the middle-to-lower portion of the bypass reach, the bedrock is angled perpendicular to flow, resulting in sediment deposition on the downstream side of the bedrock slabs.

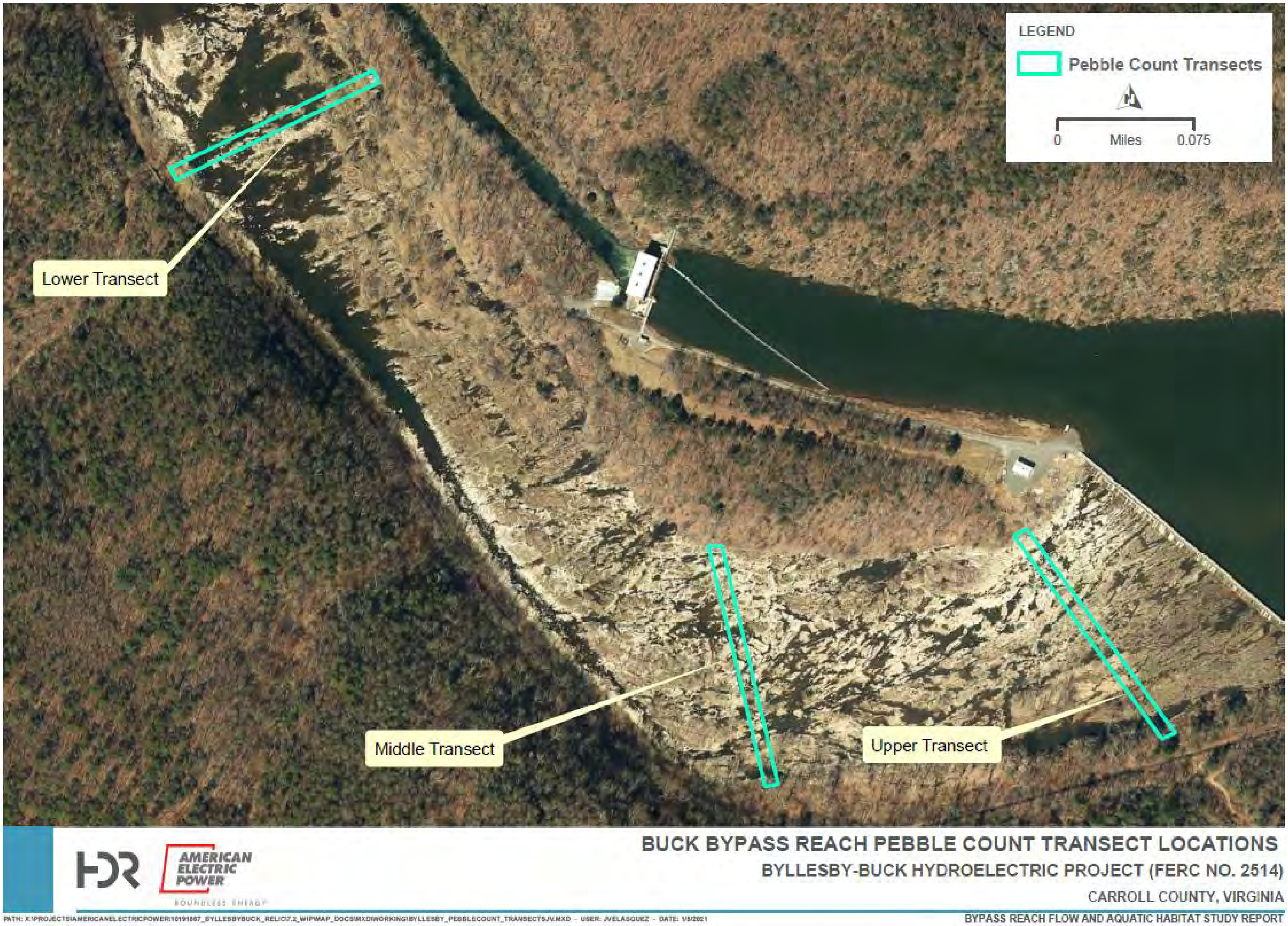


Figure 6-17. Buck Bypass Reach Pebble Count Transect Locations

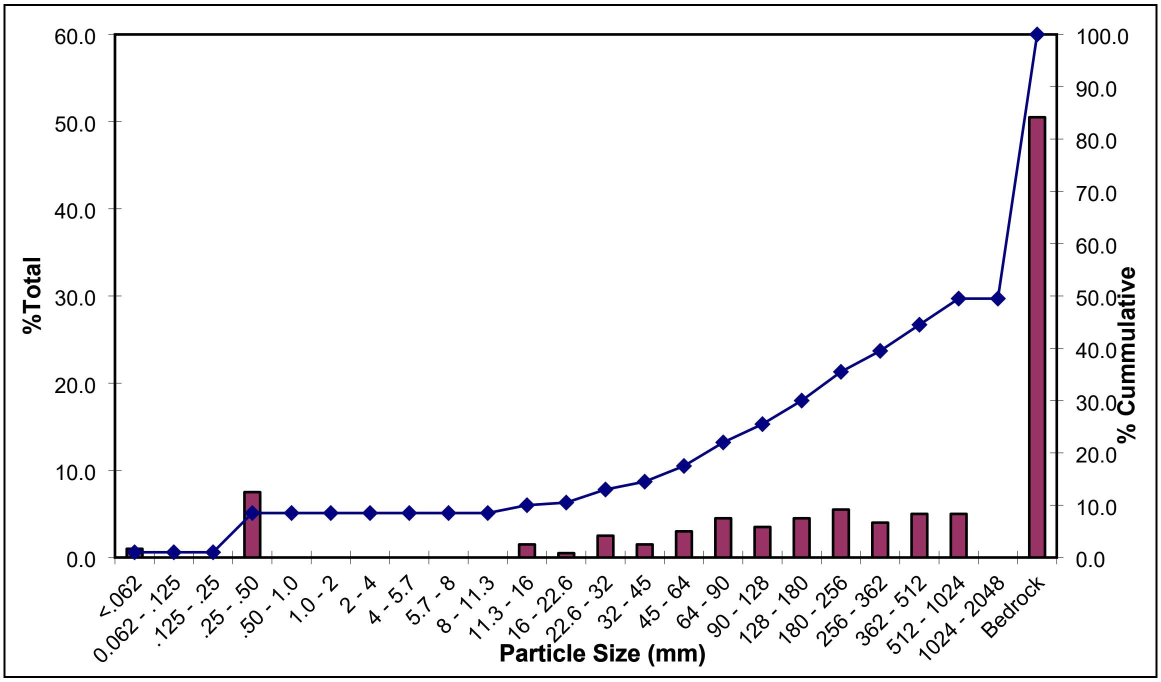


Figure 6-18. Pebble Count Particle Size Data at Upper Transect

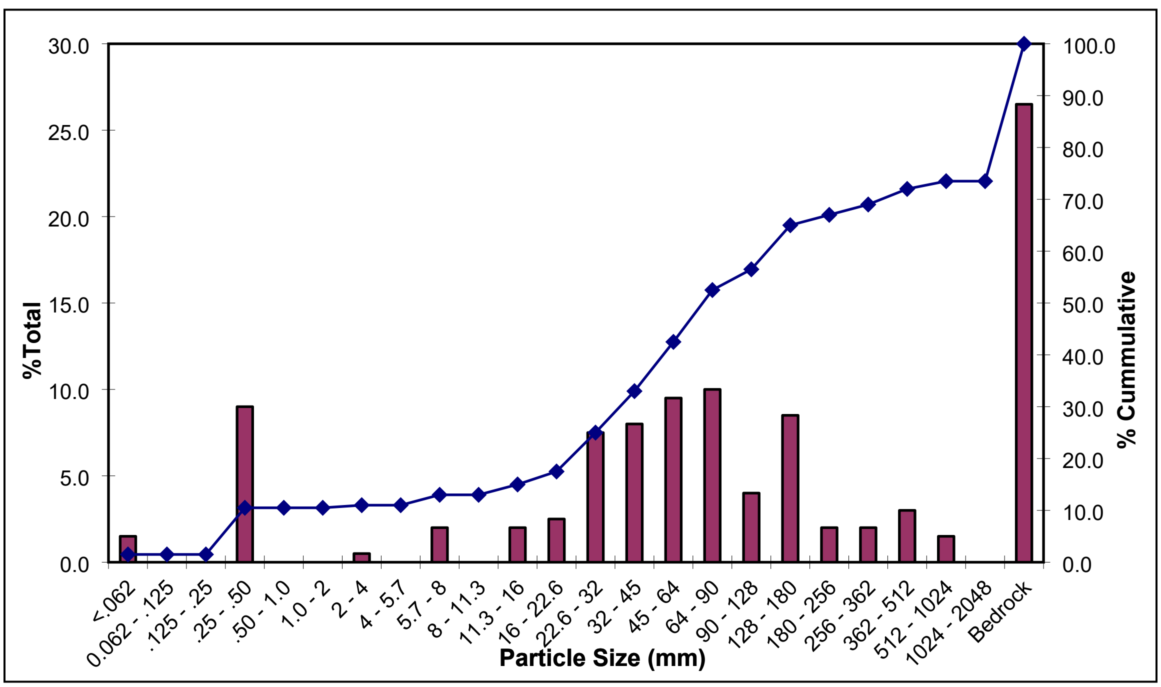


Figure 6-19. Pebble Count Particle Size Data at Middle Transect

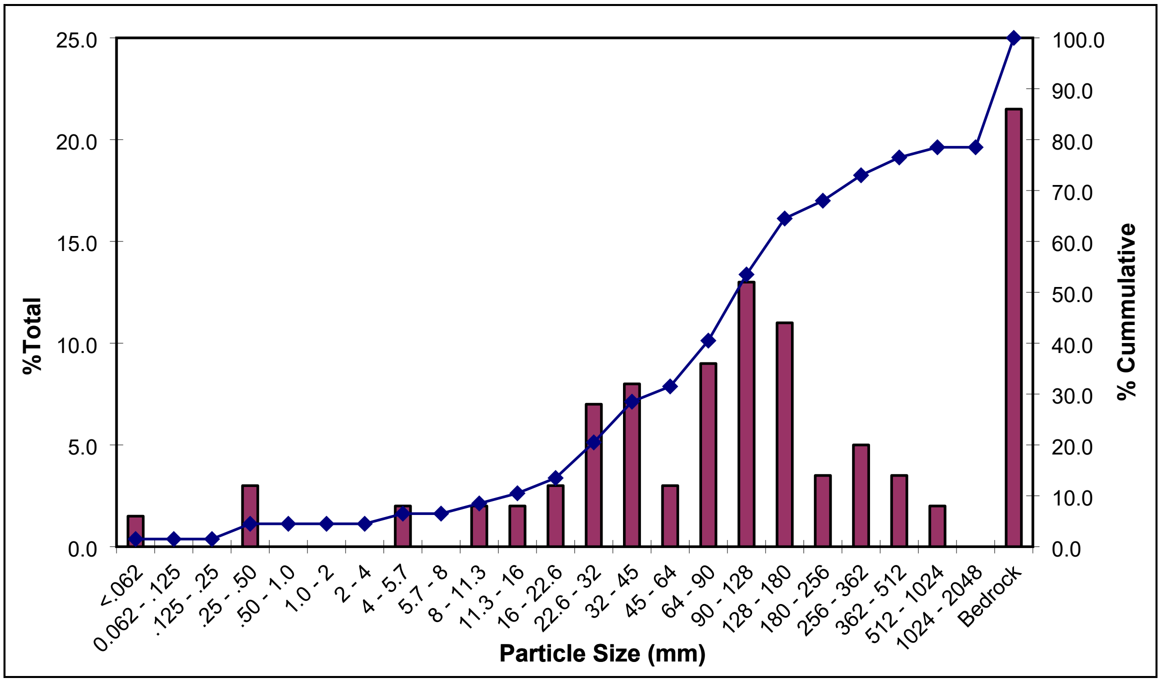


Figure 6-20. Pebble Count Particle Size Data at Lower Transect

6.5 Hydraulic Modeling

6.5.1 Hydraulic Model Calibration Flows

Results of the modeling effort for the Byllesby bypass study area are included in Attachment 1 (Byllesby Bypass Reach ICM Model Development); this report presents the final 2-D Byllesby Bypass Reach model developed using the ICM software, which was used to predict hydraulic regimes in the bypass reach study area under four different bypass flow scenarios.

Results of the modeling effort for the Buck bypass are included in Attachment 1 (Buck Bypass Reach ICM Model Development); this report presents the final 2-D Buck Bypass Reach model developed using the ICM software, which was used to predict hydraulic regimes in the bypass reach under varying flows and from varying spill locations.

To help interpret the aquatic habitat evaluation results (presented in Section 6.6), depth and velocity heat maps are provided in the Byllesby and Buck ICM reports (Attachment 1) for each of the model calibration flows. These depth and velocity heat maps, along with the substrate and cover information provided in the habitat delineation maps (Section 6.3) form the basis of the habitat modeling results. Coupled with the habitat suitability criteria for each species and life stage (provided in Attachment 2), each of these building blocks (i.e., depth, velocity, substrate, and cover) can be used to determine their respective influence on the overall habitat modeling results.

6.5.2 Habitat Model Flows

To evaluate the effect of bypass flow releases on the availability of suitable aquatic habit, multiple flow simulations were run for each bypass reach study area. For each flow simulation, the total river flow was held constant (i.e, as bypass flows increased, there was a corresponding decrease in powerhouse flows) which allows for a direct comparison of incremental differences in available habitat between model simulations.

Table 6-5 provides a matrix of habitat model flow simulations for the Byllesby study area. As a sensitivity analysis, and to gain some perspective on potential seasonal bypass flow releases, annual average exceedance flows[6] of 90 percent, 50 percent, and 10 percent were simulated at Byllesby representing relatively dry, normal, and wet years, respectively.

Table 6-6 provides a matrix of habitat model flow simulations for the Buck study area. Similar to Byllesby, annual average exceedance flows of 90 percent, 45 percent[7], and 10 percent were also simulated to provide a habitat sensitivity analysis and gain some perspective on potential seasonal bypass flow releases.

The annual average exceedance flows were determined by the hydrologic POR (1996-2020) at USGS Gage 03165500 New River at Ivanhoe, VA.

Table 6-5. Byllesby Study Area Habitat Modeling Flow Matrix

Annual Average Exceedance Flows		
10% Exceedance		
Total River Flow (cfs)	Powerhouse Flow (cfs)	Bypass Flow Release (cfs)
3,900	3,889	11
3,900	3,865	35
3,900	3,840	60
3,900	3,812	88
3,900	3,742	158
3,900	3,706	194
3,900	3,540	360
50% Exceedance		
Total River Flow (cfs)	Powerhouse Flow (cfs)	Bypass Flow Release (cfs)
1,750	1,739	11
1,750	1,715	35
1,750	1,690	60
1,750	1,662	88
1,750	1,592	158
1,750	1,556	194

[6] An annual average exceedance flow of 90 percent means 90 percent of the time during the period of record, the flow in the river is exceeded which is indicative of a relatively dry year. The 50 percent annual exceedance flow represents a normal hydrologic year and the 10 percent annual exceedance flow is indicative of a relatively wet year as the average annual river flows are only exceeded 10 percent of the time.

[7] For the Buck Development, the 45 percent exceedance flow was used to represent a normal hydrologic year as those flow simulations were completed during the hydraulic model calibration process and it is unlikely that habitat model results at the 50 percent exceedance flow would be significantly different.

Annual Average Exceedance Flows		
1,750	1,390	360
90% Exceedance		
Total River Flow (cfs)	Powerhouse Flow (cfs)	Bypass Flow Release (cfs)
740	729	11
740	705	35
740	680	60
740	652	88
740	582	158
740	546	194
740	380	360

Table 6-6. Buck Study Area Habitat Modeling Flow Matrix

Annual Average Exceedance Flows		
10% Exceedance		
Total River Flow (cfs)	Powerhouse Flow (cfs)	Bypass Flow Release (cfs)
3,935	3,918	17
3,935	3,900	35
3,935	3,865	70
3,935	3,835	100
3,935	3,785	150
3,935	3,724	211
3,935	3,581	354
3,935	3,221	714
45% Exceedance		
Total River Flow (cfs)	Powerhouse Flow (cfs)	Bypass Flow Release (cfs)
1,910	1,893	17
1,910	1,875	35
1,910	1,840	70
1,910	1,810	100
1,910	1,760	150
1,910	1,699	211
1,910	1,556	354
1,910	1,196	714
90% Exceedance		
Total River Flow (cfs)	Powerhouse Flow (cfs)	Bypass Flow Release (cfs)

Annual Average Exceedance Flows		
745	728	17
745	710	35
745	675	70
745	645	100
745	595	150
745	534	211
745	391	354
745	31	714

6.5.3 Bypass Flow Release Point Comparison

To evaluate potential differences in available habitat related to releasing flows from different locations along the Byllesby and Buck spillway structures, hydraulic model simulation results (i.e., depths and velocities) were compared for two release points at each development. For Byllesby, simulated flows were released from the trash sluice gate and from Obermeyer Gate 12 (Gate 12) which is near the right descending bank and aligns with the main flow channel (thalweg) in the bypass reach. Modeled depth and velocity results under three bypass flow releases (i.e., 35 cfs, 60 cfs, and 360 cfs) are provided in Figure 6-21and Figure 6-22, respectively. In Figure 6-21, green-shaded areas indicate greater depths due to a trash sluice gate flow release and purple-shaded areas indicate greater depths due to a flow release from Gate 12. In either case, maximum differences in depth were approximately 1 ft. Areas shaded in white indicate little to no difference in depth between the two flow release points. In Figure 6-22, blue-shaded areas indicate greater velocities due to a trash sluice gate flow release and red-shaded areas indicate greater velocities due to Gate 12 flow releases. Maximum differences in velocity were approximately 5 fps which quickly attenuated as flows traveled downstream and spread out. Similarly, areas shaded in white indicate little to no difference in velocity between the two flow release points. Overall, differences in depths and velocities are confined to the area immediately downstream from each flow release point and don't extend into the greater bypass reach area or the main river channel (as shown in the bottom left panel of Figure 6-21 and Figure 6-22).[8]

For Buck, simulated flows were released from Tainter Gate 1 (Gate 1) and Obermeyer Gate 10 (Gate 10). Gate 1 typically operates as the first-on/last-off gate along the Buck spillway structure. Gate 10 is near the center of the spillway structure and is the closest gate to the left descending bank and upper bypass reach side channel area. Modeled depth and velocity results under three bypass flow releases (i.e., 35 cfs, 100 cfs, and 354 cfs) are provided in Figure 6-23 and Figure 6-24, respectively. In Figure 6-23, green-shaded areas indicate greater depths due to Gate 1 flow releases and purple-s

[8] There are several small areas along the stream margins and also isolated pockets of water shown in the aerial background photo used for Figures 6-21 through 6-24 where hydraulic model results are not provided. These areas are typically very shallow and are confined by underwater bedrock shelfs where cracks in the bedrock allow water to enter and be retained but are not significantly influenced by the flow releases evaluated in this study (i.e., depths and velocities are not affected).

haded areas indicate greater depths due to Gate 10 flow releases. Similar to the Byllesby results, maximum differences in depth between the two Buck flow release points were approximately 1 ft. Areas shaded in white indicate little to no difference in depth between the two flow release points. In Figure 6-24, blue-shaded areas indicate greater velocities due to Gate 1 flow releases and red-shaded areas indicate greater velocities due to Gate 10 flow releases. Velocity deltas up to 5 fps were modeled immediately downstream from each flow release point but attenuated rapidly. Areas shaded in white indicate little to no difference in velocity between the two flow release points. Overall, differences in depths and velocities are confined to the area immediately downstream from each flow release point and diminish in the upper portion of the bypass reach (as shown in the far-right panel of Figure 6-23 and Figure 6-24).

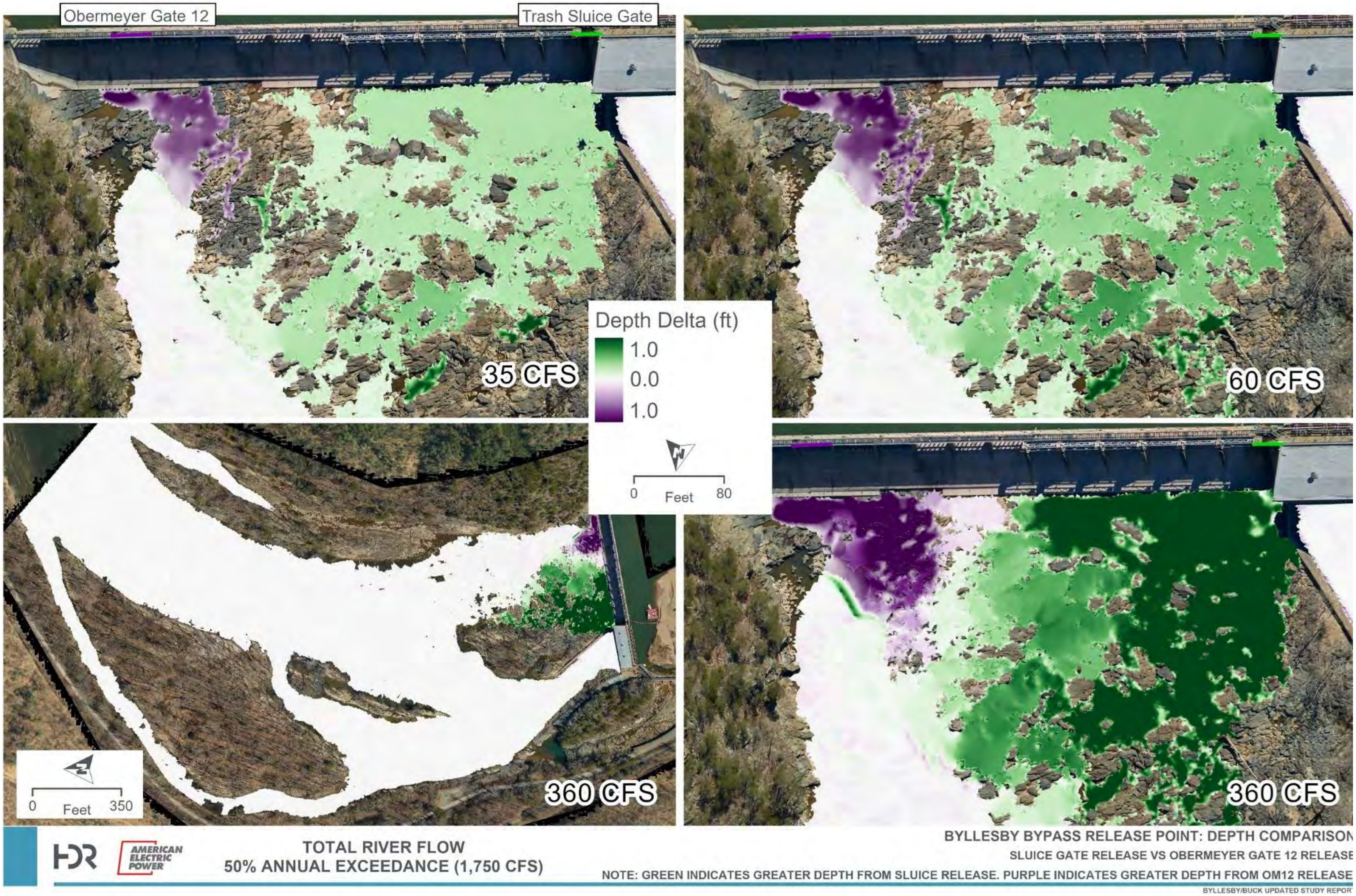


Figure 6-21. Byllesby Study Area Flow Release Location Depth Comparison

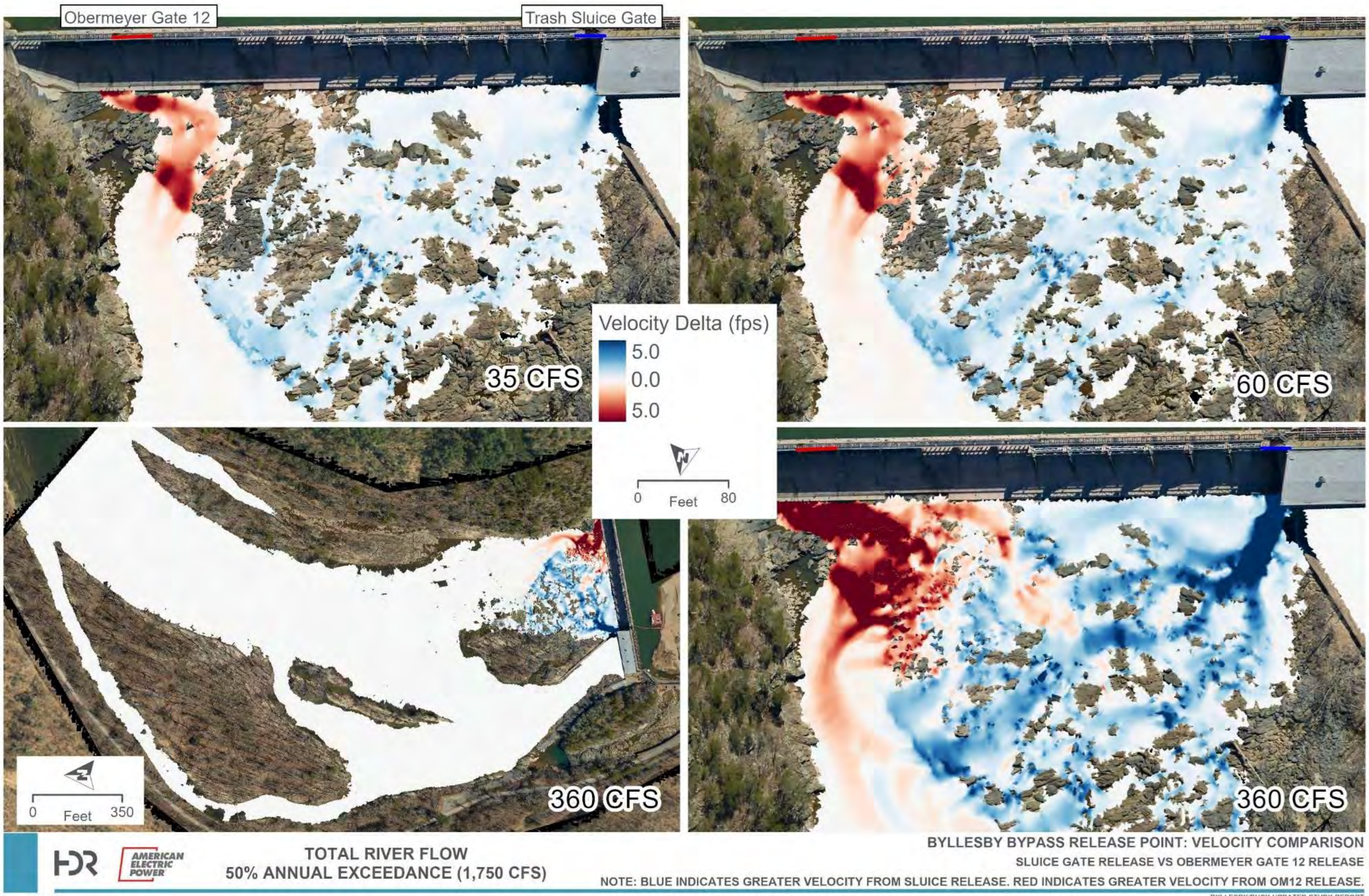


Figure 6-22. Byllesby Study Area Flow Release Location Velocity Comparison

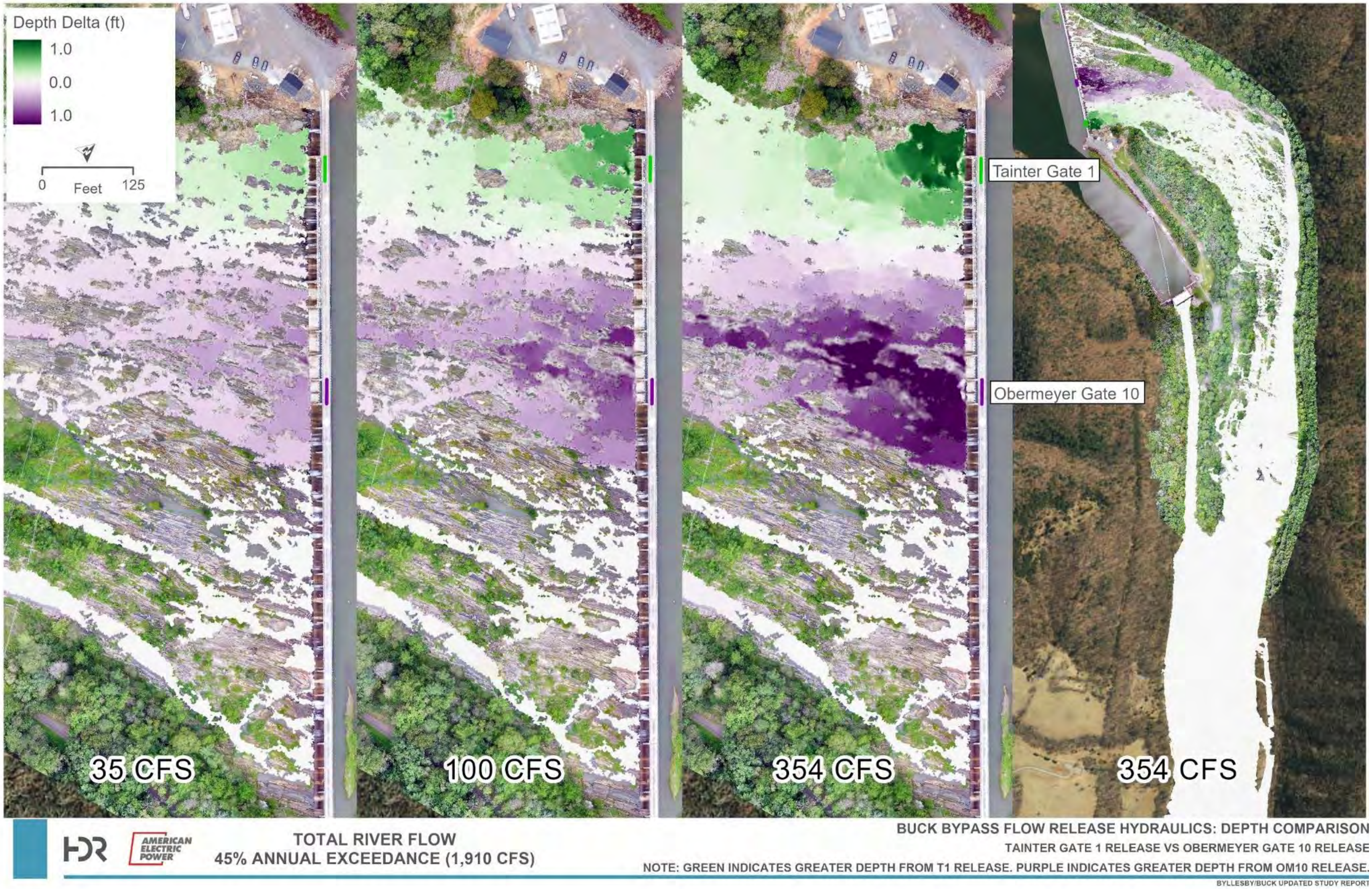


Figure 6-23. Buck Bypass Reach Flow Release Location Depth Comparison

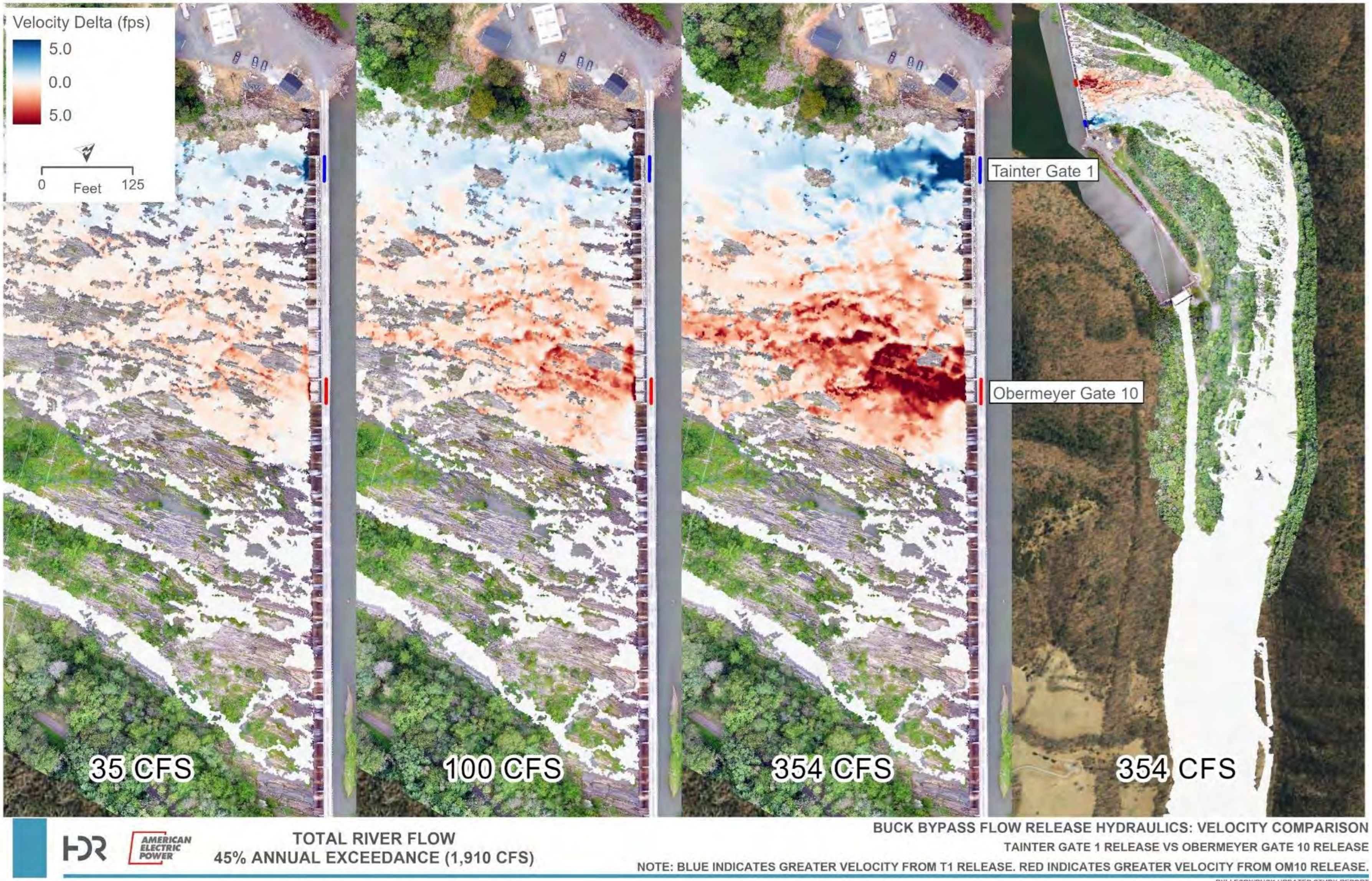


Figure 6-24. Buck Bypass Reach Flow Release Location Velocity Comparison

6.6 Aquatic Habitat Evaluation Results

6.6.1 Byllesby Habitat Model Results

The relationship between flow and usable area for Walleye (adult, juvenile, fry, and spawning life stages) and the eight species-guild representatives (i.e., two deep-fast, two deep-slow, one shallow-fast, and three shallow-slow) are provided in Figures 1 through 6 in Attachment 3 for flows ranging from 11 cfs to 360 cfs. As a sensitivity analysis, usable area results are provided for the 10 percent, 50 percent, and 90 percent exceedance flows (provided in Table 6-5) to compare the amount of potential available habitat created during relatively wet, normal, and dry hydrologic years, respectively.

Figures 1, 3, and 5 in Attachment 3 provide the usable area results for just the Byllesby bypass reach while Figures 2, 4 and 6 in Attachment 3 provide the usable area results for the entire Byllesby study area which also includes the tailrace, side-channel, cross-over channel, and downstream mainstem channel areas.

Figures 1 through 11 in Attachment 4 provide spatial habitat results maps for the eight species-guild representatives (i.e., two deep-fast, two deep-slow, one shallow-fast, and three shallow-slow) and Walleye (adult, fry, juvenile, and spawning life stages). These habitat results maps were created for four different modeled flow scenarios (11 cfs, 35 cfs, 60 cfs, and 360 cfs) using the 50 percent annual exceedance total river flow of 1,750 cfs which represents a normal hydrologic year.

Collectively, the figures in Attachments 3 and 4 can be used to determine how changes in bypass reach flows affect the amount of habitat (in square feet) that is potentially available in the Byllesby bypass reach as well as the entire modeled study area between 11 cfs and 360 cfs.

Deep-Fast Guild

Figures 1 and 2, Attachment 3 (usable area curves)
Figures 1 and 2, Attachment 4 (habitat model results maps)

While some potential habitat is available in the Byllesby bypass reach for the Deep-Fast Guild under the modeled flow range (11 cfs – 360 cfs), the amount of habitat only gradually increases with increasing flow. While there are deep pools in the bypass reach, it is likely that the velocities are too low and/or the substrate is limited (i.e., primarily bedrock). The two guild representatives for deep-fast are Shorthead Redhorse adult (which prefers coarse-mixed substrate) and Silver Redhorse adult (which prefers finer substrate sizes with cover).

While potential habitat is somewhat limited in the bypass reach for the Deep-Fast Guild, there is ample habitat (approximately 5 – 20 times more than in the bypass reach) in the greater study area which includes the tailrace, side channel area, cross-over channel, and the main channel downstream from the bypass reach. The area downstream from the tailrace includes fines (which are preferred by Silver Redhorse adult) and the mainstem and side channel areas contain coarse-mixed substrate (preferred by Shorthead Redhorse adult).

As expected, wet years provide more habitat compared to normal and dry years in the bypass reach and also the entire study area with the exception of the Shorthead Redhorse adult where normal years provide slightly more habitat than dry or wet years.

Deep-Slow Guild

Figures 1 and 2, Attachment 3 (usable area curves)
Figures 3 and 4, Attachment 4 (habitat model results maps)

An area of optimal habitat exists in the bypass reach for the Generic Deep-Slow Guild (i.e., no cover), but the amount of habitat is not affected by increasing amounts of flow. For the Deep-Slow Guild (with cover) the amount of available habitat is approximately three time greater than for the no-cover representative, but again the amount of available habitat is not affected by increasing the amount of bypass flow.

A similar trend is observed when looking at habitat results for the entire study area. While there's little to no difference in habitat results over the model simulation range, there's approximately 3 and 5 times the amount of available habitat for the no-cover and with-cover representatives (compared to the bypass reach results), respectively. This is due to the substantial amount of instream cover available throughout the modeled study area.

Wet years provide more habitat for the Deep-Slow Guild in the bypass reach, but the reverse is seen in the greater study area. This is because the greater study area receives the total river flow and as overall river flows increase during wet years, the velocities in areas of preferred habitat during normal and dry years likely become too fast.

Shallow-Fast Guild

Figures 3 and 4, Attachment 3 (usable area curves)
Figure 5, Attachment 4 (habitat model results maps)

As expected, there is little to no available habitat in the bypass reach for the Shallow-Fast Guild throughout the model simulation range as this representative prefers moderate velocities with coarse substrate. The bypass reach is likely too deep, too slow, and is mostly comprised of bedrock. Similarly, the tailrace provides zero potential habitat for this guild. However, there are several areas in the side channel, cross-over channel, and main channel that do provide habitat for the Shallow-Fast Guild although the amount of habitat does not appear to be affected by allocation of flow between the bypass reach and powerhouse flow releases. The amount of usable area is slightly higher during normal and dry years and decreases during wet years, likely because the preferred habitat areas become too deep during high flow years.

Shallow-Slow Guild

Figures 3 and 4, Attachment 3 (usable area curves)
Figures 6 and 7, Attachment 4 (habitat model results maps)

The Shallow-Slow Guild includes three categories: 1) finer substrate sizes with no cover (represented by Redbreast Sunfish spawning), 2) fine and small gravel substrate sizes with aquatic vegetation (represented by Silver Redhorse young-of-year), and 3) coarse substrate (represented by Generic Shallow-Slow Guild). These three guild representatives exhibit widely varying potential available habitat under the habitat model simulation range.

Of the three guild representatives, the Redbreast Sunfish spawning and generic coarse-substrate representatives exhibit the largest amount of potential available habitat. Bypass reach habitat model results indicate potential available habitat for the Redbreast Sunfish spawning representative is maximized at leakage flow and decreases with increasing bypass reach flows. Habitat for the generic coarse-substrate representative increases from leakage flow to approximately 60 cfs after which the amount of available habitat levels off and then starts to decrease as bypass reach flow continue to increase. It is important to note that a significant amount of the available habitat for the generic coarse-substrate representative is located in the lower portion of the bypass reach which is influenced by flows from the powerhouse which wrap around the peninsula between the tailrace and bypass reach. As a result, the habitat generated in this lower bypass reach area is a product of both bypass reach and powerhouse flow releases. Figure 6-25 illustrates how flows from the tailrace wrap around the peninsula and influence flow patterns in the lower end of the bypass reach (see white arrows indicating flow direction)[9].

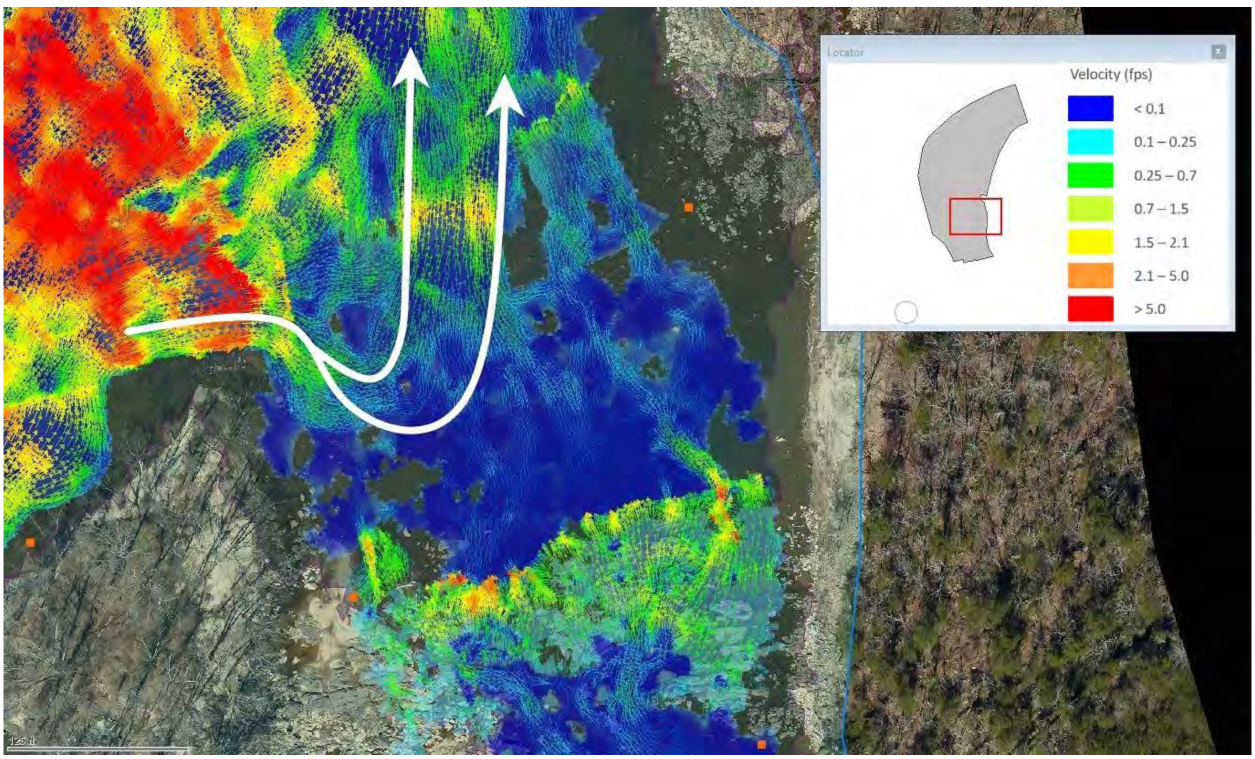


Figure 6-25. Byllesby Bypass Reach-Powerhouse Flow Mixing (Approximate North is Top of Figure)

Habitat results provided in Figure 4 (Attachment 3) indicate that there is approximately 4 times more available habitat for the generic coarse-substrate representative in the greater study area compared to the amount of habitat available in the bypass reach (Figure 3, Attachment 3). Additionally, the amount of available habitat is not significantly influenced by the split between bypass reach flow and

[9] Hydraulic model results are shown for a bypass flow of 60 cfs and powerhouse flow of 1,690 cfs. Due to differences in data projection, the aerial photography in Figure 6-25 is shifted approximately 70 ft to the west compared to the hydraulic model results.

powerhouse flow over the habitat model simulation range. As a result, habitat for this representative is not limited downstream from the Byllesby development.

As expected, dry years generally produce more available habitat for the Shallow-Slow Guild compared to normal and wet years.

The Silver Redhorse young-of-year representative prefers fine and small gravel substrate type and requires aquatic vegetation, which was not observed in the Byllesby study area. As a result, potential habitat for this guild representative is not available regardless of flow scenario. Therefore, habitat model results are not included in the figures in Attachments 3 or 4.

Walleye

Figures 5 and 6, Attachment 3 (usable area curves)
Figures 8, 9, 10, and 11, Attachment 4 (habitat model results maps)

Bypass reach habitat modeling results for Walleye fry, juvenile, and adult life stages generally show higher amounts of available habitat at lower bypass flow releases. The Walleye spawning life stage prefers higher velocities (i.e., > 2.0 ft per second), a depth range of 2–6 ft, and larger substrate sizes. Very little potential Walleye spawning habitat is available in the bypass reach, however, suitable habitat is present in the area downstream from the tailrace and in the main channel. Habitat model results indicate there is approximately 25 times more habitat available in downstream study area compared to the bypass reach for Walleye spawning. Generally, wet years provide more available habitat than dry years for all Walleye life stages and this is especially true for the spawning life stage where the amount of available habitat in the downstream study area is approximately doubled for wet years compared to normal years. Model sensitivity results for dry years show significantly less available Walleye spawning habitat.

6.6.2 Buck Habitat Model Results

The relationship between flow and usable area for Walleye (adult, juvenile, fry, and spawning life stages) and the eight species-guild representatives (i.e., two deep-fast, two deep-slow, one shallow-fast, and three shallow-slow) are provided in Figures 7 through 12 in Attachment 3 for flows ranging from 17 cfs to 700 cfs. As a sensitivity analysis, usable area results are provided at the 10 percent, 50 percent, and 90 percent exceedance flows (provided in Table 6-6) to compare the amount of potential available habitat created during relatively wet, normal, and dry hydrologic years, respectively.

Figures 7, 9 and 11 in Attachment 3 provide the usable area results for just the Buck bypass reach while Figures 8, 10, and 12 in Attachment 3 provide the usable area results for the entire Buck study area which also includes the tailrace and downstream mainstem below the confluence with the bypass reach.

Figures 12 through 22 in Attachment 4 provide spatial habitat results maps for the eight species-guild representatives (i.e., two deep-fast, two deep-slow, one shallow-fast, and three shallow-slow) and Walleye (adult, fry, juvenile, and spawning life stages). These habitat results maps were created for four different modeled flow scenarios (17 cfs, 35 cfs, 100 cfs, and 354 cfs) using the 45 percent annual exceedance total river flow of 1,911 cfs which represents a normal hydrologic year.

Collectively, the figures in Attachments 3 and 4 can be used to determine how changes in the Buck bypass reach flows affect the amount of habitat (in square feet) that is potentially available in the bypass reach as well as the entire modeled study area between 17 cfs and 700 cfs.

Deep-Fast Guild

Figures 7 and 8, Attachment 3 (usable area curves)
Figures 12 and 13, Attachment 4 (habitat model results maps)

The Deep-Fast Guild has two representatives: Shorthead Redhorse adult (which prefers coarse-mixed substrate) and Silver Redhorse adult (which prefers finer substrate sizes with cover). Because the Buck bypass reach is primarily comprised of larger substrate sizes, more habitat is available for the Shorthead Redhorse adult representative under all flow conditions (compared to the Silver Redhorse adult representative) and the amount of available habitat for the Shorthead Redhorse increases with increasing flow. There is also a significant amount of available habitat for this guild representative in the area immediately downstream from the confluence of the bypass reach and tailrace. Habitat in this area is a function of total river flow (i.e., bypass reach flow and powerhouse flow). At lower bypass flow releases, the amount of downstream habitat is approximately 9 times greater than amount of habitat available in the bypass reach. As bypass flows increase, this ratio decreases, but it would require a bypass flow release greater than 700 cfs to create an equal amount of habitat in the bypass reach compared to the downstream area.

As expected, wet years provide more habitat for the Deep-Fast Guild than normal years; and normal years provide more habitat than dry years. This trend is consistent for both the bypass reach model results as well as the model results for the entire study area.

Deep-Slow Guild

Figures 7 and 8, Attachment 3 (usable area curves)
Figures 14 and 15, Attachment 4 (habitat model results maps)

Little to no potential habitat is available for the Generic Deep-Slow Guild (i.e., no cover) in the bypass reach or the greater Buck study area over the model simulation range.

Significantly more potential habitat is available for the Deep-Slow Guild representative that prefers cover (i.e., Redbreast Sunfish adult) over the model simulation range. Preferred habitat is along the main flow pathway at lower flows and shifts to backwater areas as flows increase. A large area of potential habitat is present at the bottom end of the bypass reach (just upstream of the confluence with the tailrace) at all modeled flows.

For both Deep-Slow Guild representatives, differences in available habitat are relatively small between wet, normal, and dry years.

Shallow-Fast Guild

Figures 9 and 10, Attachment 3 (usable area curves)
Figure 16, Attachment 4 (habitat model results maps)

Minimal potential habitat is available for the Generic Shallow-Fast Guild in the bypass reach at leakage flow as this representative prefers moderate velocities with coarse substrate; however, potential habitat gradually increases up to bypass flows of approximately 350 cfs before leveling off as bypass flows continue to increase. The location of available habitat is generally along the main flow pathway and as bypass flow increases, the footprint of available habitat is for the most part unchanged, but the suitability at those locations increases. Optimal habitat also exists in the wide riffle/run area near the downstream end of the study area (i.e., below the confluence of the tailrace and bypass reach). While there is a significant amount of available habitat downstream from the confluence, approximately 60 percent of total available habitat for the Shallow-Fast Guild is within the bypass reach. The amount of available habitat is similar for normal and dry years, but decreases slightly during wet years as some areas may become too deep.

Shallow-Slow Guild

Figures 9 and 10, Attachment 3 (usable area curves)
Figures 17 and 18, Attachment 4 (habitat model results maps)

The Shallow-Slow Guild includes three categories: 1) finer substrate sizes with no cover (represented by Redbreast Sunfish spawning), 2) fine and small gravel substrate sizes with aquatic vegetation (represented by Silver Redhorse young-of-year), and 3) coarse substrate (represented by Generic Shallow-Slow Guild). These three guild representatives exhibit widely varying potential available habitat under the habitat model simulation range.

Of the three guild representatives, the Redbreast Sunfish spawning and generic coarse-substrate representatives exhibit the largest amount of potential available habitat. Bypass reach habitat model results indicate a significant amount of habitat is available for these two guild representatives at leakage flow. As bypass flows increase up to approximately 100 cfs, the amount of available habitat also increases before leveling off and then decreasing as bypass reach flows continue to increase. For the Redbreast Sunfish spawning representative, the amount of available habitat increases approximately 40 percent from leakage flow to 100 cfs. For the generic coarse-substrate representative, the amount of available habitat increases approximately 55 percent from leakage flow to 100 cfs. However, as shown on Figure 17 (Attachment 4), areas of optimal habitat for the generic coarse-substrate representative start to become fragmented in the upper half of the bypass reach as flows increase above approximately 35 cfs. As a result, gains in available habitat at bypass flows above 35 cfs are concentrated behind rock outcrops that provide velocity shelters and in backwater areas of the lower bypass reach.

Available habitat for the Redbreast Sunfish spawning representative is higher during wet years and lower during dry years. This representative is more tolerant of deeper water compared to the generic coarse-substrate representative as the suitable depth range for this species/life stage extends up to 7 ft deep. Conversely, the available habitat for the generic coarse-substrate representative is higher during normal years (compared to dry and wet years). This guild representative prefers depths less than 2 ft and velocities less than 1 fps. As a result, during dry years less backwater habitat is available and during wet years, depths and/or velocities reduce the amount of available habitat (compared to normal hydrologic years).

The Silver Redhorse young-of-year representative prefers fine and small gravel substrate type and requires aquatic vegetation, which was not observed in the Buck study area. As a result, potential habitat for this guild representative is not available regardless of flow scenario. Therefore, habitat model results are not included in the figures in Attachments 3 or 4.

Walleye

Figures 11 and 12, Attachment 3 (usable area curves)
Figures 19, 20, 21 and 22, Attachment 4 (habitat model results maps)

Bypass reach habitat modeling results for Walleye fry, juvenile, and adult life stages generally show higher amounts of available habitat at lower bypass flow releases. The Walleye spawning life stage prefers higher velocities (i.e., > 2.0 ft per second), a depth range of 2 – 6 ft, and larger substrate sizes. Very little potential Walleye spawning habitat is available in the bypass reach, however, suitable habitat is present in the area downstream from the tailrace and in the main channel.

Habitat modeling results indicate little to no suitable habitat for the Walleye adult life stage over the modeled flow range (i.e, 17 cfs – 700 cfs). This life stage prefers relatively deep, slow-moving water and the only potential habitat in the Buck Bypass reach is located in very small, sporadic, and isolated areas.

Walleye juvenile results are similar to the adult life stage, but with slightly more available habitat. An area of potential habitat is also present along the backside of the island area near the downstream end of the study reach. This area behind the island is characterized by overhead vegetation and cobble, which the Walleye juvenile life stage prefers.

Walleye fry available habitat is slightly greater than juvenile habitat, but peaks at leakage flow. Walleye fry prefer very low velocities (<0.2 fps) so available habitat decreases as flow increases.

The Walleye spawning life stage prefers higher velocities (i.e., > 2.0 ft per second), a depth range of 2–6 ft, and larger substrate sizes. While some potential Walleye spawning habitat is available in the main bypass flow channel along the left descending bank (at higher bypass flows), the largest area of potential spawning habitat is located just downstream from the confluence of the tailrace and bypass reach. Habitat model results indicate there is more than double the amount of available Walleye spawning habitat in downstream study area compared to the bypass reach.

Generally, wet years provide more available habitat than dry years for all Walleye life stages and this is especially true for the spawning life stage where the amount of available habitat in the downstream study area is approximately 5 times more during wet years compared to normal years. Model sensitivity results for dry years show significantly less available Walleye spawning habitat.

7 Summary and Discussion

This section provides a summary and discussion of the results of this study, organized by study objective for each development.

7.1 Byllesby Bypass Reach

7.1.1 Delineate and Quantify Aquatic Habitats and Substrate Types

The Byllesby bypass reach primarily consists of deep and shallow pool and shoal habitat types dominated by larger substrate sizes (i.e., bedrock and large boulders). The tailrace is a relatively deep and swift man-made channel lined with bedrock and large boulders. The cross-over channel between the tailrace and main channel is primarily comprised of run-type habitat with gravel, cobble, and sand substrate. The main channel downstream from the bypass reach consists of relatively wide riffles and runs with undulating bedrock/boulder substrate which provides instream cover. The side channel is also comprised of run/riffle habitat but is much narrower than the main channel with gravel/cobble substrates. In all, the bypass reach study area contains a wide variety of aquatic habitat and substrate types.

7.1.2 Surface Water Travel Times and Water Surface Elevation Responses – Calibration Flows

Level logger data during the bypass flow field data collection period (July 26 – September 13, 2021) was used to determine surface water travel times in the bypass reach as well as water surface elevation responses throughout the bypass reach study area under the calibration flow releases. A summary of key calibration flow findings is provided below:

- Depths increased in the bypass reach approximately 0.8 ft from Leakage Flow to Low Flow range (11 cfs to 88 cfs), approximately 0.2 ft from Low Flow to Mid Flow (88 cfs to 158 cfs), and approximately 0.5 ft from Mid Flow to High Flow (158 cfs to 194 cfs). The overall depth increase was approximately 1.5 ft from Leakage Flow to High Flow (11 cfs to 194 cfs).

- Depth increases in the main channel immediately downstream from the bypass reach were much lower than the bypass reach increasing a maximum of only 0.25 ft between Leakage Flow and High Flow.

- Bypass flow releases did not influence water surface elevations in the tailrace, cross-over channel, or side channel areas. These areas are influenced by powerhouse flow releases and not bypass flow releases.

- Because the Byllesby bypass reach is relatively short (i.e., 590 ft long), travel times of flow releases from Tainter Gate 6 to the downstream end of the bypass reach are also relatively short. For example, the Mid Flow and High Flow releases reached the downstream end of the bypass reach in 6 minutes and 2 minutes, respectively.

7.1.3 Identify and Characterize Locations of Habitat Management Interest

Habitat model results for the Byllesby bypass reach indicate suitable habitat for species and life stages that prefer deep and/or slow-moving water (e.g., Redbreast Sunfish adult and Walleye adult, juvenile, and fry). The bypass reach is relatively wide and comprised of deep and shallow pools and shoal habitat types. Therefore, increasing flow in the bypass reach only has a marginal effect on depths and velocities. As a result, the amount of available habitat in the bypass reach is very similar over the modeled flow range (between 11–360 cfs).

The bypass reach itself is only a small portion of the overall bypass reach study area. The tailrace, cross-over channel between the tailrace and main channel, the main channel downstream from the bypass reach, and side channel areas all provide a wide range of available habitat and substrate types. Habitat model results indicate these areas provide suitable habitat for each of the guilds and Walleye life stages under the modeled flow range. From an aquatic habitat perspective, maintaining run-of-river operations through the Byllesby powerhouse is more beneficial than increasing flows in the bypass reach because the tailrace, cross-over channel, main channel, and side channel are all fed by generation flows whereas only the main channel would be fed by increased bypass flows.

7.1.4 Efficacy of Existing Powerhouse Minimum Flow Requirement

The mean monthly average flow and 25th percentile monthly average flow for August (typically the lowest flow month of the year) at the USGS 03165500 New River at Ivanhoe flow gaging station from 1996 – 2020 are 1,497 cfs and 896 cfs, respectively (see Table 4-1). The mean monthly flow in August over the 1996 – 2020 POR is more than four times higher than the current FERC authorized minimum downstream flow requirement of 360 cfs (or inflow, whichever is less) and the 25th percentile flow for August is more than double the minimum downstream flow requirement.

As a result, the minimum downstream flow requirement is rarely triggered, but did occur during the POR evaluated for this study (i.e., 1996 – 2020). A review of daily average flow statistics over the POR resulted in 14 days (or 0.15 percent of total days in the POR) that Project inflows were less than or equal to 360 cfs. Six of these days occurred during August 2002 and the remaining eight occurred during August 2008, corresponding to the two most severe droughts on record. The average Project inflows during the six days in August 2002 and eight days in August 2008 were 354 cfs and 328 cfs, respectively at Byllesby.

When the minimum downstream flow requirement is triggered, Project inflows at Byllesby are either passed downstream via powerhouse generation flows or via spillway gate releases into the bypass reach. A comparison of the ICM results for these two downstream flow release scenarios indicates routing Project inflows through the powerhouse is preferable as it helps maintain flows in the side channel which is on the powerhouse side of the river channel. Routing the minimum downstream flow requirement through the spillway gates can dewater portions of the side channel as the flow path exiting the bypass reach is along the river channel opposite the side channel area.

7.1.5 Evaluate the Impacts of Seasonal Minimum Flows

The bypass reach habitat results provided in Attachment 3 (usable area figures) and Attachment 4 (habitat model results maps) only show minimal differences in the amount and location of available habitat over the modeled simulation range (i.e., 11 cfs – 360 cfs). As a result, seasonal minimum flows in the bypass reach would likely have little to no effect on species and life stages that may use the bypass reach seasonally. For example, Walleye spawning habitat is minimal in the bypass reach over the model simulation flow range. However, Walleye spawning habitat is available in the side channel area, the cross-over channel, and the main channel. All of these areas receive flow from run-of-river powerhouse operations which vary seasonally.

7.2 Buck Bypass Reach

7.2.1 Delineate and Quantify Aquatic Habitats and Substrate Types

The Buck bypass reach consists of a complex assemblage of aquatic habitat and substrate types, dominated by angular bedrock. The key difference between the Buck upper reach versus the middle to lower reaches is that the orientation of the bedrock slabs is parallel to the flow, which facilitates scour and sediment transport, while the middle to lower reaches are dominated by bedrock slabs oriented perpendicular to streamflow, which facilitates sediment deposition (on the downstream side of the slab). As a result, the Buck upper reach is approximately 50 percent bedrock while the middle to lower reaches, while still dominated by bedrock, contain more smaller-sized particles. The middle to lower transects display zones of sediment deposition and lower-velocity shelters, which create a variety of aquatic habitat for a wider range of aquatic species and life stages.

7.2.2 Surface Water Travel Times and Water Surface Elevation Responses – Calibration Flows

Flow releases from the right (looking downstream) side of the Buck spillway structure (via Tainter Gate 1) generally travel across the bypass reach toward the apex of the channel bend along the left descending bank. From there, the main flow path is along the left descending bank to the end of the bypass reach (see flow direction arrows on Figure 3-2). As a result, water surface elevations spanning a large area of the upper bypass reach along the toe of the spillway from the center of the channel to the left abutment were not affected by the calibration flow releases. This is due to a large island of higher topography in this area. Because the island area separates the right and left channels in the upper portion of the bypass reach, flow releases from Tainter Gates 1–6 and Obermeyer Gates 7–10 would likely travel a similar path.

Bypass reach flow travel time (from the spillway to the downstream end of the reach) was approximately 2 hours and 30 minutes at Low Flow (211 cfs), 1 hour and 40 minutes at Mid Flow (354 cfs) and 1 hour at High Flow (714 cfs). Details are provided in Attachment 1 – Buck Bypass Reach ICM Model Development, Section 4.1.4.

From the Leakage Flow to Low Flow range (17 cfs to 211 cfs), depths increased approximately 1.0 - 1.5 ft along the main flow path (i.e., right descending channel in the upper portion of the bypass reach and along the left descending bank in the lower portion of the reach). As the calibration flows increased to the Mid (354 cfs) to High (714 cfs) flow range, corresponding depths along the main flow path increased an additional 1.0 ft; or a total of approximately 2.5 ft deeper than at leakage flow.

7.2.3 Identify and Characterize Locations of Habitat Management Interest

The upper portion of the channel along the left descending bank is considered an area of concern from a potential fish stranding perspective. Two level loggers were placed along this channel to evaluate potential impacts to water surface elevations resulting from Tainter gate operations (see BK_LL2 and BK_LL4 locations on Figure 6-7). Water surface elevations at BK_LL2 were not affected during the High Flow release of 714 cfs (which corresponds to a 2-ft opening at Tainter Gate 1). Water surface elevations at BK_LL4 increase approximately 0.13 ft at Low Flow (211 cfs), appr oximately 0.22 ft at Mid Flow (354 cfs), and approximately 0.37 ft at High Flow (714 cfs). While the water surface elevations at BK_LL4 were impacted, this area is not in the main flow path where much higher water surface elevation changes were recorded (see Figure 6-11).

During the level logger deployment, several large rainfall runoff events occurred which resulted in Tainter gate openings greater than 2-ft (the maximum calibration flow opening). Figure 6-12 shows that spillway flows need to reach at least 5,000 cfs to affect water surface elevations at the BK_LL2 location. As a result, the existing ramping rate requirements have little to no effect on the upper portion of the left descending channel.

The potential for fish stranding in the upper bypass reach pools immediately below the spillway along the left descending bank was also evaluated.[10] Nine pools in this area (shown on Figure 7-1) were analyzed by plotting pool water surface elevation versus bypass flow releases. Figure 7-2 depicts water surface elevation versus bypass flow for each of the nine pools. Also shown on Figure 7-2 in blue text are the annual flow exceedance values for each gate opening. These exceedance values were determined using USGS gage 0316550 New River at Ivanhoe, VA and the POR from 1996 to 2020. Note the powerhouse was assumed to be operating at full capacity (3,540 cfs discharge) for this analysis. Hydraulics at these nine pools are not affected by powerhouse flows.

Water surface elevations in Pool 9 (Figure 7-1) are affected due to a backwater effect from a single gate opening (i.e., full gate opening of approximately 3,000 cfs depicted in Figure 7-2) as the main flow path in the upper bypass reach intersects with the downstream end of Pool 9. When a single gate is open, ramping rates require hold points at 2 ft and 1 ft gate openings to allow time for water in the bypass reach to gradually recede. As a result, potential fish stranding in Pool 9 under single gate operations is minimized. The water surface elevations in Pools 8 and 7 are not affected by backwater from a single gate opening but begin to increase when a second gate is opened. Water surface elevations in Pool 6 are not affected until at least three spillway gates are opened and pools across the toe of the spillway (i.e., Pools 1 – 5) are not affected until five or more spillway gates are opened.

Based on annual flow exceedance probabilities, a single gate would be opened to some extent (either partially or fully) approximately 19.7 percent of the time. However, the probability of multiple gates opened at the same time is significantly lower. The probability of two gates opened at the same time is approximately 4.0 percent, which means the water surface elevations in Ponds 7 and 8 are not affected from bypass flow releases 96.0 percent of the time. The probability of three gates opened at the same time is approximately 1.7 percent, which means the water surface elevations in Pool 6 are not affected from bypass flow releases 98.3 percent of the time. The probability of five or more gates opened at the same time drops to less than 1 percent of the time, so water surface elevations in the pools located along the downstream toe of the spillway (i.e., below the flashboard sections), are rarely affected by bypass flow releases. As a result, the potential for fish stranding in this area is minimal and is mitigated by the existing ramping rate requirements at the Buck Development.

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[10] Note that Walleye body depths are not commonly documented in the New River, however, Walleye broodstock collections were carried out on the Staunton River downstream from the Smith Mountain/Leesville Project. Walleye populations on the Staunton River are typically smaller than Walleye populations on the New River, therefore, the results may not be directly comparable; however, preliminary data from the VDWR are included in Attachment 5 (Correspondence Appendix).

Figure 7-1. Buck Left Descending Bank Pool Identification

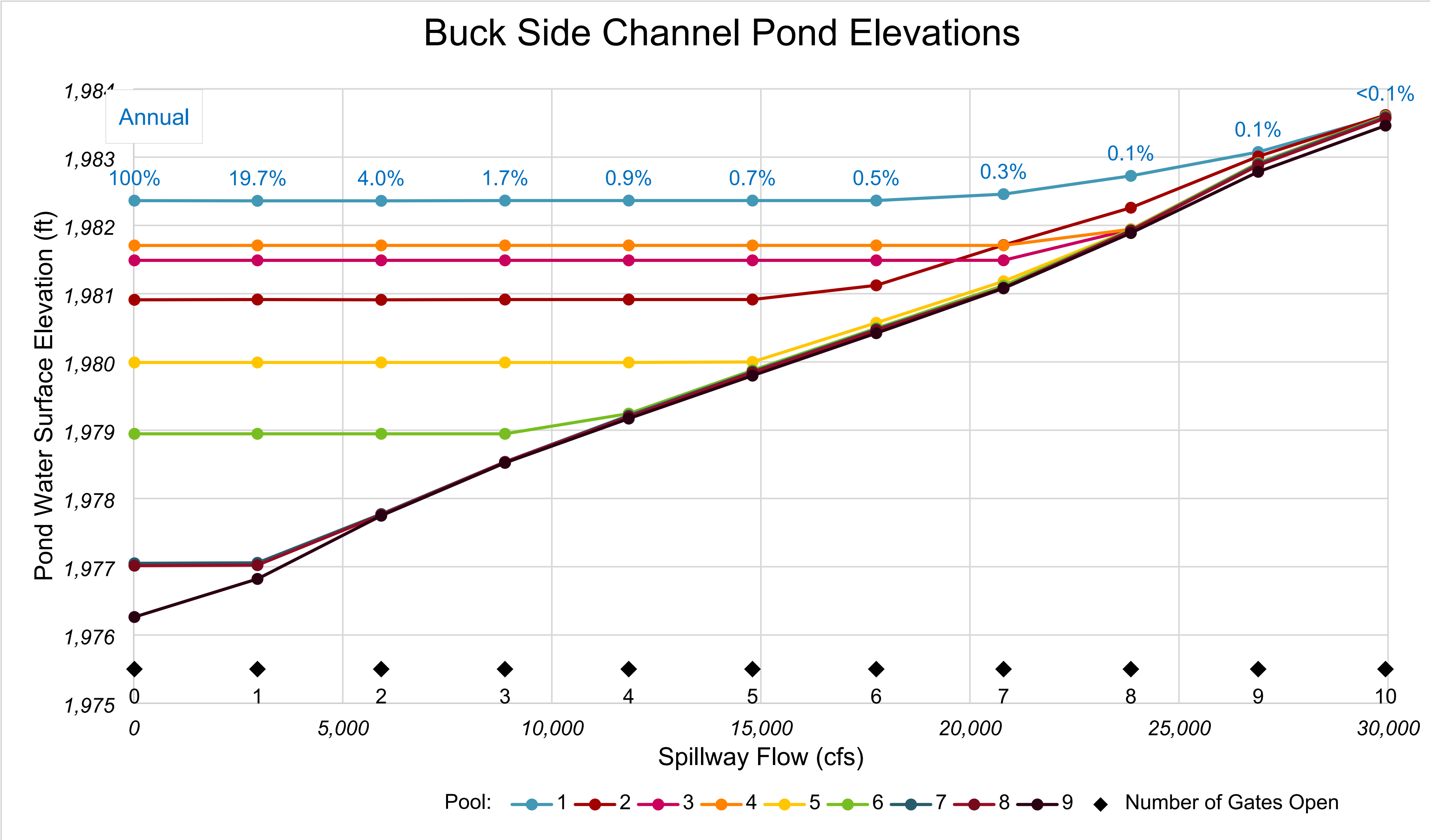

Figure 7-2. Buck Left Descending Bank Pool Water Surface Elevations vs Spillway Flow with Annual Exceedance Probabilities

7.2.4 Efficacy of Existing Ramping Rate Requirements

Under the existing FERC operating license, ramping rates are required for the Buck bypass reach to help protect fish communities. Appalachian is required to discharge flows through a 2-ft gate opening for at least three hours following any spills released through a gate opened 2 ft or more. Appalachian is then required to reduce the opening to 1 ft for at least an additional three hours, after which Appalachian may close the gate. The gradual reduction of flow allows time for fish to respond to the receding water levels, thus avoiding stranding that can occur with sudden flow discontinuation.

During the calibration flow field measurements, level loggers (set to record at 5-minute increments) captured the impact that the existing ramping rate requirements have on bypass reach water surface elevations. The decrease in water surface elevation from a 2-ft gate opening (High Flow) to a 1-ft gate opening (Mid Flow) was approximately 0.5 ft in the main flow path. From a 1-ft gate opening to a closed position, the water surface decreased an additional 1.5 – 2.0 ft in the main flow path (see Figure 6-8, Day 4 High Flow event). The seemingly disproportionate change in depth from a 2-ft to 1-ft gate opening, and a 1-ft to closed position is likely the result of the dominant bypass reach substrate type which is angled bedrock. These bedrock slabs block and trap flows in the bypass channel and their effect on water surface elevations is more pronounced at lower flows.

A potential improvement to the existing ramping rate requirements would be to add a 0.5 ft gate opening hold period to the existing requirements but shorten the hold periods to two hours each (instead of three hours). Stepping down from a 0.5 ft gate opening to a closed gate position would result in a smaller incremental change in water surface elevation in the main flow path ranging from 1.0 – 1.5 ft versus the current 1.5 – 2.0 ft when going from a 1 ft gate opening to a closed position.

7.2.5 Efficacy of Existing Powerhouse Minimum Flow Requirement

The mean monthly average flow and 25th percentile monthly average flow for August (typically the lowest flow month of the year) at the USGS 03165500 New River at Ivanhoe flow gaging station from 1996 – 2020 are 1,497 cfs and 896 cfs, respectively (see Table 4-1). The mean monthly flow in August over the 1996 – 2020 POR is more than four times higher than the current FERC authorized minimum downstream flow requirement of 360 cfs (or inflow, whichever is less) and the 25th percentile flow for August is more than double the minimum downstream flow requirement.

As a result, the minimum downstream flow requirement is rarely triggered, but did occur during the POR evaluated for this study (i.e., 1996 – 2020). A review of daily average flow statistics over the POR resulted in 14 days (or 0.15 percent of total days in the POR) that Project inflows were less than or equal to 360 cfs. Six of these days occurred during August 2002 and the remaining eight occurred during August 2008, corresponding to the two most severe droughts on record. The average Project inflows during the six days in August 2002 and eight days in August 2008 were 357 cfs and 331 cfs, respectively at Buck.

When the minimum downstream flow requirement is triggered at Buck, Project inflows can be passed through the trash sluice gate into the tailrace and/or through a Tainter or Obermeyer gate into the bypass reach. At Buck, the minimum downstream flow requirement is rarely triggered and typically occurs only during August for about a week at a time; therefore, the effect on aquatic habitat is likely negligible when considering whether the flow is released to the tailrace and/or bypass reach.

7.2.6 Evaluate the Impacts of Seasonal Minimum Flows

Seasonal minimum flows were evaluated using the habitat modeling results provided in Attachment 3 (usable area figures) and Attachment 4 (habitat model results maps) for the various habitat guilds and standalone Walleye species/life stages. Spawning life stages were of particular interest since there is a seasonal component to this life stage.

At Buck, Redbreast Sunfish spawning life stage was used as one of the representative species for the Shallow-Slow Guild (i.e., finer substrate sizes and no cover). For this representative, the amount of spawning habitat available is similar over the habitat model simulation range as the location of the potential habitat shifts from the main flow path under leakage flow conditions (i.e., 17 cfs) to the stream margins, backwater areas, and behind velocity shelters created by rock outcrops as flows in the bypass reach increase.

Potential Walleye spawning habitat was also modeled for bypass flows ranging from 17 cfs – 700 cfs. While bypass flows greater than 35 cfs produced spawning habitat mainly in the lower half of the bypass reach, the largest area of potential spawning habitat is located just downstream of the tailrace/bypass reach confluence. Habitat model results indicate there is more than double the amount of available Walleye spawning habitat in downstream study area compared to the bypass reach. Habitat in the downstream study area is heavily influenced by flows from run-of-river powerhouse operations which vary seasonally.

As a result, seasonal minimum flows in the Buck bypass reach are not likely to provide a significant amount of additional available habitat for the target species/life stages of interest.

8 Variances from FERC-Approved Study Plan

This study has been conducted in accordance with the FERC-approved RSP.

9 Germane Correspondence and Consultation

The Proposed Flow Test Scenarios technical memo was emailed by Appalachian to key agency stakeholders on August 18, 2020. On August 25, 2020, VDWR requested a conference call with Appalachian and key agency stakeholders, which was held on August 28, 2020. The Proposed Flow Test Scenarios technical memo, the Bypass Flow Test Scenario meeting notes, emails correspondence with agencies, and summaries of virtual agency meetings are included in Attachment 5.

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Attachment 1

Attachment 1 – Byllesby and Buck Bypass ICM Model Development Reports

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Byllesby Bypass Reach ICM Model Development

Byllesby-Buck Hydroelectric Project (FERC No. 2514)

April 14, 2022

Prepared by:

HDR

Prepared for:

Appalachian Power Company

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List of Acronyms

2-D	2-Dimensional
ADCP	Acoustic Doppler current profiler
AEP	American Electric Power
cfs	cubic feet per second
DTM	Digital Terrain Model
ESRI	Environmental Systems Research Institute
ft	feet/foot
GIS	Geographic Information Systems
GPS	Global Positioning System
ICM	Integrated Catchment Model
ICM Model	2-D Innovyze Infoworks Integrated Catchment Model
LiDAR	Light Detection and Ranging
Model	2-D ICM
R12 GPS	Trimble® R12 GPS
Project	Byllesby-Buck Hydroelectric Project
TIN	Triangulated Irregular Network
VGIN	Virginia Geographic Information Network

1 Project Background

1.1 Purpose and Scope

This report presents the final results of the 2-Dimensional (2-D) Byllesby Bypass Reach model developed using Innovyze Infoworks Integrated Catchment Model (ICM) software (Innovyze 2016). The 2-D Byllesby Bypass Reach ICM (Model) was used to predict hydraulic regimes in the bypass reach under varying flows. The results of the Model were used in conjunction with habitat analysis presented in the Byllesby-Buck Bypass Reach Flow and Aquatic Habitat Study Report to develop habitat suitability maps under the various flow scenarios. These maps are presented in Appendix A, Attachment 3 of the Byllesby-Buck Updated Study Report.

1.2 Study Area

The Byllesby-Buck Hydroelectric Project (FERC Project No. 2514-VA) (Project) is owned and operated by Appalachian Power Company, a subsidiary of American Electric Power (AEP). The Project is located on the New River in Carrol County, Virginia and consists of the Byllesby and Buck Dams. Byllesby Dam is approximately 7.8 miles downstream Fries, Virginia and Byllesby Dam is approximately 2.5 miles upstream of Buck Dam.

2 Model Development

2.1 Flow Study Field Data Collection

To aid calibration and validation of the Model, phased flow data collection was performed under varying flows. Fourteen level loggers (Onset® U-20 brand pressure transducers that measure water stage change with high precision) were deployed in the Byllesby Bypass reach and downstream prior to the flow tests. The Onset U-20 instrumentation details document measured water levels with an accuracy of ±0.01 feet (ft). Reference water elevations were collected using a staff gage at each level logger when installed. Level loggers recorded water surface elevation data at 5-minute intervals providing detail for travel time, and rates of rise estimations used in the Model calibration. Locations of the deployed level loggers are shown in Figure 2-1.

Four flow tests were performed over two separate trips. Prior to the flashboard repairs along the spillway, bypass flow of 88 cubic ft per second (cfs) was measured on July 28, 2021. The remaining three test flows (11, 168, 194 cfs) were performed on September 8-9, 2021. Each test was designed to capture a specific flow in the bypass reach. Flow was delivered to the bypass reach via leakage through the broken flashboard for the 88 cfs test flow. The reaming three flows were delivered via leakage and through Tainter Gate 6. Total flows in the bypass reach were recorded using a Teledyne Rio Grande® Acoustic Doppler Current Profiler (ADCP). Additional flows were measured in the side channel on the west side of the study area using a Swoffer meter, and in the tailrace/crossover channel between the bypass reach and side channel via ADCP. Gate settings and measured flows are given in Table 2-1. Figure 2-2 shows the various flow measurement locations in the bypass reach and tailrace.

Table 2-1. Byllesby Tainter Gate Settings and Bypass Reach Flow

Tainter Gate 1 Opening (ft)	Bypass Reach Flow (cfs)
Closed (Leakage)	11
Broken Flashboard (Low Flow)	88
0.5 (Mid Flow)	158
1.0 (High Flow)	194

A Trimble® R12 Global Positional System (R12 GPS) unit using Static Global Navigation Satellite System positioning with horizontal and vertical accuracies of 3 millimeters and 3.5 millimeters, respectively, was used to gather water surface elevation point data at various locations in the bypass reach under the various test flows. The R12 GPS data points are shown in Figure 2-3.

Steady-state conditions were verified in the field using temporary staff gages. All discharge measurements were made a minimum of three times or until there was less than 5 percent difference between measurements.

After the flow test periods, level logger data were downloaded and the loggers were redeployed to sample actual flow conditions for an additional three months. Data from this long-term deployment was used to further characterize the hydraulics of the bypass reach under a larger range of flow/spill conditions present outside of the two-day flow study test period.

The data collection plan enabled correlation of gate openings, flow, and water surface elevations at level logger locations within the bypass reach. The data was used to enhance understanding of travel times and rates of rise under conditions experienced during the collection period.

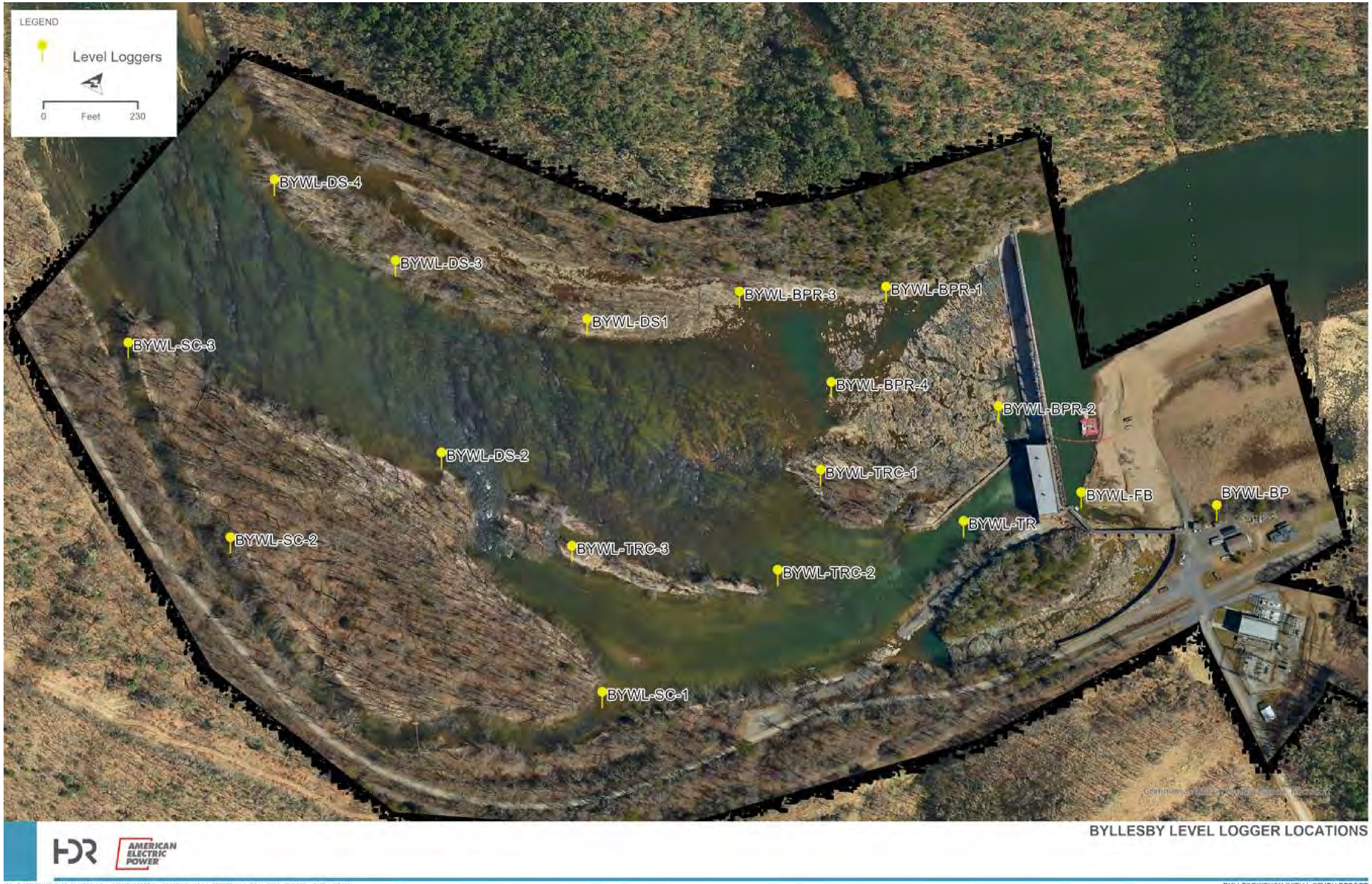

Figure 2-1. Byllesby Bypass Reach Level Logger Locations

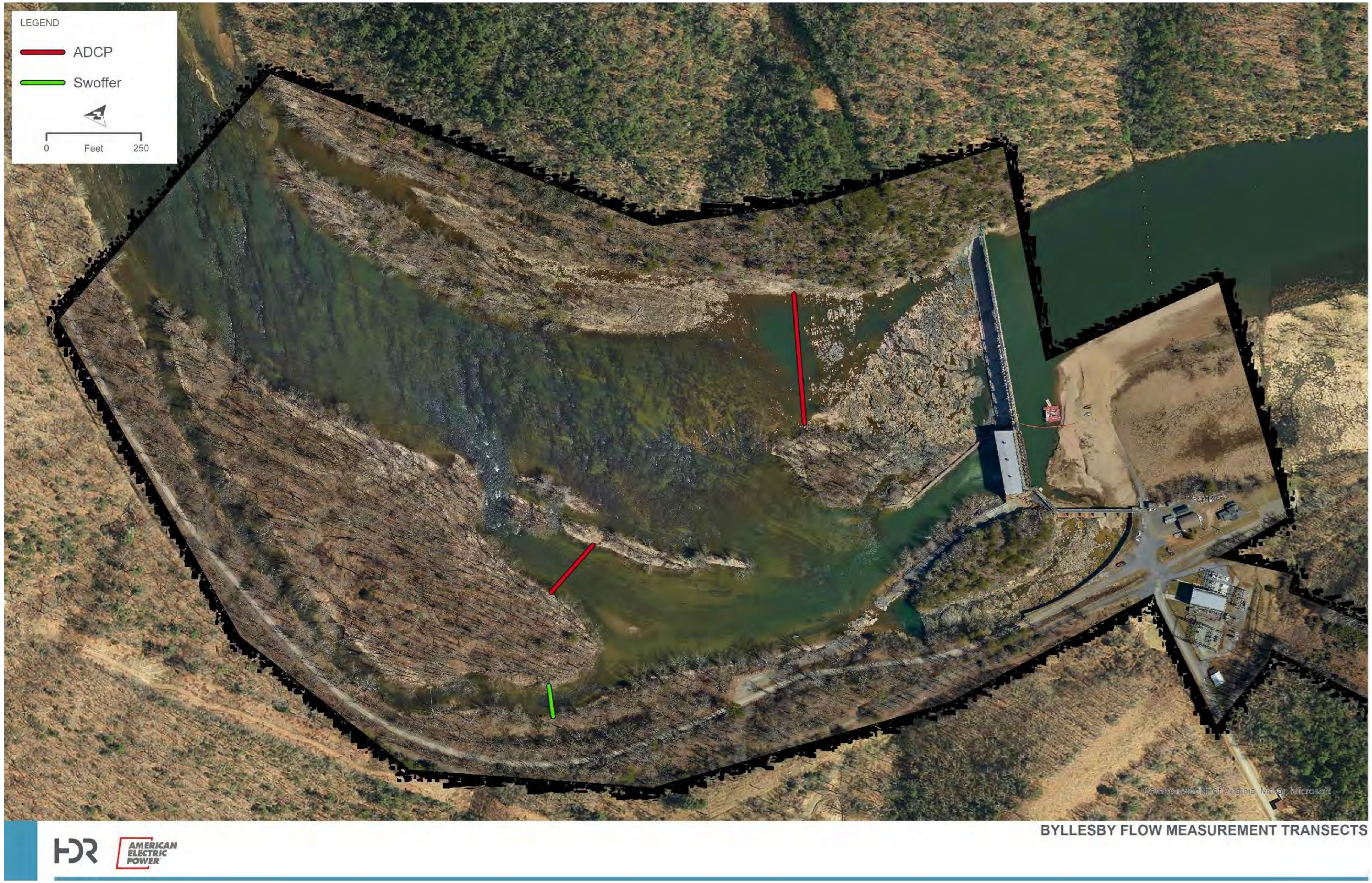

Figure 2-2. Flow Measurement Transects

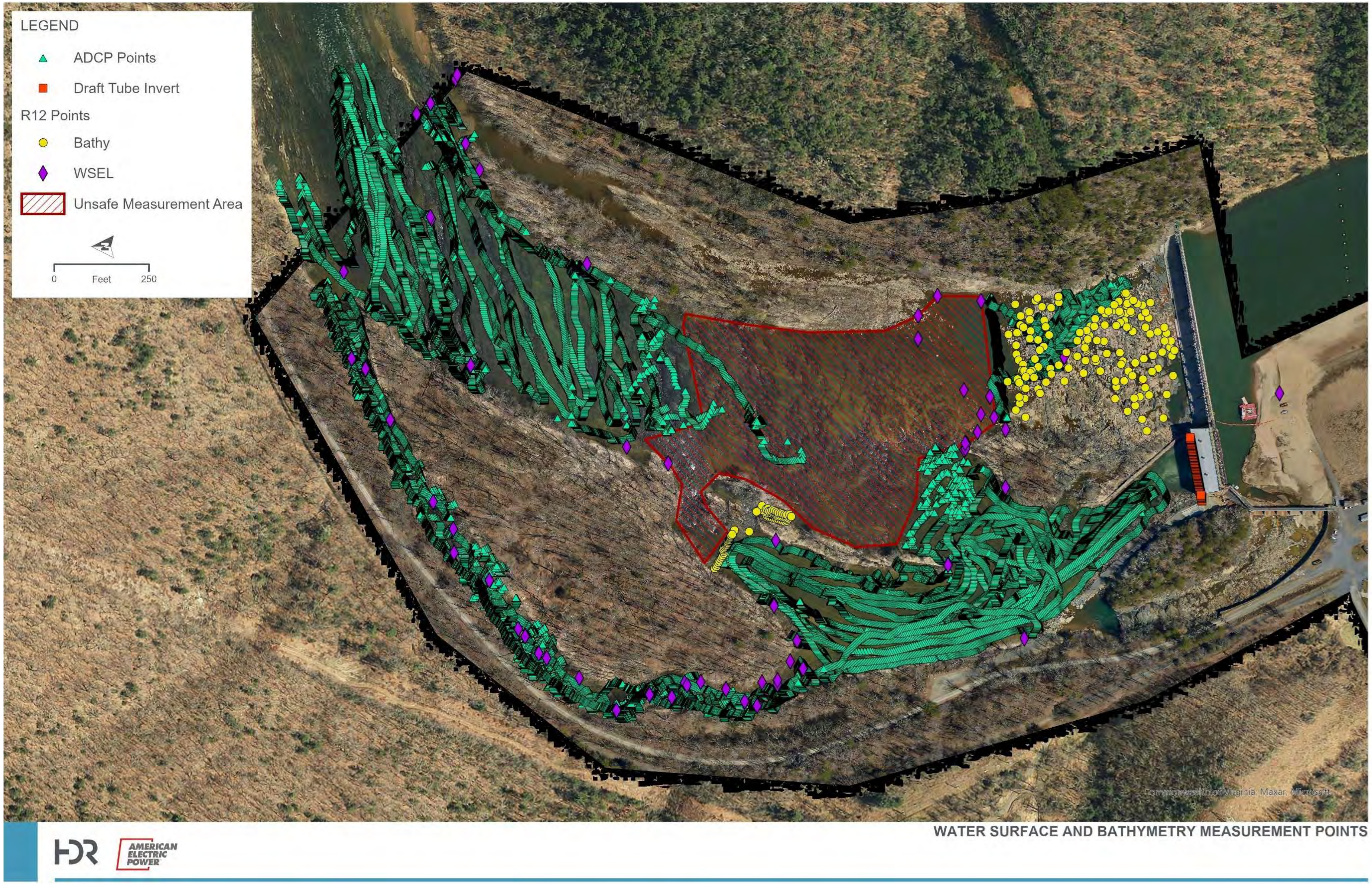

Figure 2-3. R12 Water Surface Elevation and Bathymetry Measurement Points

2.2 Terrain Data

Light Detection and Ranging (LiDAR) Data collected by the Virginia Geographic Information Network (VGIN) and available through the Virginia LiDAR web mapping application developed by VGIN was downloaded for the project site. VGIN collected the data according to the United States Geological Survey 3DEP specifications (USGS 2021) for the entire Byllesby bypass reach from the spillway extending down past the confluence with the tailrace.

Bathymetry from the flow test scenarios study was integrated into the LiDAR data in a common coordinate system and datum in areas that were underwater during the LiDAR collection. Coincident with the flow test field effort, HDR used the ADCP connected to the Global Positioning System (GPS) network to define the bathymetry downstream of Byllesby Dam. Additional bathymetry points were taken using the R12 GPS unit in the bypass reach. Measured bathymetry data is shown on Figure 2-3.

The Byllesby Powerhouse draft tube invert was defined along the edge of the powerhouse. The invert value of 2,004.5 feet above mean sea level was taken from plant drawings presented in the Byllesby Supporting Technical Information Document (STID) (Kleinschmidt 2004).

The Digital Terrain Model (DTM) used in the Byllesby Bypass Reach Hydraulic Model was developed by combining the two sources (VGIN LiDAR and ADCP) of terrain/bathymetry data using professional judgment and field observations. Detailed information on DTM development is presented in Section 3.2.

2.3 Hydraulic Model Development

2.3.1 Conventions and Assumptions

The DTM utilized in the Model was referenced to the North American Vertical Datum of 1988. The DTM was projected using the Virginia State Plane Coordinate System (i.e., U.S. Survey Foot) and horizontally referenced to the North American Datum of 1983.

The Model was developed with the following assumptions:

- In addition to LiDAR data, VGIN provides land cover data at 1-meter resolution. This dataset was used for the model Manning’s *n* roughness. Detailed discussion of the Manning’s roughness is provided in Section 3.
- Powerhouse outflows were provided by AEP via an operations spreadsheet.
- Leakage flow was measured in the bypass reach using the ADCP at the same transect as the other test flows locations. Using field observations as a guide, the leakage flow was distributed evenly among the Tainter gates. All scenarios used this setup as the base inflow condition.

2.3.2 Design Inputs

Additional design inputs include:

- Steady State inflow hydrographs formed from the base leakage flow discussed in Sections 2.1 and 2.3.1 adding 158, and 184 cfs inflows at Tainter Gate 6 for the Mid and High flow scenarios, and 88 cfs at flashboard 1 for the Low flow scenario, respectively.
- Roughness zones (Manning's *n*-values). Note the remaining 10 cfs for the Mid and High flow scenarios are provided by leakage through the other Tainter gates;
- Initial hydraulic conditions – the bypass reach and tailrace begin the simulation dry and are allowed to fill to steady state conditions.
- Boundary conditions (i.e., 2-D Zone boundary, inflow hydrographs, and downstream boundary conditions).

3 Methodology

3.1 ICM Development

Innovyze Infoworks ICM Version 11.0.5 (Innovyze 2020) was used to evaluate the hydraulics of the Bypass Reach. The Model is a fully integrated 2-D hydrodynamic model which facilitates accurate representation of flow paths while enabling complex hydraulics and hydrology to be incorporated into a single model. ICM uses the shallow water equations to develop depth averaged hydraulics results. The Model does not directly model turbulence, but accounts for energy losses due to turbulence due to bed resistance via the Manning's *n* roughness. The modeling domain extends approximately 0.55 miles downstream of the spillway and includes the side channel on the west side of the river. The domain is modeled with ICM's 2-D surface flooding module. This portion of the modeling extent is known as the 2-D Zone. The Model allows for detailed hydraulic results and provides a reasonable variability in average flow, depth, and velocity from one water column element to the next throughout the modeled area. The Model is considered appropriate for the evaluation of the bypass reach hydraulics. See Section 2.3.2 for design inputs.

3.2 Digital Terrain Model Development

The DTM used in the Model was constructed with data from the following sources:

- Virginia State LiDAR data collected from the VGIN Virginia GIS Clearinghouse database; and
- Additional bathymetry measurements collected by HDR in July 2021

The DTM was projected using the North Carolina State Plane Coordinate System (i.e., U.S. Survey Foot) and horizontally referenced to the North American Datum of 1983 and vertically referenced to the North American Vertical Datum of 1988.

LiDAR data points were discarded in areas under water during the LiDAR collection and bathymetry data was measured in 2021 using a Teledyne Rio Grande® ADCP and a Trimble® AG_GPS receiver equipped with an Omnistar® real-time differential GPS correction. Bathymetry points were measured with the ADCP using both a low-draft jet boat and via wading. Water depths were converted to elevations using the water surface elevations recorded with the R12 GPS unit at the time of data collection.

An area between the bypass reach and downstream extent was deemed unsafe for all forms of bathymetry collection. The flow in this location was both too deep and too fast for wading or canoe/kayak transportation. One attempt was made to gather data using the jet boat; however, it was determined to be too shallow. Because of this, an approximate bathymetry was modeled. In the field, the downstream collection area was determined to be an appropriate “representative sample” of the New River bathymetry in the vicinity of Byllesby Dam. Points from the downstream collection area were copied and moved into this unsafe area using aerial photography and best professional judgement to approximate the bathymetry.

Water surface elevations were taken on the edges of the unsafe area. These elevations were then used to convert the approximated depths to bathymetry and maintain the channel bottom slope. The unsafe measurement areas are shown on Figure 2-3.

The data sources were converted into triangulated irregular network (TIN) surface files and merged using Environmental Systems Research Institute (Esri™) ArcGIS Pro version 2.8.3 Geographic Information System (GIS) software (Esri 2021). The resulting DTM encompassed the entire study area and was used as the basis for developing the conceptual design for the Hydraulic & Hydrologic analysis and modeling discussed in this report.

Figure 3-1 shows the final DTM used in the Model.

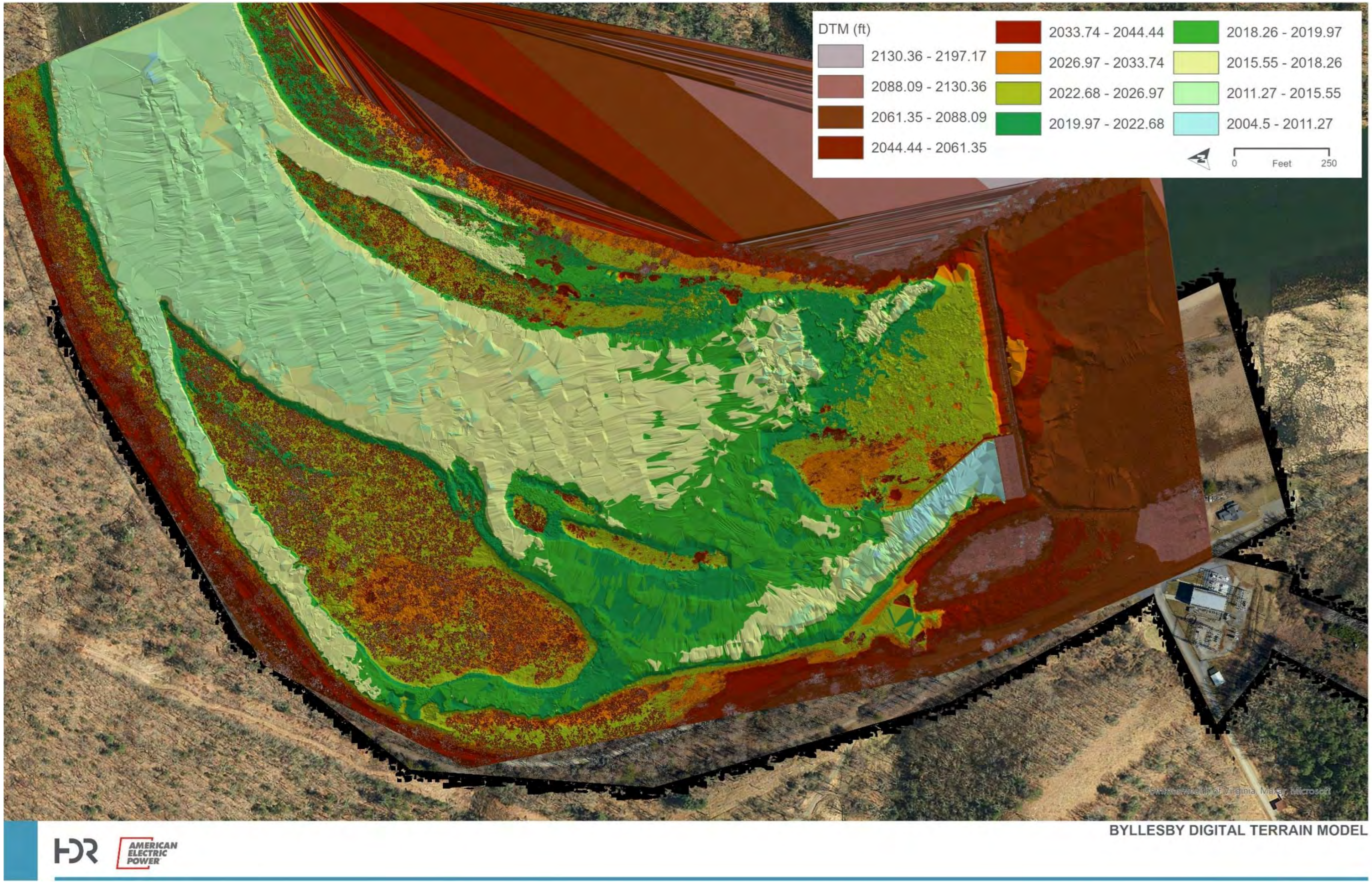

Figure 3-1. Byllesby Bypass Reach Digital Terrain Model

3.3 ICM

3.3.1 Site Topography

A TIN was created from the following topography data:

The 2-D Zone defining the Model includes approximately 0.55 miles of the New River. Figure 3-2 provides a view of the maximum extent of the 2-D Zone.

For the 2-D simulation, ICM subroutines were used to perform a meshing of the 2-D Zone. The 2-D mesh is comprised of an irregular array of triangles. Descriptions of the user input 2-D Zone data fields that are pertinent to this analysis are as follows:

- Maximum triangle area – A measure of mesh resolution used when creating a 2-D mesh; maximum allowable triangle area for areas in the 2-D Zone that are not inside of a secondary mesh zone.
- Minimum element area – Minimum mesh element area used for calculating results. Mesh elements with area less than the minimum area specified are aggregated with adjoining elements until the minimum area is met. This is done for the purpose of calculating results to improve simulation stability and run time.
- Boundary points – Boundary condition for 2-D Zone.
- Terrain-sensitive meshing – Meshing is used to increase the resolution of the mesh in areas that have a large variation in height without increasing the number of elements in relatively flat areas.
- Maximum height variation – The maximum height variation that is permitted within a single triangle. Triangles with a height variation greater than the assigned value are split provided this would not result in a triangle smaller than the Minimum element area.
- Minimum triangle angle – Minimum allowable angle between triangle vertices when creating a 2-D mesh.
- Roughness – Manning's *n* roughness values, used when creating a 2-D mesh. The roughness value assigned to mesh elements in areas in the 2-D Zone that are not in a roughness zone. Roughness values were selected from published tables (Chow 1959).

Table 3-1 provides a summary of the selected user input values for the ICM meshing routine as well as the total 2-D Zone area.

A section of the resulting mesh is shown on Figure 3-3. The model mesh contains 508,943 triangles and 507,688 elements. The approximate minimum, maximum, and average element areas are 0.23 sq ft, 99 sq ft, and 0.52 sq ft, respectively.

Table 3-1. ICM Meshing User Inputs and Area Summary

2D zone Object Properties		
Polygon definition		
ID	Byllesby 2D Zone	
Area (acre)	65.26167757	#D
Maximum triangle area (ft2)	1076.391	#D
Minimum element area (ft2)	2.500	
Mesh generation		
Boundary points	Vertical Wall	#D
Terrain-sensitive meshing	☒	
Maximum height variation (ft)	0.250	
Minimum angle (degree)	25.00	#D
Roughness (Manning's n)	0.1600	
Apply rainfall etc directly to mes	☐	
Apply rainfall etc	everywhere	#D
Rainfall profile	1	#D
Infiltration surface		#D
Turbulence model		
Rainfall percentage	100.000	#D
Mesh summary	...	
Mesh data	...	
General properties		
Notes	...	
Hyperlinks	...	
User defined properties		

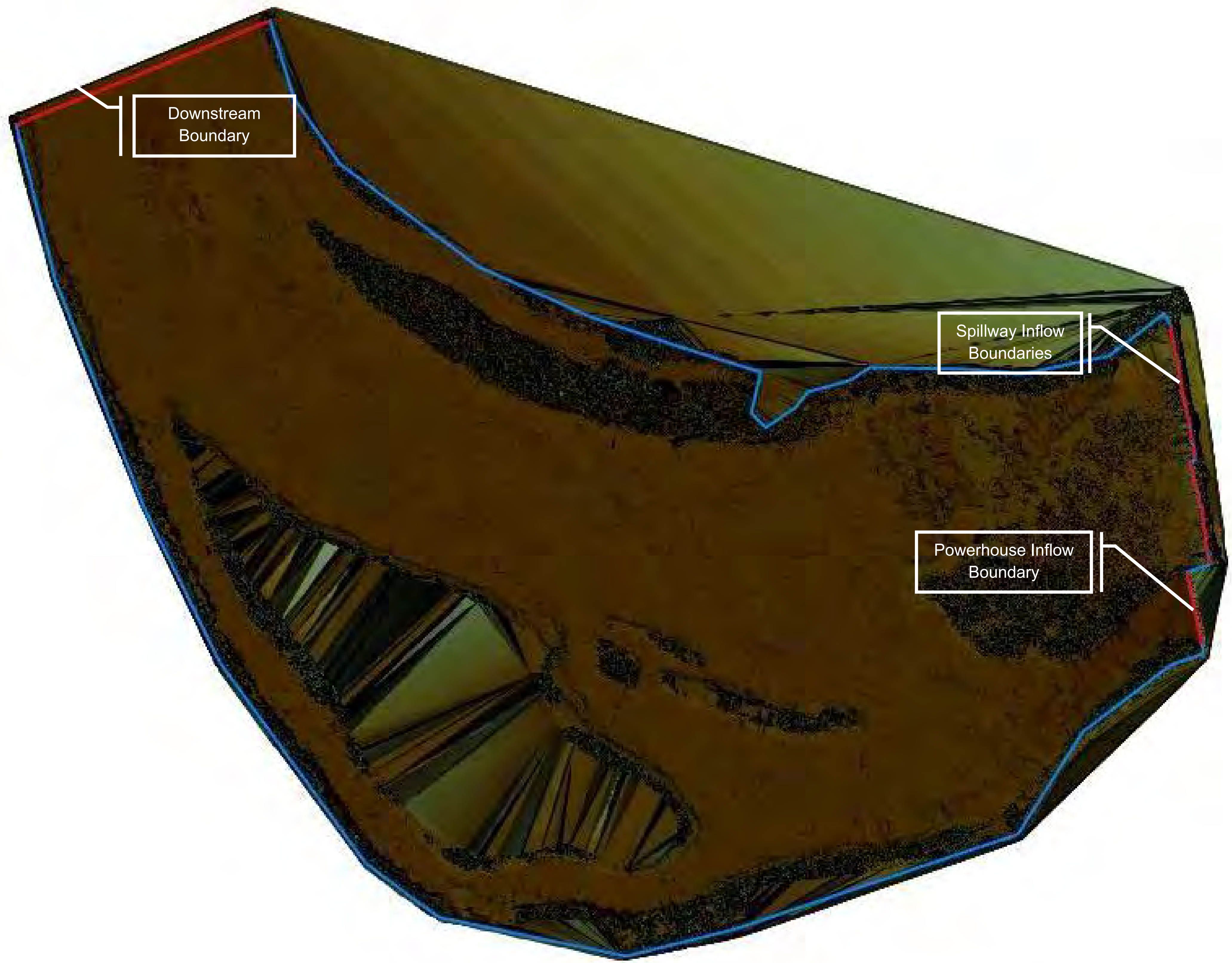

Figure 3-2. Extent of 2-D Zone and ICM Mesh (North is to the Left of the Figure)

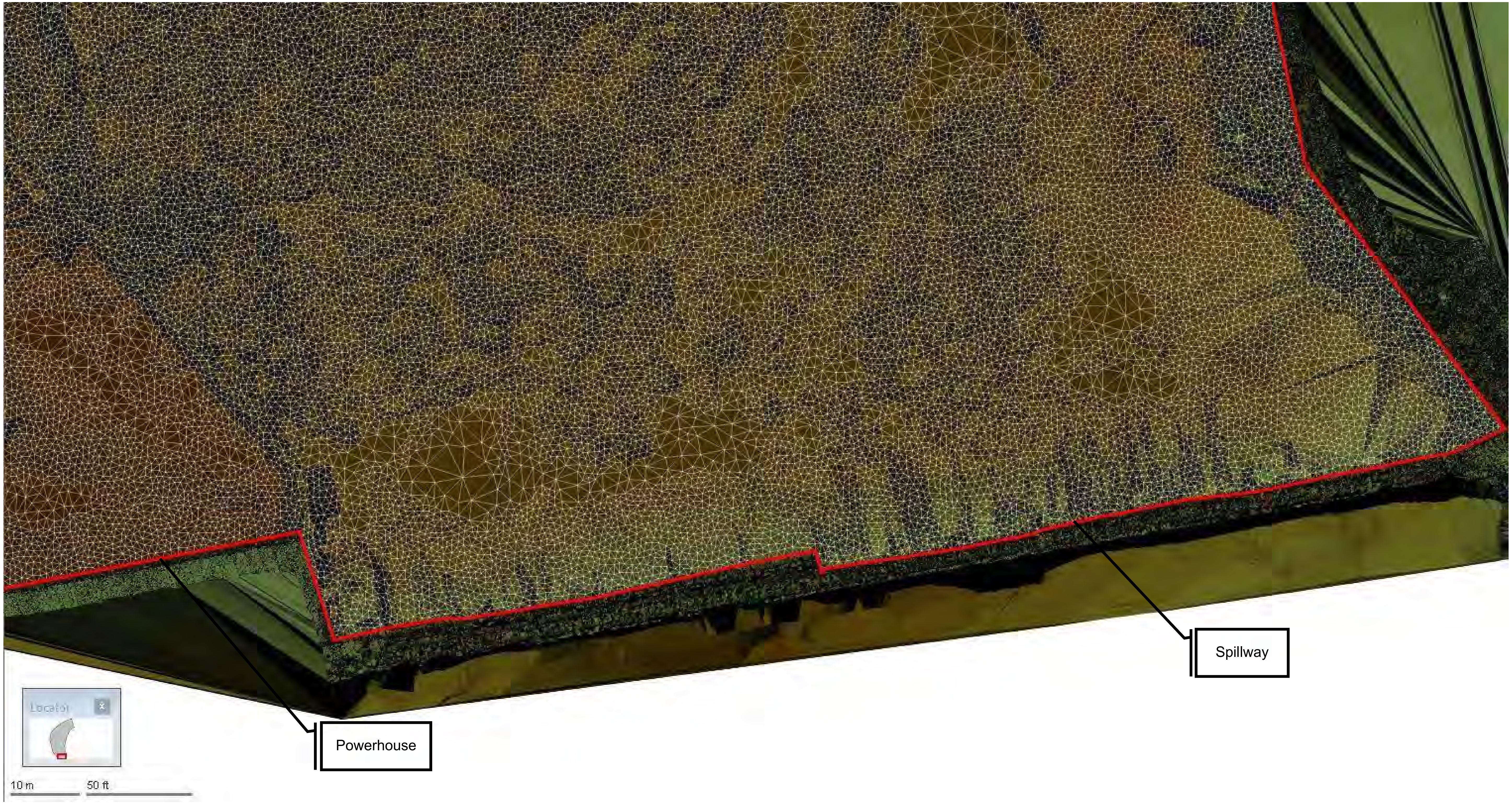

Figure 3-3. ICM Mesh Section (North is to the Top of the Figure)

3.3.2 Roughness Zones

Roughness Zones for the 2-D Zone were created in GIS using land cover data provided by VGIS. Roughness Zones were assigned a Manning's *n*-value indicated in Table 3-2 (Chow 1959). Table 3-2 presents the roughness values used in the model. The land cover is shown in Figure 3-4. Note, the open water code was separated into three separate areas to represent the main reach, side channel, and tailrace side of the domain. These three areas have distinctly different substrates that result in varied roughness values from the default open water value.

The main reach substrate is mostly bedrock, the side channel substrate is mostly cobble, and the tailrace side has mostly a sandy bottom. The roughness values for these open water areas are shown in Table 3-2.

Table 3-2. Manning's *n* Roughness Values

Description	Grid Code	Roughness
Open Water – Main Reach	11	0.025
Open Water – Side Channel	11	0.035
Open Water – Tailrace Side	11	0.050
Developed, Open Space	21	0.040
Developed, Low Intensity	22	0.100
Barren Land	31	0.025
Deciduous Forest	41	0.160
Evergreen Forest	42	0.160
Shrub/Scrub	51	0.100
Grassland/Herbaceous	71	0.035
Emergent Herbaceous Wetlands	91	0.070

The Manning's *n*-values utilized for this analysis provide a reasonable assessment of current conditions at the project site when evaluating the hydraulics of the bypass reach.

Figure 3-4. Land Cover Raster for Manning's *n* Roughness

3.3.3 Initial Hydraulic Conditions

Both the bypass reach and tailrace were allowed to start from a dry condition to allow the pools within the bypass reach to fill as they naturally would during a real-life spill event.

3.3.4 Boundary Conditions

The primary 2-D Zone boundary condition (i.e., "vertical wall" Boundary Point settings in Table 3-1) was selected based on the topography at the edge of the 2-D Zone. This boundary condition is considered to be an impermeable and infinitely high barrier that does not allow water to flow into or out of the 2-D Zone unless specified with another boundary condition.

In addition to the primary 2-D Zone boundary condition, three additional boundary conditions were incorporated into the Model. An upstream boundary condition was defined at the spillway where the leakage and Tainter Gate inflow hydrographs were applied. A second upstream boundary condition was defined at the powerhouse outlet where the powerhouse flows were introduced. See Section 2 for discussion of the model inflows. The final boundary condition was located at the downstream end of the 2-D Zone on the New River and allows water to leave to 2-D Zone assuming normal depth. Under this condition it is assumed that slope balances friction forces (normal flow) i.e., depth and velocity are kept constant when water reaches the boundary, so water can flow out of the 2-D Zone without energy losses.

4 Results

The model inputs discussed above were used to set up four scenarios which represent the four test flows. Due to the complexity of the Model and mesh representing the New River, Model outputs presented in this calculation are limited to select locations and points of interest.

4.1 Model Calibration and Verification

Field data points collected during the flow testing as well as timing of releases recorded by the level loggers in the bypass reach were used to calibrate and verify the model setup.

4.1.1 Point Water Surface Elevations

Water surface elevations collected at thirteen of the fourteen deployed level loggers were compared to water surface elevations predicted by the model. Figure 4-1 through Figure 4-4 show the water surface elevation comparisons for the four test flow scenarios. Field measurement data points are colored by magnitude of percentage difference between field and modeled water surface elevations. The ranges of percentage difference and absolute difference for the four scenarios are presented in Table 4-1.

The hydraulics downstream of Byllesby dam and resulting safety issues limit survey point data collection to the banks of the reach. A triangulation effect from the creation of the DTM occurs where the LiDAR and bathymetry data points meet; therefore, the Model must interpolate between the LiDAR and bathymetry points, which can result in overestimation of the elevations along the bank.

Because of this model limitation, accurately modeling hydraulics, including the water surface elevations along banks, is challenging.

Table 4-1. Point Water Surface Elevation Comparison

	Minimum Delta		Maximum Delta		Average Delta	
Flow	Percentage	Magnitude (ft)	Percentage	Magnitude (ft)	Percentage	Magnitude (ft)
Leakage	-0.12%	-2.5	0.13%	2.7	0.01%	0.2
Low	-0.12%	-2.4	0.08%	1.6	-0.02%	-0.3
Mid	-0.14%	-2.9	0.1%	2.1	0.01%	0.1
High	-0.16%	-3.15	0.09%	1.8	0.01%	0.2

Figure 4-1. Field vs Modeled Water Surface Elevations – Leakage Flow

Figure 4-2. Field vs Modeled Water Surface Elevations – Low Flow

Figure 4-3. Field vs Modeled Water Surface Elevations – Mid Flow

Figure 4-4. Field vs Modeled Water Surface Elevations – High Flow

4.1.2 Wetted Area Comparison

The total wetted area in the bypass reach increases with increasing test flows. Table 4-2 presents the incremental differences predicted by the model of the total modeled reach wetted area between the various test flows. Because the volume of water released from the powerhouse during the test flows was more than 10 times the volume released at the bypass, the side channel hydraulics are not affected by bypass release flows. While providing flow from Tainter Gate 6 increased the wetted area from the leakage condition in the Bypass Reach, varying the flow releases did not greatly affect the wetted area. Table 4-2 through Table 4-4 present incremental differences of wetted area for the model domain, bypass reach, and side channel, respectively.

Table 4-2. Total Model Domain Wetted Area Comparison

Bypass Reach Flow	Total Wetted Area (Acres)	Percent Delta from Leakage	Incremental Area Increase (Acres)
Leakage	37.2	N/A	N/A
Low	38.9	4.6%	1.7
Mid	38.9	4.4%	-0.1
High	39.2	5.2%	0.3

Table 4-3. Bypass Reach Wetted Area Comparison

Bypass Reach Flow	Total Wetted Area (Acres)	Percent Delta from Leakage	Incremental Area Increase (Acres)
Leakage	3.4	N/A	N/A
Low	4.4	22.7%	1.0
Mid	4.6	30.0%	0.3
High	5.7	32.8%	0.1

Table 4-4. Side Channel Wetted Area Comparison

Bypass Reach Flow	Total Wetted Area (Acres)	Percent Delta from Leakage	Incremental Area Increase (Acres)
Leakage	2.7	N/A	N/A
Low	2.8	8.7%	0.1
Mid	2.7	5.7%	-0.1
High	2.8	7.0%	0.1

4.1.3 Travel Time

Travel time measures the time it takes an inflow to travel between designated points in the bypass reach. This measurement is an important data point used for verifying a number of model inputs including the Manning's *n* roughness values presented in Section 3.3.2, inflow, and overall bypass reach slope from the LiDAR data/DTM are appropriate for the analysis. Additionally, it provides insight into model hydraulics, specifically the average velocity within the bypass reach.

Because the majority of flow (over 87%) below Byllesby dam during the test flows came from the Powerhouse, travel times due to spillway releases are limited to the Bypass Reach. For this analysis, the travel time was measured between BYWL-BPR2 and BYWL-BPR4 (for reference see Figure 2-1). Table 4-5 presents travel times measured by the level loggers and predicted by the model. A s leakage is constant, travel time is not measured for that flow condition. Additionally, a broken flashboard provided a constant flow for the Low flow scenario and the travel time was not measured.

Table 4-5. Travel Times

Bypass Reach Flow	Level Logger Time (hr:min)	Model Time (hr:min)	Delta (hr:min)
Leakage	N/A	N/A	N/A
Low	N/A	N/A	N/A
Mid	0:06	0:05	0:01
High	0:02	0:01	0:01

The model predicts slightly faster travel times than seen in the field. The small deltas between field and model data confirm the modeling inputs are appropriate and average velocities calculated are representative of field conditions.

4.1.4 Depth and Velocity Maps

Depth and velocity heat maps were generated for the four test flow scenarios. These maps are a useful tool for interpreting the habitat suitability maps presented in the Byllesby-Buck Bypass Reach Flow and Aquatic Habitat Report. Depth heat maps are presented in Figure 4-5 through Figure 4-8, and velocity heat maps are presented in Figure 4-9 through Figure 4-12.

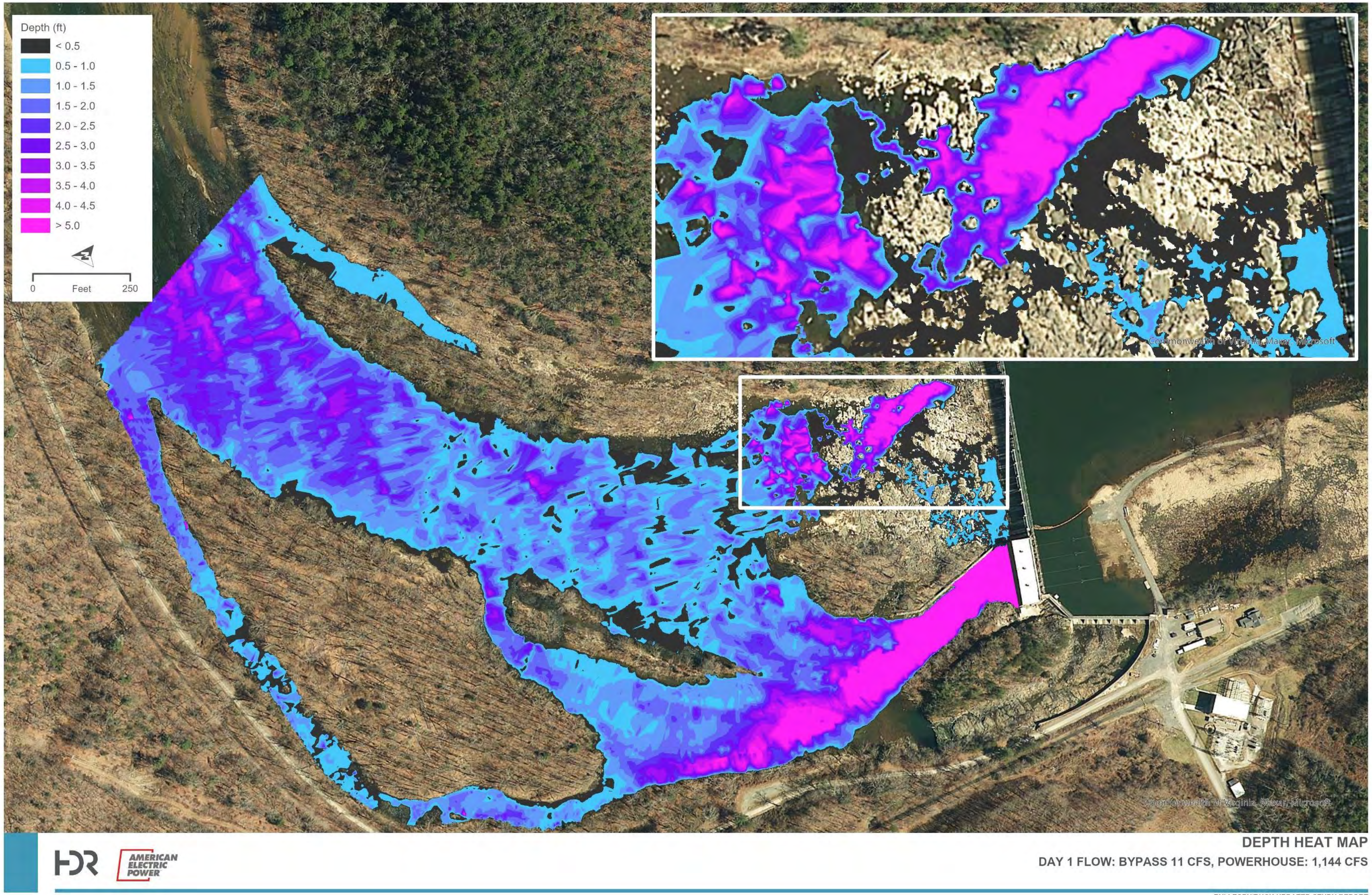

Figure 4-5. Depth Heat Map – Leakage Flow

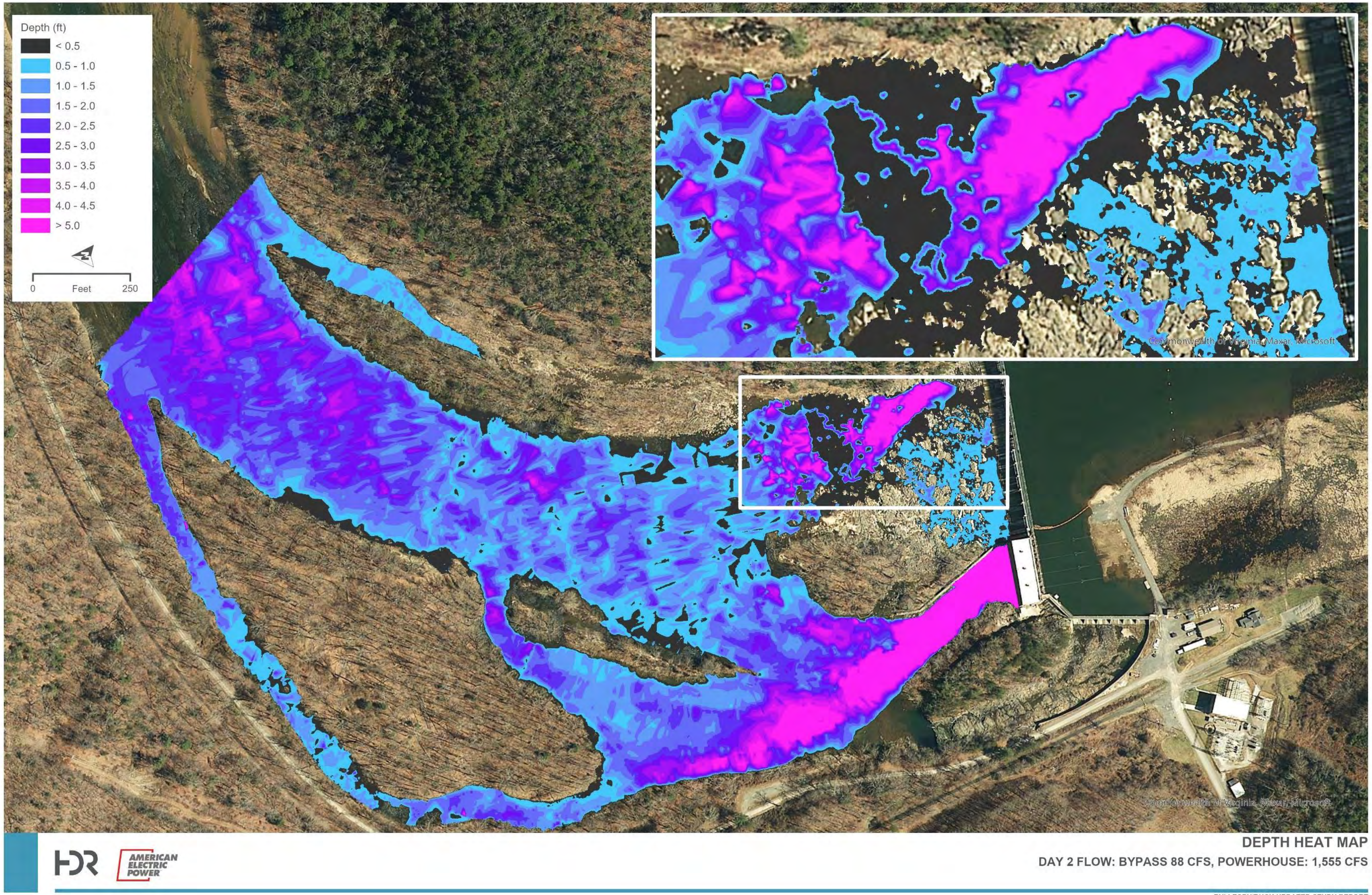

Figure 4-6. Depth Heat Map – Low Flow

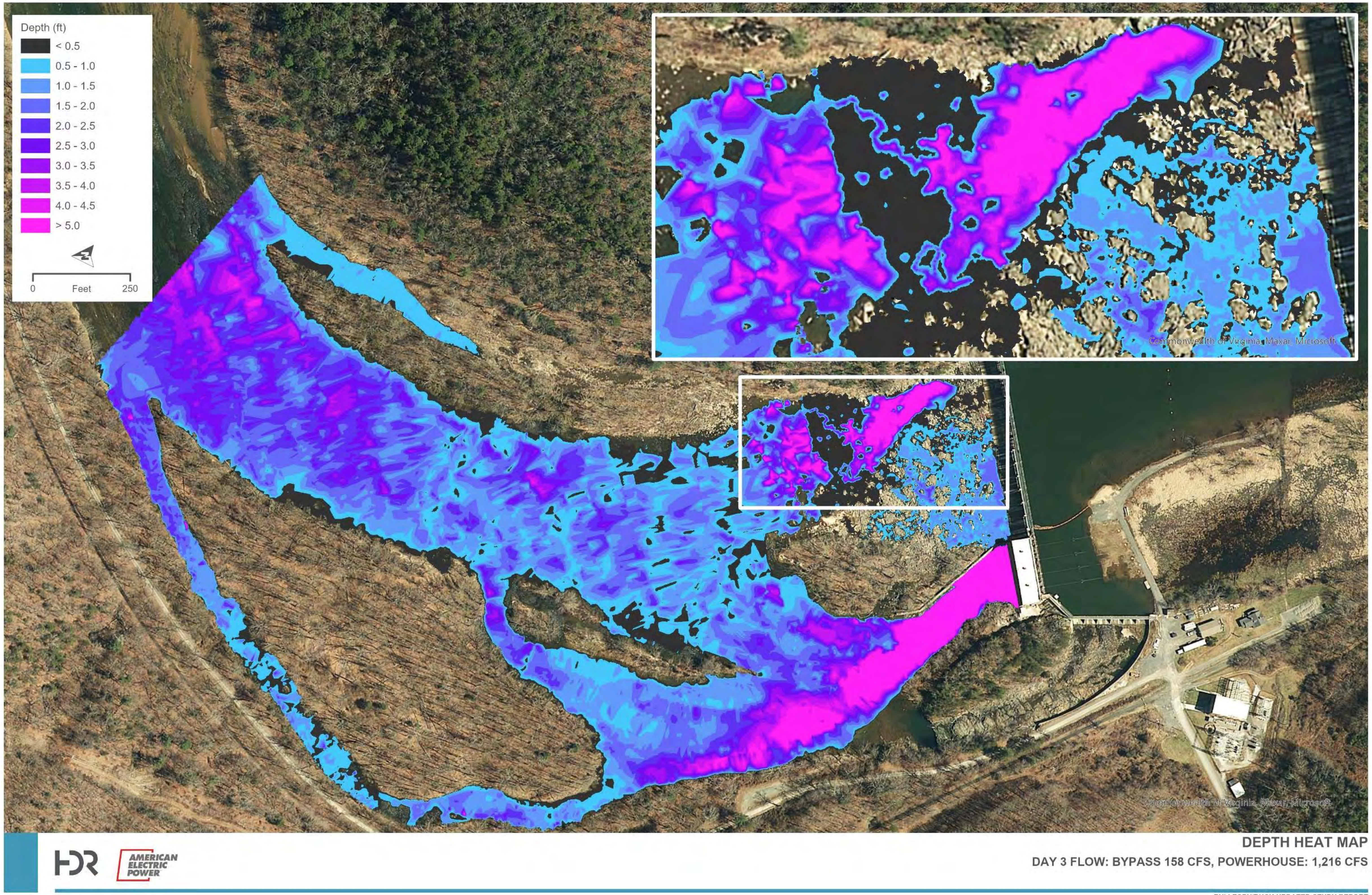

Figure 4-7. Depth Heat Map – Mid Flow

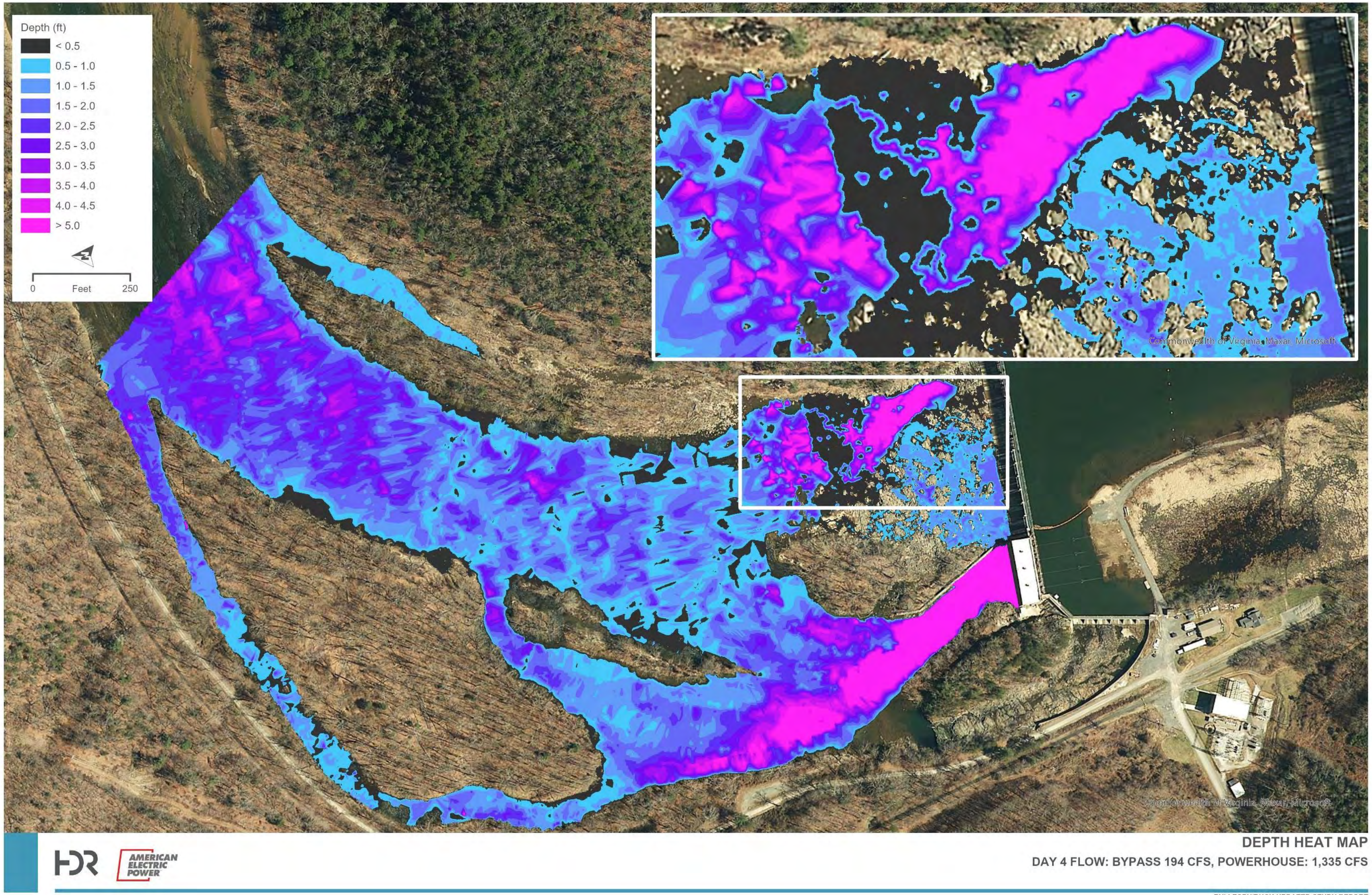

Figure 4-8. Depth Heat Map – High Flow

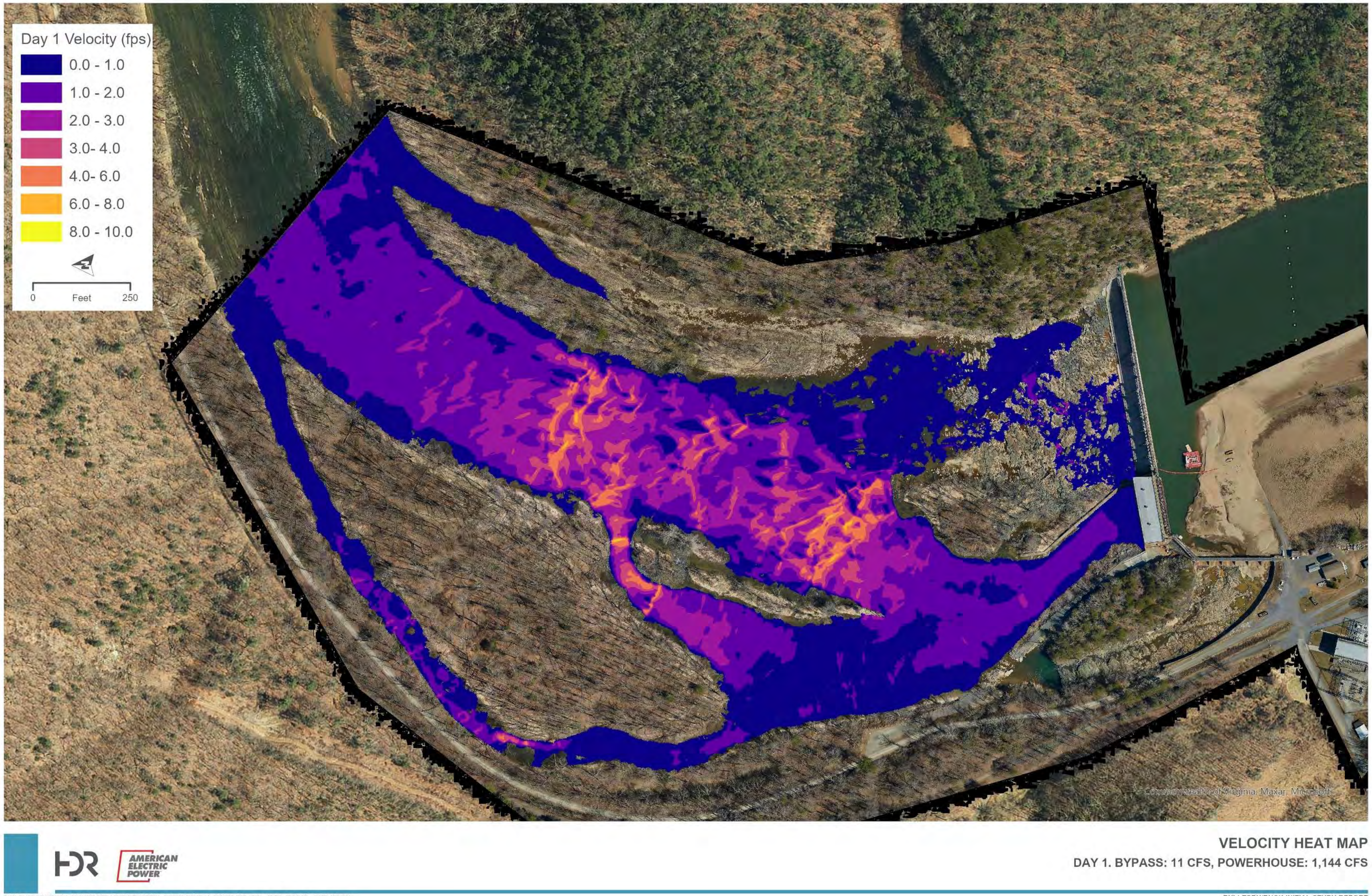

Figure 4-9. Velocity Heat Map – Leakage Flow

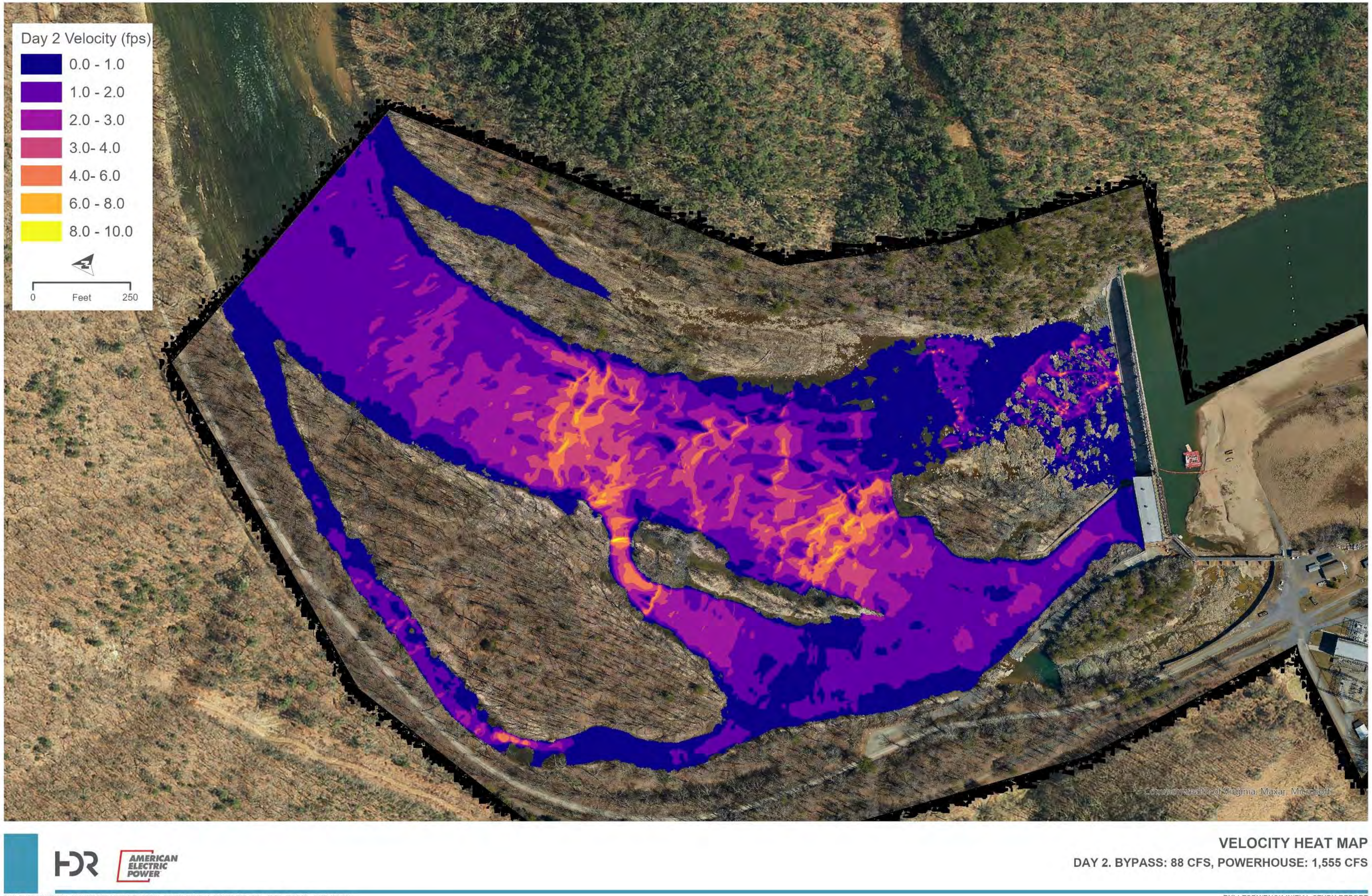

Figure 4-10. Velocity Heat Map – Low Flow

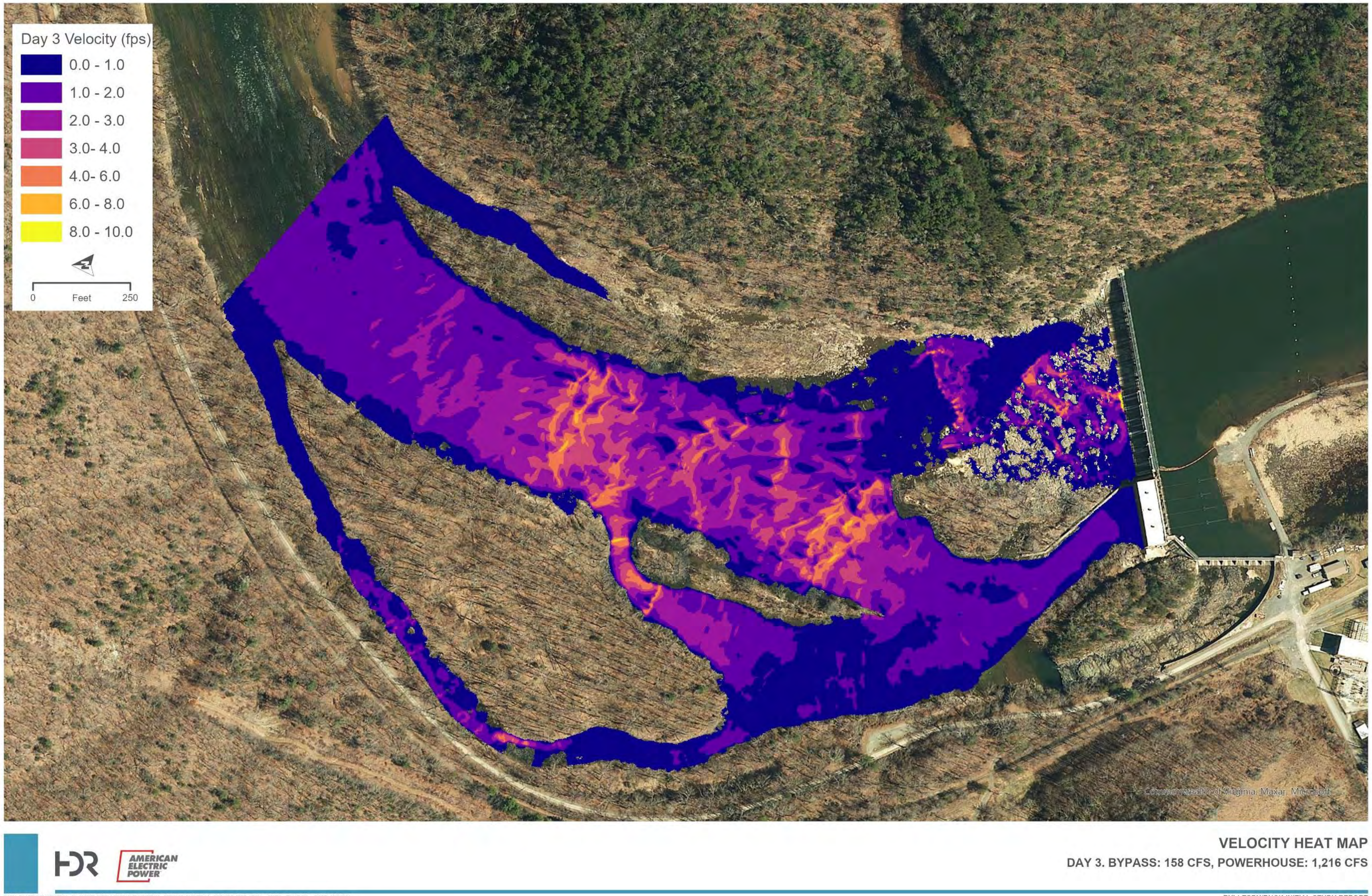

Figure 4-11. Velocity Heat Map – Mid Flow

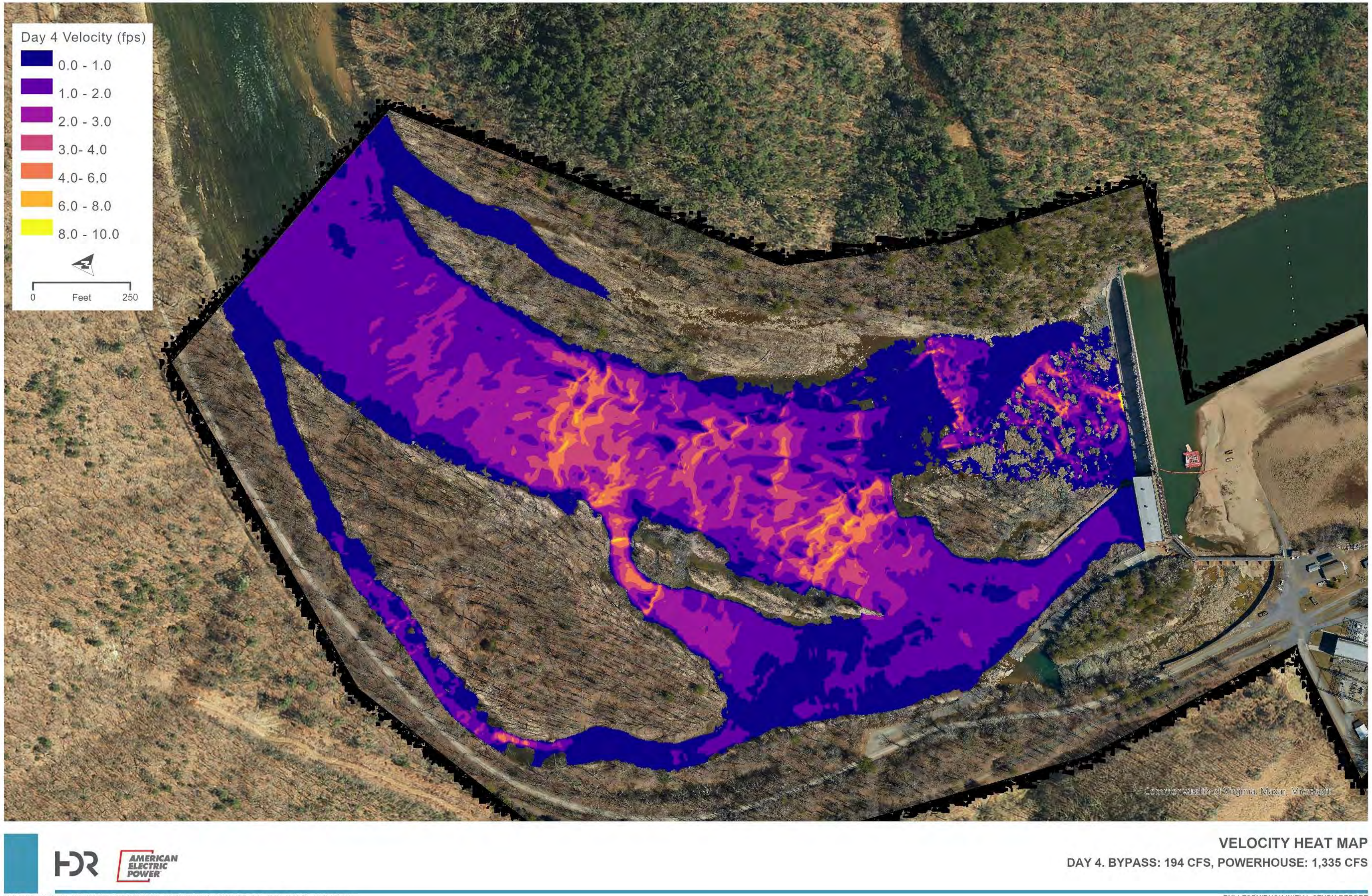

Figure 4-12. Velocity Heat Map – High Flow

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Buck Bypass Reach ICM Model Development

Byllesby-Buck Hydroelectric Project (FERC No. 2514)

April 14, 2022

Prepared by:

HDR

Prepared for:

Appalachian Power Company

APPALACHIAN POWER

An AEP Company

BOUNDLESS ENERGY

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Acronyms and Abbreviations

2-D	2-Dimensional
ADCP	Acoustic Doppler current profiler
AEP	American Electric Power
cfs	cubic feet per second
DTM	Digital Terrain Model
ESRI	Environmental Systems Research Institute
ft	feet/foot
ft msl	feet above mean sea level (NGVD29)
GIS	Geographic Information Systems
GPS	Global Positioning System
ICM	Integrated Catchment Model
ICM Model	2-D Innovyze Infoworks Integrated Catchment Model
LiDAR	Light Detection and Ranging
Model	2-D ICM Model
QSI	Quantum Spatial, Inc.
Project	Byllesby-Buck Hydroelectric Project
R10 GPS	Trimble® R10 GPS
TIN	Triangulated Irregular Network
VGIN	Virginia Geographic Information Network
WSEL	Water Surface Elevation

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1 Project Background

1.1 Purpose and Scope

This report presents the final results of the 2-Dimensional (2-D) Buck Bypass Reach model developed using Innovyze Infoworks Integrated Catchment Model (ICM) software. The 2-D Buck Bypass Reach ICM model (Model) was used to predict hydraulic regimes in the bypass reach under varying flows and from varying spill locations. The results of the Model were used in conjunction with habitat analysis presented in the Byllesby-Buck Bypass Reach Flow and Aquatic Habitat Study Report to develop habitat suitability maps under the various flow scenarios. These maps are presented in Appendix A, Attachment 3 of the Byllesby-Buck Updated Study Report.

1.2 Study Area

The Byllesby-Buck Hydroelectric Project (FERC Project No. 2514-VA) (Project) is owned and operated by Appalachian Power Company, a subsidiary of American Electric Power (AEP). The Project is located on the New River in Carrol County, Virginia and consists of the Byllesby and Buck Dams. Byllesby Dam is approximately 7.8 miles downstream Fries, Virginia and Buck Dam is approximately 2.5 miles downstream of Byllesby Dam.

2 Model Development

2.1 Flow Study Field Data Collection

To aid calibration and validation of the Model phased flow data collection was performed under varying flows. Eleven level loggers (Onset® U-20 brand pressure transducers that measure water stage change with high precision) were deployed in the Buck Bypass reach prior to the target flow releases. The Onset® U-20 instrumentation documents a measured water level with an accuracy of ±0.01 feet (ft). Reference water elevations were collected using a staff gage at each level logger when installed. Level loggers recorded water surface elevation data at 5-minute intervals providing detail for travel time, and rates of rise estimations used in the Model calibration. Locations of the deployed level loggers are shown in Figure 2-1.

Four target flow releases were performed over four days and two separate trips, September 8th through 10th and September 15th through 17th. Each target flow was designed to capture a specific/stable flow in the bypass reach. Flows were delivered to the bypass reach via leakage through the closed spillway gates and flashboard bays and/or Tainter Gate 1. Total flows in the bypass reach were recorded using a handheld manual Swoffer flow meter for the Day 1 (leakage) and Day 2 (0.5 ft gate opening) target flows and using an Acoustic Doppler current profiler (ADCP) for the Day 3 and Day 4 (1 ft and 2 ft gate opening, respectively) target flows. Gate settings and resulting flows (cubic ft per second [cfs]) are provided in Table 2-1. Figure 2-2 shows the various flow measurement locations in the bypass reach and tailrace. Note Big Branch is a small tributary that drains approximately 2.5 square miles and its confluence with the New River is approximately 800 feet upstream of the tailrace-bypass reach confluence. To isolate bypass reach flow release effects on habitat and hydraulics, the minimal flows contributed by Big Branch were not included in the study.

Table 2-1. Buck Tainter Gate 1 Settings and Bypass Reach Flow

Tainter Gate 1 Opening (ft)	Bypass Reach Flow (cfs)
Day 1: Closed (Leakage Flow)	17
Day 2: 0.5 (Low Flow)	211
Day 3: 1.0 (Mid Flow)	354
Day 4: 2.0 (High Flow)	714

In addition to the field data collected during the target flows, an Inspire 2 drone equipped with a Zenmuse X5S camera using a ground sample distance of 1-inch per pixel was used to capture an aerial imagery orthomosaic of the steady-state flow conditions for each target flow in the immediate vicinity of the bypass reach and tailrace. These orthomosaics are presented in Section 4.1.3.

A Trimble® R10 Global Positioning System (R10 GPS) using Static Global Navigation Satellite System positioning with horizontal and vertical accuracies of 3 millimeters and 3.5 millimeters, respectively, was used to gather water surface elevation point data at various locations in the bypass reach during each target flow event. Due to time constraints and satellite coverage effects, a limited number of R10 data points were gathered during the Low target flow event on September 10th. The R10 data points are colored by target flow scenario and shown in Figure 2-3.

In conjunction with the level logger and R10 data recording, point velocity and depth measurements were collected using a Swoffer flow meter at various locations during the Day 1 (Leakage) and Day 2 (Low) target flows after steady-state river conditions were reached. Due to safety concerns, depth and velocity data was not captured for the Day 3 (Mid) and 4 (High) target flow scenarios. Figure 2-4 shows point velocity and depth measurement locations.

Steady-state conditions were verified in the field using temporary staff gages. All discharge measurements were made a minimum of three times or until there was less than 5 percent difference between measurements.

Upon completion of the target flow events, the level logger data were downloaded and the loggers were redeployed to collect depth data for an additional three weeks. Data from this long-term deployment was used to further characterize the hydraulics of the bypass reach under a larger range of flow/spill conditions present outside of the two-week target flow measurement period.

The data collection plan enabled correlation of gate openings, flow, and water surface elevations at select locations within the bypass reach. The data was used to enhance understanding of travel times and rates of rise under conditions experienced during the collection period.

Figure 2-1. Buck Bypass Reach Level Logger Locations

Figure 2-2. Flow Measurement Transects

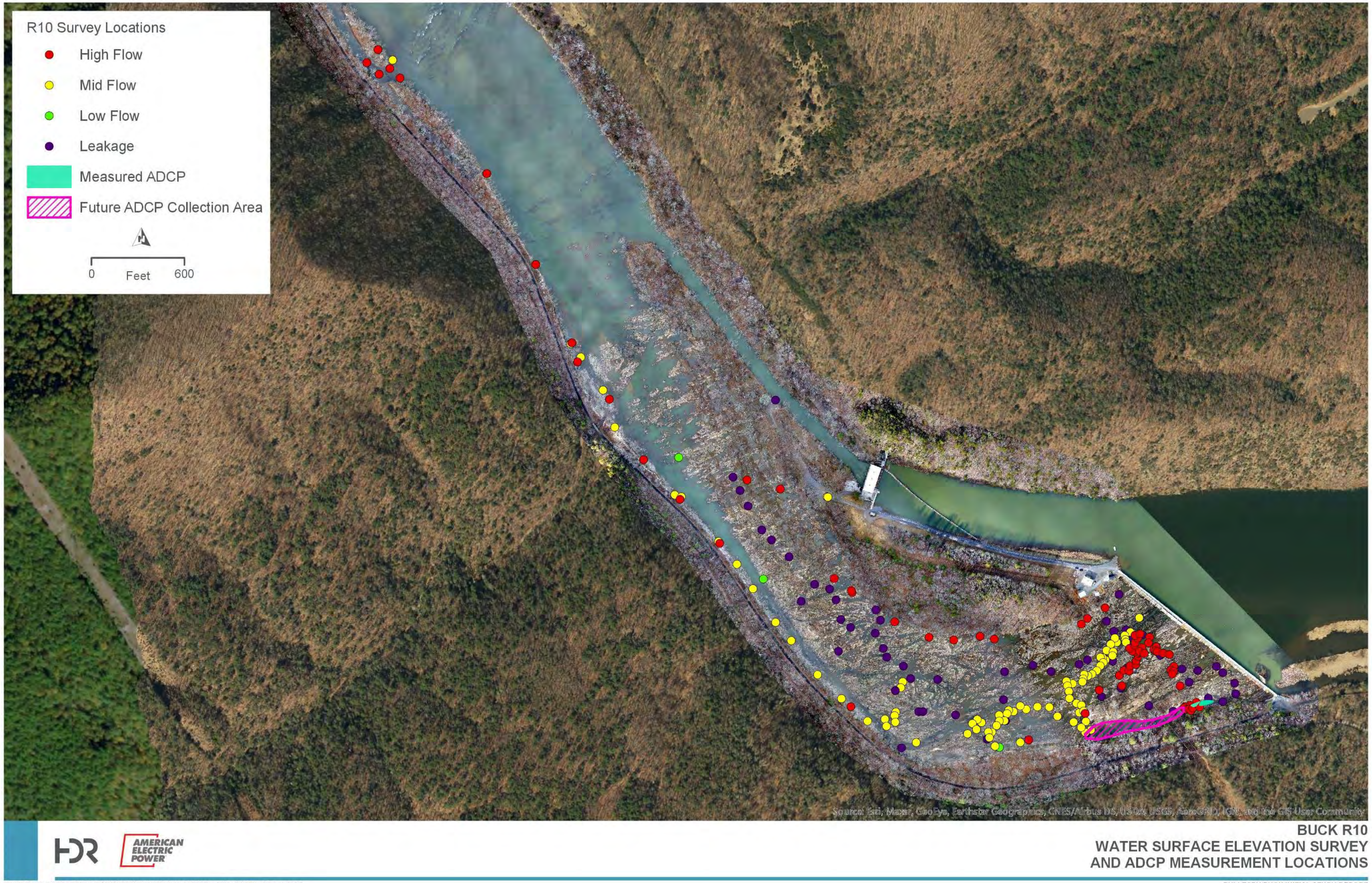

Figure 2-3. R10 Water Surface Elevation Points and ADCP Data Collection Areas

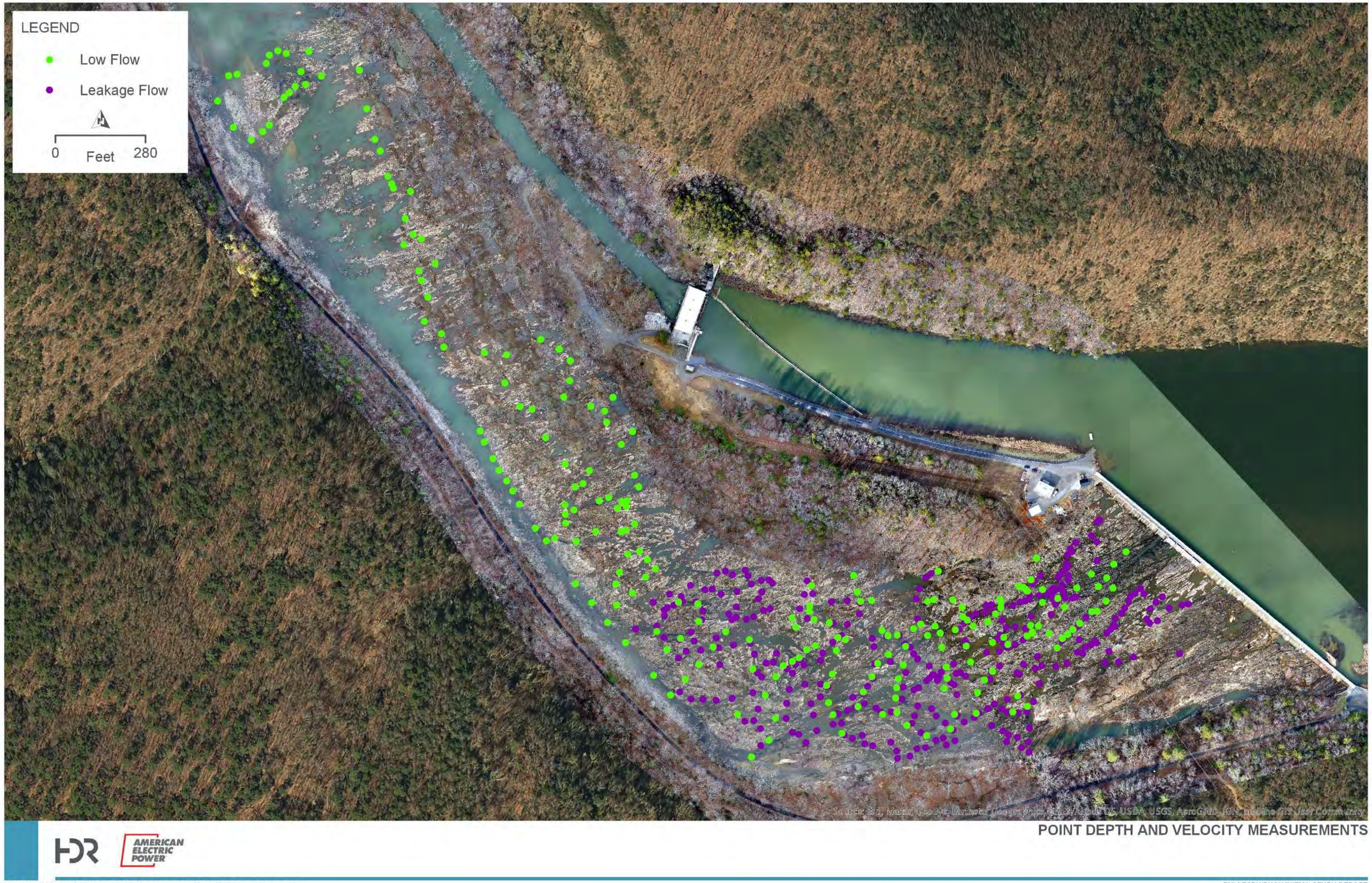

Figure 2-4. Manual Swoffer Flow Meter Depth and Velocity Point Measurements

2.2 Terrain Data

Light Detection and Ranging (LiDAR) data were collected for the entire Buck bypass reach from the spillway extending down past the confluence with the tailrace. HDR contracted with Quantum Spatial, Inc. (QSI) to collect and process LiDAR data at the lowest possible bypass channel flow (QSI 2020). Additionally, LiDAR data collected by the Virginia Geographic Information Network (VGIN) and available through the Virginia LiDAR web mapping application were downloaded. VGIN collected the data according to the United States Geological Survey 3DEP specifications (USGS 2021).

Bathymetry data collected during the target flow measurements were integrated into the LiDAR data in a common coordinate system and datum. Coincident with the target flow field effort, HDR used the ADCP connected to the Global Positioning System (GPS) network to define the bathymetry of two pools on the southwest side of the bypass reach. It is anticipated that additional bathymetry data in this area may need to be collected and incorporated into the model. Measured and anticipated ADCP bathymetry data is shown in Figure 2-3.

The additional bathymetric data was used to describe the channel below the water surface level present when the LiDAR was flown. The bathymetry was supplemented in pools by interpolating areas within the pools using professional judgment and field observed depths and elevations.

The Digital Terrain Model (DTM) used in the Buck Bypass Reach Hydraulic Model was developed by combining the three sources (QSI and VGIN LiDAR plus ADCP) of terrain/bathymetry data using professional judgment and field observations. Detailed information on DTM development is presented in Section 3.2.

2.3 Hydraulic Model Development

2.3.1 Conventions and Assumptions

The DTM utilized in the Model was referenced to the North American Vertical Datum of 1988. The DTM was projected using the Virginia State Plane Coordinate System (i.e., U.S. Survey Foot) and horizontally referenced to the North American Datum of 1983.

The Model was developed with the following assumptions:

- In addition to LiDAR data, VGIN provides land cover data at 1-meter resolution. This dataset was used for the model Manning's *n* roughness. Detailed discussion of the Manning's roughness is provided in Section 3.
- Powerhouse outflows were measured in the tailrace using the ADCP for the Day 1 (Leakage) and Day 2 (Low) target flow events. An approximate flow of 1,700 cfs was used for the Leakage and Low flow scenarios. Due to safety concerns, tailrace flows were not measured for the Day 3 (Mid) and Day 4 (High) target flow scenarios. To determine the powerhouse outflow for these cases, the measured bypass reach flow was subtracted from the reported flow measured at the USGS New River at Ivanhoe, Virginia gage approximately 1.75 miles downstream of the Buck development.

On September 15th and 16th, the USGS gage reported mean flows of 3,060 cfs and 2,640 cfs in the New River, respectively. Flows of 2,700 and 1,925 cfs were then used as powerhouse outflows for the Day 3 (Mid) and Day 4 (High) target flow scenarios, respectively. Due to the close proximity of the USGS gage, accretion flow between the Buck development and gage was considered negligible. Additionally, due to the geometry of the bypass reach and tailrace, tailrace flows are expected to have negligible impact on bypass reach hydraulics thus an approximate powerhouse outflow is appropriate for this analysis.

- Day 1 (Leakage) flow was measured in the bypass reach using the Swoffer flow meter at three locations, one downstream location to capture the total bypass reach leakage flow, and two upstream locations. Using field observations and these flow measurements, the leakage flow was distributed among the various Tainter gates, Obermeyer gates, and flashboards according to Table 2-2. All scenarios used this setup as the base inflow condition.

Table 2-2. Gate Leakage Flows

Gate	Leakage Flow (cfs)
T2	1.0
T3	1.0
T4	1.0
T5	1.0
T6	1.0
FB6	1.0
FB7	1.0
FB8	2.0
FB9	2.0
FB10	2.0
FB12	0.75
FB15	0.75
FB17	2.15
FB18	2.15

2.3.2 Design Inputs

Additional design inputs include:

- Steady-state inflow hydrographs formed from the base Leakage flow presented in Section 2.3.1 adding 211, 354, and 714 cfs inflows at Tainter Gate 1 for the Low, Mid, and High flow scenarios, respectively.
- Roughness zones (Manning's *n*-values);
- Initial hydraulic conditions – the bypass reach and tailrace begin the simulation dry and are allowed to fill to steady state conditions.
- Boundary conditions (i.e., 2-D Zone boundary, inflow hydrographs, and downstream boundary conditions).

3 Methodology

3.1 ICM Model Development

Innovyze Infoworks ICM Version 7.5 (Innovyze 2016) was used to evaluate the hydraulics of the Bypass Reach. The Model is a fully integrated 2-D hydrodynamic model which facilitates accurate representation of flow paths while enabling complex hydraulics and hydrology to be incorporated into a single model. ICM uses the shallow water equations to develop depth averaged hydraulics results. The Model does not directly model turbulence, but accounts for energy losses due to turbulence due to bed resistance via the Manning's *n* roughness. The modeling domain extends approximately 1.25 miles downstream of the Buck spillway and includes Buck tailrace. The domain is modeled with ICM's 2-D surface flooding module. This portion of the modeling extent is known as the 2-D Zone. The Model allows for detailed hydraulic results and provides a reasonable variability in average flow, depth, and velocity from one water column element to the next throughout the modeled area. The Model is considered appropriate for the evaluation of the bypass reach hydraulics. See Section 2.3.2 for design inputs.

3.2 Digital Terrain Model Development

The DTM used in the Model was constructed with data from several sources:

- Virginia State LiDAR data collected from the VGIN database;
- Supplemental site LiDAR data collected by QSI (QSI 2020); and
- Additional bathymetry measurements collected by HDR in September 2020.

The DTM was projected using the North Carolina State Plane Coordinate System (i.e., U.S. Survey Foot) and horizontally referenced to the North American Datum of 1983 and vertically referenced to the North American Vertical Datum of 1988.

LiDAR data points at two pools of concern on the south western edge of the bypass reach were discarded and bathymetry data in the pools was measured in 2020 using a Teledyne® Rio Grande Acoustic Doppler Current Profiler and a Trimble® AG_GPS receiver equipped with an Omnistar® real-time differential GPS correction. Water depths were converted to elevations using the water surface elevations recorded with the R10 unit at the time of data collection.

The three data sources were converted into triangulated irregular network (TIN) surface files and merged using Environmental Systems Research Institute (Esri™) ArcGIS version 10.3 Geographic Information System (GIS) software (ESRI 2017). The resulting DTM encompassed the entire study area and was used as the basis for developing the conceptual design for the Hydraulic & Hydrologic analysis and modeling discussed in this report.

Figure 3-1 shows the final DTM used in the model and the allocation of terrain data. Blue zones indicate contractor LiDAR data. Red zones indicate ADCP data. The reminder of the data is sourced from the VGIN LiDAR data.

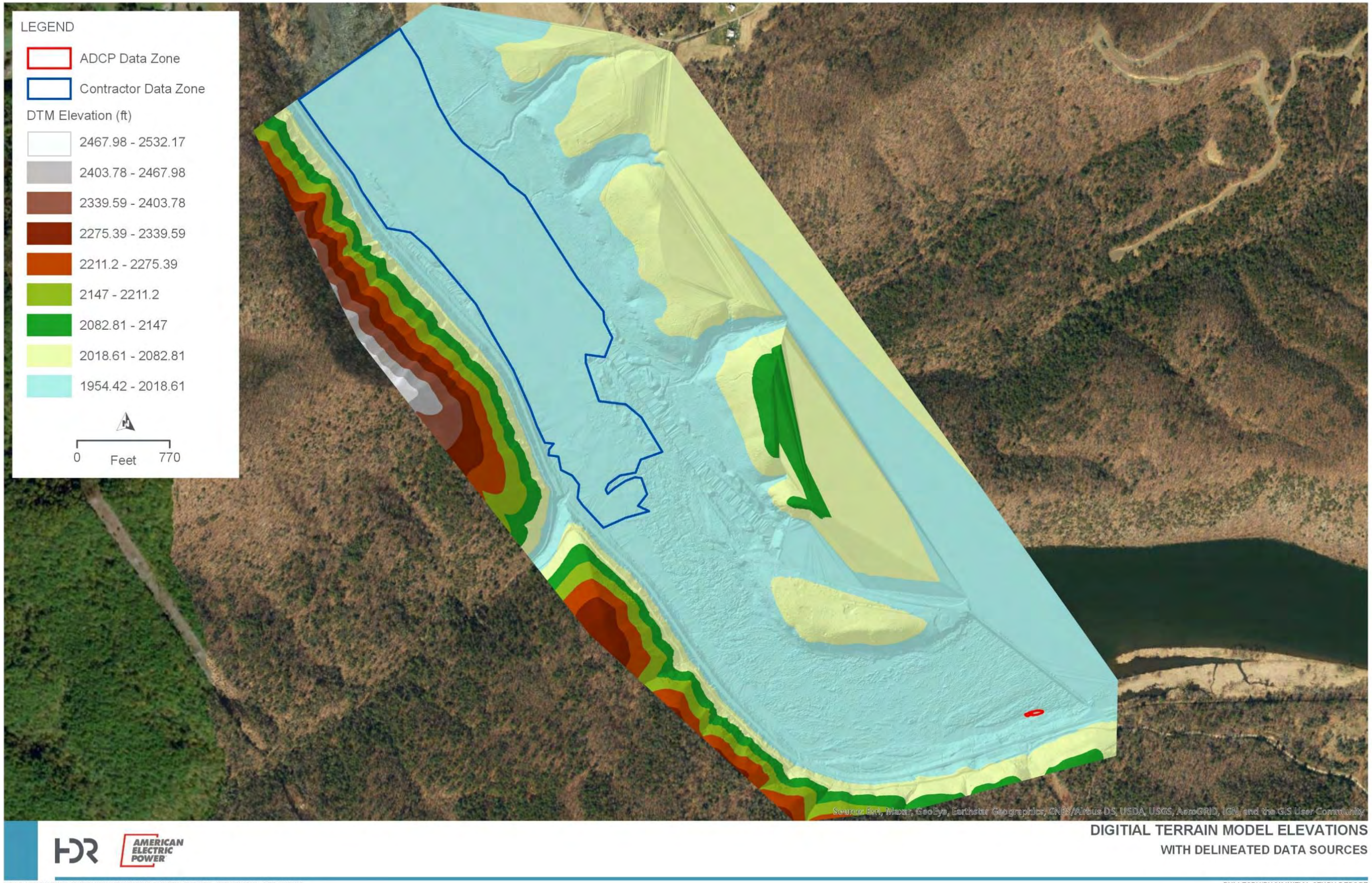

Figure 3-1. Buck Bypass Reach Digital Terrain Model and Data Sources

3.3 ICM

3.3.1 Site Topography

A TIN was created from the following topography data:

The 2-D Zone defining the Model includes approximately 1.25 miles of the New River. Figure 3-2 provides a view of the maximum extent of the 2-D Zone.

For the 2-D simulation, ICM subroutines were used to perform a meshing of the 2-D Zone. The 2-D mesh is comprised of an irregular array of triangles. Descriptions of the user input 2-D Zone data fields that are pertinent to this analysis are as follows:

- Maximum triangle area – A measure of mesh resolution used when creating a 2-D mesh; maximum allowable triangle area for areas in the 2-D Zone that are not inside of a secondary mesh zone.
- Minimum element area – Minimum mesh element area used for calculating results. Mesh elements with area less than the minimum area specified are aggregated with adjoining elements until the minimum area is met. This is done for the purpose of calculating results to improve simulation stability and run time.
- Boundary points – Boundary condition for 2-D Zone.
- Terrain-sensitive meshing – Meshing is used to increase the resolution of the mesh in areas that have a large variation in height without increasing the number of elements in relatively flat areas.
- Maximum height variation – The maximum height variation that is permitted within a single triangle. Triangles with a height variation greater than the assigned value are split provided this would not result in a triangle smaller than the Minimum element area.
- Minimum triangle angle – Minimum allowable angle between triangle vertices when creating a 2-D mesh.
- Roughness – Manning's *n* roughness values, used when creating a 2-D mesh. The roughness value assigned to mesh elements in areas in the 2-D Zone that are not in a roughness zone. Roughness values were selected from published tables (Chow 1959).

Table 3-1 provides a summary of the selected user input values for the ICM meshing routine as well as the total 2-D Zone area.

Table 3-1. ICM Meshing User Inputs and Area Summary

2D zone Object Properties		
Polygon definition		
ID	Buck 2D Zone	
Area (acre)	131.698	#D
Maximum triangle area (ft2)	750.000	
Minimum element area (ft2)	2.500	
Boundary points	Vertical Wall	#D
Terrain-sensitive meshing	☒	
Maximum height variation (ft)	0.125	
Minimum angle (degree)	25.00	#D
Roughness (Manning's n)	0.0230	
Apply rainfall etc directly to mesh	☐	
Apply rainfall etc	everywhere	#D
Rainfall profile	1	#D
Infiltration surface ID		#D
Rainfall percentage	100.000	#D
Mesh summary	----> ...	
Mesh data	----> ...	
General properties		
Notes	...	
Hyperlinks	...	
User defined properties		

A section of the resulting mesh is shown in Figure 3-3. The model mesh contains 927,926 triangles and 926,440 elements. The approximate minimum, maximum, and average element areas are 0.23 square ft, 70 square ft, and 0.57 square ft, respectively.

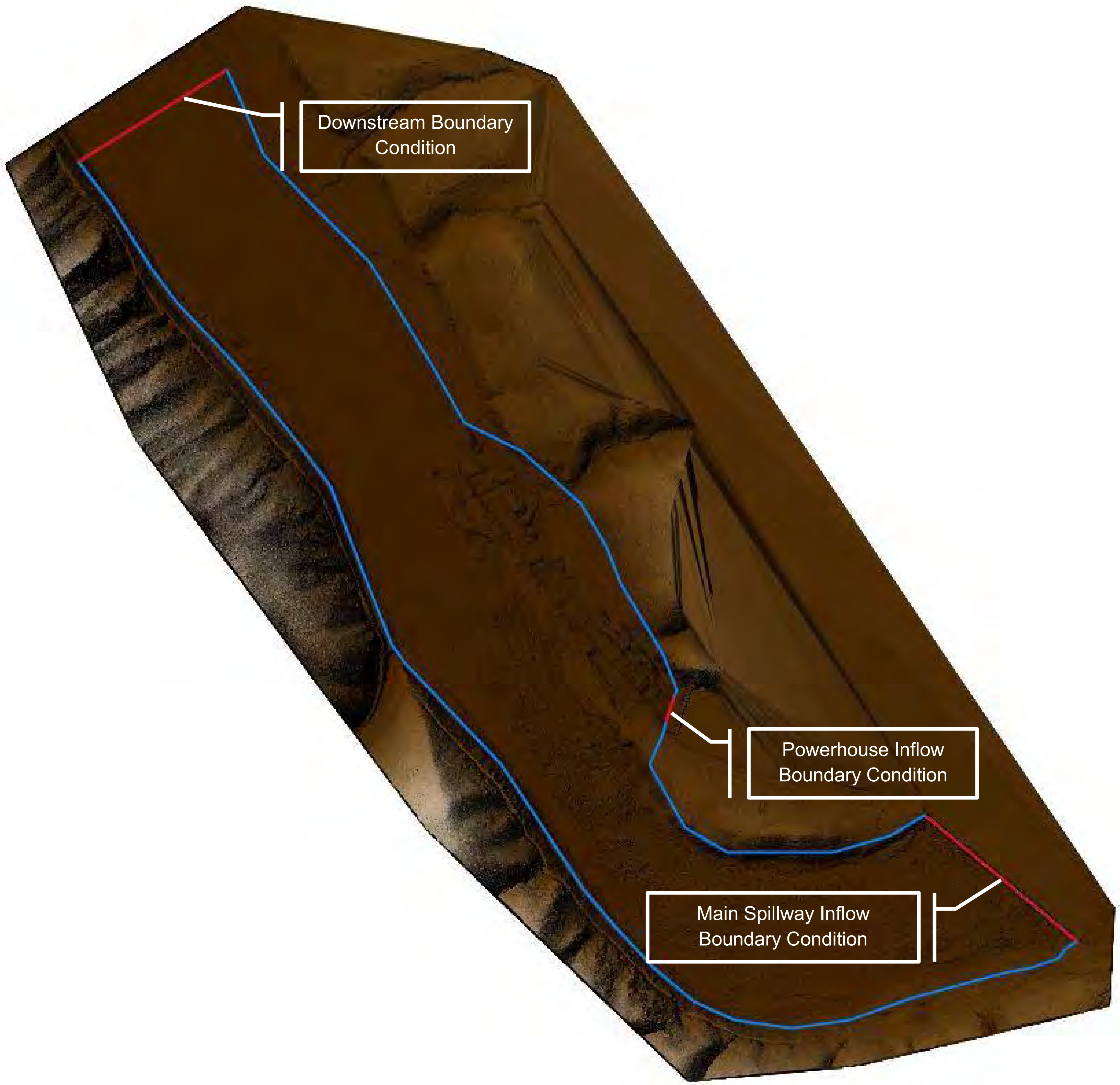

Figure 3-2. Extent of 2-D Zone and ICM Mesh (North is to the Top of the Figure)

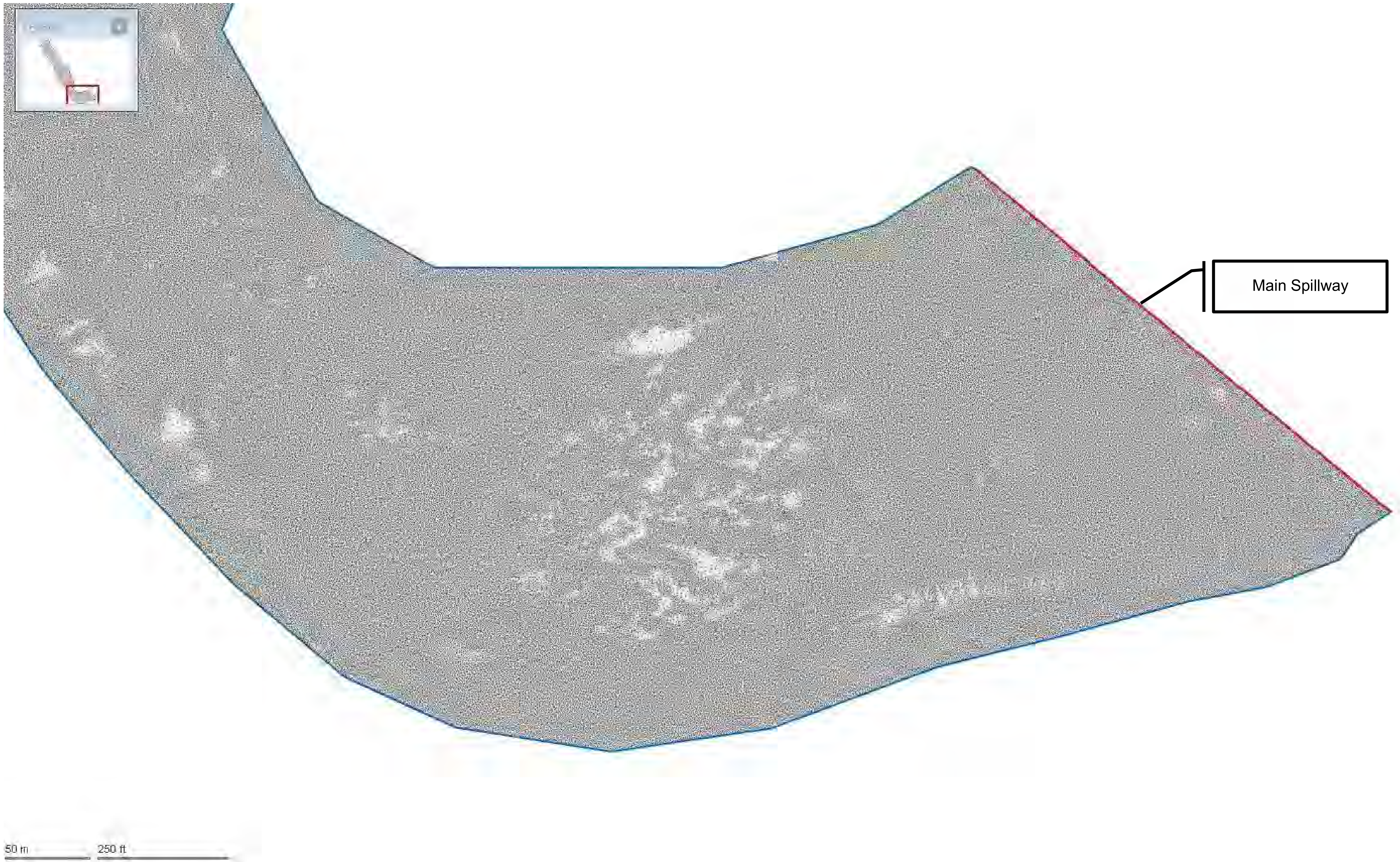

Figure 3-3. ICM Mesh Section (North is to the Top of the Figure)

3.3.2 Roughness Zones

Roughness Zones for the 2-D Zone were created in GIS using land cover data provided by VGIN. Roughness Zones were assigned a Manning's *n*-value indicated in Table 3-2 (Reference 1). Table 3-2 presents the roughness values used in the model. The land cover is shown in Figure 3-4.

Table 3-2. Manning's *n* Roughness Values

Description	Grid Code	Roughness
Open Water	11	0.040
Developed, Open Space	21	0.040
Developed, Low Intensity	22	0.100
Deciduous Forest	41	0.160
Evergreen Forest	42	0.160
Shrub/Scrub	52	0.100
Grassland/Herbaceous	71	0.035
Pasture/Hay	81	0.030

The Manning's n-values utilized for this analysis provide a reasonable assessment of current conditions at the site when evaluating the hydraulics of the bypass reach.

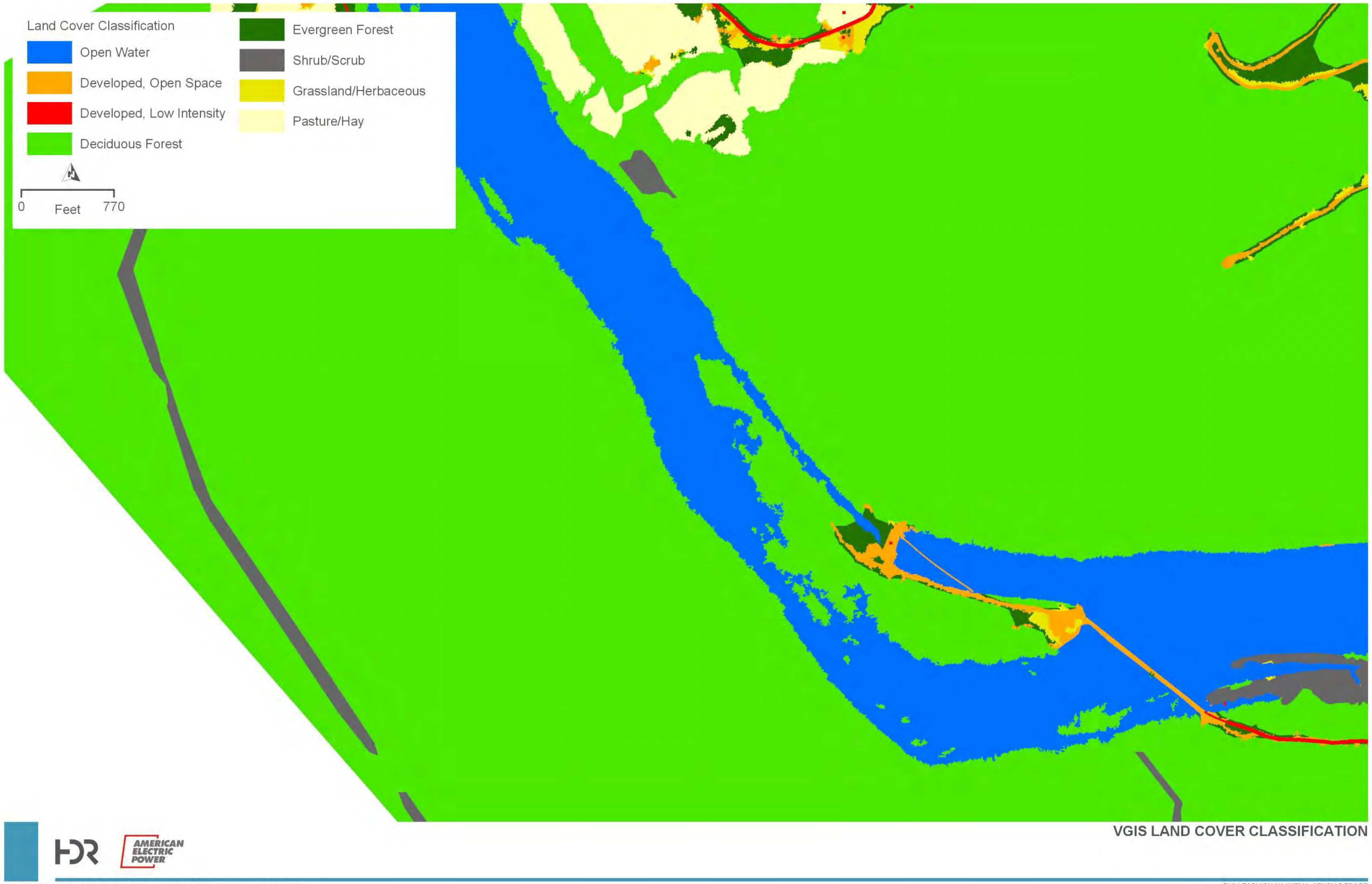

Figure 3-4. Land Cover Raster for Manning's *n* Roughness

3.3.3 Mesh Zone

A single mesh zone representing the Buck tailrace was included in the Model to represent the approximate slope of the tailrace as the tailrace water surface was not captured by the LiDAR survey. The mesh zone polygon was digitized in GIS from an aerial photograph which signifies the typical riverbank location.

3.3.4 Initial Hydraulic Conditions

Both the bypass reach and tailrace were allowed to start from a dry condition to allow the pools within the bypass reach to fill as they naturally would during a real-life spill event.

3.3.5 Boundary Conditions

The primary 2-D Zone boundary condition (i.e., "vertical wall" Boundary Point settings in Table 3-1) was selected based on the topography at the edge of the 2-D Zone. This boundary condition is considered to be an impermeable and infinitely high barrier that does not allow water to flow into or out of the 2-D Zone unless specified with another boundary condition.

In addition to the primary 2-D Zone boundary condition, three additional boundary conditions were incorporated into the Model. An upstream boundary condition was defined at the spillway where the leakage and Tainter Gate inflow hydrographs were applied. A second upstream boundary condition was defined at the powerhouse outlet where the powerhouse flows were introduced. See Section 2 for discussion of the model inflows. The final boundary condition was located at the downstream end of the 2-D Zone on the New River and allows water to leave to 2-D Zone assuming normal depth. Under this condition it is assumed that slope balances friction forces (normal flow) i.e., depth and velocity are kept constant when water reaches the boundary, so water can flow out of the 2-D Zone without energy losses.

4 Results

The model inputs discussed above were used to set up four scenarios which represent the four target flows. Due to the complexity of the Model and mesh representing the New River, Model outputs presented are limited to select locations and points of interest.

4.1 Model Calibration and Verification

Field data points collected during the target flow events, as well as timing of releases recorded by the level loggers in the bypass reach, were used to calibrate and verify the model setup.

4.1.1 Point Water Surface Elevations

Water surface elevations collected by the R10 GPS unit were compared to water surface elevations predicted by the model. Figure 4-1 through Figure 4-4 show the water surface elevation comparisons for the four target flow scenarios. Field measurement data points are colored by magnitude of percentage difference between field and modeled water surface elevations. Figure 4-5 shows the correlation between field and model water surface elevation data for all points collected with the R10

GPS unit during the four target flow days. The ranges of percentage difference and absolute difference for the four target flow scenarios are presented in Table 4-1.

Table 4-1. Point Water Surface Elevation Comparison

	Minimum Delta		Maximum Delta		Average Delta	
Flow	Percentage (%)	Magnitude (ft)	Percentage (%)	Magnitude (ft)	Percentage (%)	Magnitude (ft)
Day 1 (Leakage)	0.00	0.00	0.06	1.17	0.02	0.33
Day 2 (Low)	0.00	0.01	0.07	1.37	0.04	0.75
Day 3 (Mid)	0.00	0.00	0.12	2.30	0.02	0.38
Day 4 (High)	0.00	0.01	0.13	2.53	0.023	0.46

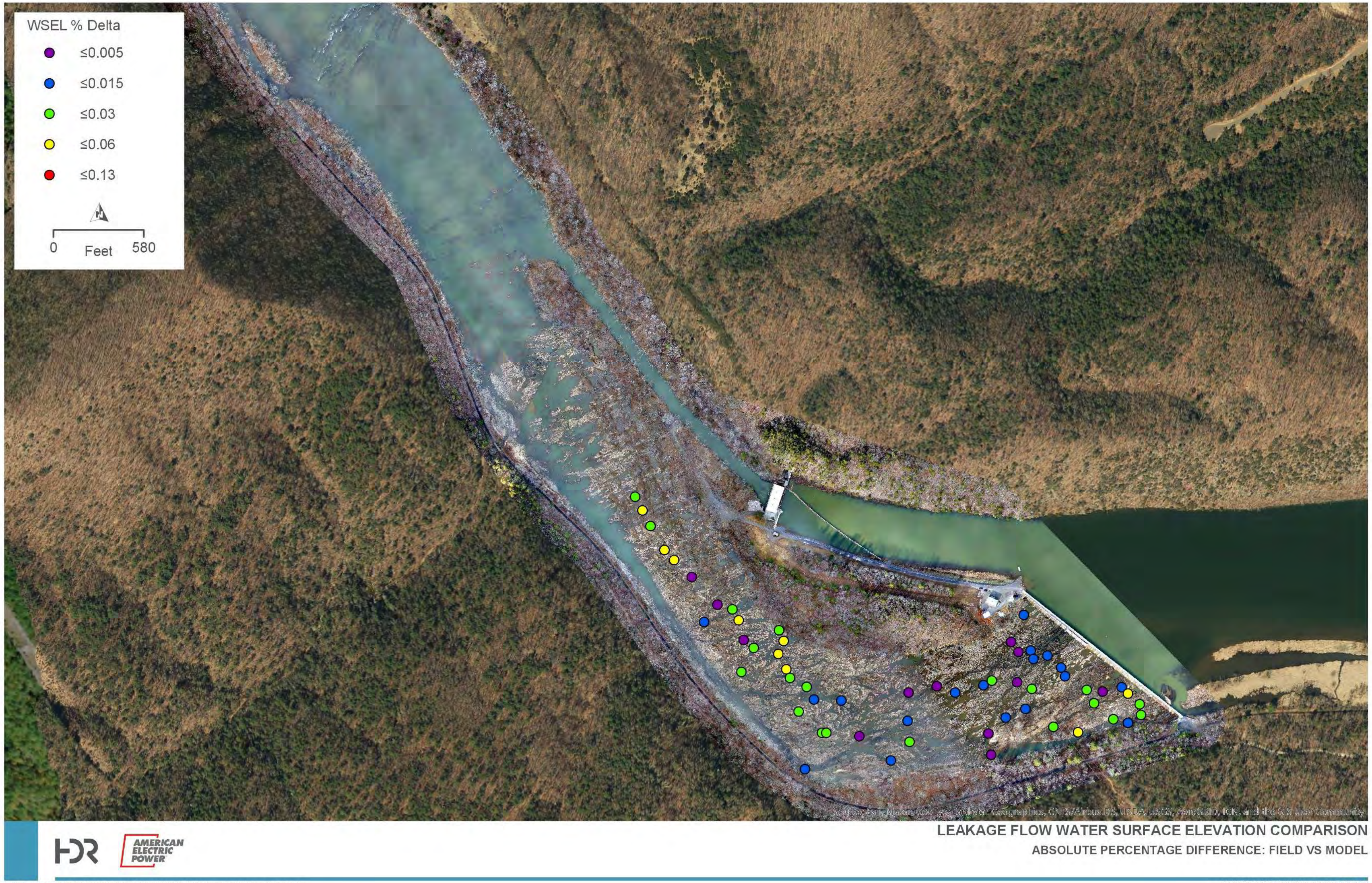

Figure 4-1. Field vs Modeled Water Surface Elevations – Day 1 (Leakage) Target Flow

Figure 4-2. Field vs Modeled Water Surface Elevations – Day 2 (Low) Target Flow

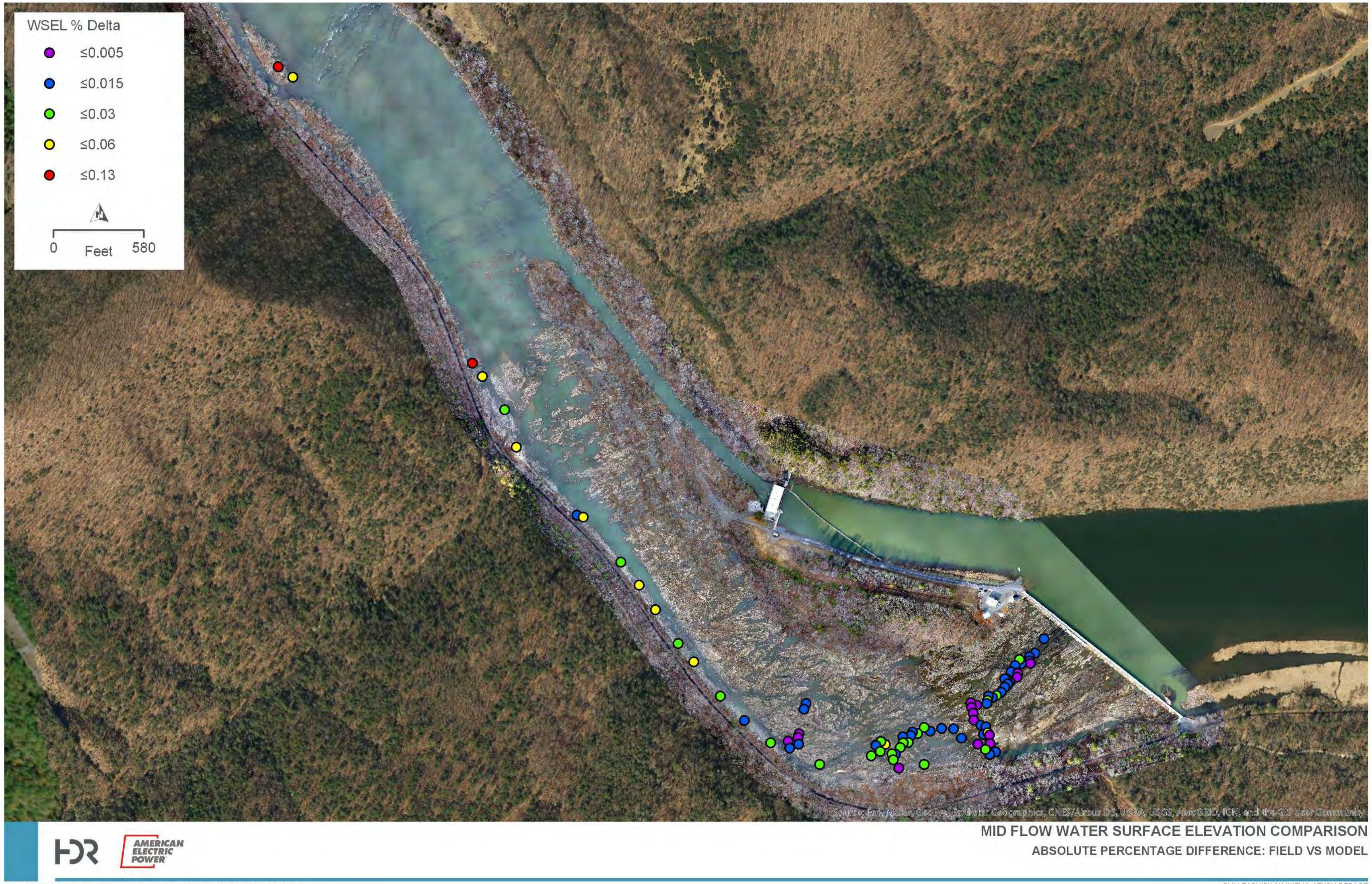

Figure 4-3. Field vs Modeled Water Surface Elevations – Day 3 (Mid) Target Flow

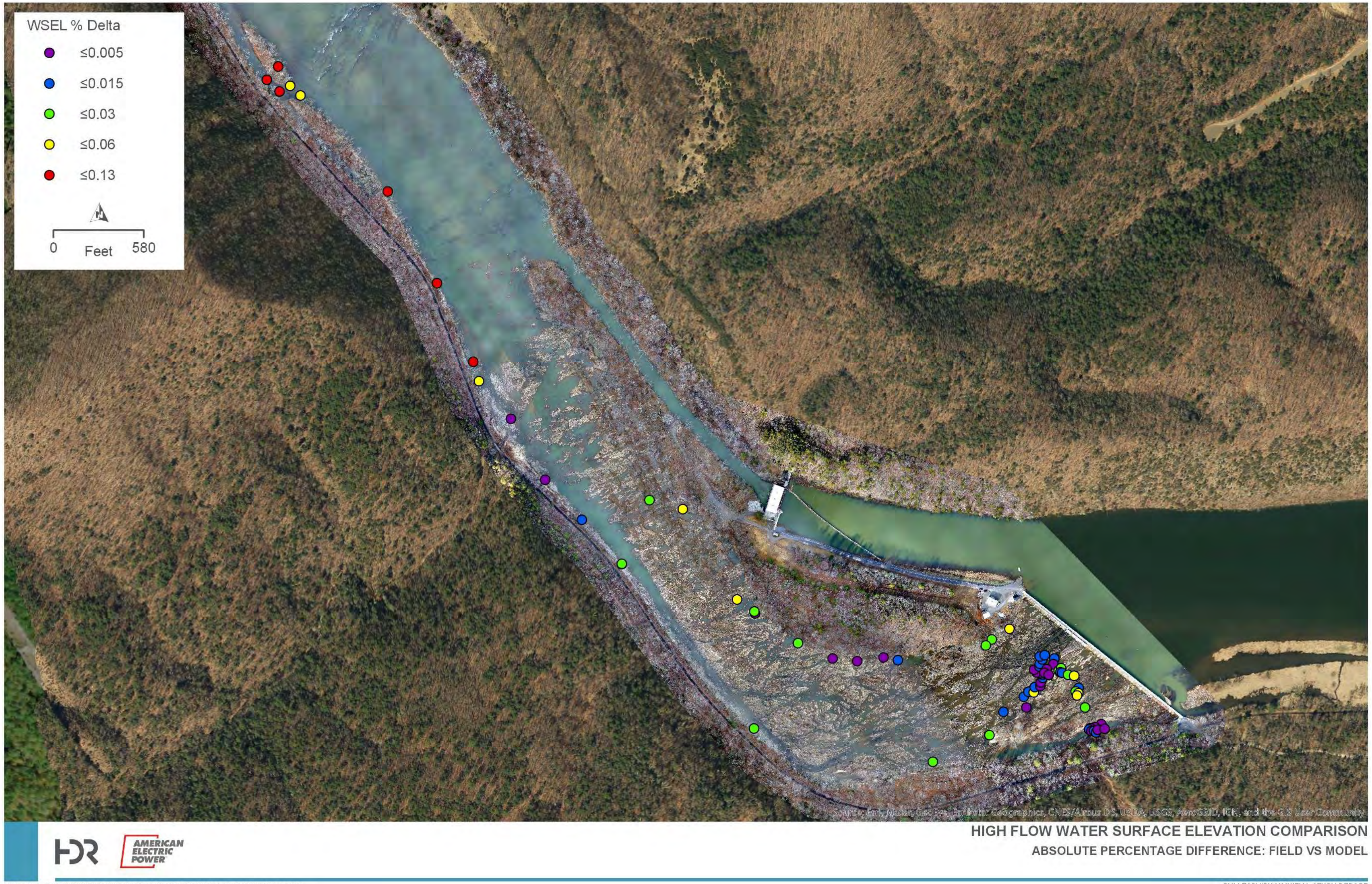

Figure 4-4. Field vs Modeled Water Surface Elevations – Day 4 (High) Target Flow

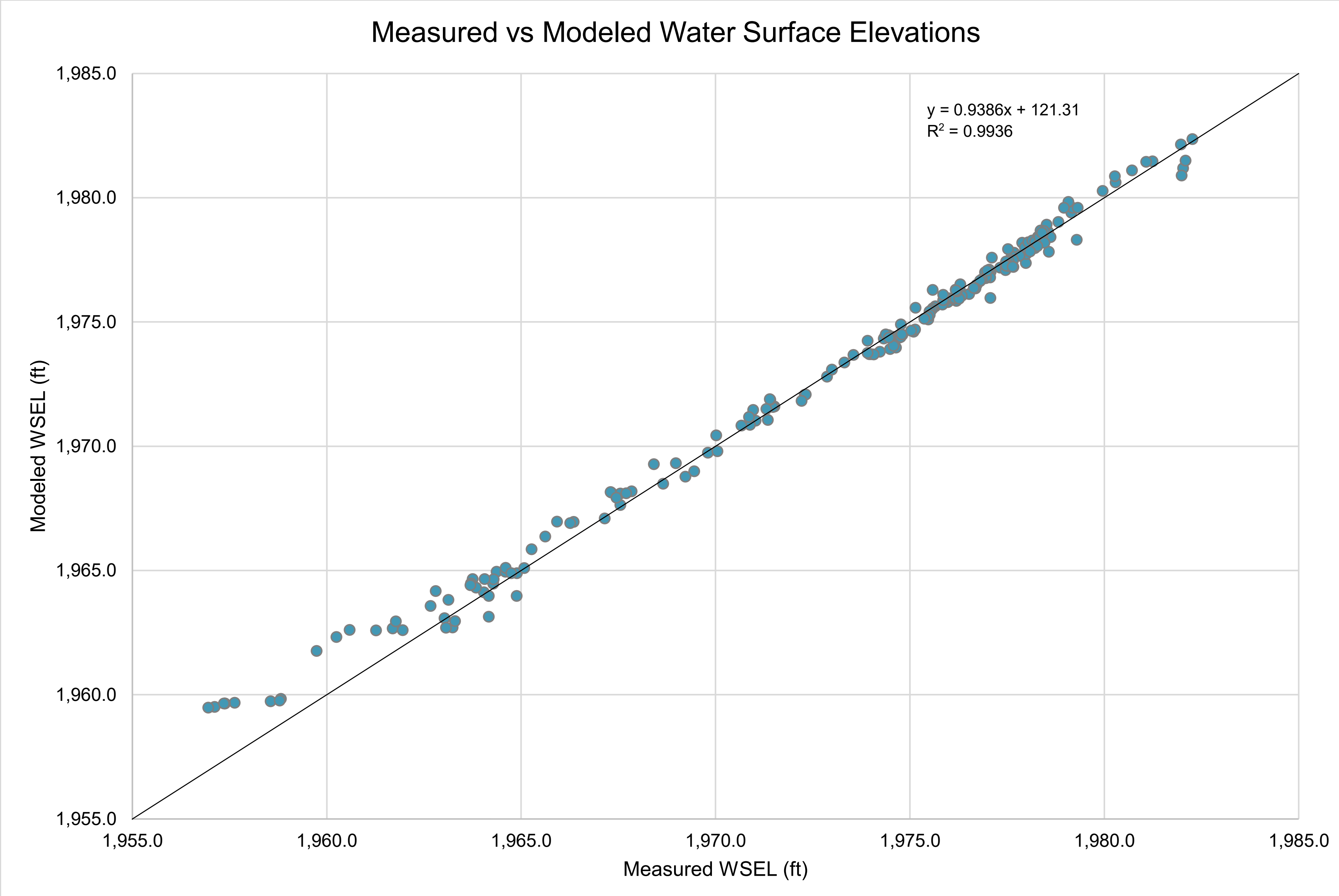

Figure 4-5. Field and Model Water Surface Elevation Correlation – All Flows

4.1.2 Point Velocity and Depth Measurements

Velocity point data collected for the Day 1 and 2 target flow scenarios were compared against velocities predicted by the model for those two scenarios. The comparison between measured field velocity data and modeled velocity for the Day 1 and 2 flow scenarios is presented in Table 4-2 and Figure 4-6 and Figure 4-7, respectively. Field velocity measurement points are colored by absolute difference from modeled velocities.

Due to the nature of a depth-averaged 2D model, matching point velocities measured within the water column is difficult as flow in the field rarely has a uniform velocity. Additional model limitations, including, but not limited to, mesh, Manning's *n* roughness polygon, and DTM resolutions reduce model accuracy near the edge of water. Section 4.1.4 discusses how average velocities across the bypass reach are modeled.

Table 4-2. Point Velocity Comparison

Flow	Field Range (ft/s)	Model Range (ft/s)	Minimum Delta (ft/s)	Maximum Delta (ft/s)	Average Delta (ft/s)
Day 1 (Leakage)	0.0 – 2.04	0.0 – 1.4	0.00	1.6	0.25
Day 2 (Low)	0.0 – 3.59	0.0 – 3.75	0.00	2.8	0.52

Due to the complex nature of the Buck Bypass reach, pool bathymetry was incorporated into the model only at the select locations shown in Figure 3-1. While LiDAR data was collected at leakage conditions, there is still significant standing water throughout the bypass reach that LiDAR cannot penetrate. Because of this, point depths were not compared between the model and data collected in the field.

Because the target flow and model scenarios were set up as steady-state analyses, these pools have very little effect on the overall model hydraulics. Velocities within pools will be slightly higher on average. The potential loss of storage volume within these pools is negligible, as they are filled under leakage flow. Because of this, it was then determined that additional bathymetry would not be required in the area outlined in Figure 2-3.

Figure 4-6. Field versus Modeled Velocities – Day 1 (Leakage) Target Flow

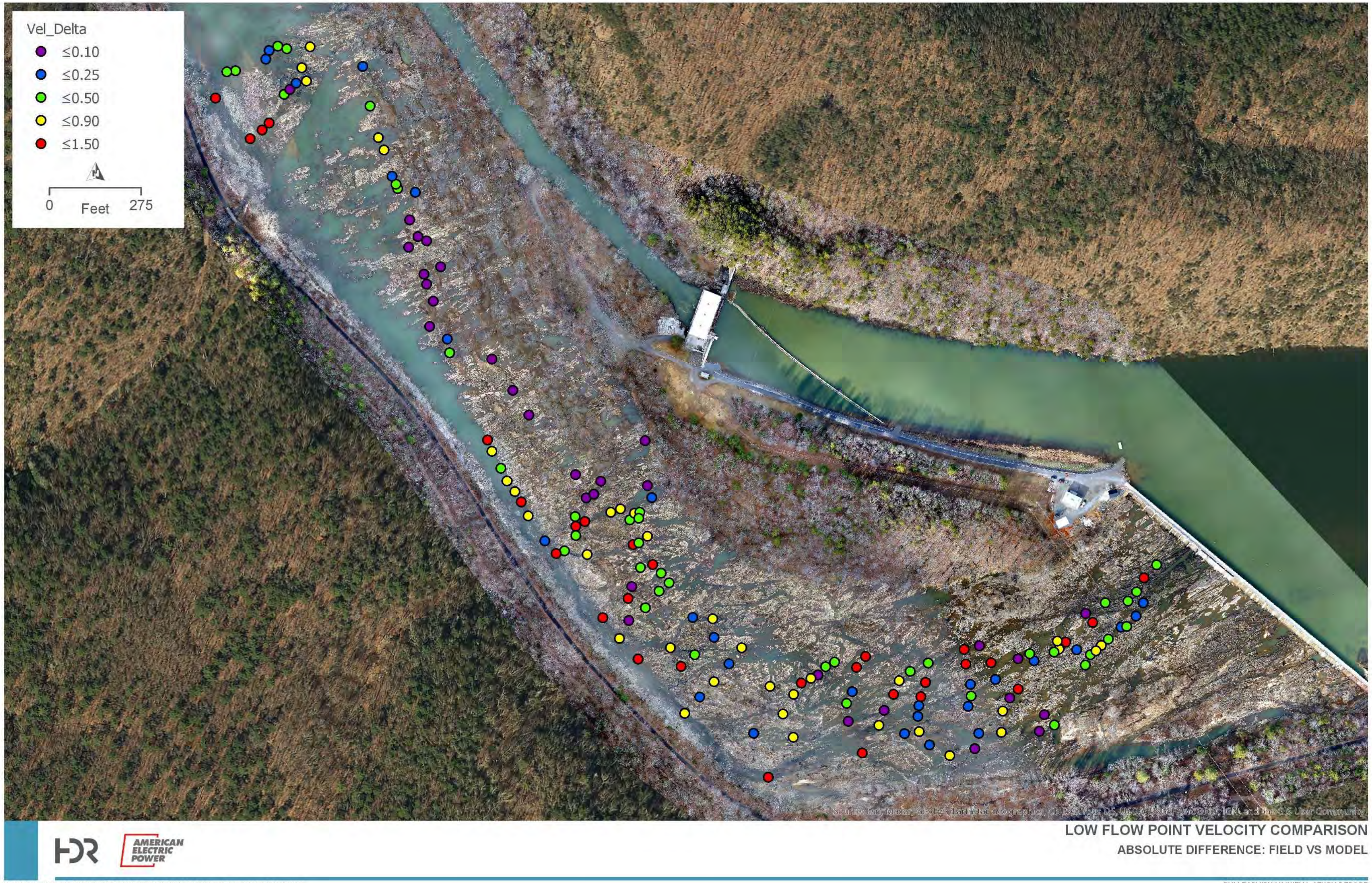

Figure 4-7. Field versus Modeled Velocities – Day 2 (Low) Target Flow

4.1.3 Wetted Area Comparison

The total wetted area in the bypass reach increases as flow increases. Table 4-3 presents the incremental differences predicted by the model of the total bypass reach wetted area between the various target flows. Table 4-4 and Table 4-5 present incremental differences of wetted area for the upper and lower sections of the bypass reach, respectively. The geology of the bypass reach bedrock can be broadly categorized as angular bedrock. This angular bedrock runs in a southeast to northwest direction and creates flow channels or pools depending on orientation. The layout of the bypass reach is such that at approximately 1/4 of the length of the bypass reach, the bedrock orientation transitions from parallel to perpendicular to the direction of flow. For this analysis, this transition area was used as the dividing line between the upper and lower sections of the bypass reach.

Table 4-3. Total Bypass Reach Wetted Area Comparison

Bypass Reach Flow	Total Wetted Area (Acres)	Percent Delta From Leakage	Incremental Area Increase (Acres)
Day 1 (Leakage)	69.6	N/A	N/A
Day 2 (Low)	78.7	113%	9.1
Day 3 (Mid)	83.4	120%	4.7
Day 4 (High)	86.5	124%	3.1

Table 4-4. Upper Bypass Reach Wetted Area Comparison

Bypass Reach Flow	Total Wetted Area (Acres)	Percent Delta From Leakage	Incremental Area Increase (Acres)
Day 1 (Leakage)	8.9	N/A	N/A
Day 2 (Low)	11.5	129%	2.6
Day 3 (Mid)	12.3	138%	0.8
Day 4 (High)	13.4	151%	0.9

Table 4-5. Lower Bypass Reach Wetted Area Comparison

Bypass Reach Flow	Total Wetted Area (Acres)	Percent Delta From Leakage	Incremental Area Increase (Acres)
Day 1 (Leakage)	60.7	N/A	N/A
Day 2 (Low)	67.2	111%	6.5
Day 3 (Mid)	71.1	117%	3.9
Day 4 (High)	73.1	120%	2.0

Figure 4-8 through Figure 4-11 present model results overlaid onto their respective target flow orthomosaic imagery. These figures provide a view of the model results that can be used as a qualitative check of the model's overall agreement with field conditions. For increased detail, only a portion of the upper section of the bypass reach is presented in these figures.

Results of the entire modeling domain are shown on Figure 4-12 through Figure 4-19. Figure 4-12 through Figure 4-15 are colored by velocity magnitude and Figure 4-16 through Figure 4-19 are colored by depth.

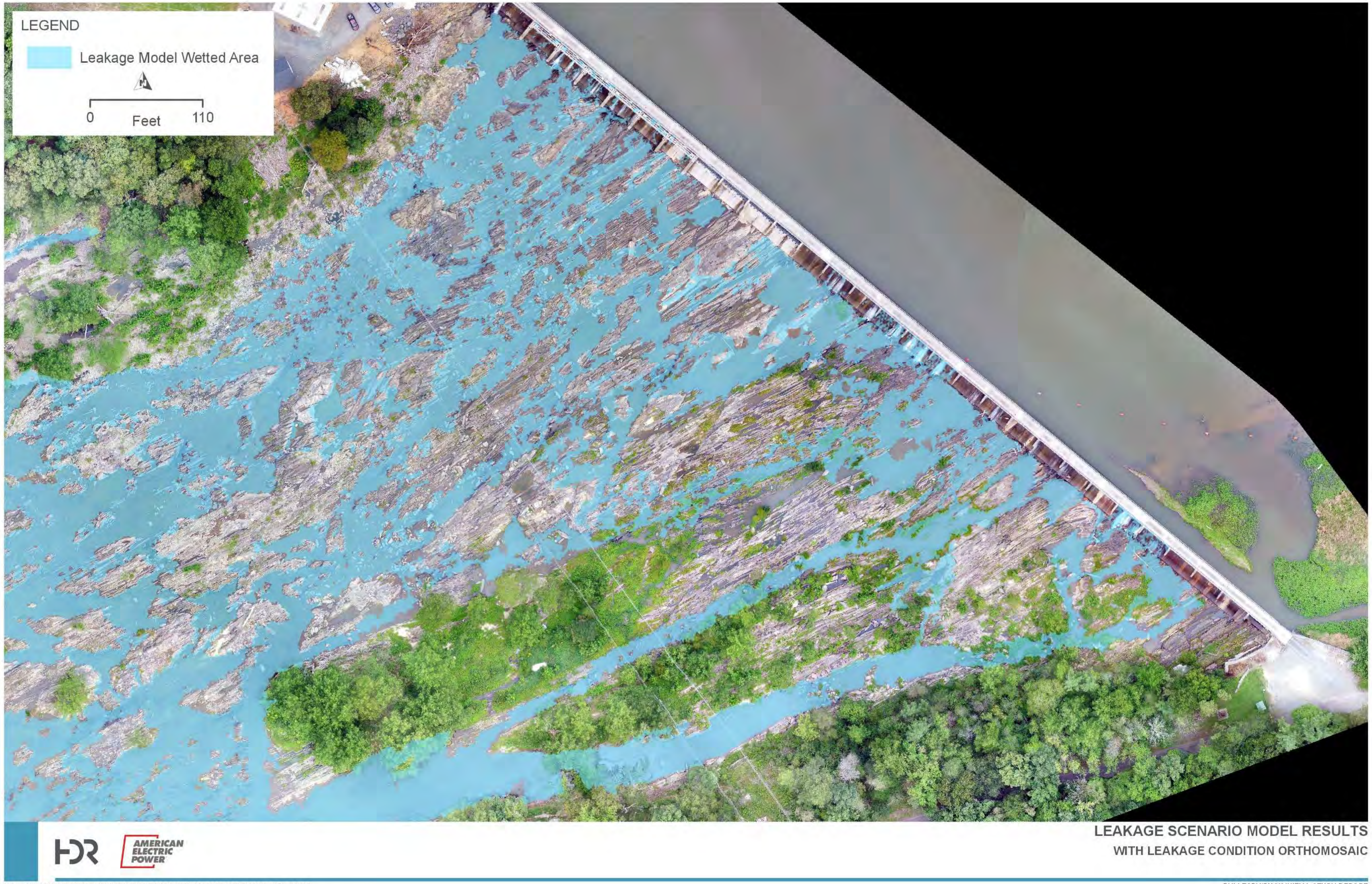

Figure 4-8. Model Results with Orthomosaic Imagery – Day 1 (Leakage) Target Flow

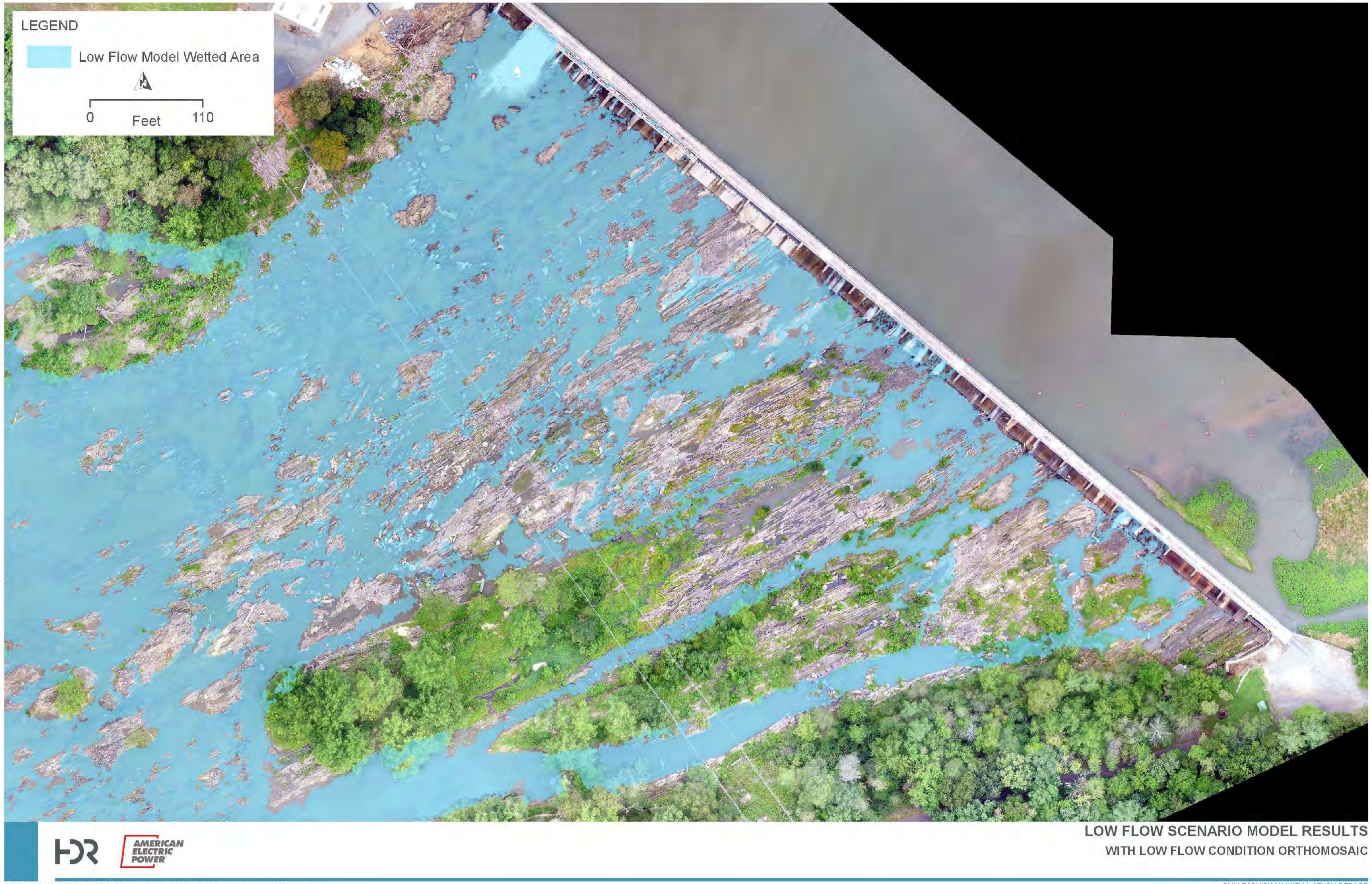

Figure 4-9. Model Results with Orthomosaic Imagery – Day 2 (Low) Target Flow

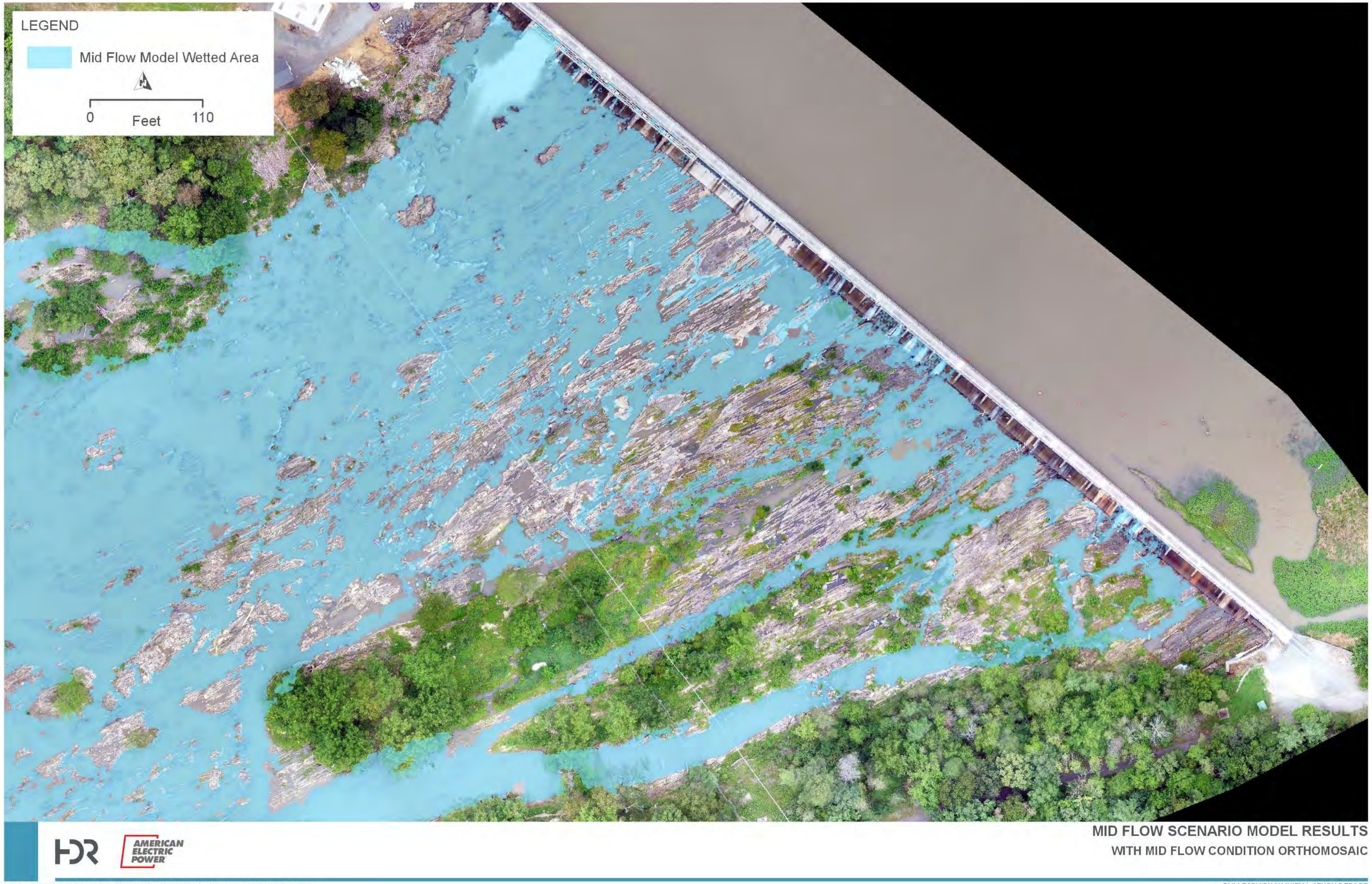

Figure 4-10. Model Results with Orthomosaic Imagery – Day 3 (Mid) Target Flow

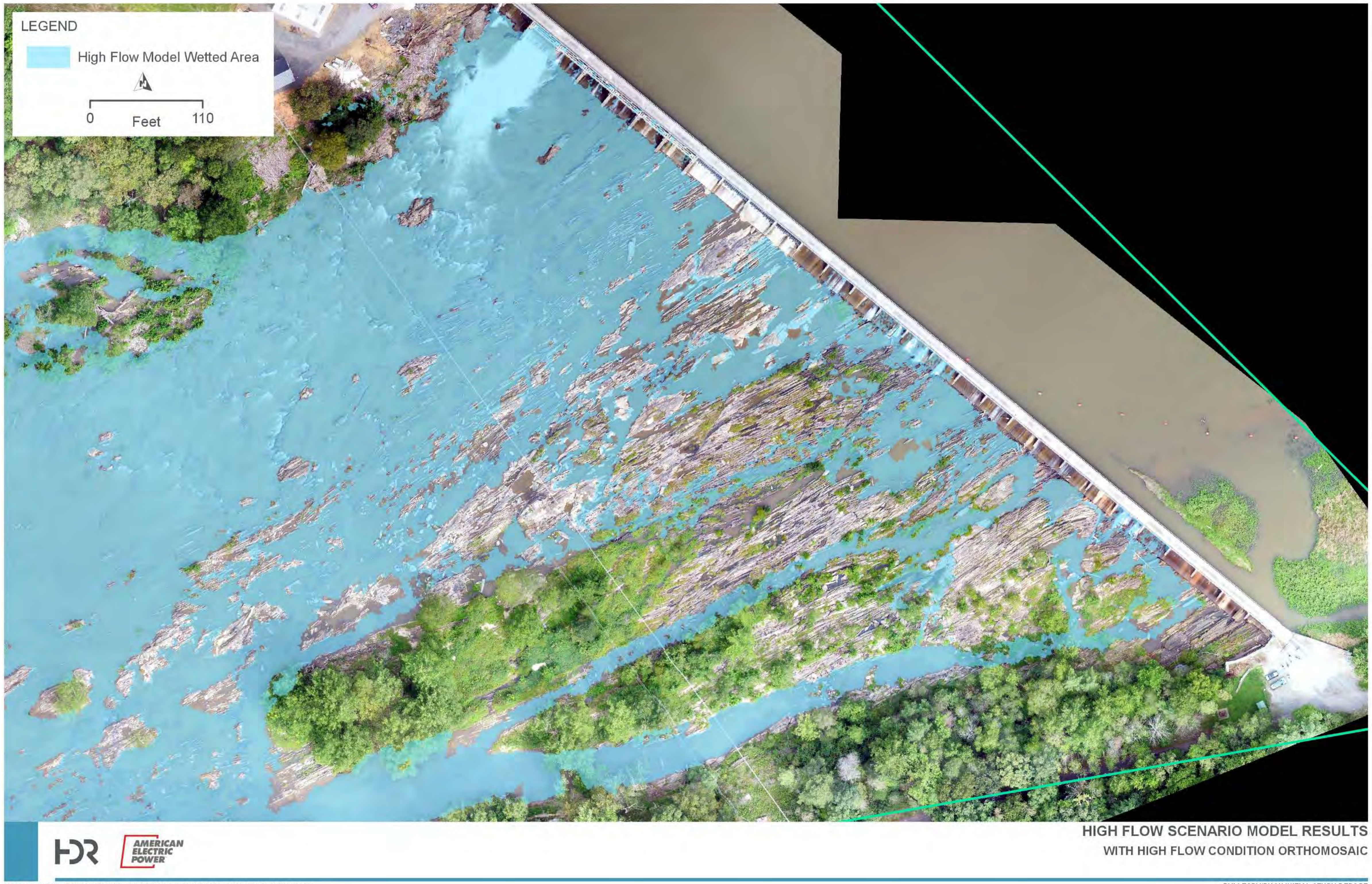

Figure 4-11. Model Results with Orthomosaic Imagery – Day 4 (High) Target Flow

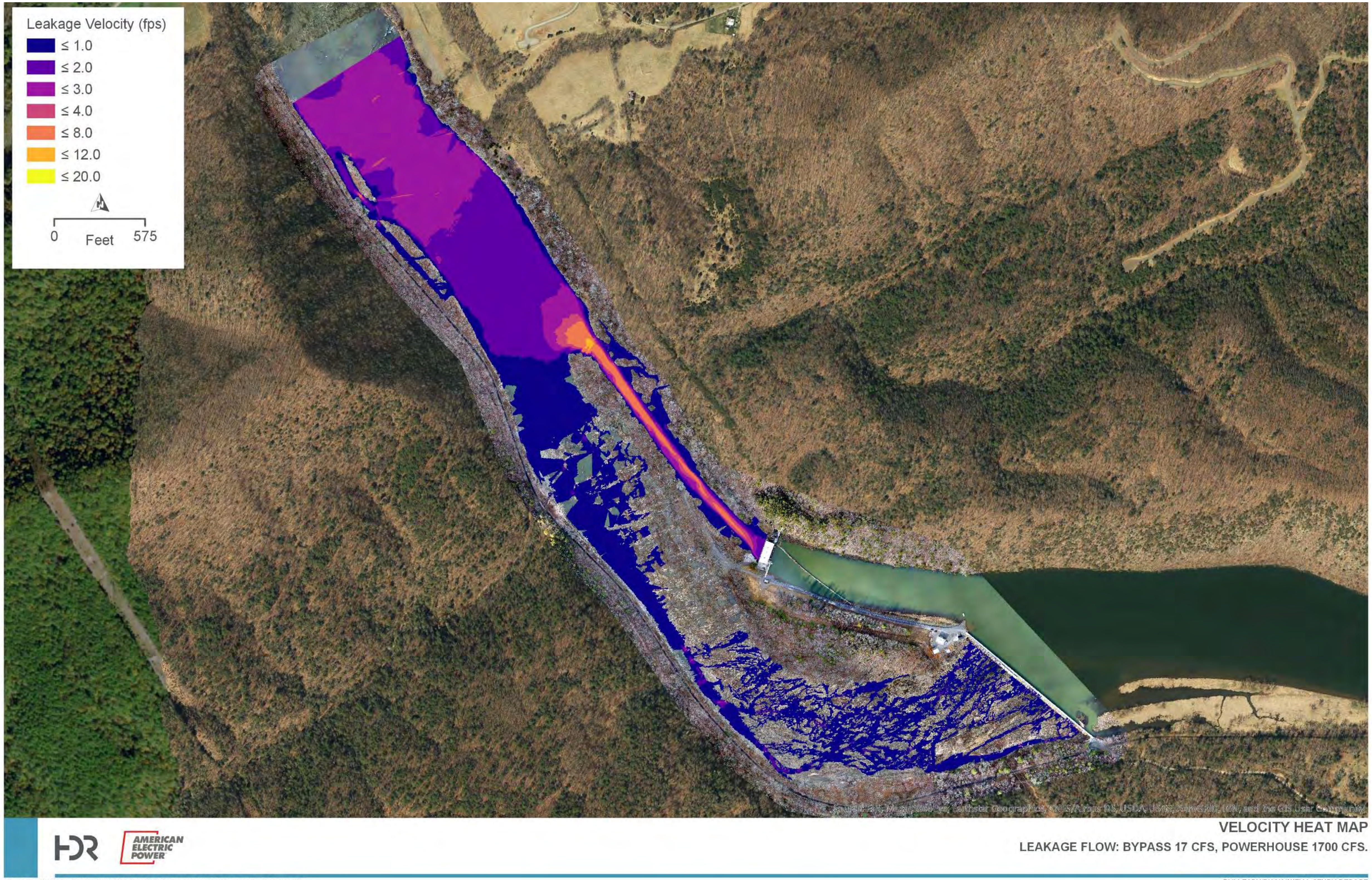

Figure 4-12. Velocity Heat Map – Day 1 (Leakage) Target Flow

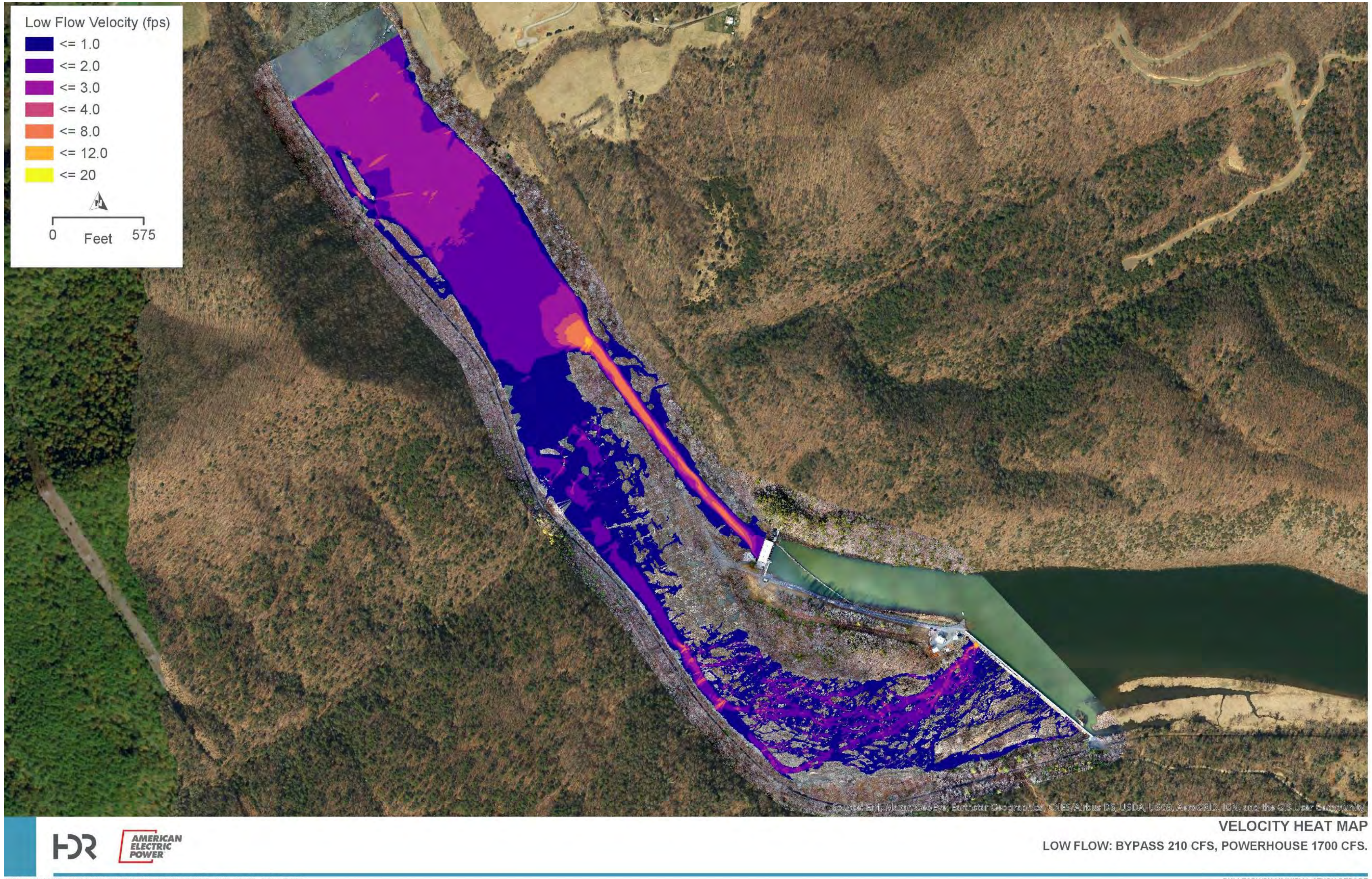

Figure 4-13. Velocity Heat Map – Day 2 (Low) Target Flow

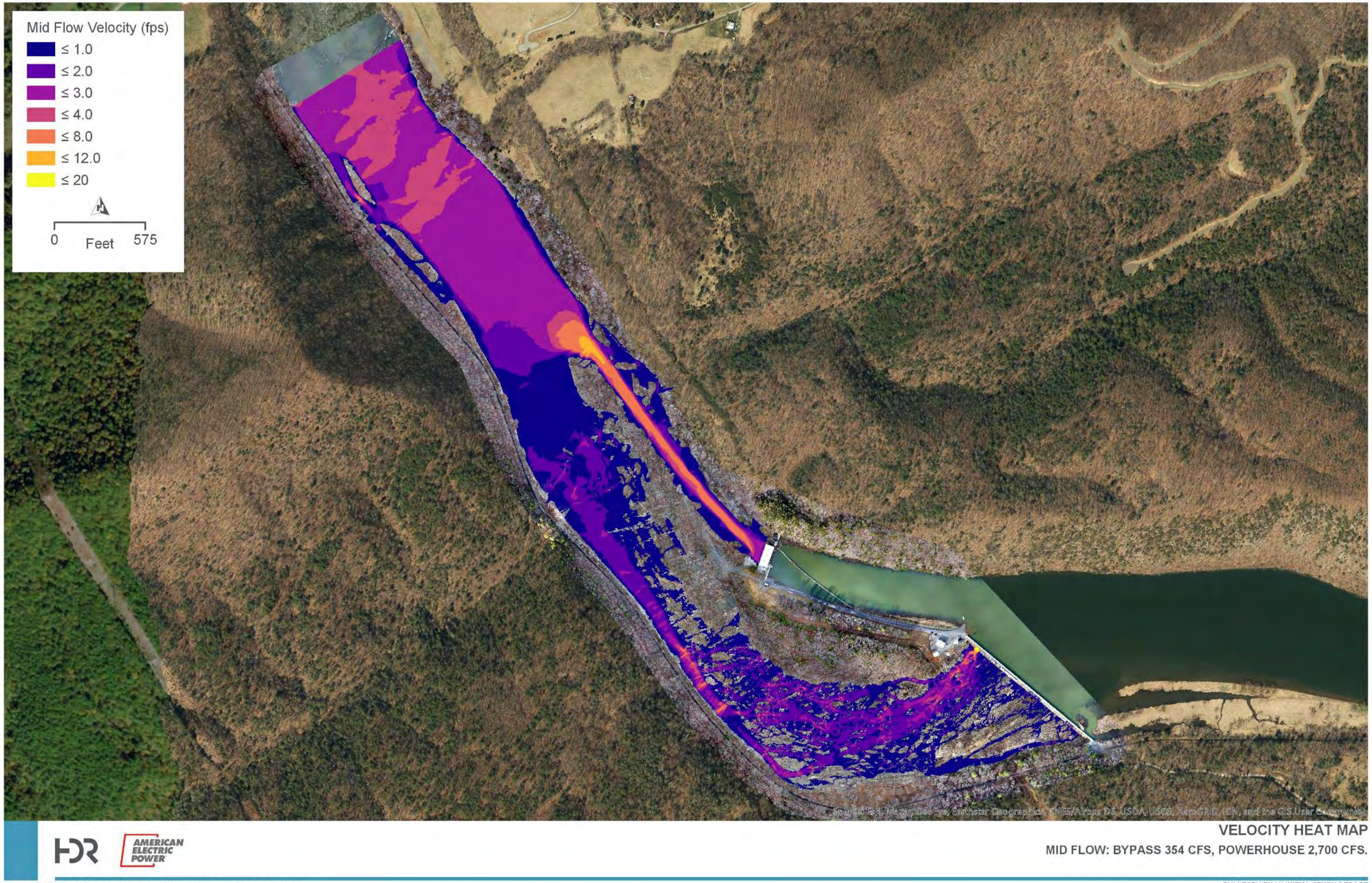

Figure 4-14. Velocity Heat Map – Day 3 (Mid) Target Flow

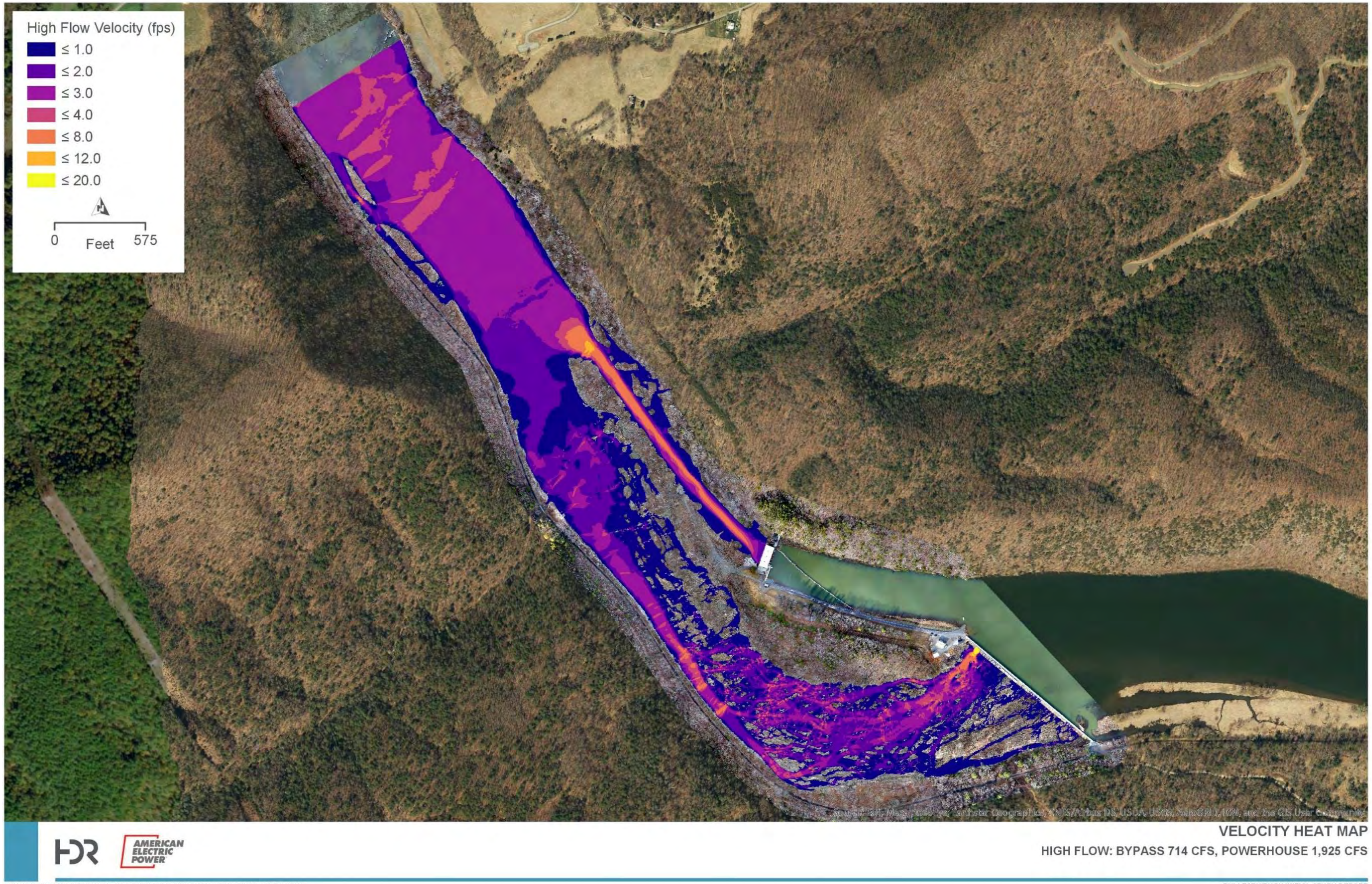

Figure 4-15. Velocity Heat Map – Day 4 (High) Target Flow

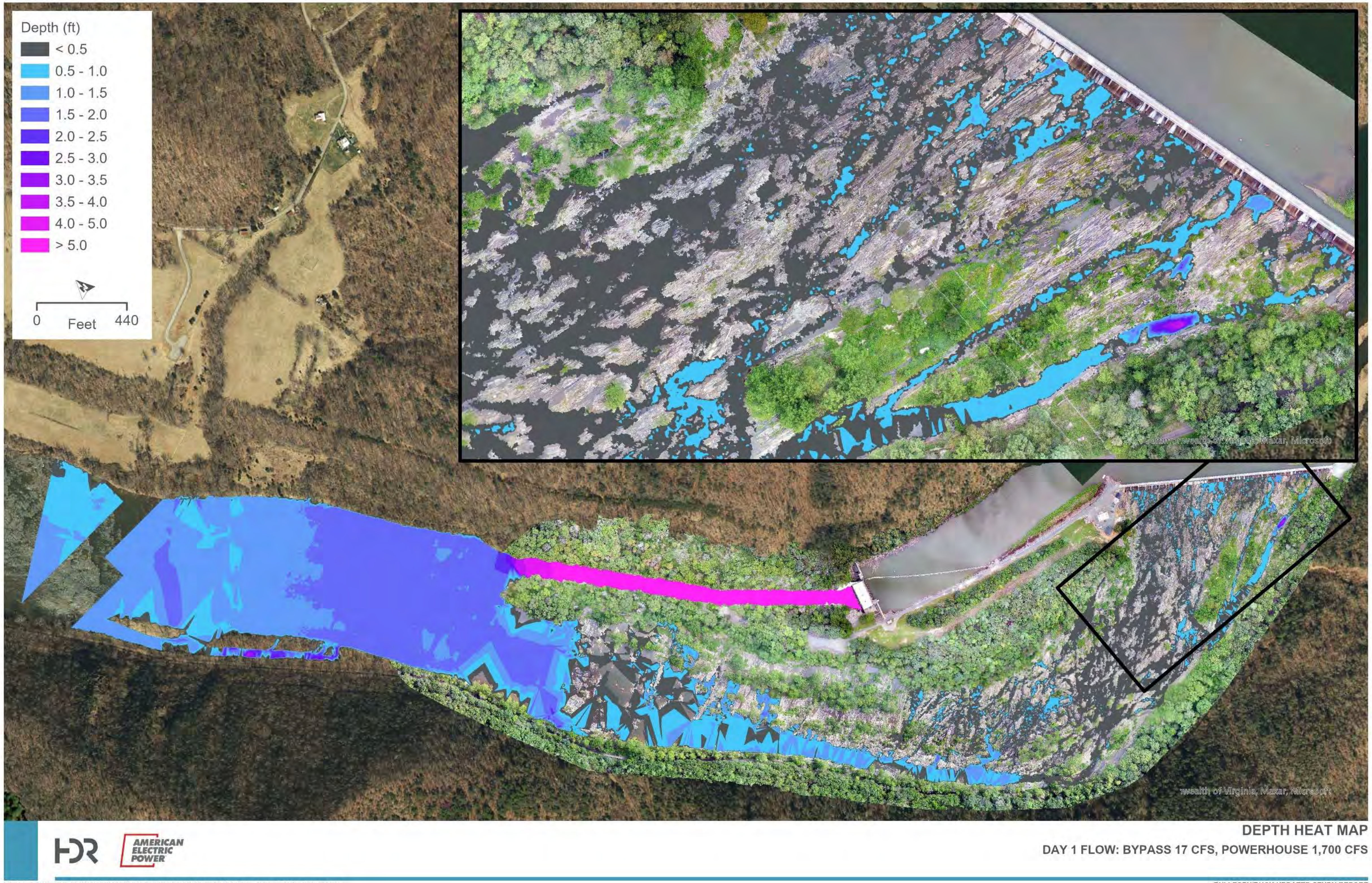

Figure 4-16. Depth Heat Map – Day 1 (Leakage) Target Flow

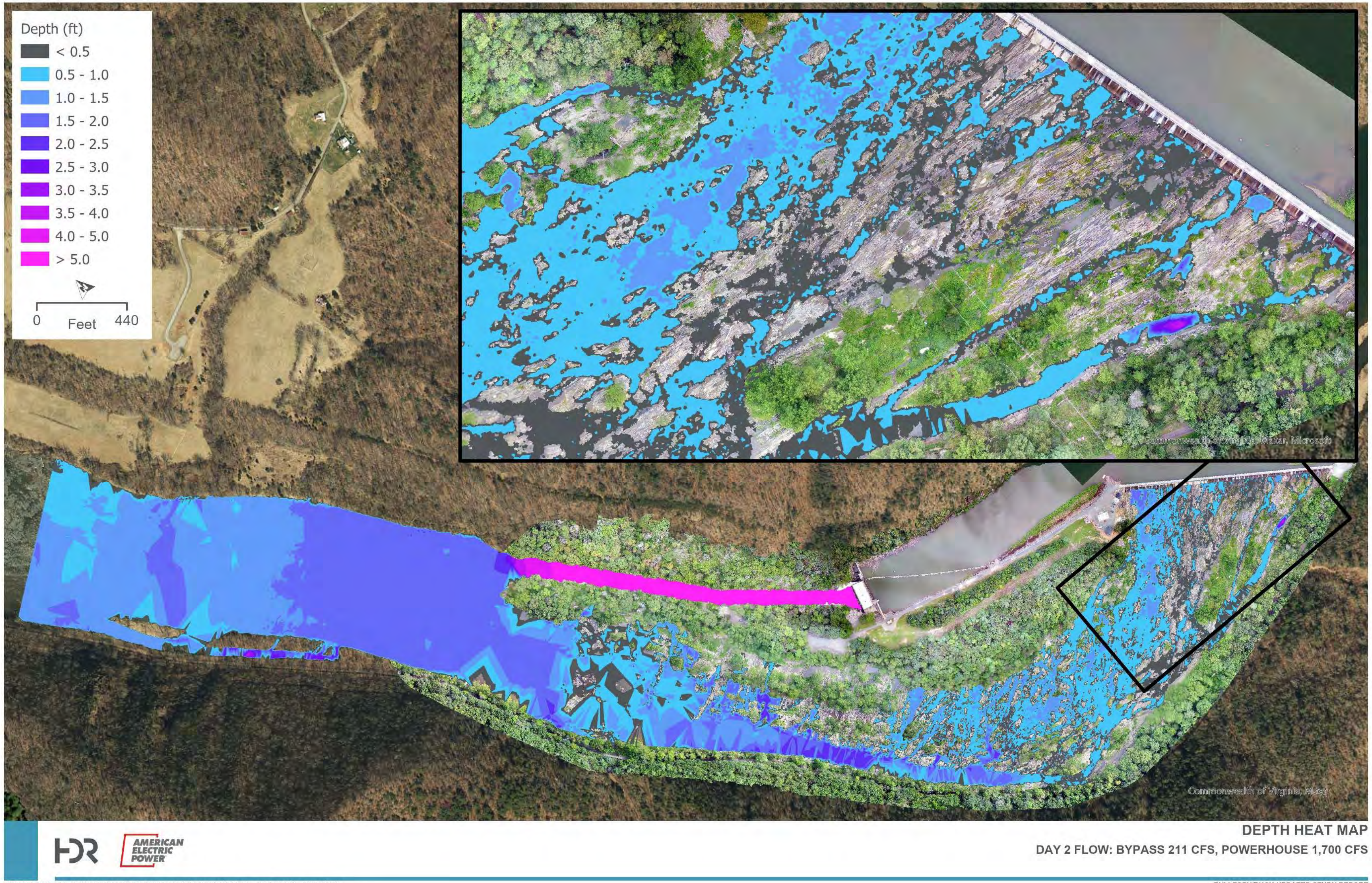

Figure 4-17. Depth Heat Map – Day 2 (Low) Target Flow

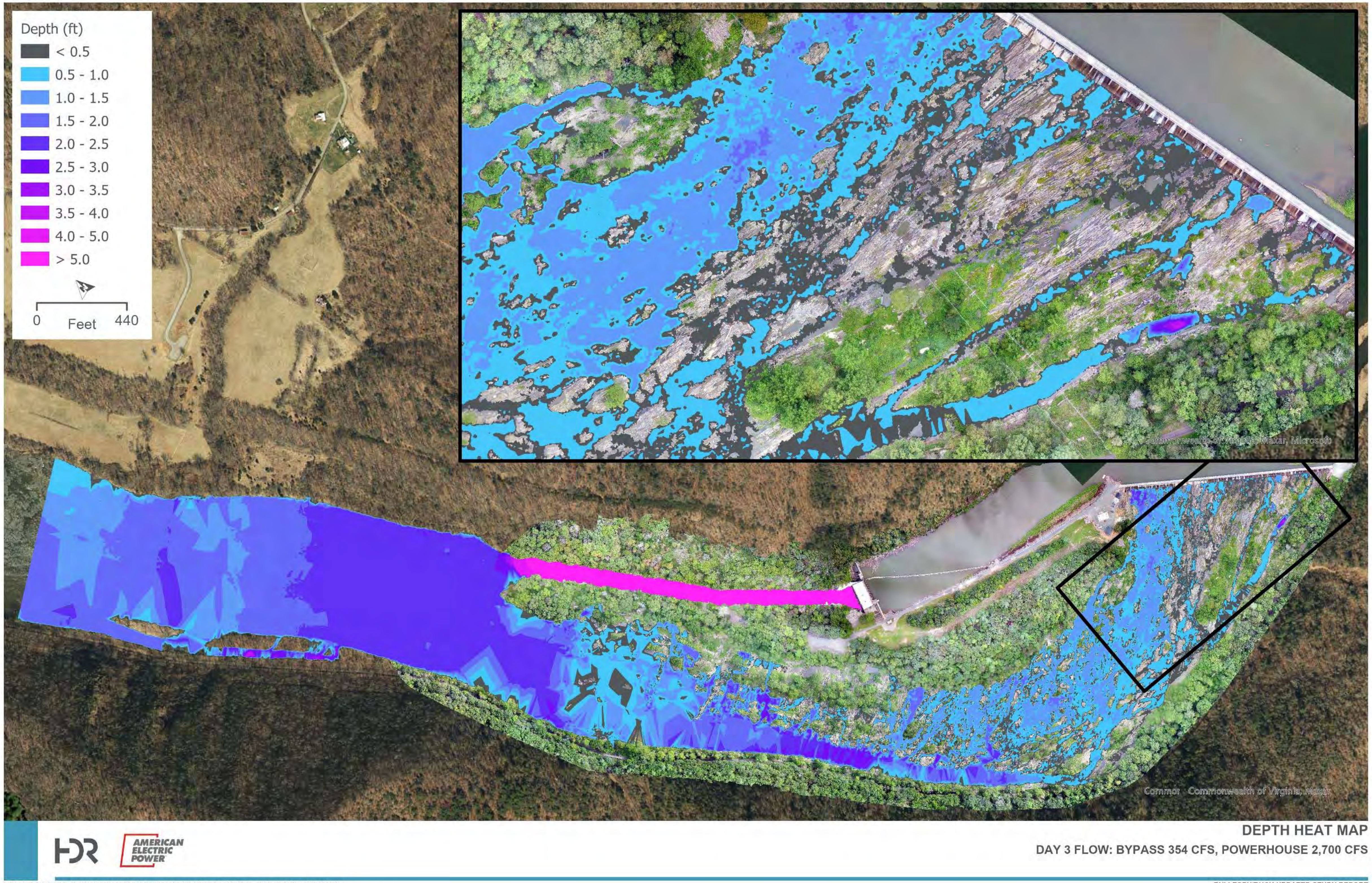

Figure 4-18. Depth Heat Map – Day 3 (Mid) Target Flow

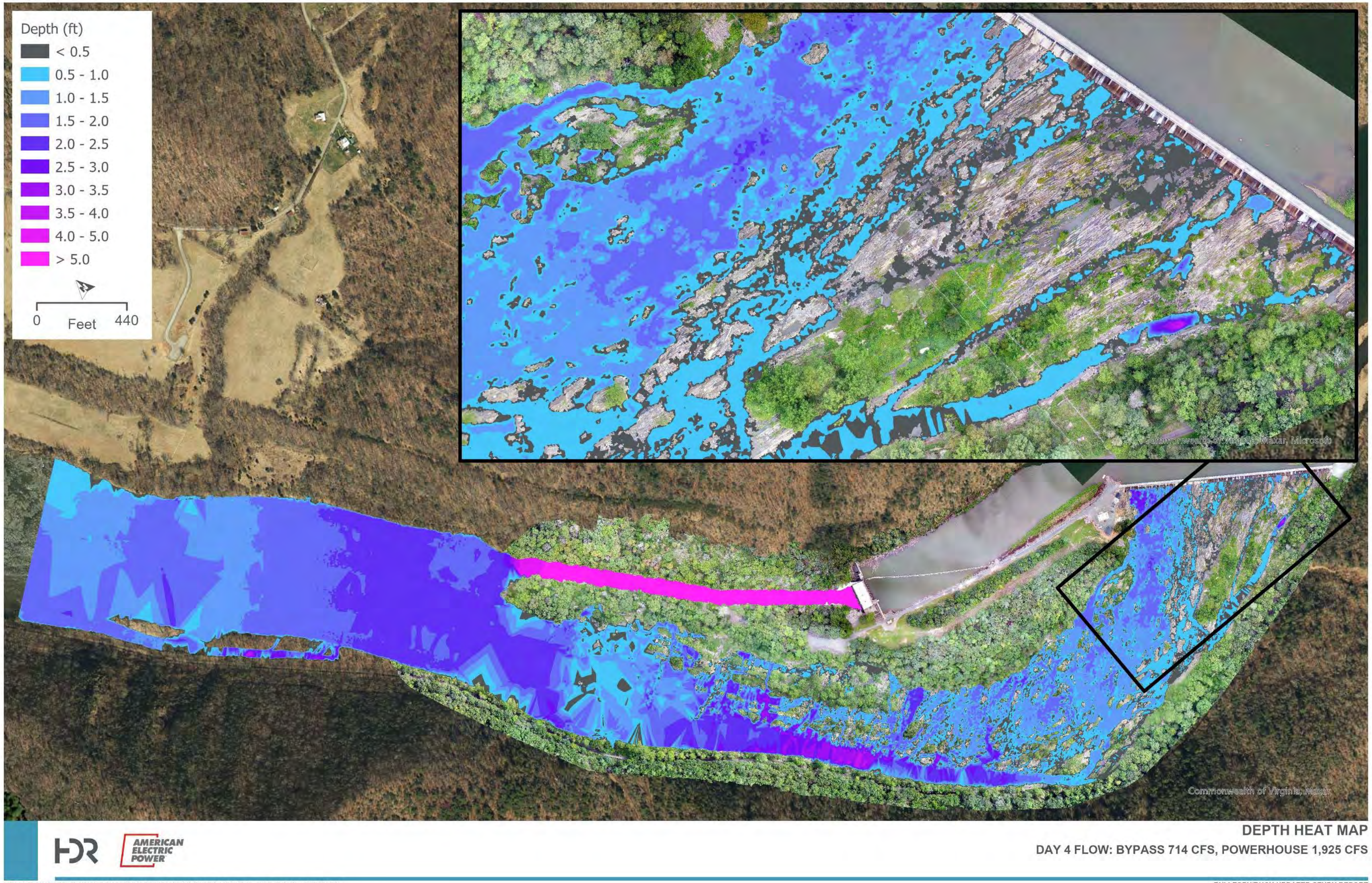

Figure 4-19. Depth Heat Map – Day 4 (High) Target Flow

4.1.4 Travel Time

Travel time measures the time it takes an inflow to travel between designated points in the bypass reach. This measurement is an important data point used for verifying a number of model inputs including the Manning's *n* roughness values presented in Section 3.3.2, inflow, and overall bypass reach slope from the LiDAR data/DTM are appropriate for the analysis. Additionally, it provides insight into model hydraulics, specifically the average velocity within the bypass reach. For this analysis, the travel time was measured between BK_LL1 and BK_LL10. For reference see Figure 2-1. Table 4-6 presents travel times measured by the level loggers and predicted by the model. As leakage is constant, travel times are not measured for that flow condition.

Table 4-6. Bypass Reach Travel Times

Bypass Reach Flow	Level Logger Time (hr:min)	Model Time (hr:min)	Delta (hr:min)
Day 1 (Leakage)	N/A	N/A	N/A
Day 2 (Low)	2:30	2:25	-0:05
Day 3 (Mid)	1:40	1:50	+0:10
Day 4 (High)	1:00	1:15	+0:15

At low flows, the model predicts slightly faster travel times than seen in the field while the opposite is true at higher flows. The small deltas between field and model data confirm the modeling inputs are appropriate and average velocities calculated are representative of field conditions.

5 References

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Attachment 2

Attachment 2 – Habitat Suitability Criteria Tables

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Table 1. Walleye HSC Table

Lifestage	Velocity (ft/s)	Velocity (m/s)	Suitability Index	Depth (ft)	Depth (m)	Suitability Index	Channel Index	Suitability Index
Fry	0	0.00	1	0	0.00	0	1	0.07
	0.08	0.02	1	1	0.30	0	2	0.15
	0.11	0.03	0.98	1.1	0.34	0.14	3	1
	0.15	0.05	0.9	1.16	0.35	0.4	4	1
	0.2	0.06	0.74	1.2	0.37	0.64	5	0.2
	0.23	0.07	0.56	1.25	0.38	0.76	6	0
	0.25	0.08	0	1.4	0.43	0.92	7	0
	--	--	--	1.45	0.44	0.96	8	1
	--	--	--	1.5	0.46	0.98	9	1
	--	--	--	1.6	0.49	1	10	1
	--	--	--	4.9	1.49	1	11	1
	--	--	--	5.1	1.55	0.98	12	1
Fry	--	--	--	5.44	1.66	0.9	13	1
	--	--	--	5.8	1.77	0.78	14	1
	--	--	--	6.2	1.89	0.58	15	0.6
	--	--	--	6.6	2.01	0.3	16	0.55
	--	--	--	7	2.13	0	17	0.5
	--	--	--	--	--	--	18	0
Juvenile	0	0.00	1	0	0.00	0	1	0.5
	0.11	0.03	1	2	0.61	0	2	1
	0.13	0.04	0.97	2.2	0.67	0.46	3	0.8
	0.18	0.05	0.88	2.4	0.73	0.66	4	0.6
	0.23	0.07	0.74	2.6	0.79	0.76	5	0.25
	0.3	0.09	0.46	2.85	0.87	0.84	6	0.1
	0.39	0.12	0.28	3.2	0.98	0.92	7	0
	0.46	0.14	0.22	3.6	1.10	0.98	8	0.8
	0.58	0.18	0.12	4	1.22	1	9	0.9
	0.73	0.22	0.08	6	1.83	1	10	0.8
	0.88	0.27	0.06	6.5	1.98	0.96	11	0.7
	1.85	0.56	0.04	7	2.13	0.9	12	0.8
	1.95	0.59	0.04	7.4	2.26	0.82	13	0.7
	2.1	0.64	0.02	7.8	2.38	0.72	14	0.8
	2.25	0.69	0	8	2.44	0.6	15	0.7
	--	--	--	8.35	2.55	0.52	16	0.9
	--	--	--	8.9	2.71	0.46	17	0.65
	--	--	--	9.4	2.87	0.44	18	0
	--	--	--	10.6	3.23	0.42	--	--
	--	--	--	18	5.49	0.4	--	--
Adult	0.00	0.00	1.00	0.00	0.00	0.00	1	0.2
	0.20	0.06	1.00	3.10	0.94	0.00	2	1
	0.25	0.08	0.98	3.40	1.04	0.20	3	1
	0.30	0.09	0.84	3.60	1.10	0.44	4	1
	0.37	0.11	0.40	3.70	1.13	0.82	5	1
	0.45	0.14	0.26	3.80	1.16	0.92	6	1
	0.6	0.18288	0.18	3.95	1.20	0.98	7	0
	1	0.3048	0.06	4	1.2192	1	8	0.6
	1.5	0.4572	0.04	10	3.048	1	9	1
	2.5	0.762	0.04	--	--	--	10	1
	2.85	0.86868	0.02	--	--	--	11	1
	3	0.9144	0	--	--	--	12	1
	--	--	--	--	--	--	13	1
	--	--	--	--	--	--	14	1
	--	--	--	--	--	--	15	1
	--	--	--	--	--	--	16	1

Lifestage	Velocity (ft/s)	Velocity (m/s)	Suitability Index	Depth (ft)	Depth (m)	Suitability Index	Channel Index	Suitability Index
	--	--	--	--	--	--	17	0.6
	--	--	--	--	--	--	18	0
Spawning	0	0.00	0.06	0	0.00	0	1	0
	0.4	0.12	0.08	1	0.30	0	2	0
	0.85	0.26	0.12	1.5	0.46	0.22	3	0.35
	1	0.30	0.14	1.8	0.55	0.42	4	1
	1.17	0.36	0.18	2.06	0.63	0.62	5	1
	1.5	0.46	0.28	2.3	0.70	0.88	6	1
	1.78	0.54	0.38	2.4	0.73	0.94	7	0
	1.97	0.60	0.46	2.5	0.76	0.99	8	0.8
	2.07	0.63	0.54	2.6	0.79	1	9	0.8
	2.15	0.66	0.62	4.97	1.51	1	10	0.8
	2.3	0.70	0.84	5.05	1.54	0.98	11	0.8
	2.4	0.73	0.94	5.8	1.77	0.6	12	0.8
	2.47	0.75	0.98	6.1	1.86	0.44	13	0.8
	2.52	0.77	1	6.25	1.91	0.3	14	0.8
	2.97	0.91	1	6.5	1.98	0	15	0.8
	3.03	0.92	0.99	--	--	--	16	0.8
	3.05	0.93	0.98	--	--	--	17	0.11
	3.2	0.98	0.86	--	--	--	18	0
	3.35	1.02	0.68	--	--	--	--	--
	3.5	1.07	0.46	--	--	--	--	--
	3.55	1.08	0.32	--	--	--	--	--
	3.58	1.09	0	--	--	--	--	--

Table 2. Shallow Guild HSC Table

Lifestage	Velocity (ft/s)	Velocity (m/s)	Suitability Index	Depth (ft)	Depth (m)	Suitability Index	Channel Index	Suitability Index
RBSFS	0.0	0.00	1.00	0.0	0.00	0.00	1	0.1
	0.4	0.12	1.00	0.5	0.15	0.00	2	0.7
	0.5	0.15	0.90	0.8	0.23	0.80	3	0.8
	1.0	0.31	0.15	1.0	0.31	1.00	4	0.5
	1.3	0.41	0.00	2.5	0.76	1.00	5	0.21
	--	--	--	3.1	0.95	0.60	6	0
	--	--	--	7.0	2.13	0.00	7	0
	--	--	--	--	--	--	8	0.2
	--	--	--	--	--	--	9	0.8
	--	--	--	--	--	--	10	0.4
	--	--	--	--	--	--	11	0.8
	--	--	--	--	--	--	12	0.8
	--	--	--	--	--	--	13	0.7
	--	--	--	--	--	--	14	0.9
	--	--	--	--	--	--	15	0.6
	--	--	--	--	--	--	16	0.9
	--	--	--	--	--	--	17	0.85
	--	--	--	--	--	--	18	0
SRHAV	0.0	0.00	0.92	0.0	0.00	0.00	1	1
	0.0	0.01	0.95	0.0	0.01	0.08	2	0
	0.1	0.02	0.97	0.1	0.02	0.10	3	0
	0.1	0.03	0.98	0.1	0.03	0.13	4	0
	0.1	0.04	0.99	0.1	0.04	0.17	5	0
	0.2	0.05	1.00	0.2	0.05	0.21	6	0
	0.2	0.06	1	0.2	0.06	0.25	7	0
	0.2	0.07	1	0.2	0.07	0.29	8	1
	0.3	0.08	0.99	0.3	0.08	0.34	9	0
	0.3	0.09	0.98	0.3	0.09	0.39	10	0
SRHAV	0.3	0.10	0.97	0.3	0.10	0.44	11	0
	0.4	0.11	0.95	0.4	0.11	0.5	12	0
	0.4	0.12	0.94	0.4	0.12	0.55	13	0
	0.4	0.13	0.92	0.4	0.13	0.6	14	0
	0.5	0.14	0.9	0.5	0.14	0.65	15	0
	0.5	0.15	0.88	0.5	0.15	0.7	16	0
	0.5	0.16	0.86	0.5	0.16	0.75	17	0
	0.6	0.17	0.83	0.6	0.17	0.79	18	1
	0.6	0.18	0.81	0.6	0.18	0.83	--	--
	0.6	0.19	0.79	0.6	0.19	0.87	--	--
	0.7	0.20	0.76	0.7	0.20	0.90	--	--
	0.7	0.21	0.74	0.7	0.21	0.92	--	--
	0.7	0.22	0.71	0.7	0.22	0.95	--	--
	0.8	0.23	0.69	0.8	0.23	0.96	--	--
	0.8	0.24	0.67	0.8	0.24	0.98	--	--
	0.8	0.25	0.64	0.8	0.25	0.99	--	--
	0.8	0.26	0.62	0.8	0.26	1	--	--
	0.9	0.27	0.6	0.9	0.27	1	--	--
	0.9	0.28	0.58	0.9	0.28	1	--	--
	1.0	0.29	0.55	1.0	0.29	1	--	--
	1.0	0.30	0.53	1.0	0.30	0.99	--	--
	1.0	0.31	0.51	1.0	0.31	0.98	--	--
	1.0	0.32	0.49	1.0	0.32	0.97	--	--
	1.1	0.33	0.47	1.1	0.33	0.96	--	--
	1.1	0.34	0.46	1.1	0.34	0.94	--	--
	1.2	0.35	0.44	1.2	0.35	0.93	--	--

Lifestage	Velocity (ft/s)	Velocity (m/s)	Suitability Index	Depth (ft)	Depth (m)	Suitability Index	Channel Index	Suitability Index
	1.2	0.36	0.42	1.2	0.36	0.91	--	--
	1.2	0.37	0.4	1.2	0.37	0.89	--	--
	1.3	0.38	0.39	1.3	0.38	0.87	--	--
	1.3	0.39	0.37	1.3	0.39	0.85	--	--
	1.3	0.40	0.35	1.3	0.40	0.83	--	--
	1.3	0.41	0.34	1.3	0.41	0.81	--	--
	1.4	0.42	0.33	1.4	0.42	0.79	--	--
	1.4	0.43	0.31	1.4	0.43	0.77	--	--
	1.4	0.44	0.3	1.4	0.44	0.75	--	--
	1.5	0.45	0.29	1.5	0.45	0.72	--	--
	1.5	0.46	0.27	1.5	0.46	0.7	--	--
	1.5	0.47	0.26	1.5	0.47	0.68	--	--
	1.6	0.48	0.25	1.6	0.48	0.66	--	--
	1.6	0.49	0.24	1.6	0.49	0.64	--	--
	1.6	0.50	0.23	1.6	0.50	0.62	--	--
	1.7	0.51	0.22	1.7	0.51	0.6	--	--
	1.7	0.52	0.21	1.7	0.52	0.58	--	--
	1.7	0.53	0.2	1.7	0.53	0.56	--	--
	1.8	0.54	0.19	1.8	0.54	0.54	--	--
	1.8	0.55	0.18	1.8	0.55	0.52	--	--
	1.8	0.56	0.17	1.8	0.56	0.5	--	--
	1.9	0.57	0.17	1.9	0.57	0.48	--	--
	1.9	0.58	0.16	1.9	0.58	0.46	--	--
	1.9	0.59	0.15	1.9	0.59	0.45	--	--
	2.0	0.60	0.14	2.0	0.60	0.43	--	--
	2.0	0.61	0.14	2.0	0.61	0.41	--	--
	2.0	0.62	0.13	2.0	0.62	0.4	--	--
	2.1	0.63	0.13	2.1	0.63	0.38	--	--
SRHAV	2.1	0.64	0.12	2.1	0.64	0.37	--	--
	2.1	0.65	0.11	2.1	0.65	0.35	--	--
	2.2	0.66	0.11	2.2	0.66	0.34	--	--
	2.2	0.67	0.1	2.2	0.67	0.33	--	--
	2.2	0.68	0.1	2.2	0.68	0.31	--	--
	2.3	0.69	0.09	2.3	0.69	0.3	--	--
	2.3	0.70	0.09	2.3	0.70	0.29	--	--
	2.3	0.71	0.09	2.3	0.71	0.28	--	--
	2.4	0.72	0.08	2.4	0.72	0.27	--	--
	2.4	0.73	0.08	2.4	0.73	0.25	--	--
	2.4	0.74	0.07	2.4	0.74	0.24	--	--
	2.5	0.75	0.07	2.5	0.75	0.23	--	--
	2.5	0.76	0.07	2.5	0.76	0.22	--	--
	2.5	0.77	0.06	2.5	0.77	0.22	--	--
	2.6	0.78	0.06	2.6	0.78	0.21	--	--
	2.6	0.79	0.06	2.6	0.79	0.2	--	--
	2.6	0.80	0.05	2.6	0.80	0.19	--	--
	2.7	0.81	0.05	2.7	0.81	0.18	--	--
	2.7	0.82	0.05	2.7	0.82	0.17	--	--
	2.7	0.83	0.05	2.7	0.83	0.17	--	--
	2.7	0.84	0.04	2.7	0.84	0.16	--	--
	2.8	0.85	0.04	2.8	0.85	0.15	--	--
	2.8	0.86	0.04	2.8	0.86	0.15	--	--
	2.9	0.87	0.04	2.9	0.87	0.14	--	--
	2.9	0.88	0.04	2.9	0.88	0.13	--	--
	2.9	0.89	0.03	2.9	0.89	0.13	--	--
	2.9	0.90	0.03	2.9	0.90	0.12	--	--
	3.0	0.91	0.03	3.0	0.91	0.12	--	--

Lifestage	Velocity (ft/s)	Velocity (m/s)	Suitability Index	Depth (ft)	Depth (m)	Suitability Index	Channel Index	Suitability Index
	3.0	0.92	0.03	3.0	0.92	0.11	--	--
	3.1	0.93	0.03	3.1	0.93	0.11	--	--
	3.1	0.94	0.03	3.1	0.94	0.1	--	--
	3.1	0.95	0.03	3.1	0.95	0.1	--	--
	3.1	0.96	0.02	3.1	0.96	0.09	--	--
	3.2	0.97	0.02	3.2	0.97	0.09	--	--
	3.2	0.98	0.02	3.2	0.98	0.08	--	--
	3.3	0.99	0.02	3.3	0.99	0.08	--	--
	3.3	1.00	0.02	3.3	1.00	0.08	--	--
	3.3	1.01	0.02	3.3	1.01	0.07	--	--
	3.3	1.02	0.02	3.3	1.02	0.07	--	--
	3.4	1.03	0.02	3.4	1.03	0.07	--	--
	3.4	1.04	0.02	3.4	1.04	0.06	--	--
	3.4	1.05	0.01	3.4	1.05	0.06	--	--
	3.5	1.06	0.01	3.5	1.06	0.06	--	--
	3.5	1.07	0.01	3.5	1.07	0.05	--	--
	3.5	1.08	0.01	3.5	1.08	0.05	--	--
	3.6	1.09	0.01	3.6	1.09	0.05	--	--
	3.6	1.10	0.01	3.6	1.10	0.05	--	--
	3.6	1.11	0.01	3.6	1.11	0.04	--	--
	3.7	1.12	0.01	3.7	1.12	0.04	--	--
	3.7	1.13	0.01	3.7	1.13	0.04	--	--
	3.7	1.14	0.01	3.7	1.14	0.04	--	--
	3.8	1.15	0.01	3.8	1.15	0.04	--	--
	3.8	1.16	0.01	3.8	1.16	0.03	--	--
	3.8	1.17	0.01	3.8	1.17	0.03	--	--
Lifestage	**Velocity (ft/s)**	**Velocity (m/s)**	**Suitability Index**	**Depth (ft)**	**Depth (m)**	**Suitability Index**	**Channel Index**	**Suitability Index**
	3.9	1.18	0.01	3.9	1.18	0.03	--	--
	3.9	1.19	0.01	3.9	1.19	0.03	--	--
	3.9	1.20	0.01	3.9	1.20	0.03	--	--
	4.0	1.21	0.01	4.0	1.21	0.03	--	--
	4.0	1.22	0.01	4.0	1.22	0.02	--	--
	4.0	1.23	0.01	4.0	1.23	0.02	--	--
	4.1	1.24	0	4.1	1.24	0.02	--	--
	--	--	--	4.1	1.25	0.02	--	--
	--	--	--	4.1	1.26	0.02	--	--
	--	--	--	4.2	1.27	0.02	--	--
	--	--	--	4.2	1.28	0.02	--	--
	--	--	--	4.2	1.29	0.02	--	--
	--	--	--	4.3	1.30	0.02	--	--
SRHAV	--	--	--	4.3	1.31	0.02	--	--
	--	--	--	4.3	1.32	0.01	--	--
	--	--	--	4.4	1.33	0.01	--	--
	--	--	--	4.4	1.34	0.01	--	--
	--	--	--	4.4	1.34	0.01	--	--
	--	--	--	4.5	1.36	0.01	--	--
	--	--	--	4.5	1.37	0.01	--	--
	--	--	--	4.5	1.38	0.01	--	--
	--	--	--	4.6	1.39	0.01	--	--
	--	--	--	4.6	1.40	0.01	--	--
	--	--	--	4.6	1.41	0.01	--	--
	--	--	--	4.7	1.42	0.01	--	--
	--	--	--	4.7	1.43	0.01	--	--
	--	--	--	4.7	1.44	0.01	--	--
	--	--	--	4.8	1.45	0.01	--	--

Lifestage	Velocity (ft/s)	Velocity (m/s)	Suitability Index	Depth (ft)	Depth (m)	Suitability Index	Channel Index	Suitability Index
	--	--	--	4.8	1.46	0.01	--	--
	--	--	--	4.8	1.47	0.01	--	--
	--	--	--	4.8	1.48	0.01	--	--
	--	--	--	4.9	1.49	0.01	--	--
	--	--	--	4.9	1.50	0	--	--
	--	--	--	5.3	1.63	0	--	--
SHSLO	0.00	0.00	0	0.00	0.00	0	1	0
	0.33	0.10	1	0.10	0.03	1	2	0
	1.00	0.31	1	2.00	0.61	1	3	1
	1.00	0.31	0	2.03	0.62	0	4	1
	--	--	--	--	--	--	5	1
	--	--	--	--	--	--	6	1
	--	--	--	--	--	--	7	0
	--	--	--	--	--	--	8	0
	--	--	--	--	--	--	9	1
	--	--	--	--	--	--	10	1
	--	--	--	--	--	--	11	1
	--	--	--	--	--	--	12	1
	--	--	--	--	--	--	13	1
	--	--	--	--	--	--	14	1
	--	--	--	--	--	--	15	1
	--	--	--	--	--	--	16	1
	--	--	--	--	--	--	17	0
	--	--	--	--	--	--	18	0
SHFST	0.00	0.00	0	0.00	0.00	0	1	0
	0.76	0.23	0.3	0.15	0.05	0.1	2	0
	1.50	0.46	1	0.25	0.08	0.8	3	0.75
	2.50	0.76	1	0.35	0.11	1	4	1
	3.50	1.07	0.4	1.20	0.37	1	5	0
	3.80	1.16	0.2	1.50	0.46	0.75	6	0
	4.00	1.22	0	2.00	0.61	0.3	7	0
	--	--	--	2.50	0.76	0.1	8	0.5
	--	--	--	6.00	1.83	0	9	0.75
	--	--	--	--	--	--	10	1
	--	--	--	--	--	--	11	0
	--	--	--	--	--	--	12	1
	--	--	--	--	--	--	13	0
	--	--	--	--	--	--	14	1
	--	--	--	--	--	--	15	0
	--	--	--	--	--	--	16	0.75
	--	--	--	--	--	--	17	0
	--	--	--	--	--	--	18	0

Table 3. Deep Guild HSC Table

Lifestage	Velocity (ft/s)	Velocity (m/s)	Suitability Index	Depth (ft)	Depth (m)	Suitability Index	Channel Index	Suitability Index
RBSFA	0.0	0.00	1.00	0.0	0.00	0.00	1	0.1
	0.8	0.23	1.00	0.2	0.06	0.00	2	0.3
	1.5	0.46	0.30	1.2	0.37	0.80	3	0.7
	3.0	0.91	0.00	2.0	0.61	1.00	4	0.8
	--	--	--	6.0	1.83	1.00	5	0.7
	--	--	--	7.5	2.29	0.60	6	0.3
	--	--	--	8.2	2.50	0.00	7	0.1
	--	--	--	--	--	--	8	0.8
	--	--	--	--	--	--	9	1
	--	--	--	--	--	--	10	0.8
	--	--	--	--	--	--	11	1
	--	--	--	--	--	--	12	0.8
	--	--	--	--	--	--	13	1
	--	--	--	--	--	--	14	0.9
	--	--	--	--	--	--	15	1
	--	--	--	--	--	--	16	0.85
	--	--	--	--	--	--	17	0.65
	--	--	--	--	--	--	18	0
DSLON	0.0	0.00	1.00	0.0	0.00	0.00	1	1
	1.0	0.31	1.00	2.0	0.61	0.00	2	1
	1.0	0.31	0.00	2.0	0.61	1.00	3	1
	2.0	0.61	0.00	10.0	3.05	1.00	4	1
	--	--	--	--	--	--	5	1
	--	--	--	--	--	--	6	1
	--	--	--	--	--	--	7	1
	--	--	--	--	--	--	8	0
	--	--	--	--	--	--	9	0
	--	--	--	--	--	--	10	0
	--	--	--	--	--	--	11	0
	--	--	--	--	--	--	12	0
DSLON	--	--	--	--	--	--	13	0
	--	--	--	--	--	--	14	0.5
	--	--	--	--	--	--	15	0.5
	--	--	--	--	--	--	16	0
	--	--	--	--	--	--	17	0
	--	--	--	--	--	--	18	0
SRHAD	0.0	0.00	0.00	0.0	0.00	0.00	1	0.1
	0.1	0.04	0.51	1.5	0.46	0.00	2	0.45
	0.4	0.12	0.62	2.4	0.73	0.57	3	0.65
	0.6	0.20	0.82	3.3	1.02	0.91	4	0.475
	0.8	0.24	1.00	3.8	1.16	1.00	5	0.35
	1.0	0.32	1.00	4.8	1.45	1.00	6	0.48
	1.2	0.36	0.91	5.2	1.59	1.00	7	0.34
	1.4	0.44	0.6	6.2	1.88	1	8	0.55
	1.7	0.52	0.27	7.1	2.18	1	9	0.82
	2.0	0.60	0.08	8.1	2.47	1	10	0.75
	2.2	0.68	0.02	9.0	2.76	1	11	0.75
	2.4	0.719	0	9.5	2.90	1	12	0.75
	--	--	--	15.0	4.56	1	13	0.75
	--	--	--	--	--	--	14	0.75
	--	--	--	--	--	--	15	0.75
	--	--	--	--	--	--	16	0.82
	--	--	--	--	--	--	17	0.75
	--	--	--	--	--	--	18	0
SHRHA	0.0	0.00	0.37	0.0	0.00	0.00	1	0.2
	0.4	0.12	0.48	0.4	0.12	0.00	2	0.38

Lifestage	Velocity (ft/s)	Velocity (m/s)	Suitability Index	Depth (ft)	Depth (m)	Suitability Index	Channel Index	Suitability Index
	0.8	0.24	0.59	0.8	0.24	0.06	3	0.7
	1.2	0.37	0.70	1.0	0.31	0.14	4	0.75
	1.6	0.49	0.80	1.2	0.37	0.26	5	0.5
	2.0	0.61	0.89	1.4	0.43	0.41	6	0.55
	2.4	0.73	0.95	1.6	0.49	0.56	7	0.3
	2.8	0.85	0.99	1.8	0.55	0.7	8	0.45
	3.2	0.98	1	2.0	0.61	0.81	9	0.7
	3.6	1.10	0.97	2.2	0.67	0.9	10	0.75
	4.0	1.22	0.91	2.4	0.73	0.96	11	0.62
	4.2	1.28	0.86	2.6	0.79	0.99	12	0.75
	4.4	1.34	0.8	2.8	0.85	1	13	0.78
	4.6	1.40	0.71	5	1.52	1	14	0.75
	4.8	1.46	0.58	12	3.66	1	15	0.78
	4.9	1.49	0.47	13	3.96	0.11	16	0.85
	5.0	1.51	0.36	14	4.27	0.09	17	0.7
	5.0	1.52	0.16	15	4.57	0.07	18	0
	5.0	1.52	0	17	5.18	0.05	--	--
	--	--	--	19	5.79	0.03	--	--
	--	--	--	24	7.32	0.01	--	--
	--	--	--	28	8.53	0	--	--

Table 4. Target Species Habitat and Suitability Criteria Source and Code Table

Species	Lifestage/ Category	Representative	Source Study	HSC Code
Walleye	Fry	--	Sutton Hydroelectric Project, Elk River, WV	WLEF
	Juvenile	--	Sutton Hydroelectric Project, Elk River, WV	WLEJ
	Adult	--	Sutton Hydroelectric Project, Elk River, WV	WLEA
	Spawning	--	Sutton Hydroelectric Project, Elk River, WV	WLES
Shallow-Slow Guild	Fine substrate, no cover	Redbreast Sunfish spawning	Smith Mountain Hydroelectric Project, Roanoke River, VA	RBSFS
	All substrate with aquatic vegetation	Silver Redhorse young-of-year	Sutton Hydroelectric Project, Elk River, WV	SRHAV
	Coarse substrate	Generic Shallow-Slow Guild	Sutton Hydroelectric Project, Elk River, WV	SHSLO
Shallow-Fast Guild	Moderate velocity with coarse substrate	Generic Shallow-Fast Guild	Claytor Hydroelectric Project New River, VA	SHFST
Deep-Slow Guild	Cover	Redbreast Sunfish adult	Smith Mountain Hydroelectric Project, Roanoke River, VA	RBSFA
	No cover	Generic Deep-Slow Guild	Sutton Hydroelectric Project, Elk River, WV	DSLON
Deep-Fast Guild	Slightly weighted for fine substrate, Cover	Silver Redhorse adult	Smith Mountain Hydroelectric Project, Roanoke River, VA	SRHAD
	Coarse-mixed substrate	Shorthead Redhorse adult	Smith Mountain Hydroelectric Project, Roanoke River, VA	SHRHA

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Attachment 3

Attachment 3 – Usable Area Curves

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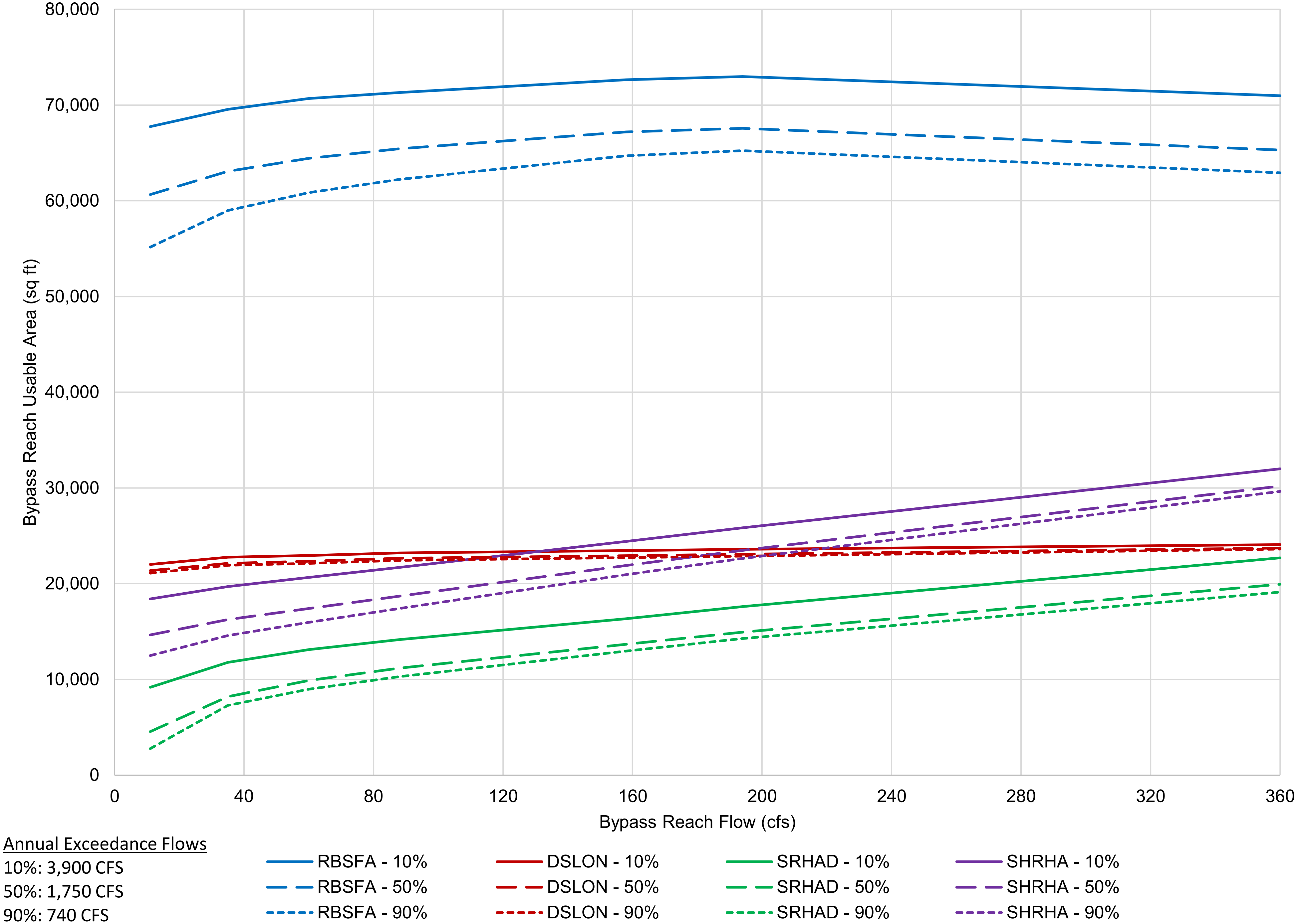
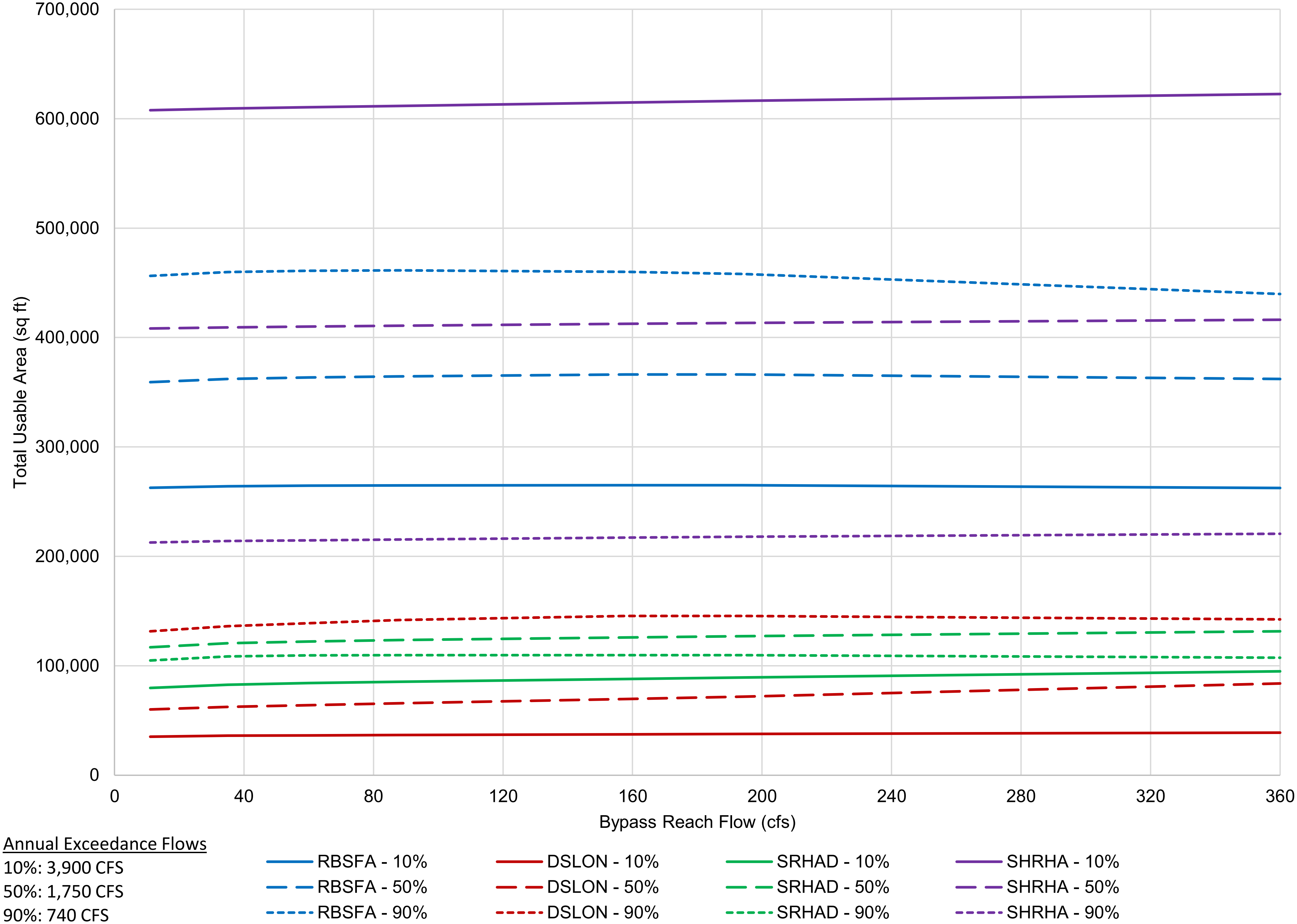
Figure 1 Byllesby Bypass Reach: Deep Guild Usable Area Curves



Annual Exceedance Flows
10%: 3,900 CFS
50%: 1,750 CFS
90%: 740 CFS

Figure 2 Byllesby Study Area: Deep Guild Usable Area Curves



Annual Exceedance Flows
10%: 3,900 CFS
50%: 1,750 CFS
90%: 740 CFS

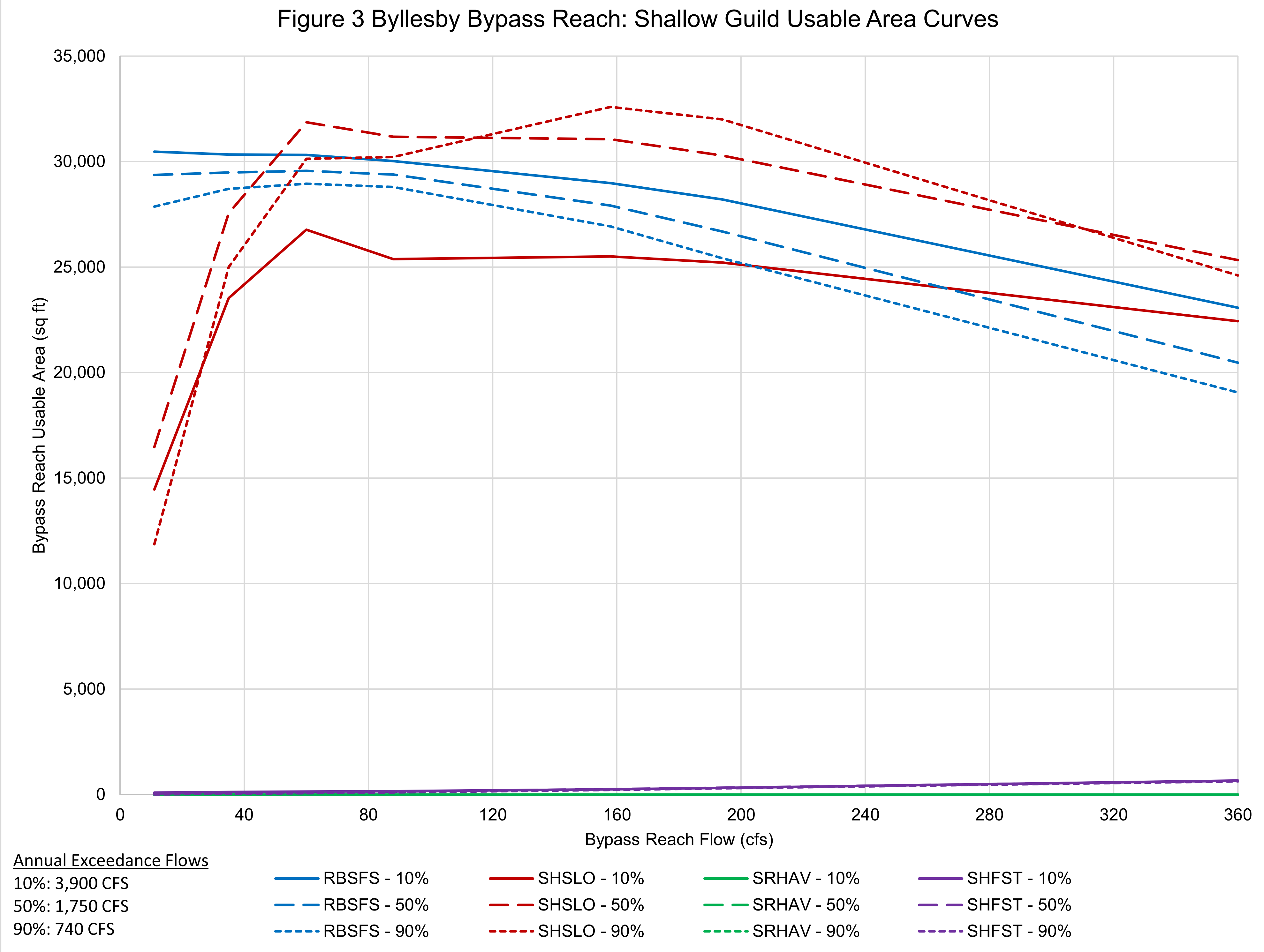
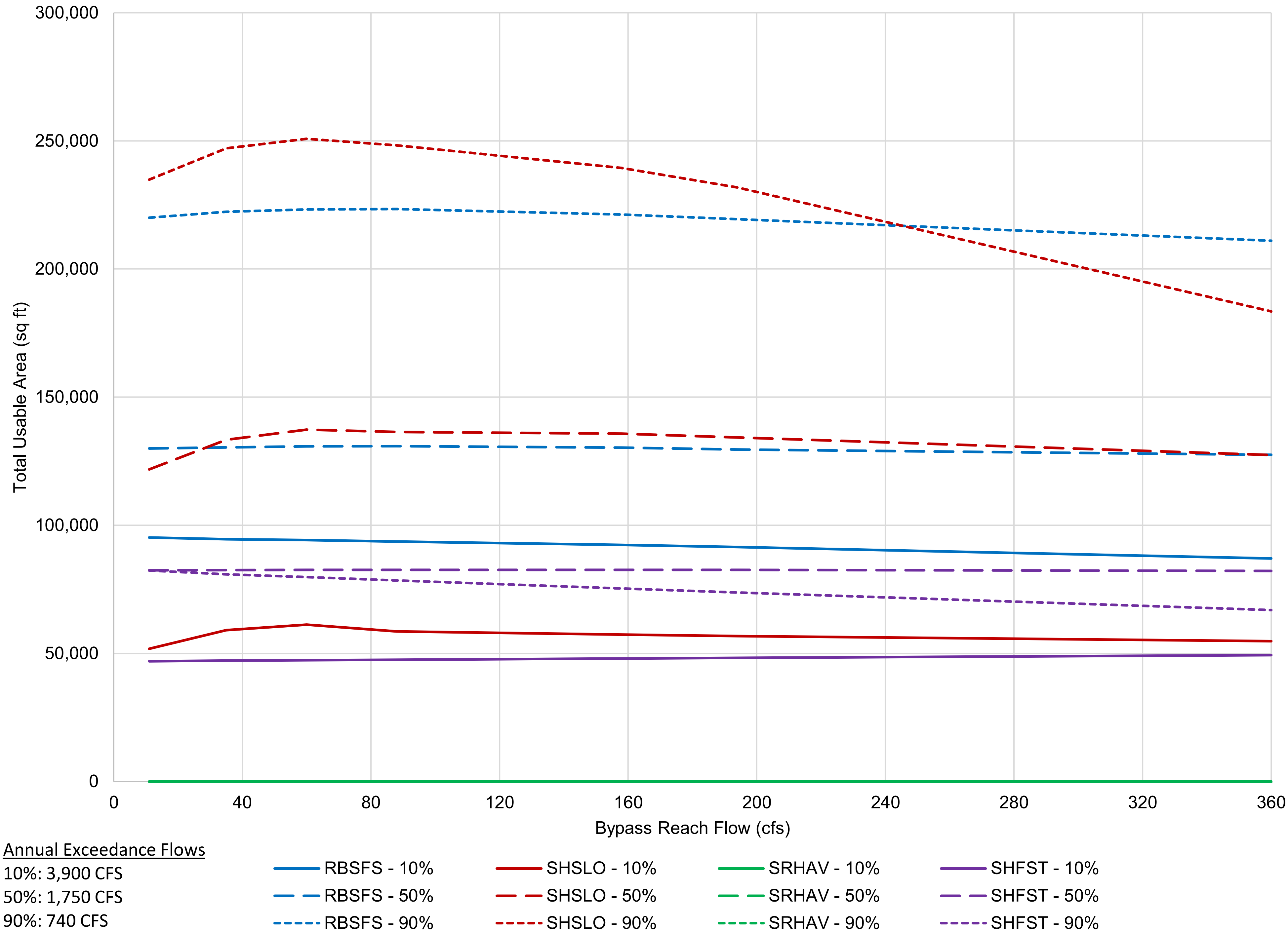


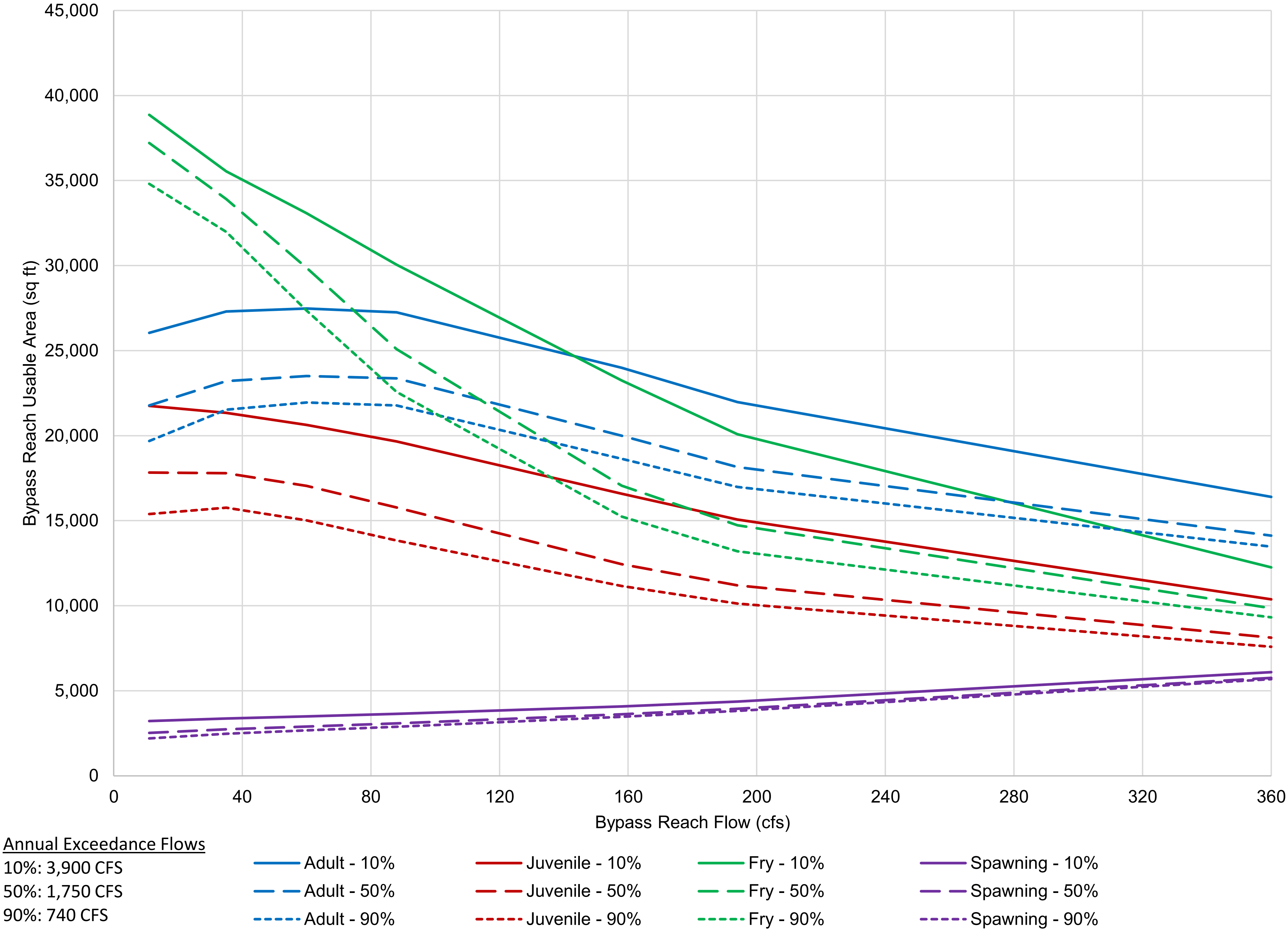
Figure 3 Byllesby Bypass Reach: Shallow Guild Usable Area Curves
Bypass Reach Usable Area (sq ft)
35,000
30,000
25,000
20,000
15,000
10,000
5,000
0
0
40
80
120
160
200
240
280
320
360
Bypass Reach Flow (cfs)
Annual Exceedance Flows
10%: 3,900 CFS
50%: 1,750 CFS
90%: 740 CFS
RBSFS - 10%
RBSFS - 50%
RBSFS - 90%
SHSLO - 10%
SHSLO - 50%
SHSLO - 90%
SRHAV - 10%
SRHAV - 50%
SRHAV - 90%
SHFST - 10%
SHFST - 50%
SHFST - 90%

Figure 4 Byllesby Study Area: Shallow Guild Usable Area Curves



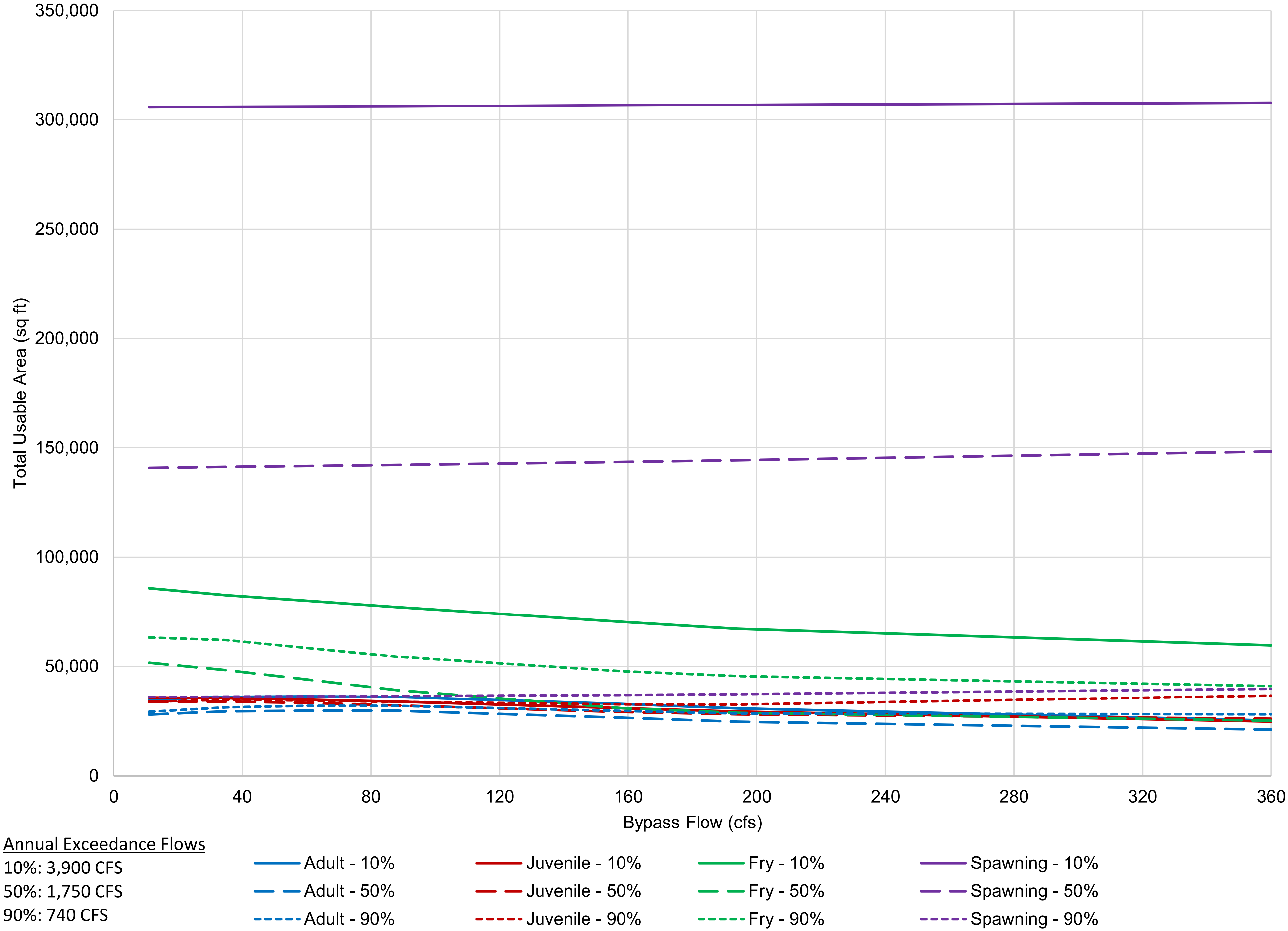
Annual Exceedance Flows
10%: 3,900 CFS
50%: 1,750 CFS
90%: 740 CFS

Figure 5 Byllesby Bypass Reach: Walleye Usable Area Curves



Annual Exceedance Flows
10%: 3,900 CFS
50%: 1,750 CFS
90%: 740 CFS

Figure 6 Byllesby Study Area: Walleye Usable Area Curves



Annual Exceedance Flows
10%: 3,900 CFS
50%: 1,750 CFS
90%: 740 CFS

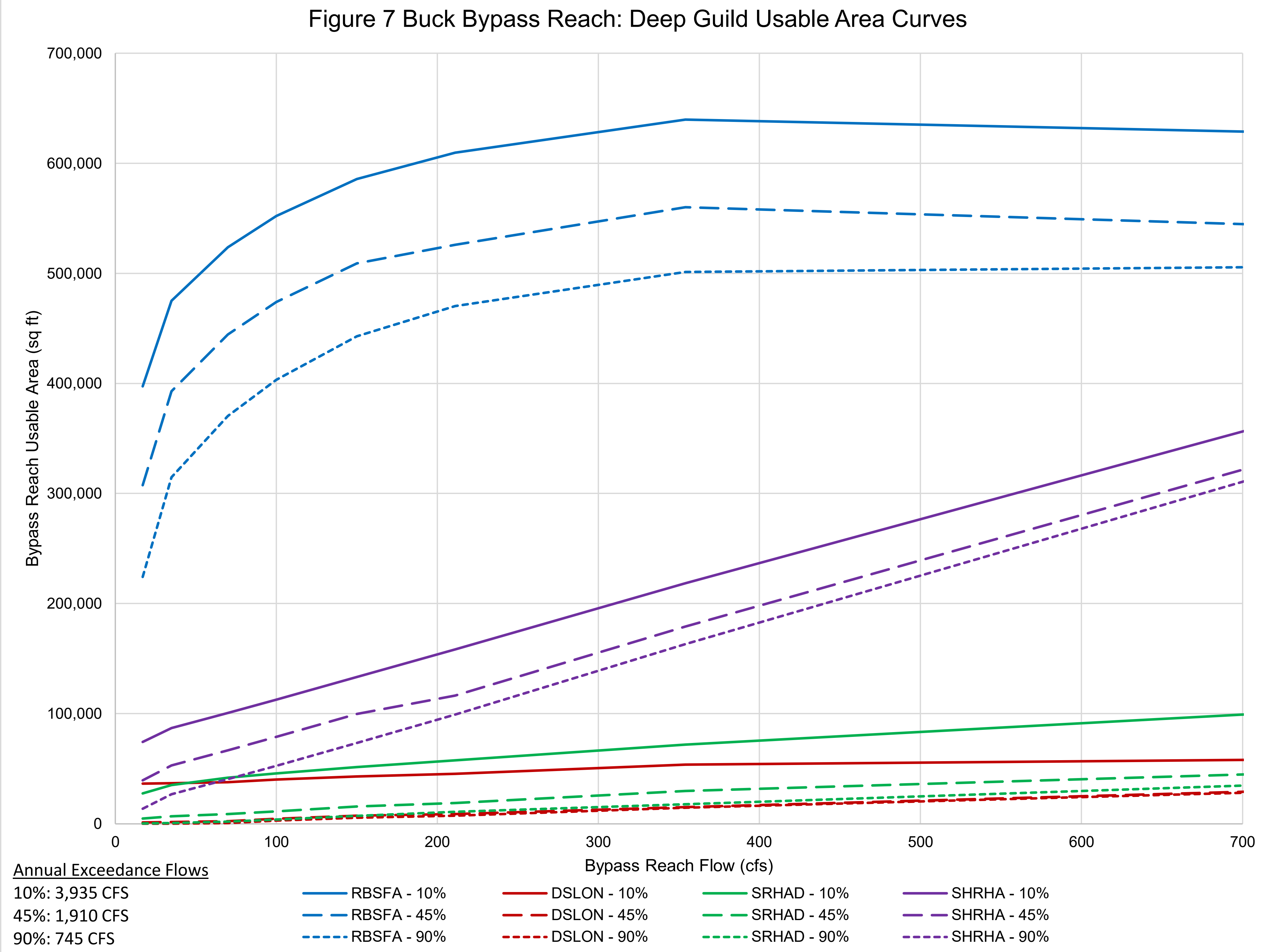
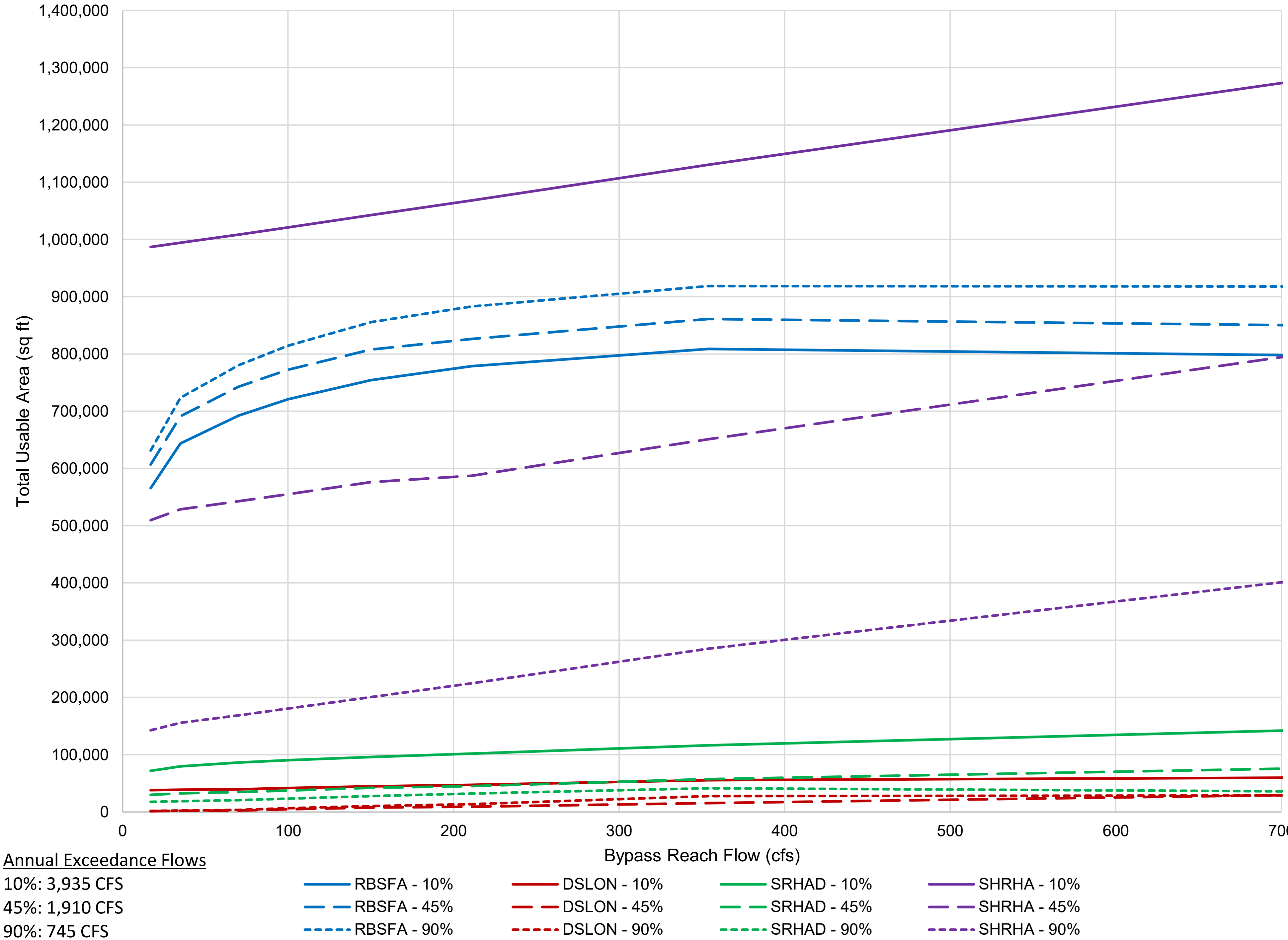


Figure 7 Buck Bypass Reach: Deep Guild Usable Area Curves
Bypass Reach Usable Area (sq ft)
700,000
600,000
500,000
400,000
300,000
200,000
100,000
0
0
100
200
300
400
500
600
700
Bypass Reach Flow (cfs)
Annual Exceedance Flows
10%: 3,935 CFS
45%: 1,910 CFS
90%: 745 CFS
RBSFA - 10%
RBSFA - 45%
RBSFA - 90%
DSLON - 10%
DSLON - 45%
DSLON - 90%
SRHAD - 10%
SRHAD - 45%
SRHAD - 90%
SHRHA - 10%
SHRHA - 45%
SHRHA - 90%

Figure 8 Buck Study Area: Deep Guild Usable Area Curves



Annual Exceedance Flows
10%: 3,935 CFS
45%: 1,910 CFS
90%: 745 CFS

Figure 9 Buck Bypass Reach: Shallow Guild Usable Area Curves

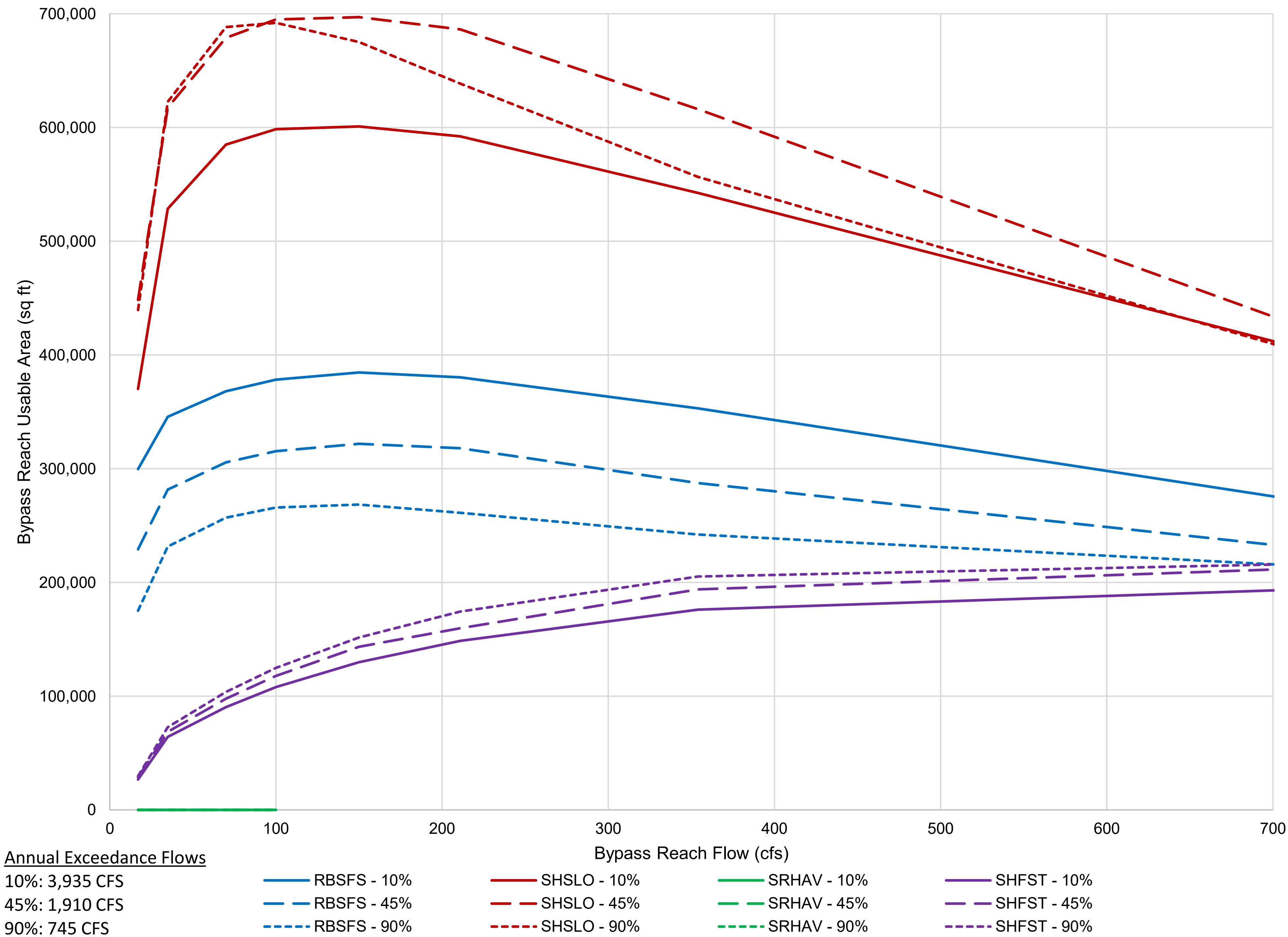
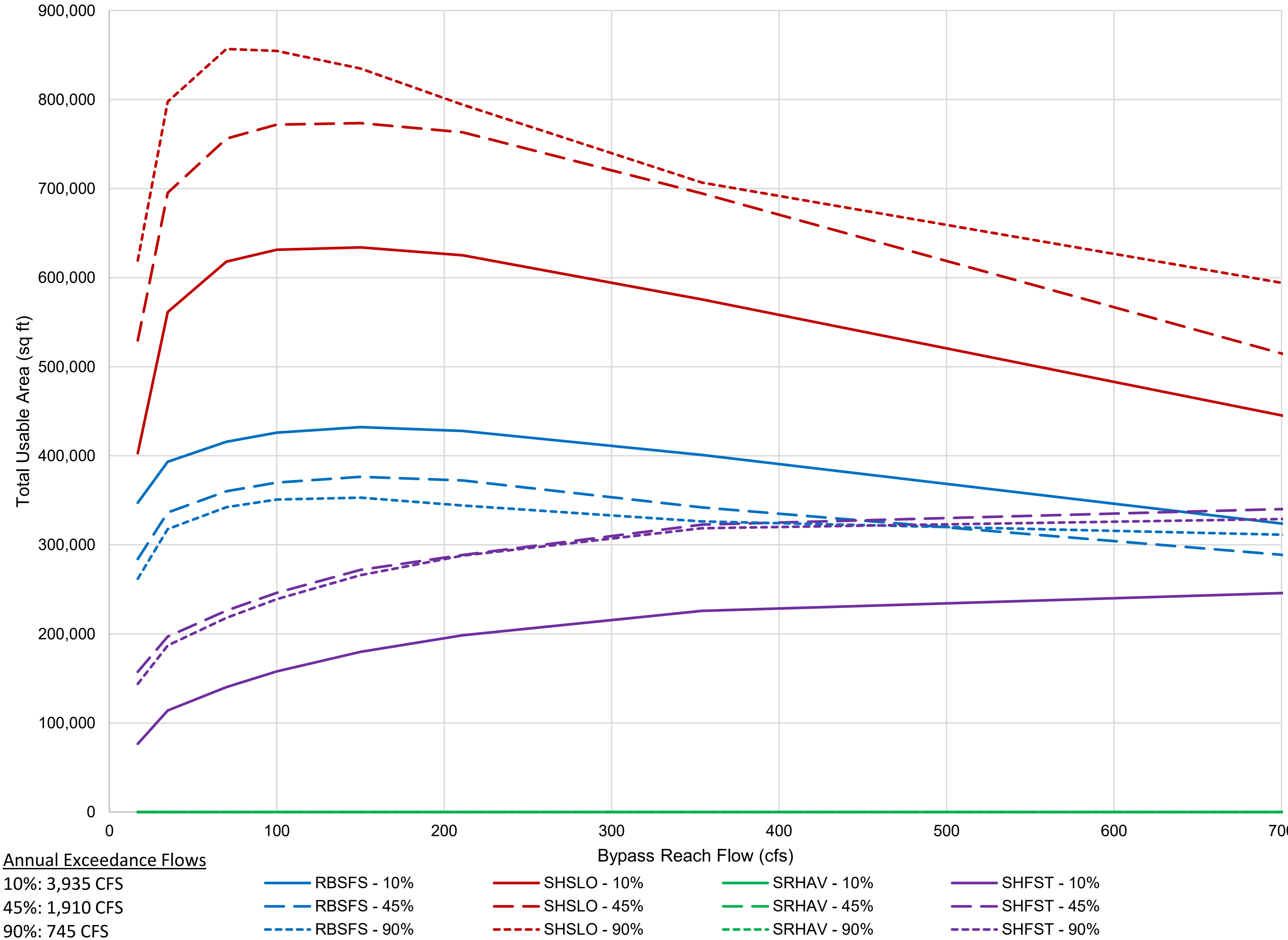


Figure 10 Buck Study Area: Shallow Guild Usable Area Curves



Annual Exceedance Flows
10%: 3,935 CFS
45%: 1,910 CFS
90%: 745 CFS

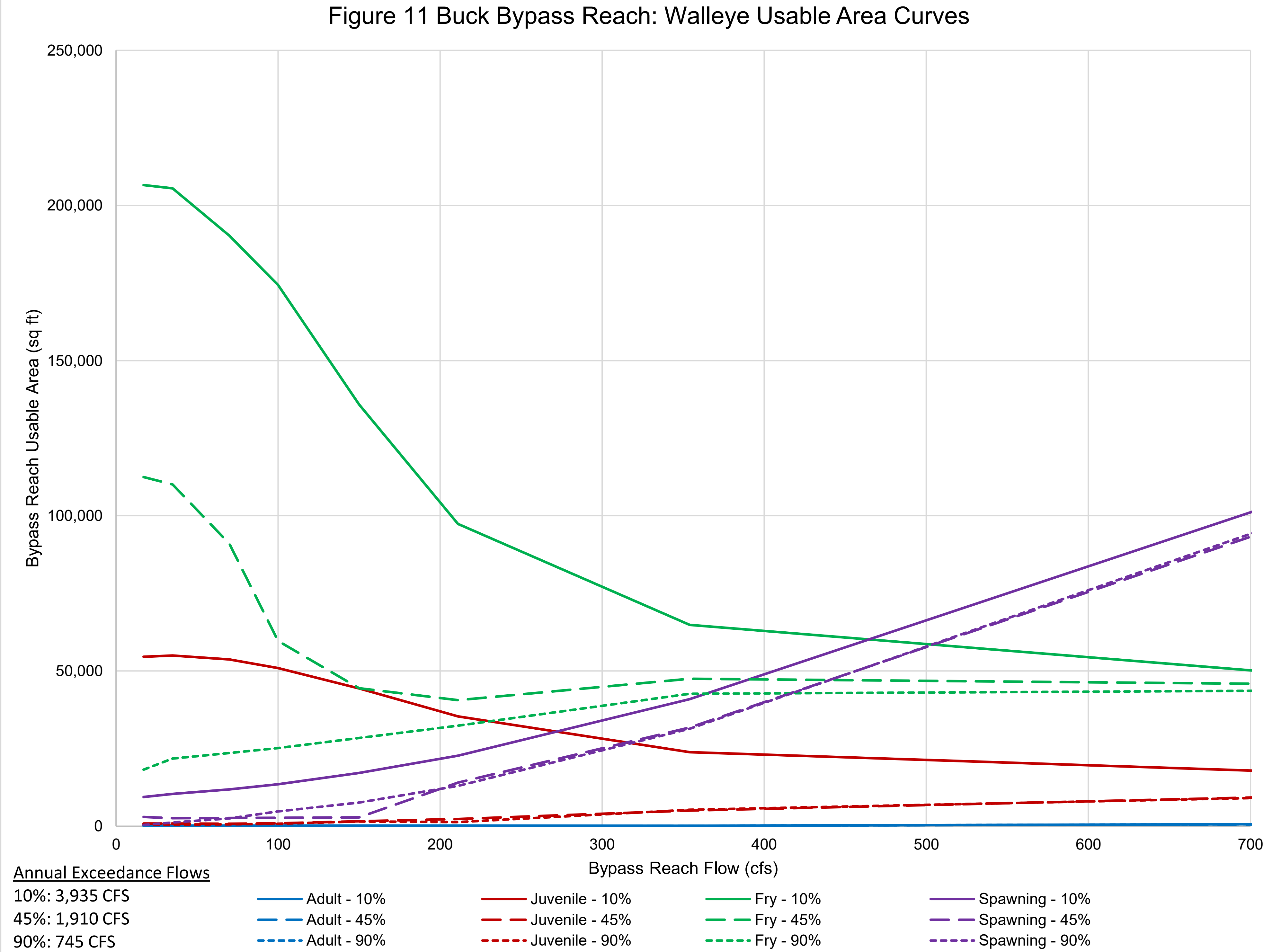
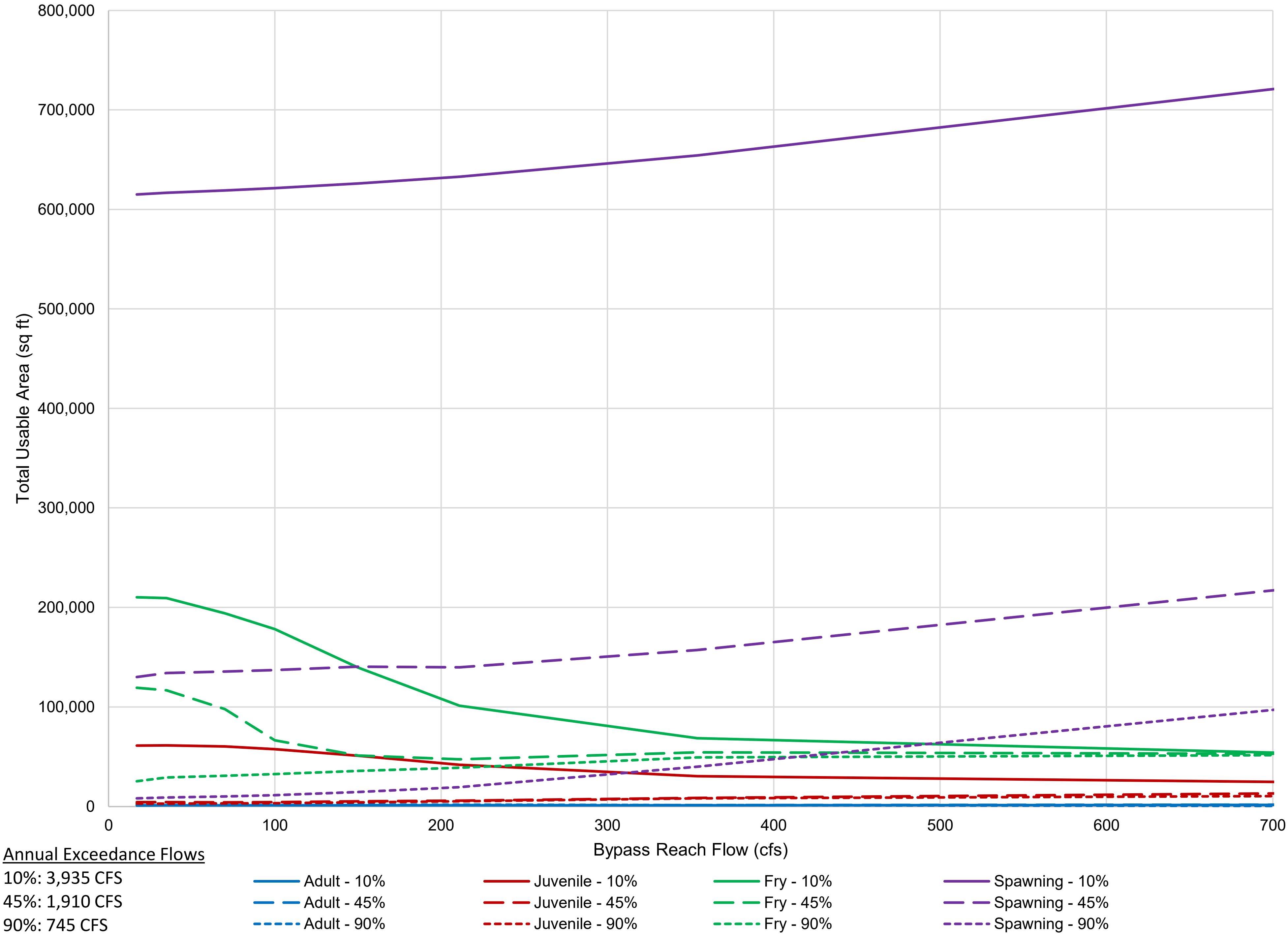


Figure 11 Buck Bypass Reach: Walleye Usable Area Curves
250,000
200,000
150,000
100,000
50,000
0
Bypass Reach Usable Area (sq ft)
0
100
200
300
400
500
600
700
Bypass Reach Flow (cfs)
Annual Exceedance Flows
10%: 3,935 CFS
45%: 1,910 CFS
90%: 745 CFS
Adult - 10%
Adult - 45%
Adult - 90%
Juvenile - 10%
Juvenile - 45%
Juvenile - 90%
Fry - 10%
Fry - 45%
Fry - 90%
Spawning - 10%
Spawning - 45%
Spawning - 90%

Figure 12 Buck Study Area: Walleye Usable Area Curves



Annual Exceedance Flows
10%: 3,935 CFS
45%: 1,910 CFS
90%: 745 CFS

Attachment 4

Attachment 4 – Habitat Model Results Maps

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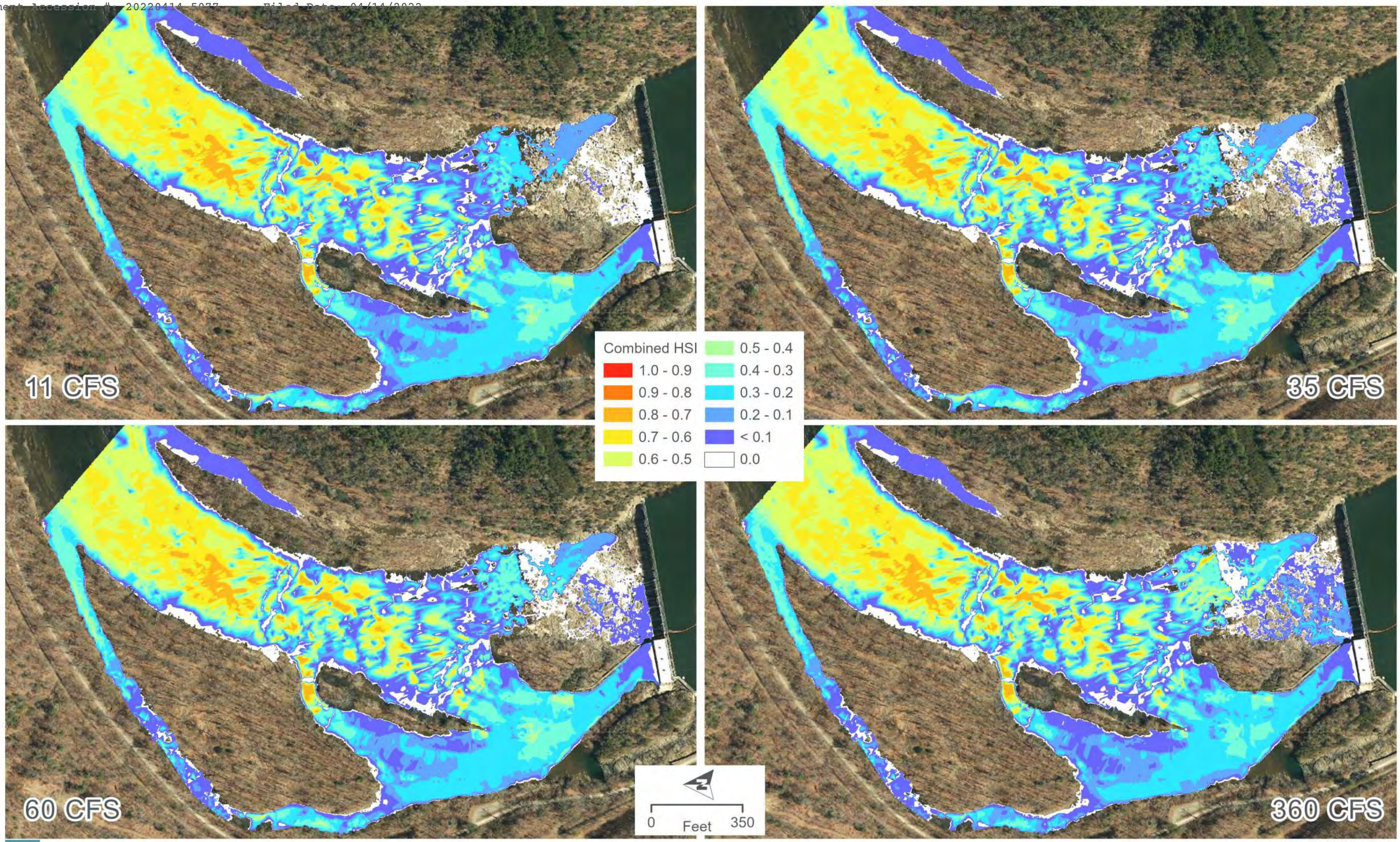


FIGURE 1
BYLLESBY

Total River Flow 50% Annual Exceedance (1,750 CFS)
Bypass Flow Released from the Trash Sluice Gate

DEEP FAST GUILD
HABITAT SUITABILITY MAP
CATEGORY: COARSE-MIXED SUBSTRATE

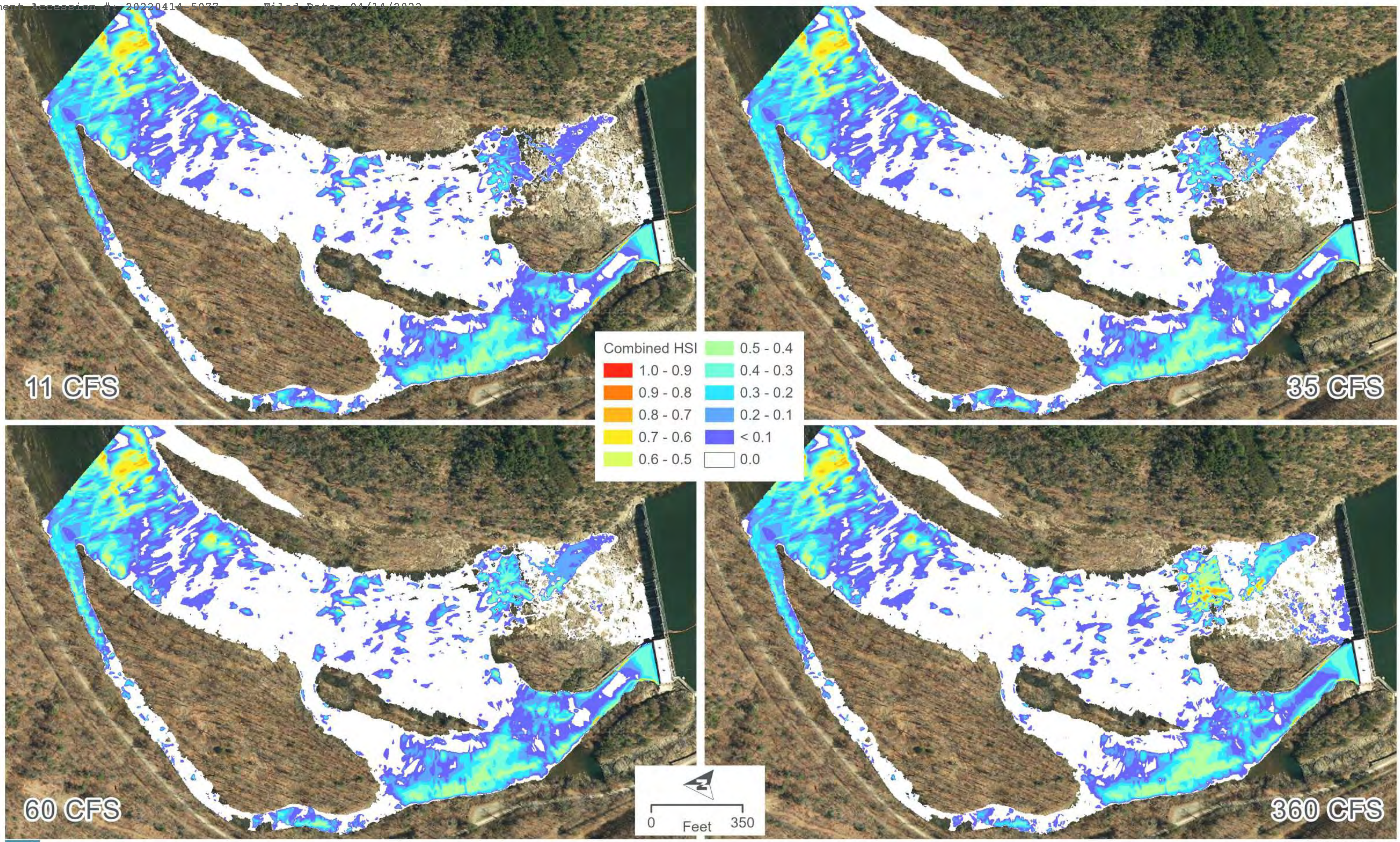
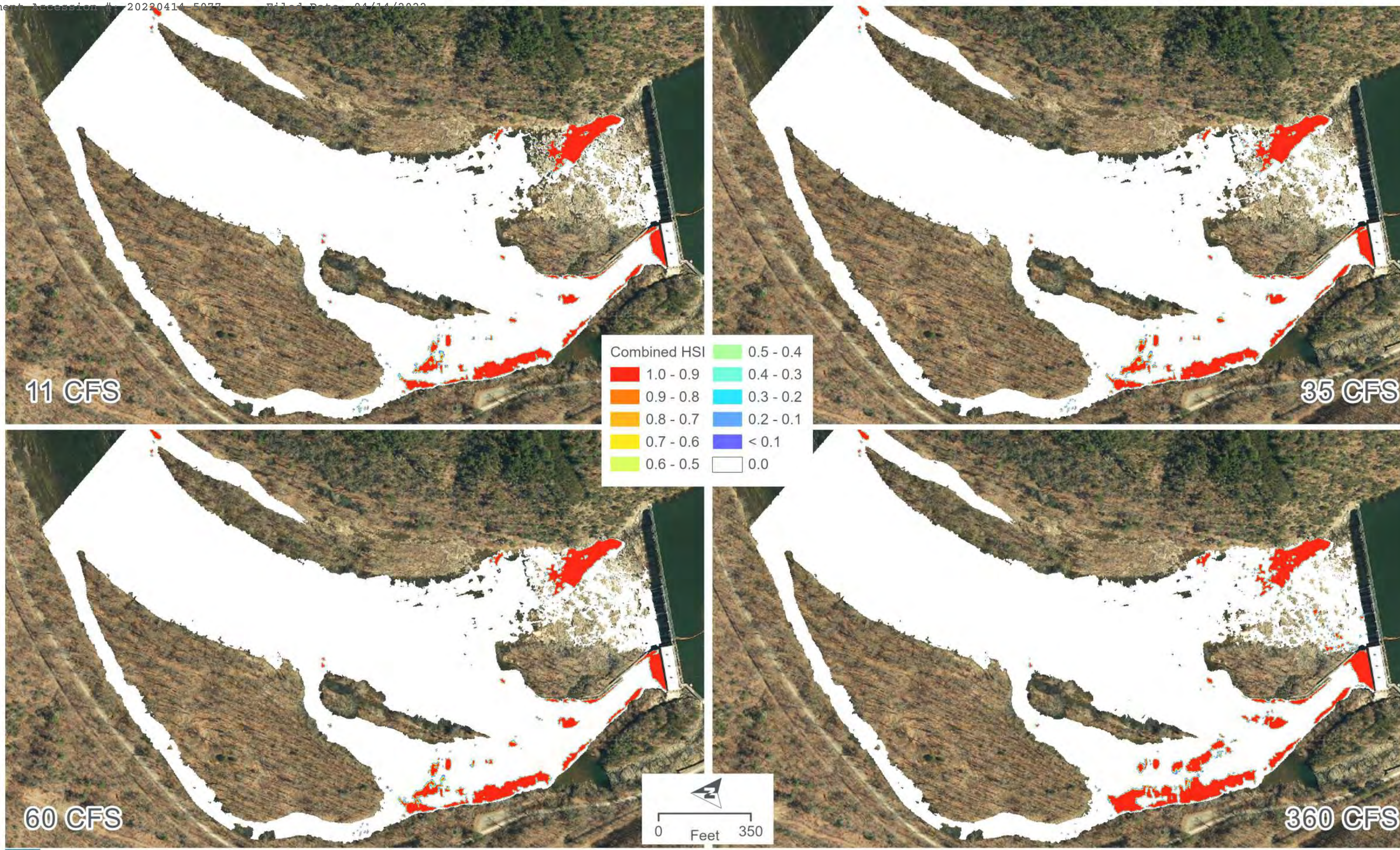


FIGURE 2
BYLLESBY

Total River Flow 50% Annual Exceedance (1,750 CFS)
Bypass Flow Released from the Trash Sluice Gate

DEEP FAST GUILD
HABITAT SUITABILITY MAP
CATEGORY: SLIGHTLY WEIGHTED FOR FINE SUBSTRATE, COVER

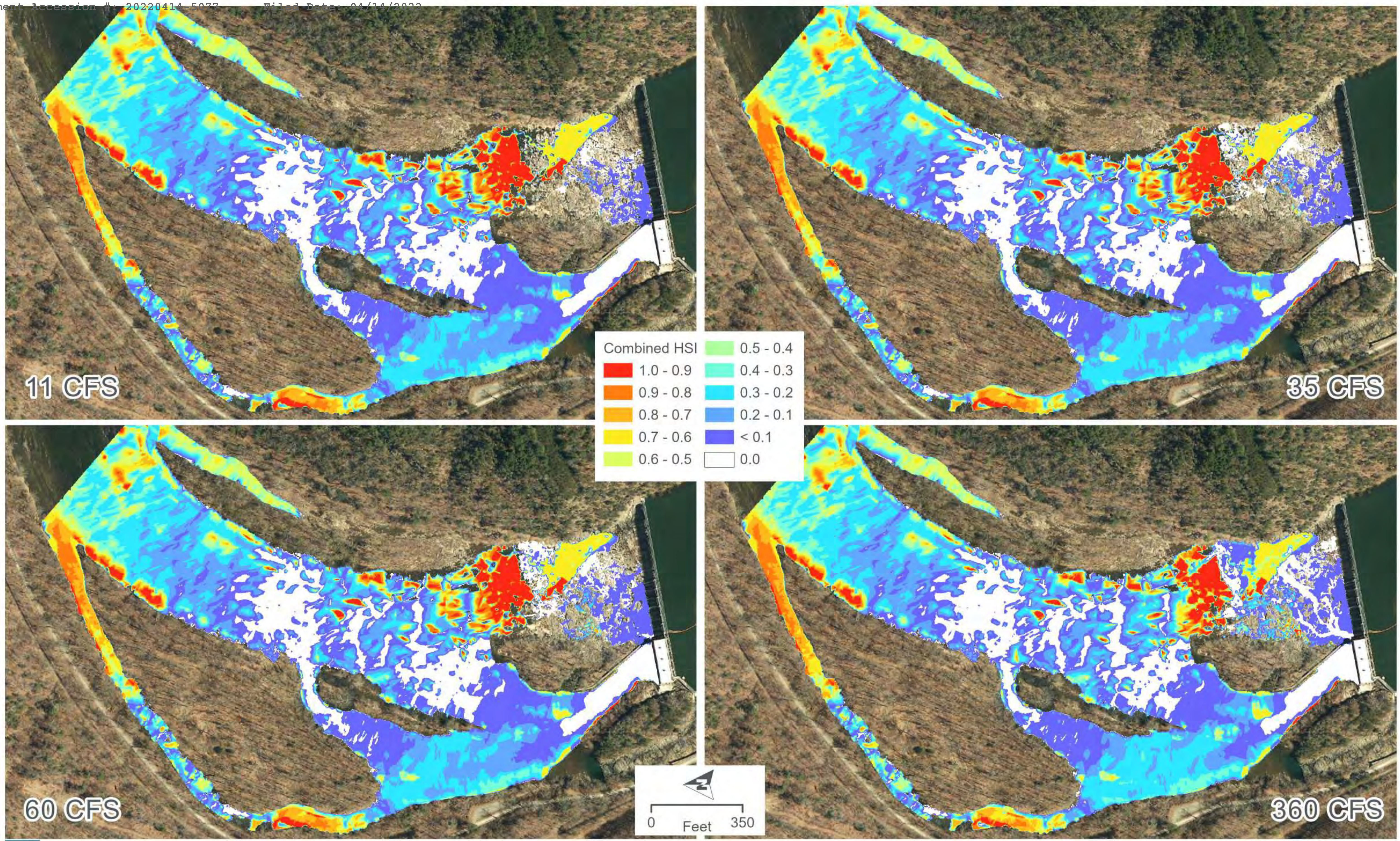


HDR AMERICAN ELECTRIC POWER

FIGURE 3
BYLLESBY

Total River Flow 50% Annual Exceedance (1,750 CFS)
Bypass Flow Released from the Trash Sluice Gate

GENERIC DEEP SLOW GUILD
HABITAT SUITABILITY MAP
CATEGORY: NO COVER

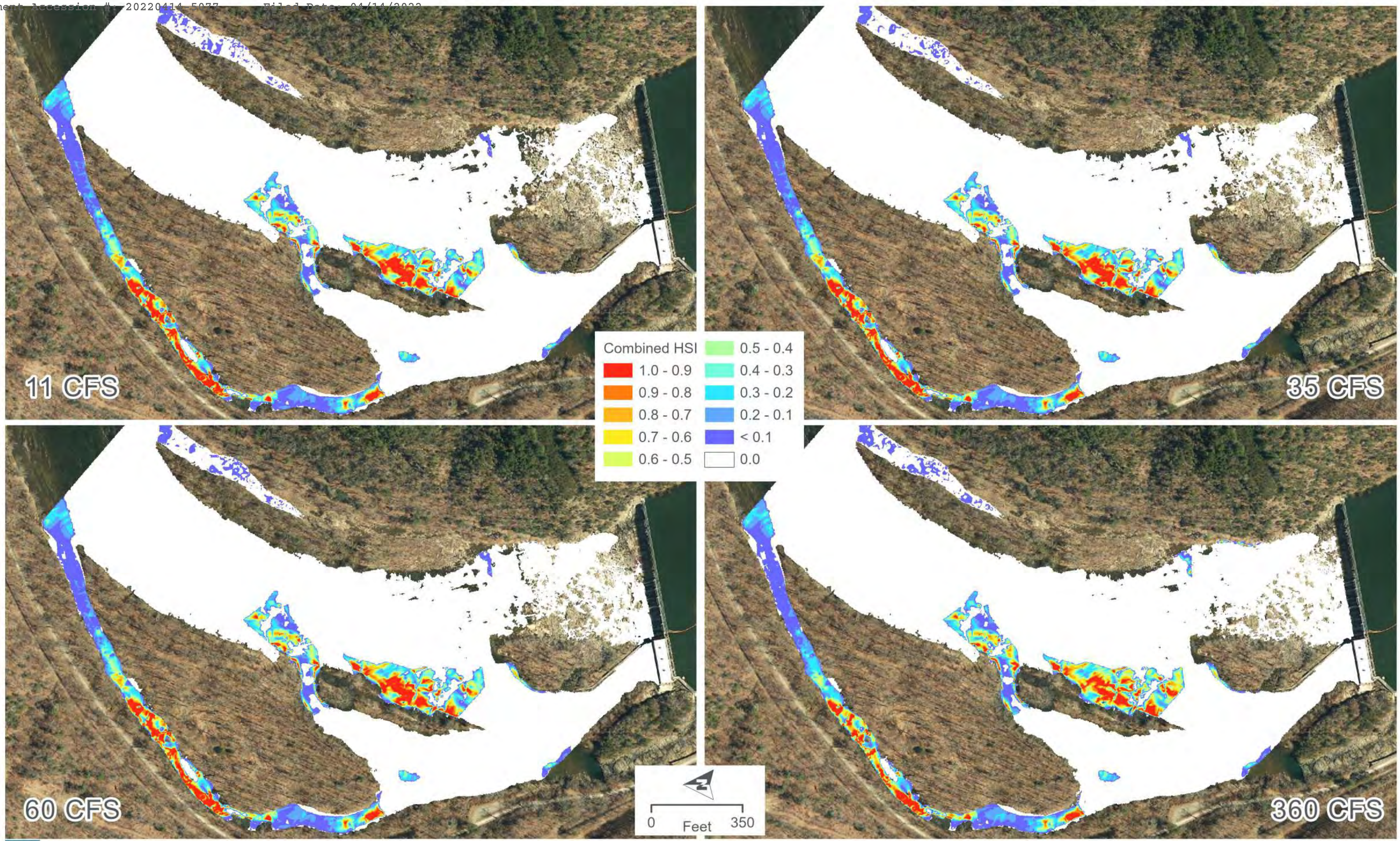


HDR AMERICAN ELECTRIC POWER

FIGURE 4
BYLLESBY

Total River Flow 50% Annual Exceedance (1,750 CFS)
Bypass Flow Released from the Trash Sluice Gate

DEEP SLOW GUILD
HABITAT SUITABILITY MAP
CATEGORY: COVER

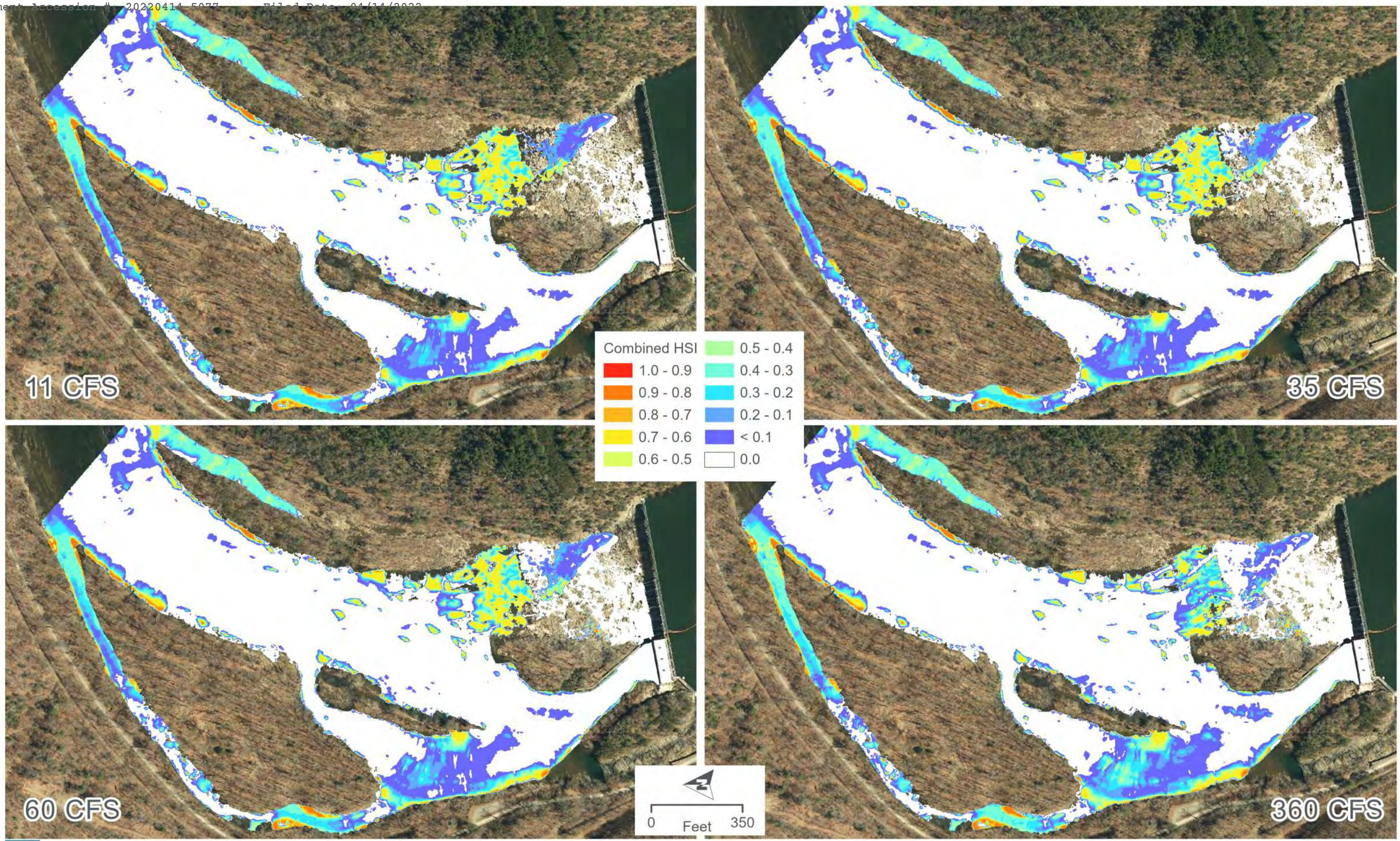


HDR AMERICAN ELECTRIC POWER

FIGURE 5
BYLLESBY

Total River Flow 50% Annual Exceedance (1,750 CFS)
Bypass Flow Released from the Trash Sluice Gate

SHALLOW FAST GUILD
HABITAT SUITABILITY MAP
CATEGORY: MODERATE VELOCITY WITH COARSE SUBSTRATE

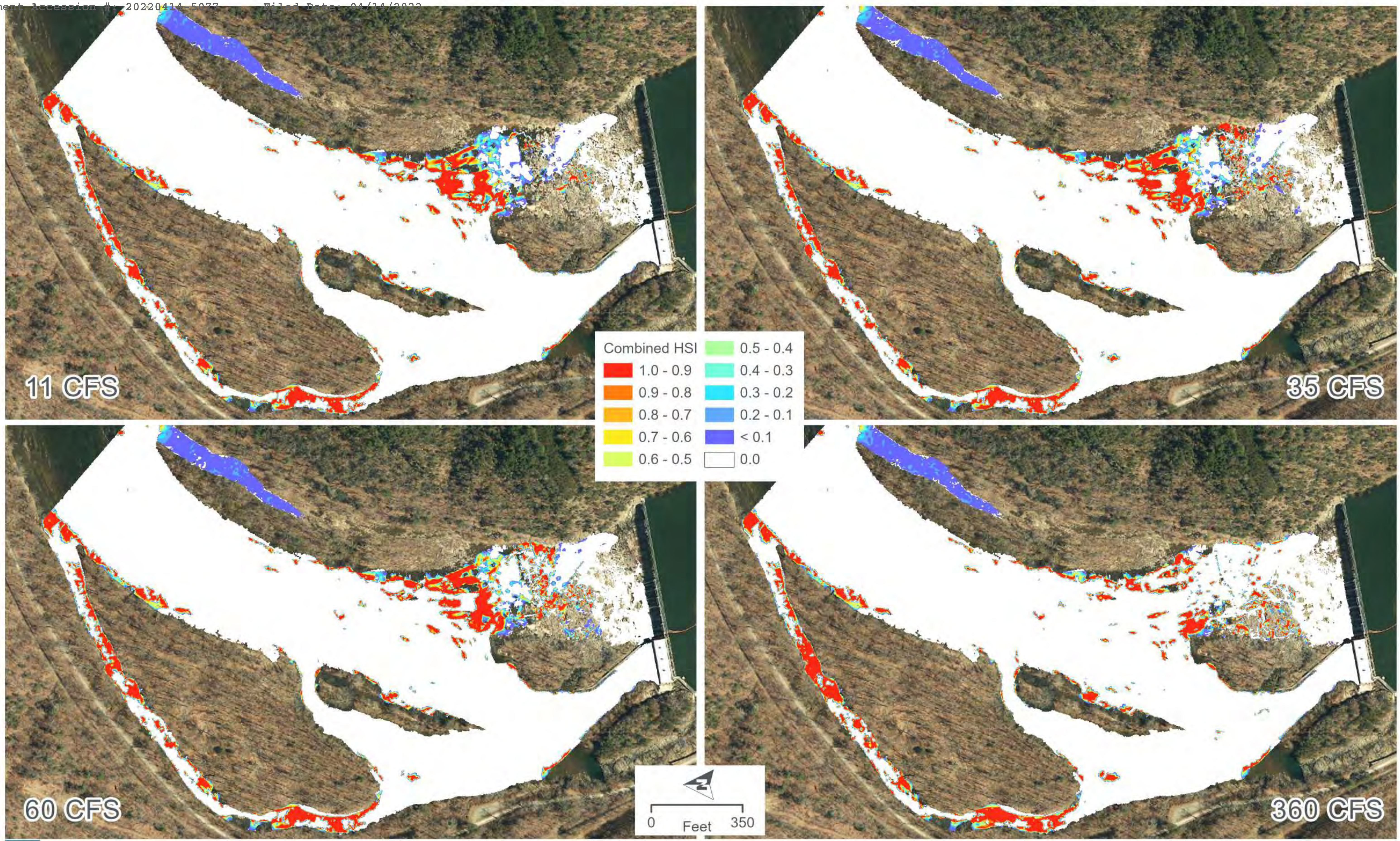


HDR AMERICAN ELECTRIC POWER

FIGURE 6
BYLLESBY

Total River Flow 50% Annual Exceedance (1,750 CFS)
Bypass Flow Released from the Trash Sluice Gate

SHALLOW SLOW GUILD
HABITAT SUITABILITY MAP
CATEGORY: FINE SUBSTRATE, NO COVER



HDR AMERICAN ELECTRIC POWER

FIGURE 7
BYLLESBY

Total River Flow 50% Annual Exceedance (1,750 CFS)
Bypass Flow Released from the Trash Sluice Gate

GENERIC SHALLOW SLOW GUILD
HABITAT SUITABILITY MAP
CATEGORY: COARSE SUBSTRATE

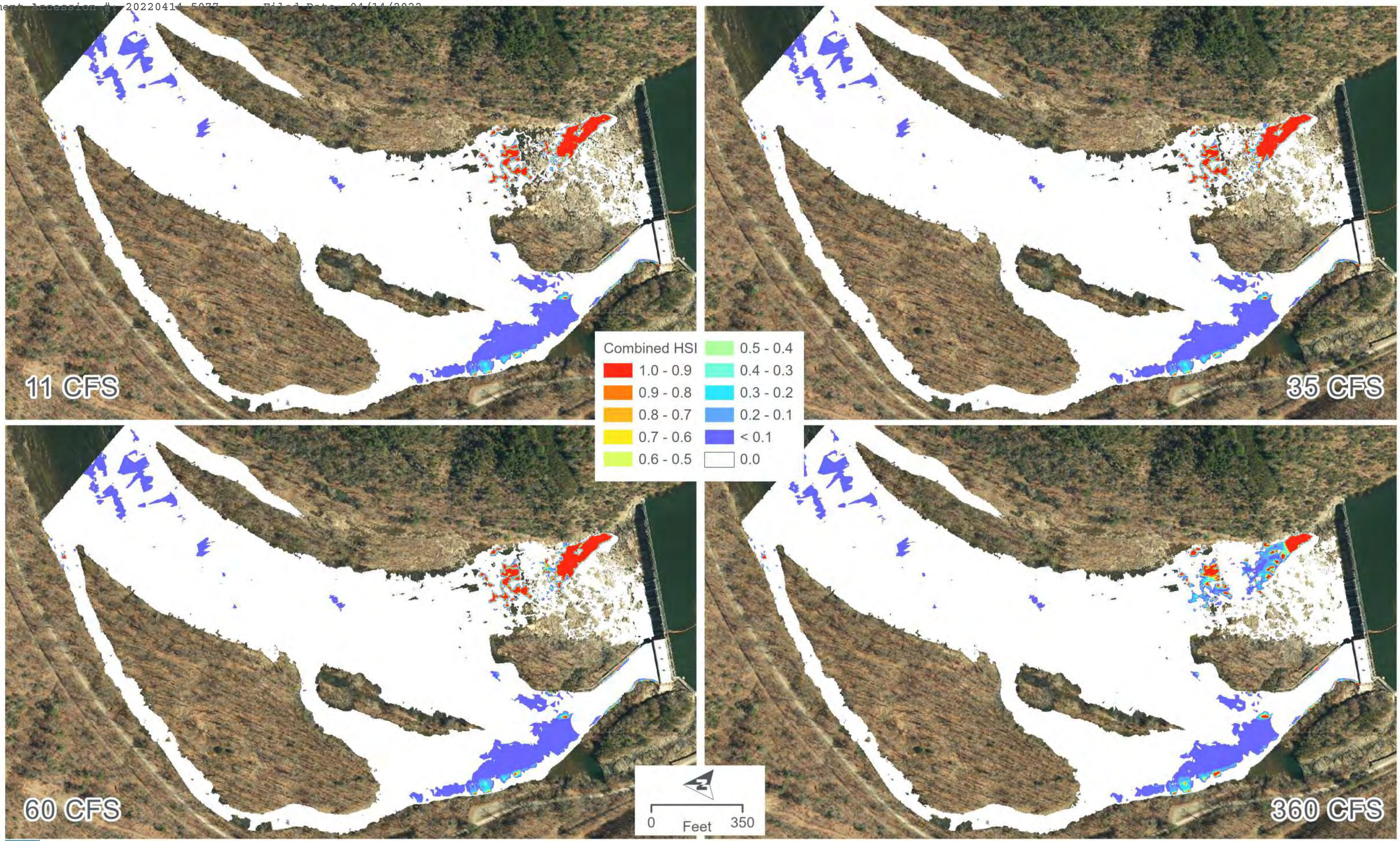
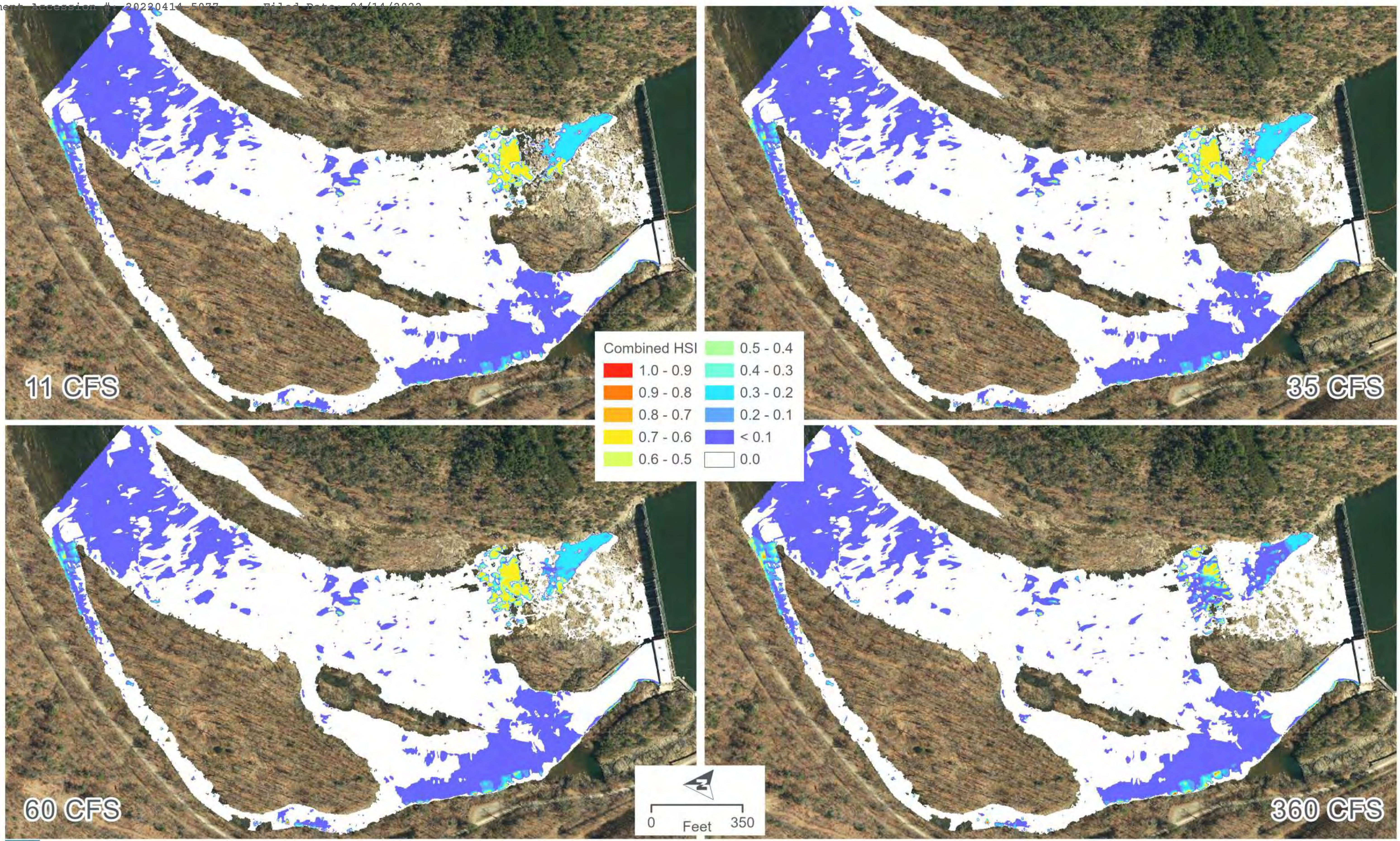


FIGURE 8
BYLLESBY

Total River Flow 50% Annual Exceedance (1,750 CFS)
Bypass Flow Released from the Trash Sluice Gate

WALLEYE ADULT
HABITAT SUITABILITY MAP

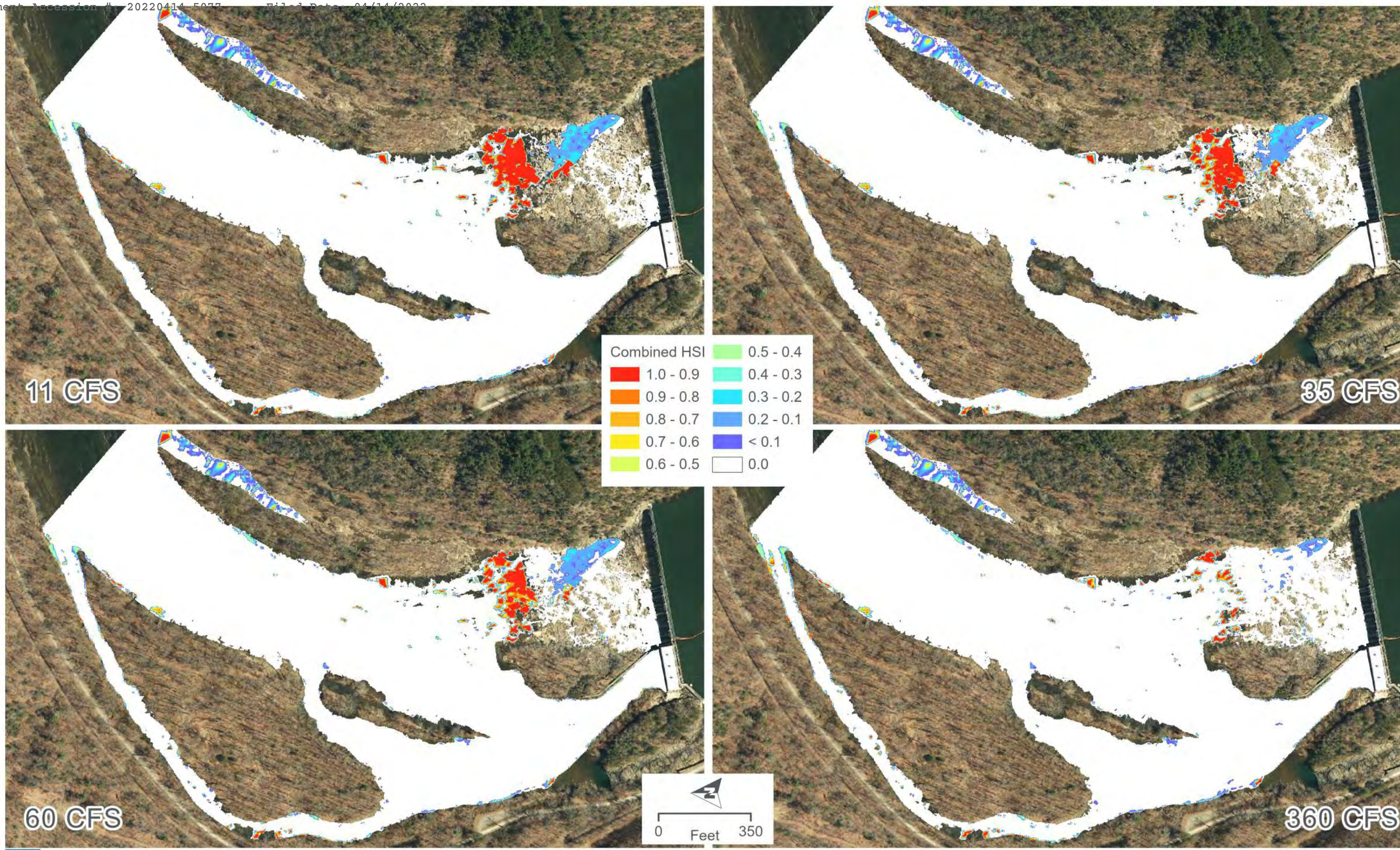


AMERICAN ELECTRIC POWER

FIGURE 9
BYLLESBY

Total River Flow 50% Annual Exceedance (1,750 CFS)
Bypass Flow Released from the Trash Sluice Gate

WALLEYE JUVENILE HABITAT SUITABILITY MAP

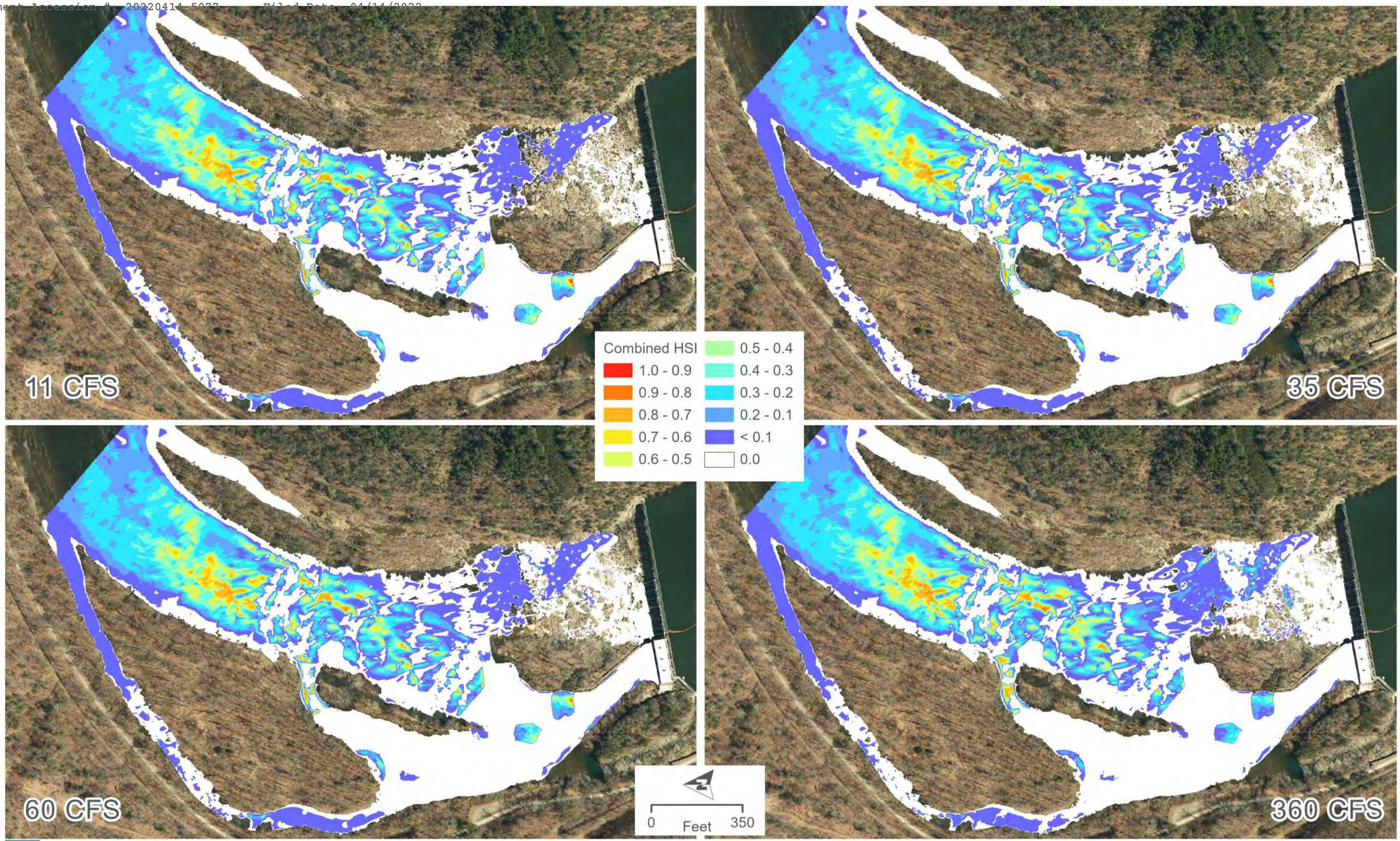


HDR AMERICAN ELECTRIC POWER

FIGURE 10
BYLLESBY

Total River Flow 50% Annual Exceedance (1,750 CFS)
Bypass Flow Released from the Trash Sluice Gate

WALLEYE FRY
HABITAT SUITABILITY MAP

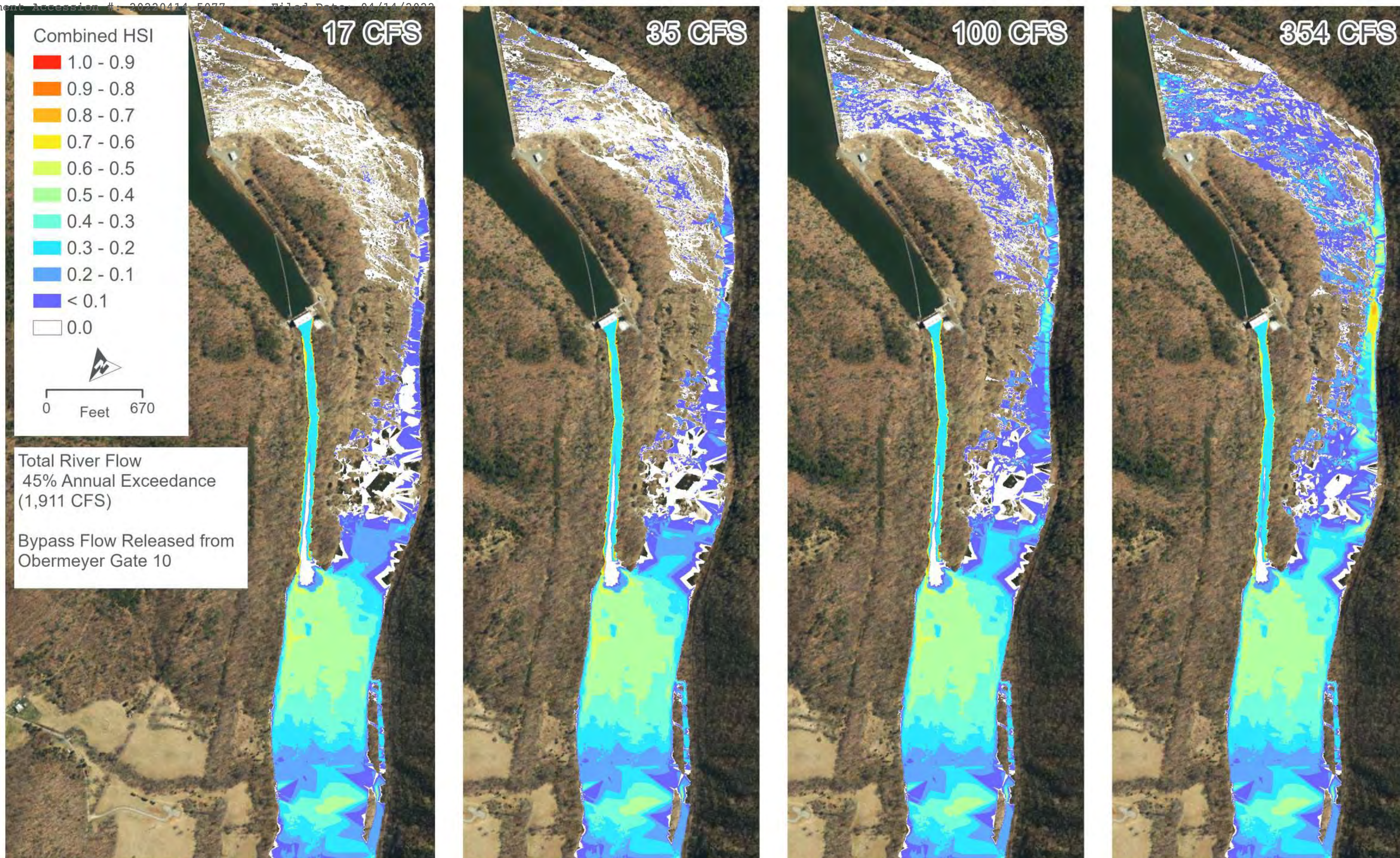


HDR AMERICAN ELECTRIC POWER

FIGURE 11
BYLLESBY

Total River Flow 50% Annual Exceedance (1,750 CFS)
Bypass Flow Released from the Trash Sluice Gate

WALLEYE SPAWNING
HABITAT SUITABILITY MAP



HDR AMERICAN ELECTRIC POWER

FIGURE 12
BUCK

DEEP FAST GUILD
HABITAT SUITABILITY MAP
CATEGORY: COARSE-MIXED SUBSTRATE

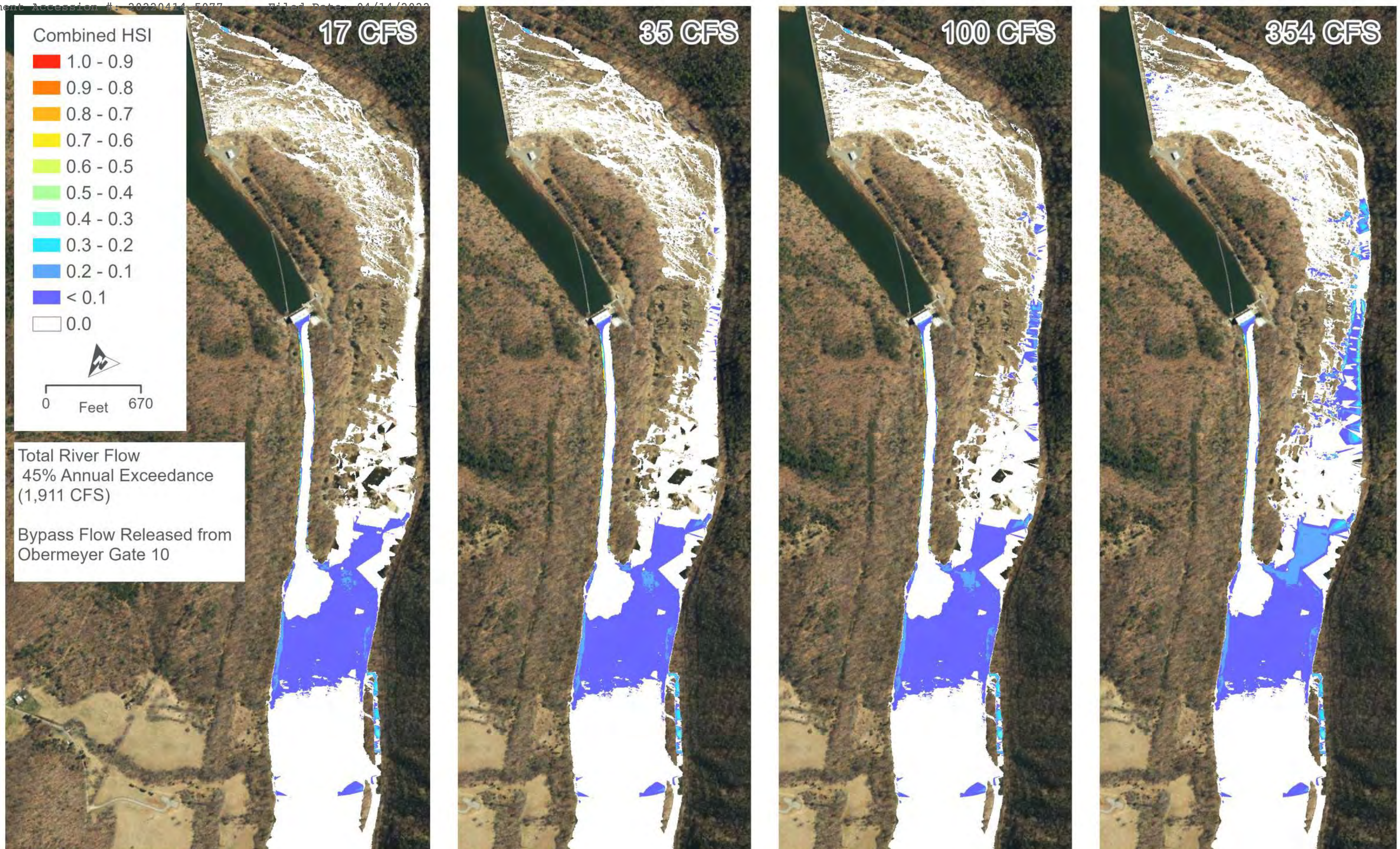


FIGURE 13
BUCK

DEEP FAST GUILD
HABITAT SUITABILITY MAP
CATEGORY: SLIGHTLY WEIGHTED FOR FINE SUBSTRATE, COVER

FIGURE 14
BUCK

GENERIC DEEP SLOW GUILD
HABITAT SUITABILITY MAP
CATEGORY: NO COVER

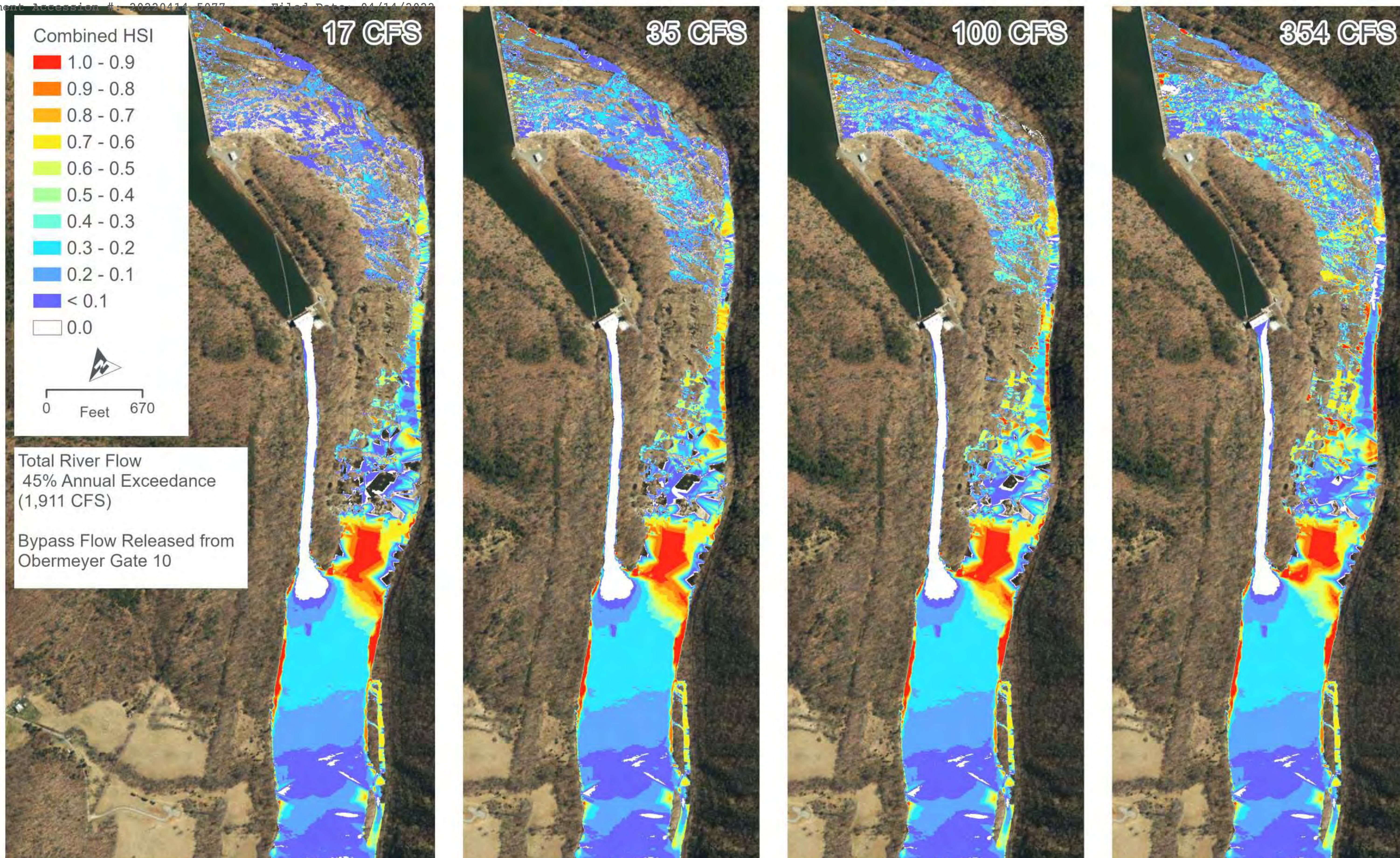
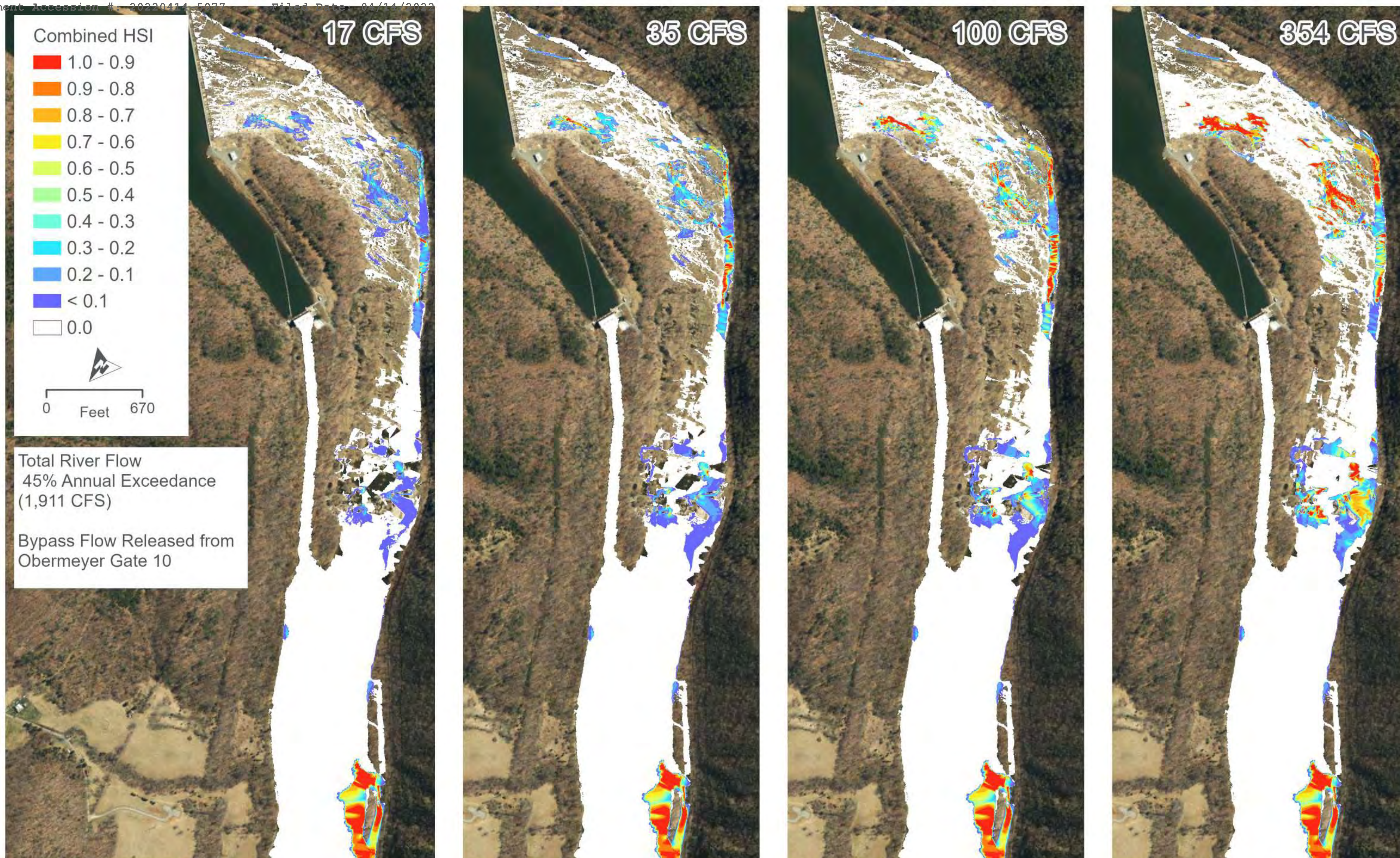


FIGURE 15
BUCK

DEEP SLOW GUILD
HABITAT SUITABILITY MAP
CATEGORY: COVER



HDR AMERICAN ELECTRIC POWER

FIGURE 16
BUCK

SHALLOW FAST GUILD
HABITAT SUITABILITY MAP
CATEGORY: MODERATE VELOCITY WITH COARSE SUBSTRATE

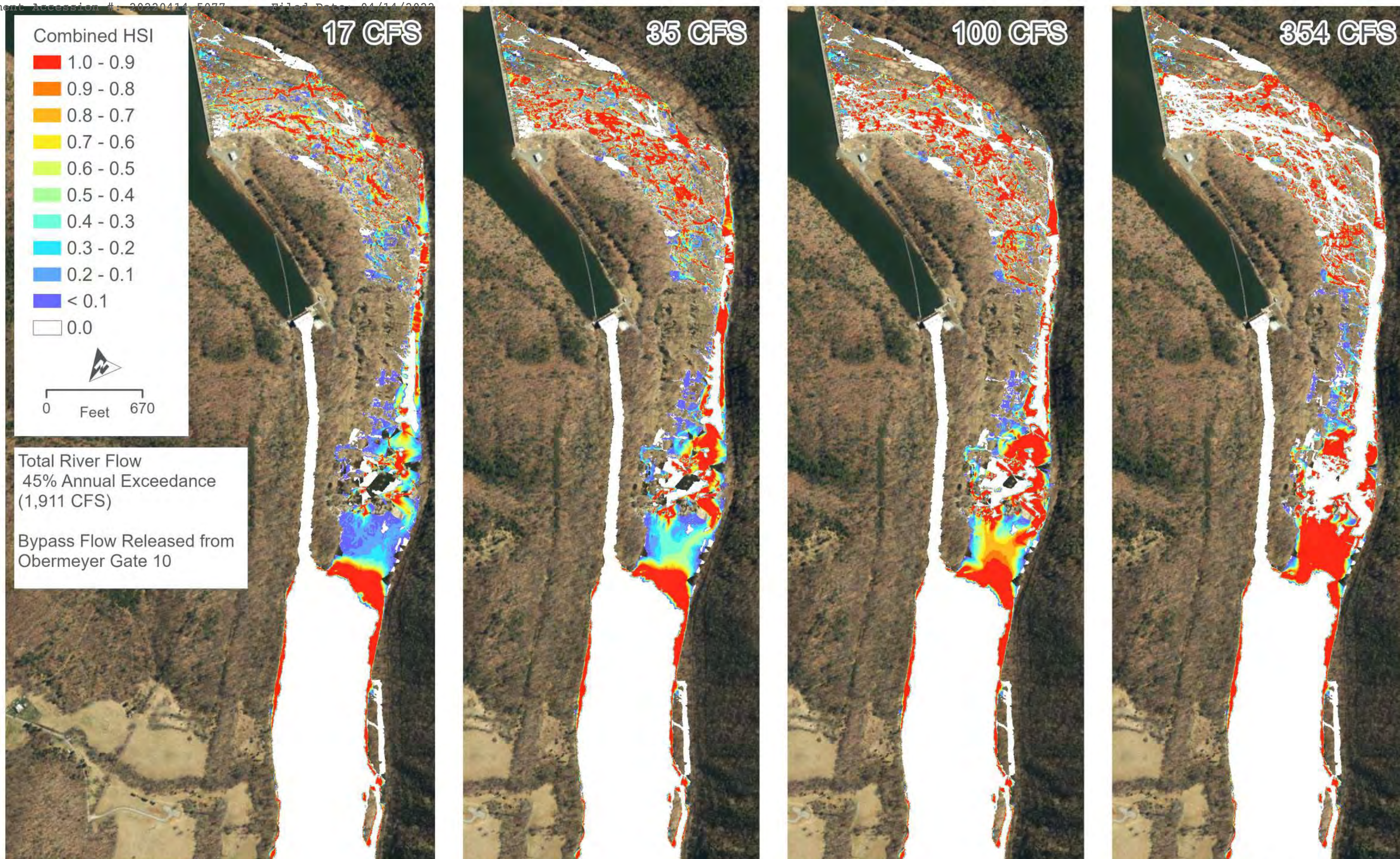


FIGURE 17
BUCK

GENERIC SHALLOW SLOW GUILD
HABITAT SUITABILITY MAP
CATEGORY: COARSE SUBSTRATE

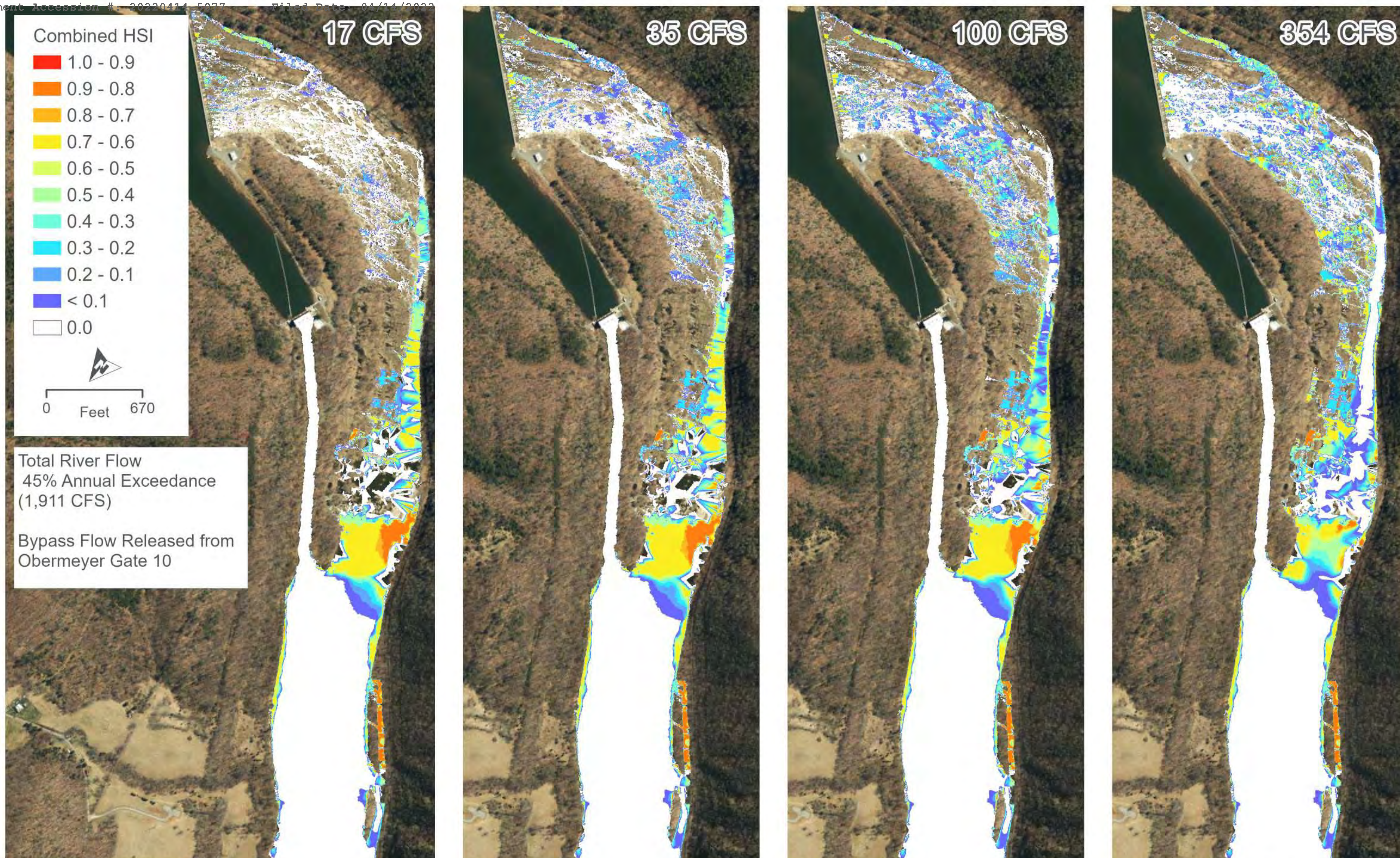


FIGURE 18
BUCK

SHALLOW SLOW GUILD
HABITAT SUITABILITY MAP
CATEGORY: FINE SUBSTRATE, NO COVER

FIGURE 19
BUCK

WALLEYE ADULT
HABITAT SUITABILITY MAP

HDR AMERICAN ELECTRIC POWER

FIGURE 20
BUCK

WALLEYE JUVENILE
HABITAT SUITABILITY MAP

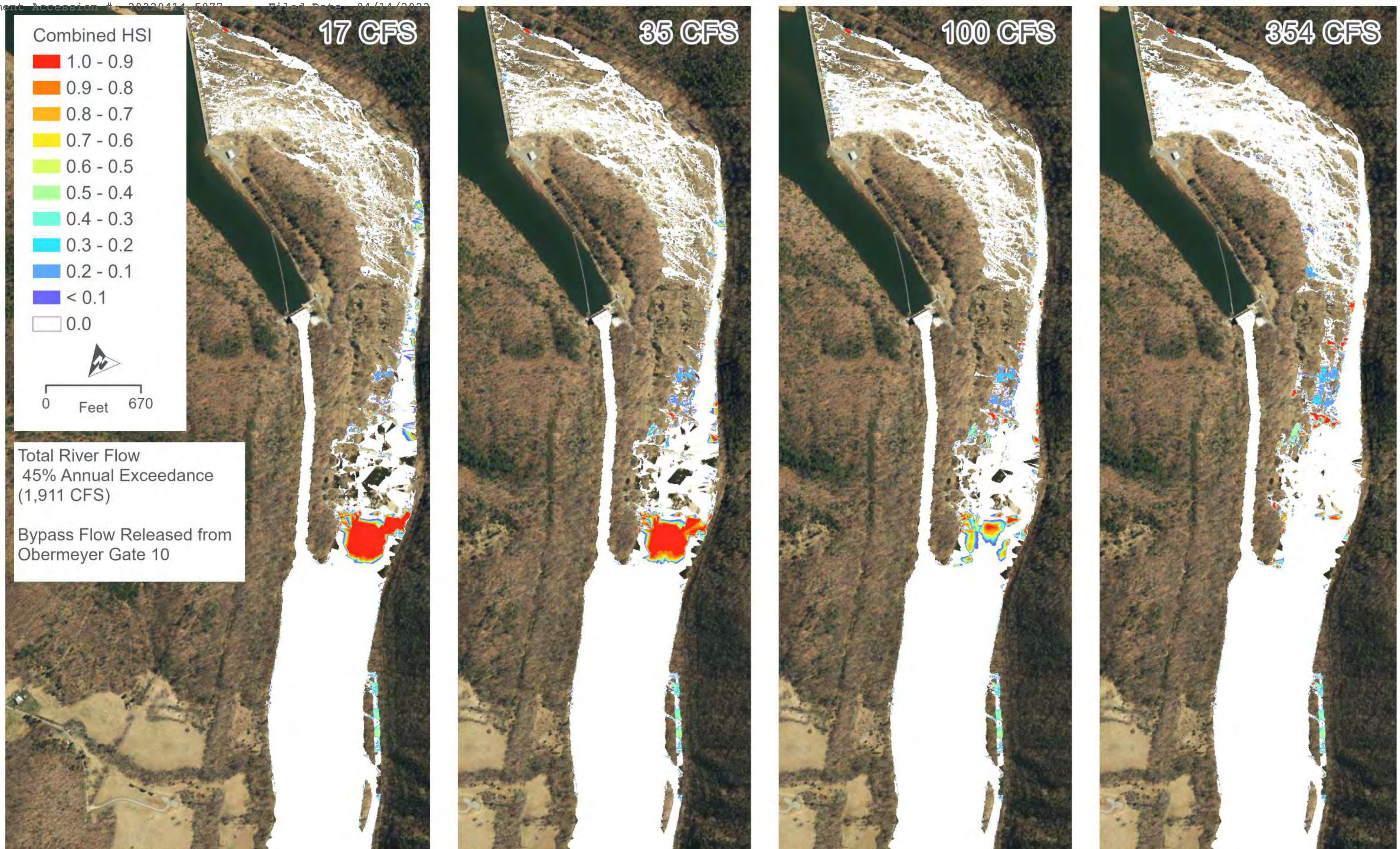


FIGURE 21
BUCK

WALLEYE FRY
HABITAT SUITABILITY MAP

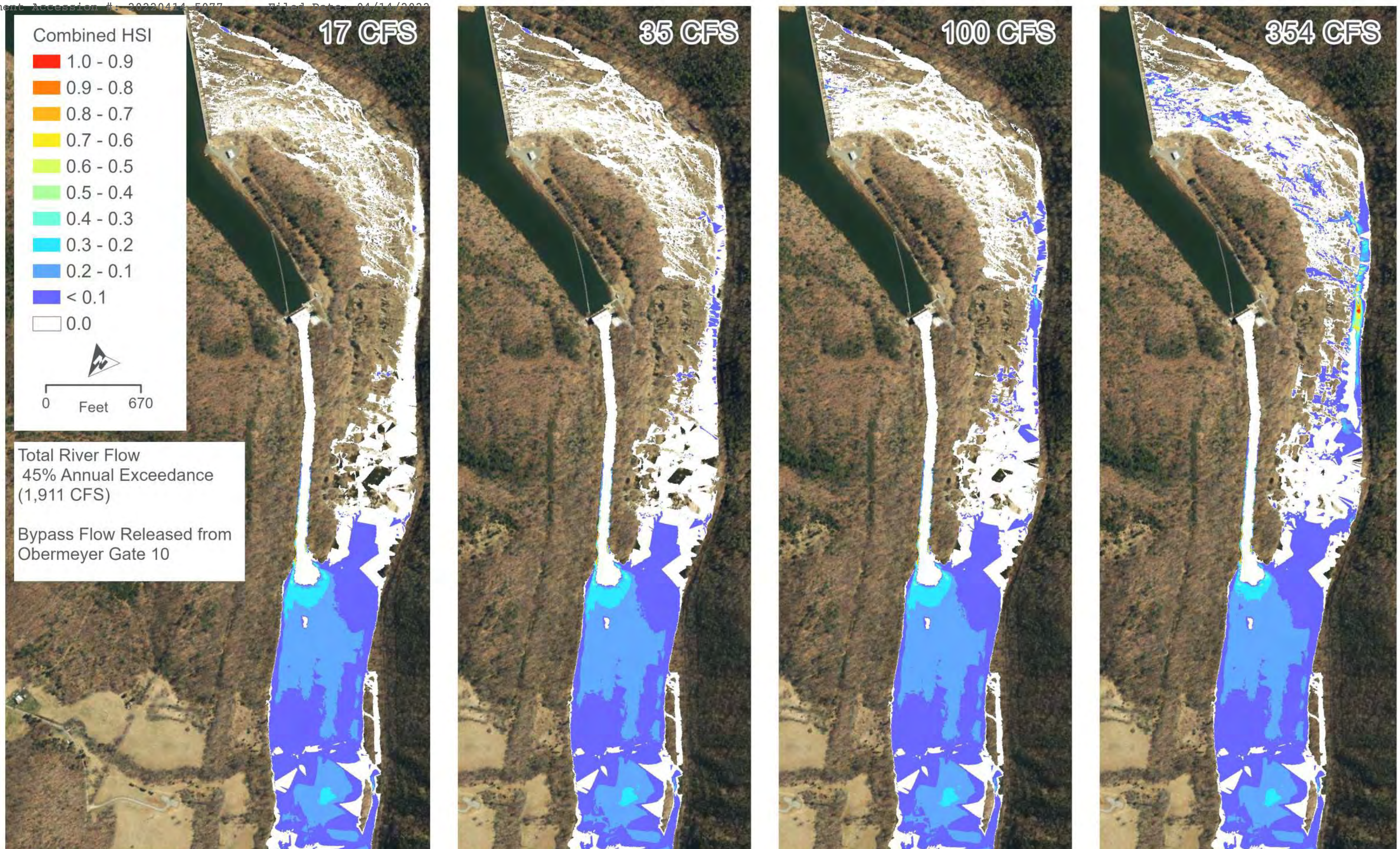


FIGURE 22
BUCK

WALLEYE SPAWNING
HABITAT SUITABILITY MAP

Attachment 5

Attachment 5 – Germane Correspondence

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Subject: FW: [EXTERNAL] Re: Byllesby-Buck Project: Flow and Bypass Reach Aquatic Habitat Study MEETING NOTES

From: Pica, Jessica E <jessica_pica@fws.gov>
Sent: Friday, September 18, 2020 4:17 PM
To: Norman, Janet <janet_norman@fws.gov>
Cc: Elizabeth B Parcell <ebparcell@aep.com>
Subject: Re: [EXTERNAL] Re: Byllesby-Buck Project: Flow and Bypass Reach Aquatic Habitat Study MEETING NOTES

Overall the notes look good. My main question was how confident are folks that calibrating the hydraulic model at lower flows could be extrapolated to higher flows. I think that's captured. I would change the word "why" to "where" in the sentence "Jessica also wanted to understand **where** additional bathymetry data were being collected."

Thanks and have a great weekend!
Jessica

From: Norman, Janet <janet_norman@fws.gov>
Sent: Friday, September 18, 2020 3:13 PM
To: Pica, Jessica E <jessica_pica@fws.gov>
Cc: Elizabeth B Parcell <ebparcell@aep.com>
Subject: Re: [EXTERNAL] Re: Byllesby-Buck Project: Flow and Bypass Reach Aquatic Habitat Study MEETING NOTES

Great, thanks! Sorry I didn't notice until now. Are you good with the depiction of our conference call in the notes?
Janet

Janet Norman
Fish and Wildlife Biologist
USFWS Chesapeake Bay Field Office
177 Admiral Cochrane Dr.
Annapolis, MD 21401
(O) 410-573-4533
(Fax) 410-269-0832
(cell) 410-320-5519

From: Pica, Jessica E <jessica_pica@fws.gov>
Sent: Friday, September 18, 2020 3:12 PM
To: Norman, Janet <janet_norman@fws.gov>
Cc: Elizabeth B Parcell <ebparcell@aep.com>
Subject: Re: [EXTERNAL] Re: Byllesby-Buck Project: Flow and Bypass Reach Aquatic Habitat Study MEETING NOTES

Hi Janet. Liz noticed that my email was wrong and forwarded me the information separately. Thanks for keeping me in the loop!

Subject: FW: [EXTERNAL] Re: Byllesby-Buck Project: Flow and Bypass Reach Aquatic Habitat Study MEETING NOTES

From: Norman, Janet <janet_norman@fws.gov>
Sent: Friday, September 18, 2020 2:49 PM
To: Kittrell, William <bill.kittrell@dwr.virginia.gov>; Elizabeth B Parcell <ebparcell@aep.com>; Pica, Jessica E <jessica_pica@fws.gov>
Cc: Copeland, John <john.copeland@dwr.virginia.gov>; Grist, Joseph <joseph.grist@deq.virginia.gov>; Brian Mcgurk <brian.mcgurk@deq.virginia.gov>; Smith, Scott (DGIF) <scott.smith@dwr.virginia.gov>; Kulpa, Sarah <Sarah.Kulpa@hdrinc.com>; Ziegler, Ty <Ty.Ziegler@hdrinc.com>; Jonathan M Magalski <jmmagalski@aep.com>; Yayac, Maggie <Maggie.Yayac@hdrinc.com>; Frederick A Colburn <facolburn@aep.com>; Dvorak, Joseph <Joseph.Dvorak@hdrinc.com>; Huddleston, Misty <Misty.Huddleston@hdrinc.com>
Subject: Re: [EXTERNAL] Re: Byllesby-Buck Project: Flow and Bypass Reach Aquatic Habitat Study MEETING NOTES

Hi Liz and team,

From my perspective, I think our discussion and questions on the Byllesby-Buck Project: Flow and Bypass Reach Aquatic Habitat Study conference call were well captured in your summary notes.

I am just noticing that there was unfortunately a typo in including our USFWS Fishway Engineer Jessica Pica on this email review routing, so I am including her in my response her.e I can't speak for her as to whether the notes captured her thoughts.

Thanks much for these efforts and the study plan ahead of us.
Janet

Janet Norman
Fish and Wildlife Biologist
USFWS Chesapeake Bay Field Office
177 Admiral Cochrane Dr.
Annapolis, MD 21401
(O) 410-573-4533
(Fax) 410-269-0832
(cell) 410-320-5519

From: Smith, Scott <scott.smith@dwr.virginia.gov>
Sent: Friday, September 18, 2020 11:09 AM
To: Kittrell, William <bill.kittrell@dwr.virginia.gov>; Elizabeth B Parcell <ebparcell@aep.com>
Subject: Re: [EXTERNAL] Re: Byllesby-Buck Project: Flow and Bypass Reach Aquatic Habitat Study MEETING NOTES

None from me, either.

From: Kittrell, William <bill.kittrell@dwr.virginia.gov>
Sent: Friday, September 18, 2020 10:09 AM
To: Elizabeth B Parcell <ebparcell@aep.com>
Cc: Copeland, John <john.copeland@dwr.virginia.gov>; Grist, Joseph <joseph.grist@deq.virginia.gov>; Norman, Janet <janet_norman@fws.gov>; Brian Mcgurk <brian.mcgurk@deq.virginia.gov>; Smith, Scott (DGIF) <scott.smith@dwr.virginia.gov>; jennifer_pica@fws.gov <jennifer_pica@fws.gov>; Kulpa, Sarah <Sarah.Kulpa@hdrinc.com>; Ziegler, Ty <Ty.Ziegler@hdrinc.com>; Jonathan M Magalski <jmmagalski@aep.com>; Yayac, Maggie <Maggie.Yayac@hdrinc.com>; Frederick A Colburn <facolburn@aep.com>; Dvorak, Joseph (Joseph.Dvorak@hdrinc.com) <Joseph.Dvorak@hdrinc.com>; Huddleston, Misty <Misty.Huddleston@hdrinc.com>
Subject: Re: [EXTERNAL] Re: Byllesby-Buck Project: Flow and Bypass Reach Aquatic Habitat Study MEETING NOTES

Liz, Thanks for providing the summary of the August 28, 2020 conference call on the Byllesby-Buck Bypass Flow and Aquatic Habitat Study. I have no additional comments/concerns at this time. Thanks. Bill.

William B. Kittrell, Jr.
Regional Fisheries Manager
P 276.783.4860 / M 276.780.0458
Virginia Department of Wildlife Resources
CONSERVE. CONNECT. PROTECT.
A 1796 Highway Sixteen, Marion, VA 24354
www.dwr.virginia.gov

On Thu, Sep 10, 2020 at 4:41 PM Elizabeth B Parcell <ebparcell@aep.com> wrote:

All,

Attached please find a meeting summary on the Byllesby-Buck Flow Study scenarios discussion held via conference call on August 28, 2020. Please let us know by the end of next week (9/18) if there are any comments.

Many thanks.

Liz

AMERICAN ELECTRIC POWER
BOUNDLESS ENERGY
ELIZABETH B PARCELL | PROCESS SUPV
EBPARCELL@AEP.COM | D:540.985.2441 | C:540.529.4191
40 FRANKLIN ROAD SW, ROANOKE, VA 24011

Meeting Summary

Project:	Byllesby-Buck Hydroelectric Project (FERC No. 2514)
Subject:	Bypass Study Flow Test Scenarios Discussion with Stakeholders
Date:	Friday, August 28, 2020
Location:	WebEx (2:00pm-3:30pm)
Attendees:	Bill Kittrell (VDGIF) John Copeland (VDGIF) Janet Norman (USFWS) Jessica Pika (USFWS) Brian McGurk for Joe Grist (VDEQ) Scott Smith (VDWR) Jon Magalski (AEP) Liz Parcell (AEP) Fred Colburn (AEP) Sarah Kulpa (HDR) Misty Huddleston (HDR) Ty Ziegler (HDR) Joe Dvorak (HDR)

Introduction

On August 18, 2020, AEP submitted a proposed flow test scenario plan for Byllesby-Buck for stakeholder review based on mutually agreed timeline discussed on a June 30th call. The purpose of the call was to work through agency questions with AEP and HDR regarding the proposed flow test scenarios and how the bypass study model will be used to assess and inform downstream flow needs for providing fish habitat and maintaining connectivity in the bypass channels.

Flow and Bypass Study Flow Study Status Update

- Ty Ziegler (HDR) kicked off the call by providing a summary of the proposed test flow scenarios presented in the memo submitted on August 18th.
    - Model inputs consist of depth, flow, substrate, and topography.
    - Ty stated that the LiDAR data and orthoimagery have been captured at the Byllesby-Buck Project and were used to build a preliminary hydraulic model to support the Flow and Bypass Reach Aquatic Habitat Study and to perform a desktop GIS-based characterization of substrates in the bypass channel.
    - Preliminary substrate characterization was field confirmed on August 17 and 18.
    - Ty discussed the flow test scenarios and clarified that tests are scheduled to take place at Byllesby and Buck in mid to late September, but is dependent on instream flow conditions and station operations. Sarah Kulpa (HDR) noted the test timing is dependent on having no-spill conditions and no precipitation events at the developments in the days prior to the tests.
    - The next step is to collect additional bathymetry data in areas that were inundated during LIDAR data collection and collect water depths, and velocities at each of the test flows to support model validation.

- Ty clarified that proposed test flows were selected to capture the current operational scenarios and a range of flows based on what the projects are capable of passing, in addition to capturing the existing license requirements.
    - Byllesby 350 cfs minimum downstream flow requirement
    - Buck ramping rate when gates have been opened greater than 2-ft
    - [*AEP Clarification – information not provided during discussion: The 350 cfs minimum downstream flow requirement of License Article 403 pertains to both developments*].

Agency Questions/Responses

Model Scenarios

- Janet Norman (USFWS) expressed concern that the proposed scenarios did not propose a sufficiently wide range of scenarios to inform an adequate evaluation of the need for increased minimum flow requirements. Scott Smith (VDWR) agreed that a test scenario at higher flows may be ideal to help evaluate specific areas for potential to serve as Walleye spawning habitat during spring months in addition to evaluating connectivity.
- Jessica Pika (USFWS's fishway engineer) was interested in understanding which model type was being used, how it worked, and if we know or will be able to identify the flow level where connectivity starts/stops downstream of Buck. Jessica also wanted to understand why additional bathymetry data were being collected.
    - Ty stated that the model will be able to answer that question.
    - Ty also provided additional data, based on field observations, about how the channel topography appears to influence connectivity when the channel is watering up or drawing down. Group discussed how the natural topography and geology of the channel directs flows to the trail side of the river and how that likely contribute to the anecdotal observations of fish getting trapped in the disconnected pool just below the dam on the left side of the river (facing downstream).
    - Ty mentioned that there may be dam operation scenarios that would be capable of releasing sufficient flow in that portion of the channel to maintain connectivity, although they may require installation of new equipment/technology.
    - Bill Kittrell (VDGIF) stated that there may be potential for permitting some form of physical channel alteration that would help maintain channel connectivity to that left-side pool (trail side of river/downstream facing).
    - Ty suggested that an evaluation could be done of the impact on connectivity of altering flows at gates where flashboards are currently experiencing leakage. Bill emphasized that flashboards have historically been part of the problem. Group discussed the challenge that flashboards present to operations and modeling of scenarios due to impacts of flashboard operation and passage of larger flows downstream, or when they are newly installed may allow more leakage flows.

- Ty explained that additional bathymetry data are needed for areas that were inundated during LIDAR collection to improve model accuracy.
- Joe Dvorak (HDR) stated that we will be using the Innovyze ICM software to develop a 2-D type model for the flow study. ICM was selected over HEC-RAS because it is better for calculating hydraulics in complex channels, better at capturing the influence of vertical spillways, and better at modeling turbulent flows.

- In response to a question from Scott Smith, Joe Dvorak clarified that the model would allow identification of wetted area, specific flow release values, and velocities and depths in specific areas under specific flow scenarios. Janet, Jessica, and Scott each indicated that they were satisfied with the explanations and stated that they anticipate and hope the model will work well and help provide answers to their questions.
- The group discussed methods and challenges for addressing leakage flows in the models. Ty stated that we intend to try and measure those flows if possible, otherwise, an effort will be made to estimate those flows for inclusion in the model.
- Janet wanted to understand how leakage flows may change over time, is there seasonality to the leakage flows, how frequently do they need replaced, etc.
    - Ty indicated that leakage flows are impacted by flashboard condition (i.e., new versus old) and if they have had time to be silted in.

Model Outputs and HSI Curves

- John Copeland (VDGIF) noted that he would like to see how Walleye use the Buck reach under different flow scenarios, preferably via field observation.
    - Janet stated that evaluation should include a seasonality component to demonstrate availability of suitable conditions throughout the year.
    - Ty clarified that this is part of the evaluation.
        - [HDR *Clarification – while not specifically discussed during the call, as part of the study plan, Walleye habitat suitability curves will be used in conjunction with the hydraulic model results to evaluate potential suitable habitat under various model flow simulations*].

- In the study report, Janet requested additional information be provided to provide characterization of normal hydrological conditions and spilling operations at the developments. The group referred to Table 4-1 in the RSP during discussion. Janet specifically requested the 25th and 75th percentiles be added to the table and better labeling.
    - Sarah suggested that a line graph may be more appropriate for the information being presented.
    - All on call agreed that more information for Table 4-1 is needed **(Action Item)** in the future study report.

- Brian McGurk (VDEQ) asked if the existing license requires monitoring of flows and gate operations. Sarah clarified that this information is monitored and available and was used to create an operations model for the developments.

Based on this discussion, AEP and HDR are proceeding with the flow demonstration study as proposed in the memo, as soon as field conditions allow. The call wrapped up with all indicating they were satisfied with the information presented and AEP's and HDR's responses to questions. Call participants expressed their appreciation of the effort made to share information and improve understand regarding the study.

Subject: FW: Byllesby-Buck Project: Flow and Bypass Reach Aquatic Habitat Study

From: Copeland, John <john.copeland@dwr.virginia.gov>
Sent: Tuesday, August 25, 2020 1:11 PM
To: Elizabeth B Parcell <ebparcell@aep.com>
Cc: Grist, Joseph <joseph.grist@deq.virginia.gov>; Norman, Janet <janet_norman@fws.gov>; Kulpa, Sarah <Sarah.Kulpa@hdrinc.com>; Yayac, Maggie <Maggie.Yayac@hdrinc.com>; Jonathan M Magalski <jmmagalski@aep.com>; Ziegler, Ty <Ty.Ziegler@hdrinc.com>; Brian Mcgurk <brian.mcgurk@deq.virginia.gov>; Kittrell, Bill (DGIF) <bill.kittrell@dwr.virginia.gov>; John Copeland <john.copeland@dwr.virginia.gov>; Smith, Scott (DGIF) <scott.smith@dwr.virginia.gov>
Subject: Re: Byllesby-Buck Project: Flow and Bypass Reach Aquatic Habitat Study

Thank you for your email communication with this group about your plans to initiate flow release scenario tests for the Byllesby Buck Project starting Monday, August 31. Most of the agency people copied on your email had a conference call regarding this proposal yesterday. I had a brief discussion and email exchange with Joe Grist (Department of Environmental Quality) yesterday and today.

During our conversation yesterday, we concluded that our questions are numerous enough that we simply could work things out much better in a conference call. I have conferred with all the agency parties: Janet Norman (USFWS), Bill Kittrell (DWR), Scott Smith (DWR instream flow expert), as well as Joe Grist (DEQ - who has appointed Brian McGurk to participate) regarding a conference call this Friday afternoon (August 28). All parties are available.

We hereby request a conference call at your convenience on Friday afternoon, August 28.

FYI - Please note that our agency email extension has changed from DGIF to DWR, effective July 1, 2020. DGIF still works, but we are requesting use of the DWR extension. This email has the corrected email addresses.

Respectfully submitted,

John R. Copeland
Fisheries Biologist III

P 540.961.8397 / M 540.871.6064

Virginia Department of Wildlife Resources

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On Tue, Aug 18, 2020 at 3:09 PM Elizabeth B Parcell <ebparcell@aep.com> wrote:

Good afternoon,

As we discussed in our June 30th ILP study update call for Appalachian's Byllesby-Buck Project, HDR has prepared a brief memo describing the flow release range and locations for the upcoming flow tests to be conducted as part of the Flow and Bypass Reach Aquatic Habitat Study. As this fieldwork is presently scheduled to begin as early as August 31, we would greatly appreciate receipt of any questions or comments on the attached by close of business Tuesday, August 25th. That will leave us time to schedule a conference call for later next week, if needed to further discuss.

Thank you for your support of this process.

Sincerely,

Liz

ELIZABETH B PARCELL | PROCESS SUPV
EBPARCELL@AEP.COM | D:540.985.2441 | C:540.529.4191
40 FRANKLIN ROAD SW, ROANOKE, VA 24011

Memo

Date:	August 17, 2020
Project:	Byllesby-Buck Hydroelectric Project (FERC No. 2514)
To:	Bill Kittrell (VDWR) John Copeland (VDWR) Joseph Grist (VDEQ) Janet Norman (USFWS)
From:	Sarah Kulpa (HDR)
CC:	Liz Parcell (AEP) Jon Magalski (AEP) Ty Ziegler (HDR)
Subject:	**Flow and Bypass Reach Aquatic Habitat Study – Proposed Flow Test Scenarios**

Appalachian Power Company's (Appalachian's) Revised Study Plan (RSP), as approved and modified by the Federal Energy Regulatory Commission (FERC), for the Byllesby-Buck Hydroelectric Project (Project) includes a Flow and Bypass Reach Aquatic Habitat Study (Study). The Project includes the Byllesby development and the Buck development, both located on the New River in Carroll County, Virginia. The Buck development is located approximately three river miles downstream of the Byllesby development and 44 miles upstream of Claytor Dam. The objectives of this Study are to conduct a flow and habitat assessment in the tailwater area and bypass reach of both developments (excluding the Byllesby development auxiliary spillway channel) using a combination of desktop, field survey, and hydraulic modeling methodologies to achieve the following goals:

1. Delineate and quantify aquatic habitat and substrate types in the Byllesby and Buck developments' bypass reaches.
2. Identify and characterize locations of habitat management interest within the Byllesby and Buck bypass reaches.
3. Develop an understanding of streamflow travel times and water surface elevation responses under variable base flow and spillway release flow combinations in the tailwater and bypass reach of each development to:
    - Demonstrate the efficacy of ramping rates required by the existing license.
    - Demonstrate the efficacy of the existing powerhouse minimum flow requirement (i.e., 360 cubic feet per second (cfs) minimum flow to maintain aquatic resources, including resident fish species, downstream of each

440 S Church Street, Suite 1000, Charlotte, NC 28202-2075
(704) 338-6700

development consisting of the tailwater areas below each powerhouse and the bypass reaches below the main spillways).

- Evaluate the impacts of providing seasonal minimum flows to the bypass reaches.

Flow and Water Level Assessment - Proposed Flow Test Scenarios

The Flow and Water Level Assessment fieldwork included in Task 3 of the Flow and Bypass Reach Aquatic Habitat Study is presently scheduled to be conducted the weeks of August 31 and September 7, 2020 (suitable inflow and field condition-dependent). The proposed flow release quantities and locations are described below. The proposed flow test scenarios are designed to capture existing (baseline) Project operations and also support the development and calibration of hydraulic models that will allow for visualization and evaluation of flow releases from other gate openings (i.e., demonstration flows at a specific gate location are not required to model flows from that location).

For the Byllesby development, the target flow scenarios (see Table 1) are designed to evaluate the effect of passing the entire minimum downstream flow requirement of 360 cfs through the bypass reach. Tainter Gate #6 is the proposed gate to pass flows as it is near the center of the spillway structure and under existing operating procedures is the first gate operated for releases into the bypass reach (see Figure 1). The three target flows proposed in Table 1 will allow a hydraulic model simulation range from leakage up to approximately 500 cfs.

For the Buck development, the target flow scenarios (see Table 1) are designed to evaluate the effect of the existing ramping rate requirements. Appalachian is required to discharge flows through a 2-foot gate opening for at least three hours following any spills released through a gate opened 2 feet (ft) or more. They are required to reduce the opening to 1 ft for at least an additional three hours, after which time the gate may be completely closed. This gradual reduction of flow allows adequate time for fish that may have traveled upstream into the bypass reach to respond to receding water levels, reducing instances of fish strandings that can potentially occur with sudden flow discontinuation.

Tainter Gate #1 will be utilized at the Buck development to pass the target flows since this reflects current operations (i.e., Tainter Gate #1 is first to open and last to close during high flow events where flows are routed into the bypass reach) (see Figure 2). Gate openings of 2 ft and 1 ft will be evaluated (as per existing ramping rate operating protocols) as well as a gate opening of 0.5 ft to represent flows that would occur between a 1-foot gate opening and leakage conditions. The three target flows proposed in Table 1 will allow a hydraulic model simulation range from leakage up to approximately 2,250 cfs.

Table 1. Byllesby-Buck Bypass Reach Aquatic Habitat Study – Proposed Flow Test Scenarios

Byllesby Bypass Reach				
Pool Range: 2078.2 - 2079.2 NGVD 29; Assume starting Pool Elevation is 2078.7 NGVD 29)				
Powerhouse Discharge Capacity: 5,868 cfs				
Powerhouse Minimum Discharge Capacity: 85 cfs/unit				
Tainter Gate #6				
Opening* (ft)	Proposed Target Flows (cfs)	Flow Test Duration (hours)	Volume (acre-ft)	Model Simulation Range (cfs)
0.0	Leakage	NA	0	Leakage ↓ 500
0.10	40	5	17	
0.25	105	5	43	
0.5	203	5	84	
Buck Bypass Reach				
Pool Range: 2002.4 - 2003.4 NGVD 29; Assume starting Pool Elevation is 2002.9 NGVD 29				
Powerhouse Discharge Capacity: 3,540 cfs				
Powerhouse Minimum Discharge Capacity: 73 cfs/unit				
Tainter Gate #1				
Opening* (ft)	Proposed Target Flows (cfs)	Flow Test Duration (hours)	Volume (acre-ft)	Model Simulation Range (cfs)
0.0	Leakage	NA	0	Leakage ↓ 2,250
0.5	224	8	148	
1.0	448	8	296	
2.0	897	8	593	

Notes: * Assume starting point is midpoint of operating range with adequate inflow to maintain pond levels during flow tests.

Figure 1. Byllesby Dam Spillway Gates

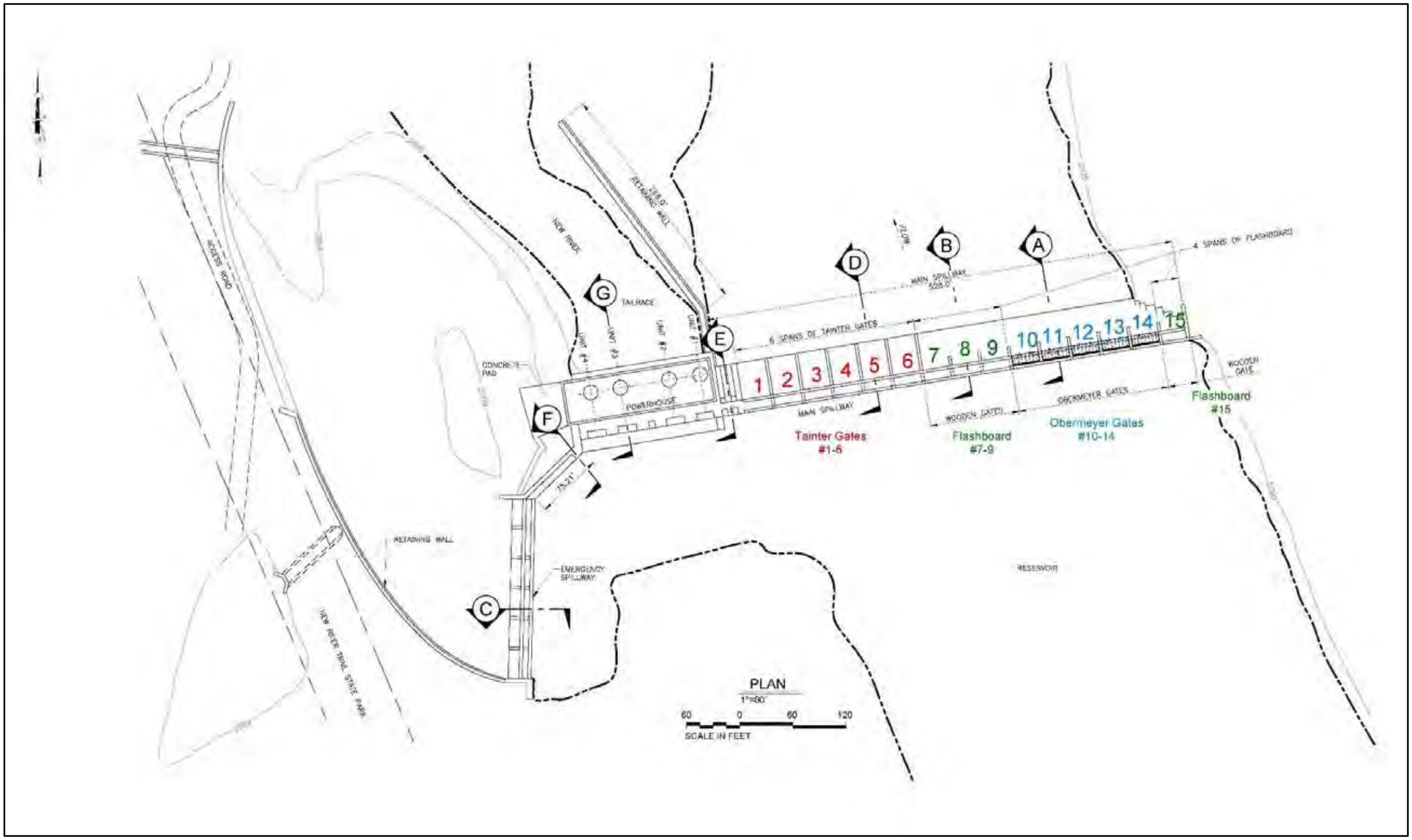
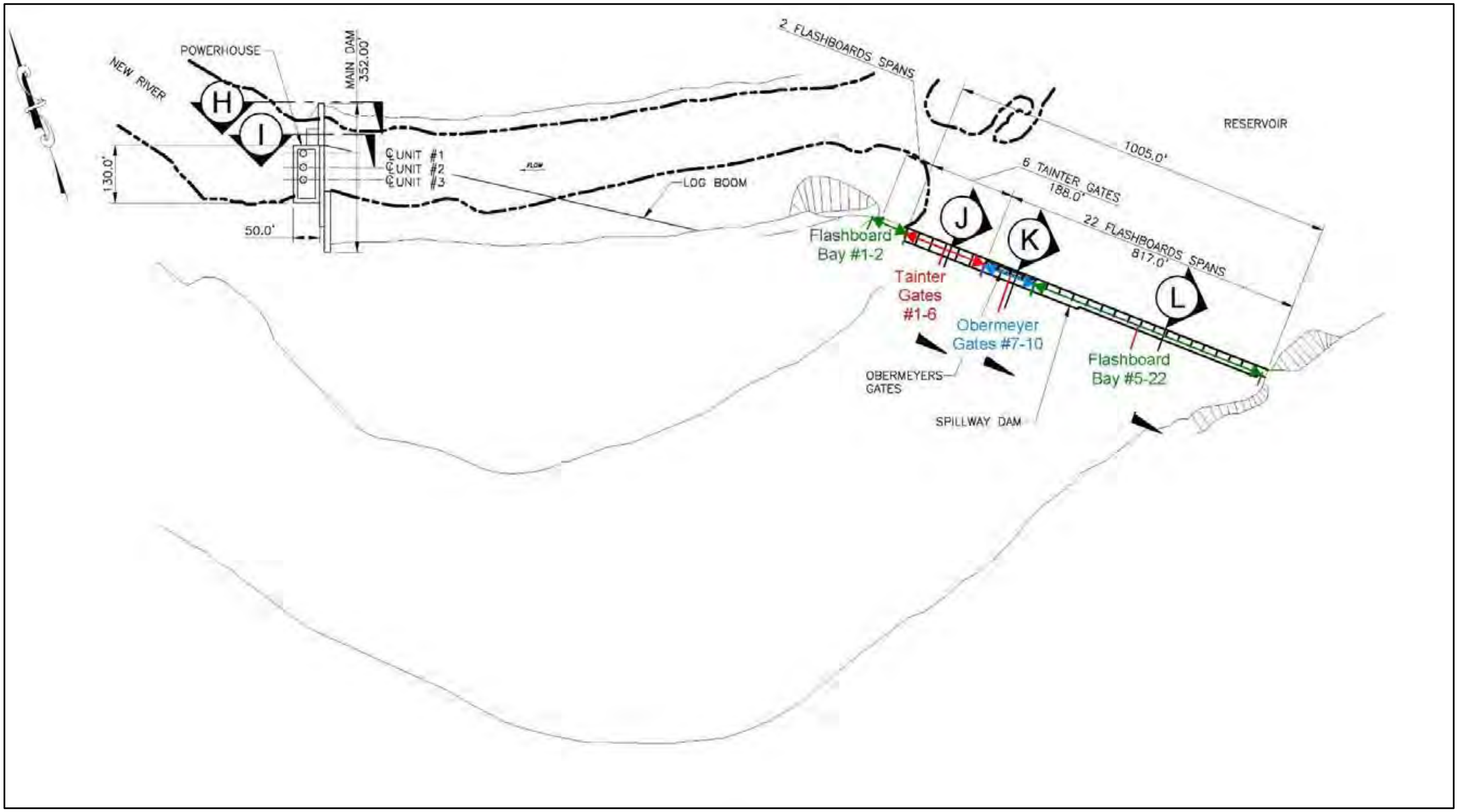


Figure 2. Buck Dam Spillway Gates



Meeting Summary

Project:	Byllesby-Buck Hydroelectric Project (P-2514)
Subject:	Buck Bypass Reach Flow and Aquatic Habitat Stakeholder Meeting
Date:	Tuesday, February 01, 2022
Location:	WebEx Virtual Meeting
Attendees:	Jonathan Magalski (AEP) Elizabeth Parcell (AEP) Fred Colburn (AEP) Sarah Kulpa (HDR) Maggie Salazar (HDR) Misty Huddleston (HDR) Ty Ziegler (HDR) Brennan Smith (HDR) Joe Dvorak (HDR) Ben Boyette (VDWR) Brian Watson (VDWR) Jeff Williams (VDWR) John Copeland (VDWR) Mike Pinder (VDWR) Scott Smith (VDWR) Janet Norman (USFWS) Rick McCorkle (USFWS) Joe Grist (VDEQ)

Overview

This document provides the meeting summary for a virtual (WebEx) meeting for Appalachian Power Company's (Appalachian) Byllesby-Buck Hydroelectric Project (Project) with primary resource agencies [U.S. Fish and Wildlife Service (USFWS), Virginia Department of Environmental Quality (VDEQ), Virginia Department of Wildlife Resources (VDWR)] to discuss study results of and preliminary agency recommendations for bypass reach flows at the Buck Development.

Introduction and Goals of the Meeting

Sarah Kulpa explained that the Updated Study Report (USR) meeting was held on December 1, 2021 and an action item from that meeting was to have a follow-up discussion on the results of the Bypass Reach and Aquatic Habitat Study, specifically related to additional evaluations performed for the Buck Development since the Initial Study Report (ISR) in January 2021. Since the time of the USR meeting, Appalachian has received comments on the USRs. Appalachian has been working to address comments from the USR meeting, revise study reports, and prepare the Final License Application (FLA). The goal of this meeting is to calibrate a path forward with the agencies. S. Kulpa noted that this meeting is a working session to clarify USFWS and VDWR's objectives for the bypass reach study at Buck, given that agencies' comments now suggest objectives beyond mitigating the risk of fish stranding. Appalachian can then take these objectives into consideration during preparation of the study report and FLA.

Fish Stranding Concerns

VDWR requested that fish stranding at Buck be discussed as the first agenda item. John Copeland explained that fish stranding has been noted by VDWR at Buck in standing, pooled water, referencing the photos and e-mail in Attachment 1. Ben Boyette is a local VDWR Conservation Officer and frequents this area. He noted that has seen pool in the Buck bypass over the last seven years, and fishermen take advantage of these. HDR confirmed field team members did not observe stranding during numerous site visits to the bypass reach over the course of 2020 and 2021. VDWR noted that the area is remote, so unless there is a report filed, they would not be aware of these occurrences (outside of Ben's observations). Ty Ziegler clarified that flashboard sections had been recently replaced and had not silted in, so there is likely higher leakage flow compared to older flashboard sections.

The VDWR provided photos (included in Attachment 1) of an isolated fish stranding in 2010, which likely followed a flashboard failure (flashboard remnants are seen in the photos, deposited sand, etc.) due to an ice dam that had broken loose the previous winter (per language in VDWR correspondence; Attachment 1).

Joe Dvorak reviewed the "side channel" location of interest in the study area (channel along the left bank below Buck Dam, as viewed looking downstream) and locations of water level loggers deployed for the study period. J. Dvorak shared modeling results to give context to the size of event needed to provide flow into the side channel at Buck and cause a stranding event. This evaluation shows that flows in the side channel are not impacted by non-flood flow releases from the gated section of the spillway, except small backwater effects at the downstream end of the lower pool. The largest rainfall event during the study period caused a spill of approximately 5,300 cubic feet per second (cfs) from the Tainter gates into the bypass reach. While this spill event caused an approximately 4-foot (ft) increase in water level below Tainter gate 1, the water level increase at the Level Logger 2 location (upper side channel pools) was approximately 0.25 ft.

J. Dvorak showed model output of the flow pattern in this area, with less than a 0.5-ft depth increase at the side channel logger location. J. Dvorak pointed out the locations of the Obermeyer gates, Tainter gates, and flashboard sections, and highlighted the "island[1]." B. Boyette noted the fish stranding he has observed is typically towards the middle of the bypass reach and not in the side channel.

Normal Gate Operations

J. Norman asked from an operations perspective, when flows are less than 5% exceedance are they always passed through Tainter Gate 1 and then 2? T. Ziegler noted that since 2010 (when the photos in Attachment 1 were taken), several Obermeyer gates were installed, with the expectation that more spillway control will reduce the occurrences of flashboard failures under high flows in the future. Fred Colburn noted that approximately 3,500 cfs can be passed through each Tainter gate. Appalachian's typical spillway operations start with Tainter Gate 1 (first open, last closed) and work up to Tainter Gate 2, 3, 4, and so on, following the established ramping rate procedure. Gates are operated in the reverse orders as inflows recede.

F. Colburn noted that he believes there was a significant icing event in the winter of 2009 (shortly before the photos in Attachment 1 were taken) that might have damaged the flashboards. F. Colburn noted that the New River is prone to flash flooding and it is not uncommon to have all six Tainter gates open

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[1] There is a small "island" in the Buck bypass that prohibits flow from the Tainter and Obermeyer gates from reaching the upper pools of the side channel area.

(approximately 18,000 cfs) at some point in the year. J. Copeland noted that he believes the fact that this was associated with a flashboard failure does not change what we've heard about fish stranding from B. Boyette.

FERC Staff USR Comments

J. Norman requested to see the tributary location that FERC had a question about on the USR. S. Kulpa noted that she thinks FERC is looking to determine when there's no spill if that tributary contributes flow to the Buck bypass reach and whether HDR accounted for this in the model (hydrologically). T. Ziegler noted it was not included in the model. A lower tributary at the end of the bypass reach was examined and HDR did not see flow from this ephemeral tributary, however it was determined that FERC was referring to a small tributary higher up in the bypass that feeds into the side channel. T. Ziegler clarified that the lower pool may be influenced by the side tributary.

J. Norman followed-up about a FERC USR comment about Eastern hellbender and if there have been any documented occurrences. USFWS answered they do not have any data on hellbender occurrences; it is a rare species so occurrences are limited. J. Copeland stated he would follow up internally and if there are any occurrences to note he will share with this group. Hellbender habitat seems limited or nonexistent in bypass reach.

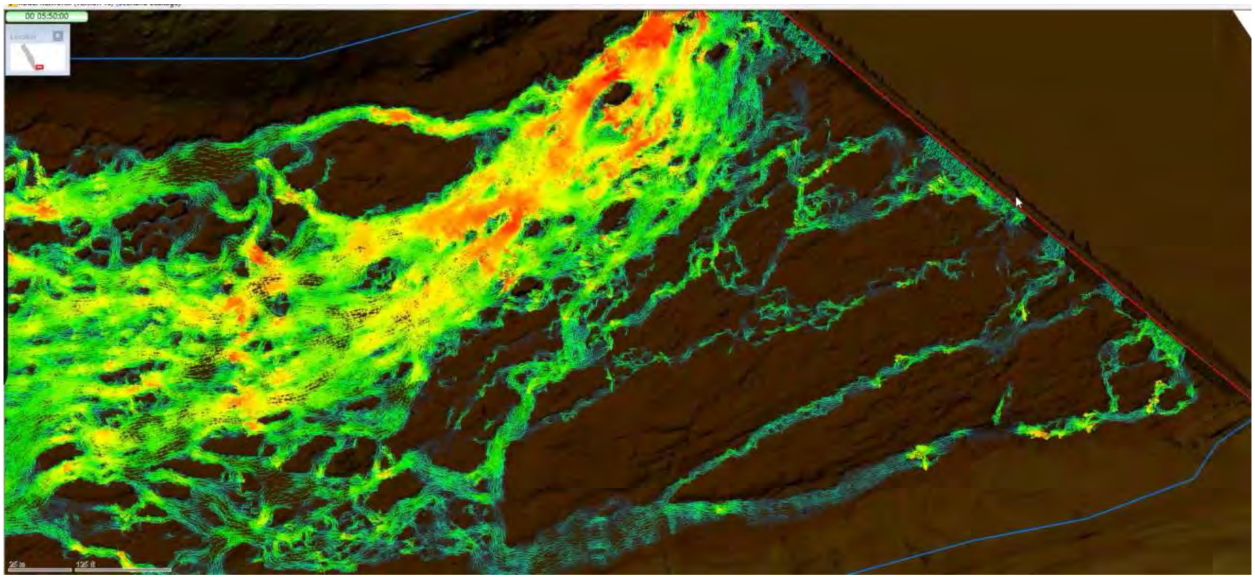
Bypass Connectivity

S. Kulpa confirmed that under leakage conditions the side channel does not have connectivity and requested clarification on what the underlying agency concerns are in this area, during what life stage, and for what species, etc. Rick McCorkle asked for clarification about the leakage flow. T. Ziegler explained that there is leakage through the Tainter gates and through flashboards. There is more leakage through the flashboards at this time since they have recently been replaced and the sediment has built up behind them. A "typical" or stable leakage cannot be determined due to variable leakage through flashboards; leakage was measured during the time of the studies as 17 cfs. J. Norman noted that there are pools present at the leakage flow, so a management goal they are interested in is to have connectivity in the pools so that aquatic species can get up into and out of these pools.

S. Kulpa noted that HDR evaluated a few options throughout the relicensing process, with the knowledge that the side channel connectivity was a concern to agencies. These options included channel fill (i.e., of pools and connecting pathways in this area), but the fill would be costly and require significant maintenance. The other option was to cut a channel to provide more connectivity, but the bedrock is very hard in the bypass reach and this may not be technically feasible or practical. The agencies did not request further discussion of these two options.

B. Boyette noted he has seen fish within 10 yards downstream of the dam. J. Copeland and Jeff Williams confirmed they thought a big flow would be required to move fish upstream and against the dam. B. Boyette noted that he sees people catch fish along the island. J. Copeland agreed with T. Ziegler that instances of fish getting close to the dam are probably not stranding; the fish are just going as far upstream as they can.

J. Dvorak showed a “mid-flow” release (approx. 350 cfs) from Tainter Gate 1:



J. Dvorak noted that anything over 5 ft/sec is shown as red (scale is continuous 0-5 ft/sec). Note that this is based on LiDAR data and not bathymetry. J. Dvorak pointed out the island and the location of the backwater effect in the side channel lower pool. J. Copeland asked what the flow would be with all gates open? Joe noted that total gate capacity (including Obermeyers) is approximately 40,000 cfs which is <0.1% annual exceedance. J. Copeland noted that to have flow to the side channel and/or island, flows would have to be high; T. Ziegler agreed and noted that it would likely require a flashboard failure to provide flow over the island. The takeaway is that <0.1% annual exceedance or a flashboard failure could cause flow to the side channel/island.

Bypass Reach Water Depth

S. Kulpa noted that about a month after the FLA the updated Bypass Reach Study Report will be filed with the requested model results. This is due to the large number of comments received on the USR. Re-running the models will take more time than is feasible given the FLA filing regulatory date. (Appalachian is not able to request an extension of time to file the FLA.) Appalachian will connect any information back to proposals in the FLA as applicable. J. Norman would like the USFWS, VDWR, VDEQ to work toward a joint flow recommendation.

R. McCorkle asked about the depth maps in the bypass reach. The USFWS is interested in how depth relates to connectivity; for example, when focused on walleye spawning, what depth would be sufficient for the species. Their management goal would be 2 times the depth of the species, i.e. if the walleye is 5 inches in depth, 10 inches of water depth in the bypass to allow for passage would be desired.

S. Kulpa stated that HDR and AEP would like to understand the flow recommendation of 354 cfs and clarified that the results provided in the USR were static flow results based off gate openings AEP could easily provide during the study. HDR and AEP are seeking to understand the management goals to provide additional flow scenarios or presentation of model scenario results to help inform agency and FERC flow recommendations, if and as applicable. R. McCorkle requested a gradient of flows and how it affects habitat flows. UFWS is interested in that but understands there is a lot of modeling that would be required. USFWS explained that 354 cfs was beneficial to walleye spawning and benefited other species.

They are also focused on endemic species – big mouth chub and Appalachian darter, which all benefit from increased flow above leakage. USFWS realized that higher flows would not be operationally feasible, so they thought 354 cfs was reasonable. USFWS made this recommendation based on the limits of the data provided in the USR.

USFWS clarified that the recommended flow release would be either monthly or seasonally dependent. For example, flows to support walleye spawning would be in the spring into the early summer; however, a lower flow during the summer could be acceptable because spawning of key species would not be occurring. USFWS additionally clarified that they are not seeking a constant 360 cfs flow through the bypass reach. USFWS provided a range of dates with species goals:

- Feb 15 - May 15th: walleye spawning period
- May 15 – July 31st: rock bass spawning
- August 1 – August 31: low flow period; maintain wetted area
- Nov 1 – Feb 15: undetermined

USFWS would want to see median monthly inflows throughout the year to be able to target the ranges.

F. Colburn noted that theoretically the Tainter gates can be opened less than 0.5-ft but that's what AEP targets as a minimum gate opening; 0.5- ft opening is around 200 cfs.

J. Dvorak noted that final depth figures at Buck would be provided in the revised Bypass Reach Flow and Aquatic Resources Study Report. R. McCorkle requested refining the scale for the study report. J. Norman requested 0-6, 6-12, 12-18 inches for the scale and more contrast in the color scale. J. Dvorak showed how the depth in the side channel is minimally affected by the change in flows through Tainter gate 1 (200 vs 364 cfs).

R. McCorkle noted that what appears to be the thalweg in the bypass reach contains habitat for walleye. R. McCorkle requested that "tailrace", meaning powerhouse tailrace, be referred to as the discharge channel because the area below a spillway can also be called a tailrace. T. Ziegler noted that, for purposes of the body depth discussion, walleye spawning habitat is non-existent with <1-ft of depth, as shown by the HSI curves. Depth between 1-ft and 1.5-ft yields a depth habitat preference value of 0.22. The HSI curve does recognize that >1 ft depth is required for walleye spawning.

S. Kulpa noted the HSI curves were previously discussed and validating or refining these curves is not feasible within the limits of the study plan. J. Norman agreed that revising the modeling effort was not being suggested but clarified agencies do need to understand the background of HSI curves. J. Norman requested background reports used for developing HSI curves be provided.

J. Copeland noted that the depths show that connectivity is limited and likely there is fish stranding in the upper bypass reach. J. Copeland noted that fish prone to fish strandings were likely small mouth bass, rock bass, red breast sunfish, and channel/flathead catfish. It appears that smaller species of fish could escape to the lower end of the bypass reach (R. McCorkle), but likely not for walleye..

J. Norman noted that USFWS seeks to maintain a healthy population for host fish for the green floater mussel.

R. McCorkle noted that 0.5-ft of water depth would be the threshold for connectivity flows, anything less would be too shallow to qualify as a connected escape route; 0.5ft increments would be useful for displaying the model depth results, just add more contrast.

T. Ziegler noted that the study report describes that historically, flows are only less than 360 cfs on handful of occasions and notes the specific days where this is the case.

VDWR suggested orthomosaic data or a follow-up call with JD Kloepfer (VDWR) to look at high-resolution aerial photography may shine more light on potential for bigmouth chub habitat.

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Attachment 1

Attachment 1 – Referenced VDWR Stranding E-mail and Photos

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Subject: FW: Byllesby-Buck USR FERC Comment re Walleye Body Depth Data
Attachments: PICT0027.JPG; PICT0030.JPG; PICT0029.JPG; PICT0032.JPG; PICT0031.JPG; PICT0033.JPG; Staunton River WAE TL Body Depth Data 25 Jan 2022.pdf

From: Copeland, John <john.copeland@dwr.virginia.gov>
Sent: Friday, January 28, 2022 2:35 PM
To: Elizabeth B Parcell <ebparcell@aep.com>
Cc: Kulpa, Sarah <sarah.kulpa@hdrinc.com>; Jonathan M Magalski <jmmagalski@aep.com>; Salazar, Maggie <Maggie.Salazar@hdrinc.com>; Williams, Jeff (DGIF) <jeff.williams@dwr.virginia.gov>; John Copeland <john.copeland@dwr.virginia.gov>
Subject: Re: Byllesby-Buck USR FERC Comment re Walleye Body Depth Data

Liz et. al.:

Walleye Body Depth Data
I wanted to respond before the weekend, since our call is Tuesday afternoon. After reading what you referenced below in the FERC comment letter, I called our statewide Walleye Committee Chairperson, George Palmer, to ask about the existence of such data. He responded (as I had already done in my head) that it would be unusual for anyone to have that data, unless a university researcher was doing something like that.

Well, since we need it for this purpose, George initiated getting preliminary data (attached here, less 1 Walleye that is included below in the email I received from Dan Michaelson) from Walleye broodstock collections they started earlier this week on the Staunton River in Brookneal and Long Island, downstream from your Smith Mountain/Leesville Project. At this point, we only have 23 Walleye total lengths and body depths to share. The team will be out 2 days next week and will collect more data then. One difference between the Staunton River and New River Walleye populations may be the ultimate body size being bigger in the New River, so any use of this data should be done with that understanding. Given a few more days, I can provide some population level comparisons between the 2 river Walleye populations (like Stock Density Indices, Average Total Lengths, etc.), but it will require me soliciting that data from George Palmer or one of his colleagues, Dan Michaelson or Hunter Hatcher in Farmville, VA. I have those statistics or can easily generate them for the New River Walleye population.

We will have the opportunity to get similar data from the New River when we start our broodstock collections in mid-late February. Using that data will be more relevant in applying it to the Buck Bypass Reach. Let's discuss it further at our meeting on February 1, because I don't know enough about your timeline to know if it's possible to get the data in that timeframe.

Stranding in the Buck Bypass Reach
I suggest we have more discussion about this one in our meeting on Tuesday. I'm in the process of interviewing current and former employees of our agency about this one. In fact, at the time you sent this email yesterday, I was interviewing retired VDWR Marion Office Conservation Police Lt. Rex Hill, who is now a Carroll County Supervisor, about events he observed stretching back into the 1970's. Formal reports are simply not available, but I can connect you with people who can testify to these events. In fact, I've asked for the current Carroll County Conservation Police Officer, Ben Boyette, to be on the call Tuesday. He's very familiar with occurrences of this nature in the Buck Bypass Reach over his years in the county and is contacting the retired county officer as well. **If possible, it would be good to put this topic up**

front in Tuesday's agenda so Officer Boyette can share his knowledge with the group and not have to sit through all the biological discussions.

I was able to get pictures of a Buck Bypass fish stranding event in 2010 subsequent to the ice dam that broke loose that winter. If you look closely at some of the pictures, you will see pieces of flashboard risers scattered throughout the bypass reach. From the vegetation observed in this photo, with trees fully leafed out, it appears to be well into at least the spring season. George Palmer sent me those pictures. I also called Bill Kittrell, retired Marion aquatics manager, to ask his recollections about it. He remembered it well, but again, no record appears to exist other than these photos (attached below, including 1 dead Walleye), nor could Bill recall the month it happened. This Walleye looks to be at least 12 inches, based on the type of teardrop net we use. We're still using the same nets.

That's all I have to report at this point.

From: Michaelson, Daniel <dan.michaelson@dwr.virginia.gov>
Sent: Wednesday, January 26, 2022 8:45 AM
To: Copeland John fhg96061 <john.copeland@dwr.virginia.gov>
Subject: WAE & truck specs

Hello John,

Attached are WAE data from yesterday (1/25/2022) at the Staunton River. I did not get the back of the data sheet copied but it was only one fish:
WAE 478 mm 84 mm (depth) M

Staunton River - Long Island - 2:51 (these are in hours and minutes by-the-way)

Two boats at Brookneal, one at Long Island.

Give me a call today if this isn't the data you're looking for. Depth measure was just a max depth of belly to top of dorsal (pretty much in front of the dorsal fin).

Dan M.

On Thu, Jan 27, 2022 at 12:48 PM Elizabeth B Parcell <ebparcell@aep.com> wrote:

> John,
>
> You may have noticed that FERC had a USR comment on walleye body depth. Specifically, they stated:
>
> *As indicated at both the USR and Initial Study Report (ISR) meetings, the potential stranding of walleye in the Buck bypassed reach during spill events in the spring spawning season is a concern. While a two-dimensional (2-D) hydraulic model was developed to simulate water depths and flow patterns in the Buck bypassed reach under the currently required ramping rate, the USR contains no information on the body depths of walleye. Therefore, to aid staff in their interpretation of the additional modeling scenario requested below in item 4, please provide body depth data for the size range of walleye that would be expected to occur in this portion of the New River during the spring spawning season. This information will help staff determine whether the existing ramping rate provides adequate escape routes (of*

sufficient water depth) for any walleye that may be attracted to intermittent spill flows and enter the Buck bypassed reach during the spring spawning season.

Any chance that you might have relevant data for the New River strain of walleye that you could share with us to support our analyses? If so, we would welcome receipt as soon as possible. If not, do you have data from nearby river systems that could be used? In either case, please specify the sample sizes for all provided body depth data. Lastly, please provide copies of any stranding reports or incidents (for walleye or other species) that VDWR may have in its possession or be aware of, as this could provide information on the potential stranding locations in the Buck bypassed reach as well as the sizes of stranded fish.

Many thanks. We appreciate your help and insight, as always.

Liz

AMERICAN ELECTRIC POWER
BOUNDLESS ENERGY

ELIZABETH B PARCELL | **PROCESS SUPV**
EBPARCELL@AEP.COM | D:540.985.2441 | C:540.529.4191
40 FRANKLIN ROAD SW, ROANOKE, VA 24011

STAUNTON RIVER

Location: Brookneal   Date: 1-25-22

Effort: 1:25 + 1:00   Gear: ______   Temp. 2 °C

Comments: 1360 cfs   WAE tagging

Species	Length	Depth (~~Length~~)	Sex (~~Length~~)	Tag (~~Length~~)	BC	Species	Length	Weight
WAE	511	110	F	601				
	458	84	M	602				
	465	80	M	603				
	502	108	F	604				
	505	92	F	605				
	485	100	F	606				
	509	104	F	607				
	449	84	M	608				
	484	100	F	609				
	425	80	M	610				
	496	95	F	611				
	382	75	M	612				
	525	111	F	613				
	494	98	F	614				
	526	100	F	615				
	510	100	F	616				
	454	88	M	617				
	470	104	F	618				
	511	108	F	619				
	501	90	F	620				
	482	99	F	621				
	486	99	F	622				

Meeting Summary

Project:	Byllesby-Buck Hydroelectric Project (P-2514)
Subject:	Byllesby Bypass Reach Flow and Aquatic Habitat Stakeholder Meeting
Date:	Wednesday, February 16, 2022
Location:	WebEx Virtual Meeting
Attendees:	Jonathan Magalski (AEP) Elizabeth Parcell (AEP) Fred Colburn (AEP) Sarah Kulpa (HDR) Maggie Salazar (HDR) Misty Huddleston (HDR) Ty Ziegler (HDR) Joe Dvorak (HDR) Jeff Williams (VDWR) John Copeland (VDWR) Janet Norman (USFWS) Rick McCorkle (USFWS) Joe Grist (VDEQ)

Overview

This document provides the meeting summary for a virtual (WebEx) meeting for Appalachian Power Company's (Appalachian) Byllesby-Buck Hydroelectric Project (Project) with primary resource agencies [U.S. Fish and Wildlife Service (USFWS), Virginia Department of Environmental Quality (VDEQ), Virginia Department of Wildlife Resources (VDWR)] to discuss study results of and preliminary agency recommendations for bypass reach flows at the Byllesby Development.

Summary of Meeting Discussion

Sarah Kulpa explained that this meeting is a follow-up to the Buck Bypass Reach Flow and Aquatic Study virtual meeting that was held of February 1, 2022. S. Kulpa noted this is a working session to clarify the USFWS and VDWR's goals and objectives for flows or aquatic habitat downstream of the Byllesby Development. Appalachian can then take these objectives into consideration during preparation of the updated revised study report and Final License Application (FLA).

S. Kulpa noted that Appalachian submitted a USR Response to Comments letter to FERC on Monday, February 14, 2022, which included a request for extension of time to file the Bypass Reach Flow and Aquatic Habitat Study Report to April 14, 2022. Maggie Salazar e-mailed out a copy of the filing to the group during the call.

Joe Dvorak showed a map comparing the difference in depth between two release points: Tainter Gate 6 and Obermeyer Gate 12. This map will be provided in the revised Study Report.

The group discussed leakage flow from Buck and Byllesby. Rick McCorkle explained that the USFWS was concerned that the model and field conditions over the last two years represent a “best case” (i.e., maximum) leakage flow scenario. HDR explained that unlike Buck, sediment build-up on the flashboards at the Byllesby spillway is unlikely due to depths in this area (i.e., over time sediment build-up will not decrease leakage flow at Byllesby). At Buck, sediment build up is likely to increase overtime, potentially decreasing leakage, although it is not ever a static measurement as the boards can also break down over time and cause more leakage. Additionally, maintenance to gates can also provide more or less leakage over time. The leakage flow provided in the field and in the model is an accurate representation given dynamic conditions. J. Dvorak clarified that at Byllesby, the Tainter gates provide the most leakage flow and not the flashboards.

R. McCorkle noted that USFWS is interested in flows at Byllesby to be provided from Obermeyer gate 12 since it appears more flow from this gate would benefit the thalweg habitat, which would be closest to the “natural condition” of the river. R. McCorkle noted it would seem that when flow is released at the Tainter gates into a higher elevation of the bypass, this may attract fish and lead to potential stranding. Janet Norman noted that she is concerned there is potential for a population trap inhibiting reproduction. John Copeland and Jeff Williams agreed that river-right releases appear to be favorable.

R. McCorkle confirmed USFWS’s management objective at Byllesby is to provide habitat for the generic shallow-slow redbreast sunfish guild (specifically the bigmouth chub). R. McCorkle noted that model results appear to show benefit to this guild at 88 cfs. J. Copeland noted that the bigmouth chub is a keystone species and VDWR supports the Service’s management objective.

Ty Ziegler noted that the comparison of conditions under leakage and 88 cfs is less than an acre of more wetted area. The release through Obermeyer gate 12 is more concentrated so it doesn’t spread into the bypass as much as release through the Tainter gate. T. Ziegler also clarified that based on the Habitat Suitability Index (HSI) data, the preferred guild requires gravel and there is not abundant gravel in the bypass reach.

J. Copeland explained that typically adult male chub will travel further distances to find small gravel and move it if necessary for spawning. R. McCorkle noted that the literature indicates that bigmouth chub uses a range of substrates from gravel to boulder. When using larger substates such as boulder, the species is likely having to travel further as gravel is a preferred substrate.

With respect to habitat preference, R. McCorkle recommended looking into the Hawks Nest relicensing to see if bigmouth chub was a modeled endemic species.

J. Norman asked if the depth mapping could be shown with 88 cfs and expressed interest in looking into depths of 1-2 feet for larger fish. Six inches would be the max body depth and 1 ft would be mid-range.

J. Dvorak showed velocity maps and noted that by increasing flow in the bypass reach, flow decreases through the powerhouse. T. Ziegler clarified that the shallow-slow habitat heat maps provided in the Updated Study Report show good habitat at the bottom end of the bypass reach. Velocity from the powerhouse and the bypass reach are both a factor of habitat. The velocity maps will be provided in the revised Study Report.

J. Dvorak presented habitat maps with river flow “fixed” to provide a better comparison than what has been provided thus far. R. McCorkle agreed that those comparisons normalize the assessment. T. Ziegler explained that the bottom portion of the bypass reach is impacted not only from bypass flow, but also powerhouse flow. The updated habitat maps will be provided in the revised Study Report.

VDWR and USFWS clarified over the course of the discussion that habitat preferences built into the HSI curves are not always represented in real-life; species can adapt to different habitats and use a range of habitat quality from low to high. R. McCorkle noted he couldn't answer the question which was better - more acres of sub-optimal habitat or fewer acres but optimal habitat.

R. McCorkle noted that bigmouth chub was found in the Byllesby bypass reach during the Fish Community Study. R. McCorkle asked what the flows were to the Byllesby bypass reach during the electrofishing survey. This was also a USR comment and will be addressed in the revised Aquatic Resources Study Report.

J. Copeland confirmed the agencies are not trying to reestablish habitat pre-dam but looking at existing conditions.

S. Kulpa clarified that the maps shown during this meeting would be provided in the revised Bypass Reach Flow and Aquatic Habitat Study Report.

R. McCorkle requested more modeling scenarios from Obermeyer gate 12. Appalachian will take the request into consideration to provide impacts of theoretic release on that side of the dam. T. Ziegler explained his hypothesis that the amount of habitat may be less (when released from Obermeyer gate 12) than compared to a Tainter gate release based on the hydraulics. R. McCorkle agreed there could be trade-offs.

J. Norman noted that in general it would be advantageous to work out these issues as a group now to avoid concerns and conflicting recommendations later in the process.

R. McCorkle would appreciate a discussion in the report about leakage flows how they may vary.

S. Kulpa noted that Appalachian may not be able to spill a steady minimum flow (e.g., 88 cfs) from the Obermeyer or Tainter gate locations and increasing/decreasing flows would be a more complex model. Ideally flow recommendations would be operationally feasible versus an idealized state.

J. Copeland noted as a follow-on to the group's previous meeting that at Buck, VDWR may seek to manage flows for flathead catfish.

During discussion, Joe Grist entered a question in the WebEx chat: "What is the end goal of this discussion for the fisheries agencies. Is it to try and reestablish habitat pre-dam (1912), improve current habitat availability, or reduce stranding occurrences/opportunities? Where is this discussion/question trying to lead to for a resolution, as it will be a similar item I would expect that will come up during the state licensing process." J. Grist had to leave the call before this item could be addressed in discussion.