Claiborne and Millers Ferry Locks and Dams Fish Passage Study

Appendix B-2: Environmental Laws and Coordination

May 2023

US Army Corps of Engineers

The Nature Conservancy

APPENDIX B-2: Environmental Laws and Coordination

US Army Corps of Engineers®

Claiborne and Millers Ferry Locks and Dams Fish Passage Study

Appendix B-2: Environmental Laws and Coordination

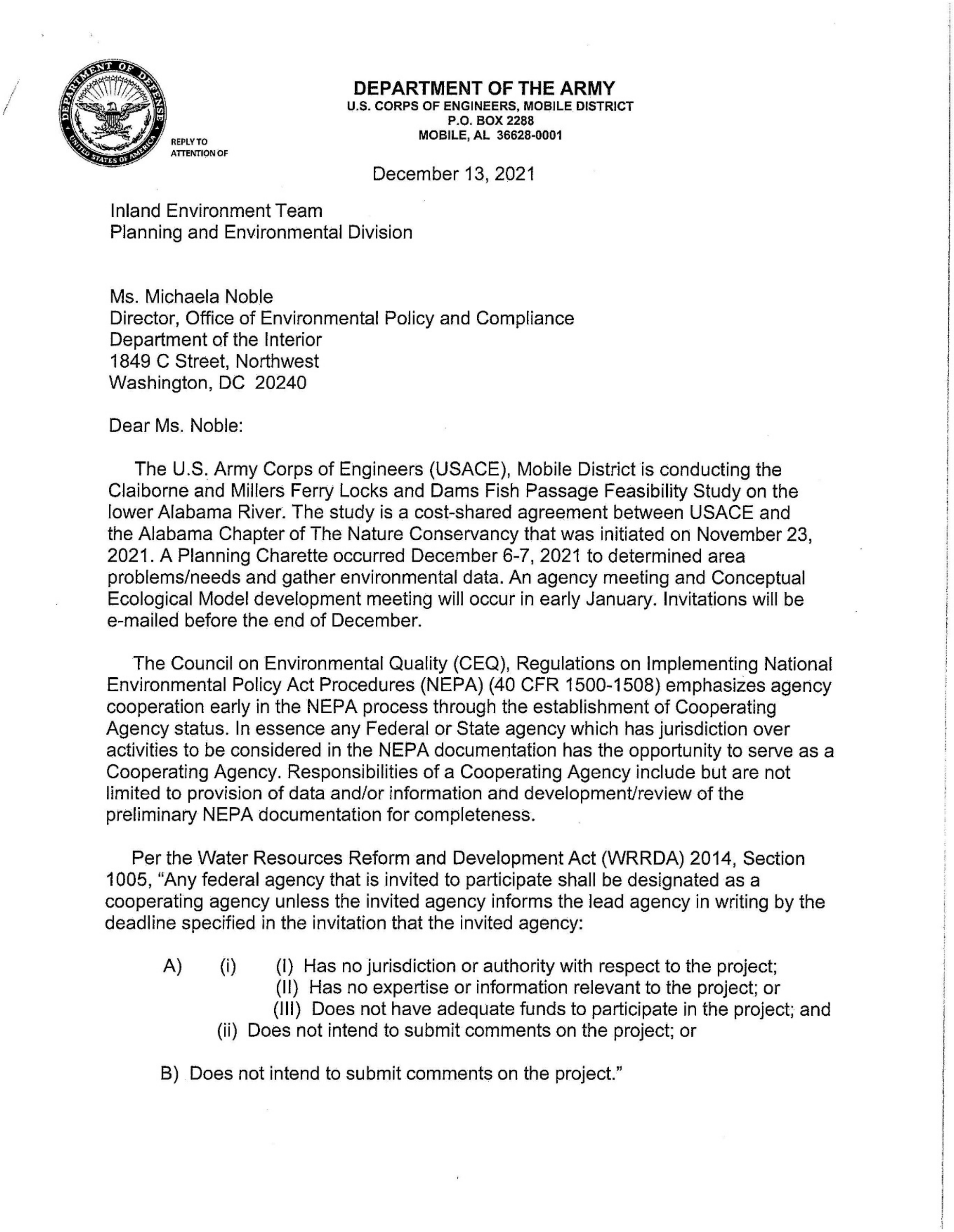
May 2023

B.1. Environmental Laws and Policies

B.1.1. *WRRDA 2014 Section 1005 Compliance*

AGENCY	ADDRESS
EPA Region 4	Sam Nunn Federal Building 61 Forsyth Street South West Atlanta, Georgia 30303
FEMA Region 4	9500 Wynlakes Place Montgomery, Alabama 36117
USGS SE Region	U.S. Geological Survey 1170 Corporate Drive, Suite 500 Atlanta, Georgia 30093
USFWS SE Region	Michael_oetker@fws.gov
USFWS DFO	bill_pearson@fws.gov
DOI	1849 C Street, Northwest Washington, DC 20240
DOI Atlanta Region	Office of Environmental Policy and Compliance, Atlanta Region Suite 1144 75 Ted Turner Drive, S.W. Atlanta, GA 30303
AHC (SHPO)	468 South Perry Street P.O. Box 300900 Montgomery, Alabama 36130-0900
NPS	100 Alabama Street, SW 1924 Building Atlanta, GA 30303
HUD	U.S. Department of Housing and Urban Development 950 22nd Street N Suite 900 Birmingham, Alabama 35203
NRCS	3381 Skyway Drive Auburn, AL 33830
ADCNR	64 N. Union Street Montgomery, Alabama 36130
ADCNR WFFRD	64 N. Union Street, Suite 551 Montgomery, Alabama 36130
ADEM	P.O. Box 301463 Montgomery, Alabama 36130-1463
ASOS	P.O. Box 5616 Montgomery, Alabama 36103-5616
AEMA	P.O. Drawer 2160 Clanton, Alabama 35046
ALDOT	P. O. Box 303050, Montgomery, Alabama 36130-3050
ALDOT Bridge Bureau	P. O. Box 303050, Montgomery, Alabama 36130-3050
ADPH	P.O. Box 303017 Montgomery, Alabama 36130-3017
ANCNR SLD	64 North Union Street Montgomery, Alabama 36130
Alabama Geological Society	Postal Office Box 866184 Tuscaloosa, Alabama 35486-0055

B.1.1.1. *Cooperating Agency Agreement Letters*



DEPARTMENT OF DEFENSE
UNITED STATES OF AMERICA

REPLY TO
ATTENTION OF

DEPARTMENT OF THE ARMY
U.S. CORPS OF ENGINEERS, MOBILE DISTRICT
P.O. BOX 2288
MOBILE, AL 36628-0001

December 13, 2021

Inland Environment Team
Planning and Environmental Division

Ms. Michaela Noble
Director, Office of Environmental Policy and Compliance
Department of the Interior
1849 C Street, Northwest
Washington, DC 20240

Dear Ms. Noble:

The U.S. Army Corps of Engineers (USACE), Mobile District is conducting the Claiborne and Millers Ferry Locks and Dams Fish Passage Feasibility Study on the lower Alabama River. The study is a cost-shared agreement between USACE and the Alabama Chapter of The Nature Conservancy that was initiated on November 23, 2021. A Planning Charette occurred December 6-7, 2021 to determined area problems/needs and gather environmental data. An agency meeting and Conceptual Ecological Model development meeting will occur in early January. Invitations will be e-mailed before the end of December.

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Per the Water Resources Reform and Development Act (WRRDA) 2014, Section 1005, "Any federal agency that is invited to participate shall be designated as a cooperating agency unless the invited agency informs the lead agency in writing by the deadline specified in the invitation that the invited agency:

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Sincerely,

Jeremy M. LaDart
Chief, Planning and Environmental
Division

DEPARTMENT OF THE ARMY
U.S. CORPS OF ENGINEERS, MOBILE DISTRICT
P.O. BOX 2288
MOBILE, AL 36628-0001

REPLY TO
ATTENTION OF

December 13, 2021

Inland Environment Team
Planning and Environmental Division

Ms. Joyce A. Stanley
Regional Environmental Protection Specialist
Department of the Interior, Office of Environmental Policy and Compliance,
Atlanta Region
Suite 1144, 75 Ted Turner Drive, Southwest
Atlanta, Georgia 30303

Dear Ms. Stanley:

The U.S. Army Corps of Engineers (USACE), Mobile District is conducting the Claiborne and Millers Ferry Locks and Dams Fish Passage Feasibility Study on the lower Alabama River. The study is a cost-shared agreement between USACE and the Alabama Chapter of The Nature Conservancy that was initiated on November 23, 2021. A Planning Charette occurred December 6-7, 2021 to determined area problems/needs and gather environmental data. An agency meeting and Conceptual Ecological Model development meeting will occur in early January. Invitations will be e-mailed before the end of December.

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Chief, Planning and Environmental
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December 13, 2021

Inland Environment Team
Planning and Environmental Division

Mr. Trey Glenn
Regional Administrator
U.S. Environmental Protection Agency, Region 4
Sam Nunn Federal Building
61 Forsyth Street South West
Atlanta, Georgia 30303

Dear Mr. Glenn:

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U.S. CORPS OF ENGINEERS, MOBILE DISTRICT
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MOBILE, AL 36628-0001

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December 13, 2021

Inland Environment Team
Planning and Environmental Division

Ms. Gracia B. Szczech
Regional Director
Federal Emergency Management Agency, Region 4
3003 Chamblee Tucker Road
Atlanta, Georgia 30341

Dear Ms. Szczech:

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Chief, Planning and Environmental
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DEPARTMENT OF THE ARMY
U.S. CORPS OF ENGINEERS, MOBILE DISTRICT
P.O. BOX 2288
MOBILE, AL 36628-0001

December 13, 2021

Inland Environment Team
Planning and Environmental Division

Mr. Leopoldo Miranda-Castro
Southeast Regional Director
U.S. Fish and Wildlife Service
1875 Century Boulevard
Atlanta, Georgia 30345

Dear Mr. Miranda-Castro:

The U.S. Army Corps of Engineers (USACE), Mobile District is conducting the Claiborne and Millers Ferry Locks and Dams Fish Passage Feasibility Study on the lower Alabama River. The study is a cost-shared agreement between USACE and the Alabama Chapter of The Nature Conservancy that was initiated on November 23, 2021. A Planning Charette occurred December 6-7, 2021 to determined area problems/needs and gather environmental data. An agency meeting and Conceptual Ecological Model development meeting will occur in early January. Invitations will be e-mailed before the end of December.

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DISTRICT P.O. BOX 2288
MOBILE, AL 36628-0001

REPLY TO
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December 13, 2021

Inland Environment Team
Planning and Environmental Division

Mr. Bill Pearson
Field Supervisor
U.S. Fish and Wildlife Service, Daphne Field Office
1208 Main Street
Daphne, Alabama 36526

Dear Mr. Pearson:

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REPLY TO
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December 13, 2021

Inland Environment Team
Planning and Environmental Division

Ms. Holly Weyers
Regional Director, Southeast Region
U.S. Geological Survey
1170 Corporate Drive, Suite 500
Atlanta, Georgia 30093

Dear Ms. Weyers:

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REPLY TO
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December 13, 2021

Inland Environment Team
Planning and Environmental Division

Mr. Pedro M. Ramos
Regional Director
National Park Service
100 Alabama Street, SW
1924 Building
Atlanta, Georgia 30303

Dear Mr. Ramos:

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Inland Environment Team
Planning and Environmental Division

Mr. Ben Malone
State Conservationist
Natural Resources Conservation Service
U.S. Department of Agriculture
3381 Skyway Drive
Auburn, Alabama 33830

Dear Mr. Malone:

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MOBILE, AL 36628-0001

REPLY TO
ATTENTION OF

Inland Environment Team
Planning and Environmental Division

Ms. Patricia A. Hoban-Moore
Director, Alabama Field Office
U.S. Department of Housing and Urban Development
950 22nd Street N Suite 900
Birmingham, Alabama 35203

Dear Ms. Hoban-Moore:

The U.S. Army Corps of Engineers (USACE), Mobile District is conducting the Claiborne and Millers Ferry Locks and Dams Fish Passage Feasibility Study on the lower Alabama River. The study is a cost-shared agreement between USACE and the Alabama Chapter of The Nature Conservancy that was initiated on November 23, 2021. A Planning Charette occurred December 6-7, 2021 to determined area problems/needs and gather environmental data. An agency meeting and Conceptual Ecological Model development meeting will occur in early January. Invitations will be e-mailed before the end of December.

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ATTENTION OF

DEPARTMENT OF THE ARMY
U.S. CORPS OF ENGINEERS, MOBILE DISTRICT
P.O. BOX 2288
MOBILE, AL 36628-0001

Inland Environment Team
Planning and Environmental Division

Ms. Amanda McBride
Alabama State Historical Preservation Officer
468 South Perry Street
P.O. Box 300900
Montgomery, Alabama 36130-0900

Dear Ms. McBride:

The U.S. Army Corps of Engineers (USACE), Mobile District is conducting the Claiborne and Millers Ferry Locks and Dams Fish Passage Feasibility Study on the lower Alabama River. The study is a cost-shared agreement between USACE and the Alabama Chapter of The Nature Conservancy that was initiated on November 23, 2021. A Planning Charette occurred December 6-7, 2021 to determined area problems/needs and gather environmental data. An agency meeting and Conceptual Ecological Model development meeting will occur in early January. Invitations will be e-mailed before the end of December.

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Sincerely,

Jeremy M. LaDart
Chief, Planning and Environmental
Division

DEPARTMENT OF DEFENSE
UNITED STATES OF AMERICA

REPLY TO
ATTENTION OF

DEPARTMENT OF THE ARMY
U.S. CORPS OF ENGINEERS, MOBILE DISTRICT
P.O. BOX 2288
MOBILE, AL 36628-0001

Inland Environment Team
Planning and Environmental Division

Mr. Steven O. Jenkins
Alabama Department Environmental Management
Field Operation Division
Post Office Box 301463
Montgomery, Alabama 36130-1463

Dear Mr. Jenkins:

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DEPARTMENT OF THE ARMY
U.S. CORPS OF ENGINEERS, MOBILE DISTRICT
P.O. BOX 2288
MOBILE, AL 36628-0001

REPLY TO
ATTENTION OF

Inland Environment Team
Planning and Environmental Division

The Honorable John H. Merrill
Alabama Secretary of State
Post Office Box 5616
Montgomery, Alabama 36103-5616

Dear Representative Merrill:

The U.S. Army Corps of Engineers (USACE), Mobile District is conducting the Claiborne and Millers Ferry Locks and Dams Fish Passage Feasibility Study on the lower Alabama River. The study is a cost-shared agreement between USACE and the Alabama Chapter of The Nature Conservancy that was initiated on November 23, 2021. A Planning Charette occurred December 6-7, 2021 to determined area problems/needs and gather environmental data. An agency meeting and Conceptual Ecological Model development meeting will occur in early January. Invitations will be e-mailed before the end of December.

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DEPARTMENT OF THE ARMY
U.S. CORPS OF ENGINEERS, MOBILE DISTRICT
P.O. BOX 2288
MOBILE, AL 36628-0001

REPLY TO
ATTENTION OF

December 13, 2021

Inland Environment Team
Planning and Environmental Division

Mr. Chris M. Blankenship
Commissioner
Alabama Department of Conservation and Natural Resources
64 North Union Street
Montgomery, Alabama 36130

Dear Mr. Blankenship:

The U.S. Army Corps of Engineers (USACE), Mobile District is conducting the Claiborne and Millers Ferry Locks and Dams Fish Passage Feasibility Study on the lower Alabama River. The study is a cost-shared agreement between USACE and the Alabama Chapter of The Nature Conservancy that was initiated on November 23, 2021. A Planning Charette occurred December 6-7, 2021 to determined area problems/needs and gather environmental data. An agency meeting and Conceptual Ecological Model development meeting will occur in early January. Invitations will be e-mailed before the end of December.

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DEPARTMENT OF THE ARMY
U.S. CORPS OF ENGINEERS, MOBILE DISTRICT
P.O. BOX 2288
MOBILE, AL 36628-0001

December 13, 2021

Inland Environment Team
Planning and Environmental Division

Mr. Charles F. Sykes
Director, Wildlife and Freshwater Fisheries Division
Alabama Department of Conservation and Natural Resources
64 North Union Street
Montgomery, Alabama 36130

Dear Mr. Sykes:

The U.S. Army Corps of Engineers (USACE), Mobile District is conducting the Claiborne and Millers Ferry Locks and Dams Fish Passage Feasibility Study on the lower Alabama River. The study is a cost-shared agreement between USACE and the Alabama Chapter of The Nature Conservancy that was initiated on November 23, 2021. A Planning Charette occurred December 6-7, 2021 to determined area problems/needs and gather environmental data. An agency meeting and Conceptual Ecological Model development meeting will occur in early January. Invitations will be e-mailed before the end of December.

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U.S. CORPS OF ENGINEERS, MOBILE DISTRICT
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MOBILE, AL 36628-0001

December 13, 2021

Inland Environment Team
Planning and Environmental Division

Mr. John R. Cooper
Transportation Director
Alabama Department of Transportation
1409 Coliseum Boulevard
Montgomery, Alabama 36110

Dear Mr. Cooper:

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REPLY TO
ATTENTION OF

December 13, 2021

Inland Environment Team
Planning and Environmental Division

Mr. William Colquett, P.E.
Bridge Engineer
Alabama Department of Transportation, Bridge Bureau
1409 Coliseum Boulevard
Montgomery, Alabama 36130-3050

Dear Mr. Colquett:

The U.S. Army Corps of Engineers (USACE), Mobile District is conducting the Claiborne and Millers Ferry Locks and Dams Fish Passage Feasibility Study on the lower Alabama River. The study is a cost-shared agreement between USACE and the Alabama Chapter of The Nature Conservancy that was initiated on November 23, 2021. A Planning Charette occurred December 6-7, 2021 to determined area problems/needs and gather environmental data. An agency meeting and Conceptual Ecological Model development meeting will occur in early January. Invitations will be e-mailed before the end of December.

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REPLY TO
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December 13, 2021

Inland Environment Team
Planning and Environmental Division

Ms. Amanda McBride
Alabama Historical Commission, State Historic Preservation Officer
468 South Perry Street
Montgomery, Alabama 36130-0900

Dear Ms. McBride:

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REPLY TO
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December 13, 2021

Inland Environment Team
Planning and Environmental Division

Ms. Patti Powell
Director, State Lands Division
Alabama Department of Conservation and Natural Resources
64 North Union Street
Montgomery, Alabama 36130

Dear Ms. Powell:

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U.S. CORPS OF ENGINEERS, MOBILE DISTRICT
P.O. BOX 2288
MOBILE, AL 36628-0001

December 13, 2021

Inland Environment Team
Planning and Environmental Division

Mr. Lance R. Lefleur
Director
Alabama Department of Environmental Management
Post Office Box 301463
Montgomery, Alabama 36130-1463

Dear Mr. Lefleur:

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P.O. BOX 2288
MOBILE, AL 36628-0001

REPLY TO
ATTENTION OF

December 13, 2021

Inland Environment Team
Planning and Environmental Division

Mr. Brian Hastings
Director
Alabama Department of Emergency Management
Post Office Box 2160
Clanton, Alabama 35046

Dear Mr. Hastings:

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MOBILE, AL 36628-0001

December 13, 2021

Inland Environment Team
Planning and Environmental Division

Dr. Scott Harris
State Health Officer
Alabama Department of Public Health
Post Office Box 303017
Montgomery, Alabama 36130-3017

Dear Dr. Harris:

The U.S. Army Corps of Engineers (USACE), Mobile District is conducting the Claiborne and Millers Ferry Locks and Dams Fish Passage Feasibility Study on the lower Alabama River. The study is a cost-shared agreement between USACE and the Alabama Chapter of The Nature Conservancy that was initiated on November 23, 2021. A Planning Charette occurred December 6-7, 2021 to determined area problems/needs and gather environmental data. An agency meeting and Conceptual Ecological Model development meeting will occur in early January. Invitations will be e-mailed before the end of December.

The Council on Environmental Quality (CEQ), Regulations on Implementing National Environmental Policy Act Procedures (NEPA) (40 CFR 1500-1508) emphasizes agency cooperation early in the NEPA process through the establishment of Cooperating Agency status. In essence any Federal or State agency which has jurisdiction over activities to be considered in the NEPA documentation has the opportunity to serve as a Cooperating Agency. Responsibilities of a Cooperating Agency include but are not limited to provision of data and/or information and development/review of the preliminary NEPA documentation for completeness.

Per the Water Resources Reform and Development Act (WRRDA) 2014, Section 1005, "Any federal agency that is invited to participate shall be designated as a cooperating agency unless the invited agency informs the lead agency in writing by the deadline specified in the invitation that the invited agency:

A) (i) (I) Has no jurisdiction or authority with respect to the project;
    (II) Has no expertise or information relevant to the project; or
    (III) Does not have adequate funds to participate in the project; and
  (ii) Does not intend to submit comments on the project; or

B) Does not intend to submit comments on the project."

Please know that “designation as a participating or cooperating agency does not imply that the participating or cooperating agency supports a proposed project or has any jurisdiction over, or special expertise with respect to evaluation of, the project.” Please respond via letter with your agency’s position. Should your agency wish to decline, please respond with a reasoning consistent with WRRDA 2014, quoted above. Failure to respond in either the affirmative or negative will be treated as confirmation of cooperating agency agreement.

As lead agency, USACE, Mobile District is requesting your involvement as a cooperating agency in this effort and would appreciate your response no later than 30 days after the date of this letter. We look forward to working with you on this project and if you should have any questions, please contact Ms. Heather Bulger at (251) 694-3889 or via email at heather.p.bulger@usace.army.mil.

Sincerely,

Jeremy M. LaDart
Chief, Planning and Environmental
Division

DEPARTMENT OF DEFENSE UNITED STATES OF AMERICA

REPLY TO
ATTENTION OF

DEPARTMENT OF THE ARMY
U.S. CORPS OF ENGINEERS, MOBILE DISTRICT
P.O. BOX 2288
MOBILE, AL 36628-0001

December 13, 2021

Inland Environment Team
Planning and Environmental Division

Mr. Mark D. Bartlett
Division Administrator
Alabama Division, Federal Highway Administration
9500 Wynlakes Place
Montgomery, Alabama 36117

Dear Mr. Bartlett:

The U.S. Army Corps of Engineers (USACE), Mobile District is conducting the Claiborne and Millers Ferry Locks and Dams Fish Passage Feasibility Study on the lower Alabama River. The study is a cost-shared agreement between USACE and the Alabama Chapter of The Nature Conservancy that was initiated on November 23, 2021. A Planning Charette occurred December 6-7, 2021 to determined area problems/needs and gather environmental data. An agency meeting and Conceptual Ecological Model development meeting will occur in early January. Invitations will be e-mailed before the end of December.

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Jeremy M. LaDart
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DEPARTMENT OF DEFENSE
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U.S. CORPS OF ENGINEERS, MOBILE DISTRICT
P.O. BOX 2288
MOBILE, AL 36628-0001

December 13, 2021

Inland Environment Team
Planning and Environmental Division

Mr. Richard Esposito
Alabama Geological Society
Postal Office Box 866184
Tuscaloosa, Alabama 35486-0055

Dear Mr. Esposito:

The U.S. Army Corps of Engineers (USACE), Mobile District is conducting the Claiborne and Millers Ferry Locks and Dams Fish Passage Feasibility Study on the lower Alabama River. The study is a cost-shared agreement between USACE and the Alabama Chapter of The Nature Conservancy that was initiated on November 23, 2021. A Planning Charette occurred December 6-7, 2021 to determined area problems/needs and gather environmental data. An agency meeting and Conceptual Ecological Model development meeting will occur in early January. Invitations will be e-mailed before the end of December.

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As lead agency, USACE, Mobile District is requesting your involvement as a cooperating agency in this effort and would appreciate your response no later than 30 days after the date of this letter. We look forward to working with you on this project and if you should have any questions, please contact Ms. Heather Bulger at (251) 694-3889 or via email at heather.p.bulger@usace.army.mil.

Sincerely,

Jeremy M. LaDart
Chief, Planning and Environmental
Division

B.1.2. *Section 106: National Historic Preservation Act of 1966*

B.1.2.1. *Draft Programmatic Agreement*

PROGRAMMATIC AGREEMENT
AMONG
THE U.S. ARMY CORPS OF ENGINEERS, THE ALABAMA STATE HISTORIC PRESERVATION OFFICER, AND THE ADVISORY COUNCIL ON HISTORIC PRESERVATION REGARDING THE CLAIBORNE AND MILLERS FERRY LOCKS AND DAMS FISH PASSAGE FEASBILITY STUDY

WHEREAS, the U.S. Army Corps of Engineers, Mobile District (Corps), is proposing to install natural bypass channels at Millers Ferry and Claiborne Locks and Dams (Project) as a result of the Claiborne and Millers Ferry Locks and Dams Fish Passage Feasibility Study authorized in Section 216 of the Flood Control Act of 1970, Public Law 91-611 (33 U.S.C. 549a) ; and

WHEREAS, the Project is being developed to improve the quality of the environment, due to significantly changed physical conditions by establishing fish passage through restoring connectivity in the Alabama and Cahaba Rivers; and

WHEREAS, the Corps proposes to construct natural bypass channels circumventing the dam to include either low gradient earthen or rocky channels which mimic natural stream structure and would include attraction flow and provide passage to aquatic species; and

WHEREAS, the Project alignment at Millers Ferry Lock and Dam will have a channel length of 8500 ft, bottom width of 100 ft, channel slope of 0.005, side slope of 1V:3H and be constructed of rock (Enclosure 1) and the Project alignment at Claiborne Lock and Dam will have a channel length of 2100 ft, bottom width of 75ft, channel slop of 0.013 and side slope of 1V:3H (Enclosure 2); and

WHEREAS, the Project comprises both the development and implementation of the Project, and the Corps will be the Lead Federal Agency for compliance with 54 U.S.C. § 306108 (National Historic Preservation Act (NHPA) Section 106); and

WHEREAS, the Corps has determined that the Project constitutes an Undertaking, as defined in 36 C.F.R. § 800.16(y), and therefore is subject to Section 106 of the NHPA, and will hereby be referred to as the Undertaking; and

WHEREAS, the Corps has determined that the Undertaking has the potential to affect properties that could be eligible for listing in the National Register of Historic Places (NRHP) and have consulted with the Alabama State Historic Preservation Officer (SHPO) pursuant to the NHPA; and

WHEREAS, the Corps has determined that the Area of Potential Effects (APE) for the Undertaking includes areas within the projected alignments of both natural bypass channels and any disposal areas utilized during construction; and

WHEREAS, the Corps has identified at least four potential Historic Properties in the APE at the Claiborne alignment and at least three potential Historic Properties in the APE at the Millers Ferry alignment, that may be affected by the undertaking; and

WHEREAS, the Corps as lead federal agency, with the concurrence of SHPO, has decided to comply with Section 106 of the NHPA for the Undertaking through the execution and implementation of a Programmatic Agreement (Agreement), following 36 C.F.R. § 800.14(b); and

WHEREAS, the Nature Conservancy (TNC) is the non-Federal sponsor for the Project and has been invited to be a Concurring Party to this Agreement; and

WHEREAS, in accordance with 36 C.F.R. § 800.2(c)(2)(ii)(A), 800.3(f)(2), and 800.14(b)(2)(i), the Corps has contacted Federally Recognized Native American Tribes, via letter(s), phone call(s), email(s) and meetings, to invite them to consult on the Undertaking and this Agreement, including the Absentee-Shawnee Tribe of Oklahoma, the Alabama-Coushatta Tribes of Texas, the Alabama-Quassarte Tribal Town, the Caddo Nation of Oklahoma, the Catawba Indian Nation, the Cherokee Nation, the Chickasaw Nation, the Chitimacha Tribe of Louisiana, the Choctaw Nation of Oklahoma, The Coushatta Tribe of Louisiana, Eastern Band of the Cherokee Nation, the Eastern Shawnee Tribe of Oklahoma, the Jena Band of Choctaw Indians of Louisiana, the Kialegee Tribal Town of Oklahoma, the Miccosukee Tribe of Indians of Florida, the Mississippi Band of Choctaw Indians, Muscogee (Creek) Nation, the Poarch Band of Creek Indians, the Quapaw Tribe of Indians of Oklahoma, Shawnee Tribe of Oklahoma, the Seminole Nation of Oklahoma, the Seminole Tribe of Florida, the Thlopthlocco Tribal Town, Tunica-Biloxi Indian Tribe of Louisiana, and the United Keetoowah Band of Cherokee Indians in Oklahoma; and

WHEREAS, in accordance with 36 C.F.R. § 800.2(c)(5), the Corps has contacted additional interested parties via letter(s), phone call(s), email(s), and meetings, to invite them to consult on the Undertaking and this Agreement, including other non-Federally listed Tribes and Native American individuals and other interested parties; and

WHEREAS, in accordance with 36 C.F.R. § 800.14(b)(3), the Corps invited the Advisory Council on Historic Preservation (ACHP) per 36 C.F.R. § 800.6(a)(1)(C) to participate in consultations to resolve potential adverse effects of the Undertaking, including development of this Agreement on DATE and CONCLUSION; and

WHEREAS, in accordance with 36 C.F.R. § 800.6(a)(4) and 36 C.F.R. § 800.14(b)(2)(ii), the Corps held a series of public meetings to notify the public of the Undertaking and provide an opportunity for members of the public to comment on the Project and the Section 106 process. These were conducted on DATES in LOCATIONS; and

NOW, THEREFORE, the signatories agree that the Undertaking shall be implemented in accordance with the following stipulations in order to take into account the effects of the undertaking on Historic Properties.

STIPULATIONS

The Corps shall ensure that the following measures are carried out:

I. TIME FRAMES AND REVIEW PROCEDURES

A. Document and Deliverable Review. For all documents and deliverables produced in compliance with this Agreement, the Corps will have thirty (30) calendar days to review. After completing its review, the Corps shall provide a hard copy draft document via mail or digital copies via email to the SHPO, Concurring Parties, and Federally Recognized Tribes, and other interested parties for review. Any written comments provided by the SHPO, Federally Recognized Tribes, and other interested parties within thirty (30) calendar days from the date of receipt shall be considered in the revision of the document or deliverable. The Corps shall document and report the written comments received for the document or deliverable and how comments were addressed. The Corps shall provide a revised final document or deliverable to the SHPO for concurrence. The SHPO shall have thirty (30) calendar days to respond. Failure of the SHPO, Concurring Parties, and Native American interested parties and Tribes to respond within thirty (30) calendar days of any submittal shall not preclude the Corps from moving to the next step in this Agreement. A copy of the final document shall be provided to the Signatories and to any consulting parties who request it, as appropriate per **Stipulation X (Confidentiality)**.

B. Disagreement. Should the SHPO, Federally Recognized Tribes, or an interested party object to the findings of NRHP eligibility and/or findings of effect within the final document or deliverable submitted for concurrence, the Corps, SHPO, Federally Recognized Tribes, and interested parties shall consult for a period not to exceed fifteen (15) calendar days following the receipt of SHPO's, a Federally Recognized Tribe's, or an interested party's written objection in an effort to come to agreement on the issues to which the SHPO, Federally Recognized tribe, or interested party has objected. Should the SHPO, a Federally Recognized Tribe, or interested party be unable to agree on the issues to which the SHPO, a Federally Recognized Tribe, or an interested party has objected, the SHPO, and the Corps shall proceed in accordance with **Stipulation XI (Dispute Resolution)**, below. The timeframe to consult to resolve a disagreement or objection may be extended by mutual consent of the Signatories.

II. AREA OF POTENTIAL EFFECTS

A. **DETERMINATION OF THE AREA OF POTENTIAL EFFECTS.** The APE for Project activities has been determined by the Corps as Lead Federal Agency. It includes the Milers Ferry natural bypass channel alignment, the Claiborne natural bypass channel alignment and disposal sites that may be affected by proposed improvement measures. Maps of the APE are provided in Appendix A.

B. **APE REVISIONS**. If the APE boundaries are revised during the course of the Project, the Corps will delineate the revised areas and consult on that revision in accordance with **Stipulation I (Timeframes and Review Procedures),** and the Corps shall determine the potential for Project activities in a revised APE to affect potential Historic Properties according to **Stipulation III A (Identification of Historic Properties)**.

III. IDENTIFICATION, EVALUATION, AND DETERMINATION OF EFFECT

The Corps shall complete any identification and evaluation of Historic Properties prior to proceeding with construction. Much of the APE has already been inventoried prior to the construction of the locks and dams. These identified various potential Historic Properties which will be subjected to a Phase II investigation and evaluation.

A. Identification of Historic Properties. Pursuant to 36 C.F.R. § 800.4 and in consultation with the Signatories and consulting parties of this agreement, the Corps shall conduct Phase I archaeological surveys to identify Historic Properties when the APE boundaries are revised to included areas that have not been surveyed pursuant to 36 C.F.R. § 336.0(6). Prior to surveying these areas, the Corps shall coordinate with the SHPO, Federally Recognized Tribes, and other interested parties according to **Stipulation II (Area of Potential Effect)** of this Agreement. The scope of the Phase I inventory and contents of the survey report are listed below:

1. Submit a scope of work (SOW) for Phase I fieldwork for review and approval by the SHPO and for review and comment by Federally Recognized Tribes and other interested parties.

2. Conduct archival research to determine the known history and pre-Contact history of the area prior to fieldwork.

3. Conduct an archaeological survey to locate potentially NRHP eligible objects, vessels, or sites within the APE.

4. Prepare a survey report that includes the nature of the project, methods, pre-Contact and historic contexts, and inventory of findings, an evaluation of all findings for significance and integrity, conclusions, and recommendations. A draft and draft final survey report will be submitted to the SHPO, Federally Recognized Tribes, and other interested parties for review and comment following **Stipulation I (Timeframes and Review Procedures)** of this Agreement.

B. Evaluation and Determination of Effect. Findings determined to be cultural resources will be assessed by a qualified professional for their eligibility for listing in the NRHP consistent with the *Secretary of Interior's Standards for Evaluation*, 36 C.F.R. § 60.4. If during the Phase I archaeological survey of the APE, findings are made which could represent Historic Properties, these sites could be subjected to a Phase II evaluation to determine if they are NRHP eligible resources. The scope of Phase II evaluations along with a description of the contents of the evaluation report are listed below:

1. Submit a SOW for Phase II fieldwork for review and approval by the SHPO and for review and comment by Federally Recognized Tribes and other interested parties.

2. Phase II Objectives: The objective of the Phase II evaluation is to collect data regarding site significance and integrity from which determinations of NRHP eligibility can be made. Field methods for the Phase II investigation could include additional archaeological work to capture more detailed data on sites and objects and asses for NRHP eligibility.

3. A draft Phase II Survey, Evaluation, and Determination of Effects report will be prepared within 60 days following the completion of the fieldwork. The draft report will include a description of project purposes, specific methods guiding the Phase II resource survey work including the results of fieldwork with site descriptions and locational data. The report will also contain evaluations of site significance using NRHP eligibility criteria and determinations of effects. Specific sites requiring mitigation measures will also be identified in this report. The Corps shall prepare and submit the draft and final Phase II Survey, Evaluation, and Determination of Effects Reports in accordance with **Stipulation I (Timeframes and Review Procedures)**. Confidentiality regarding the nature and location of archaeological sites and any other cultural resource discussed in any Phase II report under this agreement shall be maintained. Also, if any information provided to the Corps by Native American tribes or others who wish to control the dissemination of that information, the Corps will make a

good faith effort to do so, to the extent permissible by law according to **Stipulation X (Confidentiality)** of this Agreement.

If SHPO, any Federally Recognized Tribes, or other interested parties disagree with the Corps' determinations of NRHP eligibility and effects, the Corps shall notify the SHPO, Federally Recognized Tribes, and other parties of the dispute and consult with the SHPO. If the dispute cannot be resolved, the Corps shall seek a formal determination of eligibility from the Keeper of the National Register. The Keeper's determination will be final in accordance with 36 C.F.R. 63.4.

Avoidance of adverse effects to Historic Properties is always the preferred treatment approach. However, it may not be possible to redesign the Project in order to avoid resources within the APE. The Corps will apply the criteria of adverse effect, pursuant to 36 C.F.R. § 800.5(a)(1), to all Historic Properties within the APE. If the Corps determines that Historic Properties will be adversely affected, **Stipulation IV (Historic Properties Treatment Plan)**, below, will be followed.

IV. HISTORIC PROPERTIES TREATMENT PLAN

If it is determined that project activities will result in adverse effects, the Corps, in consultation with the SHPO, Federally Recognized Tribes, and other interested parties shall develop a Historic Properties Treatment Plan (HPTP) to resolve all adverse effects resulting from the Project, which would be appended to this PA. The HPTP shall outline the minimization and mitigation measures necessary to resolve the adverse effects to Historic Properties. Proposed mitigation measures may include, but are not limited to, oral history, interpretive brochures, data recovery, or publications depending on their criterion for eligibility. Development of appropriate measures shall include consideration of Historic Property types and provisions for avoidance or protection of Historic Properties where possible.

If adverse effects are identified, the HPTP shall be in effect before construction commences. The HPTP may be amended and appended to this PA without amending the PA.

A. Review: The Corps shall submit the Draft HPTP to the SHPO, Federally Recognized Tribes, and other interested parties for review and comment pursuant to **Stipulation I (Timeframes and Review Procedures)**.

B. Reporting: Reports and other data pertaining to archaeological site locations and the treatment of effects to Historic Properties will be distributed to Federally Recognized Tribes and other interested parties, tribes, and other members of the public, consistent with **Stipulation X (Confidentiality)** of this PA, unless parties have indicated through consultation that they do not want to receive a report or data.

C. Amendments/Addendums/Revisions: If a Historic Property that is not covered by the existing HPTP is discovered within the APE subsequent to the initial inventory effort, or if there are previously unexpected effects to a Historic Property, or if the Corps and SHPO agree that a modification to the HPTP is necessary, the Corps shall prepare an addendum to the HPTP. The Corps shall then submit the addendum to the SHPO, Federally Recognized Tribes, and other interested parties for review and comment, and if necessary, shall follow the provisions of **Stipulation IX (New Discoveries)**. The HPTP may cover multiple discoveries for the same property type.

D. Data Recovery: When data recovery is proposed, the Corps, in consultation with the SHPO, Federally Recognized Tribes, and other interested parties shall ensure that specific Research Designs are developed consistent with the *Secretary of the Interior's Standards and Guidelines for Archaeology and Historic Preservation* and the ACHP's "Recommended Approach for Consultation on Recovery of Significant Information from Archaeological Sites" (ACHP, May 18, 1999).

V. QUALIFICATIONS

A. Professional Qualifications: All technical work required for historic preservation activities implemented pursuant to this Agreement shall be carried out by or under the direct supervision of a person or persons meeting, at a minimum, the *Secretary of Interior's Professional Qualifications Standards* for archeology or history, as appropriate (48 FR 44739). "Technical work" here means all efforts to inventory, evaluate, and perform subsequent treatment such as data recovery excavation or recordation of potential Historic Properties that is required under this Agreement. This stipulation shall not be construed to limit peer review, guidance, or editing of documents by SHPO and associated Project consultants.

B. Historic Preservation Standards: Historic preservation activities carried out pursuant to this Agreement shall meet the *Secretary of Interior's Standards and Guidelines for Archaeology and Historic Preservation* (48 FR 44716-44740), as well as standards and guidelines for historic preservation activities established by the SHPO. The Corps shall ensure that all reports prepared pursuant to this Agreement will be provided to the Signatories, Federally Recognized Tribes, and other interested parties, and are distributed in accordance with **Stipulation X (Confidentiality)**, and meet published standards of the Alabama Historical Commission, Administrative Code, Chapter 460-X-9.02(4) as updated in 2006 (Standards for Reports) and *Preservation Planning Bulletin* Number 4(a), "Archaeological Resources Management Reports (ARMR): Recommended Contents and Format" (December 1989).

VI. CONSULTATION WITH TRIBES AND INTERESTED PARTIES

A. In consultation with Federally Recognized Tribes and other interested Native American parties or individuals, the Corps will make a reasonable and good-faith effort to identify Historic Properties of traditional religious and cultural importance. As the Lead Federal Agency, the Corps shall ensure that consultation regarding site condition assessment, monitoring efforts, and determinations of eligibility and effects with other interested Native American parties and individuals continues throughout the implementation of the Agreement. The Corps shall be responsible for transmitting all relevant documents and deliverables to Federally Recognized Tribes and other interested Native American parties or individuals as part of their tribal consultation responsibility.

B. Federally Recognized Tribes and other interested Native American parties and individuals may choose not to sign this Agreement as a Concurring Party. However, the Corps will make a good faith effort to contact Federally Recognized Tribes and other interested Native American parties and individuals, not acting as Concurring Parties to the Agreement, with potential interest in consulting on site condition assessment efforts and on the proposed treatment of Historic Properties or potential Historic Properties. Efforts to identify these individuals or groups may include using online databases, consultations for previous projects, and using personal and professional knowledge. The Corps will then contact each identified organization and individual by phone, mail, or email inviting them to consult on additional Phase I efforts, Phase II investigations, site assessment efforts, and proposed treatments of Historic Properties or potential Historic Properties. Consultations may be carried out through either letters of notification, public meetings, environmental assessments/environmental impact statements, and/or other methods requested by a Federally Recognized Tribe or other interested Native American parties or individuals. Failure of any contacted group or individual to comment within thirty (30) calendar days shall not preclude the Corps from proceeding with the Project.

C. The Corps shall make a reasonable and good-faith effort to ensure that Native American Tribes or other interested parties, acting as either Concurring Parties or those expressing interest in the project, will be invited to participate in the implementation of the terms of this Agreement. Review periods shall be consistent with **Stipulation I (Timeframes and Review Procedures).** The Corps shall ensure that all reviewers from Federally Recognized Tribes and other interested parties shall receive copies of all reports.

VII. TREATMENT OF HUMAN REMAINS

A. In the event that Native American human remains, as well as Native American funerary objects, sacred objects, or objects of cultural patrimony are encountered within the APE during the Project, those remains and objects are subject to the Native American Graves Protection and Repatriation Act

(NAGPRA) (25 U.S.C. 3001 *et seq.*) and treatment under NAGPRA's implementing regulations at 43 C.F.R. Part 10. When NAGPRA items are discovered inadvertently, an appropriate Corps official must be notified immediately upon the discovery. The Corps shall follow the requirements of 43 C.F.R. §10.3 for consultation; notification; development of excavation, treatment, and disposition plans as needed; and the requirements of 43 C.F.R. §10.6 for NAGPRA item disposition. The Corps will also notify the SHPO, Federally Recognized Tribes, other interested Native American parties, and individuals within 24 hours in the event that Native American human remains, Native American funerary objects, sacred objects, or objects of cultural patrimony are encountered. Confidentiality regarding the nature and locations of Native American remains, funerary objects, sacred objects, or objects of cultural patrimony under this agreement shall be maintained. Also, if any information provided to the Corps by Native American tribes or others who wish to control the dissemination of that information, the Corps will make a good faith effort to do so, to the extent permissible by law according to **Stipulation X (Confidentiality)** of this Agreement.

B. In the event non-native human remains or unmarked human burials are encountered within the APE, those remains will be subject to the Alabama Historical Commission, Administrative Code, Chapter 460-X-10 (Burials) and Alabama's Burial Act, § 13A-7-23.1, as amended. When unmarked human burials or non-native human skeletal remains are inadvertently found, the appropriate Corps official must be notified immediately upon the discovery. The Corps will follow the requirements regarding notification, treatment, and jurisdiction under Chapter 460-X-10(f) (Notification).

VIII. PUBLIC CONSULTATION AND PUBLIC NOTICE

A. The interested public will be invited to provide input during the implementation of this document. The Corps shall carry this out through letters of notification, public meetings, and environmental assessment/environmental impact statements. The Corps shall ensure that any comments received from members of the public are taken under consideration and incorporated where appropriate. Review periods shall be consistent with **Stipulation I (Timeframes and Review Procedures)**. In seeking input from the interested public, locations of Historic Properties will be handled in accordance with **Stipulation X (Confidentiality)**. In cases where the release of location information may cause harm to the Historic Property, this information will be withheld from the public in accordance with Section 304 of the NHPA (54 U.S.C. § 307103).

IX. NEW DISCOVERIES

A. If new and unanticipated Historic Properties are inadvertently discovered during implementation of the Undertaking, the Mobile District will cease all work in the vicinity of the discovery until it can be evaluated. If the property is determined to be NRHP eligible, the Corps shall consult with the SHPO, Federally Recognized Tribes, and other interested parties to develop a treatment plan according to **Stipulation IV (Historic Properties Treatment Plan)**.

B. The Corps will implement the HPTP once it has been reviewed by Federally Recognized Tribes and other interested parties according to **Stipulation I (Timeframes and Review Procedures)** and the HPTP has been approved by SHPO.

X. CONFIDENTIALITY

Confidentiality regarding the specific nature and location of the archaeological sites and any other cultural resource discussed in this Agreement shall be maintained to the extent allowable by law. Dissemination of such information shall be limited to appropriate Corps personnel, contractors, Federally Recognized Tribes, the SHPO, and other parties involved in planning, reviewing and implementing this Agreement and in accordance with Section 304 of the NHPA (54 U.S.C. § 307103). When information is provided to the Corps by Native American tribes or others who wish to control the dissemination of that information more than described above, the Corps will make a good faith effort to do so, to the extent permissible by law.

XI. DISPUTE RESOLUTION

A. Should any signatory or concurring party to this Agreement object at any time to any actions proposed or the manner in which the terms of this agreement are implemented, the Corps shall consult with such party to resolve the objection. If the Corps determines that such objection cannot be resolved, the Corps will:

1. Forward all documentation relevant to the dispute, including the District's proposed resolution, to the ACHP. The ACHP shall provide the Corps with its advice on the resolution of the objection within thirty (30) days of receiving adequate documentation. Prior to reaching a final decision on the dispute, the Corps shall prepare a written response that takes into account any timely advice or comments regarding the dispute from the ACHP, signatories and concurring parties, and provide them with a copy of this written response. The District will then proceed according to its final decision.

2. If the ACHP does not provide its advice regarding the dispute within the thirty (30) day time period, the Corps may make a final decision on the dispute and proceed accordingly. Prior to reaching such a final decision, the Corps shall prepare a written response that takes into account any timely comments regarding the dispute from the signatories and concurring parties to the Agreement, and provide them and the ACHP with a copy of such written response.

3. The Corps' responsibility to carry out all other actions subject to the terms of this Agreement that are not the subject of the dispute remain unchanged.

B. At any time during implementation of the measures stipulated in this Agreement should an objection pertaining to the Agreement be raised by a Native American Tribe, or a member of the public, the Corps shall notify the Signatory and Concurring Parties and take the objection under consideration, consulting with the objecting party and, should the objecting party request, any of the Signatory and Concurring Parties to this Agreement, for no longer than fifteen (15) calendar days. The Corps shall consider the objection, and in reaching its decision, will consider all comments provided by the other signatories and concurring parties. Within fifteen (15) calendar days following closure of the comment period, the Corps will render a decision regarding the objection and respond to the objecting party. The Corps will promptly notify the other signatories and concurring parties of its decision in writing, including a copy of the response to the objecting party. The Corps' decision regarding resolution of the objection will be final. Following issuance of its final decision, the Corps may authorize the action that was the subject of the dispute to proceed in accordance with the terms of that decision. The Corps' responsibility to carry out all other actions under this Agreement shall remain unchanged.

C. Should any Signatory Party to this Agreement object in writing to the determination of National Register eligibility, the objection will be addressed pursuant to 36 C.F.R. § 800.4(c)(2).

XII. NOTICES

A. All notices, demands, requests, consents, approvals or communications from all parties to this Agreement to other parties to this Agreement shall be either personally delivered, sent by United States Mail, or emailed, and all parties shall be considered in receipt of the materials five (5) calendar days after deposit in the United States mail or the on the day after being emailed.

B. If Signatory and Concurring Parties agree in advance in writing or by email, facsimiles, emails, or copies of signed documents may be used as if they bore original signatures.

C. If Signatory Parties agree, hard copies and/or electronic communications may be used for formal communication amongst themselves for activities in support of **Stipulation I (Time Frames and Review Procedures).**

XIII. AMENDMENTS, NONCOMPLIANCE, AND TERMINATION

A. Amendements: Any Signatory to this Agreement may propose that the Agreement be amended, whereupon the Corps shall consult with the SHPO to consider such amendment. This Agreement may be amended when such an amendment is agreed to in writing by both signatories. The amendment will be effective on the date a copy signed by both signatories is filed with the ACHP.

All attachments to this Agreement, and other instruments prepared pursuant to this agreement including, but not limited to, the maps of the APE may be individually revised or updated through consultation consistent with **Stipulation I (Timeframes and Review Procedures)** and agreement in writing of the Signatories without requiring amendment of this Agreement, unless the Signatories through such consultation decide otherwise. In accordance with **Stipulation VI (Consultations with Tribes and Other Interested Parties)** and **Stipulation VIII (Public Consultation and Public Notice)**, the Federally Recognized Tribes, and other interested parties, will receive amendments to the Project's description, any Phase I or Phase II survey reports and maps of the APE, and HPTPs, as appropriate, and copies of any amendment(s) to the Agreement.

B. Termination: Any signatory to this Agreement may terminate this Agreement. If this Agreement is not amended as provided for in **Stipulation XIII.A. (Amendments)** or if any Signatory proposes termination of this Agreement for other reasons, the Signatory proposing termination shall notify the other Signatories in writing, explain the reasons for proposing termination, and consult with the other Signatory to seek alternatives to termination, within thirty (30) calendar days of the notification.

1. Should such consultation result in an agreement on an alternative to termination, the Signatories shall proceed in accordance with that agreement and amend the Agreement as required.

2. Should such consultation fail, the Signatory proposing termination may terminate this Agreement by promptly notifying the other Signatories and Concurring Parties in writing.

3. Beginning with the date of termination, the Corps shall ensure that until and unless a new agreement is executed for the actions covered by this Agreement, such undertakings shall be reviewed individually in accordance with 36 C.F.R. § 800.4-800.6.

C. Duration: This Agreement shall remain in effect for a period of five (5) years after the date it takes effect and shall automatically expire and have no further force or effect at the end of this five-year period unless it is terminated prior to that time. No later than ninety (90) calendar days prior to the expiration date of the Agreement, the Corps shall initiate consultation to determine if the Agreement should be allowed to expire automatically or whether it should be extended, with or without amendments, as the Signatories may determine. Unless the Signatories unanimously agree through such consultation on an alternative to automatic expiration of this Agreement, this Agreement shall automatically expire and have no further force or effect in accordance with the timetable stipulated herein.

XIV. EFFECTIVE DATE

This Agreement shall take effect on the date that it has been fully executed by the Corps and SHPO.

EXECUTION of this Agreement by the Corps and SHPO and the implementation of its terms evidence that the Corps has taken into account the effects of this undertaking on Historic Properties and afforded the ACHP an opportunity to comment.

PROGRAMMATIC AGREEMENT
BETWEEN
THE U.S. ARMY CORPS OF ENGINEERS AND
THE ALABAMA STATE HISTORIC PRESERVATION OFFICER REGARDING THE MOBILE HARBOR, MOBILE ALABAMA, GENERAL REEVALUATION STUDY

SIGNATORIES TO THIS AGREEMENT:

U.S. ARMY CORPS OF ENGINEERS, MOBILE DISTRICT

BY:____DATE :___________
Jeremy Chapman, Colonel, U.S. Army Corps of Engineers, District Commander

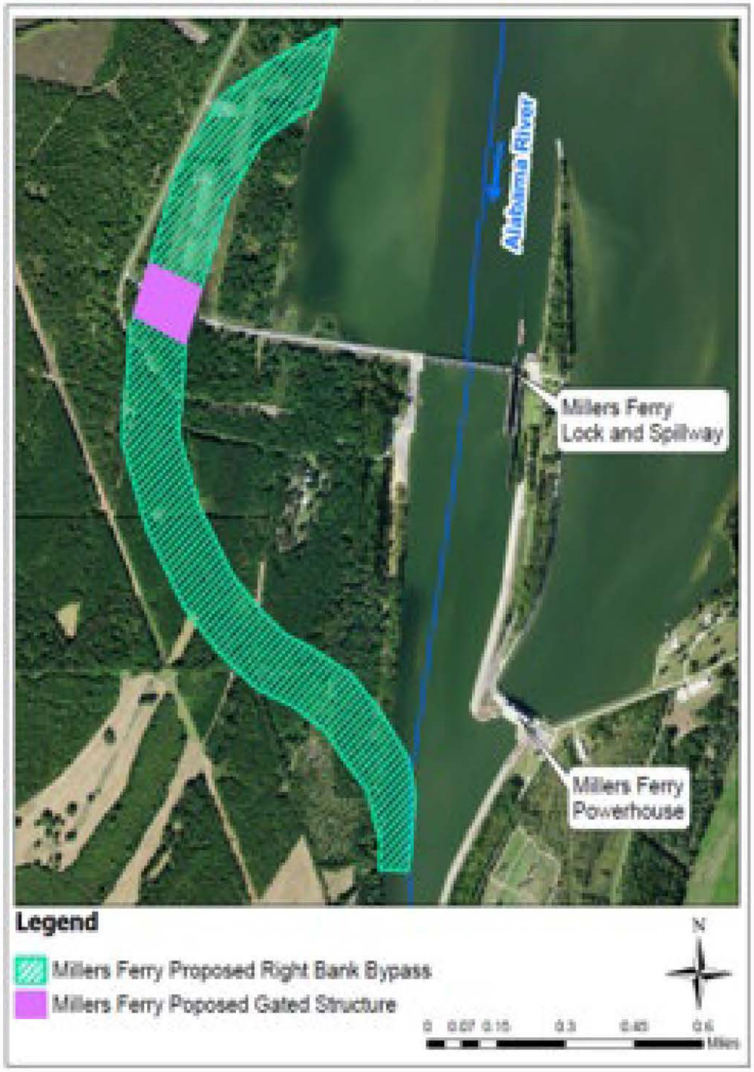
ALABAMA STATE HISTORIC PRESERVATION OFFICER

BY:____DATE:____________
Lee Anne Wofford, Deputy State Historic Preservation Officer

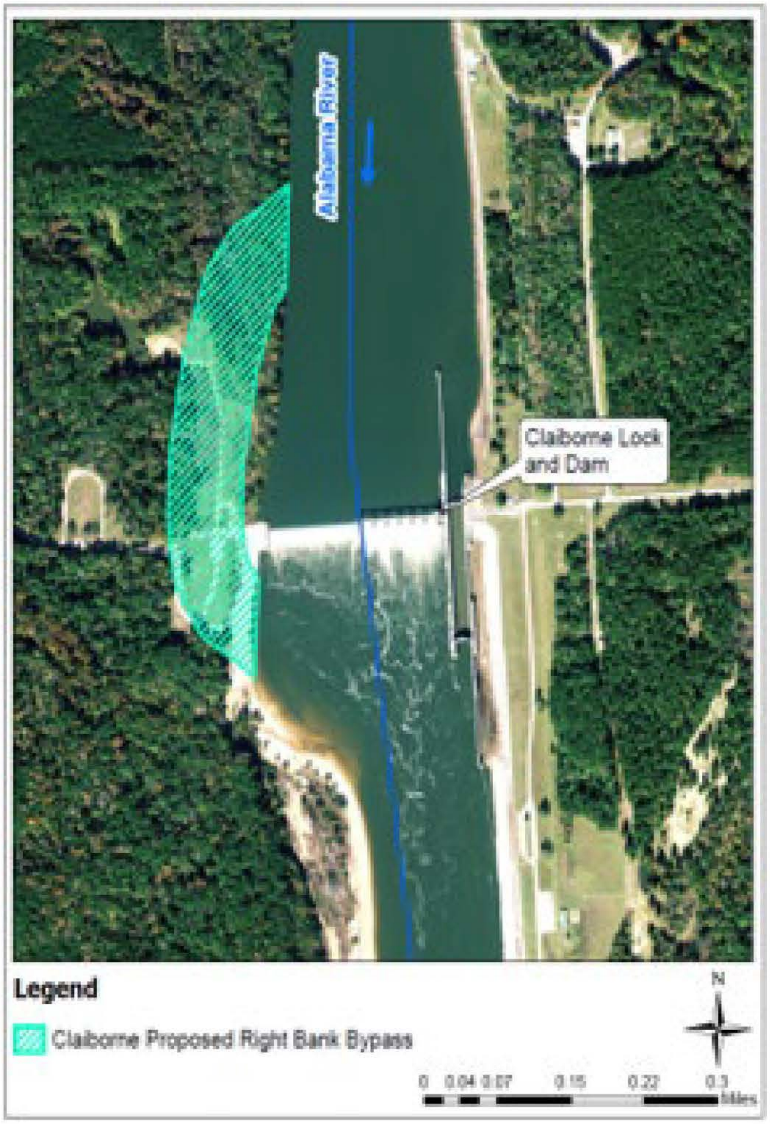
PROGRAMMATIC AGREEMENT
BETWEEN
THE U.S. ARMY CORPS OF ENGINEERS AND
THE ALABAMA STATE HISTORIC PRESERVATION OFFICER REGARDING THE MOBILE HARBOR, MOBILE ALABAMA, GENERAL REEVALUATION STUDY

CONCURRING PARTIES:

Appendix A



Enclosure 1: Millers Ferry natural bypass channel proposed alignment



Enclosure 2: Claiborne natural bypass channel proposed alignment

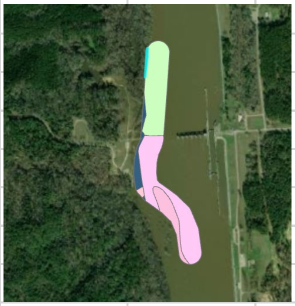
B.1.3. *Clean Water Act*

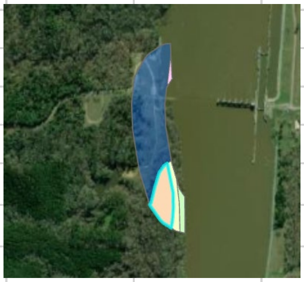
B.1.3.1. *Wetland Mitigation*

B.1.3.1.1. *Evaluation*

A desktop evaluation of impacts to wetlands was conducted by comparing the project footprints with the National Wetland Inventory Layer. Impacts were then converted into potential Wetland Credits. Market research indicated a current market value of wetland credits within the HUC unit as $42,000 a credit

Fish Passage Wetland			
Claiborne			
Rock Weir			
Type	Acerage	Credits	Cost
PFO1A	0.27	0.675	$28,350.00
PFO1C	0.08	0.2	$8,400.00
Total	0.35	0.875	$ 36,750.00
Bypass			
Type	Acerage	Credits	
PFO1C	1.36	3.4	$142,800.00
PF05/6Fh	3.06	7.65	$321,300.00
Total	4.42	11.05	$ 464,100.00





Millers Ferry			
Bypass			
Type	Acerage	Credits	Cost
PF01A	3.11	7.775	$326,550.00
PFO1A	6.53	16.325	$685,650.00
PFO6Fh	1.16	2.9	$121,800.00
PSS1/4A	25.02	62.55	$2,627,100.00
PSS4/1A	0.2	0.5	$21,000.00
PFO1A	19.11	47.775	$2,006,550.00
Total	55.13	137.825	$ 5,788,650.00
	28.75		
Rock Weir			
Type	Acerage	Credits	
PFO1A	0.42	1.05	$44,100.00
PFO1C	1.56	3.9	$163,800.00
PFO1A	0.29	0.725	$30,450.00
Total	2.27	5.675	$ 238,350.00
	0.71		
aproximatly 2.5 credits per			
$42k per credit			

B.1.3.1.2. *Coordination and Mitigation*

Coordination with U.S. Fish & Wildlife Service (USFWS) suggests project may require compensatory mitigation.

A wetlands functional assessment will be performed based upon a refined project alignment to determine final cost of mitigation wetlands, if any.

B.1.3.2. *Water Quality Certification*

State Water Quality Certification will be obtained prior to final report

B.1.3.3. *404(b)1 Evaluation*

SECTION 404(B)(1) EVALUATION FOR
CLAIBORNE AND MILLERS FERRY LOCKS AND DAMS FISH PASSAGE
CLARKE, DALLAS, AND MONROE COUNTIES, AL

I. PROJECT DESCRIPTION:

A. Location. Millers Ferry Lock and Dam and Claiborne Lock and Dam, Monroe, Dallas and Clarke Counties, Alabama. (**Figure B-8** and **Figure B-9**).

B. General Description. As illustrated in **Figure B-10**, the Tentatively Selected Plan would involve the construction of a natural bypass at both Claiborne and Millers Ferry Locks and Dams.

Figure B-1: Study Area

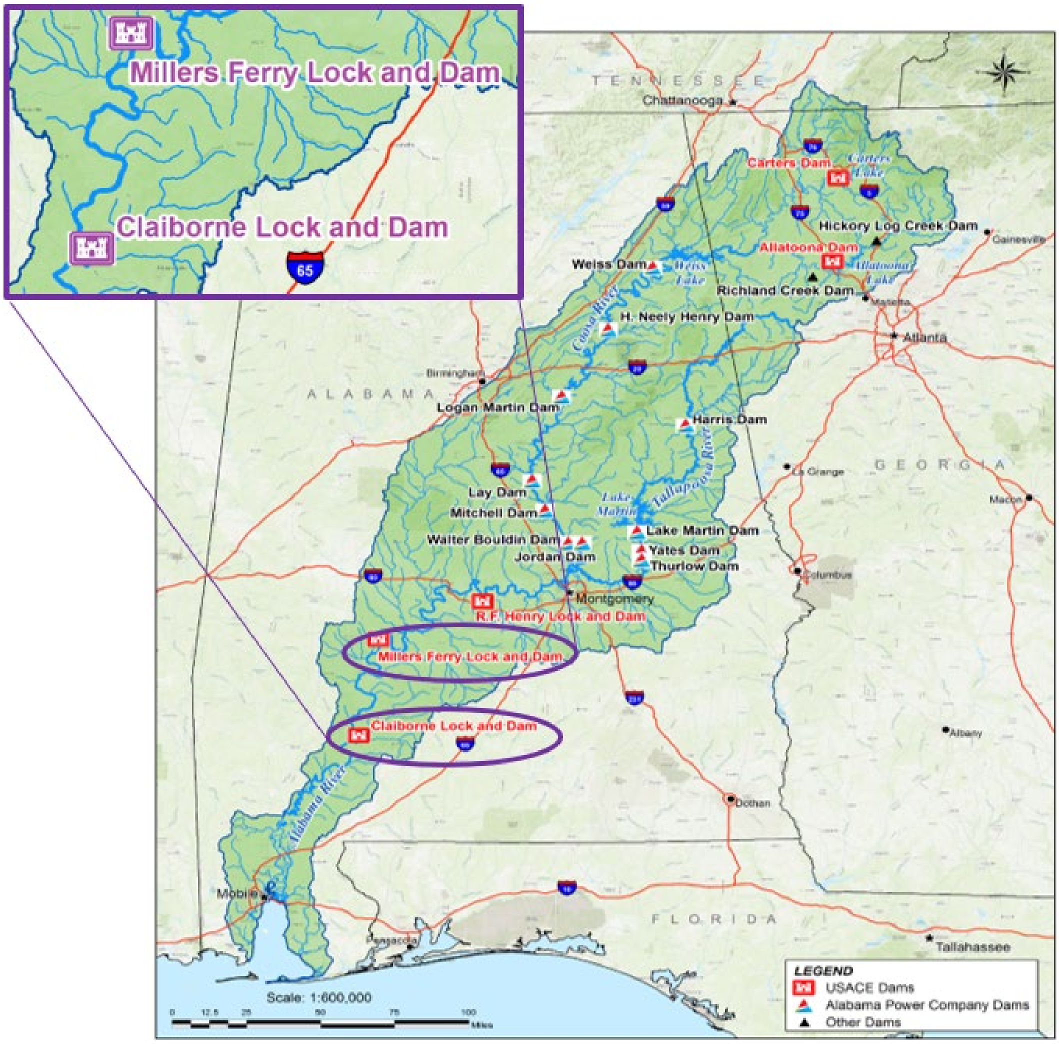


Figure B-2: Conceptual Footprint of Proposed Work

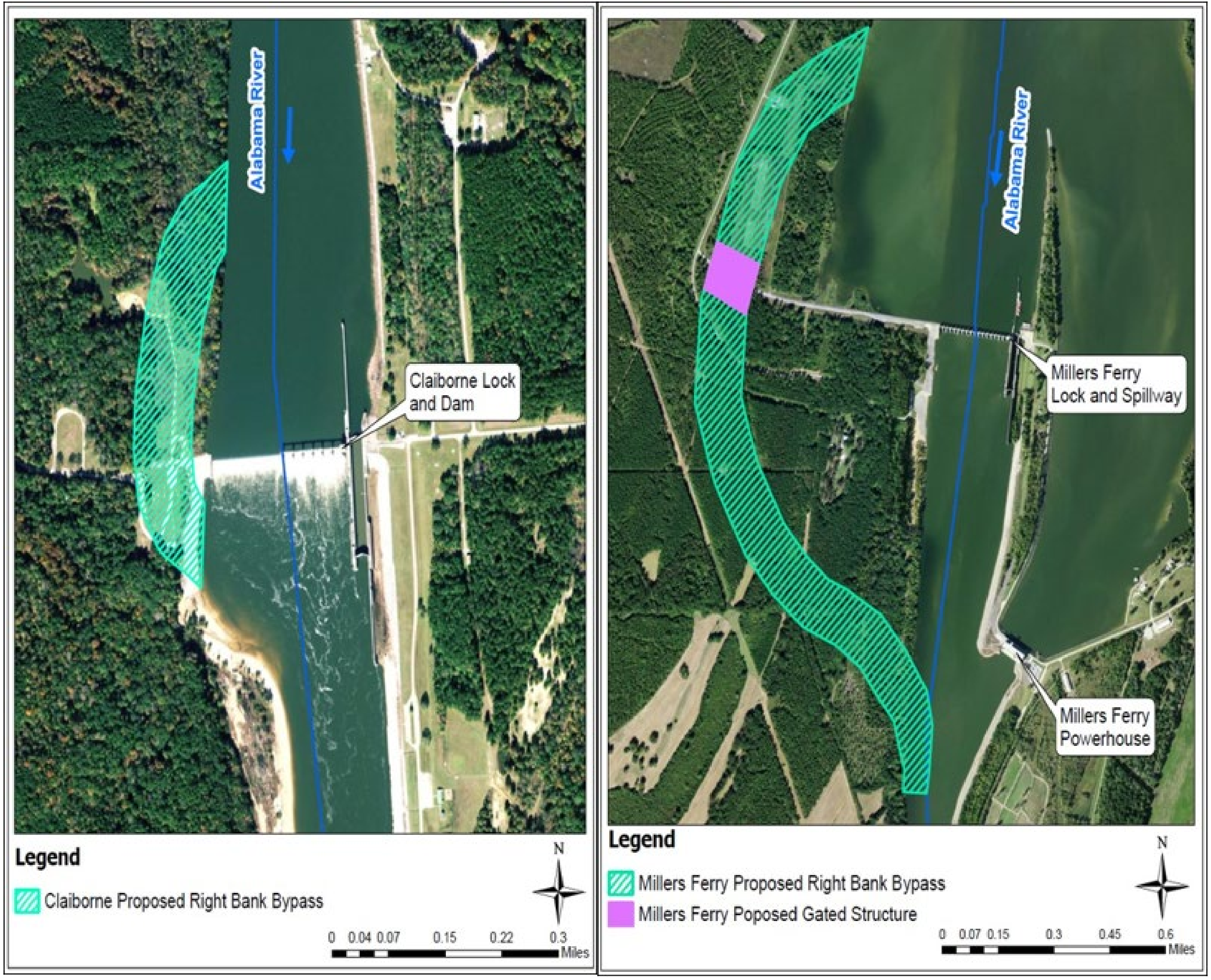
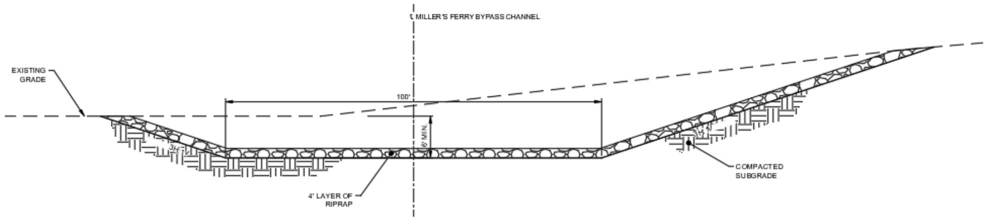
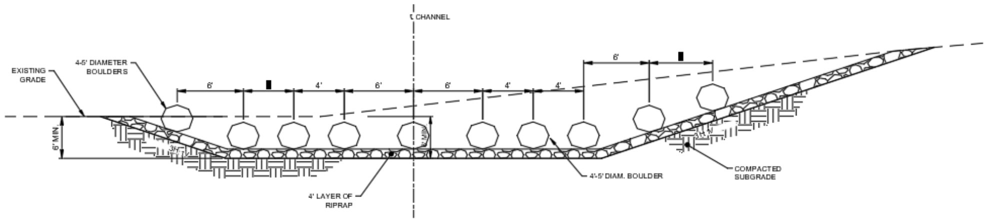


Figure B-3: Conceptual Design of Proposed Work



A5 MILLER'S FERRY BYPASS CHANNEL TYPICAL SECTION STA. 0+00 TO STA. 85+02.31
SCALE:



A5 POOL RIFFLE TYPICAL SECTION
SCALE:

Authority and Purpose.

This study is authorized by Section 216 of the Flood Control Act of 1970 (33 U.S.C. 549a). Section 216 “authorizes investigations for modification of completed projects or their operations when found advisable due to significantly changed physical or economic conditions and for improving the quality of the environment in overall public interest.” [i]

C. General Description of Fill Material.

(1) General Characteristic of Material. Reference **Table B.4-1**.

(2) Quantity of Material. Reference **Table B.4-1** for materials to be dredged.

Table B.4-1: Quantities for Dredged Material

Location	**Total Estimated Quantities (cubic yards)**
Claiborne	**482,000**
Millers Ferry	**2,000,000**

(3) Source of Material. The source of material will be from onsite and an approved location.

D. Description of the Proposed Discharge Site.

(1) Location. The natural bypass channels will be constructed along the riverbank and riverbed with the Alabama River and near the existing facilities.

(2) Size. TBD

(3) Type of Site. The proposed work would be performed along the riverbank and riverbed within the Alabama River.

(4) Type of Habitat. The Alabama River within the Study Area consists of sediment heavy bottom either in the Millers Ferry and Claiborne pools or immediately downstream of the dams and subject to high flows and velocities.

(5) Timing and Duration of Discharge. Duration of construction would take approximately two and a half years to complete.

E. Description of Disposal Method. Material excavated from the natural bypass channels would be disposed of in an approved placement site to be identified during the pre-construction engineering and design phase.

II. Factual Determinations:

A. Physical Substrate Determinations.

(1) Substrate Elevation and Slope. TBD

(2) Sediment Type. TBD

(3) Dredged/Fill Material Movement. TBD

(4) Physical Effects on the Benthos. Benthos would be adversely impacted through direct disturbance to riverbed but this impact would be short-term during the construction phase. Indirect impacts to the immediate vicinity may occur due to increase local turbidity during construction.

(5) Actions Taken to Minimize Impacts (Subpart H). Construction Best Management Practices (BMPs) and an Erosion, Sediment, and Pollution Control Plan (ESPCP) would be implemented to contain potential increased turbidity resulting from the disposal and construction.

B. Water Circulation, Fluctuation, and Salinity Determinations.

(1) Salinity. Not applicable.

(2) Water Chemistry. Water chemistry would not be significantly impacted.

(3) Clarity. Water clarity would be temporarily decreased in the vicinity of the construction activities. These impacts would subside once construction activities are completed.

(4) Color. Color would not be significantly impacted.

(5) Taste. Taste would not be significantly impacted.

(6) Dissolved Gas Levels. Dissolved gas levels would not be significantly affected.

(7) Nutrients. Nutrient levels would not be significantly impacted.

(8) Eutrophication. Eutrophication would not be significantly impacted.

C. Water Circulation, Fluctuation, and Salinity Gradient Determinations:

(1) Current Patterns and Circulation.

(a) Current Patterns and Flow. Minor flow would be diverted into the new natural bypass channels at each site. Overall current patterns and flow would not be significantly impacted.

(b) Velocity. Velocity would not be significantly impacted.

(2) Stratification. There would be no impacts on water stratification.

(3) Hydrologic Regime. There would be no significant impacts on the hydrologic regime.

(4) Normal Water Level Fluctuations. There would be no significant impacts on water level fluctuations.

(5) Salinity Gradients. Not applicable.

D. Suspended Particulate/Turbidity Determinants.

(1) Expected Changes in Suspended Particulate and Turbidity Levels in Vicinity of Disposal Sites. A temporary increase in suspended particulates and turbidity levels would occur in the immediate vicinity of the construction zone. These impacts will subside when the activities are completed.

(2) Effects on Chemical and Physical Properties of the Water Column.

(a) Light Penetration. Increases in suspended solids concentrations will be nominal and temporary. No significant impacts to light penetration are anticipated.

(b) Dissolved Oxygen. Dissolved oxygen will not be significantly impacted.

(c) Toxic Metals and Organics. No significant increases in toxic metals and organics are expected to occur due to the construction activities.

(d) Pathogens. Pathogen levels will not be affected as a result of this project.

(e) Aesthetics. The area would be permanently altered from the construction of the natural bypass channels. Aesthetics would improve with enhanced connectivity of the Alabama River.

(3) Effects on biota.

(a) Primary Production, Photosynthesis. Temporary, localized impacts to primary production or photosynthesis levels may result from turbidity plumes generated by construction activities. These effects would be localized and would subside upon project completion.

(b) Suspension/Filter Feeders. Suspension/filter feeders in the immediate vicinity of the project footprint would be adversely impacted. Relocation would occur to minimize impacts. Species within the surrounding vicinity would not be significantly affected by this action. Increased turbidity will be contained using (BMPs and an ESCP.

(c) Sight Feeders. Sight feeders would vacate the vicinity and may be temporarily affected by increased turbidity. These effects would subside upon completion of the construction activities.

(4) Actions taken to Minimize Impacts (Subpart H). Construction BMPs and an ESPCP would be implemented in order to minimize impacts. Federal and State Agency coordination is ongoing to ensure adverse impacts to federally listed species are minimized.

E. Contaminant Determinations. The sediment within the riverbed is sand and gravel; therefore, the proposed project site would not act as an environmental sink and temporarily increased turbidity would not spread contaminants to the surrounding area.

F. Aquatic Ecosystem and Organism Determinations.

(1) Effects on plankton. There may be temporary effects on plankton in the immediate vicinity of the construction zone due to increased turbidity; however, these effects would be localized and short-term.

(2) Effects on Benthos. Benthic organisms within the construction zone that are sessile would be lost. Benthic organisms would recolonize the area following construction. Adjacent benthic communities would be indirectly impacted from increased turbidity. No significant impacts would result from this project.

(3) Effects on Nekton. Nektonic species are expected to be temporarily affected during construction and may evacuate the immediate vicinity; however, they are expected to return once turbidity levels return to pre-project conditions. No significant impacts are anticipated.

(4) Effects on Aquatic Food Web. This project would pose no significant impacts to the aquatic food web.

(5) Effects on Special Aquatic Sites.

  (a) Sanctuaries and Refuges. No sanctuaries or refuges occur within the proposed project area; therefore, there would be no impacts resulting from this project.

  (b) Wetlands. Approximately 59 acres of wetlands may be impacted. A survey would be conducted to verify and delineate any existing wetlands.

  (c) Mud Flats. No mud flats exist within the project vicinity; therefore, there would be no impacts as a result of the project.

  (d) Vegetated Shallows. No vegetated shallows would be affected by this

  (e) Coral Reefs. Not applicable.

  (f) Riffle and Pool Complexes. No riffle or pool complexes would be affected by this project.

(6) Threatened and Endangered Species. The USACE determined the proposed alternative would have No Effect on the Georgia Rockcress and the Southern Clubshell and May Affect but is not Likely to Adversely Affect the Inflated Heelsplitter and Alabama Sturgeon. The USACE also determined the proposed alternative would not adversely modify critical habitat for the Alabama Sturgeon. Informal Section 7 coordination has been initiated with the U.S. Fish and Wildlife Service.

(7) Other Wildlife. No significant impacts to wildlife are anticipated.

(8) Actions to Minimize Impacts. Impacts to the species will be minimized by Reasonable and Prudent Measures.

G. Proposed Fill Site Determination.

(1) Mixing Zone Determination. This activity does not require a mixing zone determination. The nature of the construction activities and constituent concentrations preclude the need for a mixing zone determination.

(2) Determination of Compliance with Applicable Water Quality Standards. The proposed action will comply with applicable water quality standards as established by the Alabama Department of Environmental Management (ADEM).

(3) Potential Effects on Human Use Characteristics.

(a) Municipal and Private Water Supply. This project would not significantly impact municipal or private water supplies.

(b) Recreation and Commercial Fisheries. Fishing activities at the sites would be altered by construction of this project but ample other sites exist for anglers.

(c) Water Related Recreation. The proposed action would temporarily disrupt water-related recreation at the construction site; however, no negative long-term effects are anticipated from the action. Recreationers would be able to access surrounding areas for enjoyment.

(d) Aesthetics. Aesthetics would be permanently impacted as a result of the proposed action. The proposed alternative would divert a portion of the natural river into a man-made structure designed to pass fish.

(e) Parks, National and Historic Monuments, National Seashores, Wilderness Areas, Research Sites, and Similar Preserves. No parks, national historic monuments, national seashores, wilderness areas, research sites and similar preserves in the vicinity will be adversely impacted as a result of this project.

(f) Other Effects. Not applicable.

(4) Determination of Cumulative Effects on the Aquatic Ecosystem. Significant benefits to aquatic species, including Federally listed fish and mussels, would occur.

(5) Determination of Secondary Effects on the Aquatic Ecosystem. Temporary and localized impacts may occur downstream of the construction activities.

III. Findings of Compliance or Noncompliance with the Restrictions on Discharge.

A. No significant adaptations of the guidelines were made relative to this evaluation.

B. The proposed discharge represents the least environmentally damaging practicable alternative that would accomplish the project objectives.

C. Based on the nature of the fill material, construction activities would be in compliance with applicable state Water Quality Standards. Furthermore, Water Quality Certification will be obtained from the State of Alabama prior to construction activities.

D. The fill material would not violate the Toxic Effluent Standard of Section 307 of the Clean Water Act.

E. The placement of fill material would not jeopardize the continued existence of any Federally listed endangered or threatened species or their critical habitat.

F. The proposed discharge of fill material would not contribute to significant degradation of waters of the United States. Nor would it result in significant adverse effects on human health and welfare, including municipal and private water supplies, recreation and commercial fishing; life stages of organisms dependent upon the aquatic ecosystem; ecosystem diversity, productivity and stability; or recreational, aesthetic or economic values.

G. Appropriate and practicable steps to minimize potential adverse impacts of the discharge on the aquatic ecosystem include:

   (1) Locations, times and duration of the project have been selected to minimize potential adverse impacts to the aquatic ecosystem.

   (2) An interdisciplinary team has evaluated sites, and project designs have been altered per their recommendations.

DATE:______________________________ ______________________________

JEREMY J CHAPMAN
Colonel, U.S. Army
District Commander

B.1.4. *Endangered Species Act*

B.1.4.1. *Biological Assessment*

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CLAIBORNE AND MILLERS FERRY LOCKS AND DAMS FISH PASSAGE STUDY

BIOLOGICAL ANALYSIS

Prepared using IPaC

Generated by Terry Rickey (terry.w.rickey@usace.army.mil)

March 29, 2023

The purpose of this document is to assess the effects of the proposed project and determine whether the project may affect any federally threatened, endangered, proposed, or candidate species. If appropriate for the project, this document may be used as a biological assessment (BA), as it is prepared in accordance with legal requirements set forth under Section 7 of the Endangered Species Act (16 U.S.C. 1536 (c)).

In this document, any data provided by U.S. Fish and Wildlife Service is based on data as of February 7, 2023.

Prepared using IPaC version 6.89.0-rc6

CLAIBORNE AND MILLERS FERRY LOCKS AND DAMS FISH PASSAGE STUDY BIOLOGICAL ASSESSMENT

TABLE OF CONTENTS

1 DESCRIPTION OF THE ACTION

1.1 PROJECT NAME

Claiborne and Millers Ferry Locks and Dams Fish Passage Study

1.2 EXECUTIVE SUMMARY

The purpose of the study is to evaluate Federal interest in establishing fish passage through restoring connectivity in the Alabama and Cahaba Rivers. The project directly addresses the loss of habitat connectivity for fish movement in the river system. The Tentatively Selected Plan includes the construction of a natural bypass channel at both Claiborne and Millers Ferry Locks and Dams. Both bypass channels would be constructed along the right descending bank of the Alabama River with natural materials such as soil, riprap embankment protection, and stone weirs to create riffle pools.

1.3 EFFECT DETERMINATION SUMMARY

SPECIES (COMMON NAME) OR CRITICAL HABITAT	**SCIENTIFIC NAME**	**LISTING STATUS**	**PRESENT IN ACTION AREA**	**EFFECT DETERMINATION**
Alabama Pearlshell*	Margaritifera marrianae	Endangered	No	NE
Alabama Sturgeon	Scaphirhynchus suttkusi	Endangered	Yes	NLAA
Alligator Snapping Turtle	Macrochelys temminckii	Proposed Threatened	Excluded from analysis	Excluded from analysis
Georgia Rockcress	Arabis georgiana	Threatened	Yes	NLAA
Gulf Sturgeon	Acipenser oxyrinchus (=oxyrhynchus) desotoi	Threatened	Yes	NLAA
Inflated Heelsplitter	Potamilus inflatus	Threatened	Yes	NLAA
Monarch Butterfly	Danaus plexippus	Candidate	Excluded from analysis	Excluded from analysis
Orangenacre Mucket*	Hamiota perovalis	Threatened	No	NE
Southern Clubshell	Pleurobema decisum	Endangered	Yes	NLAA
Tulotoma Snail	Tulotoma magnifica	Threatened	Yes	NLAA
Alabama Sturgeon critical habitat	Scaphirhynchus suttkusi	Final	No	NE

***** This species or critical habitat is included in the biological analysis due to the Action Area being larger than the original Project Area on which the Official Species List was based.

1.4 PROJECT DESCRIPTION

1.4.1 LOCATION

LOCATION

Monroe and Wilcox counties, Alabama

1.4.2 DESCRIPTION OF PROJECT HABITAT

The Mobile-Tensaw Delta and Cahaba River are nationally recognized, significantly diverse ecosystems. Alabama ranks one of the highest in the continental U.S. for aquatic diversity in both total and endemic populations. Alabama is home to 93 native reptiles (Reptiles 2020) and 450 fish species, which is, “the most found in any other state or province in North America” (Mettee, 2016). Additionally, Encyclopedia of Alabama states: “Alabama is home to the most diverse fauna of freshwater mussels in all of North America, with 180 species” (Garner, 2013). Boshung and Mayden (2004) documented 185 fish species historically occurring within the Alabama River drainage including 161 native species, 2 euryhaline species, 4 marine species, and 18 introduced species. Williams et al. (2008) document 51 mussel species historically occurring within the Alabama River drainage area.

The project area consists of two existing lock and dam projects on the lower Alabama River: Claiborne and Millers Ferry. These structures impede migratory fish from reaching historic spawning habitat and limits freshwater mussel spatial distribution.

Millers Ferry Lock and dam is located in the Gulf Coastal Plain physiographic province. The topography in the area is characterized by rolling hills and prairie land. Claiborne Lock and Dam site is within the Southern Red Hills Divisions of the Gulf Coastal Plain physiographic province. Existing habitat within the study area ranges from heavily to moderately disturbed areas. The surrounding habitat includes forested riparian settings.

1.4.3 PROJECT PROPONENT INFORMATION

Provide information regarding who is proposing to conduct the project, and their contact information. Please provide details on whether there is a Federal nexus.

REQUESTING AGENCY

Department of Defense

Army Corps of Engineers

FULL NAME

Terry Rickey

STREET ADDRESS

109 St Joseph St

CITY	STATE	ZIP
Mobile	AL	36602

PHONE NUMBER	E-MAIL ADDRESS
2516943857	terry.w.rickey@usace.army.mil

LEAD AGENCY

Lead agency is the same as requesting agency

1.4.4 PROJECT PURPOSE

The purpose of this project is evaluate Federal interest in establishing fish passage and restoring connectivity in the Alabama and Cahaba Rivers. The project directly addresses the loss of habitat connectivity for fish movement in the river system. Individually, these rivers are nationally significant, but holistically may be in the top 5 in the U.S. for biodiversity. The restoration of connectivity is widely recognized as critical to maintaining biodiversity and ecosystem functions. The Tentatively Selected Plan includes the construction of a natural bypass channel at both Claiborne and Millers Ferry Locks and Dams. Both bypass channels would be constructed along the right descending bank of the Alabama River with natural materials such as soil, riprap embankment protection, and stone weirs to create riffle pools. Millers Ferry Natural Bypass Channel includes control gate structures and two vehicular bridges.

1.4.5 PROJECT TYPE AND DECONSTRUCTION

This project is a maintain concrete dam, field surveys and rechannelization project.

1.4.5.1 PROJECT MAP

LEGEND

🟦 Project footprint

▨ Bank Protection: Bank protection (structure)

🟨 Bridge: Construct bridge parapets, finish grading, fuel and maintain vehicles and equipment on-site, geomorphic, hydrology, hydraulics, and sediment transport analysis field work, geotechnical investigation, grading, staging area construction, topographic surveys, bridge structure (structure)

🟪 Claiborne Bypass: Channelized stream section (structure)

🟦 Layer 5: Addition of fill, barge staging, biological survey (freshwater), biological surveys (terrestrial), construct abutment walls, construct bridge parapets, construct cofferdam, construct piles, cultural resource surveys, debris removal, excavate soils/sediments, finish grading, fuel and maintain vehicles and equipment on-site, geomorphic, hydrology, hydraulics, and sediment transport analysis field work, geotechnical investigation, grading, install & anchor bank protection, install slide gate, prepare the project site (terrestrial), remove temporary diversion dam, restore vegetation, staging area construction, topographic surveys, vegetation removal, bank protection (structure), bridge structure (structure), channelized stream section (structure)

🟩 Millers Ferry Bypass: Construct abutment walls, construct piles, debris removal, excavate soils/sediments, install & anchor bank protection, install slide gate, prepare the project site (terrestrial), vegetation removal, channelized stream section (structure)

1.4.5.2 BANK PROTECTION

STRUCTURE COMPLETION DATE

Unspecified

REMOVAL/DECOMMISSION DATE (IF APPLICABLE)

Not applicable

STRESSORS

- Change in channel morphology

DESCRIPTION

The channel that is constructed for fish passage will have rip rap or another type of protective measure to prevent erosion of the channel.

1.4.5.3 BRIDGE STRUCTURE

STRUCTURE COMPLETION DATE

Unspecified

REMOVAL/DECOMMISSION DATE (IF APPLICABLE)

Not applicable

STRESSORS

- Increase in contaminants
- Increase in vehicle traffic

DESCRIPTION

At Millers Ferry Lock and Dam, there will be two bridges constructed. One will allow for project personnel to be able to access the west side of the dam. The other bridge will be to allow public to cross the project to be able to access the river or property between the fish passage and river. At Claiborne Lock and Dam, one bridge will be needed for project personnel to access the west portion of the project. At this time, it is unknown if the bridge at Claiborne will be a pedestrian or a vehicular bridge. Both bridges at Millers Ferry will need to be vehicular.

The vehicle bridge crossing to the spillway at Millers ferry will consist of a 3-span bridge, with a total bridge length of +/- 76ft. The superstructure for the bridges would be steel girders and beams supporting steel grating. Bridge girders shall be fixed at one end and free at the other to allow for expansion and contraction. The substructure would consist of pier walls and concrete abutments. It is anticipated the substructure will be pile supported.

1.4.5.4 CHANNELIZED STREAM SECTION

STRUCTURE COMPLETION DATE
Unspecified

REMOVAL/DECOMMISSION DATE (IF APPLICABLE)
Not applicable

STRESSORS

- Change in channel morphology
- Increase in water velocity

DESCRIPTION
The channel will be excavated to a depth to be determined in more detailed design. At Millers Ferry the natural bypass channel will start above the dam at elevation 75 ft and end below the dam at elevation 31 ft descending at a 0.005 ft/ft slope for 8500 feet. At Claiborne the natural bypass channel will start above the dam at an elevation of 33 feet and end below the dam at an elevation of 3 feet descending at a 0.013 ft/ft slope over 2100 feet. Average channel velocities at Millers Ferry and Claiborne are 4.2 ft/s and 4.0 ft/s respectively.

1.4.5.5 ADDITION OF FILL

ACTIVITY START DATE
Unspecified

ACTIVITY END DATE
Unspecified

STRESSORS

- Decrease in vegetation
- Increase in contaminants
- Change in topography
- Increase in soil compaction
- Increase in noise
- Increase in soil disturbance
- Increase in vehicle traffic

DESCRIPTION
Excavated materials will be used as appropriate to create the needed geometry for the project.

1.4.5.6 BARGE STAGING

ACTIVITY START DATE

Unspecified

ACTIVITY END DATE

Unspecified

STRESSORS

This activity is not expected to have any impact on the environment.

DESCRIPTION

Barges will be staged around the construction area in water.

1.4.5.7 BIOLOGICAL SURVEY (FRESHWATER)

ACTIVITY START DATE

Unspecified

ACTIVITY END DATE

Unspecified

STRESSORS

- Increase in human presence
- Increase in noise

DESCRIPTION

Biological surveys will be evaluate the baseline for the monitoring adaptive management plan.

1.4.5.8 BIOLOGICAL SURVEYS (TERRESTRIAL)

ACTIVITY START DATE
Unspecified

ACTIVITY END DATE
Unspecified

STRESSORS

- Increase in human presence
- Increase in noise

DESCRIPTION
Biological surveys will be completed for timber sales, planting replacement analysis, and other project functions.

1.4.5.9 CONSTRUCT ABUTMENT WALLS

ACTIVITY START DATE
Unspecified

ACTIVITY END DATE
Unspecified

STRESSORS

- Decrease in vegetation
- Change in streamflow
- Increase in soil compaction
- Increase in noise
- Increase in soil disturbance

DESCRIPTION
Abutment walls will be constructed in the Millers Ferry natural bypass channel as a structural base for the bridging and slide gate structure. These will be constructed "in the dry" before flow is put in the channel.

1.4.5.10 CONSTRUCT BRIDGE PARAPETS

ACTIVITY START DATE
Unspecified

ACTIVITY END DATE
Unspecified

STRESSORS
- Decrease in vegetation
- Increase in soil compaction
- Increase in noise
- Increase in soil disturbance

DESCRIPTION
Bridge parapets will be constructed for the three bridges associated with this project

1.4.5.11 CONSTRUCT COFFERDAM

ACTIVITY START DATE
Unspecified

ACTIVITY END DATE
Unspecified

STRESSORS
- Change in channel morphology
- Change in streamflow
- Increase in human presence
- Increase in noise
- Increase in vehicle traffic

DESCRIPTION
Cofferdams will be constructed to separate the water bodies from the construction areas

1.4.5.12 CONSTRUCT PILES

ACTIVITY START DATE
Unspecified

ACTIVITY END DATE
Unspecified

STRESSORS

- Decrease in vegetation
- Increase in soil moisture/saturation
- Change in topography
- Increase in soil compaction
- Increase in sedimentation rates
- Increase in human presence
- Increase in noise
- Increase in soil disturbance
- Increase in vehicle traffic

DESCRIPTION
Two to three piles will be constructed in the natural bypass channel to support the bridging and slide gate structures.

1.4.5.13 CULTURAL RESOURCE SURVEYS

ACTIVITY START DATE
Unspecified

ACTIVITY END DATE
Unspecified

STRESSORS

- Change in vegetation structure
- Decrease in vegetation
- Increase in human presence
- Increase in soil disturbance

DESCRIPTION
Cultural resources surveys will be completed along the project footprint.

1.4.5.14 DEBRIS REMOVAL

ACTIVITY START DATE
Unspecified

ACTIVITY END DATE
Unspecified

STRESSORS

- Decrease in vegetation
- Increase in contaminants
- Increase in soil compaction
- Increase in human presence
- Increase in noise
- Increase in vehicle traffic

DESCRIPTION
Debris will be removed from the project area

1.4.5.15 EXCAVATE SOILS/SEDIMENTS

ACTIVITY START DATE
Unspecified

ACTIVITY END DATE
Unspecified

STRESSORS

- Decrease in vegetation
- Increase in contaminants
- Increase in soil moisture/saturation
- Change in topography
- Increase in dust
- Increase in soil compaction
- Increase in erosion
- Increase in sedimentation rates
- Increase in human presence
- Increase in noise
- Increase in soil disturbance
- Increase in vehicle traffic

DESCRIPTION
At Millers Ferry 2 million cubic yards of material will be excavated. At Claiborne 482 thousand cubic yards of material will be excavated.

1.4.5.16 FINISH GRADING

ACTIVITY START DATE
Unspecified

ACTIVITY END DATE
Unspecified

STRESSORS

- Decrease in vegetation
- Increase in contaminants
- Change in topography
- Increase in dust
- Increase in soil compaction
- Increase in human presence
- Increase in noise
- Increase in soil disturbance

DESCRIPTION
Finish grading we occur after the excavation and rough grading of the project

1.4.5.17 FUEL AND MAINTAIN VEHICLES AND EQUIPMENT ON-SITE

ACTIVITY START DATE
Unspecified

ACTIVITY END DATE
Unspecified

STRESSORS

- Increase in contaminants
- Increase in human presence
- Increase in noise

DESCRIPTION
Construction equipment will be maintained and fueled every morning, an appropriate staging area will be selected.

1.4.5.18 GEOMORPHIC, HYDROLOGY, HYDRAULICS, AND SEDIMENT TRANSPORT ANALYSIS FIELD WORK

ACTIVITY START DATE

Unspecified

ACTIVITY END DATE

Unspecified

STRESSORS

- Increase in dust
- Increase in soil compaction
- Increase in noise

DESCRIPTION

The current need for geotechnical and hydrological field work is unknown, but may include geotechnical core sampling, stream gauging, and further field studies.

1.4.5.19 GEOTECHNICAL INVESTIGATION

ACTIVITY START DATE

Unspecified

ACTIVITY END DATE

Unspecified

STRESSORS

- Change in vegetation structure
- Decrease in vegetation
- Increase in human presence
- Increase in noise
- Increase in vehicle traffic

DESCRIPTION

It is planned to do further geotechnical investigation within the project footprints to determine soil types and if rock will be encountered. The timeframe of this investigation is currently unknown.

1.4.5.20 GRADING

ACTIVITY START DATE
Unspecified

ACTIVITY END DATE
Unspecified

STRESSORS

- Decrease in vegetation
- Change in topography
- Increase in soil compaction
- Increase in noise
- Increase in soil disturbance

DESCRIPTION
The area will be graded to create channels with a 3:1 horizontal to vertical slope.

1.4.5.21 INSTALL & ANCHOR BANK PROTECTION

ACTIVITY START DATE
Unspecified

ACTIVITY END DATE
Unspecified

STRESSORS

- Decrease in vegetation
- Increase in water turbidity
- Increase in soil compaction
- Increase in human presence
- Increase in noise
- Increase in soil disturbance

DESCRIPTION
The channel that is constructed for fish passage will have rip rap or another type of protective measure to prevent erosion of the channel.

1.4.5.22 INSTALL SLIDE GATE

ACTIVITY START DATE

Unspecified

ACTIVITY END DATE

Unspecified

STRESSORS

- Decrease in vegetation
- Increase in streams
- Increase in soil compaction
- Increase in noise
- Increase in soil disturbance

DESCRIPTION

Steel fabricated sluice gates constructed to withstand maximum hydrostatic pressures at flood stage and debris impact will be used to control the flow of water in the bypass channel at Millers Ferry. The gates will be mechanically operated from an offsite location. Remote operation design details will be developed during the pre-construction, engineering, and design phase.

1.4.5.23 PREPARE THE PROJECT SITE (TERRESTRIAL)

ACTIVITY START DATE
Unspecified

ACTIVITY END DATE
Unspecified

STRESSORS

- Change in vegetation structure
- Decrease in vegetation
- Increase in fuel load
- Change in channel morphology
- Decrease in soil stability
- Increase in illuminance level
- Increase in soil moisture/saturation
- Increase in water turbidity
- Increase in impervious surfaces
- Increase in dust
- Increase in soil compaction
- Change in surface runoff
- Increase in erosion
- Increase in sedimentation rates
- Increase in human presence
- Increase in noise
- Increase in soil disturbance
- Increase in vehicle traffic

DESCRIPTION
All vegetation, timber, and debris we be removed from the bypass channel footprint and properly disposed of.

1.4.5.24 REMOVE TEMPORARY DIVERSION DAM

ACTIVITY START DATE
Unspecified

ACTIVITY END DATE
Unspecified

STRESSORS

- Increase in water turbidity
- Increase in human presence
- Increase in noise

DESCRIPTION
Installed cofferdams will be removed after construction.

1.4.5.25 RESTORE VEGETATION

ACTIVITY START DATE
Unspecified

ACTIVITY END DATE
Unspecified

STRESSORS

- Increase in vegetation
- Increase in nutrients
- Increase in human presence
- Increase in noise
- Increase in soil disturbance
- Increase in vehicle traffic

DESCRIPTION
Appropriate vegetation will be planted after construction of the bypass channel to restore the natural biodiversity and stabilize new structures.

1.4.5.26 STAGING AREA CONSTRUCTION

ACTIVITY START DATE
Unspecified

ACTIVITY END DATE
Unspecified

STRESSORS

- Change in vegetation structure
- Decrease in vegetation
- Increase in fuel load
- Increase in contaminants
- Increase in soil compaction
- Increase in human presence
- Increase in noise
- Increase in vehicle traffic

DESCRIPTION
Depending on materials needed, at both locations a Conex box or other lockable storage unit will be placed at a minimum.

1.4.5.27 TOPOGRAPHIC SURVEYS

ACTIVITY START DATE
Unspecified

ACTIVITY END DATE
Unspecified

STRESSORS

- Increase in human presence
- Increase in noise

DESCRIPTION
A topographical survey will be preformed after real estate acquisition and again post-construction.

1.4.5.28 VEGETATION REMOVAL

ACTIVITY START DATE
Unspecified

ACTIVITY END DATE
Unspecified

STRESSORS

- Change in vegetation structure
- Decrease in vegetation
- Increase in fuel load
- Increase in contaminants
- Decrease in soil stability
- Increase in nutrients
- Increase in water turbidity
- Increase in dust
- Increase in soil compaction
- Increase in surface runoff
- Increase in human presence
- Increase in noise
- Increase in soil disturbance
- Increase in vehicle traffic

DESCRIPTION
Vegetation will need to be removed in the area that the fish passage will be constructed. Once all of the excavation and rock placement is complete, the area will be reseeded.

1.4.6 ANTICIPATED ENVIRONMENTAL STRESSORS

Describe the anticipated effects of your proposed project on the aspects of the land, air and water that will occur due to the activities above. These should be based on the activity deconstructions done in the previous section and will be used to inform the action area.

1.4.6.1 ANIMAL FEATURES

Individuals from the Animalia kingdom, such as raptors, mollusks, and fish. This feature also includes byproducts and remains of animals (e.g., carrion, feathers, scat, etc.), and animal-related structures (e.g., dens, nests, hibernacula, etc.).

1.4.6.2 PLANT FEATURES

Individuals from the Plantae kingdom, such as trees, shrubs, herbs, grasses, ferns, and mosses. This feature also includes products of plants (e.g., nectar, flowers, seeds, etc.).

1.4.6.2.1 CHANGE IN VEGETATION STRUCTURE

ANTICIPATED MAGNITUDE

A large change in vegetation structure will occur along the entire project footprint as all vegetation will be removed. Plants similar to the existing biota will be replanted post-construction as appropriate.

STRESSOR LOCATION

LEGEND

🟦 Project footprint

🟨 Stressor location

CONSERVATION MEASURES

No conservation measures for this stressor

STRUCTURES AND ACTIVITIES

- Staging area construction
- Geotechnical investigation
- Vegetation removal
- Prepare the project site (terrestrial)
- Cultural resource surveys

1.4.6.2.2 DECREASE IN VEGETATION

ANTICIPATED MAGNITUDE

Vegetation will be removed from 165 acres at Millers Ferry and 30 acres at Claiborne.

STRESSOR LOCATION

LEGEND

🟦 Project footprint

🟨 Stressor location

CONSERVATION MEASURES

No conservation measures for this stressor

STRUCTURES AND ACTIVITIES

- Staging area construction
- Excavate soils/sediments
- Debris removal
- Geotechnical investigation
- Vegetation removal
- Construct bridge parapets
- Prepare the project site (terrestrial)
- Install & anchor bank protection
- Grading
- Construct piles
- Finish grading
- Construct abutment walls
- Install slide gate
- Addition of fill
- Cultural resource surveys

1.4.6.2.3 INCREASE IN FUEL LOAD

ANTICIPATED MAGNITUDE

Downed timber will increases the fire fuel load in the project area.

STRESSOR LOCATION

LEGEND

🟦 Project footprint

🟨 Stressor location

CONSERVATION MEASURES

- Remove fuel sources

STRUCTURES AND ACTIVITIES

- Staging area construction
- Vegetation removal
- Prepare the project site (terrestrial)

1.4.6.2.4 INCREASE IN VEGETATION

ANTICIPATED MAGNITUDE

Increase in vegetation will occur after the project is completed and will restore some native biota.

STRESSOR LOCATION

LEGEND

🟦 Project footprint

🟨 Stressor location

CONSERVATION MEASURES

No conservation measures for this stressor

STRUCTURES AND ACTIVITIES

- Restore vegetation

1.4.6.3 AQUATIC FEATURES

Bodies of water on the landscape, such as streams, rivers, ponds, wetlands, etc., and their physical characteristics (e.g., depth, current, etc.). This feature includes the groundwater and its characteristics. Water quality attributes (e.g., turbidity, pH, temperature, DO, nutrients, etc.) should be placed in the Environmental Quality Features.

1.4.6.3.1 CHANGE IN CHANNEL MORPHOLOGY

ANTICIPATED MAGNITUDE

At each bypass channel approximately 5,000 cubic feet a second of flow will now travel through the natural bypass channel instead of through the current spillway structures or the Millers Ferry Powerhouse.

STRESSOR LOCATION

LEGEND

🟦 Project footprint

🟨 Stressor location

CONSERVATION MEASURES

No conservation measures for this stressor

STRUCTURES AND ACTIVITIES

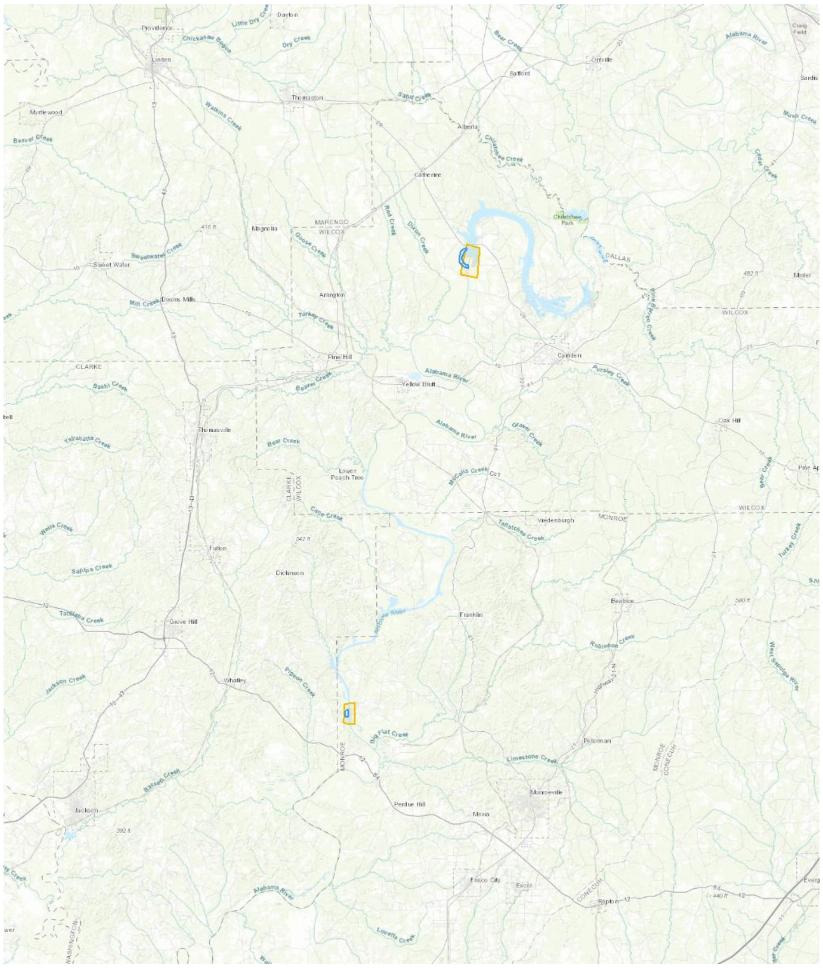
- Prepare the project site (terrestrial)
- Channelized stream section
- Bank protection
- Construct cofferdam

1.4.6.3.2 CHANGE IN STREAMFLOW

ANTICIPATED MAGNITUDE

At each bypass channel approximately 5,000 cubic feet a second of flow will now travel through the natural bypass channel instead of through the current spillway structures or the Millers Ferry Powerhouse.

STRESSOR LOCATION



LEGEND

🟦 Project footprint

🟨 Stressor location

CONSERVATION MEASURES

No conservation measures for this stressor

STRUCTURES AND ACTIVITIES

- Construct abutment walls
- Construct cofferdam

1.4.6.3.3 INCREASE IN STREAMS

ANTICIPATED MAGNITUDE

Each bypass channel construction will create a new stream.

STRESSOR LOCATION

LEGEND

🟦 Project footprint

🟨 Stressor location

CONSERVATION MEASURES

No conservation measures for this stressor

STRUCTURES AND ACTIVITIES

- Install slide gate

1.4.6.3.4 INCREASE IN WATER VELOCITY

ANTICIPATED MAGNITUDE

This stressor is not expected to occur; the following explanation has been provided:

After construction flows through the bypass channel can be moderated with the slide gate minimizing increases in water velocities.

CONSERVATION MEASURES

- Control of flow

STRUCTURES AND ACTIVITIES

- Channelized stream section

1.4.6.4 CHEMICALS / CONTAMINANTS

Substances that pollute, spoil, or poison the environment (e.g., herbicides, heavy metals, oil, etc.).

1.4.6.4.1 INCREASE IN CONTAMINANTS

ANTICIPATED MAGNITUDE

There will be a small increase in contaminates from increased runoff and traffic in the area.

STRESSOR LOCATION

LEGEND

🟦 Project footprint

🟨 Stressor location

CONSERVATION MEASURES

- Seeding
- Matting

STRUCTURES AND ACTIVITIES

- Staging area construction
- Excavate soils/sediments
- Debris removal
- Fuel and maintain vehicles and equipment on-site
- Vegetation removal
- Finish grading
- Bridge structure
- Addition of fill

1.4.6.5 ENVIRONMENTAL QUALITY FEATURES

Abiotic attributes of the landscape (e.g., temperature, moisture, slope, aspect, etc.).

1.4.6.5.1 DECREASE IN SOIL STABILITY

ANTICIPATED MAGNITUDE

This stressor is not expected to occur; the following explanation has been provided:

No unstable soils will be left after the construction of the project

CONSERVATION MEASURES

- Amoring
- Seeding

STRUCTURES AND ACTIVITIES

- Vegetation removal
- Prepare the project site (terrestrial)

1.4.6.5.2 INCREASE IN ILLUMINANCE LEVEL

ANTICIPATED MAGNITUDE

After project construction, the bypass channels will likely be lit for safety at night.

STRESSOR LOCATION

LEGEND

🟦 Project footprint

🟨 Stressor location

CONSERVATION MEASURES

No conservation measures for this stressor

STRUCTURES AND ACTIVITIES

- Prepare the project site (terrestrial)

1.4.6.5.3 INCREASE IN NUTRIENTS

ANTICIPATED MAGNITUDE

An increase in nutrients is expected as a result of increased impervious surfaces created by construction, this will be minimized by decreasing runoff through seeding, mulching, and matting

STRESSOR LOCATION

LEGEND

🟦 Project footprint

🟨 Stressor location

CONSERVATION MEASURES

- Seeding
- Matting

STRUCTURES AND ACTIVITIES

- Vegetation removal
- Restore vegetation

1.4.6.5.4 INCREASE IN SOIL MOISTURE/SATURATION

ANTICIPATED MAGNITUDE

A minor increases in soil moisture will occur as the top vegetative is removed during the grading process.

STRESSOR LOCATION

LEGEND

🟦 Project footprint

🟨 Stressor location

CONSERVATION MEASURES

No conservation measures for this stressor

STRUCTURES AND ACTIVITIES

- Excavate soils/sediments
- Prepare the project site (terrestrial)
- Construct piles

1.4.6.5.5 INCREASE IN WATER TURBIDITY

ANTICIPATED MAGNITUDE

A minor increase in turbidity is expected as a result of this project. During construction work near the streambank, increases in bare soil, and increases in impervious surfaces will contribute to increased turbidity.

STRESSOR LOCATION

LEGEND

🟦 Project footprint

🟨 Stressor location

CONSERVATION MEASURES

- Amoring
- Seeding
- Matting
- Mulching

STRUCTURES AND ACTIVITIES

- Vegetation removal
- Prepare the project site (terrestrial)
- Install & anchor bank protection
- Remove temporary diversion dam

1.4.6.6 LANDFORM (TOPOGRAPHIC) FEATURES

Topographic (landform) features that typically occur naturally on the landscape (e.g., cliffs, terraces, ridges, etc.). This feature does not include aquatic landscape features or man-made structures.

1.4.6.6.1 CHANGE IN TOPOGRAPHY

ANTICIPATED MAGNITUDE

The topography of the sites will be altered by the construction of the natural bypass channels. The current topography will be replaced by a stream channel of varying depth with a 100 foot bottom width and 3:1 sides.

STRESSOR LOCATION

LEGEND

🟦 Project footprint

🟨 Stressor location

CONSERVATION MEASURES

No conservation measures for this stressor

STRUCTURES AND ACTIVITIES

- Excavate soils/sediments
- Grading
- Construct piles
- Finish grading
- Addition of fill

1.4.6.6.2 INCREASE IN IMPERVIOUS SURFACES

ANTICIPATED MAGNITUDE

Some impervious surfaces will be temporarily created by the construction of this project.

STRESSOR LOCATION

LEGEND

🟦 Project footprint

🟨 Stressor location

CONSERVATION MEASURES

- Seeding
- Matting
- Mulching

STRUCTURES AND ACTIVITIES

- Prepare the project site (terrestrial)

1.4.6.7 SOIL AND SEDIMENT

The topmost layer of earth on the landscape and its components (e.g., rock, sand, gravel, silt, etc.). This feature includes the physical characteristics of soil, such as depth, compaction, etc. Soil quality attributes (e.g, temperature, pH, etc.) should be placed in the Environmental Quality Features.

1.4.6.7.1 INCREASE IN DUST

ANTICIPATED MAGNITUDE

A minor increases in dust will occur at both project areas.

STRESSOR LOCATION

LEGEND

🟦 Project footprint

🟨 Stressor location

CONSERVATION MEASURES

No conservation measures for this stressor

STRUCTURES AND ACTIVITIES

- Excavate soils/sediments
- Vegetation removal
- Prepare the project site (terrestrial)
- Finish grading
- Geomorphic, hydrology, hydraulics, and sediment transport analysis field work

1.4.6.7.2 INCREASE IN SOIL COMPACTION

ANTICIPATED MAGNITUDE

Moderate soil compaction will occur from the presence and use of heavy machinery.

STRESSOR LOCATION

LEGEND

🟦 Project footprint

🟨 Stressor location

CONSERVATION MEASURES

No conservation measures for this stressor

STRUCTURES AND ACTIVITIES

- Staging area construction
- Excavate soils/sediments
- Debris removal
- Vegetation removal
- Construct bridge parapets
- Prepare the project site (terrestrial)
- Install & anchor bank protection
- Grading
- Construct piles
- Finish grading
- Construct abutment walls
- Geomorphic, hydrology, hydraulics, and sediment transport analysis field work
- Install slide gate
- Addition of fill

1.4.6.8 ENVIRONMENTAL PROCESSES

Abiotic processes that occur in the natural environment (e.g., erosion, precipitation, flood frequency, photoperiod, etc.).

1.4.6.8.1 CHANGE IN SURFACE RUNOFF

ANTICIPATED MAGNITUDE

Minor changes in surface runoff will occur due to the increase in impervious surfaces and open soils.

STRESSOR LOCATION

LEGEND

🟦 Project footprint

🟨 Stressor location

CONSERVATION MEASURES

- Seeding
- Matting
- Mulching

STRUCTURES AND ACTIVITIES

- Prepare the project site (terrestrial)

1.4.6.8.2 INCREASE IN EROSION

ANTICIPATED MAGNITUDE

Minor increases in erosion will occur due to increased exposed soils.

STRESSOR LOCATION

LEGEND

🟦 Project footprint

🟨 Stressor location

CONSERVATION MEASURES

- Amoring
- Seeding
- Matting
- Mulching

STRUCTURES AND ACTIVITIES

- Excavate soils/sediments
- Prepare the project site (terrestrial)

1.4.6.8.3 INCREASE IN SEDIMENTATION RATES

ANTICIPATED MAGNITUDE

Minor increases in erosion will occur due to increased exposed soils.

STRESSOR LOCATION

LEGEND

🟦 Project footprint

🟨 Stressor location

CONSERVATION MEASURES

- Amoring
- Seeding
- Matting
- Mulching

STRUCTURES AND ACTIVITIES

- Excavate soils/sediments
- Prepare the project site (terrestrial)
- Construct piles

1.4.6.8.4 INCREASE IN SURFACE RUNOFF

ANTICIPATED MAGNITUDE

Minor increases in erosion will occur due to increased exposed soils.

STRESSOR LOCATION

LEGEND

🟦 Project footprint

🟨 Stressor location

CONSERVATION MEASURES

- Amoring
- Seeding
- Matting
- Mulching

STRUCTURES AND ACTIVITIES

- Vegetation removal

1.4.6.9 HUMAN ACTIVITIES

Human actions in the environment (e.g., fishing, hunting, farming, walking, etc.).

1.4.6.9.1 INCREASE IN HUMAN PRESENCE

ANTICIPATED MAGNITUDE

A major temporary increase in human presence will occur during the construction of this project. After construction a minor increase in human presence is expectation for Operations and Maintenance of the project.

STRESSOR LOCATION

LEGEND

🟦 Project footprint

🟨 Stressor location

CONSERVATION MEASURES

No conservation measures for this stressor

STRUCTURES AND ACTIVITIES

- Staging area construction
- Excavate soils/sediments
- Debris removal
- Geotechnical investigation
- Fuel and maintain vehicles and equipment on-site
- Vegetation removal
- Prepare the project site (terrestrial)
- Install & anchor bank protection
- Construct piles
- Topographic surveys
- Finish grading
- Construct cofferdam
- Remove temporary diversion dam
- Biological survey (freshwater)
- Restore vegetation
- Cultural resource surveys
- Biological surveys (terrestrial)

1.4.6.9.2 INCREASE IN NOISE

ANTICIPATED MAGNITUDE

A major temporary increase in noise will occur during the construction of this project. After construction a minor increase in noise is expectation for Operations and Maintenance of the project.

STRESSOR LOCATION

LEGEND

🟦 Project footprint

🟨 Stressor location

CONSERVATION MEASURES

No conservation measures for this stressor

STRUCTURES AND ACTIVITIES

- Staging area construction
- Excavate soils/sediments
- Debris removal
- Geotechnical investigation
- Fuel and maintain vehicles and equipment on-site
- Vegetation removal
- Construct bridge parapets
- Prepare the project site (terrestrial)
- Install & anchor bank protection
- Grading
- Construct piles
- Topographic surveys
- Finish grading
- Construct abutment walls
- Geomorphic, hydrology, hydraulics, and sediment transport analysis field work
- Install slide gate
- Addition of fill
- Construct cofferdam
- Remove temporary diversion dam
- Biological survey (freshwater)
- Restore vegetation
- Biological surveys (terrestrial)

1.4.6.9.3 INCREASE IN SOIL DISTURBANCE

ANTICIPATED MAGNITUDE

The soils of the sites will be altered by the construction of the natural bypass channels. The current topography will be replaced by a stream channel of varying depth with a 100 foot bottom width and 3:1 sides.

STRESSOR LOCATION

LEGEND

🟦 Project footprint

🟨 Stressor location

CONSERVATION MEASURES

No conservation measures for this stressor

STRUCTURES AND ACTIVITIES

- Excavate soils/sediments
- Vegetation removal
- Construct bridge parapets
- Prepare the project site (terrestrial)
- Install & anchor bank protection
- Grading
- Construct piles
- Finish grading
- Construct abutment walls
- Install slide gate
- Addition of fill
- Restore vegetation
- Cultural resource surveys

1.4.6.9.4 INCREASE IN VEHICLE TRAFFIC

ANTICIPATED MAGNITUDE

A major temporary increase in vehicle traffic will occur during the construction of this project. After construction a minor increase in vehicle traffic will occur due to operation and maintenance of the project.

STRESSOR LOCATION

LEGEND

🟦 Project footprint

🟨 Stressor location

CONSERVATION MEASURES

No conservation measures for this stressor

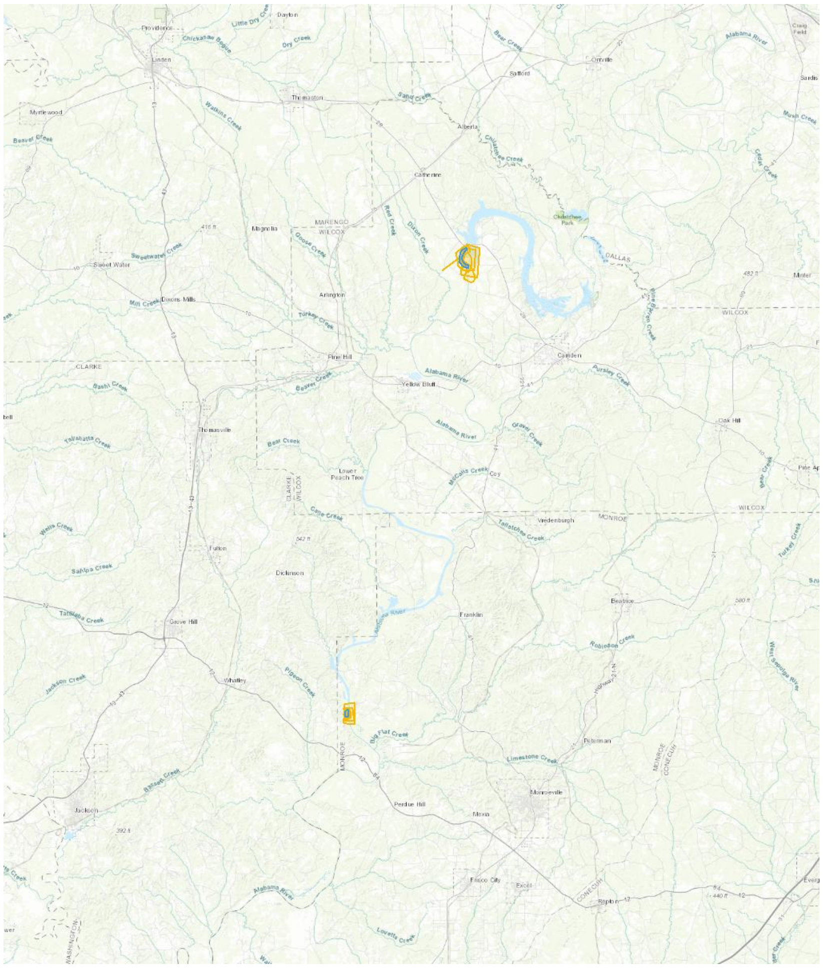
STRUCTURES AND ACTIVITIES

- Staging area construction
- Excavate soils/sediments
- Debris removal
- Geotechnical investigation
- Vegetation removal
- Prepare the project site (terrestrial)
- Construct piles
- Bridge structure
- Addition of fill
- Construct cofferdam
- Restore vegetation

1.4.6.10 SPECIES INTERACTIONS / INTRODUCTIONS

Interactions that occur between two or more different species (e.g., competition, pollination, predation, symbiosis, etc.).

1.5 ACTION AREA



LEGEND

🟦 Project footprint

🟨 Stressor location

1.6 CONSERVATION MEASURES

1.6.1 AMORING

DESCRIPTION

Rip rap or other stones will be placed to protect the streambank from erosion.

STRESSORS

- Decrease in soil stability
- Increase in erosion
- Increase in sedimentation rates
- Increase in surface runoff
- Increase in water turbidity

1.6.2 CONTROL OF FLOW

DESCRIPTION

Flow through the Millers Ferry Bypass Channel will be controlled with a slide gate that will allow for flow to be stopped during periods of high or low water.

STRESSORS

- Increase in water velocity

RESOURCE NEEDS

- streamflow
- streamflow (Flow less than 6.6 per second)

1.6.3 MATTING

DESCRIPTION

Erosion control matting (or blankets) will be placed on exposed soils to control erosion.

STRESSORS

- Change in surface runoff
- Increase in contaminants
- Increase in erosion
- Increase in impervious surfaces
- Increase in nutrients
- Increase in sedimentation rates
- Increase in surface runoff
- Increase in water turbidity

1.6.4 MULCHING

DESCRIPTION

Mulch from a Biological source can be placed at the site to prevent erosion and reduce exposed soils

STRESSORS

- Change in surface runoff
- Increase in erosion
- Increase in impervious surfaces
- Increase in sedimentation rates
- Increase in surface runoff
- Increase in water turbidity

1.6.5 PRECONSTRUCTION SURVEY

DESCRIPTION

A preconstruction survey for wetlands and plants will be conducted.

DIRECT INTERACTIONS

- crushing

1.6.6 REMOVE FUEL SOURCES

DESCRIPTION

Downed woody debris and cleared timber will be removed form the site.

STRESSORS

- Increase in fuel load

1.6.7 SEEDING

DESCRIPTION

Seeding of grasses for erosion control purposes.

STRESSORS

- Change in surface runoff
- Decrease in soil stability
- Increase in contaminants
- Increase in erosion
- Increase in impervious surfaces
- Increase in nutrients
- Increase in sedimentation rates
- Increase in surface runoff
- Increase in water turbidity

1.6.8 SELECTIVE SPUDDING

DESCRIPTION

Care will be taken to reduce the number of "spud drops" by the barges in and around the project area.

DIRECT INTERACTIONS

- vehicle / vessel strike

1.7 PRIOR CONSULTATION HISTORY

The USFWS was invited to participate in the Initial Project Charette in December of 2021

A final scope of work for a Fish and Wildlife Coordination Act Report was delivered to the USFWS in August 2022

The initial Planning Assistance Letter was received from the USFWS in October 2022

1.8 OTHER AGENCY PARTNERS AND INTERESTED PARTIES

- USEPA Region 4
- FEMA Region 4
- Federal Highway Administration
- USGS Southeast Region
- USFWS Southeast Region
- Department of Interior Atlanta Region
- AHC Advisory Council on Historic Preservation
- NPS
- U.S. Department of Housing and Urban Development
- NRCS
- ADCNR
- ADEM
- Alabama Secretary of State
- Alabama Emergency Management Agency
- Alabama Department of Transportation
- Alabama Department of Public Health

1.9 OTHER REPORTS AND HELPFUL INFORMATION

RELEVANT DOCUMENTATION

- FWCA PAL USACE AL River fish passage WJP

2 SPECIES EFFECTS ANALYSIS

This section describes, species by species, the effects of the proposed action on listed, proposed, and candidate species, and the habitat on which they depend. In this document, effects are broken down as direct interactions (something happening directly to the species) or indirect interactions (something happening to the environment on which a species depends that could then result in effects to the species).

These interactions encompass effects that occur both during project construction and those which could be ongoing after the project is finished. All effects, however, should be considered, including effects from direct and indirect interactions and cumulative effects.

2.1 ALABAMA PEARLSHELL

This species has been excluded from analysis in this environmental review document.

JUSTIFICATION FOR EXCLUSION

5 year review indicated that Alabama Pearshell is extirpated from the Alabama River.

2.2 ALABAMA STURGEON

2.2.1 STATUS OF THE SPECIES

This section should provide information on the species' background, its biology and life history that is relevant to the proposed project within the action area that will inform the effects analysis.

2.2.1.1 LEGAL STATUS

The Alabama Sturgeon is federally listed as 'Endangered' and additional information regarding its legal status can be found on the ECOS species profile.

2.2.1.2 RECOVERY PLANS

Available recovery plans for the Alabama Sturgeon can be found on the ECOS species profile.

2.2.1.3 LIFE HISTORY INFORMATION

The Alabama sturgeon (Scaphirhyncus suttkusi) was listed as an endangered species on May 5, 2000 (65 FR 26438). Its historic range encompassed all major rivers in the Mobile Basin, below the Fall Line, including the Alabama, Tombigbee, and Cahaba River systems. Recent collections are restricted to the lower Alabama River below Millers Ferry Lock and Dam to the confluence of the Tombigbee River and in the lower Cahaba River near its confluence with the Alabama River; however, records are extremely rare. The last capture of an Alabama sturgeon was on April 3, 2007 by the biologists at the Alabama Department of Conservation and Natural Resources (ADCNR). The Alabama sturgeon is one of the rarest and most endangered fish in the nation and may be close to extinction.

IDENTIFIED RESOURCE NEEDS

Rivers

River channel with stable sand and gravel river bottoms, and bedrock walls, including associated mussel beds

Streamflow

A range of flows with A minimum 7-day flow of 4,640 cubic feet per second during normal hydrologic conditions, measured in the alabama river at montgomery.

2.2.1.4 CONSERVATION NEEDS

From the 5-year review "The Alabama sturgeon is endemic to rivers of the Mobile River Basin below the Fall Line (Mettee et al. 1996, p. 83; Boschung and Mayden 2004, p. 109). Its current range includes the Alabama River from R.F. Henry Lock and Dam downstream to the confluence of the Tombigbee River. The species is also known to survive in the Cahaba River. Only eight Alabama sturgeon have been captured, or reported captured and released in the decade prior to listing despite numerous efforts. These fish were collected from several locations in the Alabama River between Millers Ferry Lock and Dam and its confluence with the Tombigbee River (Rider and Hartfield 2007, p. 490). Since federal listing in 2000 only two Alabama sturgeon have been captured or reported captured: the first in July 2000 within lower Cahaba River, and the second in April 2007 within the Alabama River below Claiborne Lock and Dam by the Alabama Department of Conservation and Natural Resources (ADCNR). Recent efforts to study e-DNA have detected Alabama sturgeon presence within the Alabama River; however exact locations of occupancy cannot be determined."

2.2.2 ENVIRONMENTAL BASELINE

The environmental baseline describes the species' health ***within the action area only*** *at the time of the consultation, and does not include the effects of the action under review. Unlike the species information provided above, the environmental baseline is at the scale of the Action area.*

2.2.2.1 SPECIES PRESENCE AND USE

The Alabama sturgeon is endemic to rivers of the Mobile River Basin below the Fall Line (Mettee et al. 1996; Boschung and Mayden 2004; Kuhajda 2004). Its historical range encompassed nearly 1,600 kilometers (km) (1,000 miles (mi)) in the Mobile River Basin in Alabama and Mississippi. There are records of Alabama sturgeon from nearly all the major rivers in the Mobile River Basin including the Black Warrior, Tombigbee, Alabama, Coosa, Tallapoosa, Mobile, Tensaw, and Cahaba Rivers (Burke and Ramsey 1985, 1995). Its current range includes the Alabama River from R.F. Henry Lock and Dam downstream to the confluence of the Tombigbee River, including the Cahaba River (~402 km or 250 mi). Despite extensive efforts in the decade prior to its listing, only nine Alabama sturgeon were captured, or reported captured and released (Rider and Hartfield 2007). Since its listing in 2000, only three individuals have been captured, as mentioned above.

Alabama Sturgeon likely encounter the Claiborne damming structure as a barrier to upstream passage in the spring as they move upstream to spawn. There is the potential for Alabama Sturgeon to pass over the dam during periods of very high flow.

Millers Ferry: Alabama Sturgeon that pass over Claiborne will encounter Millers Ferry Lock and Dam where upstream movement is not possible.

In the Alabama River, the types of long, free-flowing habitats needed by Alabama sturgeon larvae to drift and develop may no longer exist. The maximum length of free-flowing habitat currently available to Alabama sturgeon larvae is about 161 km.

2.2.2.2 SPECIES CONSERVATION NEEDS WITHIN THE ACTION AREA

Alabama sturgeon need long stretches of River for successful spawning.

2.2.2.3 HABITAT CONDITION (GENERAL)

STREAMFLOW (A RANGE OF FLOWS WITH A MINIMUM 7-DAY FLOW OF 4,640 CUBIC FEET PER SECOND DURING NORMAL HYDROLOGIC CONDITIONS, MEASURED IN THE ALABAMA RIVER AT MONTGOMERY.)

This is the normal flow regime through the structures

2.2.2.4 INFLUENCES

From the Final Listing Rule "The Alabama sturgeon's historic range consisted of about 1,600 km (1,000 mi) of river habitat in the Mobile River Basin in Alabama and Mississippi. There are records of sturgeon captures from the Black Warrior, Tombigbee, Alabama, Coosa, Tallapoosa, Mobile, Tensaw, and Cahaba Rivers (Burke and Ramsey 1985, 1995). The Alabama sturgeon was once common in Alabama, and perhaps also in Mississippi. The total 1898 commercial catch of shovel-nose sturgeons (i.e., Alabama sturgeon) from Alabama was reported as 19,000 kg (42,000 lb) in a statistical report to Congress (U.S. Commission of Fish and Fisheries 1898). Of this total, 18,000 kg (39,800 lb) came from the Alabama River and 1,000 kg (2,200 lb) from the Black Warrior River. Given that an average Alabama sturgeon weighs about 1 kg (2 lb), the 1898 commercial catch consisted of approximately 20,000 fish. These records indicate a substantial historic population of Alabama sturgeon.

Between the 1898 report and 1970, little information was published regarding the Alabama sturgeon. An anonymous article published in the Alabama Game and Fish News in 1930 stated that the sturgeon was not uncommon; however, by the 1970s, it had become rare. In 1976, Ramsey considered the sturgeon as endangered and documented only six specimens from museums. Clemmer (1983) was able to locate 23 Alabama sturgeon specimens in museum collections, with the most recent collection dated 1977. Clemmer also found that commercial fishermen in the Alabama and Tombigbee Rivers were familiar with the sturgeon, calling it hackleback, buglemouth trout, or devilfish. During the mid-1980s, Burke and Ramsey (1985, 1995) conducted a status survey to determine the distribution and abundance of the Alabama sturgeon. Interviews were conducted with commercial fishermen on the Alabama and Cahaba Rivers, some of whom reported catch of Alabama sturgeon as an annual event. However, with the assistance of commercial fishermen, Burke and Ramsey were able to collect only five Alabama sturgeons, including two males, two gravid females, and one juvenile about 2 years old. Burke and Ramsey (1985) concluded that the Alabama sturgeon had been extirpated from 57 percent (950 km or 589 mi) of its range and that only 15 percent (250 km or 155 mi) of its former habitat had the potential to support a good population. An additional sturgeon was taken in 1985 in the Tensaw River and photographed, but the specimen was lost (Mettee, Geologic Survey of Alabama, pers. comm. 1997). In 1990 and 1992, biologists from the Alabama Department of Conservation and Natural Resources (ADCNR), with the assistance of the Corps, conducted searches for Alabama sturgeon using a variety of sampling techniques, without success (Tucker and Johnson 1991, 1992). However, some commercial and sports fishermen continued to report recent catches of small sturgeon in Millers Ferry and Claiborne Reservoirs and in the lower Alabama River (Tucker and Johnson 1991, 1992)."

2.2.2.5 ADDITIONAL BASELINE INFORMATION

The last Alabama Sturgeon caught on the Alabama River was captured in 2006. eDNA sampling has confirmed that individuals are still present in the Alabama river.

2.2.3 EFFECTS OF THE ACTION

This section considers and discusses all effects on the listed species that are caused by the proposed action and are reasonably certain to occur, including the effects of other activities that would not occur but for the proposed action.

2.2.3.1 INDIRECT INTERACTIONS

RESOURCE NEED	**STRESSORS**	**CONSERVATION MEASURES**	**AMOUNT OF RESOURCE IMPACTED**	**INDIVIDUALS AFFECTED**
Rivers (river channel with stable sand and gravel river bottoms, and bedrock walls, including associated mussel beds)			***This resource is not present in the action area*** Areas around the project are heavily influenced by sedimentation and washing from flows through the damming structures.	***There will be no impacts to this resource, so no individuals will be affected.***
Streamflow (a range of flows with a minimum 7-day flow of 4,640 cubic feet per second during normal hydrologic conditions, measured in the alabama river at montgomery.)	Change in streamflow		***There will be no impacts to this resource*** Project will not change overall flow through the project	***There will be no impacts to this resource, so no individuals will be affected.***

2.2.3.2 DIRECT INTERACTIONS

DIRECT IMPACT	**CONSERVATION MEASURES**	**INDIVIDUALS IMPACTED**	**IMPACT EXPLANATION**
Fish passage		Yes	Fish Passage is a positive impact to the species
Vehicle / vessel strike	Selective spudding	No	Boats will operate at low speeds.

2.2.4 CUMULATIVE EFFECTS

There are no additional cumulative effects in the project area.

2.2.5 DISCUSSION AND CONCLUSION

DETERMINATION: **NLAA**

COMPENSATION MEASURES

(7)(a)1 is forthcoming.

2.3 ALLIGATOR SNAPPING TURTLE

This species has been excluded from analysis in this environmental review document.

JUSTIFICATION FOR EXCLUSION

USACE is not coordinating for non listed Species

2.4 GEORGIA ROCKCRESS

2.4.1 STATUS OF THE SPECIES

This section should provide information on the species' background, its biology and life history that is relevant to the proposed project within the action area that will inform the effects analysis.

2.4.1.1 LEGAL STATUS

The Georgia Rockcress is federally listed as 'Threatened' and additional information regarding its legal status can be found on the ECOS species profile.

2.4.1.2 RECOVERY PLANS

Available recovery plans for the Georgia Rockcress can be found on the ECOS species profile.

2.4.1.3 LIFE HISTORY INFORMATION

No description available

IDENTIFIED RESOURCE NEEDS

Bare ground

Bare ground with little to no leaf litter.

Rock ledges

Shallow soils over rocky bluff/ ledges

2.4.1.4 CONSERVATION NEEDS

From the 2018 Recovery Outline:

"The primary threats to this plant include habitat destruction, modification, and fragmentation.

Recovery needs for Georgia rockcress include continued surveys and monitoring, threat abatement, and research: 1. Continue public outreach to provide education and explore opportunities to work on private property. 2. Develop and implement management strategies for the species to include aspects like invasive species control. 3. Conduct regular monitoring at all accessible sites. 4. Conserve and manage existing populations and habitat. 5. Establish methods to effectively reintroduce and monitor Georgia rockcress. 6. Enhance the suitability of known sites and potential reintroduction sites. 7. Conserve germplasm (genetic material; e.g. seed) and promote genetic diversity. 8. Conduct studies of genetic variation within and between known sites. 9. Determine the minimum number of populations required to ensure survival of Georgia rockcress. 10. Define population regulation factors. 11. Look for opportunities to protect existing occurrences through acquisition, easements and/or management agreements. 12. Develop and implement management strategies for the GA rockcress, initially with the two State parks in Alabama."

2.4.2 ENVIRONMENTAL BASELINE

The environmental baseline describes the species' health ***within the action area only*** *at the time of the consultation, and does not include the effects of the action under review. Unlike the species information provided above, the environmental baseline is at the scale of the Action area.*

2.4.2.1 SPECIES PRESENCE AND USE

The known historical range of Georgia rockcress is within the Ridge and Valley, Piedmont and Southeastern Plains ecoregions of Alabama and Georgia

Georgia rockcress occupy steep river bluffs with shallow soils over rock, exposed rock outcroppings, and eroding sandy riverbanks.

Primary habitat element identified in the 2021 Species Status Assessment (SSA) were:

A mature, mixed-level canopy with spatial heterogeneity, providing mottled shade and often including species such as eastern red cedar, America hophornbeam, chinquapin oak, white ash, southern sugar maple, and redbud with a rich diversity of grasses and forbs characterizing the herb layer.

Well-drained soils that are buffered or circumneutral generally within regions underlain or otherwise influenced by limestone or granite-gneiss.

Large river bluffs with steep and/or shallow soils that are subject to localized disturbances that limit the accumulation of leaf litter and competition

In their 2021 SSA the USFWS identified an extant populations of Georgia rockcress at Prairie Bluff (~1 mile from project location) and at Portland Landing (~10 miles) from the project.

Mobile District personel completed a habitat assessment of the project area and found no suitable habitat or individuals. Areas that may have had suitable habitat contained a high volume of leaf litter/ or heavy understory growth that competitively excludes Georgia rockcress.

2.4.2.2 SPECIES CONSERVATION NEEDS WITHIN THE ACTION AREA

No specific conservation needs overlap the project area. Planting the area with Georgia Rockcress may be possible post construction.

2.4.2.3 HABITAT CONDITION (GENERAL)

No population or suitable habitat was seen during the project survey.

SUPPORTING DOCUMENTATION

- IMG-2554
- IMG-2550
- IMG-2528
- IMG-2535

2.4.2.4 INFLUENCES

From the 2018 Recovery Outline

"Historically, suitable habitat for this species was destroyed by quarrying, residential development, timber harvesting, road building, recreation, and hydropower dam construction; one or more of these activities pose ongoing current threats to all known populations. Given the extremely small size of Georgia rockress populations, projects that destroy even a small amount of habitat can have a serious impact on this species, including existing genetic diversity of the species. Currently, the primary threat to extant populations of Georgia rockcress is the ongoing invasion of nonnative species into suitable habitat. Quarrying, residential development, timber harvesting, road building, recreation sites (such as campsites or mowing of fields) and other activities open the canopy, destroy soil profiles and disrupt hydrology. These changes fragment Georgia rockcress, creating more edge habitat and promoting invasion of nonnative species (Honu and Gibson 2006). Edges function as sources of propagules for disturbed habitats and represent complex environmental gradients with changes in light availability, temperature, humidity, wind speed, and soil moisture, with plant species responding directly to environmental changes (Meiners et al. 1999). Edge effect, including any canopy break due to timber harvest, fields, or maintained rights-of-way, may penetrate as far as 175 meters (574 feet), resulting in changes in community composition (Fraver 1994; Meiners et al. 1999; Gehlhausen et al. 2000; Honu and Gibson 2006). "

2.4.2.5 ADDITIONAL BASELINE INFORMATION

Mobile District Biologist preformed a habitat assessment of the project area and saw no suitable habitat, leaf burden was high above the erosion line.

2.4.3 EFFECTS OF THE ACTION

This section considers and discusses all effects on the listed species that are caused by the proposed action and are reasonably certain to occur, including the effects of other activities that would not occur but for the proposed action.

2.4.3.1 INDIRECT INTERACTIONS

RESOURCE NEED	STRESSORS	CONSERVATION MEASURES	AMOUNT OF RESOURCE IMPACTED	INDIVIDUALS AFFECTED
Bare ground (bare ground with little to no leaf litter.)			***This resource is not present in the action area*** Project survey	***There will be no impacts to this resource, so no individuals will be affected.***

RESOURCE NEED	**STRESSORS**	**CONSERVATION MEASURES**	**AMOUNT OF RESOURCE IMPACTED**	**INDIVIDUALS AFFECTED**
Rock ledges (shallow soils over rocky bluff/ ledges)			***This resource is not present in the action area*** Project survey	***There will be no impacts to this resource, so no individuals will be affected.***

2.4.3.2 DIRECT INTERACTIONS

DIRECT IMPACT	**CONSERVATION MEASURES**	**INDIVIDUALS IMPACTED**	**IMPACT EXPLANATION**
Crushing	Preconstruction survey	No	Final survey of project area before construction to confirm the absence of individuals again

2.4.4 CUMULATIVE EFFECTS

Population is general improving and state and federal actions are being undertaken to improve habitats and protections.

2.4.5 DISCUSSION AND CONCLUSION

DETERMINATION: NLAA

2.5 GULF STURGEON

2.5.1 STATUS OF THE SPECIES

This section should provide information on the species' background, its biology and life history that is relevant to the proposed project within the action area that will inform the effects analysis.

2.5.1.1 LEGAL STATUS

The Gulf Sturgeon is federally listed as 'Threatened' and additional information regarding its legal status can be found on the ECOS species profile.

2.5.1.2 RECOVERY PLANS

Available recovery plans for the Gulf Sturgeon can be found on the ECOS species profile.

2.5.1.3 LIFE HISTORY INFORMATION

No description available

IDENTIFIED RESOURCE NEEDS

Freshwater resources

Gulf sturgeon live a portion of their life cycle in freshwater

Gravel

Clean gravel

Interstitial spaces

Interstitial spaces in cobble or gravel for spawning

Streamflow

Flow less than 6.6 per second

2.5.1.4 CONSERVATION NEEDS

From the Five-Year Review:

"Standardization of survey and monitoring protocols are being implemented through multiple initiatives to assess the status of Gulf Sturgeon populations across the range. A range-wide study of juvenile sturgeon recruitment, mortality and habitat use is in progress through the Juvenile Sturgeon Dynamics Project, as is the development and implementation of a modern tagging database and data management protocols through the Population Status and Trends Study. During the latter project, specific metrics will be calculated and evaluated for inter-basin comparison of population trends. Areas of data insufficiency will be identified, providing managers the information needed to direct limited resources toward filling those gaps. Given that the recovery status of a species has much to do with the future risk of extinction, these important studies will assess the population status, trajectory, and viability of each of the seven populations, taking into consideration stochastic threats such as hurricane-related mortality, red tide, and pointsource pollution discharges. In tandem, these studies will identify factors that limit each of the seven populations from achieving higher population growth rates, lower mortality rates, or higher abundances. Future restoration and recovery efforts will be informed by this improved understanding of population status and the relative impacts of the myriad threats to recovery

2.5.2 ENVIRONMENTAL BASELINE

The environmental baseline describes the species' health ***within the action area only*** *at the time of the consultation, and does not include the effects of the action under* *review. Unlike the species information provided above, the environmental baseline is at the scale of the Action area.*

2.5.2.1 SPECIES PRESENCE AND USE

Gulf Sturgeon are known to occur in the Alabama River basin. Individuals have been found downstream of Claiborne Lock and Dam. Gulf sturgeon reproduction is not known to currently occur in several basins where it most likely occurred historically including the Mobile River Basin. A recent survey collected two Gulf sturgeon in Mobile Bay near Fairhope, AL (Mettee et al. 2009) after intensive netting.

Gulf sturgeon travel great distances to use specific areas for spawning in the spring, for “holding” in the summer and fall, and for feeding in the winter.

2.5.2.2 SPECIES CONSERVATION NEEDS WITHIN THE ACTION AREA

Dams in the project area currently inhibit upstream movement

2.5.2.3 HABITAT CONDITION (GENERAL)

FRESHWATER RESOURCES (GULF STURGEON LIVE A PORTION OF THEIR LIFE CYCLE IN FRESHWATER)

Project area contains both shallow and deep fresh water

STREAMFLOW (FLOW LESS THAN 6.6 PER SECOND)

Streamflow is generally less that 6.6 feet per second

2.5.2.4 INFLUENCES

No suitable population of Gulf Sturgeon exists above Claiborne Lock and Dam

2.5.2.5 ADDITIONAL BASELINE INFORMATION

No additional baseline information is available.

2.5.3 EFFECTS OF THE ACTION

This section considers and discusses all effects on the listed species that are caused by the proposed action and are reasonably certain to occur, including the effects of other activities that would not occur but for the proposed action.

2.5.3.1 INDIRECT INTERACTIONS

RESOURCE NEED	STRESSORS	CONSERVATION MEASURES	AMOUNT OF RESOURCE IMPACTED	INDIVIDUALS AFFECTED
Freshwater resources (gulf sturgeon live a portion of their life cycle in freshwater)	Change in channel morphology Change in streamflow Increase in streams		***There will be no impacts to this resource*** Overall bathometry and depth profile of the area will not dramatically change	***There will be no impacts to this resource, so no individuals will be affected.***
Gravel (clean gravel)			***This resource is not present in the action area*** Site Visit	***There will be no impacts to this resource, so no individuals will be affected.***
Interstitial spaces (interstitial spaces in cobble or gravel for spawning)			***This resource is not present in the action area*** Clean substrates are not available above or below the dam	***There will be no impacts to this resource, so no individuals will be affected.***
Streamflow (flow less than 6.6 per second)	Change in channel morphology	Control of flow	***There will be no impacts to this resource***	***There will be no impacts to this resource, so no***

RESOURCE NEED	**STRESSORS**	**CONSERVATION MEASURES**	**AMOUNT OF RESOURCE IMPACTED**	**INDIVIDUALS AFFECTED**
	Change in streamflow		During high flows the structure gate at Millers Ferry will be closed. At Claiborne average flows are not expected to exceed 6.6 ft/s.	***individuals will be affected.***

2.5.3.2 DIRECT INTERACTIONS

DIRECT IMPACT	**CONSERVATION MEASURES**	**INDIVIDUALS IMPACTED**	**IMPACT EXPLANATION**
Fish passage		Yes	Fish passage is a benefit to the species.

2.5.4 CUMULATIVE EFFECTS

No additional cumulative effects are in the project area.

2.5.5 DISCUSSION AND CONCLUSION

DETERMINATION: NLAA

2.6 INFLATED HEELSPLITTER

2.6.1 STATUS OF THE SPECIES

This section should provide information on the species' background, its biology and life history that is relevant to the proposed project within the action area that will inform the effects analysis.

2.6.1.1 LEGAL STATUS

The Inflated Heelsplitter is federally listed as 'Threatened' and additional information regarding its legal status can be found on the ECOS species profile.

2.6.1.2 RECOVERY PLANS

Available recovery plans for the Inflated Heelsplitter can be found on the ECOS species profile.

2.6.1.3 LIFE HISTORY INFORMATION

The inflated heelsplitter has an oval, compressed to moderately inflated, thin shell. The valves may gape anteriorly. The umbos are low, and there is a prominent posterior wing that may extend anterior to the beak in young individuals. The shell is brown to black and may have green rays in young individuals. The umbonal cavity is very shallow and the nacre is pink to purple. Maximum shell length is about 140 millimeters (5 1/2 inches) in adults (Stern 1976). It is most similar to the pinkpapershell (Potamilus ohioensis), yet is easily distinguished by shell morphology (Hartfield 1988). The shell and teeth of the inflated heelsplitter are more delicate, and the shell is darker and has a pointed posterior, whereas the pink papershell has a rounded posterior. The inflated heelsplitter appears more inflated due to a more developed and rounded posterior ridge. The posterior wing of the inflated heelsplitter is more pronounced and abruptly rounded over the dorsum. The pink papershell may lack much of a wing, and when pronounced, it may be only slightly rounded and extend scarcely above the dorsum (Hartfleld 1988).

IDENTIFIED RESOURCE NEEDS

- Calcium carbonate (caco3)
- Dissolved oxygen
- Host species
- Microorganisms
- Organic matter
- Streamflow
- Substrate structure and characteristics
- Water depth
- Water temperature

2.6.1.4 CONSERVATION NEEDS

No specific conservation needs in project area

2.6.2 ENVIRONMENTAL BASELINE

The environmental baseline describes the species' health ***within the action area only*** *at the time of the consultation, and does not include the effects of the action under review. Unlike the species information provided above, the environmental baseline is at the scale of the Action area.*

2.6.2.1 SPECIES PRESENCE AND USE

A 1998 survey of the Alabama River revealed only one live specimen of Inflated Heelsplitter in the Alabama River near the Baldwin/ Clark County line (Hartfield and Garner 1998).

Inflated heelsplitter have been collected from a variety of habitats such as silt, mud, sand, and gravel in a variety of hydrological regimes (Hartfield 1998). Heelsplitter have also been found in impounded water bodies that have some flow such as the Oliver pool on the Black Warrior River near Tuscaloosa, AL.

2.6.2.2 SPECIES CONSERVATION NEEDS WITHIN THE ACTION AREA

No specific conservation needs in project area.

2.6.2.3 HABITAT CONDITION (GENERAL)

CALCIUM CARBONATE (CACO3)
Calcium carbonate is found in the Alabama River

DISSOLVED OXYGEN
Disolved Oxygen is present in the Alabama River

HOST SPECIES
The fresh water drum, the only host fish for Inflated heelsplitter is present in this reach of the Alabama River

MICROORGANISMS
Primary producers and primary biomass are present in these reaches of the Alabama River

ORGANIC MATTER
Organic matter is present in this reach of the Alabama River

STREAMFLOW
Variable streamflows are found at both Millers Ferry and Claiborne

SUBSTRATE STRUCTURE AND CHARACTERISTICS
Substrate of varying types exist in the project area

WATER DEPTH
Shallow and deep waters are available around the project area

WATER TEMPERATURE
A variety of water temperatures exist depending on the time of year and hydraulic conditions

2.6.2.4 INFLUENCES

The overall Inflated heelsplitter population is stable. An increases in population has been seen in the Western Mobile River Basin (Black Warrior and Tombigbee Rivers). There is no evidence of self-sustaining populations occurring outside of the western Mobile River Basin or Amite River.

2.6.2.5 ADDITIONAL BASELINE INFORMATION

There is no indication of a self-stable population of Inflated heelsplitter in the Alabama River.

2.6.3 EFFECTS OF THE ACTION

This section considers and discusses all effects on the listed species that are caused by the proposed action and are reasonably certain to occur, including the effects of other activities that would not occur but for the proposed action.

2.6.3.1 INDIRECT INTERACTIONS

RESOURCE NEED	STRESSORS	CONSERVATION MEASURES	AMOUNT OF RESOURCE IMPACTED	INDIVIDUALS AFFECTED
Calcium carbonate (caco3)	Change in channel morphology Increase in vehicle traffic Increase in contaminants Decrease in vegetation Increase in soil compaction Increase in surface runoff Increase in soil disturbance Change in topography Change in streamflow Increase in erosion Increase in impervious surfaces Change in surface runoff		***There will be no impacts to this resource*** No changes to water chemistry are expected as an effect of this project	***There will be no impacts to this resource, so no individuals will be affected.***
Dissolved oxygen	Change in channel morphology Increase in vehicle traffic Increase in contaminants Decrease in vegetation Increase in soil compaction Increase in nutrients Increase in surface runoff Increase in soil disturbance Change in topography Change in streamflow Increase in erosion Increase in impervious surfaces Change in surface runoff		***There will be no impacts to this resource*** No major changes to water chemistry are predicted as a a result of this project	***There will be no impacts to this resource, so no individuals will be affected.***

RESOURCE NEED	**STRESSORS**	**CONSERVATION MEASURES**	**AMOUNT OF RESOURCE IMPACTED**	**INDIVIDUALS AFFECTED**
Host species	Change in channel morphology Increase in vehicle traffic Increase in contaminants Increase in noise Decrease in vegetation Increase in soil compaction Increase in water turbidity Increase in nutrients Increase in surface runoff Increase in soil disturbance Change in topography Change in streamflow Increase in sedimentation rates Increase in erosion Increase in impervious surfaces Change in surface runoff		***There will be no impacts to this resource*** This project is intended to provide increased mobility to host fish such as the freshwater drum	***There will be no impacts to this resource, so no individuals will be affected.***

RESOURCE NEED	STRESSORS	CONSERVATION MEASURES	AMOUNT OF RESOURCE IMPACTED	INDIVIDUALS AFFECTED
Microorganisms	Change in channel morphology Increase in vehicle traffic Increase in contaminants Decrease in vegetation Increase in soil compaction Increase in water turbidity Increase in nutrients Increase in surface runoff Increase in soil disturbance Change in topography Change in streamflow Increase in sedimentation rates Increase in erosion Increase in impervious surfaces Change in surface runoff		***There will be no impacts to this resource*** No changes to primary productivity are likely to occur as a result of this project.	***There will be no impacts to this resource, so no individuals will be affected.***

RESOURCE NEED	**STRESSORS**	**CONSERVATION MEASURES**	**AMOUNT OF RESOURCE IMPACTED**	**INDIVIDUALS AFFECTED**
Organic matter	Increase in vehicle traffic Decrease in vegetation		***There will be no impacts to this resource*** No decrease in organic matter is expected as a result of this project	***There will be no impacts to this resource, so no individuals will be affected.***
Streamflow	Change in channel morphology Increase in vehicle traffic Decrease in vegetation Increase in soil compaction Increase in surface runoff Change in topography Change in streamflow Increase in impervious surfaces Change in surface runoff	Control of flow	***There will be no impacts to this resource*** Flows will be controlled through the Millers Ferry Bypass and not excessive at Claiborne	***There will be no impacts to this resource, so no individuals will be affected.***

RESOURCE NEED	**STRESSORS**	**CONSERVATION MEASURES**	**AMOUNT OF RESOURCE IMPACTED**	**INDIVIDUALS AFFECTED**
Substrate structure and characteristics	Change in channel morphology Increase in vehicle traffic Decrease in vegetation Increase in soil compaction Increase in water turbidity Increase in surface runoff Increase in soil disturbance Change in topography Change in streamflow Increase in sedimentation rates Increase in erosion Increase in impervious surfaces Change in surface runoff		***There will be no impacts to this resource*** No major changes to substrate type or assemblage are predicted as a result of this action	***There will be no impacts to this resource, so no individuals will be affected.***

RESOURCE NEED	**STRESSORS**	**CONSERVATION MEASURES**	**AMOUNT OF RESOURCE IMPACTED**	**INDIVIDUALS AFFECTED**
Water depth	Change in channel morphology Change in topography Change in streamflow Change in surface runoff		Minor changes in water depth are predicted	***No individuals will be affected*** No individual Inflated heelsplitter occur in the project area.
Water temperature	Change in channel morphology Increase in vehicle traffic Decrease in vegetation Increase in soil compaction Increase in surface runoff Change in topography Change in streamflow Increase in impervious surfaces Change in surface runoff		***There will be no impacts to this resource*** No major changes in water temperature are predicted as a result of this project.	***There will be no impacts to this resource, so no individuals will be affected.***

2.6.3.2 DIRECT INTERACTIONS

No direct interactions leading to effects on species are expected to occur from the proposed project.

2.6.4 CUMULATIVE EFFECTS

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2.6.5 DISCUSSION AND CONCLUSION

DETERMINATION: NLAA

2.7 MONARCH BUTTERFLY

This species has been excluded from analysis in this environmental review document.

JUSTIFICATION FOR EXCLUSION

Not required by law

2.8 ORANGENACRE MUCKET

This species has been excluded from analysis in this environmental review document.

JUSTIFICATION FOR EXCLUSION

The Orange mucket is believed extirpated from the mainstem of the Alabama River.

2.9 SOUTHERN CLUBSHELL

2.9.1 STATUS OF THE SPECIES

This section should provide information on the species' background, its biology and life history that is relevant to the proposed project within the action area that will inform the effects analysis.

2.9.1.1 LEGAL STATUS

The Southern Clubshell is federally listed as 'Endangered' and additional information regarding its legal status can be found on the ECOS species profile.

2.9.1.2 RECOVERY PLANS

Available recovery plans for the Southern Clubshell can be found on the ECOS species profile.

2.9.1.3 LIFE HISTORY INFORMATION

The southern clubshell is a medium sized mussel with lengths up to 93 mm long (Williams et al. 2008), with a thick shell, and heavy hinge plate and teeth. The shell outline is roughly rectangular, produced posteriorly with the umbos usually terminal to the anterior margin. The posterior ridge is moderately inflated and ends abruptly with little development of the posterior slope at the dorsum of the shell. The periostracum is yellow to yellow-brown with occasional green rays or spots on the umbo in young specimens (68 FR 14752).

IDENTIFIED RESOURCE NEEDS

Dissolved oxygen

All stages of life cycle require highly oxygenated water.

Substrate structure and characteristics

All stages of lifecycle require sand and gravel substrate

2.9.1.4 CONSERVATION NEEDS

No specific conservation needs in project area.

2.9.2 ENVIRONMENTAL BASELINE

The environmental baseline describes the species' health ***within the action area only*** *at the time of the consultation, and does not include the effects of the action under review. Unlike the species information provided above, the environmental baseline is at the scale of the Action area.*

2.9.2.1 SPECIES PRESENCE AND USE

Based on the 2019 5-year review, the southern clubshell population is considered improving. The population is common to abundant and is now thought to have stronger densities than at the time of listing. The strongest populations include localized reaches of the Conasauga River, Coosa River, Big Canoe Creek, Cahaba River, Bogue Chitto Creek, Bull Mountain Cree, Buttahatchee River, and Sipsey River. The nearest known population, Bogue Chitto Creek, contained an estimated density of 0.44 individuals per square meter in 2014. The southern clubshell was (1) the most abundant mussel species collected across nine sites in Bull Mountain Creek, (2) the third most frequently encountered mussel in the Buttahatchee River drainage, and (3) had the highest densities in the Sipsey River. Combined, over 2,900 individuals were collected with densities ranging between 0.36-17.71 per square meter which suggests that the populations are increasing.

2.9.2.2 SPECIES CONSERVATION NEEDS WITHIN THE ACTION AREA

No specific conservation needs in project area.

2.9.2.3 HABITAT CONDITION (GENERAL)

DISSOLVED OXYGEN (ALL STAGES OF LIFE CYCLE REQUIRE HIGHLY OXYGENATED WATER.)
Downstream of both dams areas of high oxygenation exist below the spillway.

2.9.2.4 INFLUENCES

Southern Clubshell are affected by habitat fragmentation from impoundment

2.9.2.5 ADDITIONAL BASELINE INFORMATION

No populations of Southern Clubshell are know in the Mainstem of the Alabama River outside of a population north of Selma, AL

2.9.3 EFFECTS OF THE ACTION

This section considers and discusses all effects on the listed species that are caused by the proposed action and are reasonably certain to occur, including the effects of other activities that would not occur but for the proposed action.

2.9.3.1 INDIRECT INTERACTIONS

RESOURCE NEED	STRESSORS	CONSERVATION MEASURES	AMOUNT OF RESOURCE IMPACTED	INDIVIDUALS AFFECTED
Dissolved oxygen (all stages of life cycle require highly oxygenated water.)	No exposure path			***There will be no impacts to this resource, so no individuals will be affected.***
Substrate structure and characteristics (all stages of lifecycle require sand and gravel substrate)			***This resource is not present in the action area*** Gravel and sand are not present directly in the project area.	***There will be no impacts to this resource, so no individuals will be affected.***

2.9.3.2 DIRECT INTERACTIONS

No direct interactions leading to effects on species are expected to occur from the proposed project.

2.9.4 CUMULATIVE EFFECTS

The Southern Clubshell population is improving. The construction of this project will allow for movement of Southern Clubshell glochidia up and downstream of Millers Ferry and Claiborne

2.9.5 DISCUSSION AND CONCLUSION

DETERMINATION: NLAA

2.10 TULOTOMA SNAIL

2.10.1 STATUS OF THE SPECIES

This section should provide information on the species' background, its biology and life history that is relevant to the proposed project within the action area that will inform the effects analysis.

2.10.1.1 LEGAL STATUS

The Tulotoma Snail is federally listed as 'Threatened' and additional information regarding its legal status can be found on the ECOS species profile.

2.10.1.2 RECOVERY PLANS

Available recovery plans for the Tulotoma Snail can be found on the ECOS species profile.

2.10.1.3 LIFE HISTORY INFORMATION

Tulotoma is a gill-breathing operculate snail in the family Viviparidae. Its shell is large and globular and typically ornamented with spiral lines of knob-like structures. Its adult size and ornamentation distinguish it from all other freshwater snails in the Coosa-Alabama River system.

IDENTIFIED RESOURCE NEEDS

- Boulders
  - >2 per m2
- Dissolved oxygen
  - All stage of tulatoma snail life cycle require well oxygenated water

2.10.1.4 CONSERVATION NEEDS

Mobile River Basin recovery plan (USFWS, 2000) calls for: (1) use to fullest extent existing laws, regulations, and policies to portect listed populations and their habitats, and to develop and encourage a stream management strategy that places high priority on conservation; (2) encourage voluntary stewardship through joint initiatives and individual actions as the only practical and economical means of minimizing adverse effects of private land use and activities within watersheds; (3) continue to promote research efforts on life histories, sensitivities, and requirements of imperiled aquatic species, and develop technological capabilities to maintain and propagate them.

2.10.2 ENVIRONMENTAL BASELINE

The environmental baseline describes the species' health ***within the action area only*** *at the time of the consultation, and does not include the effects of the action under review. Unlike the species information provided above, the environmental baseline is at the scale of the Action area.*

2.10.2.1 SPECIES PRESENCE AND USE

At the time of listing, the tulotoma had not been located in the Alabama River drainage system for at least 50 years. However, between 2006 and 2008, three new populations were discovered in the Alabama River. One population was below the Claiborne Lock and Dam, Monroe County, Alabama (USFWS 2011) (Figure 1). Another population was discovered below the R.F. Henry Lock and Dam, Autauga and Lowndes Counties, Alabama (USFWS 2011) and contained both juvenile and adult tulotomas. The third colony was located below Millers Ferry Lock and Dam in Wilcox County, Alabama (J. Powell pers. comm. 2008). Surveys conducted in 2010 by Garner et al. (2016) reconfirmed two of these Alabama River populations below the R.F. Henry Lock and Dam. In addition, they discovered three new tulotoma populations in the Alabama River: Two populations downstream of the R.F. Henry Lock and Dam and one population in the dam’s upstream pool (Garner et al. 2016). Recruitment was observed at four of the five sites (Garner et al. 2016).

2.10.2.2 SPECIES CONSERVATION NEEDS WITHIN THE ACTION AREA

High flow when possible to prevent stranding and allow for high DO

2.10.2.3 HABITAT CONDITION (GENERAL)

DISSOLVED OXYGEN (ALL STAGE OF TULATOMA SNAIL LIFE CYCLE REQUIRE WELL OXYGENATED WATER)

Dissolved oxygen is often high directly below both dams as a result of the mechanical mixing of the water passing over the spillways.

2.10.2.4 INFLUENCES

In the Mobile River basin, the greatest threats are dams (for navigation, water supply, electricity, recreation, and flood control), channelization (causing accelerated erosion, altered depth; and loss of habitat diversity, substrate stability, and riparian canopy), dredging (for navigation or gravel mining), mining (for coal, sand, gravel, or gold) in locally concentrated areas, pollution- point source (industrial waste effluent, sewage treatment plants, carpet and fabric mills, paper mills and refineries in mainstem rivers), pollution- nonpoint source (construction, agriculture, silviculture, urbanization).

2.10.2.5 ADDITIONAL BASELINE INFORMATION

Populations of Tulatoma snail have been found below both Millers Ferry and Claiborne Locks and Dams, these populations occur downstream of the project area and it is believed that velocities directly below the dam are too high for snails to attach to substrate.

2.10.3 EFFECTS OF THE ACTION

This section considers and discusses all effects on the listed species that are caused by the proposed action and are reasonably certain to occur, including the effects of other activities that would not occur but for the proposed action.

2.10.3.1 INDIRECT INTERACTIONS

RESOURCE NEED	STRESSORS	CONSERVATION MEASURES	AMOUNT OF RESOURCE IMPACTED	INDIVIDUALS AFFECTED
Boulders (>2 per m2)			***This resource is not present in the action area*** Large boulders are not present in the project direct impact area.	***There will be no impacts to this resource, so no individuals will be affected.***
Dissolved oxygen (all stage of tulatoma snail life cycle require well oxygenated water)	No exposure path			***There will be no impacts to this resource, so no individuals will be affected.***

2.10.3.2 DIRECT INTERACTIONS

No direct interactions leading to effects on species are expected to occur from the proposed project.

2.10.4 CUMULATIVE EFFECTS

No new influences are expected in the project area.

2.10.5 DISCUSSION AND CONCLUSION

DETERMINATION: NLAA

3 CRITICAL HABITAT EFFECTS ANALYSIS

3.1 ALABAMA STURGEON CRITICAL HABITAT

This critical habitat has been excluded from analysis in this environmental review document.

JUSTIFICATION FOR EXCLUSION

In both project areas Criteria 4 (Long sections of free-flowing water to allow spawning migrations and development of eggs and larvae.) are not present due to the impoundment and movement limitations cause by the dams.

4 SUMMARY DISCUSSION AND CONCLUSION

4.1 SUMMARY DISCUSSION

Based on the suitable habitat availability along with the direct and indirect adverse and beneficial impacts, the USACE determined the proposed alternative would have No Effect on the Alabama pearlshell, Orangeacre mucket and May Affect but is not Likely to Adversely Affect the Alabama sturgeon, Georgia Rockcress, Gulf sturgeon, Inflated heelsplitter, Southern clubshell, and Tulatoma snail. The USACE also determined the proposed alternative would not adversely modify critical habitat for the Alabama Sturgeon.

4.2 CONCLUSION

The proposed alternative would have No Effect on the Alabama pearlshell, Orangeacre mucket and May Affect but is not Likely to Adversely Affect the Alabama sturgeon, Georgia Rockcress, Gulf sturgeon, Inflated heelsplitter, Southern clubshell, and Tulatoma snail. The proposed alternative also would not adversely modify critical habitat for the Alabama Sturgeon.

B.1.4.2. *Biological Opinion*

To be included upon receipt from U.S. Fish and Wildlife Service, Daphne Field Office.

B.1.5. *Fish and Wildlife Coordination Act*

B.1.5.1. *Planning Aid Letter*

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United States Department of the Interior

FISH AND WILDLIFE SERVICE
1208-B Main Street
Daphne, Alabama 36526

IN REPLY REFER TO:
2023-0009362

Colonel Jeremy J. Chapman, District Commander
U.S. Army Corps of Engineers, Mobile District
P.O. Box 2288
Mobile, AL 36628

Dear Colonel Chapman:

The U.S. Fish and Wildlife Service (Service) has prepared this Planning Aid Letter (PAL) to provide information that will help inform a feasibility study on fish passage in the Alabama River at Claiborne and Millers Ferry locks and dams. This PAL is provided in accordance with the Fish and Wildlife Coordination Act of 1958 (FWCA) (48 Stat. 401, as amended; 16 U.S.C. § 661 *et seq*.) and section 7 of the Endangered Species Act of 1973 (ESA) (87 Stat. 884, as amended; 16 U.S.C. § 1531 *et seq*.). This PAL does not constitute the report of the Secretary of the Interior as required by section 2(b) of the FWCA, nor does it constitute a biological opinion under section 7 of the ESA. The purpose of this PAL is to provide the U.S. Army Corps of Engineers (Corps) with information that identifies fish and wildlife resource values and issues, including endangered species issues. These comments are based on previous studies and government documents as well as new datasets and information provided by state and federal agencies and other partners. Continued efforts will be made to provide additional information and expertise in the form of another PAL and/or the draft FWCA report. A separate consultation will occur regarding the potential impacts of the Corps' proposal on federally threatened and endangered species protected under the ESA.

Fish Passage

Dams can contribute to declines in aquatic species populations, but migratory fishes in particular are affected when these structures prevent access to habitat for spawning (Hershey et al. 2022). Fish ladders were first designed and implemented in North America around 200 years ago (Matica 2020). Different types of fish passage structures have been developed over time; however, they are usually designed for a target species and do not consider the needs of the native fish community (Matica 2020). These structures are also designed to facilitate upstream migration and do not fully consider the importance of downstream movements of fishes post-spawn (Larinier 2001). Mortality from interaction with hydraulic turbines or over spillways can negatively affect population numbers and stability (Larinier 2001). Downstream passage can involve the use of screens to prevent fish from interacting with turbines, of surface bypasses, or of behavioral guidance devices, although the latter devices are considered experimental (Larinier 2001). Downstream fish passage success is dependent on understanding how fishes respond to accelerating flows at different times of their life cycles and how they respond to different screens or attractants at passage structures (Enders et al. 2009).

In addition to adult fish migrating downstream post-spawn, downstream dispersal of juvenile fishes is also important for population stability and survival (Pavlov and Mikheev 2017). Larval drift of broadcast spawners like sturgeon is also affected by restricted flows at dams (Marotz and Lorang 2018), which can prevent successful reproduction. Complicated life histories of aquatic species and the challenges associated with the barriers and effects of restricted flows from dams has created the need for managers to develop a toolkit for successful mitigation strategies (Katopodis 2005). This toolkit should include methods that analyze the relationship between fish migration and hydrographs, fish attraction to passage structures, passage structure hydraulics and fish passibility, fish screen hydraulics and fish responses, and development of natural structures that contain fish habitat (Katopodis 2005).

The goal of this feasibility study is to evaluate fish passage structures on the Alabama River at Claiborne Lock and Dam and at Millers Ferry Lock and Dam (L&D). The following sections discuss the study area and its aquatic resources, proposed alternatives the Corps have identified, and recommendations from the Service to consider moving forward.

Study Area

The Alabama River is part of the Alabama-Coosa-Tallapoosa River System, which has five Corps operated dams, 11 private dams, and 16 reservoirs and comprises the eastern part of the Mobile River drainage (Freeman et al. 2005). This study will focus on the reach of the Alabama River immediately below Claiborne L&D upstream to Millers Ferry L&D pool (60.5 river miles). However, if fish passage structures are constructed at both Claiborne and Millers Ferry L&D and fish passage is successful, then habitat for aquatic species, especially migratory fishes and some species of freshwater mussels, from the Mobile Delta to R.F. Henry L&D on the Alabama River would be connected for the first time since 1970. In addition, these species would also be able to access the free-flowing waters of the Cahaba River, a major tributary of the Alabama River.

Millers Ferry L&D is located in Wilcox County about 133 miles upstream of the mouth of the Alabama River, 10 miles northwest of Camden, and 30 miles southwest of Selma, Alabama (Corps 2015). Construction began in 1964 and was completed in 1970. This structure includes a concrete gravity-type dam, a gated spillway, earth dikes, a navigation lock and control station, and a 90-megawatt power plant. Millers Ferry L&D is primarily used for hydropower and navigation. It is also authorized for public recreation, water quality, and fish and wildlife conservation and mitigation purposes (Corps 2015). William “Bill” Dannelly Lake extends approximately 105 miles upstream with the lower 25 miles located in Wilcox County and the upper 80 miles located in Dallas County. It has a volume of 346,254 acre-feet at full capacity (Corps 2015).

Claiborne L&D is located downstream of Millers Ferry L&D in Monroe County, Alabama, approximately 72.5 miles upstream of the mouth of the Alabama River (Corps 2014). Construction began on this structure in 1966 and was completed in 1970. This structure includes a concrete gravity-type dam, a gated spillway, an un-gated free overflow spillway, earth dikes, and a navigation lock and control station. Claiborne L&D is primarily used as a navigation structure and regulates hydropower releases from Millers Ferry L&D. Other authorized purposes include water quality, public recreation, and fish and wildlife conservation and mitigation; however, the Corps does not consider recreation when making water control decisions (Corps 2014). This structure is also not used for flood risk management storage. Claiborne Lake extends about 60 miles upstream with the lower 28 miles located in Monroe and Clarke counties and the upper 32 miles located in Wilcox County. It has a volume of 102,480 acre-feet at full capacity (Corps 2014).

Fish and Wildlife Resources

Alabama River

Today, 44% of the Alabama River is inundated by reservoirs created by dams that were built from 1914 through the 1980s for hydropower generation and navigation (Freeman et al. 2005). As a result, altered flow regimes have negatively affected the diversity of the aquatic community. Dams create deep pool habitats with slow flows that collect silt and sediment that can favor non-native or invasive species (Boschung, Jr. and Mayden 2004). Natural flow regimes help keep sand, gravel, and cobble substrates well oxygenated and free of silt and sediment, which provides essential habitat for many native species of fish, mussels, crayfish, snails, and other macroinvertebrates (Boschung, Jr. and Mayden 2004). Free-flowing riverine habitat is still found in the main stem of the Alabama River below dams and in major tributaries free from impoundments (Freeman et al. 2005); however, these sections of riverine habitat are fragmented which has caused declines in populations and genetic diversity of fishes, freshwater mussels, and other aquatic species. Surveys of sand and gravel bar habitat in the Alabama River have documented the importance of preserving this habitat to prevent further loss of fish biodiversity (Haley and Johnston 2014). Dredging and other anthropogenic activities continue to damage and destroy this bar habitat (Haley and Johnston 2014).

Degraded water quality in the Alabama River has also negatively affected the diversity of the aquatic community. Flow control at dams can lead to low dissolved oxygen events during periods of elevated water temperatures (Hartline et al. 2020). Although flow management strategies attempt to avoid these events, little is known about how nongame fishes cope with these conditions; additionally, lack of research and data on these species' reactions to adverse conditions means they are likely underrepresented when water quality criteria for dissolved oxygen levels are developed (Hartline et al. 2020).

The Alabama Department of Environmental Management (ADEM) is required by Section 303(d) of the Clean Water Act to identify impaired waters in the state (ADEM 2022). In 2022, ADEM listed 13 tributaries of the Alabama River that were impaired because of high levels of nutrients, pesticides, siltation, pathogens (*E. coli*), and/or metals (mercury) (ADEM 2022). Claiborne Lake, including Claiborne L&D, is listed for high levels of metals (mercury) due to atmospheric deposition (ADEM 2022).

Bioaccumulation of mercury in fishes can inhibit reproduction, growth, and survival; furthermore, age, fish size, and life history characteristics all determine the severity of these effects in different species (Crump and Trudeau 2009; Zillioux 2015; Zheng et al. 2019). Sediment-bound pollutants or toxicants can be introduced into streams along with extrinsic sediments (Niraula et al. 2016). Toxicants, which include pesticides, ammonia, metals, and ions such as potassium, chloride, and sulfate, can disrupt growth, feeding, and reproduction in freshwater mussels, and prolonged exposure to toxicants can lead to death (Naimo 1995; Newton et al. 2003; Bringolf et al. 2007; Wang et al. 2016; Ciparis et al. 2019). Wang et al. (2016) also found that the few species of freshwater mussels that have been tested in toxicological studies are often common species that may be less sensitive to toxicants than species with a narrow endemic range. Freshwater gastropods, especially listed species, are more underrepresented in these studies even though they may be more sensitive to some toxicants than freshwater mussels (Gibson et al. 2016). Maintaining and improving water quality will be essential for long-term conservation of the diverse aquatic community in the Alabama River and for the recovery of its threatened and endangered species.

At-risk and federally listed species

There are several at-risk and federally listed species in or near the study area (Table 1) that could be affected by the addition of fish passage at Claiborne and Millers Ferry L&D. The following paragraphs briefly summarize life history information for each species.

Table 1. A list of at-risk and listed species that may be present in the study area or affected by fish passage at Claiborne and Millers Ferry L&D. Listed species are classified as threatened or endangered and are protected under ESA. At-risk species are those that are petitioned for listing, proposed threatened, proposed endangered, under discretionary review, or a candidate for listing. This table should not be used for Section 7 consultation, and additional species may be added in future PALs and/or in the draft FWCA report.

COMMON NAME	SCIENTIFIC NAME	TYPE	FEDERAL STATUS
Georgia rockcress	*Arabis georgiana*	Plant	Threatened
Spotted rocksnail	*Leptoxis picta*	Snail	At-risk
Tulotoma snail	*Tulotoma magnifica*	Snail	Threatened
Inflated heelsplitter	*Potamilus inflatus*	Clam	Threatened
Southern clubshell	*Pleurobema decisum*	Clam	Endangered
Alabama sturgeon	*Scaphirhynchus suttkusi*	Fish	Endangered
Gulf sturgeon	*Acipenser oxyrinchus* (=*oxyrhynchus*) *desotoi*	Fish	Threatened

Georgia rockcress is a perennial herb in the mustard family (Brassicaceae) that grows up to 90 cm (35.4 in) tall (Service 2021). It grows in a variety of dry conditions, including shallow soil accumulations on rocky bluffs, ecotones of gently sloping rock outcrops, and in sandy loam along eroding riverbanks. It is occasionally found in adjacent mesic woods, but it will not persist in heavily shaded conditions. This species is adapted to high or moderately high light intensities and occurs on soils which are circumneutral to slightly basic. It is thought that seed dispersal mainly occurs by gravity and wind; however, surface runoff or flowing rivers likely facilitate long-distance dispersal (Service 2021).

The spotted rocksnail has a shell that is globose in shape with an ovate and broadly rounded aperture (Garner et al. 2022). Juveniles have interrupted color bands that disappear in adults (Whelan et al. 2014). Females lay clutches of eggs that are coated with mucus in a spiral pattern (Whelan et al. 2014). Historically, this species was found in the Alabama River from Claiborne upstream to the Coosa River below Wetumpka, which is below the Fall Line, and from the confluence of the Alabama and Cahaba rivers upstream to Lily Shoals in Bibb County (Whelan et al. 2017). Currently, this species can be found in the Alabama River from river miles 46.0 to 231.5 and at one reintroduction site in the Cahaba River near Centreville (Whelan et al. 2017).

Tulotoma snails have dark brown or black globosely conic shells with irregularly convex to straight whorls (Garner et al. 2022). Most shells have spiral bands of tubercles and are up to 35 mm in length (Garner et al. 2022). This species can be found in localized areas of the main stem Alabama and Coosa rivers and in the free-flowing lower reaches of several tributaries (Garner et al. 2016; Garner et al. 2022). Although this species has been found under large rocks and in bedrock crevices, side-scan sonar has been successfully used to target the boulder habitat that tulotoma snails are more commonly found in (Garner et al. 2016).

The inflated heelsplitter is a unionid mussel endemic to the Mobile Basin that has a thin, moderately inflated shell (Williams et al. 2008). Generally, males are larger than females, and this species is considered a long-term brooder. Females release glochidia in the summer, and freshwater drum (*Aplodinotus grunniens*) are the only known host fish for this species. (Williams et al. 2008). Inflated heelsplitters grow rapidly, mature after one year of growth, and live for approximately eight years (Brown and Daniel 2014). These mussels inhabit large rivers and are found in slow to moderate current with sandy and muddy substrates (Williams et al. 2008).

The southern clubshell is a freshwater mussel that grows up to 93 mm in length and has a thick shell with an elliptical outline (Williams et al. 2008). This species is found in large creeks and rivers throughout the Mobile Basin in flow with gravel and sand substrates. Southern clubshell are short-term brooders and gravid females release orange or white conglutinates filled with glochidia in June and July. Blacktail shiner (*Cyprinella venusta*) and striped shiner (*Luxilus chrysocephalus*) have been identified as primary and secondary fish hosts (Williams et al. 2008).

The Alabama sturgeon is a benthic fish that eats macroinvertebrates and grows to lengths of 0.7 to 0.8m (2.3 to 2.6 ft) (Mettee et al. 1996). Most of its fins are brownish orange, and the body near the lateral scutes is yellow to tan while its belly and anal fin are white. Alabama sturgeon are endemic to the Mobile River basin, and several specimens have been collected from the Alabama River, including three adults downstream of Claiborne L&D (Mettee et al. 1996). Gravid females were collected in late March 1969 at the mouth of the Cahaba River; however, females collected in April and May 1985 from the Alabama River were not gravid (Mettee et al. 1996). Although specific spawning areas and larval drift have not been documented in Alabama sturgeon, it is likely that they spawn on hard bottom substrates in deep water and that successful larval development is dependent on long stretches of highly oxygenated, free-flowing water (Service 2009; Kuhajda and Rider 2016).

Alabama sturgeon critical habitat was designated in 2009 and encompasses 524 km (326 mi) of river channel in the Alabama and Cahaba rivers (Service 2009). The designated area in the Alabama River extends a total of 394 km (245 mi) from its confluence with Tombigbee River upstream to R.F. Henry L&D. In the Cahaba River, a total of 130 km (81 mi) of critical habitat is designated from its confluence with the Alabama River upstream to its cross with U.S. Highway

82 (Service 2009). Critical habitat is defined as areas that are occupied by the species and areas that are essential to its conservation, including those that are not occupied at the time of listing (Service 2009).

Similar to the Alabama sturgeon, Gulf sturgeon are benthic and feed on organisms that live in sediment, including bivalves, snails, crustaceans, and other macroinvertebrates (Service 2022). Gulf sturgeon are a considered a subspecies of Atlantic sturgeon (*Acipenser oxyrinchus oxyrinchus*), grow up to lengths of 2.7 m (9 ft), and live for up to 50 years (NOAA 2022). Gulf sturgeon are anadromous and migrate from freshwater rivers to marine foraging habitat in the Gulf of Mexico in the winter (Service 2022). These habitats are usually less than 7 m deep and well oxygenated with low turbidity and coarse or find sand substrates (Service 2022). Although these fish begin migrating to freshwater rivers in February and spawn in the spring (Mettee et al. 1996), fall spawning has also been documented in the Suwanee and Choctawhatchee rivers in Florida (Service 2022).

Fishes

At least 184 fishes are native to the Alabama River, with 33 of these species considered endemic (Freeman et al. 2005; Haley and Johnston 2014). In 2005, ten fishes, including seven endemic species, were federally listed, and at least 28 fish species were considered vulnerable by experts (Freeman et al. 2005). From 2010-2011, fish assemblage surveys on the Alabama River from Dixie Landing at river mile 22 upstream to Claiborne L&D only documented 48 species (Haley and Johnston 2014). These samples were not similar to historical samples and indicate a temporal shift in the fish community and a loss of diversity (Haley and Johnston 2014). Of the known fishes that inhabit the Alabama and/or Cahaba rivers, five are federally listed, including Alabama sturgeon, Gulf sturgeon, blue shiner, Cahaba shiner, and goldline darter (Table 2). Frecklebelly madtom and coal darter are currently under review for federal protection (Table 2).

Table 2. A list of fishes that are present in the Alabama and/or Cahaba rivers and their state and federal status (ADCNR and GSA unpublished dataset). Note that blue shiners (*Cyprinella caerulea)* are currently extirpated from both river systems. SP denotes a species that is state protected under the Alabama State Invertebrate Species Regulation 220-2-.98. The state ranking system abbreviations are defined as follows: S1 = critically imperiled, S2 = imperiled, S3 = vulnerable, S4 = apparently secure, S5 = secure, SX = presumed extirpated, and SE = exotic (ADCNR 2017).

COMMON NAME	**SCIENTIFIC NAME**	**STATE STATUS**	**FEDERAL STATUS**
Chestnut lamprey	*Ichthyomyzon castaneus*	S5	-
Southern brook lamprey	*Ichthyomyzon gagei*	S5	-
Least brook lamprey	*Lampetra aepyptera*	S5	-
Gulf sturgeon	*Acipenser oxyrinchus desotoi*	S2, SP	Threatened
Alabama sturgeon	*Scaphirhynchus suttkusi*	S1, SP	Endangered
Paddlefish	*Polyodon spathula*	S3	-

Alligator gar	*Atractosteus spatula*	S3	-
Spotted gar	*Lepisosteus oculatus*	S5	-
Longnose gar	*Lepisosteus osseus*	S5	-
Bowfin	*Amia calva*	S5	-
Mooneye	*Hiodon tergisus*	S3	-
American eel	*Anguilla rostrata*	S4	-
Bay anchovy	*Anchoa mitchilli*	S5	-
Alabama shad	*Alosa alabamae*	S1	-
Skipjack Herring	*Alosa chrysochloris*	S3	-
Gulf Menhaden	*Brevoortia patronus*	S5	-
Gizzard Shad	*Dorosoma cepedianum*	S5	-
Threadfin Shad	*Dorosoma petenense*	S5	-
Largescale Stoneroller	*Campostoma oligolepis*	S5	-
Goldfish	*Carassius auratus*	-	-
Grass carp	*Ctenopharyngodon idella*	-	-
Blue shiner	*Cyprinella caerulea*	S1, SP	Threatened
Alabama shiner	*Cyprinella callistia*	S5	-
Tricolor shiner	*Cyprinella trichroistia*	S5	-
Blacktail shiner	*Cyprinella venusta*	S5	-
Common carp	*Cyprinus carpio*	-	-
Cypress minnow	*Hybognathus hayi*	S3	-
Mississippi silvery minnow	*Hybognathus nuchalis*	S4	-
Clear chub	*Hybopsis winchelli*	S5	-
Bighead carp	*Hypopthalmichthys nobilis*	-	-
Striped shiner	*Luxilus chrysocephalus*	S5	-
Pretty shiner	*Lythrurus bellus*	S5	-
Mountain shiner	*Lythrurus lirus*	S4	-
Cherryfin shiner	*Lythrurus roseipinnis*	S5	-
Mobile chub	*Macrhybopsis boschungi*	S3	-
Coosa chub	*Macrhybopsis etnieri*	S4	-
Silver chub	*Macrhybopsis storeriana*	S5	-
Bluehead chub	*Nocomis bellicus*	S5	-
Golden shiner	*Notemigonus crysoleucas*	S5	-
Orangefin shiner	*Notropis ammophilus*	S5	-
Longjaw minnow	*Notropis amplamala*	S5	-
Burrhead shiner	*Notropis asperifrons*	S5	-
Emerald shiner	*Notropis atherinoides*	S5	-
Rough shiner	*Notropis baileyi*	S5	-

Cahaba shiner	*Notropis cahabae*	S1, SP	Endangered
Silverside shiner	*Notropis candidus*	S5	-
Ironcolor shiner	*Notropis chalybaeus*	S1, SP	-
Rainbow shiner	*Notropis chrosomus*	S5	-
Fluvial shiner	*Notropis edwardraneyi*	S4	-
Longnose shiner	*Notropis longirostris*	S5	-
Taillight shiner	*Notropis maculatus*	S4	-
Coastal shiner	*Notropis petersoni*	S5	-
Silverstripe shiner	*Notropis stilbius*	S5	-
Weed shiner	*Notropis texanus*	S5	-
Skygazer shiner	*Notropis uranoscopus*	S3	-
Mimic shiner	*Notropis volucellus*	S5	-
Pugnose minnow	*Opsopoeodus emiliae*	S5	-
Riffle minnow	*Phenacobius catostomus*	S5	-
Bluntnose minnow	*Pimephales notatus*	S5	-
Fathead minnow	*Pimephales promelas*	S5	-
Bullhead minnow	*Pimephales vigilax*	S5	-
Sailfin shiner	*Pteronotropis hypselopterus*	S5	-
Flagfin shiner	*Pteronotropis signipinnis*	S5	-
Bluenose shiner	*Pteronotropis welaka*	S2	-
Creek chub	*Semotilus atromaculatus*	S5	-
Dixie chub	*Semotilus thoreauianus*	S5	-
Quillback	*Carpiodes cyprinus*	S5	-
Highfin carpsucker	*Carpiodes velifer*	S5	-
Southeastern blue sucker	*Cycleptus meridionalis*	S4	-
Creek chubsucker	*Erimyzon oblongus*	S5	-
Lake chubsucker	*Erimyzon sucetta*	S5	-
Sharpfin chubsucker	*Erimyzon tenuis*	S5	-
Alabama hog sucker	*Hypentelium etowanum*	S5	-
Smallmouth buffalo	*Ictiobus bubalus*	S5	-
Spotted sucker	*Minytrema melanops*	S5	-
River redhorse	*Moxostoma carinatum*	S5	-
Black redhorse	*Moxostoma duquesnei*	S5	-
Golden redhorse	*Moxostoma erythrurum*	S5	-
Blacktail redhorse	*Moxostoma poecilurum*	S5	-
Black bullhead	*Ameiurus melas*	S5	-
Yellow bullhead	*Ameiurus natalis*	S5	-
Brown bullhead	*Ameiurus nebulosus*	S5	-
Blue catfish	*Ictalurus furcatus*	S5	-
Channel catfish	*Ictalurus punctatus*	S5	-

Black madtom	*Noturus funebris*	S5	-
Tadpole madtom	*Noturus gyrinus*	S5	-
Speckled madtom	*Noturus leptacanthus*	S5	-
Frecklebelly madtom	*Notutus munitus*	S1, SP	Under Review
Freckled madtom	*Noturus nocturnus*	S5	-
Flathead catfish	*Pylodictis olivaris*	S5	-
Redfin pickerel	*Esox americanus*	S5	-
Chain pickerel	*Esox niger*	S5	-
Pirate perch	*Aphredoderus sayanus*	S5	-
Striped mullet	*Mugil cephalus*	S5	-
Stout silverside	*Labidesthes vanhyningi*	S5	-
Inland silverside	*Menidia beryllina*	S5	-
Atlantic needlefish	*Strongylura marina*	S5	-
Western starhead topminnow	*Fundulus blairae*	S4	-
Blackstripe topminnow	*Fundulus notatus*	S5	-
Bayou topminnow	*Fundulus notti*	S5	-
Blackspotted topminnow	*Fundulus olivaceus*	S5	-
Southern studfish	*Fundulus stellifer*	S5	-
Rainwater killifish	*Lucania parva*	S4	-
Western mosquitofish	*Gambusia affinis*	S5	-
Eastern mosquitofish	*Gambusia holbrooki*	S5	-
Least killifish	*Heterandria formosa*	S4	-
Banded sculpin	*Cottus carolinae*	S5	-
White bass	*Morone chrysops*	S5	-
Yellow bass	*Morone mississippiensis*	S5	-
Striped bass	*Morone saxatilis*	S3	-
Shadow bass	*Ambloplites ariommus*	S5	-
Flier	*Centrarchus macropterus*	S5	-
Bluespotted sunfish	*Enneacanthus gloriosus*	S4	-
Redbreast sunfish	*Lepomis auritus*	S5	-
Green sunfish	*Lepomis cyanellus*	S5	-
Warmouth	*Lepomis gulosus*	S5	-
Orangespotted sunfish	*Lepomis humilis*	S5	-
Bluegill	*Lepomis macrochirus*	S5	-
Dollar sunfish	*Lepomis marginatus*	S5	-
Longear sunfish	*Lepomis megalotis*	S5	-
Redear sunfish	*Lepomis microlophus*	S5	-
Redspotted sunfish	*Lepomis miniatus*	S5	-

Cahaba bass	*Micropterus cahabae*	S5	-
Alabama bass	*Micropterus henshalli*	S5	-
Largemouth bass	*Micropterus salmoides*	S5	-
White crappie	*Pomoxis annularis*	S5	-
Black crappie	*Pomoxis nigromaculatus*	S5	-
Naked sand darter	*Ammocrypta beanii*	S5	-
Southern sand darter	*Ammocrypta meridiana*	S5	-
Crystal darter	*Crystallaria asprella*	S3, SP	-
Redspot darter	*Etheostoma artesiae*	S5	-
Bluntnose darter	*Etheostoma chlorosoma*	S5	-
Swamp darter	*Etheostoma fusiforme*	S5	-
Harlequin darter	*Etheostoma histrio*	S5	-
Greenbreast darter	*Etheostoma jordani*	S5	-
Johnny darter	*Etheostoma nigrum*	S5	-
Goldstripe darter	*Etheostoma parvipinne*	S5	-
Cypress darter	*Etheostoma proeliare*	S5	-
Alabama darter	*Etheostoma ramseyi*	S5	-
Rock darter	*Etheostoma rupestre*	S5	-
Speckled darter	*Etheostoma stigmaeum*	S5	-
Gulf darter	*Etheostoma swaini*	S5	-
Backwater darter	*Etheostoma zonifer*	S5	-
Goldline darter	*Percina aurolineata*	S2, SP	Threatened
Coal darter	*Percina brevicauda*	S2	Under Review
Mobile logperch	*Percina kathae*	S5	-
Freckled darter	*Percina lenticula*	S3	-
Blackside darter	*Percina maculata*	S5	-
Blackbanded darter	*Percina nigrofasciata*	S5	-
Dusky darter	*Percina sciera*	S5	-
River darter	*Percina shumardi*	S5	-
Gulf logperch	*Percina suttkusi*	S5	-
Saddleback darter	*Percina vigil*	S5	-
Walleye	*Sander vitreus*	S4	-
Freshwater drum	*Aplodinotus grunniens*	S5	-
Everglades pygmy sunfish	*Elassoma evergladei*	S3	-
Banded pygmy sunfish	*Elassoma zonatum*	S5	-
Southern flounder	*Paralichthys lethostigma*	-	-
Hogchoker	*Trinectes maculatus*	S5	-

Freshwater mussels

Alabama has more freshwater mussels than any other state at approximately 173 species that represent 43 genera and both Margaritiferidae and Unionidae families (Williams et al. 2008). The Mobile River basin has roughly 73 species of mussels with 34 of these species considered endemic. The eastern part of this drainage, which includes the Alabama River, has about 67 species with 30 considered endemic (Williams et al. 2008). Of the known mussel species that inhabit the Alabama and/or Cahaba rivers, 13 are federally listed and seven are under review for federal protection (Table 3).

Table 3. A list of freshwater mussels and their host fishes that are present in the Alabama and/or Cahaba rivers and their state and federal status (ADCNR and GSA unpublished dataset). Known host fishes are also noted. SP denotes a species that is state protected under the Alabama State Invertebrate Species Regulation 220-2-.98. The state ranking system abbreviations are defined as follows: S1 = critically imperiled, S2 = imperiled, S3 = vulnerable, S4 = apparently secure, S5 = secure, SX = presumed extirpated, and SE = exotic (ADCNR 2017).

COMMON NAME	SCIENTIFIC NAME	HOST FISH(ES)	STATE STATUS	FEDERAL STATUS
Alabama pearlshell	*Margaritifera marrianae*	Redfin pickerel, Chain pickerel	S1, SP	Endangered
Amblema	*Amblema* sp.		S4	-
Rock pocketbook	*Arcidens confragosus*	American eel, Rock bass, White crappie, Skipjack herring, Channel catfish	S3	-
Alabama rainbow	*Cambraunio nebulosa*	Cahaba bass, Largemouth bass	S2, SP	Under Review
Coosa orb	*Cyclonaias kieneriana*	-	S5	-
Butterfly	*Ellipsaria lineolata*	-	S4	-
Alabama spike	*Elliptio arca*	Southern sand darter, Redspot darter, Blackbanded darter	S1, SP	Under Review
Delicate spike	*Elliptio arctata*	-	S2, SP	Under Review
Elephantear	*Elliptio crassidens*	-	S4	-
Upland combshell	*Epioblasma metastriata*	-	SX	Endangered
Southern combshell	*Epioblasma penita*	Mobile logperch, Blackbanded darter	SX, SP	Endangered
Gulf pigtoe	*Fusconaia cerina*	Alabama shiner, Blacktail shiner, Pretty shiner, Orangefin shiner, Emerald shiner, Silverstripe	S4	-

		shiner, Bluntnose minnow		
Round pearlshell	*Glebula rotundata*	Hogchoker, Green sunfish, Bluegill, Bay anchovy, Spotted gar	S4	-
Finelined pocketbook	*Hamiota altilis*	Cahaba bass, Alabama bass, Largemouth bass	S2, SP	Threatened
Orangenacre mucket	*Hamiota perovalis*	Cahaba bass, Alabama bass, Largemouth bass	S2, SP	Threatened
Little spectaclecase	*Leaunio lienosa*	Green sunfish, Bluegill, Largemouth bass, Brown bullhead	S5	-
Southern pocketbook	*Lampsilis ornata*	Alabama bass, Largemouth bass	S5	-
Southern fatmucket	*Lampsilis straminea*	Bluegill, Alabama bass, Largemouth bass	S4	-
Yellow sandshell	*Lampsilis teres*	Green sunfish, Largemouth bass, White crappie, Black crappie, Spotted gar, Longnose gar	S5	-
Alabama heelsplitter	*Lasmigona alabamensis*	Skipjack herring	S3	-
Etowah heelsplitter	*Lasmigona etowaensis*	Banded sculpin	S2, SP	Under Review
Black sandshell	*Ligumia recta*	Largemouth bass, White crappie, Walleye	S2, SP	-
Alabama moccasinshell	*Medionidus acutissimus*	Naked sand darter, Southern sand darter, Johnny darter, Speckled darter, Gulf darter, Mobile logperch, Blackbanded darter, Saddleback darter	S1, SP	Threatened

Coosa moccasinshell	*Medionidus parvulus*	Mobile logperch, Blackbanded darter	SX, SP	Endangered
Washboard	*Megalonaias nervosa*	Bluegill, Longear sunfish, Alabama bass, Largemouth bass, White crappie, Black crappie, Mooneye, Brown bullhead, Longnose gar	S5	-
Threehorn wartyback	*Obliquaria reflexa*	Gizzard shad, Blacktail shiner, Bluntnose minnow, Mooneye, Walleye, Freshwater drum	S5	-
Southern hickorynut	*Obovaria arkansasensis*	-	S1, SP	-
Alabama hickorynut	*Obovaria unicolor*	Naked sand darter, Southern sand darter, Redspot darter, Johnny darter, Gulf darter, Blackbanded darter, Dusky darter	S2, SP	Under Review
Bankclimber	*Plectomerus dombeyanus*	-	S5	-
Southern clubshell	*Pleurobema decisum*	Alabama shiner, Blacktail shiner, Striped shiner, Clear chub	S2, SP	Endangered
Ovate clubshell	*Pleurobema perovatum*	Striped shiner	S1, SP	Endangered
Warrior pigtoe	*Pleurobema rubellum*	Alabama shiner, Blacktail shiner, Creek chub	S1, SP	Endangered
Heavy pigtoe	*Pleurobema taitianum*	-	S1, SP	Endangered
True pigtoe	*Pleurobema verum*	-	SX	-
Fragile papershell	*Potamilus fragilis*	Freshwater drum	S5	-
Inflated heelsplitter	*Potamilus inflatus*	Freshwater drum	S2, SP	Threatened
Bleufer	*Potamilus purpuratus*	Freshwater drum	S5	-
Alabama creekmussel	*Pseudodontiodeus connasaugaensis*	Banded sculpin, Yellow bullhead	S2, SP	-

Triangular kidneyshell	*Ptychobranchus foremanianus*	Mobile logperch, Blackbanded darter	S1, SP	Endangered
Giant floater	*Pyganodon grandis*	Largemouth bass, White crappie, Black crappie, Yellow bullhead, Brown bullhead	S5	-
Southern mapleleaf	*Quadrula apiculata*	Channel catfish	S4	-
Ridged mapleleaf	*Quadrula rumphiana*	Channel catfish	S5	-
Ebonyshell	*Reginaia ebena*	-	S5	-
Pondmussel	*Sagittunio subrostrata*	Bowfin, Largemouth bass, Tadpole madtom	S4	-
Rayed creekshell	*Strophitus radiatus*	-	S2, SP	Under Review
Southern monkeyface	*Theliderma johnsoni*	-	S2, SP	-
Stirrupshell	*Theliderma stapes*	-	SX	Endangered
Southern purple lilliput	*Toxolasma corvunculus*	-	S1, SP	Under Review
Lilliput	*Toxolasma parvum*	-	S4	-
Pistolgrip	*Tritogonia verrucosa*	Weed shiner, Black bullhead, Yellow bullhead, Brown bullhead, Channel catfish	S4	-
Gulf mapleleaf	*Tritogonia nobilis*	Channel catfish	S3	-
Fawnsfoot	*Truncilla donaciformis*	Freshwater drum	S3	-
Pondhorn	*Uniomerus tetralasmus*	-	S4	-
Paper pondshell	*Utterbackia imbecillis*	Largemouth bass, Black crappie	S5	-
Southern rainbow	Villosa vibex	Longear sunfish, Largemouth bass	S5	Endangered

Crayfish, gastropods, and other macroinvertebrates
Similar to fishes and freshwater mussels, dam construction also negatively impacts populations of native crayfishes, gastropods, and other macroinvertebrates (Tiemann 2013; Krajenbrink et al. 2019; Barnett and Adams 2021). There are currently records of 31 different species of crayfish from the Alabama and Cahaba rivers, including one under review for federal status and 11 that are state protected (Schuster et al. 2022; Table 4).

Table 4. The 11 species listed in this table are crayfish found in the Alabama and/or Cahaba rivers that are state protected and/or under review for federal protection (ADCNR and GSA unpublished dataset). SP denotes a species that is state protected under the Alabama State Invertebrate Species Regulation 220-2-.98. The state ranking system abbreviations are defined

as follows: S1 = critically imperiled, S2 = imperiled, S3 = vulnerable, S4 = apparently secure, S5 = secure, SX = presumed extirpated, and SE = exotic (ADCNR 2017).

COMMON NAME	SCIENTIFIC NAME	STATE STATUS	FEDERAL STATUS
Angular dwarf crayfish	*Cambarellus lesliei*	S1, SP	-
Speckled burrowing crayfish	*Creaserinus danielae*	S2, SP	Under Review
Shrimp crayfish	*Faxonius lancifer*	S2, SP	-
Prominence riverlet crayfish	*Hobbseus prominens*	S2, SP	-
Cockscomb crayfish	*Procambarus clemmeri*	S2, SP	-
Panhandle crayfish	*Procambarus evermanni*	S2, SP	-
Southern prairie crayfish	*Procambarus h. hagenianus*	S2, SP	-
Celestial crayfish	*Procambarus holifieldi*	S2, SP	-
Smoothnose crayfish	*Procambarus hybus*	S2, SP	-
Spur crayfish	*Procambarus lewisi*	S2, SP	-
Criscross crayfish	*Procambarus marthae*	S2, SP	-

There are currently records of 53 unique species of gastropods in the Alabama and Cahaba rivers which represent 10 families, including Lymnaeidae, Physidae, Planorbidae, Viviparidae, Amnicolidae, Emmericidae, Hydrobiidae, Lithoglyphidae, Pleuroceridae, and Pomatiopsidae (ADCNR and GSA unpublished dataset). Twenty of these species are state and/or federally protected or under review (Table 5).

Table 5. The 20 species listed in this table are gastropods found in the Alabama and/or Cahaba rivers that are state protected and/or have federal status or are under review (ADCNR and GSA unpublished dataset). SP denotes a species that is state protected under the Alabama State Invertebrate Species Regulation 220-2-.98. The state ranking system abbreviations are defined as follows: S1 = critically imperiled, S2 = imperiled, S3 = vulnerable, S4 = apparently secure, S5 = secure, SX = presumed extirpated, and SE = exotic (ADCNR 2017).

COMMON NAME	SCIENTIFIC NAME	STATE STATUS	FEDERAL STATUS
Cahaba ancylid	*Rhodacmea cahawbensis*	S1, SP	-
Cylindrical lioplax	*Lioplax cyclostomatiformis*	S1, SP	Endangered
Tulotoma	*Tulotoma magnifica*	S2, SP	Threatened
Watercress snail	*Fontigens nickliniana*	S1, SP	-
Coosa pyrg	*Marstonia hershleri*	S1, SP	-
Cahaba pebblesnail	*Clappia cahabensis*	S2, SP	-
Flat pebblesnail	*Lepyrium showalteri*	S1, SP	Endangered
Mud elimia	*Elimia alabamensis*	S3	Under Review
Ample elimia	*Elimia ampla*	S2, SP	Under Review
Lilyshoals elimia	*Elimia annettae*	S2, SP	Under Review
Princess elimia	*Elimia bellacrenata*	S1, SP	Under Review
Cockle elimia	*Elimia cochliaris*	S1, SP	Under Review
Teardrop elimia	*Elimia lachryma*	S1, SP	Under Review

Caper elimia	*Elimia olivula*	S3	Under Review
Compact elimia	*Elimia showalterii*	S3	Under Review
Puzzle elimia	*Elimia varians*	S2, SP	-
Squat elimia	*Elimia variata*	S2, SP	-
Round rocksnail	*Leptoxis ampla*	S2, SP	Threatened
Oblong rocksnail	*Leptoxis compacta*	S1	Under Review
Spotted rocksnail	*Leptoxis picta*	S2, SP	Under Review

Effects on crayfishes, gastropods, and other macroinvertebrates will be further explored in a future PAL and/or in the draft FWCA report.

Proposed Alternatives

The Corps began this feasibility study with an initial array of 17 alternatives, which included partial and/or full structure removal at one or both dam locations. The following alternatives have been selected for consideration for habitat modelling and economic analysis:

- Alternative 1: No action
- Alternative 3: Fixed weir rock arch both dams
- Alternative 5d: Natural bypass channel both dams
- Alternative 12b: Fixed weir rock arch at Claiborne L&D and natural bypass channel at Millers Ferry L&D
- Alternative 13b: Natural bypass channel at Claiborne L&D and fixed weir rock arch at Miller's Ferry L&D

The Corps has noted that additives for attraction to fish passage structures will be added to these alternatives and evaluated in the future. Currently, 19 priority fishes are being modelled to evaluate habitat availability and fish passibility of the different passage structures (Table 6).

Table 6. The priority species listed in this table are being used as a representative subset of the fish community to evaluate the fish passibility of each alternative (ADCNR and GSA unpublished dataset). SP denotes a species that is state protected under the Alabama State Invertebrate Species Regulation 220-2-.98. The state ranking system abbreviations are defined as follows: S1 = critically imperiled, S2 = imperiled, S3 = vulnerable, S4 = apparently secure, S5 = secure, SX = presumed extirpated, and SE = exotic (ADCNR 2017).

COMMON NAME	**SCIENTIFIC NAME**	**STATE STATUS**	**FEDERAL STATUS**
Mobile logperch	*Percina kathae*	S5	-
Gulf logperch	*Percina suttkusi*	S5	-
Blacktail shiner	*Cyprinella venusta*	S5	-
Freshwater drum	*Aplodinotus grunniens*	S5	-
Chain pickerel	*Esox niger*	S5	-
Largemouth bass	*Micropterus salmoides*	S5	-
Skipjack herring	*Alosa chrysochloris*	S3	-
Alabama shad	*Alosa alabamae*	S1	-
Striped bass	*Morone saxatilis*	S3	-

Crystal darter	*Crystallaria asprella*	S3, SP	-
River redhorse	*Moxostoma carinatum*	S5	-
Southeastern blue sucker	*Cycleptus meridionalis*	S4	-
Alabama sturgeon	*Scaphirhynchus suttkusi*	S1, SP	Endangered
Gulf sturgeon	*Acipenser oxyrinchus (=oxyrhynchus) desotoi*	S2, SP	Threatened
Mississippi silvery minnow	*Hybognathus nuchalis*	S4	-
Southern walleye	*Sander* sp. cf. *vitreus*	S4	-
American eel	*Anguilla rostrata*	S4	-
Smallmouth buffalo	*Ictiobus bubalus*	S5	-
Paddlefish	*Polyodon spathula*	S3	-

Recommendations

In addition to additives for fish attraction to proposed passage structures, which could include changes to the regulation of flow, we also recommend the Corps consider mitigation measures that will facilitate downstream migration of fishes and restore natural flow regimes as much as possible. As discussed, downstream migration is an essential component of many migratory fishes' life cycles, and mortality from interaction with hydraulic turbines or over spillways can negatively affect population numbers and stability (Larinier 2001). Downstream passage can involve the use of screens to prevent fish from interacting with turbines, of surface bypasses, or of behavioral guidance devices, although the latter devices are considered experimental (Larinier 2001). Restoration of natural flows would also benefit native aquatic species, including several listed and at-risk fishes, freshwater mussels, crayfish, and gastropods, by re-connecting populations and improving water quality and habitat.

Our recommendations in this PAL are preliminary. We look forward to receiving the results of the habitat modelling and economic analyses of different fish passage alternatives that the Corps is currently conducting and the selection of the final alternative. If you have any questions about this PAL, please contact Morgan Brizendine of my staff at (251) 441-5839 or at morgan_brizendine@fws.gov. Please refer to the reference number located at the top of this letter in future phone calls or written correspondence.

Sincerely,

WILLIAM PEARSON
Digitally signed by WILLIAM PEARSON
Date: 2022.10.31 15:59:38 -05'00'

William J Pearson
Field Supervisor
Alabama Ecological Services Field Office

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B.1.5.2. *Coordination Act Report*

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March 3, 1849

United States Department of the Interior

FISH AND WILDLIFE SERVICE
1208-B Main Street
Daphne, Alabama 36526

APR 14 2023

IN REPLY REFER TO:
2023-0009362

Colonel Jeremy J. Chapman, District Commander
U.S. Army Corps of Engineers, Mobile District
P.O. Box 2288
Mobile, AL 36628

Dear Colonel Chapman:

The U.S. Fish and Wildlife Service (Service) has prepared this Draft Fish and Wildlife Coordination Act Report (DFWCAR) to provide comments and recommendations on the Claiborne and Millers Ferry Locks and Dams Fish Passage Study (Alabama River, Alabama). This DFWCAR is provided in partial fulfillment and accordance with the Fish and Wildlife Coordination Act of 1958 (FWCA; 48 Stat. 401, as amended, 16 U.S.C. §661 et seq.). In addition, our comments are submitted pursuant to our authorities under the Endangered Species Act of 1973 (ESA; 87 Stat. 884, as amended, 16 U.S.C. §1531 et seq.), Migratory Bird Treaty Act of 1918 (MBTA; as amended, 16 U.S.C. §703 et seq.), and Executive Order 13186 for the Conservation of Migratory Birds, Bald and Golden Eagle Protection Act (BGEPA; as amended, 16 U.S.C. §668 et seq.). This DFWCAR does not constitute the final report of the Secretary of the Interior as required by section 2(b) of the FWCA, nor does it constitute a biological opinion under section 7 of the ESA. A separate consultation will occur regarding the potential impacts of the Corps' proposal on federally threatened and endangered species protected under the ESA.

The purpose of this DFWCAR is to provide the U.S. Army Corps of Engineers (Corps) with information that identifies fish and wildlife resource values and issues, including endangered species concerns. These comments are based on previous studies and government documents as well as new datasets and information provided by state and federal agencies and other partners. Continued efforts will be made to provide additional information and expertise in the form of a final FWCAR. This DFWCAR will be concurrently distributed to the National Oceanic Atmospheric Administration and the Alabama Department of Conservation and Natural Resources. We have requested that they provide comments or other information to be used in our final report.

After comparing the No Action Alternative and the Tentatively Selected Plan (TSP) of constructing natural bypass structures at both Claiborne and Millers Ferry L&D, the Service prefers the TSP. However, more information on design, particularly on details that will address downstream migration, additives for fish attraction to passage structures, and other factors that will affect the passability of the structures, will be needed in order for the Service to fully evaluate this alternative in the final FWCAR. In addition, the Service recommends that the

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Corps consider wetland mitigation, migratory bird conservation measures, and recreational area preservation or improvement to conserve all habitats potentially affected by the project and to benefit all resources.

We look forward to continuing to work with the Corps as they begin the next phase of this study and finalize the design of their selected alternative.

If you have any questions about this DFWCAR, please contact Morgan Brizendine of my staff by phone at 251-441-5839 or by e-mail at morgan_brizendine@fws.gov.

Sincerely,

WILLIAM PEARSON
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William J. Pearson
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Enclosures

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EXECUTIVE SUMMARY

The U.S. Army Corps of Engineers (Corps), under Section 216 of the Flood Control Act of 1970, has recognized that Claiborne and Millers Ferry Locks and Dams (L&D) on the lower Alabama River have impeded the historical migration of numerous fish species, including listed species like the Alabama sturgeon, and have led to loss of habitat connectivity that also affects other native aquatic species. The Claiborne and Millers Ferry Locks and Dams Fish Passage Study will address ecosystem restoration of the Alabama River in a feasibility report that will be finalized in 2024. Objectives of the study include increasing spatial distribution of aquatic species while encouraging balanced native populations in the Alabama River system; increasing habitat connectivity for migration, spawning, foraging, and nurseries for native fish and mussel species in the Alabama River system; and restoring a more natural flow regime to improve migration and post-spawning life cycle requirements. This Draft Fish and Wildlife Coordination Act Report (DFWCAR) describes the status of fish and wildlife resources in the study area, including endangered species concerns, describes the proposed alternatives, evaluates the Tentatively Selected Plan (TSP), and provides U.S. Fish and Wildlife Service (Service) conservation measures and recommendations.

Based on the analyses presented by the Corps on March 1, 2023, the Service tentatively supports the selected alternative (5d) of construction of natural bypass structures at both Claiborne and Millers Ferry L&D and currently prefers this option over the No Action Alternative. However, more information on design, particularly on details that will address downstream migration, additives for fish attraction to passage structures, and other factors that will affect the passability of the structures, including but not limited to the timing and duration of flows through the bypass channel, will be needed in order for the Service to fully evaluate this alternative in the final FWCAR. In addition, the Service recommends that the Corps consider wetland mitigation, migratory bird conservation measures, and recreational area preservation or improvement to conserve all habitats potentially affected by the project and to benefit all resources. We also recommend implementing criteria from the Service's *Fish Passage Engineering Design Criteria* (2017) guidelines and conservation measures from the East Gulf Coastal Plain Joint Venture Implementation Plan when feasible.

TABLE OF CONTENTS

INTRODUCTION

Authority

The Claiborne and Millers Ferry Locks and Dams Fish Passage Study (Alabama River, Alabama) is authorized by Section 216 of the Flood Control Act of 1970 (33 U.S.C. 549a) for "investigations for modification of completed projects or their operations when found advisable due to significantly changed physical or economic conditions and for improving the quality of the environment in the overall public interest" (Corps 2022). The Service's involvement in this study is authorized by the Fish and Wildlife Coordination Act (FWCA; 48 Stat. 401, as amended; 16 U.S.C. § 661 et seq.). Under the National Letter of Agreement, the Corps transferred funds to the Service for completion of this report.

Purpose and Scope

The Corps, under Section 216 of the Flood Control Act of 1970, has recognized that Claiborne and Millers Ferry Locks and Dams (L&D) on the lower Alabama River have impeded the historical migration of numerous fish species, including listed species like the Alabama sturgeon (Corps 2022), and have led to loss of habitat connectivity that also affects other native aquatic species. This study will address ecosystem restoration of the Alabama River in a feasibility report that will be finalized in 2024, and the following planning objectives have been identified (Corps 2022):

- Increase spatial distribution of aquatic species while encouraging balanced native populations in the Alabama River system.
- Increase habitat connectivity for migration, spawning, foraging, and nurseries for native fish and mussel species in the Alabama River system.
- Restore a more natural flow regime to improve migration and post-spawning life cycle requirements.

During the Tentatively Selected Plan (TSP) milestone meeting on March 1, 2023, the Corps also identified the following constraints for the study:

- Avoid/minimize adverse impacts to threatened and endangered species.
- Avoid impacts to dam head limits and access to Corps facilities.
- Minimize impacts to authorized purposes of navigation and hydropower.

Prior Studies and Reports

The following studies and/or reports are pertinent documents used to produce the DFWCAR:

U.S. Army Corps of Engineers (Corps). 2022. Approval of Review Plan for the Claiborne and Millers Ferry Locks and Dams Fish Passage Study, Alabama River, Alabama. Memorandum for Commander, Mobile District, Mobile, Alabama. 18 pp.

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DESCRIPTION OF STUDY AREA

Lower Alabama River Dams

The Alabama River is part of the Alabama-Coosa-Tallapoosa River System, which has five Corps operated dams, 11 private dams, and 16 reservoirs and comprises the eastern part of the Mobile River drainage (Freeman et al. 2005; Figure 1). This study will focus on the reach of the Alabama River immediately below Claiborne L&D upstream to Millers Ferry L&D pool (60.5 river miles). However, if fish passage structures are constructed at both Claiborne and Millers Ferry L&D and fish passage is successful, then habitat for aquatic species, especially migratory fishes and some species of freshwater mussels, from the Mobile Delta to R.F. Henry L&D on the Alabama River would be connected for the first time since 1970. In addition, these species would also be able to access the free-flowing waters of the Cahaba River, a major tributary of the Alabama River.

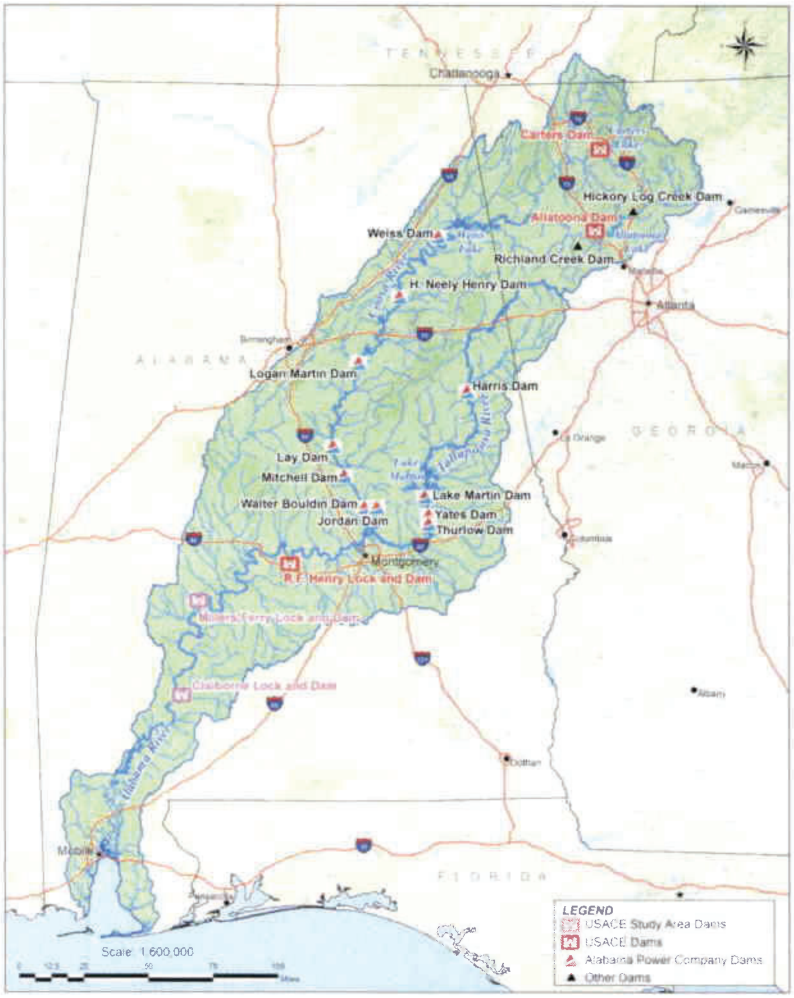


Figure 1. Map of the Alabama-Coosa-Tallapoosa River system that shows both public and private dam facilities. Claiborne and Millers Ferry L&D are the two lowermost dams and are part of the Corps' fish passage study. Map provided by the Corps during the TSP milestone meeting on March 1, 2023.

Millers Ferry L&D is located in Wilcox County about 133 miles upstream of the mouth of the Alabama River, 10 miles northwest of Camden, and 30 miles southwest of Selma, Alabama (Corps 2015). Construction began in 1964 and was completed in 1970. This structure includes a concrete gravity-type dam, a gated spillway, earth dikes, a navigation lock and control station, and a 90-megawatt power plant. Millers Ferry L&D is primarily used for hydropower and navigation. It is also authorized for public recreation, water quality, and fish and wildlife conservation and mitigation purposes (Corps 2015). William "Bill" Dannelly Reservoir extends approximately 105 miles upstream with the lower 25 miles located in Wilcox County and the upper 80 miles located in Dallas County. It has a volume of 346,254 acre-feet at full capacity (Corps 2015).

Claiborne L&D is located downstream of Millers Ferry L&D in Monroe County, Alabama, approximately 72.5 miles upstream of the mouth of the Alabama River (Corps 2014).

Construction began on this structure in 1966 and was completed in 1970. This structure includes a concrete gravity-type dam, a gated spillway, an un-gated free overflow spillway, earth dikes, and a navigation lock and control station. Claiborne L&D is primarily used as a navigation structure and regulates hydropower releases from Millers Ferry L&D. Other authorized purposes include water quality, public recreation, and fish and wildlife conservation and mitigation; however, the Corps does not consider recreation when making water control decisions (Corps 2014). This structure is also not used for flood risk management storage. Claiborne Reservoir extends about 60 miles upstream with the lower 28 miles located in Monroe and Clarke counties and the upper 32 miles located in Wilcox County. It has a volume of 102,480 acre-feet at full capacity (Corps 2014).

Alabama River Water Quality

Today, 44% of the Alabama River is inundated by reservoirs created by dams that were built from 1914 through the 1980s for hydropower generation and navigation (Freeman et al. 2005). As a result, altered flow regimes have negatively affected the diversity of the aquatic community. Dams create deep pool habitats with slow flows that collect silt and sediment that can favor non-native or invasive species (Boschung, Jr. and Mayden 2004). Natural flow regimes help keep sand, gravel, and cobble substrates well oxygenated and free of silt and sediment, which provides essential habitat for many native species of fish, mussels, crayfish, snails, and other macroinvertebrates (Boschung, Jr. and Mayden 2004). Free-flowing riverine habitat is still found in the main stem of the Alabama River below dams and in major tributaries free from impoundments (Freeman et al. 2005); however, these sections of riverine habitat are fragmented which has caused declines in populations and genetic diversity of fishes, freshwater mussels, and other aquatic species. Surveys of sand and gravel bar habitat in the Alabama River have documented the importance of preserving this habitat to prevent further loss of fish biodiversity (Haley and Johnston 2014). Dredging and other anthropogenic activities continue to damage and destroy this bar habitat (Haley and Johnston 2014).

Degraded water quality in the Alabama River has also negatively affected the diversity of the aquatic community. Flow control at dams can lead to low dissolved oxygen events during periods of elevated water temperatures (Hartline et al. 2020). Although flow management strategies attempt to avoid these events, little is known about how nongame fishes cope with these conditions; additionally, lack of research and data on these species' reactions to adverse conditions means they are likely underrepresented when water quality criteria for dissolved oxygen levels are developed (Hartline et al. 2020).

The Alabama Department of Environmental Management (ADEM) is required by Section 303(d) of the Clean Water Act to identify impaired waters in the state (ADEM 2022). In 2022, ADEM listed 13 tributaries of the Alabama River that were impaired because of high levels of nutrients, pesticides, siltation, pathogens (*E. coli*), and/or metals (mercury) (ADEM 2022). Claiborne Lake, including Claiborne L&D, is listed for high levels of metals (mercury) due to atmospheric deposition (ADEM 2022).

Bioaccumulation of mercury in fishes can inhibit reproduction, growth, and survival; furthermore, age, fish size, and life history characteristics all determine the severity of these effects in different species (Crump and Trudeau 2009; Zillioux 2015; Zheng et al. 2019).

Sediment-bound pollutants or toxicants can be introduced into streams along with extrinsic sediments (Niraula et al. 2016). Toxicants, which include pesticides, ammonia, metals, and ions such as potassium, chloride, and sulfate, can disrupt growth, feeding, and reproduction in freshwater mussels, and prolonged exposure to toxicants can lead to death (Naimo 1995; Newton et al. 2003; Bringolf et al. 2007; Wang et al. 2016; Ciparis et al. 2019). Wang et al. (2016) also found that the few species of freshwater mussels that have been tested in toxicological studies are often common species that may be less sensitive to toxicants than species with a narrow endemic range. Freshwater gastropods, especially listed species, are more underrepresented in these studies even though they may be more sensitive to some toxicants than freshwater mussels (Gibson et al. 2016). Maintaining and improving water quality will be essential for long-term conservation of the diverse aquatic community in the Alabama River and for the recovery of its threatened and endangered species.

FISH AND WILDLIFE RESOURCES

Federally Listed and At-risk Species

There are several at-risk and federally listed species potentially present in or near the study area (Table 1) that could be affected by the addition of fish passage at Claiborne and Millers Ferry L&D. The following paragraphs briefly summarize life history information for each species.

Table 1. A list of at-risk and listed species that may be present in the study area or affected by fish passage at Claiborne and Millers Ferry L&D. Listed species are classified as threatened or endangered and are protected under ESA. At-risk species are those that are petitioned for listing, proposed threatened, proposed endangered, under discretionary review, or a candidate for listing. This table should not be used for Section 7 consultation, and additional species may be added in the final FWCAR.

COMMON NAME	SCIENTIFIC NAME	TYPE	FEDERAL STATUS
Georgia rockcress	*Arabis georgiana*	Plant	Threatened
Alligator snapping turtle	*Macrochelys temminckii*	Reptile	Proposed threatened
Spotted rocksnail	*Leptoxis picta*	Snail	Under review
Tulotoma snail	*Tulotoma magnifica*	Snail	Threatened
Inflated heelsplitter	*Potamilus inflatus*	Clam	Threatened
Southern clubshell	*Pleurobema decisum*	Clam	Endangered
Alabama sturgeon	*Scaphirhynchus suttkusi*	Fish	Endangered
Gulf sturgeon	*Acipenser oxyrinchus (=oxyrhynchus) desotoi*	Fish	Threatened

Georgia rockcress

Georgia rockcress is a perennial herb in the mustard family (Brassicaceae) that grows up to 90 cm (35.4 in) tall (Service 2021b). It grows in a variety of dry conditions, including shallow soil accumulations on rocky bluffs, ecotones of gently sloping rock outcrops, and in sandy loam along eroding riverbanks. It is occasionally found in adjacent mesic woods, but it will not persist in heavily shaded conditions. This species is adapted to high or moderately high light intensities and occurs on soils which are circumneutral to slightly basic. It is thought that seed dispersal mainly occurs by gravity and wind; however, surface runoff or flowing rivers likely facilitate long-distance dispersal (Service 2021b).

Alligator snapping turtle
The alligator snapping turtle is the largest species of freshwater turtle in North America and can be found throughout river basins that drain into the Gulf of Mexico (Service 2021a). Most nesting occurs from April to May in the southern portion of the range, and nests have been observed from approximately 8 to 656 ft (2.5 to 200 m) landward from the nearest water body (Service 2021a). This species is associated with deep water habitats like large rivers, major tributaries, bayous, canals, swamps, lakes, ponds, and oxbows. Shallow water is occupied by adults in the summer and by hatchlings and juveniles, while deeper depths are occupied in late summer and mid-winter (Service 2021a).

Spotted rocksnail
The spotted rocksnail has a shell that is globose in shape with an ovate and broadly rounded aperture (Garner et al. 2022). Juveniles have interrupted color bands that disappear in adults (Whelan et al. 2014). Females lay clutches of eggs that are coated with mucus in a spiral pattern (Whelan et al. 2014). Historically, this species was found in the Alabama River from Claiborne upstream to the Coosa River below Wetumpka, which is below the Fall Line, and from the confluence of the Alabama and Cahaba rivers upstream to Lily Shoals in Bibb County (Whelan et al. 2017). Currently, this species can be found in the Alabama River from river miles 46.0 to 231.5 and at one reintroduction site in the Cahaba River near Centreville (Whelan et al. 2017).

Tulotoma snail
Tulotoma snails have dark brown or black globosely conic shells with irregularly convex to straight whorls (Garner et al. 2022). Most shells have spiral bands of tubercles and are up to 35 mm in length (Garner et al. 2022). This species can be found in localized areas of the main stem Alabama and Coosa rivers and in the free-flowing lower reaches of several tributaries (Garner et al. 2016; Garner et al. 2022). Although this species has been found under large rocks and in bedrock crevices, side-scan sonar has been successfully used to target the boulder habitat that tulotoma snails are more commonly found in (Garner et al. 2016).

Inflated heelsplitter
The inflated heelsplitter is a unionid mussel endemic to the Mobile Basin that has a thin, moderately inflated shell (Williams et al. 2008). Generally, males are larger than females, and this species is considered a long-term brooder. Females release glochidia in the summer, and freshwater drum (*Aplodinotus grunniens*) are the only known host fish for this species. (Williams et al. 2008). Inflated heelsplitters grow rapidly, mature after one year of growth, and live for approximately eight years (Brown and Daniel 2014). These mussels inhabit large rivers and are found in slow to moderate current with sandy and muddy substrates (Williams et al. 2008).

Southern clubshell
The southern clubshell is a freshwater mussel that grows up to 93 mm in length and has a thick shell with an elliptical outline (Williams et al. 2008). This species is found in large creeks and rivers throughout the Mobile Basin in flow with gravel and sand substrates. Southern clubshell

are short-term brooders and gravid females release orange or white conglutinates filled with glochidia in June and July. Blacktail shiner (*Cyprinella venusta*) and striped shiner (*Luxilus chrysocephalus*) have been identified as primary and secondary fish hosts (Williams et al. 2008).

Alabama sturgeon
The Alabama sturgeon is a benthic fish that eats macroinvertebrates and grows to lengths of 0.7 to 0.8m (2.3 to 2.6 ft) (Mettee et al. 1996). Most of its fins are brownish orange, and the body near the lateral scutes is yellow to tan while its belly and anal fin are white. Alabama sturgeon are endemic to the Mobile River basin, and several specimens have been collected from the Alabama River, including three adults downstream of Claiborne L&D (Mettee et al. 1996). Gravid females were collected in late March 1969 at the mouth of the Cahaba River; however, females collected in April and May 1985 from the Alabama River were not gravid (Mettee et al. 1996). Although specific spawning areas and larval drift have not been documented in Alabama sturgeon, it is likely that they spawn on hard bottom substrates in deep water and that successful larval development is dependent on long stretches of highly oxygenated, free-flowing water (Service 2009; Kuhajda and Rider 2016).

From 1997 to 2007, biologists used intensive, conventional efforts to sample Alabama sturgeon and only collected seven specimens (Pfleger et al. 2016). The last specimen from the Alabama River was observed below Robert F. Henry Lock and Dam in 2009. One environmental DNA (eDNA) sample collected in December 2014 detected Alabama sturgeon below Miller's Ferry L&D, while samples collected in April, May, and July of 2015 detected the species at multiple sites, including Claiborne and Millers Ferry L&D (Pfleger et al. 2016). Precipitated eDNA sampling methodology has been used to detect Alabama sturgeon in both surface and benthic samples (Janosik et al. 2021). Benthic samples showed the first detections of the species in the Tombigbee River, which may provide overwintering habitat. Positive detections for Alabama sturgeon were also noted in the Alabama, Cahaba, and Mobile rivers in August and in the Alabama River in April (Janosik et al. 2021).

Alabama sturgeon critical habitat was designated in 2009 and encompasses 524 km (326 mi) of river channel in the Alabama and Cahaba rivers (Service 2009). The designated area in the Alabama River extends a total of 394 km (245 mi) from its confluence with Tombigbee River upstream to R.F. Henry L&D. In the Cahaba River, a total of 130 km (81 mi) of critical habitat is designated from its confluence with the Alabama River upstream to its cross with U.S. Highway 82 (Service 2009). Critical habitat is defined as areas that are occupied by the species and areas that are essential to its conservation, including those that are not occupied at the time of listing (Service 2009).

Gulf sturgeon
Similar to the Alabama sturgeon, Gulf sturgeon are benthic and feed on organisms that live in sediment, including bivalves, snails, crustaceans, and other macroinvertebrates (Service 2022). Gulf sturgeon are considered a subspecies of Atlantic sturgeon (*Acipenser oxyrinchus oxyrinchus*), grow up to lengths of 2.7 m (9 ft), and live for up to 50 years (NOAA 2022). Gulf sturgeon are anadromous and migrate from freshwater rivers to marine foraging habitat in the Gulf of Mexico in the winter (Service 2022). These habitats are usually less than 7 m deep and well oxygenated with low turbidity and coarse or find sand substrates (Service 2022). Although

these fish begin migrating to freshwater rivers in February and spawn in the spring (Mettee et al. 1996), fall spawning has also been documented in the Suwanee and Choctawhatchee rivers in Florida (Service 2022). Gulf sturgeon have been detected during spring months using eDNA sampling in the Alabama, Cahaba, and Tombigbee rivers and below Claiborne, Millers Ferry, and Robert F. Henry L&D (Pfleger et al. 2016).

Fishes

At least 184 fishes are native to the Alabama River, with 33 of these species considered endemic (Freeman et al. 2005; Haley and Johnston 2014). In 2005, ten fishes, including seven endemic species, were federally listed, and at least 28 fish species were considered vulnerable by experts (Freeman et al. 2005). From 2010-2011, fish assemblage surveys on the Alabama River from Dixie Landing at river mile 22 upstream to Claiborne L&D only documented 48 species (Haley and Johnston 2014). These samples were not similar to historical samples and indicate a temporal shift in the fish community and a loss of diversity (Haley and Johnston 2014). Of the known fishes that inhabit the Alabama and/or Cahaba rivers, five are federally listed, including Alabama sturgeon, Gulf sturgeon, blue shiner, Cahaba shiner, and goldline darter (Table 2). Frecklebelly madtom and coal darter are currently under review for federal protection (Table 2).

Table 2. A list of fishes that are present in the Alabama and/or Cahaba rivers and their state and federal status (ADCNR and GSA unpublished dataset). Note that blue shiners (*Cyprinella caerulea)* are currently extirpated from both river systems. SP denotes a species that is state protected under the Alabama State Nongame Species Regulation 220-2-.92, Protection of Sturgeon 220-2-.26(4), or Prohibition of Taking or Possessing Paddlefish 220-2-.94. The state ranking system abbreviations are defined as follows: S1 = critically imperiled, S2 = imperiled, S3 = vulnerable, S4 = apparently secure, S5 = secure, SX = presumed extirpated, and SE = exotic (ADCNR 2017).

COMMON NAME	SCIENTIFIC NAME	STATE STATUS	FEDERAL STATUS
Chestnut lamprey	*Ichthyomyzon castaneus*	S5	-
Southern brook lamprey	*Ichthyomyzon gagei*	S5	-
Least brook lamprey	*Lampetra aepyptera*	S5	-
Gulf sturgeon	*Acipenser oxyrinchus desotoi*	S2, SP	Threatened
Alabama sturgeon	*Scaphirhynchus suttkusi*	S1, SP	Endangered
Paddlefish	*Polyodon spathula*	S3	-
Alligator gar	*Atractosteus spatula*	S3	-
Spotted gar	*Lepisosteus oculatus*	S5	-
Longnose gar	*Lepisosteus osseus*	S5	-
Bowfin	*Amia calva*	S5	-
Mooneye	*Hiodon tergisus*	S3	-
American eel	*Anguilla rostrata*	S4	-
Bay anchovy	*Anchoa mitchilli*	S5	-

Alabama shad	*Alosa alabamae*	S1	-
Skipjack Herring	*Alosa chrysochloris*	S3	-
Gulf Menhaden	*Brevoortia patronus*	S5	-
Gizzard Shad	*Dorosoma cepedianum*	S5	-
Threadfin Shad	*Dorosoma petenense*	S5	-
Largescale Stoneroller	*Campostoma oligolepis*	S5	-
Goldfish	*Carassius auratus*	-	-
Grass carp	*Ctenopharyngodon idella*	-	-
Blue shiner	*Cyprinella caerulea*	S1, SP	Threatened
Alabama shiner	*Cyprinella callistia*	S5	-
Tricolor shiner	*Cyprinella trichroistia*	S5	-
Blacktail shiner	*Cyprinella venusta*	S5	-
Common carp	*Cyprinus carpio*	-	-
Cypress minnow	*Hybognathus hayi*	S3	-
Mississippi silvery minnow	*Hybognathus nuchalis*	S4	-
Clear chub	*Hybopsis winchelli*	S5	-
Bighead carp	*Hypopthalmichthys nobilis*	-	-
Striped shiner	*Luxilus chrysocephalus*	S5	-
Pretty shiner	*Lythrurus bellus*	S5	-
Mountain shiner	*Lythrurus lirus*	S4	-
Cherryfin shiner	*Lythrurus roseipinnis*	S5	-
Mobile chub	*Macrhybopsis boschungi*	S3	-
Coosa chub	*Macrhybopsis etnieri*	S4	-
Silver chub	*Macrhybopsis storeriana*	S5	-
Bluehead chub	*Nocomis bellicus*	S5	-
Golden shiner	*Notemigonus crysoleucas*	S5	-
Orangefin shiner	*Notropis ammophilus*	S5	-
Longjaw minnow	*Notropis amplamala*	S5	-
Burrhead shiner	*Notropis asperifrons*	S5	-
Emerald shiner	*Notropis atherinoides*	S5	-
Rough shiner	*Notropis baileyi*	S5	-
Cahaba shiner	*Notropis cahabae*	S1, SP	Endangered
Silverside shiner	*Notropis candidus*	S5	-
Ironcolor shiner	*Notropis chalybaeus*	S1, SP	-
Rainbow shiner	*Notropis chrosomus*	S5	-
Fluvial shiner	*Notropis edwardraneyi*	S4	-
Longnose shiner	*Notropis longirostris*	S5	-
Taillight shiner	*Notropis maculatus*	S4	-

Coastal shiner	*Notropis petersoni*	S5	-
Silverstripe shiner	*Notropis stilbius*	S5	-
Weed shiner	*Notropis texanus*	S5	-
Skygazer shiner	*Notropis uranoscopus*	S3	-
Mimic shiner	*Notropis volucellus*	S5	-
Pugnose minnow	*Opsopoeodus emiliae*	S5	-
Riffle minnow	*Phenacobius catostomus*	S5	-
Bluntnose minnow	*Pimephales notatus*	S5	-
Fathead minnow	*Pimephales promelas*	S5	-
Bullhead minnow	*Pimephales vigilax*	S5	-
Sailfin shiner	*Pteronotropis hypselopterus*	S5	-
Flagfin shiner	*Pteronotropis signipinnis*	S5	-
Bluenose shiner	*Pteronotropis welaka*	S2	-
Creek chub	*Semotilus atromaculatus*	S5	-
Dixie chub	*Semotilus thoreauianus*	S5	-
Quillback	*Carpiodes cyprinus*	S5	-
Highfin carpsucker	*Carpiodes velifer*	S5	-
Southeastern blue sucker	*Cycleptus meridionalis*	S4	-
Creek chubsucker	*Erimyzon oblongus*	S5	-
Lake chubsucker	*Erimyzon sucetta*	S5	-
Sharpfin chubsucker	*Erimyzon tenuis*	S5	-
Alabama hog sucker	*Hypentelium etowanum*	S5	-
Smallmouth buffalo	*Ictiobus bubalus*	S5	-
Spotted sucker	*Minytrema melanops*	S5	-
River redhorse	*Moxostoma carinatum*	S5	-
Black redhorse	*Moxostoma duquesnei*	S5	-
Golden redhorse	*Moxostoma erythrurum*	S5	-
Blacktail redhorse	*Moxostoma poecilurum*	S5	-
Black bullhead	*Ameiurus melas*	S5	-
Yellow bullhead	*Ameiurus natalis*	S5	-
Brown bullhead	*Ameiurus nebulosus*	S5	-
Blue catfish	*Ictalurus furcatus*	S5	-
Channel catfish	*Ictalurus punctatus*	S5	-
Black madtom	*Noturus funebris*	S5	-
Tadpole madtom	*Noturus gyrinus*	S5	-
Speckled madtom	*Noturus leptacanthus*	S5	-
Frecklebelly madtom	*Notutus munitus*	S1, SP	Under Review
Freckled madtom	*Noturus nocturnus*	S5	-
Flathead catfish	*Pylodictis olivaris*	S5	-
Redfin pickerel	*Esox americanus*	S5	-

Chain pickerel	*Esox niger*	S5	-
Pirate perch	*Aphredoderus sayanus*	S5	-
Striped mullet	*Mugil cephalus*	S5	-
Stout silverside	*Labidesthes vanhyningi*	S5	-
Inland silverside	*Menidia beryllina*	S5	-
Atlantic needlefish	*Strongylura marina*	S5	-
Western starhead topminnow	*Fundulus blairae*	S4	-
Blackstripe topminnow	*Fundulus notatus*	S5	-
Bayou topminnow	*Fundulus notti*	S5	-
Blackspotted topminnow	*Fundulus olivaceus*	S5	-
Southern studfish	*Fundulus stellifer*	S5	-
Rainwater killifish	*Lucania parva*	S4	-
Western mosquitofish	*Gambusia affinis*	S5	-
Eastern mosquitofish	*Gambusia holbrooki*	S5	-
Least killifish	*Heterandria formosa*	S4	-
Banded sculpin	*Cottus carolinae*	S5	-
White bass	*Morone chrysops*	S5	-
Yellow bass	*Morone mississippiensis*	S5	-
Striped bass	*Morone saxatilis*	S3	-
Shadow bass	*Ambloplites ariommus*	S5	-
Flier	*Centrarchus macropterus*	S5	-
Bluespotted sunfish	*Enneacanthus gloriosus*	S4	-
Redbreast sunfish	*Lepomis auritus*	S5	-
Green sunfish	*Lepomis cyanellus*	S5	-
Warmouth	*Lepomis gulosus*	S5	-
Orangespotted sunfish	*Lepomis humilis*	S5	-
Bluegill	*Lepomis macrochirus*	S5	-
Dollar sunfish	*Lepomis marginatus*	S5	-
Longear sunfish	*Lepomis megalotis*	S5	-
Redear sunfish	*Lepomis microlophus*	S5	-
Redspotted sunfish	*Lepomis miniatus*	S5	-
Cahaba bass	*Micropterus cahabae*	S5	-
Alabama bass	*Micropterus henshalli*	S5	-
Largemouth bass	*Micropterus salmoides*	S5	-
White crappie	*Pomoxis annularis*	S5	-
Black crappie	*Pomoxis nigromaculatus*	S5	-
Naked sand darter	*Ammocrypta beanii*	S5	-

Southern sand darter	*Ammocrypta meridiana*	S5	-
Crystal darter	*Crystallaria asprella*	S3, SP	-
Redspot darter	*Etheostoma artesiae*	S5	-
Bluntnose darter	*Etheostoma chlorosoma*	S5	-
Swamp darter	*Etheostoma fusiforme*	S5	-
Harlequin darter	*Etheostoma histrio*	S5	-
Greenbreast darter	*Etheostoma jordani*	S5	-
Johnny darter	*Etheostoma nigrum*	S5	-
Goldstripe darter	*Etheostoma parvipinne*	S5	-
Cypress darter	*Etheostoma proeliare*	S5	-
Alabama darter	*Etheostoma ramseyi*	S5	-
Rock darter	*Etheostoma rupestre*	S5	-
Speckled darter	*Etheostoma stigmaeum*	S5	-
Gulf darter	*Etheostoma swaini*	S5	-
Backwater darter	*Etheostoma zonifer*	S5	-
Goldline darter	*Percina aurolineata*	S2, SP	Threatened
Coal darter	*Percina brevicauda*	S2	Under Review
Mobile logperch	*Percina kathae*	S5	-
Freckled darter	*Percina lenticula*	S3	-
Blackside darter	*Percina maculata*	S5	-
Blackbanded darter	*Percina nigrofasciata*	S5	-
Dusky darter	*Percina sciera*	S5	-
River darter	*Percina shumardi*	S5	-
Gulf logperch	*Percina suttkusi*	S5	-
Saddleback darter	*Percina vigil*	S5	-
Southern walleye	*Sander sp. cf. vitreus*	S4	-
Freshwater drum	*Aplodinotus grunniens*	S5	-
Everglades pygmy sunfish	*Elassoma evergladei*	S3	-
Banded pygmy sunfish	*Elassoma zonatum*	S5	-
Southern flounder	*Paralichthys lethostigma*	-	-
Hogchoker	*Trinectes maculatus*	S5	-

Alabama and Gulf sturgeon have been discussed in the previous section. In addition to these species, the Corps and other partners have identified priority fishes for passage that reflect community diversity of the Alabama River (Table 6), including Mobile logperch, Gulf logperch, blacktail shiner, freshwater drum, chain pickerel, largemouth bass, skipjack herring, Alabama shad, striped bass, crystal darter, river redhorse, southeastern blue sucker, Mississippi silvery minnow, southern walleye, American eel, smallmouth buffalo, and paddlefish. The following paragraphs provide a brief summary of each species.

Mobile and Gulf logperch
The Mobile logperch is a slender bodied percid that reaches lengths of about 6 inches. This species likely spawns from midspring to early summer in gravel substrates with moderate currents in creeks and rivers (Boschung Jr. and Mayden 2004). Mobile logperch are endemic throughout the Mobile Basin, except in headwater streams, and are more frequently found above the Fall Line (Boschung Jr. and Mayden 2004). This species is the known fish host for several state protected and federally protected freshwater mussels, including southern combshell (endangered), Alabama moccasinshell (threatened), Coosa moccasinshell (endangered), and triangular kidneyshell (endangered) (Table 3).

Gulf logperch likely have a similar biology when compared to Mobile logperch. This species is often found in gravel-bottomed runs of large creeks and rivers and distributed throughout Gulf Coast drainages below the Fall Line in the Tombigbee and Alabama rivers west to Lake Pontchartrain tributaries (Boschung Jr. and Mayden 2004).

Blacktail shiner
Blacktail shiner and their subspecies can be found in schools from the Suwannee River drainage in Florida west to the Rio Grande in Texas and north in the Mississippi Basin to central Missouri and southern Illinois (Boschung Jr. and Mayden 2004). Blacktail shiner occupy moderately large, clear streams with sandy substrate and spawn from March to October (Boschung and Mayden 2004). Shiners are common fish hosts for freshwater mussels, and blacktail shiner are the known fish host for Gulf pigtoe, threehorn wartyback, southern clubshell (endangered), and warrior pigtoe (endangered) (Table 3).

Freshwater drum
Freshwater drum are silver, deep bodied fishes that are found in a variety of habitats and range throughout much of mid-America from the Rock Mountains to the Appalachians and from Hudson Bay south to Guatemala (Boschung Jr. and Mayden 2004). This species is not found in Gulf Coast streams east of Mobile Basin. Adults spawn in May when the temperature is 20°C (Boschung Jr. and Mayden 2004). Freshwater drum are the known fish hosts for Amblema, butterfly, threehorn wartyback, fragile papershell, bluefer, and inflated heelsplitter (threatened) (Table 3).

Chain pickerel
Chain pickerel are widely ranging esocids that are adapted to live in a variety of habitats from lakes and impoundments with vegetation to large streams (Boschung Jr. and Mayden 2004). They are able to tolerate warmer water temperatures and higher levels of salinity than other esocids. In Alabama, they spawn from fall to spring when temperatures range from 6° to 16°C and broadcast eggs over vegetation and detritus in swampy streams and flooded lowlands (Boschung Jr. and Mayden 2004). Chain pickerel are known fish hosts for Alabama pearlshell (Table 3; Fobian et al. 2019).

Largemouth bass
The largemouth bass is a centrarchid whose native range includes Alabama and can be found in lakes, ponds, reservoirs, and pools of rivers (Boschung Jr. and Mayden 2004). This species is a popular sport fish and is the fish host for a variety of freshwater mussels, including Amblema,

little spectaclecase, southern pocketbook, southern fatmucket, yellow sandshell, black sandshell, washboard, giant floater, pondmussel, paper pondshell, and southern rainbow (Table 3). Largemouth bass are also fish hosts for state protected and federally protected species, including Alabama rainbow (under review), finelined pocketbook (threatened), and orangenacre mucket (threatened) (Table 3).

Skipjack herring

Skipjack herring are clupeids that have premaxilla that meet at an obtuse angle and 18 to 24 gill rakers on the lower limb of the first gill arch (Boschung Jr. and Mayden 2004). Although considered anadromous, skipjack herring are able to survive and reproduce in landlocked populations where silt-free sand and gravel substrates are available for spawning (Boschung Jr. and Mayden 2004). This species typically spawns from March to April in the main channels of large rivers and has a lifespan of approximately 4 years.

Historically, this species was found in the Missouri-Mississippi and Ohio river basins (Boschung Jr. and Mayden 2004). Today, it is known from the Gulf Coast in Florida to Texas, from freshwater rivers in Florida to Texas, and throughout the Mobile Basin below the Fall Line. Its populations in Alabama are considered stable (Boschung Jr. and Mayden 2004). Skipjack herring are fish hosts for several species of freshwater mussels, including rock pocketbook, elephantear, Alabama heelsplitter, and ebonyshell (Table 3).

Alabama shad

The Alabama shad is an anadromous species that differs from other clupeids with premaxillaries that meet at an acute angle and 42 to 48 gill rakers on the lower limb of the first gill arch (Boschung Jr. and Mayden 2004). Adult 3-year-old males and 4-year-old females migrate up rivers from February to April to spawn in areas with coarse sand and gravel substrate and moderate current (Boschung Jr. and Mayden 2004). Fertilized eggs need clean, silt-free substrate in order to develop and hatch. Construction of dams and impoundments has fragmented and altered suitable habitat, which has contributed to the decline of this species (Smith et al. 2011).

Alabama shad were historically found throughout the Mississippi and Ohio river basins and their tributaries from Arkansas to West Virginia and in Gulf Coast tributaries from the Suwannee River in Florida to Mississippi (Boschung Jr. and Mayden 2004). In Alabama, it was found throughout the Mobile Basin below the Fall Line and in coastal rivers (Boschung Jr. and Mayden 2004). Although it has been petitioned for listing, the Alabama shad is not federally protected; however, ADCNR considers this species critically imperiled (S1), and it is rarely encountered during routine sampling efforts (Smith et al. 2011). Since 1994, five Alabama shad have been collected in the Alabama River (Rider et al. 2021). One specimen was collected below Claiborne L&D in 1994 and 2001 and below Millers Ferry L&D in 1995 and 1997. Biologists spent 129.5 hours conducting electrofishing surveys targeting Alabama shad from 2009-2018 and did not collect any of these fish (Rider et al. 2021).

Striped bass

Striped bass are anadromous fish that migrate to free-flowing rivers with sand, gravel, and rocky substrate to spawn (Boschung Jr. and Mayden 2004). In Alabama, this species was known to migrate up the Alabama River to the Coosa and Tallapoosa rivers before the construction of dams and may have been potamodromous or able to complete its life cycle within freshwater Gulf Coast streams (Boschung Jr. and Mayden 2004). Although the Alabama Marine Resources Division has attempted to restore Gulf Coast striped bass in the Alabama River by stocking, it is unlikely that the population is self-sustaining (Boschung Jr. and Mayden 2004).

Crystal darter

Crystal darters have long, slender bodies with enlarged pectoral fins and can be differentiated from other darters because they have a combination of 4 dark saddles and a forked caudal fin (Boschung Jr. and Mayden 2004). Historically, this species ranged from the upper Mississippi and Ohio river basins south to Arkansas and the Gulf Slope. In Alabama, this species was found in the Mobile Basin below the Fall Line and in the Conecuh-Escambia river system (Boschung Jr. and Mayden 2004). Crystal darters were last collected in the Alabama River in 1975 and are likely only occur in the lower Cahaba, lower Tallapoosa, and Conecuh river systems. They begin spawning in February when water temperatures are 12°C in moderate to swift currents of side-channel riffles with gravel substrate (Boschung Jr. and Mayden 2004). Although crystal darters are not known fish hosts, other species of darters are known fish hosts of multiple species of freshwater mussels in Alabama (Table 3).

River redhorse

River redhorse are one of the largest species of *Moxostoma* and have large molariform teeth that they use to crush mollusk shells (Boschung Jr. and Mayden 2004). River redhorse are distributed in Gulf Slope drainages from the Escambia River to Pearl River and the Mobile Basin, as well as in the upper Mississippi and Ohio basins. This species' stronghold in Alabama is the Cahaba River, where adults spawn over a 10-day period in mid-April when water temperatures range from 22.2° to 24.4°C. River redhorse have been collected in the Alabama River below Millers Ferry L&D but have not been collected further downstream in the Alabama River or in the lower Tombigbee River (Boschung Jr. and Mayden 2004).

Southeastern blue sucker

Southeastern blue sucker are large catostomids that have small heads and long dorsal fins (Boschung Jr. and Mayden 2004). This species was historically distributed throughout large rivers in the Mobile Basin and the Pascagoula and Pearl river drainages. During spawning runs, males turn an unusual deep blue color (Boschung Jr. and Mayden 2004), and in the Alabama River below Millers Ferry L&D, adults spawn in late March with water temperatures ranging from 15-17°C (Mettee et al. 2004b). Surveys from 1995-2004 documented adults who spawned annually below Millers Ferry L&D for 10 years and two males that moved upstream and downstream past Claiborne L&D. One sonic and anchor tagged male was captured and recaptured for a total of 1,288 days and was detected 100 miles downstream of its original release site at Millers Ferry in 1999 and 93 miles upstream of its last detection in 2002 (Mettee et al. 2004b). Although the southeastern blue sucker is not a known host fish for freshwater mussels in Alabama, amblema have been documented using other catostomid species (Table 3).

Mississippi silvery minnow

Mississippi silvery minnows reach a maximum standard length of about 130 mm (5.12 in) (Boschung Jr. and Mayden 2004). This species is usually found in the eddy currents of pools and backwaters of moderately large streams where they feed on algae and organic detritus.

These minnows are distributed throughout the Mississippi Basin from Minnesota to Louisiana, the Mobile Basin below the Fall Line, and west to the Brazos River in Texas and are likely extirpated from the Tennessee River. Although Mississippi silvery minnows are not known host fish, other species of minnows are host fishes for freshwater mussels in Alabama, including Gulf pigtoe (Table 3).

Southern walleye

Walleye are percids with large, glassy eyes that are native east of the Continental Divide in North America (Boschung Jr. and Mayden 2004). Southern walleye, also called Gulf Coast walleye, are genetically unique when compared to northern walleye and are native to the Mobile Basin (MDWFP 2023). ADCNR has documented a spawning population in Hatchet Creek, a tributary of Lake Mitchell, and a population in the Mulberry Fork, a tributary of the Black Warrior River (DeWitt 2017). ADCNR has also received reports from the public indicating these fish are present in the Cahaba, Tombigbee, and Alabama rivers (DeWitt 2017). Walleye are known host fish for black sandshell (Table 3).

American eel

American eels have elongated bodies with no pelvic fins and olive-green backs that fade to yellowish or white bellies (Boschung Jr. and Mayden 2004). This species is widely distributed and can be found in freshwater streams from Iceland to Colombia, which includes the Tennessee River drainage, Mobile Basin, and coastal streams from the Apalachicola to the Escatawpa rivers. American eels are catadromous, and elvers migrate from marine to fresh waters to feed and grow for several years before returning to the sea to spawn. These migrations are inhibited by dams (Boschung Jr. and Mayden 2004). ADCNR biologists have collected American eels in rocky shoals in the Coosa and Tallapoosa rivers below Jordan and Thurlow dams (ADCNR 2023b), and in the Cahaba River as far upstream as Shoal Creek in Shelby County, Alabama (Moss 2006). In 1992 and 1993, ADCNR also collected this species in beds of aquatic vegetation and by undercut mud banks in the Mobile Delta (ADCNR 2023b). American eels are known host fish for rock pocketbook (Table 3).

Smallmouth buffalo

Smallmouth buffalo have deep bodies, relatively small and conical heads, and small inferior mouths (Boschung Jr. and Mayden 2004). This species is found in large rivers throughout the Mississippi River drainage and from the Mobile Basin to the Rio Grande. In Alabama, smallmouth buffalo are common in the Tennessee River and its large tributaries and in large rivers of the Mobile Basin (Boschung Jr. and Mayden 2004). Smallmouth buffalo were tracked in the Alabama River from its confluence with the Tombigbee River upstream to Millers Ferry L&D (RKM 225) from 2017-2020, and acoustic telemetry receiver arrays were positioned in the tailrace of Claiborne L&D to monitor fish movement (Hershey et al. 2022). During the study, 35 of 157 tagged smallmouth buffalo, including 16 females, 14 males, and 5 unknown sex fish, successfully passed Claiborne L&D. Passage for smallmouth buffalo was mainly limited to periods of high flow, and ripe male and female fish were noted in the Claiborne L&D tailrace (Hershey et al. 2022).

Paddlefish

Paddlefish are known for their unique spatula-like snout and heterocercal tail, which has unequal upper and lower lobes (Boschung Jr. and Mayden 2004). Historically, this species was widely distributed from the Des Moines and Platte rivers in the Midwest south to large streams of the Mississippi River drainage and Gulf Slope drainages from the Mobile Basin to the San Jacinto River in Texas. In Alabama, paddlefish are currently limited to the Mobile Basin below the Fall Line, and its numbers are declining in the Alabama River, especially above Millers Ferry L&D (Boschung Jr. and Mayden 2004). From 2002-2004, 33 paddlefish below Millers Ferry L&D and 5 below Claiborne L&D were sonic tagged and tracked (Mettee et al. 2004a). Of these fish, an individual moved through the lock chamber at Millers Ferry to Dannelly Reservoir, 31 fish inhabited the Alabama River between Claiborne and Millers Ferry L&D, and 20 fish moved downstream of Claiborne L&D. Six of the fish that moved downstream of Claiborne L&D travelled 180 miles to the Tensaw River below the I-65 bridge, which may indicate this area provides summer habitat for paddlefish that spawn in the Alabama River (Mettee et al. 2004a). Hershey et al. (2022) also tracked paddlefish in addition to smallmouth buffalo in the Alabama River from 2017-2020, and noted that 49 of 163 tagged paddlefish successfully passed Claiborne L&D. The paddlefish that passed were generally longer, and 8 were female, 17 were male, and the remaining fish were of unknown sex (Hershey et al. 2022).

Freshwater Mussels

Freshwater mussels are filter feeders that influence ecosystem processes, including community respiration, algal clearance rates, and concentrations of ammonia, nitrate, and phosphorus in the water column (Williams et al. 2008). Presence of mussels usually indicates clean, flowing water and a lack of pollution, contaminants, and pesticides in an aquatic environment. Freshwater mussels provide food for some fishes, crayfish, salamanders, turtles, and other wildlife (Williams et al. 2008). Female freshwater mussels produce glochidia, which are larval parasites that must attach to host fish gills for the first few weeks of life in order to survive; furthermore, some species have evolved different host fish attraction strategies, including active mantle lures and conglutinates that both mimic host fish food. Hosts fishes, particularly those who migrate long distances, can transfer glochidia to new areas or between populations before they drop to the substrate as juveniles (Williams et al. 2008).

Alabama has more freshwater mussels than any other state at approximately 178 species that represent 43 genera and both Margaritiferidae and Unionidae families (Williams et al. 2008). The Mobile River basin has roughly 73 species of mussels with 34 of these species considered endemic. The eastern part of this drainage, which includes the Alabama River, has about 67 species with 30 considered endemic (Williams et al. 2008). Of the known mussel species that inhabit the Alabama and/or Cahaba rivers, 13 are federally listed and seven are under review for federal protection (Table 3).

Table 3. A list of freshwater mussels and their host fishes that are present in the Alabama and/or Cahaba rivers and their state and federal status (ADCNR and GSA unpublished dataset; Williams et al. 2008). Known host fishes are also noted. SP denotes a species that is state protected under the Alabama State Invertebrate Species Regulation 220-2-.98. The state ranking system abbreviations are defined as follows: S1 = critically imperiled, S2 = imperiled, S3 = vulnerable, S4 = apparently secure, S5 = secure, SX = presumed extirpated, and SE = exotic (ADCNR 2017).

COMMON NAME	SCIENTIFIC NAME	HOST FISH(ES)	STATE STATUS	FEDERAL STATUS
Alabama pearlshell	*Margaritifera marrianae*	Redfin pickerel, Chain pickerel	S1, SP	Endangered
Amblema	*Amblema* sp.	Centrarchids, Catostomids, Perch, Shiners, Freshwater drum, Channel catfish	S4	-
Rock pocketbook	*Arcidens confragosus*	American eel, Rock bass, White crappie, Skipjack herring, Channel catfish	S3	-
Alabama rainbow	*Cambraunio nebulosa*	Cahaba bass, Largemouth bass	S2, SP	Under Review
Coosa orb	*Cyclonaias kieneriana*	-	S5	-
Butterfly	*Ellipsaria lineolata*	Freshwater drum	S4	-
Alabama spike	*Elliptio arca*	Southern sand darter, Redspot darter, Blackbanded darter	S1, SP	Under Review
Delicate spike	*Elliptio arctata*	-	S2, SP	Under Review
Elephantear	*Elliptio crassidens*	Skipjack herring	S4	-
Upland combshell	*Epioblasma metastriata*	-	SX	Endangered
Southern combshell	*Epioblasma penita*	Mobile logperch, Blackbanded darter	SX, SP	Endangered
Gulf pigtoe	*Fusconaia cerina*	Alabama shiner, Blacktail shiner, Pretty shiner, Orangefin shiner, Emerald shiner, Silverstripe shiner, Bluntnose minnow	S4	-
Round pearlshell	*Glebula rotundata*	Hogchoker, Green sunfish, Bluegill, Bay anchovy, Spotted gar	S4	-
Finelined pocketbook	*Hamiota altilis*	Cahaba bass, Alabama bass, Largemouth bass	S2, SP	Threatened

Orangenacre mucket	*Hamiota perovalis*	Cahaba bass, Alabama bass, Largemouth bass	S2, SP	Threatened
Little spectaclecase	*Leaunio lienosa*	Green sunfish, Bluegill, Largemouth bass, Brown bullhead	S5	-
Southern pocketbook	*Lampsilis ornata*	Alabama bass, Largemouth bass	S5	-
Southern fatmucket	*Lampsilis straminea*	Bluegill, Alabama bass, Largemouth bass	S4	-
Yellow sandshell	*Lampsilis teres*	Green sunfish, Largemouth bass, White crappie, Black crappie, Spotted gar, Longnose gar	S5	-
Alabama heelsplitter	*Lasmigona alabamensis*	Skipjack herring	S3	-
Etowah heelsplitter	*Lasmigona etowaensis*	Banded sculpin	S2, SP	Under Review
Black sandshell	*Ligumia recta*	Largemouth bass, White crappie, Walleye	S2, SP	-
Alabama moccasinshell	*Medionidus acutissimus*	Naked sand darter, Southern sand darter, Johnny darter, Speckled darter, Gulf darter, Mobile logperch, Blackbanded darter, Saddleback darter	S1, SP	Threatened
Coosa moccasinshell	*Medionidus parvulus*	Mobile logperch, Blackbanded darter	SX, SP	Endangered
Washboard	*Megalonaias nervosa*	Bluegill, Longear sunfish, Alabama bass, Largemouth bass, White crappie, Black crappie, Mooneye, Brown bullhead, Longnose gar	S5	-

Threehorn wartyback	*Obliquaria reflexa*	Gizzard shad, Blacktail shiner, Bluntnose minnow, Mooneye, Walleye, Freshwater drum	S5	-
Southern hickorynut	*Obovaria arkansasensis*	-	S1, SP	-
Alabama hickorynut	*Obovaria unicolor*	Naked sand darter, Southern sand darter, Redspot darter, Johnny darter, Gulf darter, Blackbanded darter, Dusky darter	S2, SP	Under Review
Bankclimber	*Plectomerus dombeyanus*	-	S5	-
Southern clubshell	*Pleurobema decisum*	Alabama shiner, Blacktail shiner, Striped shiner, Clear chub	S2, SP	Endangered
Ovate clubshell	*Pleurobema perovatum*	Striped shiner	S1, SP	Endangered
Warrior pigtoe	*Pleurobema rubellum*	Alabama shiner, Blacktail shiner, Creek chub	S1, SP	Endangered
Heavy pigtoe	*Pleurobema taitianum*	-	S1, SP	Endangered
True pigtoe	*Pleurobema verum*	-	SX	-
Fragile papershell	*Potamilus fragilis*	Freshwater drum	S5	-
Inflated heelsplitter	*Potamilus inflatus*	Freshwater drum	S2, SP	Threatened
Bleufer	*Potamilus purpuratus*	Freshwater drum	S5	-
Alabama creekmussel	*Pseudodontiodeus connasaugaensis*	Banded sculpin, Yellow bullhead	S2, SP	-
Triangular kidneyshell	*Ptychobranchus foremanianus*	Mobile logperch, Blackbanded darter	S1, SP	Endangered
Giant floater	*Pyganodon grandis*	Largemouth bass, White crappie, Black crappie, Yellow bullhead, Brown bullhead	S5	-
Southern mapleleaf	*Quadrula apiculata*	Channel catfish	S4	-
Ridged mapleleaf	*Quadrula rumphiana*	Channel catfish	S5	-
Ebonyshell	*Reginaia ebena*	Skipjack herring	S5	-

Pondmussel	*Sagittunio subrostrata*	Bowfin, Largemouth bass, Tadpole madtom	S4	-
Rayed creekshell	*Strophitus radiatus*	-	S2, SP	Under Review
Southern monkeyface	*Theliderma johnsoni*	-	S2, SP	-
Stirrupshell	*Theliderma stapes*	-	SX	Endangered
Southern purple lilliput	*Toxolasma corvunculus*	-	S1, SP	Under Review
Lilliput	*Toxolasma parvum*	Green sunfish, Johnny darter, Warmouth, Orangespotted sunfish, Bluegill, White crappie	S4	-
Pistolgrip	*Tritogonia verrucosa*	Weed shiner, Black bullhead, Yellow bullhead, Brown bullhead, Channel catfish	S4	-
Gulf mapleleaf	*Tritogonia nobilis*	Channel catfish	S3	-
Fawnsfoot	*Truncilla donaciformis*	Freshwater drum	S3	-
Pondhorn	*Uniomerus tetralasmus*	Golden shiner	S4	-
Paper pondshell	*Utterbackia imbecillis*	Largemouth bass, Black crappie	S5	-
Southern rainbow	*Villosa vibex*	Longear sunfish, Largemouth bass	S5	-

Crayfish, Gastropods, and Benthic Macroinvertebrates

Crayfish are important in aquatic ecosystems because they are often the largest invertebrates with the largest biomass represented in these systems (Schuster et al. 2022). They are predators that eat other invertebrates, small fishes and amphibians, snails, and vegetation, and they provide food for some fishes and other wildlife. Crayfish live in nearly all freshwater aquatic habitats and some species build burrows (Schuster et al. 2022).

Fifty-eight species of crayfish, including 20 endemics, are found in the Mobile River basin (Schuster et al. 2022). There are currently records of 31 different species of crayfish from the Alabama and Cahaba rivers, including one under review for federal status and 11 that are state protected (Table 4; Schuster et al. 2022).

Table 4. The 11 species listed in this table are crayfish found in the Alabama and/or Cahaba rivers that are state protected and/or under review for federal protection (ADCNR and GSA unpublished dataset). SP denotes a species that is state protected under the Alabama State Invertebrate Species Regulation 220-2-.98. The state ranking system abbreviations are defined as follows: S1 = critically imperiled, S2 = imperiled, S3 = vulnerable, S4 = apparently secure, S5 = secure, SX = presumed extirpated, and SE = exotic (ADCNR 2017).

COMMON NAME	SCIENTIFIC NAME	STATE STATUS	FEDERAL STATUS
Angular dwarf crayfish	*Cambarellus lesliei*	S1, SP	-
Speckled burrowing crayfish	*Creaserinus danielae*	S2, SP	Under Review
Shrimp crayfish	*Faxonius lancifer*	S2, SP	-
Prominence riverlet crayfish	*Hobbseus prominens*	S2, SP	-
Cockscomb crayfish	*Procambarus clemmeri*	S2, SP	-
Panhandle crayfish	*Procambarus evermanni*	S2, SP	-
Southern prairie crayfish	*Procambarus h. hagenianus*	S2, SP	-
Celestial crayfish	*Procambarus holifieldi*	S2, SP	-
Smoothnose crayfish	*Procambarus hybus*	S2, SP	-
Spur crayfish	*Procambarus lewisi*	S2, SP	-
Criscross crayfish	*Procambarus marthae*	S2, SP	-

Freshwater snails, also called gastropods, scrape algae and feed on organic debris in streams and provide a food source for some fishes, turtles, and other wildlife (Johnson 2019). They are used as indicators of good water quality because of their sensitivity to pollution and contaminants. North America has the highest species richness of freshwater snails in the world, and 120 species were once found in the Mobile River basin; unfortunately, 38 of those species are now considered extinct (Johnson 2019). There are currently records of 53 unique species of gastropods in the Alabama and Cahaba rivers which represent 10 families, including Lymnaeidae, Physidae, Planorbidae, Viviparidae, Amnicolidae, Emmericidae, Hydrobiidae, Lithoglyphidae, Pleuroceridae, and Pomatiopsidae (ADCNR and GSA unpublished dataset). Twenty of these species are state and/or federally protected or under review (Table 5).

Table 5. The 20 species listed in this table are gastropods found in the Alabama and/or Cahaba rivers that are state protected and/or have federal status or are under review (ADCNR and GSA unpublished dataset). SP denotes a species that is state protected under the Alabama State Invertebrate Species Regulation 220-2-.98. The state ranking system abbreviations are defined as follows: S1 = critically imperiled, S2 = imperiled, S3 = vulnerable, S4 = apparently secure, S5 = secure, SX = presumed extirpated, and SE = exotic (ADCNR 2017).

COMMON NAME	SCIENTIFIC NAME	STATE STATUS	FEDERAL STATUS
Cahaba ancylid	*Rhodacmea cahawbensis*	S1, SP	-
Cylindrical lioplax	*Lioplax cyclostomatiformis*	S1, SP	Endangered
Tulotoma	*Tulotoma magnifica*	S2, SP	Threatened
Watercress snail	*Fontigens nickliniana*	S1, SP	-
Coosa pyrg	*Marstonia hershleri*	S1, SP	-
Cahaba pebblesnail	*Clappia cahabensis*	S2, SP	-
Flat pebblesnail	*Lepyrium showalteri*	S1, SP	Endangered
Mud elimia	*Elimia alabamensis*	S3	Under Review
Ample elimia	*Elimia ampla*	S2, SP	Under Review
Lilyshoals elimia	*Elimia annettae*	S2, SP	Under Review

Princess elimia	*Elimia bellacrenata*	S1, SP	Under Review
Cockle elimia	*Elimia cochliaris*	S1, SP	Under Review
Teardrop elimia	*Elimia lachryma*	S1, SP	Under Review
Caper elimia	*Elimia olivula*	S3	Under Review
Compact elimia	*Elimia showalterii*	S3	Under Review
Puzzle elimia	*Elimia varians*	S2, SP	-
Squat elimia	*Elimia variata*	S2, SP	-
Round rocksnail	*Leptoxis ampla*	S2, SP	Threatened
Oblong rocksnail	*Leptoxis compacta*	S1	Under Review
Spotted rocksnail	*Leptoxis picta*	S2, SP	Under Review

Benthic macroinvertebrates are important in aquatic food webs because they convert energy from aquatic plants, algae, and detritus to fishes. Caddisfly fauna were unknown in Alabama until statewide collections were evaluated in 1986 and three new species were identified (Harris 1986). In 1991, caddisflies were assessed again throughout Alabama, and 342 species representing 58 genera and 19 families were identified (Harris et al. 1991). Specimens from four families represented 71% of caddisfly fauna collected, which included Hydroptilidae (103 species), Leptoceridae (58 species), Hydropsychidae (48 species), and Polycentropodidae (34 species). In the Alabama River basin, 142 unique species of caddisflies were collected (Harris et al. 1991).

Benthic macroinvertebrates, including larval mayflies (*Ephemeroptera*), stoneflies (*Plecoptera*), and caddisflies (*Trichoptera*), are also used as biological indicators to monitor stream water quality and can be used to measure stream restoration success (Kenney et al. 2009). The Alabama Department of Environmental Management routinely collects macroinvertebrate samples to evaluate water quality of streams across the state (ADEM 2020).

Migratory Birds

The study area at Claiborne and Millers Ferry L&D is located within the Mississippi Flyway. Several species of migratory birds from the Service's Birds of Conservation Concern (BCC) list could be present in this area, including:

- American kestrel (*Falco sparverius paulus*)
- Bachman's sparrow (*Aimophila aestivalis*)
- Bald eagle (*Haliaeetus leucocephalus*)
- Brown-headed nuthatch (*Sitta pusilla*)
- Cerulean warbler (*Dendroica cerulea*)
- Chimney swift (*Chaetura pelagica*)
- Kentucky warbler (*Oporonis formosus*)
- Prairie warbler (*Dendroica discolor*)
- Prothonotary warbler (*Protonotaria citrea*)
- Red-headed woodpecker (*Melanerpes erythrocephalus*)
- Ruddy turnstone (*Arenaria interpres morinella*)
- Swallow-tailed kite (*Elanoides forficatus*)
- Wood thrush (*Hylocichla mustelina*)

Stressors like vegetation removal, invasive species introduction, artificial lighting, collision, entrapment, noise, chemical contamination, and fire can negatively affect migratory birds.

Wetlands

Wetlands are important in freshwater and marine ecosystems because they improve water quality, stabilize banks, reduce flood stages, and provide habitat for fish, birds, and other wildlife (McPherson 1996). In 2009, a national study estimated that the U.S. had approximately 110.1 million acres of wetlands, which was a decline of 62,300 acres from 2004 estimates (Dahl 2011). Of all wetlands, about 95% were classified as freshwater with four types identified, including forested wetlands (49.5%), freshwater emergent (26.3%), shrub wetlands (17.8%), and freshwater ponds (6.4%) (Dahl 2011). In 1992, the Service estimated that there were approximately 2.3 million to 3.1 million acres of wetlands in Alabama (McPherson 1996). Forested wetlands were mostly identified as bottom-land forests in alluvial flood plains, and a 50-mile conservation tract is protected within the Mobile-Tensaw River Delta. Scrub-shrub wetlands and emergent wetlands were identified as small and isolated, while riverine wetlands were identified as common in slow-flowing rivers in the Coastal Plain, which is the region south of the Fall Line (McPherson 1996). Water from river flooding and groundwater have supplied extensive areas of wetlands in the Coastal Plain. Over the past 200 years, as much as 50% of the estimated 7.6 million acres of wetlands in Alabama have been converted to other land uses, and 10% of interior wetlands were lost from 1956-1979 (McPherson 1996). Wetland restoration targets for the Upper Mississippi and Missouri basins have been estimated at 7% of the watershed to achieve water quality improvement and flood control on a landscape scale (Mitch and Gosselink 2000).

Recreational Features

The Alabama River in addition to Claiborne and William "Bill" Dannelly (Millers Ferry) reservoirs provide fishing and boating opportunities for the public. Millers Ferry Reservoir is known for its high-quality largemouth bass and spotted bass (*Micropterus punctulatus*) fisheries, and anglers also target white crappie, black crappie, channel catfish, and blue catfish in the reservoir and striped bass in its tailwaters (ADCNR 2023c). Millers Ferry Reservoir generated an estimated $2,528,141 in revenue in 2015 from associated angler expenses, including fuel, lodging, food, tournament fees, equipment, and bait (Gratz 2017). In Claiborne Reservoir, anglers target the same species except for spotted bass (ADCNR 2023a). USACE also provides camping facilities near both reservoirs and manages approximately 5,600 acres of publicly accessible land for hunting along the Alabama River (Corps 2023).

DESCRIPTION OF NO ACTION ALTERNATIVE

No Action Alternative

Dams prevent upstream and downstream migrations of fish as they search for food, shelter, and suitable spawning areas (Katopodis et al. 2001). Dams also alter the condition of upstream and downstream habitats, which can contribute to declines in all riverine fishes, but migratory fishes in particular are affected when these structures prevent access to habitat for spawning (Hershey et al. 2022). Freshwater mussels depend on fish hosts to complete their life cycles and fish host migrations to facilitate gene flow between populations (Vaughn 2012). Additionally, dams alter downstream habitats, which can cause a mussel extinction gradient until flowing, riverine habitat is recovered (Vaughn and Taylor 1999). Altered distribution and declining abundance of migratory fishes and freshwater mussels can lead to ecosystem-level effects, including loss of nutrient and energy inputs, reduced primary production and detrital processing, and reduced stream productivity, nutrient retention, and benthic stability (Freeman et al. 2003). In addition to localized effects, multiple dams in a river basin can result in cumulative effects that need to be further evaluated for effective conservation and management of riverine species (Cooper et al. 2016).

Similar to fishes and freshwater mussels, loss of suitable riverine habitat and population fragmentation from dam construction also negatively impacts populations of native crayfishes (Barnett and Adams 2021), gastropods (Tiemann 2013), and benthic macroinvertebrates (Krajenbrink et al. 2019). Downstream populations of round rocksnail are more diverse than upstream populations, which indicates the conservation importance of uninterrupted gene flow between populations of gastropods (Whelan et al. 2019).

The Mobile River Basin supports a diverse aquatic community, which includes an endemic fauna of 40 fish, 33 freshwater mussel, and 110 gastropod species (Service 2000). These species have been negatively affected by channelization and impoundment of rivers, mining and dredging operations, and point and nonpoint pollution. At least 17 species of mussels and 37 gastropods are now considered extinct (Service 2000; Foighil et al. 2011; Whelan et al. 2012), and more than 20 fishes and mollusks are currently protected under the Endangered Species Act with nearly as many species under review for federal protection (Tables 2, 4, and 5). Continued degradation of riverine habitat and loss of aquatic species will persist without restoration of natural flow regimes to rivers in this ecosystem.

Fish Passage

Fish ladders were first designed and implemented in North America around 200 years ago (Katopodis and Williams 2011; Matica 2020). Different types of fish passage structures have been developed over time; however, they are usually designed for a target species and do not consider the needs of the native fish community (Matica 2020). These structures are also designed to facilitate upstream migration and do not fully consider the importance of downstream movements of fishes post-spawn (Larinier 2001). Mortality from interaction with hydraulic turbines or over spillways can negatively affect population numbers and stability (Larinier 2001). Downstream passage can involve the use of screens to prevent fish from interacting with turbines, of surface bypasses, or of behavioral guidance devices, although the latter devices are considered experimental (Larinier 2001). Downstream fish passage success is dependent on understanding how fishes respond to accelerating flows at different times of their life cycles and how they respond to different screens or attractants at passage structures (Enders et al. 2009). In addition to adult fish migrating downstream post-spawn, downstream dispersal of juvenile fishes is also important for population stability and survival (Pavlov and Mikheev 2017). Larval drift of broadcast spawners like sturgeon is also affected by restricted flows at dams (Marotz and Lorang 2018), which can prevent successful reproduction.

Conventional fish passage structures use materials like concrete for construction, while nature-like fishways, also called bypass channels, use ecological materials like rock to mimic natural conditions (Katopodis et al. 2001). Bypass channels were developed in the 1990s to create habitat and facilitate movement for diverse aquatic communities and migratory fishes (Katopodis and Williams 2012). Often, these channels are the preferred passage solution for low-head barriers, provided there is ample space for construction. Several variations of bypass channels are used worldwide, but pool and riffle and rocky ramp are the most commonly used types (Katopodis and Williams 2012). Pool and riffle bypass channels are built in stair-step configurations that connect short, steep sections called riffles to flat, long reaches called pools, while rocky ramps are typically long, sloping channels with refugia designed to provide resting areas for fishes. Efficiency and passability of bypass channels are dependent on similar factors to other fish passage structures, including entrance location (Katopodis and Williams 2012).

PROPOSED ALTERNATIVES AND TENTATIVELY SELECTED PLAN

The Corps began this study with an initial array of 17 alternatives, which was focused into 10 alternatives that included partial and/or full dam removal at one or both locations. Alternatives that included full and/or partial dam removal were screened from further consideration because of impacts to navigation, hydropower, and water supply and the estimated cost of removal. The following alternatives were selected for final consideration for habitat modelling and economic analysis:

- Alternative 1: No action
- Alternative 3: Fixed weir rock arch both dams
- Alternative 5d: Natural bypass channel both dams
- Alternative 12b: Fixed weir rock arch at Claiborne L&D and natural bypass channel at Millers Ferry L&D
- Alternative 13b: Natural bypass channel at Claiborne L&D and fixed weir rock arch at Miller's Ferry L&D

The Corps used two planning suite models, including the cost effectiveness/incremental cost analysis (CE/ICA) model and the multi-criteria decision analysis (MCDA) model, to rank each alternative. Table 6 describes the criteria and metrics used for these analyses. Alternative 5d, which includes natural bypass channels at both Claiborne and Millers Ferry L&D, was announced by the Corps as the tentatively selected plan (TSP) on March 1, 2023. The following paragraphs detail the criteria and metrics used to evaluate the final array of alternatives and how Alternative 5d was scored.

Table 6. Criteria and metrics used for analysis of final array. This table was presented by the Corps during the TSP milestone meeting on March 1, 2023.

Criteria	Metric	Description
Cost	Dollars—real estate and construction	Class four cost estimates for final array
Ecological Lift	Habitat Units	Fish Passage Connectivity Index x Habitat
Named Entity Recognition (NER) Benefits	Habitat Benefit Analysis	Determined using CE/ICA (Habitat Units and Cost)
National Economic Development (NED) Benefits	Impact to Hydropower—MWH/Dollars	Determine lost or gained hydropower in MWH and convert to dollars

Environmental Quality (EQ) Benefits	Habitat Units	Fish Passage Connectivity Index x Habitat
Regional Economic Development (RED) Benefits	Employment and Value Added	Use RECONS to compare final array
Other Social Effects (OSE) Benefits	Habitat Units	Actions to halt biodiversity loss generally benefit the climate
Sponsor Support	Yes/No	Does the sponsor support the alternative?

A group of 19 priority fishes selected by experts to represent the diversity of the fish community were modelled to evaluate habitat availability and fish passability of the different alternatives (Table 7). These fishes were incorporated into a fish passage connectivity index (FPCI) model to obtain a connectivity value for each alternative by assessing passability, encounterability, passage location, and time of passage available. Alternative 5d, which includes natural bypass channels at both dams, scored the highest of all alternatives with an FPCI value of 0.523. The Nature Conservancy assessed and quantified available habitat for each species within the study area. These habitat units were calculated by multiplying the connectivity values by the available habitat on a per species basis and then averaged. Alternative 5d had the highest average habitat units available at 1,005,661 units and the highest environmental quality (EQ) score.

Table 7. The priority species listed in this table are being used as a representative subset of the fish community to evaluate the fish passability of each alternative (ADCNR and GSA unpublished dataset). SP denotes a species that is state protected under the Alabama State Nongame Species Regulation 220-2-.92, Protection of Sturgeon 220-2-.26(4), or Prohibition of Taking or Possessing Paddlefish 220-2-.94. The state ranking system abbreviations are defined as follows: S1 = critically imperiled, S2 = imperiled, S3 = vulnerable, S4 = apparently secure, S5 = secure, SX = presumed extirpated, and SE = exotic (ADCNR 2017).

COMMON NAME	SCIENTIFIC NAME	STATE STATUS	FEDERAL STATUS
Mobile logperch	*Percina kathae*	S5	-
Gulf logperch	*Percina suttkusi*	S5	-
Blacktail shiner	*Cyprinella venusta*	S5	-
Freshwater drum	*Aplodinotus grunniens*	S5	-
Chain pickerel	*Esox niger*	S5	-
Largemouth bass	*Micropterus salmoides*	S5	-
Skipjack herring	*Alosa chrysochloris*	S3	-
Alabama shad	*Alosa alabamae*	S1	-
Striped bass	*Morone saxatilis*	S3	-
Crystal darter	*Crystallaria asprella*	S3, SP	-
River redhorse	*Moxostoma carinatum*	S5	-
Southeastern blue sucker	*Cycleptus meridionalis*	S4	-
Alabama sturgeon	*Scaphirhynchus suttkusi*	S1, SP	Endangered
Gulf sturgeon	*Acipenser oxyrinchus (=oxyrhynchus) desotoi*	S2, SP	Threatened

Mississippi silvery minnow	*Hybognathus nuchalis*	S4	-
Southern walleye	*Sander* sp. cf. *vitreus*	S4	-
American eel	*Anguilla rostrata*	S4	-
Smallmouth buffalo	*Ictiobus bubalus*	S5	-
Paddlefish	*Polyodon spathula*	S3	-

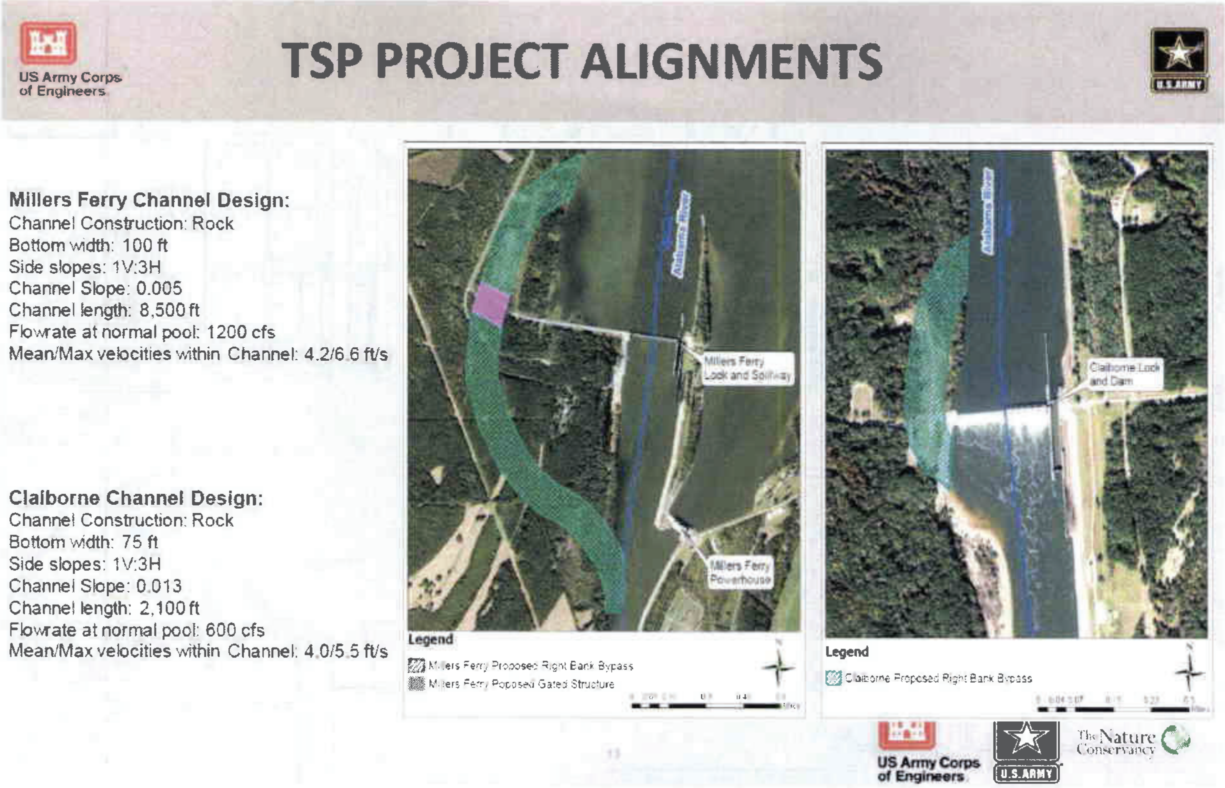
Total project cost estimates were calculated by evaluating several factors, including construction and construction management, real estate, PED, contingencies, and escalation estimates. An abbreviated risk analysis method was used to estimate contingencies. The total project cost for Alternative 5d was the lowest at $188 million, and it was also the most cost effective (CE) at $8.45 average cost per habitat unit.

Impact to hydropower (MWH/dollar), impact to navigation (tonnage/dollar), and impact to recreation (unit-day) values were calculated and combined to provide a national economic development (NED) account score for each alternative for 2023. Alternative 1 (no action) had the highest value at $18,621,994 while Alternative 5d had a lower value at $17,315,220.

The Corps used a certified regional economic model called Regional Economic System (RECONS) to determine MCDA scores for each alternative. Alternative 5d was ranked among the lowest with $347,992,000 gross regional product for Alabama and 3,211 full-time equivalent jobs created. The Corps used an other social effects (OSE) analysis to evaluate benefits to disadvantaged communities and focused on increased ecosystem resiliency metrics. Alternative 5d was ranked the highest with a score of 1.000.

Finally, a comprehensive plan determination multi-criteria decision analysis (MCDA), which incorporated EQ, RED, NED, and OSE values, was used to rank all alternatives. Alternative 5d had the highest comprehensive score at 3.538. The Corps also noted that natural bypass structures at both dams is the preferred alternative of The Nature Conservancy, the non-federal sponsor.

Channel design for Millers Ferry natural bypass includes rock channel construction, 100 ft bottom width, 1V:3H side slopes, 0.005 channel slope, 8,500 ft channel length, 1200 cfs flow rate at normal pool elevation, 4.2 ft/s mean velocity within channel, and 6.6 ft/s maximum velocity within channel (Figure 2). Channel design for Claiborne natural bypass includes rock channel construction, 75 ft bottom width, 1V:3H side slopes, 0.013 channel slope, 2,100 ft channel length, 600 cfs flow rate at normal pool elevation, 4.0 ft/s mean velocity within channel, and 5.5 ft/s maximum velocity within channel (Figure 2). The Corps has noted that additives for attraction to fish passage structures will be added to each structure; however, those additives have not been added to the overall structure design at the time of this report.



US Army Corps of Engineers

TSP PROJECT ALIGNMENTS

Millers Ferry Channel Design:
Channel Construction: Rock
Bottom width: 100 ft
Side slopes: 1V:3H
Channel Slope: 0.005
Channel length: 8,500 ft
Flowrate at normal pool: 1200 cfs
Mean/Max velocities within Channel: 4.2/6.6 ft/s

Claiborne Channel Design:
Channel Construction: Rock
Bottom width: 75 ft
Side slopes: 1V:3H
Channel Slope: 0.013
Channel length: 2,100 ft
Flowrate at normal pool: 600 cfs
Mean/Max velocities within Channel: 4.0/5.5 ft/s

Figure 2. Initial design of natural bypass structures at Claiborne and Millers Ferry L&D (USACE, TSP Milestone Meeting, March 1, 2023).

FISH AND WILDLIFE CONSERVATION MEASURES AND RECOMMENDATIONS

The following conservation measures are provided to minimize loss of or damage to fish and wildlife resources and to provide for the improvement of such resources. The Service recommends the Corps implement these measures to reduce impacts and to benefit fish and wildlife. The Corps has requested section 7 consultation regarding the construction of natural bypass structures at Claiborne and Millers Ferry L&D, which will be addressed in a separate document.

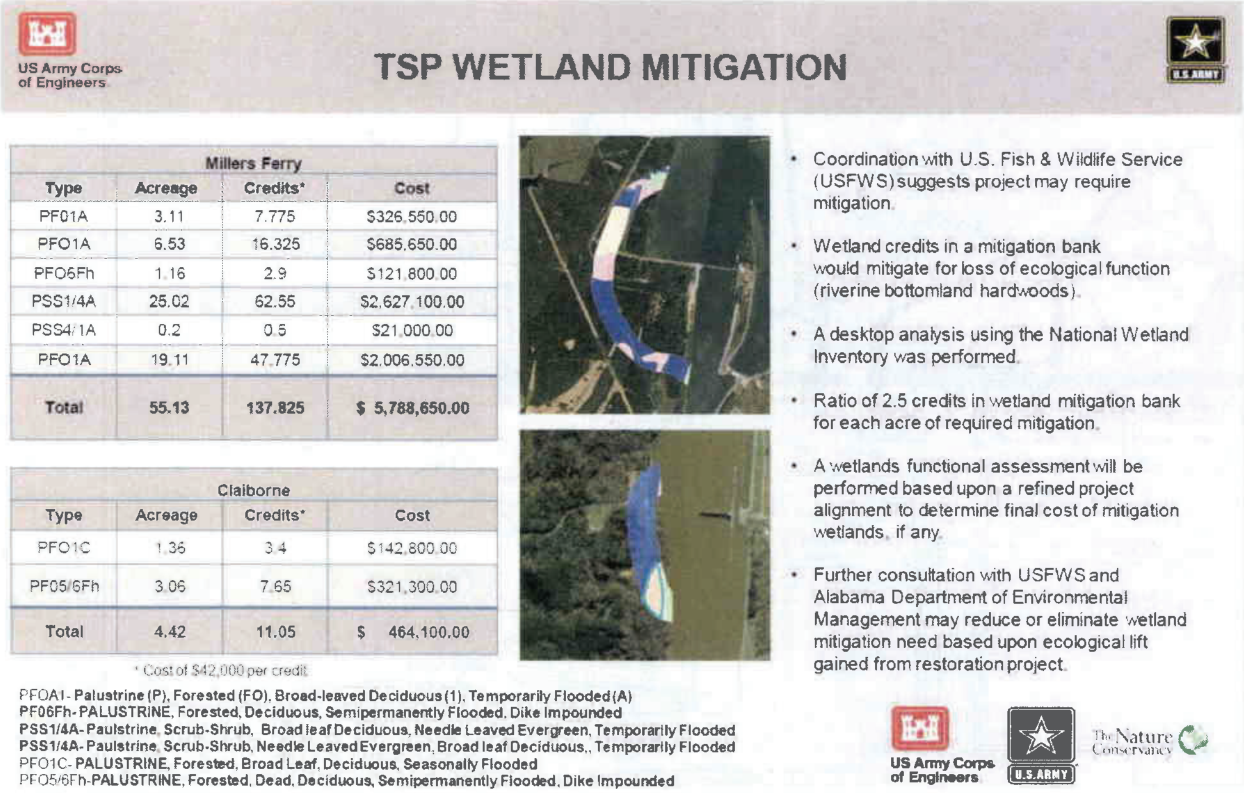
Fish Passage

Complicated life histories of aquatic species and the challenges associated with the barriers and effects of restricted flows from dams have created the need for managers to develop a toolkit for successful mitigation strategies (Katopodis 2005). This toolkit should include methods that analyze the relationship between fish migration and hydrographs, fish attraction to passage structures, passage structure hydraulics and fish passability, fish screen hydraulics and fish responses, and development of natural structures that contain instream fish habitat (Katopodis 2005).

In addition to additives for fish attraction to proposed passage structures, which could include changes to the regulation of flow, we also recommend the Corps consider mitigation measures that will facilitate downstream migration of fishes and restoration of natural flow regimes as much as possible. Downstream migration is an essential component of many migratory fishes' life cycles, and mortality from interaction with hydraulic turbines or over spillways can negatively affect population numbers and stability (Larinier 2001). Downstream passage can be improved by utilizing screens to prevent fish from interacting with turbines or of behavioral guidance devices, although the latter devices are considered experimental (Larinier 2001). Restoration of natural flows would also benefit other native aquatic species, including several listed and at-risk fishes, freshwater mussels, crayfish, and gastropods, by restoring connectivity and improving water quality and habitat. We recommend implementing criteria from the Service's *Fish Passage Engineering Design Criteria* (2017) guidelines when feasible.

Wetland Mitigation

The Service recommends the Corps conserve all habitats potentially affected by construction of fish passage structures in order to achieve conservation of all species. Avoidance and minimization of modification of wetland habitat is recommended. If impacts to wetlands cannot be avoided, then the Service recommends that, at minimum, the current status of the affected resource is maintained, if not improved. The Corps discussed a potential wetland mitigation plan during the TSP milestone meeting on March 1, 2023, which analyzed a ratio of 2.5 mitigation bank credits per acre of affected wetland (Figure 3).



US Army Corps of Engineers

TSP WETLAND MITIGATION

Millers Ferry			
Type	Acreage	Credits*	Cost
PF01A	3.11	7.775	$326,550.00
PFO1A	6.53	16.325	$685,650.00
PFO6Fh	1.16	2.9	$121,800.00
PSS1/4A	25.02	62.55	$2,627,100.00
PSS4/1A	0.2	0.5	$21,000.00
PFO1A	19.11	47.775	$2,006,550.00
Total	**55.13**	**137.825**	**$ 5,788,650.00**

Claiborne			
Type	Acreage	Credits*	Cost
PFO1C	1.36	3.4	$142,800.00
PF05/6Fh	3.06	7.65	$321,300.00
Total	4.42	11.05	$ 464,100.00

* Cost of $42,000 per credit

- Coordination with U.S. Fish & Wildlife Service (USFWS) suggests project may require mitigation.
- Wetland credits in a mitigation bank would mitigate for loss of ecological function (riverine bottomland hardwoods).
- A desktop analysis using the National Wetland Inventory was performed.
- Ratio of 2.5 credits in wetland mitigation bank for each acre of required mitigation.
- A wetlands functional assessment will be performed based upon a refined project alignment to determine final cost of mitigation wetlands, if any.
- Further consultation with USFWS and Alabama Department of Environmental Management may reduce or eliminate wetland mitigation need based upon ecological lift gained from restoration project.

PFOA1- Palustrine (P), Forested (FO), Broad-leaved Deciduous (1), Temporarily Flooded (A)
PF06Fh- PALUSTRINE, Forested, Deciduous, Semipermanently Flooded, Dike Impounded
PSS1/4A- Paulstrine, Scrub-Shrub, Broad leaf Deciduous, Needle Leaved Evergreen, Temporarily Flooded
PSS1/4A- Paulstrine, Scrub-Shrub, Needle Leaved Evergreen, Broad leaf Deciduous,, Temporarily Flooded
PFO1C- PALUSTRINE, Forested, Broad Leaf, Deciduous, Seasonally Flooded
PFO5/6Fh-PALUSTRINE, Forested, Dead, Deciduous, Semipermanently Flooded, Dike Impounded

Figure 3. Potential wetland mitigation plan for the Corps' selected alternative. Presented at the TSP milestone meeting on March 1, 2023.

The Service recognizes that the goal of avoiding or minimizing losses can include physical modification of replacement habitat to convert it to the same type lost, restoration or rehabilitation of previously altered habitat, increased management of similar replacement habitat so that the in-kind value of the lost habitat is replaced, or a combination of these measures (46

FR 15, January 23, 1981). We look forward to continued discussions with the Corps to finalize a solution for wetland mitigation.

Migratory Birds

Multiple species of migratory birds from the Service's Birds of Conservation Concern (BCC) list could be present in the study area around Claiborne and Millers Ferry L&D. The Service recommends the Corps follow the nationwide conservation standards to conserve these species and implement conservation measures from the East Gulf Coastal Plain Joint Venture Implementation Plan (Greene et al. 2021), which identifies long-term goals and objectives that will improve sustainability of priority bird populations, if feasible.

Recreational Areas

The Service recommends that the Corps maintain, replace, or create recreational features in the vicinity of the study area around Claiborne and Millers Ferry L&D. These features can allow access to the river in different ways and allow the public to appreciate fish and wildlife resources. Any recreational features incorporated into this project should achieve these objectives.

USFWS POSITION

Based on the analyses presented by the Corps on March 1, 2023, the Service tentatively supports the selected alternative (5d) of construction of natural bypass channels at both Claiborne and Millers Ferry L&D and currently prefers this option over the No Action Alternative. However, more information on design, particularly on details that will address downstream migration, additives for fish attraction to passage structures, and other factors that will affect the passability of the structures, including but not limited to the timing and duration of flows through the bypass channel, will be needed in order for the Service to fully evaluate this alternative in the final FWCAR. In addition, the Service recommends that the Corps consider wetland mitigation, migratory bird conservation measures, and recreational area preservation or improvement to conserve all habitats potentially affected by the project and to benefit all resources. We look forward to continuing to work with the Corps and other partners and stakeholders during the next phase of the study to finalize the design of the selected alternative and to conserve fish and wildlife resources.

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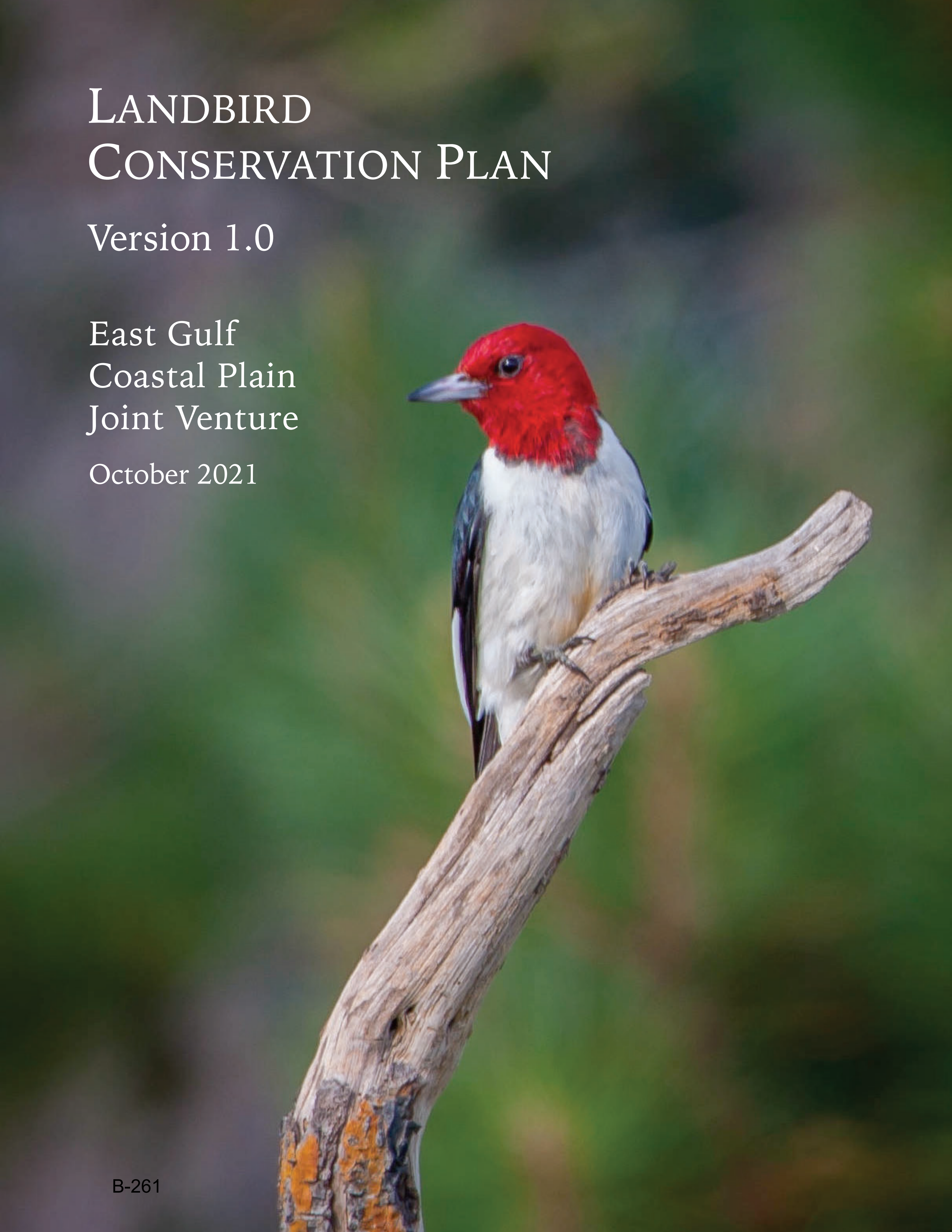
Landbird Conservation Plan

Version 1.0

East Gulf
Coastal Plain
Joint Venture

October 2021



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The East Gulf Coastal Plain Joint Venture thanks the many partners whose insight, input, and review were critical to this plan's completion.

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www.egcpjv.org

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Cover Photograph: Red-headed Woodpecker, Michael Carlo,
U.S. Fish and Wildlife Service

Executive Summary

The East Gulf Coastal Plain Joint Venture (**EGCPJV**) is a public-private partnership that provides a framework for regionally integrated bird conservation planning for the long-term sustainability of bird populations and their ecological communities. The EGCPJV's Technical Advisory Team, under the direction of the Management Board, formed the Landbird Working Group (LWG) to address the population and habitat needs of landbirds, a group of species which have declined precipitously in North America since 1970 (Rosenberg et al. 2019). The LWG was tasked with the development of a Landbird Conservation Plan (hereafter, the Plan) to include, at a minimum, quantified landbird population and habitat objectives for species that breed within the East Gulf Coastal Plain (EGCP) region. This Plan is the first in a series of plans for conservation of various avifaunal taxa within the EGCP. Bird populations are under increasing pressures from habitat loss and fragmentation, degradation and conversion to other land cover types and uses, in addition to myriad other stressors. This Plan sets initial population and habitat objectives for priority landbirds, which breed in five broadly defined terrestrial systems: Eastern Interior Grasslands, Eastern Shrub-Scrub, Freshwater Forested Wetlands, Pine-Dominated Woodlands and Savannas, and Upland Hardwood & Pine-Hardwood Woodlands and Forests. The Plan describes the process for selecting priority systems and species and reports a transparent, science-based approach to answering three fundamental questions in conservation planning:

- **How many birds?**
- **How much habitat?**
- **Where is the current habitat available and where do we need more?**

We determined priority landbird species (Chapter 2) based on priority lists in the Partners in Flight Landbird Conservation Plan (Rosenberg et al. 2016), the Partners in Flight (PIF) Avian Conservation Assessment Database (ACAD; Panjabi et al. 2019), the EGCPJV Implementation Plan (EGCPJV 2008), the U.S. Fish and Wildlife Service's (USFWS) Birds of Management Concern (USFWS 2008), State Wildlife Action Plans (SWAPs), and plans and lists from adjacent migratory bird joint ventures (hereafter, JVs). Priority species were selected if they (1) met priority list criteria, (2) were representative of the species using each terrestrial system in the JV, and (3) had sufficient data to calculate population and/or habitat objectives. The initial list was refined using an average weighted scoring process, trends in the most recent 10 years of North American Breeding Bird Survey (BBS) data, and species ranges. Each of the resulting 29 priority species was assigned to one or more of the five terrestrial systems prioritized in the Plan.

Population objectives (Chapter 3) for priority species were developed using the 10- and 30-year population targets in the Partners in Flight Landbird Conservation Plan (Rosenberg et al. 2016) to stabilize and/or increase bird populations in decline. The LWG used a step-down process to refine population targets for **Bird Conservation Regions (BCRs) 27 and 29** within the geography based on the proportion of current populations occurring within the JV boundary. Habitat objectives were set for each broadly defined terrestrial system/habitat type using population objectives and species density estimates. American Woodcock and Red-cockaded Woodpecker have existing plans (Kelley et al. 2008 and USFWS 2003, respectively) that specify population and habitat objectives within the East Gulf

Coastal Plain geography, and we chose to defer to these plans in lieu of calculating objectives based on the Partners in Flight Landbird Conservation Plan (Rosenberg et al. 2016). The working group determined that the species requiring the most habitat area to meet its population objective would be used to set the baseline habitat objective for each habitat type (Chapter 4). Habitat objectives were then allocated geographically for each State-by-BCR area based on the relative restoration potential of each habitat type for each State-by-BCR area compared to the JV. For example, Mississippi x BCR-27 contains 46% of the JV-wide restoration potential for Eastern Interior Grasslands; thus, we allocated 46% of the JV-wide habitat objective for grasslands to Mississippi. Geographically-allocated habitat objectives and information about habitat condition inform how individual organizations can concentrate conservation efforts to meet local and regional objectives.

> **"Geographically-allocated habitat objectives and information about habitat condition inform how individual organizations can concentrate conservation efforts to meet local and regional objectives."**

The determination of priority species, population objectives, and habitat objectives includes many decision points and assumptions. We explicitly state critical assumptions (Chapter 3) and recognize the need to re-evaluate processes and associated assumptions as new information becomes available. This document represents our best estimation of the amount and placement of suitable habitat to meet breeding bird population objectives derived from national bird conservation plans. These objectives will be revisited regularly, and this Plan will be revised in subsequent iterations to include other aspects of landbird conservation (e.g., habitat objectives for wintering species, threats to habitat types; Chapter 5). This Plan outlines priority bird species for the East Gulf Coastal Plain and presents population and habitat objectives for these species by habitat. Throughout the Plan, we refer to the geography within our JV's administrative boundary in BCR 27 (Southeastern Coastal Plain) and the small portion within BCR 29 (the Piedmont) as the East Gulf Coastal Plain. Objective setting plays a critical role in supporting successful conservation delivery by our partners. We address how objectives support conservation decisions of administrators and land managers and acknowledge how defined goals provide a means to measure our success in conserving sustainable bird populations and communities (Chapter 5). Defining measurable population goals serves as a means to meet our overarching goal of conserving sustainable bird populations and their communities (USFWS 2008).

Acronyms and Abbreviations Used

ac	acres
ACAD	Avian Conservation Assessment Database
AI	Area Importance, referring to a score designated by Partners in Flight
BBS	Breeding Bird Survey
BCR	Bird Conservation Region
EGCP	East Gulf Coastal Plain (referring to the physiographic region)
EGCPJV	East Gulf Coastal Plain Joint Venture
FIA	Forest Inventory & Analysis Program
GAP	Gap Analysis Project
JV	Joint Venture
NABCI	North American Bird Conservation Initiative
NLCD	National Land Cover Database
PIF	Partners in Flight
SECAS	Southeast Conservation Adaptation Strategy
SWAP	State Wildlife Action Plan
USFWS	United States Fish and Wildlife Service
USGS	United States Geological Survey

Landbird Conservation Plan
East Gulf Coastal Plain

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Introduction

The **East Gulf Coastal Plain Joint Venture** (EGCPJV) administrative boundary approximates the East Gulf Coastal Plain (EGCP) physiographic region defined by Partners in Flight (PIF; EGCPJV 2008). Although Joint Ventures generally align with Bird Conservation Regions (BCRs), delineation of JV boundaries is an imperfect process and often results in sections of **multiple BCRs residing within a single JV**. The EGCPJV's geographic area covers the portion of North American Bird Conservation Initiative (NABCI) BCR 27 (Southeastern Coastal Plain) that lies west of the Alabama-Georgia state line, includes much of the panhandle of Florida, much of central and southern Alabama and Mississippi, parts of western Tennessee and Kentucky, and eastern Louisiana. In central Alabama, the EGCPJV boundary also encompasses approximately 2.5 million acres (ac) of BCR 29 (Piedmont) and 670,000 ac of BCR 28 (Appalachian Mountains). To the west, the EGCPJV includes 724,000 ac of BCR 26 (Mississippi Alluvial Valley), mostly in Louisiana. To the north, the geography includes 135,000 ac of BCR 24 (Central Hardwoods). This plan establishes population and habitat objectives for only BCRs 27 and 29 intersecting the administrative boundaries, as other BCRs are included in plans of the adjoining JVs: Appalachian Mountains, Atlantic Coast, Central Hardwoods, Gulf Coast, and Lower Mississippi Valley (Figure 1).

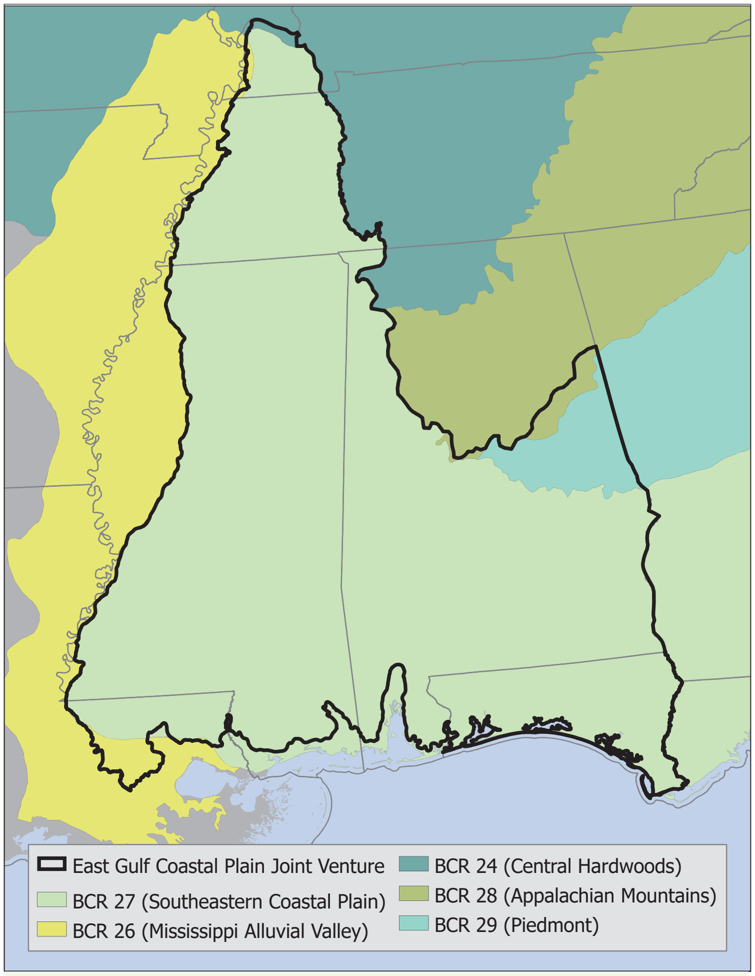

Figure 1. The East Gulf Coastal Plain Joint Venture boundary relative to adjacent Joint Ventures.

Some birds of the East Gulf Coastal Plain, from left: Eastern Towhee/Jean Weller; Wood Thrush/Steve Maslowski; Prothonotary Warbler/National Digital Library; Eastern Wood-Pewee/Alan Schmierer

The East Gulf Coastal Plain: Physical Features and Vegetation

The EGCPJV's geography includes 62.63 million ac of diverse lands and waters. Forest is the predominant land cover: 23% pine, 12% upland hardwoods, 12% mixed pine-hardwood forest, and 14% woody (or forested) wetlands (Figure 2, Table 1; Yang et al. 2018). Agricultural land use (~20%) is common, particularly in the Black Belt prairie, the Loess Hills bordering the Mississippi Alluvial Valley, and parts of southern Alabama. Developed areas (<7%), shrub-scrub conditions (<6%), and predominantly herbaceous land cover (<4%) are less common.

Historically, evergreen forest was prevalent in the EGCP physiographic region with the most common evergreen forest types dominated by longleaf pine (*Pinus palustris*), slash pine (*P. elliotti*), and loblolly pine (*P. taeda*), often with a co-dominant oak species (LANDFIRE 2014). Current composition of pine has shifted toward loblolly and shortleaf pine due to their economic importance to modern silvicultural practices. Ranked from greatest to least abundance by basal area, the current ratio of loblolly, shortleaf, slash, and longleaf pines is 4:2:1:1, respectively (Wilson et al. 2013).

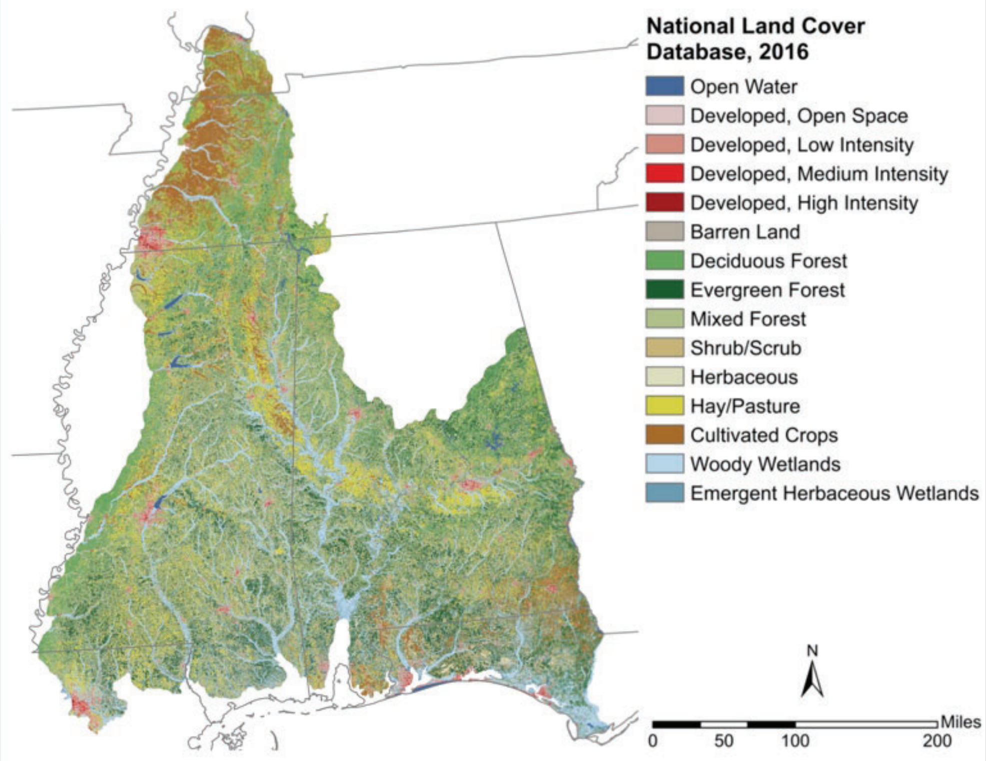

Figure 2. Land use class and cover types in the East Gulf Coastal Plain derived from National Land Cover Database 2016 (Yang et al. 2018).

Deciduous forest is concentrated along the Tennessee River and the Loess Hills and floodplain forests adjacent to the Mississippi Alluvial Valley. Mixed pine-hardwood forest is distributed throughout the region. Agricultural development has substantially affected the landscape with approximately 12.45 million ac in agricultural production (hay, pasture, and cultivated crops), an area nearly equivalent to the geography's evergreen forests. Cultivated crops include corn (*Zea mays*), cotton (*Gossypium hirsutum*), soybeans (*Glycine max*), wheat (*Triticum aestivum*), and peanuts (*Arachis hypogaea*) (USDA 2019). These are primarily located in areas of western Tennessee and Kentucky, the Black Belt Prairie region of Mississippi and Alabama, and along the Alabama-Florida state line.

The EGCP generally includes three ecological subregions (from McNab et al. 2007):

Table 1. Area (hectares and acres) of each land use class and cover type in the East Gulf Coastal Plain (source: National Land Cover Database 2016 [Yang et al. 2018]).

LAND COVER	HECTARES	ACRES	%
Evergreen Forest	5,803,385	14,339,521	23.2
Woody Wetlands	3,576,039	8,835,996	14.3
Hay/Pasture	3,159,287	7,806,249	12.7
Mixed Forest	3,122,317	7,714,899	12.5
Deciduous Forest	3,049,630	7,535,298	12.2
Cultivated Crops	1,877,414	4,638,882	7.5
Developed, including Open Space	1,666,164	4,116,908	6.7
Shrub/Scrub	1,473,366	3,640,524	5.9
Herbaceous	971,363	2,400,130	3.9
Emergent Herbaceous Wetlands	213,153	526,678	0.9
Barren Land	55,039	135,995	0.2
Total	**24,967,157**	**61,691,080**	**100**

Coastal Plains—Middle Section (Subregion 231B): Strongly rolling to hilly terrain with soils ranging from sands and silt to chalk and clays. Vegetation is variable and historically included oak-pine, loblolly-shortleaf pine, and oak-hickory cover types.

This subregion also includes the Blackland Prairie Ecoregion, a mosaic of prairie, shrubland, and forest named for its soil's dark, rich color. Prairies occurred in two distinct areas: the Black Belt, which runs in a narrow strip from east-central Mississippi to Georgia and northward in discrete fragments into Tennessee, and the smaller, more southerly Jackson Prairie Belt. Surveys from the General Land Office in the 1830s show approximately 356,000 ac of prairies occurring in the Black Belt of Alabama and Mississippi and an additional 48,000 ac in the Jackson Prairie Belt in central Mississippi (Barone 2005a, b). Because of its historic soil fertility, the Blackland Prairie Ecoregion has undergone major, agriculture-related shifts in land use, including the growth of cotton plantations beginning in the late eighteenth century and more recent increases in wheat, corn, soybeans, peanuts, and pine plantings (Webster and Bowman 2008). These prairie belts have been reduced significantly from their pre-1830 extent, with perhaps only 500 ac of prairie remaining in Mississippi (Schotz et al. 2014) and with remnant fragments often occurring on drier or heavy clay soils less conducive to agriculture (Barone and Hill 2007). Prairie and shrubland loss in this subregion has ramifications for numerous disturbance-dependent bird species (Gilbert and Ferguson 2019).

Coastal Plains—Loess Section (Subregion 231H): Irregular plains and gently rolling hills with deep, fine-textured loess soils. Historic cover included oak-pine, loblolly-shortleaf pine, oak-hickory, and oak-gum-cypress forest types.

Gulf Coastal Plains and Flatwoods Section (Subregion 232B): Flat landscape of irregular or smooth plains on sand and clay soils. Longleaf-slash pine, loblolly-shortleaf pine, and oak-hickory forest types have historically dominated this section with oak-gum-cypress forests occurring along rivers.

Natural Disturbances, History, and Land Use

Longleaf pine woodland/Chuck Bargeron, University of Georgia, Bugwood.org

Disturbance regimes are key in maintaining many vegetative communities in this geography. Natural and anthropogenic fire has shaped much of the uplands and flatwoods into a pyric landscape (Stanturf et al. 2002). The geography also hosts a diverse array of coastal, riverine, and non-alluvial wetlands moderated by hydroperiod, soils, and relatively infrequent fire. Tornadoes, hurricanes, and ice storms also provide isolated, seasonal disturbances which reset the forest succession process (Peterson 2000).

The EGCP's climate, topography, frequent lightning strikes, and early anthropogenic management converged to sustain a pyric landscape resulting in the dominance of floristically diverse longleaf pine ecosystems in the Lower and Middle Coastal Plains (Van Lear et al. 2005, Frost 2006, White and Harley 2016). Longleaf pine ecosystems occupied as much as 60 million ac in the southeastern U.S. prior to European settlement (Outcalt and Sheffield 1996). The frequent fire regime of the Coastal Plain was characterized by low-intensity fire occurring predominantly during the growing season at a biannual to 3-year fire return interval (Frost 2006, Huffman 2006, Stambaugh et al. 2011, White and Harley 2016). The resulting vegetative composition and structure promoted fire adaptations in numerous wildlife species, including many high-profile species currently at risk [e.g., Gopher Tortoise (*Gopherus polyphemus*), Pine Snake (*Pituophis melanoleucus*), Bachman's Sparrow (*Peucaea aestivalis*), and Red-cockaded Woodpecker (*Dryobates borealis*)].

Due to demand for longleaf pine timber and turpentine, grazing practices, clearing for row crops, and disruption of a frequent-fire regime, the extent of longleaf pine ecosystems declined to 20 million ac by 1935 (Landers et al. 1995, Outcalt and Sheffield 1996, Frost 2006). Large-scale fire suppression continued through the 1980s until concerns about declining fire-adapted wildlife [e.g., Northern Bobwhite (*Colinus virginianus*), Wild Turkey (*Meleagris gallopavo*)] and a modernized understanding of ecosystem processes and wildfire fuel mitigation strategies led to a renewed interest in managing land with fire (Van Lear et al. 2005, Frost 2006). By this time, longleaf pine ecosystems had been reduced to less than 3 million ac, with remnants concentrated in the panhandle of Florida, southern Alabama, and the Red Hills region of southwestern Georgia (Landers et al. 1995, Outcalt and Sheffield 1996). A fragmented landscape, establishment of shade-tolerant, fire-sensitive tree species [e.g., maple (*Acer* spp.) and hickory (*Carya* spp.)], landowner practices, smoke management concerns, and cost remain

Forested wetland in Florida/Ryan Hagerty, U.S. Fish and Wildlife Service

obstacles to the restoration of a pyrogenic landscape (Ryan et al. 2013, Wonkka et al. 2015).

While fire shaped the EGCP's uplands and piney flatwoods, the additional influence of hydroperiod and soils defined the various forested and non-forested coastal, riverine, and non-alluvial wetlands. Wetland hydroperiods may be derived from seasonal rainfall, riverine flooding, groundwater, or deep groundwater sources (Winger 1986), and fire can be moderately infrequent (Wade et al. 2000). Wetlands contain enormous biodiversity and provide key habitat for wintering Henslow's Sparrows (*Centronyx henslowii*; Plentovich et al. 1999, Tucker and Robinson 2003, Brooks and Stouffer 2011) and Rusty Blackbirds (*Euphagus carolinus*; Greenberg and Matsuoka 2010, Luscier et al. 2010), both of which have suffered widespread and large population declines. Mitigation, landowner assistance programs, and promotion of forested wetland restoration and management for waterfowl and riparian songbirds are addressing wetland loss, but often with mixed results. Dedicated conservation funding, including the federal Duck Stamp, paid for primarily by waterfowl hunters, appears to be aiding the recovery of waterfowl species, the only taxonomic group currently on the rise (Rosenberg et al. 2019). Hopefully, forested wetland and riparian forest landbirds will follow waterfowl's upward trajectory as habitat conservation and restoration efforts continue.

A study of North American avifauna abundance found that 2.5 billion (or 27%) of landbirds have been lost since 1970, with grassland birds incurring the highest proportional losses in abundance (53%; Rosenberg et al. 2019). Future land use and climate change models project additional habitat loss for numerous wildlife species (Bateman et al. 2016), and potential declines in habitat quantity and quality are greatest for species associated with open vegetative structure (Martinuzzi et al. 2013, Martinuzzi et al. 2015). Also of concern is increasing development pressure near areas set aside for conservation (e.g., National Wildlife Refuges; Hamilton et al. 2016), which can decrease connectivity among protected sites, reduce use of prescribed fire as a management tool, and alter hydrology—reducing suitable habitat surrounding these areas. As a result, agencies, public-private partnerships, and non-governmental organizations are re-evaluating conservation strategies, habitat goals, and apportionment of responsibilities in the context of land-use scenario and climate change vulnerability assessments (Bagne et al. 2014, Galbraith et al. 2014, Culp et al. 2017, Rempel and Hornseth 2017).

The East Gulf Coastal Plain Joint Venture: History and Purpose

The EGCPJV is a public-private partnership seeking to advance the sustainable conservation of bird populations and their habitats. Formed as a science-based, strategic approach to conservation at an ecoregional scale rather than a jurisdiction formed by political boundaries, the EGCPJV convenes Federal, State, non-governmental agency, university, and private stakeholders to address bird conservation in response to regional opportunities and threats.

The EGCPJV **Implementation Plan**, first published in 2008 (EGCPJV 2008), established the JV's mission to protect and restore bird populations of the EGCP geography by coordinating the effective conservation of key habitats. The Implementation Plan articulated the EGCPJV's commitment to a science-based approach to conservation that is strategically implemented at the landscape-scale to maximize conservation benefits and to leverage human and financial resources. The Implementation Plan positioned the JV as a key communicator and platform for alignment of bird conservation priorities for partner organizations and the broader regional conservation community.

Eastern Kingbird/Jim Hudgins, U.S. Fish and Wildlife Service

The Implementation Plan also established the EGCPJV's mission and strategic conservation framework. To advance the mission of sustainably protecting and restoring bird populations, management goals for priority species and their habitats are key. The partnership has devoted its past resources to decision support (e.g., Open Pine Decision Support Tool), which serves as the basis for subsequent conservation planning and delivery. The partnership is currently focusing on the identification of taxonomic priorities and the quantification of bird population and habitat objectives. The EGCPJV builds upon the North American Bird Conservation Initiative (NABCI), the PIF Landbird Conservation Plan, the National Bobwhite Conservation Initiative, and numerous species recovery plans, which contribute to the growing body of knowledge pertaining to priority bird species' ecology, population status, threats, response to management, and paths to recovery.

> "The EGCPJV's Landbird Conservation Plan sets biologically-derived habitat and population objectives. The intent is for partner organizations, as individuals and in collaboration, to use objectives to focus the delivery of on-the-ground conservation projects."

The EGCPJV's Landbird Conservation Plan (hereafter, Plan) draws from the Implementation Plan and other national and regional bird conservation efforts to set biologically-derived habitat and population objectives. The intent is for partner organizations, as individuals and in collaboration, to use objectives to focus the delivery of on-the-ground conservation projects.

Goals of the Landbird Conservation Plan

The Plan defines quantitative, spatially-explicit bird population and habitat objectives derived from biological planning and conservation design processes. This Plan addresses three key questions:

1. How many birds are needed to sustain populations?
2. How much habitat is needed to sustain bird population targets identified in #1?
3. Where is current habitat, and where is additional habitat needed?

The Plan should assist partners in identifying strategies for conservation delivery that maximize contributions toward bird population objectives (EGCPJV 2008). These strategies are designed to either increase populations or lessen the rate of decline in species in steep decline. The Plan is a component of the JV's overall bird conservation strategy. The partnership is developing a suite of conservation plans for landbirds, waterbirds, shorebirds, and waterfowl, used in concert with decision support tools and partner expertise to support management decisions and prioritize conservation projects.


Black Belt Prairie, Mississippi/Dwayne Estes

Overview of Process

The Plan identifies priority species and establishes both population and habitat objectives to inform future conservation delivery. This Plan has 10- and 30-year objectives to align with continental planning horizons (e.g., Partners in Flight Landbird Conservation Plan; Rosenberg et al. 2016) and sets expectations for evaluation of conservation delivery. Plan revision will be based on conservation delivery, monitoring, and evaluation outcomes (Figure 3).

The Landbird Working Group (hereafter, LWG) identified priority species (refer to Chapter 2) using a weighted process, which included the **Partners in Flight Watch List**, State Wildlife Action Plans


Bachman's Sparrow/Alan Schmierer

(SWAPs), plans from neighboring JVs, and other efforts. Each priority species was associated with one or more vegetative communities or systems (e.g., Eastern Interior Grasslands, Freshwater Forested Wetlands, Pine-dominated Woodlands and Savannas).

To develop population and habitat objectives, the LWG used a step-down process from the PIF Landbird Conservation Plan and species recovery plans prepared by the U.S. Fish and Wildlife Service (for Red-cockaded Woodpecker) and a taskforce and working group collaborating with the Association of Fish and Wildlife Agencies (for American Woodcock). Population and habitat objectives were established for states based on estimates of current bird populations, habitat availability, and the proportion of restorable habitat encompassed in each State-by-BCR area of the geography (refer to Chapters 3 and 4).

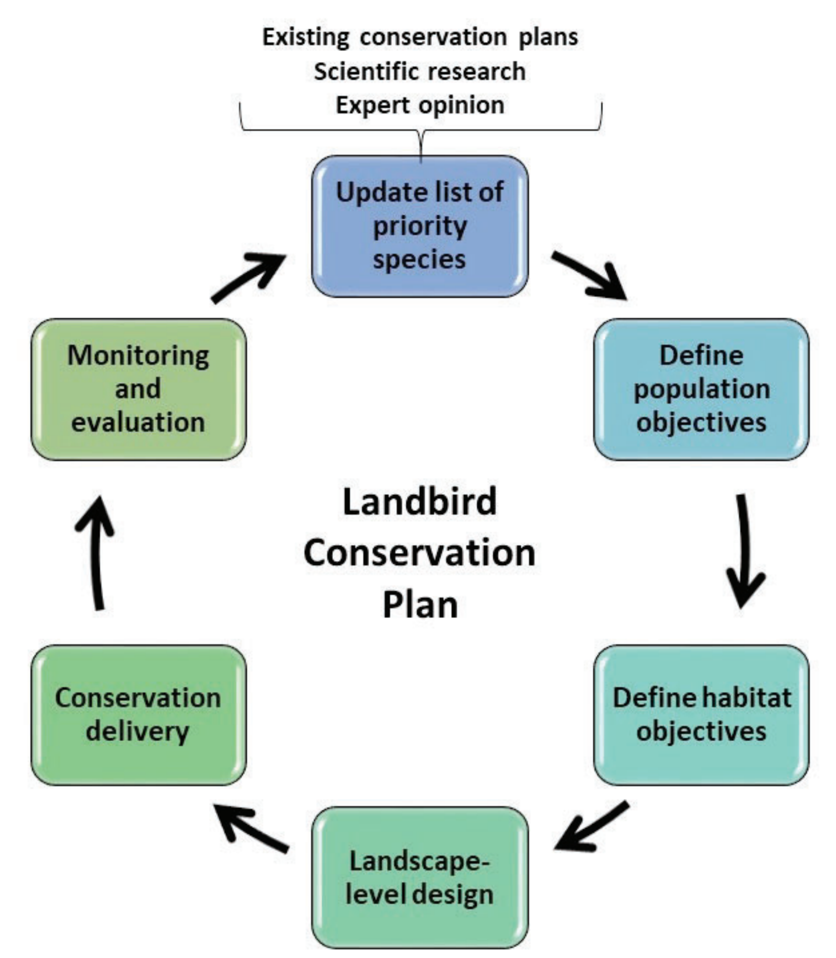

Figure 3. The East Gulf Coastal Plain Joint Venture Landbird Conservation Plan outlines an iterative process emphasizing collaborative, strategic, and outcome-driven avian conservation.

Ultimately, the success of the Plan is contingent on delivering habitat at the right spatial scale and location and on bird populations responding as predicted to improvements in habitat availability and condition.

Priority Landbird Species

Overview

Upon the partnership's formation, the EGCPJV's Technical Advisory Team and Management Board selected priority habitats to drive initial conservation efforts. Priority habitats were selected based on conservation concern for species associated with each habitat type, the importance of each habitat to partner organizations, and the current quantity and quality of habitats within the geography (EGCPJV 2008). The habitat framework includes five broadly defined terrestrial systems: Eastern Interior Grasslands, Eastern Shrub-Scrub, Freshwater Wetland, Pine-dominated Woodlands and Savannas, and Upland Hardwood & Pine-Hardwood communities (Table 2). For habitat type descriptions, refer to the Appendices of the Implementation Plan (EGCPJV 2008).

Table 2. The East Gulf Coastal Plain Joint Venture habitat framework (from EGCPJV 2008).

EGCPJV Habitat Framework
Eastern Interior Grasslands Communities
Meadows & Prairies
Agricultural & Cropland
Pasture
Rank Herbaceous/Grasses
Eastern Shrub-Scrub Communities
Early-successional Hardwood/Pine
Manmade/Disturbed
Freshwater Wetland Communities
Freshwater Forested Wetlands
Bottomland Hardwood
Cypress-Tupelo
Bay Swamps & Depressional Wetlands
Shrub-scrub Swamp
Beaver Ponds/Meadows
Riparian
Riparian Woodland
Riparian Scrub/Edge
Pine-Dominated Communities
Pine Flatwoods/Mesic Pine (Open/Savanna)
Pine Uplands & Sandhills (Open/Savanna)
Pine Plantations
Other Pine Forest
Upland Hardwood & Pine-Hardwood Communities
Mixed Hardwoods
Loess Bluffs
Tennessee Plateau
Pine-Hardwood
Hardwood Plantations

The identification of priority bird species was the next step to refine biological planning within priority habitat types. However, many species prioritization "lists" identifying important species to drive conservation efforts exist at the federal, regional, and state levels. These lists often incorporate stakeholder efforts to identify priority species, and they frequently account for species population trends, range, and threats to sustainable populations. The LWG acknowledged the extensive science behind existing prioritization efforts and, as a first step, aggregated priority lists from continental, regional, and state plans. The LWG then developed a comprehensive weighting structure, described below, to identify and rank EGCPJV's priority landbird species.

The initial species list included any landbirds addressed in the following:

- EGCPJV Implementation Plan (EGCPJV 2008),
- PIF Landbird Conservation Plan (Rosenberg et al. 2016),
- U.S. Fish and Wildlife Service (USFWS) Birds of Conservation Concern (USFWS 2008),
- Most recent SWAPs for
    - Alabama (ADCNR et al. 2015),
    - Florida (FWC 2012),
    - Kentucky (Kentucky's Comprehensive Wildlife Conservation Strategy 2013),
    - Louisiana (Holcomb et al. 2015),
    - Mississippi (Mississippi Museum of Natural Science 2015),
    - Tennessee (Tennessee SWAP Team 2015),
- and conservation plans from adjacent JVs.

Adjoining JV plans included:

- the Gulf Coast JV Landbird Conservation Plan (Vermillion et al. 2012) and
- Lower Mississippi Valley JV Landbird Plan (Twedt et al. 1999).

Supporting information came from:

- Central Hardwoods JV (Jones-Farrand et al. 2009, Bonnot et al. 2011, 2013),
- Atlantic Coast JV (ACJV, unpubl. report), and
- Appalachian Mountains JV (AMJV, unpubl. report).

Loggerhead Shrike/Alan Schmierer

Expert opinion and existing literature supported identification of associated habitat types for each species, and weighted rankings were used in combination with 10- and 30-year rates of decline from North American Breeding Bird Survey (BBS; Sauer et al. 2017) to finalize the list of priority bird species by habitat type.

The LWG identified 118 species for consideration within the Landbird Conservation Plan. In order to refine the list of landbird species into a set of manageable priorities, the LWG used a hierarchical decision process, which included existing bird conservation efforts (Table 3), species population trends from the BBS, relative importance of the EGCP to the species, species characteristics, and habitat type. The final priority list of 29 landbird species (see Table 4 below) was intended to reflect species suitable for long-term biological planning and conservation delivery. This prioritization process was intentionally designed to be iterative and responsive to new science and shifting conservation needs.

Prioritizing Species: Using a Weighted-Average Approach

To be consistent with landbird priorities in overlapping and adjacent geographies, the LWG considered 16 existing bird conservation plans and databases to refine the species list and set priorities (Table 3). Each plan was assigned a weight based on the plan's importance to landbird priorities in the EGCPJV's geography. Species listed as Red, Yellow, or Tan Watch List species in the PIF Continental Landbird Conservation Plan received the greatest weight (20%) due to continental importance (Rosenberg et al. 2016). PIF assigns Watch List status based on relative vulnerability of all landbirds for six factors: population size, breeding distribution, non-breeding distribution, threats during breeding season, threats during non-breeding season, and population trend. Scores for each factor ranging from 5 (highest) to 1 (lowest) were used to develop continental concern groups with population goals:

- Red Watch List ("Recover"): Species with high vulnerability due to small population and range, high threats to breeding and non-breeding distributions and rangewide declines.
- Yellow Watch List ("Reverse Decline"): Species in decline with moderate to high threats.
- Common Birds in Steep Decline or Tan Watch List ("Stabilize"): Species in steep decline that are sufficiently abundant to prevent or delay PIF watch list status or federal listing under the Endangered Species Act of 1973 (ESA; 16 U.S.C. § 1531 et seq.).

Table 3. A weighted-average process was used to prioritize bird species in the East Gulf Coastal Plain Landbird Conservation Plan. Species received a weighted average score from 0 (lowest) to 1.0 (highest) based on occurrence in 16 existing bird conservation plans.

WEIGHT ASSIGNMENTS TO EXISTING BIRD CONSERVATION PLANS	
PIF Landbird Conservation Plan 2016: Continental Concern Group	20.0%
Species of Greatest Conservation Need in State Wildlife Action Plans (Alabama, 2015; Florida, 2012; Kentucky, 2013; Louisiana, 2015; Mississippi, 2015; Tennessee, 2015; 10% per plan)	60.0%
Area Importance (AI) in PIF Avian Conservation Assessment Database (ACAD) AI must be ≥ 4	5.0%
PIF Avian Conservation Assessment Database (ACAD) Regional Concern for BCR 27 and BCR 29	5.0%
USFWS Birds of Management Concern	2.5%
EGCPJV Implementation Plan 2008	2.5%
Priority in JV plans: Atlantic Coast, Lower Mississippi Valley (1.9% per plan)*	3.8%
Priority in JV plans: Appalachian Mountains, Central Hardwoods, or Gulf Coast (0.4% per plan)*	1.2%

*See section below for explanation of varying weights among JV plans.

Each state wildlife agency is responsible for developing a SWAP, which is updated every 10 years. Wildlife agencies develop lists of Species of Greatest Conservation Need within each SWAP based on conservation status, current and future threats, and socio-economic importance of species in their state. These lists are used to focus strategic conservation efforts and maximize state conservation successes. Landbirds identified as Species of Greatest Conservation Need in EGCPJV member states—Alabama, Florida, Kentucky, Louisiana, Mississippi, and Tennessee—each received a 10% weight if the species was identified in the most recent respective plan. Thus, 80% of weighting in the Plan's species prioritization process was derived from state-level SWAPs and the PIF Continental Landbird Plan.

While the PIF Continental Watch List provides a comprehensive list of species vulnerable to decline, the List generally does not incorporate regionality of species distributions. Thus, regional lists based solely on the PIF Continental Watch List include many species at the periphery of their range. PIF's ACAD (Panjabi et al. 2019) considers relative density and percent of species population within a BCR to develop an Area Importance (AI) score for each species occurring in each BCR (Panjabi et al. 2019). An AI score indicates the relative importance of a JV or region to a species based on the percent of the breeding population in the JV or region of interest. For the EGCPJV Landbird Conservation Plan, species with an AI score of $\geq$ 4, meaning at least 20% of the breeding population is captured in the EGCP, received an additional 5% weighting.

PIF ACAD also has a Regional Concern designation for each BCR (Panjabi et al. 2019). Species of regional importance are identified based on multiple continental and regional AI criteria. Thus, a species need not be included on a PIF Continental Watch List to receive a Regional Concern designation. The LWG gave the PIF ACAD Regional Concern designation an additional 5% weighting.

The USFWS has developed a list of Birds of Management Concern, which includes bird species, subspecies, populations, and geographic segments of populations warranting management or conservation attention. These species are under federal jurisdiction afforded under the Migratory Bird Treaty Act (50 CFR Part 10). To be eligible for Birds of Management Concern designation, species must be a high-priority gamebird, on the Birds of Conservation Concern 2008 list (USFWS 2008), a federally-listed species under the Endangered Species Act, or a species or population that is considered overabundant, thus leading to management conflicts (USFWS 2011). Landbirds with the Birds of Management Concern designation received an additional 2.5% weighting in the species prioritization process.


Male Northern Bobwhite/Ben Robinson

The EGCPJV's 2008 Implementation Plan identified 53 landbird species for consideration in biological planning within priority habitats identified in the habitat framework (Table 2). The selection of these landbirds was based on an evaluation of all breeding, wintering, and resident birds of the EGCP with relative conservation status and socioeconomic importance to the region (EGCPJV 2008). Landbirds in the Implementation Plan received a 2.5% weighting in this Plan to maintain continuity with the foundational priorities and implementation goals identified by public and private partners during the JV's formation.

The five neighboring JVs have each developed a landbird conservation plan and/or a landbird priority species list. Landbirds prioritized by neighboring JVs with a high degree of similarity in vegetative types to the EGCPJV (i.e., Atlantic Coast and Lower Mississippi Valley JVs) received 1.9% weighting. Landbirds prioritized by the other neighboring JVs (i.e., Appalachian Mountains, Central Hardwoods, and Gulf Coast JVs) received 0.4% weighting.

The LWG calculated a weighted average score ranging from 1.0 (highest prioritization) to 0 (lowest prioritization) based on the weighting assignments given to existing bird conservation plans (Table 3). An exhaustive list of species was considered for prioritization and Appendix A presents species' weighted average scores and their association with existing conservation plans.

Two priority landbird species identified in the EGCPJV Implementation Plan: Rusty Blackbird and Grasshopper Sparrow/ Alan Schmierer

Finalizing Selection of Priority Species

The LWG next assigned each species to primary and secondary habitat types based on known life-history characteristics. Species could be assigned to one or more of five broadly defined terrestrial systems: Eastern Interior Grasslands, Freshwater Forested Wetlands, Eastern Shrub-Scrub, Pine-dominated Woodlands and Savannas, and Upland Hardwood & Pine-Hardwood communities (Table 2). LWG members provided expert opinion via a vote to determine habitat type assignments for each species remaining in consideration. If at least three LWG members assigned a species to a habitat type, the habitat type served as the species' primary association.

Some species were assigned multiple habitat types as primary habitat associations. For example, Northern Bobwhite was classified as using Eastern Interior Grasslands and Pine-dominated Woodlands and Savannas. Species not assigned a primary habitat type (e.g., generalist species) were removed from consideration as priority species in this Plan. Six species were ultimately assigned more than one primary habitat type: American Kestrel (southeastern subspecies; *Falco sparverius paulus*), Cerulean Warbler (*Setophaga cerulea*), Eastern Kingbird (*Tyrannus tyrannus*), Kentucky Warbler (*Geothlypis formosa*), Northern Bobwhite, and Yellow-billed Cuckoo (*Coccyzus americanus*).

After assigning each species primary habitat types, additional information was collected to assess each species distribution. First, an evaluation was made as to whether the species' range was peripheral to the EGCP in order to direct conservation efforts to areas where core population needs could be addressed. Species excluded were Golden-winged Warbler (*Vermivora chrysoptera*), Canada Warbler

(*Cardellina canadensis*), Least Flycatcher (*Empidonax minimus*), Ruffed Grouse (*Bonasa umbellus*), Brown Creeper (*Certhia americana*), Black-capped Chickadee (*Poecile atricapillus*), Black-throated Blue Warbler (*Setophaga caerulescens*), Short-eared Owl (*Asio flammeus*), LeConte's Sparrow (*Ammospiza leconteii*), Bobolink (*Dolichonyx oryzivorus*), Greater Prairie-chicken (*Tympanuchus cupido*), Lark Sparrow (*Chondestes grammacus*), White-tailed Kite (*Elanus leucurus*), Burrowing Owl (*Athene cunicularia*), Vesper Sparrow (*Pooecetes gramineus*), Savannah Sparrow (*Passerculus sandwichensis*), and Bell's Vireo (*Vireo bellii*).

After removing marginal-range species, it was next determined if the weighted average score of the species was ≥0.5. All species with a core range and ≥0.5 weighted average within each habitat type were retained. However, if the species weighted average was <0.5 but the population was experiencing a significant 10-year decline based on the North American BBS, it was also retained. This included Yellow-billed Cuckoo, Eastern Wood-Pewee (*Contopus virens*), Field Sparrow (*Spizella pusilla*), Eastern Meadowlark (*Sturnella magna*), Eastern Kingbird, Eastern Towhee (*Pipilo erythrophthalmus*), and Indigo Bunting (*Passerina cyanea*).

The final priority landbird list includes 29 species (Table 4). These breeding species are in need of conservation in this geography and are assumed to be representative of species requiring similar habitats.

> **"The final priority landbird list includes 29 species (Table 4). These breeding species are in need of conservation in this geography and are assumed to be representative of species requiring similar habitats."**

Louisiana Waterthrush/Alan Schmierer

Table 4. Priority landbirds in the East Gulf Coastal Plain by primary habitat type.

PRIORITY LANDBIRDS ASSOCIATED WITH PRIMARY HABITAT TYPES	
Eastern Interior Grasslands	
American Kestrel (SE)	*Falco sparverius paulus*
Eastern Kingbird	*Tyrannus tyrannus*
Eastern Meadowlark	*Sturnella magna*
Field Sparrow	*Spizella pusilla*
Grasshopper Sparrow	*Ammodramus savannarum*
Henslow's Sparrow	*Centronyx henslowii*
Loggerhead Shrike	*Lanius ludovicianus*
Northern Bobwhite	*Colinus virginianus*
Eastern Shrub-Scrub	
Eastern Kingbird	*Tyrannus tyrannus*
Eastern Towhee	*Pipilo erythrophthalmus*
Indigo Bunting	*Passerina cyanea*
Painted Bunting	*Passerina ciris*
Prairie Warbler	*Setophaga discolor*
Freshwater Forested Wetland	
American Woodcock	*Scolopax minor*
Cerulean Warbler	*Setophaga cerulea*
Kentucky Warbler	*Geothlypis formosa*
Louisiana Waterthrush	*Parkesia motacilla*
Prothonotary Warbler	*Protonotaria citrea*
Rusty Blackbird	*Euphagus carolinus*
Swainson's Warbler	*Limnothlypis swainsonii*
Swallow-tailed Kite	*Elanoides forficatus*
Yellow-billed Cuckoo	*Coccyzus americanus*
Pine-Dominated	
American Kestrel (SE)	*Falco sparverius paulus*
Bachman's Sparrow	*Peucaea aestivalis*
Northern Bobwhite	*Colinus virginianus*
Red-cockaded Woodpecker	*Dryobates borealis*
Upland Hardwood & Pine-Hardwood	
Cerulean Warbler	*Setophaga cerulea*
Chuck-will's-widow	*Antrostomus carolinensis*
Eastern Whip-poor-will	*Antrostomus vociferous*
Eastern Wood-Pewee	*Contopus virens*
Kentucky Warbler	*Geothlypis formosa*
Red-headed Woodpecker	*Melanerpes erythrocephalus*
Wood Thrush	*Hylocichla mustelina*
Worm-eating Warbler	*Helmitheros vermivorum*
Yellow-billed Cuckoo	*Coccyzus americanus*


Eastern Meadowlark/Alan Schmierer


Kentucky Warbler/Alan Schmierer


American Kestrel/Alan Schmierer

Setting Population and Habitat Objectives

Overview

The LWG set population and habitat objectives for species in five broadly defined terrestrial systems: Eastern Interior Grasslands, Eastern Shrub-Scrub, Freshwater Forested Wetlands, Pine-dominated Woodlands and Savannas, and Upland Hardwood & Pine-Hardwood Woodlands and Forests. For Eastern Interior Grasslands, population and habitat objectives were set for two habitat subtypes, prairie and agricultural land cover. Prairie is important to some grassland bird species negatively associated with agricultural land use (e.g., Eastern Kingbird and Eastern Meadowlark; Gilbert and Ferguson 2019), whereas other grassland species readily use improved pasture and field edges (e.g., Loggerhead Shrike; Froehly et al. 2019).

Objective setting involved a seven-step process: 1) estimate current population sizes, 2) determine current population size in each habitat type, 3) calculate population objectives, 4) determine a range of species densities, 5) calculate habitat objectives, 6) assign habitat objectives to State-by-BCR areas, and 7) calculate the State-by-BCR habitat shortage (Figure 4).

Step 1. **Estimate current populations** in the East Gulf Coastal Plain.

Step 2. **Determine current population size in each habitat type** by multiplying the JV population size by the proportion of each habitat type in the EGCP landscape. For species assigned to more than one primary habitat type, current population size is divided between primary habitat types.

Step 3. **Calculate population objectives** by multiplying current population in each habitat type by the PIF population goal (Rosenberg et al. 2016).

Step 4. **Determine range of species densities** for each species in each of its primary habitat types.

Step 5. **Calculate habitat objectives** by multiplying population objectives (Step 3) by species density ranges (Step 4), using information specific to habitat type.

Step 6. **Assign habitat objectives to State-by-BCR areas** using condition indices in the SECAS Blueprint. Divide restorable area in each State-by-BCR area by total restorable area in the EGCP. Then, multiply this restorability proportion by JV-wide habitat objectives.

Step 7. **Calculate the State-by-BCR habitat shortage** by subtracting the State-by-BCR habitat objective from current State-by-BCR habitat availability.

Figure 4. The seven-step process for establishing population and habitat objectives in the Plan.

Habitat objectives were assigned to State-by-BCR areas based on indicators of past habitat occurrence and restorability. Habitat shortages were calculated as the difference between estimates of current habitat availability and habitat objective for each State-by-BCR area.

Estimating Current Populations in the EGCP

To establish population objectives, the LWG began with estimates of current population size from PIF's ACAD. The ACAD uses landbird population estimates derived primarily from count data by the North American BBS with adjustments for species detectability (Link and Sauer 2002, Sauer et al. 2013, Sauer et al. 2017, Panjabi et al. 2019). When necessary, count data were extrapolated for portions of species ranges occurring outside BBS coverage (Panjabi et al. 2019). Other data were used when appropriate (Rosenberg et al. 2016) per details provided in the Handbook to the PIF Landbird Population Estimates Database (Will et al. 2018). The ACAD did not estimate population sizes for American Woodcock, Eastern Whip-poor-will, or Rusty Blackbird. For all other priority species, the LWG estimated current population sizes based on the process described below.

A three-step process was used to calculate population estimates of priority landbird species:

1. Calculate population estimates for each species in BCRs 27 and 29.
2. Calculate the proportion of each species' potential distribution in BCR 27's and BCR 29's within the JV's geographical boundary.
3. Calculate BCR population estimate to the EGCP.

Step 1. Calculating population estimates for each species in BCRs 27 and 29:

Population estimates were calculated for each priority species in each BCR determining the percentage of a species range occurring in a BCR as the percentage of the global population occurring in a BCR and multiplying that by the global population size:

$\text{Population}_{\text{BCR 27}} = \text{Population}_{\text{Global}} \times (\%\ \text{Population}_{\text{Global}}$ in BCR 27)

$\text{Population}_{\text{BCR 29}} = \text{Population}_{\text{Global}} \times (\%\ \text{Population}_{\text{Global}}$ in BCR 29)

Example: Population estimates for Bachman's Sparrow are calculated as follows:

$\text{Population}_{\text{BCR 27}} = 170{,}000 \times 0.6567$, where 0.6567 is the $\%\ \text{Population}_{\text{Global}}$ in BCR 27

$\text{Population}_{\text{BCR 27}} = 111{,}639$

$\text{Population}_{\text{BCR 29}} = 170{,}000 \times 0.007$, where 0.007 is the $\%\ \text{Population}_{\text{Global}}$ in BCR 29

$\text{Population}_{\text{BCR 29}} = 1{,}190$

Step 2. Determining the proportion of species' potential distribution by BCR:

U.S. Geological Survey's (USGS) Gap Analysis Project (GAP) delineated species range and predicted distribution maps for more than 2,000 species occurring in the United States (USGS 2018). GAP's predicted distribution maps were generated based on suitable environmental and land cover conditions for individual species using remotely-sensed data (USGS 2018). Habitat suitability for each species was determined by Birds of North America (Poole and Gill 1996) and Birds of the World (Poole and Gill 2020) species accounts and peer-reviewed literature. These predicted distribution maps were intended for use at the landscape scale and could not be adjusted for fine-scale or highly ephemeral vegetation structure (e.g., shrub cover at individual properties).

Species distributions occur well outside the JV boundaries and often in multiple BCRs. To determine the extent a species distribution which occurs in the EGCP portion of BCR 27 or BCR 29 or, alternatively, to determine the responsibility the partnership has for a species relative to other JVs, the LWG used GAP predicted species distribution maps to calculate the proportion of the predicted distribution in the EGCP portion of BCRs 27 and 29 for each species (see equation below).

Step 3. Calculate the species population estimate for the EGCP:

The population estimate for each species in the JV was then calculated by multiplying the BCR-level population estimate by the ratio of potential species distribution (measured in acres) in each BCR then summing across BCRs within the JV geography.

$$\text{Population}_{\text{EGCP}} = [\text{Population}_{\text{BCR 27}} \text{ x } (\text{Distribution}_{\text{BCR 27 in EGCP}} / \text{Distribution}_{\text{BCR 27}})] +$$

$$[\text{Population}_{\text{BCR 29}} \text{ x } (\text{Distribution}_{\text{BCR 29 in EGCP}} / \text{Distribution}_{\text{BCR 29}})]$$

A complete list of priority landbird species and their respective population estimates is provided in Table 6 (see p. 22). Six species were assigned to more than one primary habitat type. For these species, the LWG determined the proportion of each habitat type currently in the EGCP and divided the JV-wide population estimate accordingly.

Continuing with the Bachman's Sparrow example:

$$\text{Population}_{\text{EGCP}} = [111{,}639 \text{ x } (44{,}072{,}871 / 87{,}666{,}846)] + [1{,}190 \text{ x } (794{,}942 / 4{,}619{,}726)]$$

$$\text{Population}_{\text{EGCP}} = 56{,}124 + 204$$

$$\text{Population}_{\text{EGCPJV}} = 56{,}328$$

For example, Cerulean Warbler was assigned to Forested Wetlands and Upland Hardwood & Pine-Hardwood Woodlands and Forests. Based on estimates of the proportion of each habitat type using National Land Cover Database 2016 (Yang et al. 2018), the LWG apportioned 25% of Cerulean Warbler's JV-wide population estimate to Forested Wetlands and 75% to Upland Hardwoods & Pine-Hardwood Woodlands and Forests.

After reflecting on how grassland birds use the various sub-classes of Eastern Interior Grasslands (see Table 2 in Chapter 2), the LWG decided to apportion population estimates of grassland priority species to two sub-classes: prairie and agriculture. The Grassland Condition Index in the Middle Southeast geography of the Southeast Conservation Adaptation Strategy (SECAS) Blueprint (Gray and Jones-Farrand 2019; Appendix D) estimates the occurrence of prairie and agricultural land covers. The LWG used condition index scores of nine and higher to delineate prairie and scores of two to eight to delineate agricultural land cover. Using the relative proportion of these two sub-classes (86% agriculture, 14% prairie) of Eastern Interior Grasslands, the LWG apportioned population estimates of grassland priority species to each sub-class.

Setting Population Objectives

Population objectives were established using the current population estimates (described above) and conservation targets. Population objectives were designed to align with 10-year and 30-year conservation targets in the PIF Landbird Conservation Plan (Rosenberg et al. 2016) and to allow conservation partners, many of which have their own 10-year plans, to track progress at two time intervals. Of the 29 EGCP priority landbird species, 18 are listed in a PIF continental concern group and have a continental population objective calculated in the PIF Landbird Conservation Plan (Rosenberg et al. 2016). Continental population objectives were set differently for Red Watch List, Yellow Watch List, and Tan Watch List species.

For Red Watch List species, Bachman's Sparrow and Red-cockaded Woodpecker, continental population objectives were straightforward, encouraging population increases of 25-35% in the 10-year short-term with 30-year long-range increases of at least 75%.

Yellow Watch List population objectives were flexible to individual species' needs, with short-term objectives related to stabilizing populations by slowing the rate of decline and long-range objectives of small population increases. Although a 10-year population objective allowing for a population decline seems counter-intuitive, the rates of decline allowed in the PIF Landbird Conservation Plan are lower than current estimated rates of decline. For example, Cerulean Warbler populations have experienced a loss of 72% between 1970 and 2014, marking one of the most dramatic songbird declines in PIF ACAD records. Thus, allowing small population losses during a stabilization period is preferable to current rates of decline and is compatible with 30-year population objectives of increasing bird numbers.

For Tan Watch List species, called "Common Birds in Steep Decline", the population objectives aimed to reduce the current rate of decline by 40-65%, allowing for a decline of 10% to 25% from current population numbers as conservation efforts occur over the next 30 years.

- **Red Watch List ("Recover")**
    - 10-year objective: Increase population 25-35%
    - 30-year objective: Increase population 75-100%
- **Yellow Watch List ("Reverse Decline")**
    - 10-year objective: Reduce rate of population decline, allowing 2-22% short-term decline
    - 30-year objective: Increase population 5-15% for long-term population health
    - Exception: Henslow's Sparrow; Increase population 3% in EGCP $_{\text{BCR 29}}$
- **Common Birds in Steep Decline or Tan Watch List ("Stabilize")**
    - 10-year objective: Stabilize populations, allowing 5-25% decline
    - 30-year objective: Limit population decline to 10-25%

PIF population objectives and the corresponding habitat objectives were intended for bird conservation within species' respective breeding ranges. The geography provides critical wintering habitat for some priority landbird species (e.g., Henslow's Sparrow, Rusty Blackbird). However, there is difficulty in estimating current wintering population sizes, as wintering objectives are absent for these species in the PIF Plan (Rosenberg et al. 2016). Wintering population objectives will be addressed in a subsequent update to this Plan when additional data are available.

In addition to PIF population objectives, the Red-cockaded Woodpecker has population objectives outlined in its Recovery Plan (USFWS 2003) due to its protected status under the U.S. Endangered Species Act. The LWG started with Recovery Plan population objectives for BCR 27 to formulate Red-cockaded Woodpecker population and habitat objectives within the JV boundary. Additionally, although American Woodcock does not have a PIF population objective, the American Woodcock Conservation Plan (Kelley et al. 2008) outlines population targets. For the remaining 10 species without PIF or recovery plan population objectives, the LWG assigned maintenance objectives (i.e., maintain current habitat availability to support these species populations).

Eastern Whip-poor-will and Rusty Blackbird population estimates do not exist in ACAD, and neither have recovery or conservation plans. Because population objectives are based on population estimates, no objectives were calculated. Again, the LWG assigned maintenance objectives for these species and, as data become available, population objectives will be calculated and included in future updates to the Plan.

Setting Habitat Objectives

JV-wide Habitat Objectives. The range of PIF population objectives and the variable densities of birds found in habitat of varying quality led us to present population objectives as ranges. The smaller value represents the minimum acreage required to reach the smallest population objective, and the largest value represents the maximum acreage required to meet the largest population objective. Targeted surveys could lead to more precise habitat objectives.

Habitat objectives were calculated based on population objectives and estimated density for each species. To obtain species density estimates, the LWG conducted a systematic literature search for publications with density estimates for the 18 priority species with PIF continental concern group designations. We included publications from all habitat types and BCRs in the eastern United States in our search. The LWG used published density estimates to propose a density range for each species (see Appendix C). For some species, density estimates were limited or entirely lacking for this geography. Therefore, estimates from neighboring BCRs and JVs were used to inform proposed densities, with preference for estimates from similar vegetative communities, locations closest to BCR 27, and studies with large sample sizes. Single publications were found with density data for American Woodcock and Chuck-will's-widow, so the LWG defaulted to habitat objectives set in the Conservation Plan (Kelley et al. 2008) for American Woodcock, and set no habitat objectives for Chuck-will's-widow. The LWG defaulted to habitat objectives for Red-cockaded Woodpecker set forth in the Recovery Plan (USFWS 2003).

Because population objectives and species density estimates are presented as ranges, four possible habitat objectives can be calculated (Table 5). The lower and upper bounds are calculated as follows:

$$\text{Habitat Objective}_{\text{Lower}} = \text{Population Objective}_{\text{Lower}} / \text{Density}_{\text{Upper}}$$

$$\text{Habitat Objective}_{\text{Upper}} = \text{Population Objective}_{\text{Upper}} / \text{Density}_{\text{Lower}}$$

Table 5. Matrix of tradeoffs between population objectives and species density values.

		Species Density	
		Lower	Upper
Population Objective	Lower	- Meets the minimum PIF population goal - Considers issues with resilience and encroachment - May fail to meet the minimum PIF goal if widespread habitat loss occurs	- Meets the minimum PIF population goal - Requires the least land area - Requires high quality habitat - Considers habitat maintenance
	Upper	- Meets the PIF "best-case" population goal - Requires the most land area - Considers issues with resilience and encroachment	- Meets the PIF "best-case" population goal - Requires high quality habitat - Considers habitat maintenance

Minimum PIF population goals (Rosenberg et al. 2016) can be met by maintaining fewer acres of high-quality habitat, which support high densities of birds. In contrast, meeting maximum population goals in a landscape with lower quality habitat requires maintenance of many more acres. If landscapes support high bird densities, the higher PIF population goal (and the resulting EGCP population objective) may be achieved in a much smaller area. Alternatively, partner agencies may have opportunities to manage for landbird species at varying habitat qualities and densities in order to meet objectives.

Again, using Bachman's Sparrow as an example: lower and upper bounds of the 10-year habitat objective are calculated thus:

$$\text{Habitat Objective}_{\text{Lower}} = \text{Population Objective}_{\text{Lower}} / \text{Density}_{\text{Upper}}$$

$$\text{Habitat Objective}_{\text{Lower}} = 70{,}411 / 0.243$$

$$\text{Habitat Objective}_{\text{Lower}} = 289{,}757$$

$$\text{Habitat Objective}_{\text{Upper}} = \text{Population Objective}_{\text{Upper}} / \text{Density}_{\text{Lower}}$$

$$\text{Habitat Objective}_{\text{Upper}} = 76{,}044 / 0.162$$

$$\text{Habitat Objective}_{\text{Upper}} = 469{,}407$$

It is assumed that in meeting all population and habitat objectives, conservation delivery improves and provides additional habitat, resulting in increasing bird populations. However, caution must be used in assuming higher density always indicates increasing population trends. In some instances, habitat isolation or fragmentation may result in high densities of breeding pairs but lower nesting success (i.e., population sink; Van Horne 1983).

Further, habitat loss occurring within the same timeframe is not considered. An agency or partnership choosing to manage low-density populations to achieve the lowest population goal may be set back due to habitat losses occurring outside the agency's or partnership's control.

> "An agency or partnership choosing to manage low-density populations to achieve the lowest population goal may be set back due to habitat losses occurring outside the agency's or partnership's control."

The lower and upper bounds of population and habitat objectives for all 29 priority landbird species are provided in Table 6. In Appendix D, a range of habitat objectives based on varying densities are presented and should support decisions driven by biological, land area, and human and financial constraints.

Table 6. Ten- and thirty-year population and habitat objectives for priority landbird species in the East Gulf Coastal Plain.

Population and Habitat Objectives for Priority Landbird Species					
	Current EGCP Population	10-year Population Objective	10-year Habitat Objective (ac)	30-year Population Objective	30-year Habitat Objective (ac)
Partners in Flight Continental Concern Group: **Red Watch List ("Recover")** **Population Objective:** Recovery Plan target, or increase current population by 25-35% by 2030 and 75-100% by 2050.					
Bachman's Sparrow	56,100	70,400-76,000	290,000-469,800	98,600-112,700	406,000-696,000
Red-cockaded Woodpecker[1]	6,100	3,100[2]	610,000	3,100[2]	610,000
Partners in Flight Continental Concern Group: **Yellow Watch List ("Reverse Decline")** **Population Objective:** Stabilize population with no more than 2-22% decline by 2030; increase population by 5-15% by 2050.					
Cerulean Warbler	1,700	1,300-1,600	3,600-16,300	1,800-1,900	4,800-19,100
Eastern Whip-poor-will[3]	unknown				
Henslow's Sparrow[4,5]					
Kentucky Warbler	247,600	196,600-247,000	694,000-10,173,000	264,700-289,900	934,300-11,937,700
Prairie Warbler	577,500	482,100-605,700	1,749,900-10,576,700	649,000-710,800	2,355,700-12,411,500
Prothonotary Warbler	424,500	331,300-416,300	511,700-2,057,300	446,000-488,500	688,800-2,414,200
Red-headed Woodpecker	134,300	106,500-133,800	328,900-3,306,300	143,400-157,000	442,800-3,879,800
Wood Thrush	1,031,300	855,600-1,075,000	2,114,400-26,564,900	1,151,800-1,261,500	2,846,200-31,173,100

POPULATION AND HABITAT OBJECTIVES FOR PRIORITY LANDBIRD SPECIES , CONTINUED

	Current EGCP Population	10-year Population Objective	10-year Habitat Objective (ac)	30-year Population Objective	30-year Habitat Objective (ac)
Partners in Flight Continental Concern Group: **Common Birds in Steep Decline ("Stabilize")** **Population Objective:** Slow rate of decline, stabilizing population at no more than 5-25% decline by 2030; stabilize population with no more than 10- 25% decline compared to current population by 2050.					
Chuck-will's-widow	1,178,300	897,500-1,136,900	not calculated[6]	897,500-1,077,100	not calculated[6]
Eastern Meadowlark	416,400	329,800-417,700	1,555,800-9,619,000	329,800-395,700	1,555,800-9,112,700
Field Sparrow	413,200	326,600-413,700	3,595,800-13,172,500	326,600-391,900	3,595,800-12,479,200
Grasshopper Sparrow	90,000	83,200-105,400	383,100-1,301,600	83,200-99,800	383,100-1,233,100
Loggerhead Shrike	137,500	103,700-131,300	427,000-3,245,300	103,700-124,400	427,000-3,074,500
Northern Bobwhite	269,800	205,100-259,800	862,200-4,701,800	205,100-246,200	862,200-4,454,300
Rusty Blackbird[3]	unknown				
Yellow-billed Cuckoo	756,000	585,400-741,500	11,418,500-15,321,100	585,400-702,500	11,418,500-14,514,700
Partners in Flight Continental Concern Group: **None** **Population Objective:** Maintain and monitor current populations.					
American Kestrel (SE)[7]	700				
American Woodcock	unknown	550,000[2]	2,718,200[2]	550,000[2]	2,718,200[2]
Eastern Kingbird	1,201,200				
Eastern Towhee	6,368,300				
Eastern Wood-Pewee	389,300				
Indigo Bunting	6,456,500				
Louisiana Waterthrush	25,000				
Painted Bunting	99,700				
Swainson's Warbler	53,100				
Swallow-tailed Kite	5,100				
Worm-eating Warbler	35,300				

[1] Red-cockaded Woodpecker population objective is given as number of potential breeding groups (PBGs), defined as an adult female and adult male occupying the same cluster with or without one or more helpers (USFWS 2003).

[2] Population and habitat objectives for Red-cockaded Woodpecker and American Woodcock were established in Recovery Plan for the Red-cockaded Woodpecker (USFWS 2003) and in American Woodcock Conservation Plan (Kelley et al. 2008).

[3] Population estimates are not available for Eastern Whip-poor-will and Rusty Blackbird. Current population size must be known to calculate population objectives based on PIF-established objectives (Rosenberg et al. 2016). Since these species do not have a recovery plan with USFWS that might otherwise provide objectives, objectives for Eastern Whip-poor-will and Rusty Blackbird remain uncalculated.

[4] Henslow's Sparrow breeds only in the BCR 29 portion of the EGCPJV geography. The BCR 27 portion of the EGCP remains an important component of Henslow's Sparrow wintering grounds, and this will be addressed in subsequent versions of the Plan.

[5] Henslow's Sparrow is the only species in the Yellow Watch List "Prevent Decline" category.

[6] Density estimates were not available for calculating habitat objectives.

[7] The LWG suspects that the current population estimate for American Kestrel under-represents actual population size due to detection issues for this species.

State-by-BCR Habitat Objectives. Habitat objectives were also calculated for each species at the State-by-BCR level, and expressed in terms of current habitat amount (typically high or moderate quality), 10-year habitat objectives, and habitat shortages (i.e., additional habitat needed to meet 10-year objectives, where appropriate). State-by-BCR habitat objectives were subtracted from current habitat availability to yield habitat shortages. When habitat classes exhibited

Prescribed burns in longleaf pine help maintain habitat quality/Amity Bass, Louisiana Dept. of Wildlife and Fisheries

What is a habitat condition index?

The LWG used habitat condition indices developed for the Middle Southeast portion of the SECAS - Conservation Blueprint (Gray and Jones-Farrand 2019) to identify habitat condition for each JV habitat class. Condition index scores of 0-14 reflect a range from non-habitat (0), to potential (i.e., restorable) habitat (1-13), to highest quality, intact habitat (14) for each JV priority habitat class. Scores greater than 0 were used to apportion habitat objectives based on the proportion of current or restorable habitat in each State-by-BCR area relative to the entire EGCP. For example, for Eastern Interior Grasslands, prairie was defined as Grassland Condition Index scores of $\geq$9, and improved agriculture was defined by scores of 3-8. For Freshwater Forested Wetlands, Upland Hardwood & Pine-Hardwood Woodlands and Forests, Upland Hardwood Forests, and Upland Hardwood Woodlands, the LWG defined current habitat as having moderate or high quality within fragmented or intact landscapes (for example, Forested Wetlands Condition Index scores of 7, 8, 10, 11, 13, and 14). See Appendix E for more information.

shortages, restorable acres (i.e., potential habitat) of each priority habitat class were used in calculations. Habitat quality was determined using habitat condition indices derived from the Middle Southeast portion of the SECAS Blueprint for JV habitat classes (Gray and Jones-Farrand 2019; see box and Appendix E).

In cases of habitat shortage State-by-BCR habitat objectives were calculated by dividing the area of low quality or potential habitat (i.e., restorable habitat) in each State-by-BCR by the total restorable area of each habitat type in the EGCP. This restorability factor was then multiplied by JV-wide habitat objectives. For example, 26.95% of restorable Eastern Interior Grasslands occur in Alabama-BCR 27. The JV-wide habitat objective for Eastern Interior Grasslands was multiplied by 0.2695 to determine Alabama-BCR 27's habitat objective.

Population and habitat objectives were then summarized by primary habitat class, with habitat objectives further defined for each State-by-BCR (see next chapter). For each habitat class, the species with the greatest habitat-area requirement served as the representative target species when estimating habitat objectives at the State-by-BCR level. If the habitat area requirement for the target species was met, it was assumed habitat objectives for all other priority species in the habitat class were also met. One underlying assumption of this Plan is that our target species are truly representative of a group of priority avifauna within a given habitat type. However, the LWG is aware species may have varying habitat condition requirements.

> **"For each habitat class, the species with the greatest habitat-area requirement served as the representative target species. If the habitat area requirement for the target species was met, it was assumed habitat objectives for all other priority species in the habitat class were also met."**

Bachman's Sparrow/Eric Soehren

Critical Assumptions

Underpinning the Plan's population and habitat objectives are key assumptions which need to be considered as part of bird population monitoring efforts:

1. All LWG members had similar or equal influence over the processes and decisions made in this Plan.
2. The LWG assumes the Plan will result in better, more efficient, and effective conservation decisions and on-the-ground actions (i.e., implementation), thereby leading to improvement in habitat quantity and/or quality. The LWG assumes the Plan will be used to inform conservation delivery. Outcome-based and effects monitoring can evaluate this assumption and determine the return-on-investment of human and financial resources.
3. Selection of priority species is inherently subjective. Species prioritization was influenced, unintentionally and otherwise, by a number of factors: the plans chosen and the weighting assigned to each plan to calculate average weighted scores; criteria for species removal and inclusion; and the biases of LWG members.
4. Species assignments to one or more primary habitat types, based on literature and expert opinion, are assumed accurate and representative for all species and habitat types in the EGCP. The LWG assigned species to primary habitat types during an internal review. These habitat assignments have not been reviewed externally.
5. Current population estimates and GAP species distribution maps are assumed to be representative of actual species' distributions.
6. Population objectives for American Woodcock and Red-cockaded Woodpecker were established by recovery plans (Kelley et al. 2008 and USFWS 2003, respectively). It was assumed that those recovery plans include more regionally-appropriate and directed objectives than objectives from the PIF Landbird Conservation Plan (Rosenberg et al. 2016).
7. Population objectives are stated in terms of abundance without regard to population demographics. Thus, rates of population loss or increase disproportionately affected by one demographic group are not accounted for in the population objective calculations.
8. Density estimates used to calculate habitat objectives are representative of both the quantity of various land covers and quality of habitat across the EGCP. Density can be a misleading indicator of habitat quality (Van Horne 1983); isolated patches of habitat with high densities of breeding pairs and nests can have low productivity (i.e., population sink).

Red-cockaded Woodpecker/Alan Schmierer

9. Condition indices used to calculate current habitat availability and total current and restorable habitat accurately represent the condition of priority habitat types in the EGCP. All underlying assumptions of the condition indices, including definitions of habitat type and quality, are inherent assumptions in the Plan's presented calculations of habitat shortages.

10. Increasing habitat availability on the landscape is assumed, by default, to result in realized population responses (i.e., increases in density or abundance) and lead to corresponding population increases. Habitat objectives do not incorporate populations' reproductive potential (or among-species variation), barriers to dispersal (e.g., isolation of populations, habitat connectivity, environmental permeability), density-dependent mechanisms, source-sink population dynamics, habitat and community saturation points, or factors that influence populations on migratory pathways or wintering grounds.

11. A species with the greatest habitat-area requirements is a reasonable proxy for other species assigned to a given habitat type and is broadly representative of the avian community.

12. Restoration to achieve habitat objectives will occur on appropriate sites within suitable dispersal distance of existing populations and where ongoing habitat management to maintain habitat quality is feasible.

Swallow-tailed Kite/Alan Schmierer

Terrestrial Systems: Objectives and Condition Summary

Eastern Interior Grasslands

GRASSLANDS AT-A-GLANCE

Representative Priority Species:
Eastern Meadowlark & Field Sparrow

Current Prairie: 276,856 ac
JV-wide Objective: 148,000 to 702,900 ac
JV-wide Prairie Shortage: Up to 426,000 ac

Current Improved Ag: 9,217,091 ac
JV-wide Objective: 3,485,900 to 12,615,500 ac
JV-wide Improved Ag Shortage: Up to 3,398,400 ac

Eastern Interior Grassland/Sara Hollerich, USFWS

Habitat Description and Current Status

Eastern Interior Grasslands are comprised of meadows and prairies, pasture and cropland, and other land covers dominated by grasses. The geography currently contains an estimated 276,856 ac of prairie and 9.2 million ac of improved agricultural land cover. Although the Implementation Plan (EGCPJV 2008) emphasizes the importance of native warm-season grasses, very little natural prairie remains in the EGCP, and agriculture practices often favor non-native and/or cool-season grasses. Most remaining Eastern Interior Grasslands are located in the former Black Belt and Jackson Prairie Belt of Alabama and Mississippi. Expansion and intensification of agricultural land use is often cited as the leading cause for declining grassland birds, sparking research and implementation of set-aside programs such as the Conservation Reserve Program (McConnell and Burger 2011, Evans et al. 2014, West et al. 2016, Quinn et al. 2017).

Priority Bird Species

Species in this terrestrial system include grassland obligates and species whose occupancy is often associated (either positively or negatively) with some level of agricultural land use (e.g., Eastern Kingbird and Eastern Meadowlark [Gilbert and Ferguson 2019]; Loggerhead Shrike [Froehly et al. 2019]). Due to the wide range of habitat needs and land cover use by grassland birds, the LWG developed habitat objectives for "true" prairie (i.e., remnants of the Black Belt and Jackson Prairie Belt) and for agricultural land (including improved pasture and hay fields, or "improved agriculture"). The LWG does not include row crops grown in monoculture as grassland bird habitat.

Calculating Habitat Objectives

The LWG calculated habitat objectives separately for prairie and agricultural land use using the Grassland Condition Index developed as an update to the SECAS Conservation Blueprint (Gray and Jones-Farrand 2019).

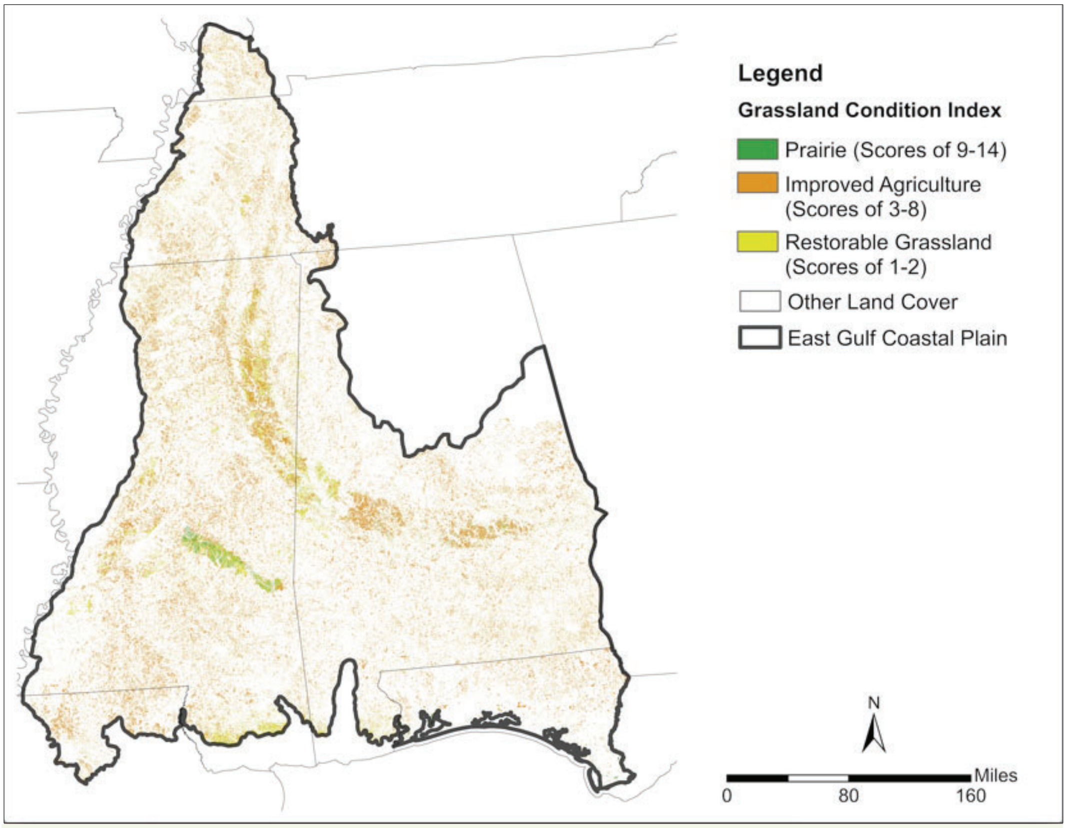

Figure 5. Prairie, improved agriculture, and restorable Eastern Interior Grasslands in the East Gulf Coastal Plain (Gray and Jones-Farrand 2019).

The Grassland Condition Index describes grasslands in terms of site quality (high, moderate, low) and landscape quality (intact, fragmented, very fragmented) and assigns an index score ranging from 1 (potential habitat very far from a moderate or large patch of existing habitat) to 14 (grassland with high quality within an intact landscape). The Grassland Condition Index also assigns a management objective (maintain, enhance, restore). For the purposes of this Plan, prairie is defined as having an index score of at least 9, and improved agriculture land use is defined as having an index score of 3 to 8 (Figure 5).

Separate prairie and agricultural land use habitat objectives were calculated by multiplying grassland species' total habitat objectives by the proportion of current landscape in prairie and agricultural land use. This calculation assumes that the Eastern Interior Grasslands priority species select habitat types and conditions in the same proportion at which they occur on the landscape. While studies have documented negative associations of occupancy with agriculture (Murphy 2003, Gilbert and Ferguson 2019), this Plan relies on species density estimates to account for differential selection and preference. For example, if prairie can sustain a particular species at a higher density, then the potential selection or preference for prairie is reflected in the species' habitat objective).

Eastern Interior Grasslands serve as the primary habitat type for eight species of priority landbird species. Six species are in a PIF continental concern group and thus have 10-year and 30-year habitat objectives (Table 7). Based on area-size requirements to meet 10-year habitat objectives, Eastern Meadowlark and Field Sparrow set the minimum habitat targets for prairie and improved agriculture, respectively.

Table 7. Ten- and thirty-year habitat objectives (ac) for priority landbirds associated with Eastern Interior Grasslands. The species in bold sets habitat objectives for this suite of priority birds.

HABITAT OBJECTIVES FOR PRIORITY SPECIES IN EASTERN INTERIOR GRASSLANDS		
	10-year Habitat Objective (ac)	30-year Habitat Objective (ac)
Grassland: Prairie[1]		
American Kestrel (SE)	Maintain enough habitat to support current populations.	
Eastern Kingbird		
Eastern Meadowlark	**148,000-702,900**	**148,000-665,900**
Field Sparrow	109,900-557,000	109,900-527,600
Grasshopper Sparrow	28,000-177,300	28,000-168,000
Henslow's Sparrow	Wintering species	
Loggerhead Shrike	58,200-442,000	58,200-418,700
Northern Bobwhite	71,700-318,000	71,700-301,200
Grassland: Improved Agriculture[2]		
American Kestrel (SE)	Maintain enough habitat to support current populations.	
Eastern Kingbird		
Eastern Meadowlark	1,407,800-8,916,100	1,407,800-8,446,800
Field Sparrow	**3,485,900-12,615,500**	**3,485,900-11,951,600**
Grasshopper Sparrow	355,100-1,124,400	355,100-1,065,200
Henslow's Sparrow	Wintering species	
Loggerhead Shrike	368,900-2,803,300	368,900-2,655,800
Northern Bobwhite	636,900-4,033,500	636,900-3,821,300

[1] Grassland Condition Index score of at least 9

[2] Grassland Condition Index scores 3-8

Eastern Meadowlark requires the most prairie habitat to achieve 10-year and 30-year minimum population objectives. Maintaining 148,000 to 702,900 ac of prairie should allow other priority species to meet their respective population and habitat objectives in the prairie subcategory of Eastern Interior Grasslands. Field Sparrow and Northern Bobwhite exhibited large variances in density based on habitat quality, site location, and other factors.

Field Sparrow/Laurie Sheppard, USFWS

If Eastern Interior Grasslands are maintained in high quality and with connectivity which can support higher bird densities, less habitat may be required to meet population objectives.

> “Focusing efforts in Alabama and Mississippi could produce a substantial landscape-level impact if conservation connects enhanced and restored grasslands to prairie in the Black Belt and Jackson Prairie Belt regions.”

Eastern Interior Grasslands currently occupy 9.5 million ac, of which only 276,856 ac qualify as prairie. The bulk of the grassland shortage (both prairie and improved agriculture) occurs in Alabama and Mississippi (Table 8). Focusing efforts in these two states could produce a substantial landscape-level impact if conservation connects enhanced and restored grasslands to prairie in the Black Belt and Jackson Prairie Belt regions. Florida and Mississippi are the only states that currently meet the lower-range 10-year Eastern Interior Grasslands habitat objective for prairie (Table 8).

Table 8. Eastern Interior Grasslands 10-yr habitat objectives (ac), determined by target species Eastern Meadowlark (prairie) and Field Sparrow (agricultural land use), for each State-by-BCR area within the East Gulf Coastal Plain.

Habitat Objectives for each State-by-BCR							
	AL		FL	KY	LA	MS	TN
	BCR 27	BCR 29					
Grasslands: Prairie[1]							
Current Habitat	53,301	0	88,216	49	99	134,351	840
10-year Objective	39,900-189,400	3,100-14,600	16,500-78,600	2,600-12,400	5,200-24,900	67,900-322,600	12,700-60,400
Habitat Needed to Meet Objectives	0-136,100	3,100-14,600	Maintain current levels	2,600-12,400	5,100-24,800	0-188,200	11,900-59,600
Grasslands: Improved Agriculture[2]							
Current Habitat	2,547,826 (55,574)[3]	214,611 (0)	1,060,155 (18,409)	178,212 (0)	366,654 (6,326)	3,991,981 (34,175)	857,652 (346)
10-year Objective	939,400-3,399,900	72,200-261,100	389,700-1,410,400	61,400-222,000	123,400-446,600	1,600,000-5,790,500	299,800-1,084,900
Habitat Needed to Meet Objectives	0-852,100	0-46,500	0-350,200	0-43,800	0-79,900	0-1,798,500	0-227,200

[1] Grassland Condition Index score of at least 9

[2] Grassland Condition Index scores 3-8

[3] Included parenthetically under improved agriculture are acres with appropriate burn history and/or vegetation height (index scores 5 and 8), which may support species often classified as grassland-obligate or negatively associated with some agricultural land uses

Eastern Shrub-Scrub

SHRUB-SCRUB AT-A-GLANCE

Representative Priority Species:
Prairie Warbler

Current Shrub-Scrub: 2,002,286 ac
JV-wide Objective: 90,400 to 151,500 ac
Shrub-Scrub Shortage: Not applicable

Note: *Current habitat availability estimate likely discounts ephemeral shrub-scrub structural conditions provided in regenerating pine stands and fallow agriculture fields.*

Shrub-scrub habitat/John Gruchy, Mississippi Dept. of Wildlife, Fisheries and Parks

Habitat Description and Current Status

Eastern Shrub-Scrub includes early successional hardwood and pine and manmade or disturbed environments. The geography currently contains an estimated 2 million ac of Eastern Shrub-Scrub, as determined by the National Land Cover Database (NLCD) 2016 class "shrub-scrub" (Figure 6; Yang et al. 2018). Eastern Shrub-Scrub historically occurred in a climax successional condition within mosaics of prairie, shrubland, and woodland. Today, much of Eastern Shrub-Scrub occurs as ephemeral shrubland within planted pine mosaics where shrubby conditions occur in the first five years after planting (Jones et al. 2009, Lane et al 2011a,b, Iglay et al. 2012, Jones et al. 2012).

Prairie Warbler/Alan Schmierer

In timberlands with regular harvest and relatively even flow of timber volume, the percentage of area in shrub-scrub condition is relatively constant, though the conditions shift across the landscape as regenerating stands transition to closed canopy and older stands are harvested (Greene et al. 2019a,b). Although satellite data show concentrations of shrubland in the panhandle of Florida and areas of Alabama, Mississippi, and Louisiana where pine plantings are common, the condition and amount of climax Eastern Shrub-Scrub is largely unknown. It is also uncertain the extent to which young pine stands are classified as shrub-scrub versus pine forest in NLCD.

> "The condition and amount of climax Eastern Shrub-Scrub is largely unknown."

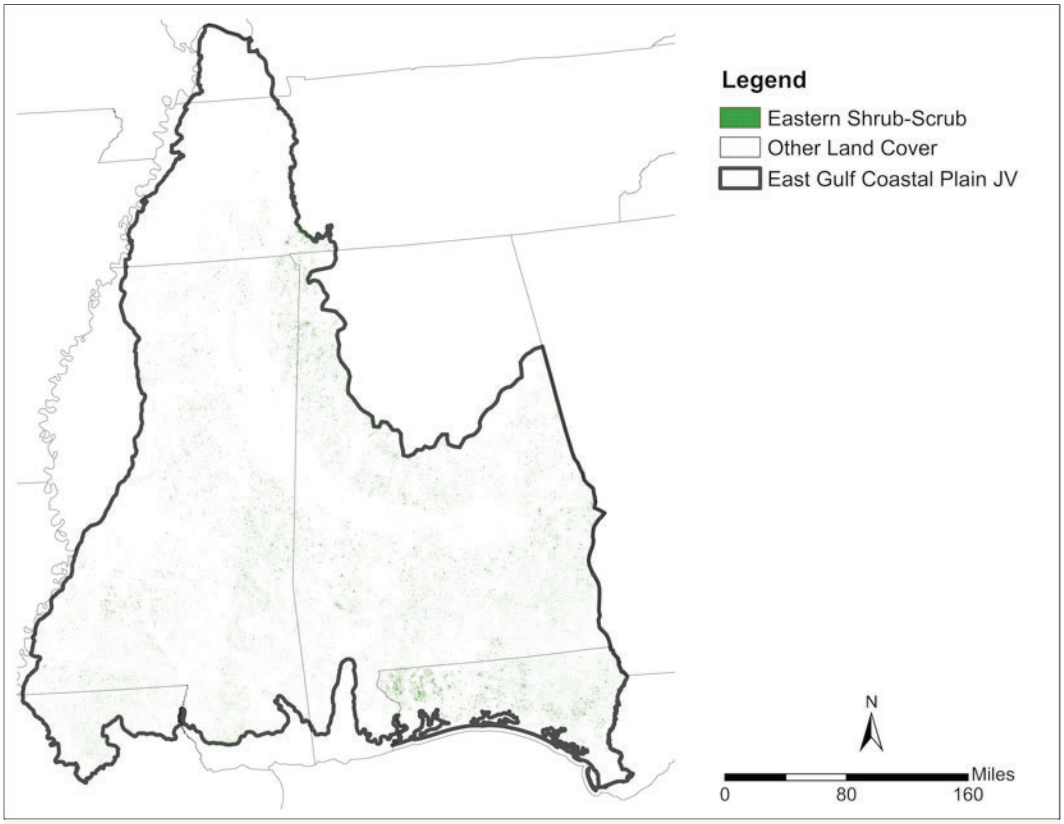

Figure 6. Occurrence of Eastern Shrub-Scrub terrestrial system in the East Gulf Coastal Plain (National Land Cover Database 2016; Yang et al. 2018).

Priority Bird Species

Eastern Shrub-Scrub serves as the primary habitat type for five priority landbird species. Prairie Warbler is the only species in the PIF continental concern group, thus it serves as the target species for Eastern Shrub-Scrub habitat objectives (Table 9). Prairie Warbler's density estimates vary substantially, leading to wide ranges in Eastern Shrub-Scrub habitat objectives.

Table 9. Ten- and thirty-year habitat objectives (ac) for priority landbirds primarily associated with Eastern Shrub-Scrub. The species in bold sets habitat objectives for this suite of priority birds.

HABITAT OBJECTIVES FOR PRIORITY SPECIES IN EASTERN SHRUB-SCRUB		
	10-year Habitat Objective (ac)	30-year Habitat Objective (ac)
Eastern Kingbird	Maintain enough habitat to support current populations.	
Eastern Towhee		
Indigo Bunting		
Painted Bunting		
Prairie Warbler	**90,400-151,400**	**121,700-177,700**

Calculating Habitat Objectives

Updates to the SECAS Conservation Blueprint did not include Shrub-Scrub as a priority land cover class. As a result, NLCD 2016 landcover of "shrub-scrub" was used to calculate current habitat, restorability, and habitat shortages. The NLCD layer was extracted through the SECAS Blueprint condition indices. No areas classified as a habitat in a condition index layer were considered potential shrub-scrub, which eliminated the potential to double count.

Although Eastern Shrub-Scrub is present in each State-by-BCR area, Alabama, Florida, and Mississippi could have enough acreage to support priority avifauna (Table 10). Kentucky and Tennessee currently meet the 10-year habitat objective. All priority species assigned to Eastern Shrub-Scrub use habitat types other than climax shrub-scrub, including fallow agricultural fields, regenerating pine stands, ecotones and edges. Inclusion of these secondary and ephemeral habitat types may be necessary to meet population and habitat objectives. For edge- and area-sensitive species, enhancing and restoring low-quality Eastern Shrub-Scrub in intact landscapes may accelerate population recovery.

> "For edge- and area-sensitive species, enhancing and restoring low-quality Eastern Shrub-Scrub in intact landscapes may accelerate population recovery."

Table 10. Current habitat, 10-year objectives, and habitat shortages (ac) of Eastern Shrub-Scrub for each State-by-BCR area in the East Gulf Coastal Plain as determined by Prairie Warbler. Current habitat is determined by the percentage of current shrubland encompassed by a state (Yang et al. 2018).

HABITAT OBJECTIVES FOR EACH STATE-BY-BCR							
	AL		FL	KY	LA	MS	TN
	BCR 27	BCR 29					
Current Habitat	748,582	77,833	333,641	1,144	78,755	697,612	64,719
10-year Objective	33,800-56,600	3,500-5,900	15,000-25,200	50-100	3,600-6,000	31,500-52,800	2,900-4,900
Habitat Shortage	Maintain current levels	Maintain current levels	Maintain current levels	Maintain current levels	Maintain current levels	Maintain current levels	Maintain current levels

Forested Wetlands At-A-Glance

Representative Priority Species:
American Woodcock

Current Forested Wetlands: 2,906,000 ac[1]

JV-wide Objective: 1,359,100 to 2,718,200 ac

Forested Wetlands Shortage: No JV-wide shortage, but local shortages do occur in State-by-BCR areas and site quality varies across JV.

[1] In moderate to high site quality and fragmented to intact landscapes

Fall cypress at Sam D. Hamilton Noxubee National Wildlife Refuge, MS/USFWS

Habitat Description and Current Status

Freshwater Forested Wetlands include bottomland hardwoods, cypress-tupelo, bay swamps and depressional wetlands, shrub-scrub swamp, and beaver ponds and meadows. Wetlands contain enormous biodiversity and provide key wintering habitat for Henslow's Sparrows (Plentovich et al. 1999, Tucker and Robinson 2003, Brooks and Stouffer 2011) and Rusty Blackbirds (Greenberg and Matsuoka 2010, Luscier et al. 2010). The EGCP geography currently has an estimated 2.9 million ac of Freshwater Forested Wetlands in moderate to high quality within fragmented or intact landscapes.

Priority Bird Species

Forested Wetlands serve as the primary habitat type for nine priority landbird species. Five of these species are in a PIF continental concern group and have 10-year and 30-year habitat objectives (Table 11). American Woodcock requires the most Forested Wetland to achieve 10-year and 30-year minimum population objectives.

American Woodcock/Ricky Layson, Ricky Layson Photography, Bugwood.org

Table 11. Ten- and thirty-year habitat objectives (ac) for priority landbird species primarily associated with Freshwater Forested Wetlands. The species in bold sets habitat objectives for this suite of priority birds.

HABITAT OBJECTIVES FOR PRIORITY SPECIES IN FRESHWATER FORESTED WETLANDS		
	10-year Habitat Objective (ac)	30-year Habitat Objective (ac)
American Woodcock	**1,359,100-2,718,200**	**1,359,100-2,718,200**
Cerulean Warbler	900-4,000	1,200-4,700
Kentucky Warbler	170,600-2,500,000	229,600-2,933,700
Louisiana Waterthrush	Maintain enough habitat to support current populations.	
Prothonotary Warbler	511,700-2,057,300	688,800-2,414,200
Rusty Blackbird	Maintain enough habitat to support current populations.	
Swainson's Warbler		
Swallow-tailed Kite		
Yellow-billed Cuckoo	507,900-1,500,900	507,900-1,421,900

Calculating Habitat Objectives

Habitat objectives were calculated using the Forested Wetlands Condition Index from the SECAS Blueprint update (Gray and Jones-Farrand 2019). The Forested Wetland Condition Index describes this habitat type in terms of site quality (high, moderate, low) and landscape quality (intact, fragmented, very fragmented) and assigns an index score ranging from 0 to 14 (Figure 7).

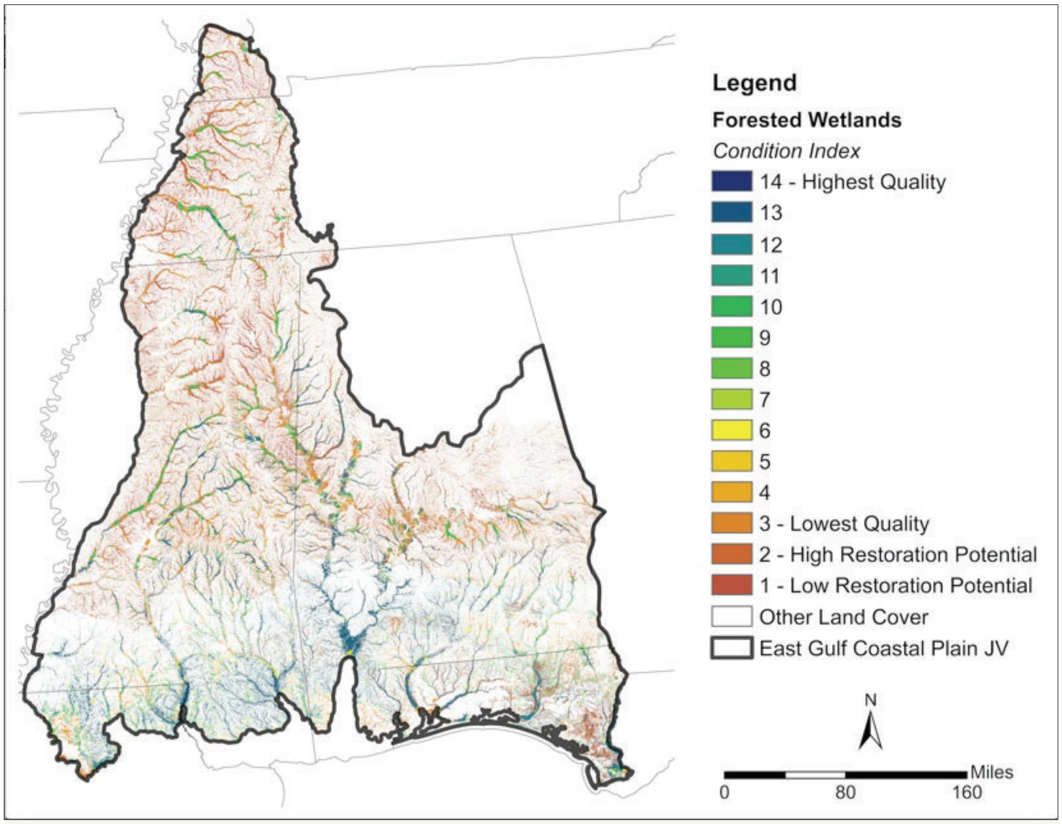

Figure 7. Forested Wetlands in the East Gulf Coastal Plain (Gray and Jones-Farrand 2019).

Forested Wetlands currently occupy 16.7 million ac, and approximately 2.9 million ac are in high or moderate site quality in either an intact or fragmented landscape. The BCR 27 portion of Alabama, Florida, Louisiana, and Mississippi currently meet their 10-year habitat objectives (Table 12). For Forested Wetland species insensitive to fragmentation or edge, an additional 773,143 ac of habitat occurs in very fragmented landscapes of high or moderate site quality. For edge- and area-sensitive species, enhancing and restoring low quality Forested Wetlands in intact landscapes may accelerate population recovery (Table13).

Table 12. Current habitat, 10-year objectives, and habitat shortages (ac) of Forested Wetlands for each State-by-BCR area within the East Gulf Coastal Plain.

Habitat Objectives for each State-by-BCR							
	AL		FL	KY	LA	MS	TN
	BCR 27	BCR 29					
Forested Wetlands: High or Moderate Site Quality in Intact or Fragmented Landscape[1]							
Current Habitat	1,051,963	20,715	306,230	11,073	248,892	1,136,651	130,476
10-year Objective	409,800- 819,500	21,700- 43,500	133,500- 266,900	31,500- 63,100	61,400- 122,900	551,900- 1,103,800	149,000- 298,200
Habitat Needed to Meet Objectives	Maintain current levels	1,000- 22,800	Maintain current levels	20,400- 52,000	Maintain current levels	Maintain current levels	0-167,700

[1] Forested Wetland Condition Index scores of 7, 8, 10, 11, 13, or 14

Table 13. Forested Wetlands current habitat availability (ac) is determined by the percentage of current or restorable forested wetlands in the East Gulf Coastal Plain encompassed by a state.

Current Habitat Condition for each State-by-BCR							
	AL		FL	KY	LA	MS	TN
	BCR 27	BCR 29					
Forested Wetlands: High or Moderate Site Quality in Intact or Fragmented Landscape[1]							
Current	1,051,963	20,715	306,230	11,073	248,892	1,136,651	130,476
Forested Wetlands: High or Moderate Site Quality in Very Fragmented Landscape[2]							
Current	235,355	3,746	42,742	12,916	58,964	313,853	105,548
Forested Wetlands: Low Site Quality in Intact Landscape[3]							
Current	681,402	11,354	325,815	378	178,897	625,087	13,764

[1] Forested Wetland Condition Index scores of 7, 8, 10, 11, 13, or 14

[2] Forested Wetland Condition Index scores of 4 or 5

[3] Forested Wetland Condition Index score of 12

Pine-dominated Woodlands and Savannas

PINE AT-A-GLANCE

Representative Priority Species:
Red-cockaded Woodpecker

Current High Quality, Intact Pine-dominated Woodlands and Savannas:
626,187 ac

JV-wide Objective: 610,000 ac

RCW Habitat Shortage: No JV-wide deficit due to ample habitat availability in Florida, but local deficits are apparent in Alabama, Louisiana, and Mississippi. Continuing prescribed burning will be central to maintaining current pine woodlands and savannas.

Longleaf Pine Woodlands/Chuck Bargeron, University of Georgia, Bugwood.org

Habitat Description and Current Status

Pine-dominated Woodlands and Savannas include pine flatwoods and mesic pine, pine uplands and sandhills, and pine plantations with an emphasis on open woodland and savanna conditions. The geography currently has an estimated 4.8 million ac of high and moderate quality Pine-dominated Woodlands and Savannas in intact and fragmented landscapes, though only 626,186 ac are considered high quality, intact habitat. Although progress has been made to restore longleaf pine and frequent fire regimes in much of the Southeastern Coastal Plain, much of the Southeast's pinelands remain in closed-canopy forest or pine plantations. A substantial amount of potential open-pine habitat in good configuration is of poor condition, and much also has poor landscape configuration (Gray and Jones-Farrand 2019). The limited acres in both good configuration and condition are concentrated in southeastern Alabama and Florida's panhandle, an area with a legacy of longleaf pine retention and prescribed fire practices on private lands (Landers et al. 1995, Outcalt and Sheffield 1996).

The trajectory of pine growth and industry standard management practices result in pine plantation stands rotating through periods of regeneration (also called early successional or shrub-scrub condition), canopy closure prior to a timber thinning, and open forest after thinning and prior to final harvest. In parts of the geography with a high proportion of evergreen forest in pine plantations, such as central Mississippi, southern Alabama, and Florida's panhandle, timberlands provide a shifting mosaic of ephemeral open forest conditions, which can be used by Bachman's Sparrow and Northern Bobwhite for about 4 years (Iglay et al. 2018, Greene et al. 2019a,b).

Priority Bird Species

Pine-dominated Woodlands and Savannas serve as the primary habitat type for four priority landbird species. Three of these species are in a PIF continental concern group and have 10-year and 30-year habitat objectives (Table 14). Red-cockaded Woodpecker requires the most habitat to achieve 10-year and 30-year minimum population objectives.

Table 14. Ten- and thirty-year habitat objectives (ac) for priority landbird species primarily associated with Pine-dominated Woodlands and Savannas. The species in bold sets habitat objectives for this suite of priority landbirds.

Habitat Objectives for Priority Species in Pine-dominated		
	10-year Habitat Objective (ac)	30-year Habitat Objective (ac)
American Kestrel (SE)	Maintain enough habitat to support current populations.	
Bachman's Sparrow	290,000-469,800	406,000-696,000
Northern Bobwhite	153,600-350,200	153,600-331,800
Red-cockaded Woodpecker[1]	**610,000**	**610,000**

[1] 10- and 30-year habitat objectives based from Red-cockaded Woodpecker Recovery Plan (USFWS 2003).

Calculating Habitat Objectives

The LWG calculated habitat objectives for the Pine-dominated habitat type using three condition indices from the SECAS Blueprint Update: Longleaf Pine Flatwoods, Longleaf Pine Woodlands, and Shortleaf-Loblolly Pine Woodlands (Gray and Jones-Farrand 2019). These condition indices are analogous to other indices developed for the Blueprint. The highest quality pine woodlands and savannas are concentrated in the panhandle of Florida and southern Alabama with some significant patches occurring in southern Mississippi (Figure 8). Existing pine woodlands and flatwoods that could be enhanced to higher quality have the greatest footprint in southern Mississippi and adjacent to the Black Belt Prairie region.

Ten-year objectives for Pine-dominated Woodlands and Savannas as determined by Red-cockaded Woodpecker are presented in Table 15. Because Red-cockaded Woodpecker has specific habitat requirements with a narrow range of structural and vegetative conditions, additional site quality and landscape conditions may be needed to support the larger suite of open pine species. Also, if open pine-associated species occupy moderate-condition sites at lower densities, there may be sufficient habitat currently on the ground to meet requirements for species with less specific habitat requirements than Red-cockaded Woodpecker (Table 16). Furthermore, species that are less edge- and area-sensitive could occupy fragmented landscapes with high quality. However, the landscapes' risk to additional fragmentation and site degradation needs careful consideration.

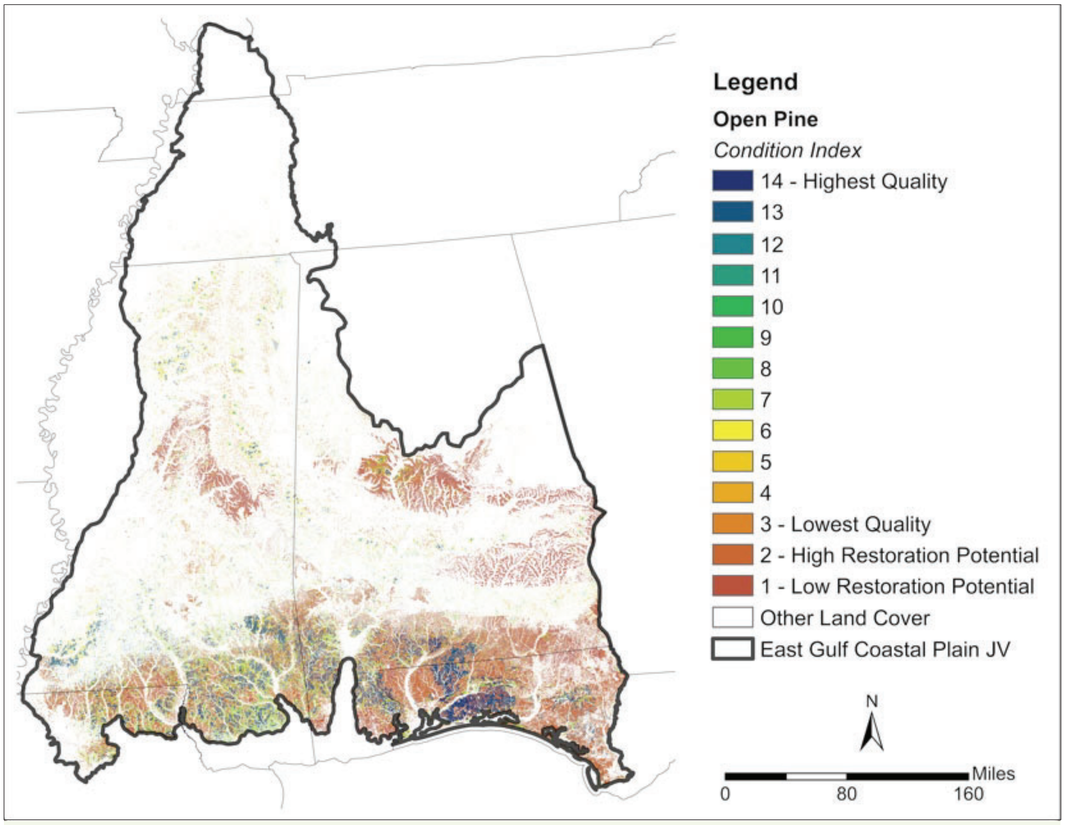

Figure 8. Condition summary of Pine-dominated Woodlands and Savannas, commonly referred to as "open pine," in the East Gulf Coastal Plain (Gray and Jones-Farrand 2019).

Table 15. Current habitat, 10-year objectives, and habitat shortages (ac) for High quality, intact Pine-dominated Woodlands and Savannas for each State-by-BCR area within the East Gulf Coastal Plain as determined by Red-cockaded Woodpecker. (Note: Red-cockaded Woodpecker does not have a range of population/habitat objectives so single values are displayed.)

HABITAT OBJECTIVES FOR EACH STATE-BY-BCR							
	AL		FL	KY	LA	MS	TN
	BCR 27	BCR 29					
Pine-dominated Woodlands and Savannas: High Quality, Intact							
Current Habitat	168,662	0	286,716	0	28,027	142,720	62
10-year Habitat Objective	226,100	4,500	128,400	0	42,000	207,600	1,400
Habitat Needed to Meet Objective	57,400	4,400	Maintain current levels	Maintain current levels	14,000	64,900	1,300

Table 16. Pine-dominated Woodlands and Savannas current habitat availability (ac) as determined by the percentage of current or restorable pine habitats in the East Gulf Coastal Plain at the State-by-BCR level.

Current Habitat Condition for each State-by-BCR								
		AL		FL	KY	LA	MS	TN
		BCR 27	BCR 29					
Pine-dominated Woodlands and Savannas: High Quality in Intact or Fragmented Landscape								
High Quality	Intact Landscape[1]	168,662	0	286,716	0	28,027	142,720	62
	Fragmented Landscape[2]	246,584	1,369	60,348	12	57,870	331,924	7,470
Pine-dominated Woodlands and Savannas: Moderate Quality in Intact or Fragmented Landscape								
Moderate Quality	Intact Landscape[3]	427,165	35	335,994	0	70,544	548,968	203
	Fragmented Landscape[4]	587,359	9,042	113,873	12	152,592	1,196,052	21,071
Pine-dominated Woodlands and Savannas: Low Quality in Intact Landscape, Restoration Potential, Other								
Low Quality	Intact Landscape[5]	48,220	22	29,648	0	15,078	157,137	74
High Restoration Potential (Near existing med-large habitat patches)[6]		1,786,475	10,719	1,787,259	0	387,142	1,281,449	2
Other Pine Woodland and Forest Condition[7]		1,816,321	78,530	271,321	0	232,205	1,007,694	2,792

[1] Condition index score of 14

[2] Condition index score of 5, 8, or 11

[3] Condition index score of 13

[4] Condition index score of 4, 7, or 10

[5] Condition index score of 12

[6] Condition index score of 2

[7] Condition index scores not included in above categories

HARDWOODS & PINE-HARDWOODS AT-A-GLANCE

Representative Priority Species: Yellow-billed Cuckoo

Current Hardwoods & Pine-Hardwoods: 6,976,884 ac[1]

JV-wide Objective: 10,910,700 to 13,820,200 ac

Hardwoods & Pine-Hardwoods Shortage: 3,933,800 to 6,843,300 ac

[1] In moderate to high site quality and fragmented to intact landscapes

Pine-Hardwoods/USDA Forest Service

Habitat Description and Current Status

Upland Hardwood & Pine-Hardwood Woodlands and Forests include mixed hardwoods (e.g., Loess bluffs, the Tennessee Plateau), pine-hardwood forest, and hardwood plantations. The geography currently encompasses an estimated 6.98 million ac of these habitats. In the most recent Southern Forest Futures Project report for the Southern States, Upland Hardwood & Pine-Hardwood Woodlands and Forests were forecasted to decline in area through 2060 in every future land use-urbanization scenario examined (Wear and Greis 2013). Reduction in Upland Hardwoods was strongly linked to the rate of urbanization, and losses were forecasted as substantial (8-14% of Upland Hardwoods current area for all southern states) regardless of timber markets (Wear and Greis 2013). The Southern Forest Futures Project forecasted a 17-38% decline in the current cover of oak-pine forest type for the southern states, and these declines were more influenced by timber markets than rates of urbanization. Although a greater proportion of these woodlands and forests are forecasted to be lost in the Piedmont and Southern Appalachians, even small reductions in this geography can greatly impact priority species. Conservation of Upland Hardwood & Pine-Hardwood Woodlands and Forests is critical in order to meet population objectives for priority species.

Priority Bird Species

Hardwoods & Pine-Hardwoods serve as the primary habitat type for nine priority landbird species. Five species are in PIF continental concern groups and have 10-year and 30-year habitat objectives (Table 17). Yellow-billed Cuckoo requires the most habitat to achieve 10-year and 30-year minimum population objectives, thus was selected as the representative species for this habitat type. Due to large variances in bird density across various habitat qualities, locations, site uses, and other factors, the range of habitat objectives for Kentucky Warbler, Red-headed Woodpecker, and Wood Thrush are quite wide.

Table 17. Ten- and thirty-year habitat objectives (ac) for priority landbird species primarily associated with Upland Hardwood & Pine-Hardwood Woodlands and Forests. The species in bold sets habitat objectives for this suite of priority birds.

HABITAT OBJECTIVES FOR PRIORITY SPECIES IN UPLAND HARDWOOD & PINE-HARDWOOD WOODLANDS AND FORESTS		
	10-year Habitat Objective (ac)	30-year Habitat Objective (ac)
Cerulean Warbler	2,700-12,300	3,700-14,400
Chuck-will's-widow	Maintain enough habitat to support current populations.	
Eastern Whip-poor-will		
Eastern Wood-Pewee		
Kentucky Warbler	523,500-7,673,000	704,700-9,004,100
Red-headed Woodpecker	328,900-3,306,200	442,800-3,879,800
Wood Thrush	2,114,400-26,564,900	2,846,200-31,173,133
Worm-eating Warbler	Maintain enough habitat to support current populations.	
Yellow-billed Cuckoo	**10,910,700-13,820,200**	**10,910,600-13,092,800**

Calculating Habitat Objectives

The LWG calculated habitat objectives for this grouping using three condition indices developed for the SECAS Blueprint: Mixed Forest, Upland Hardwood Forest, and Upland Hardwood Woodland (Gray and Jones-Farrand 2019). The greatest concentration of high-quality hardwoods and mixed forests occurs in Alabama, Mississippi, and in small pockets of Tennessee (Figure 9). In Tennessee, a nearly continuous, north-south swath along the Tennessee River contains an abundance of this habitat type in moderate to high quality, but in a currently fragmented landscape. Other places with notable restoration potential include Central Mississippi and along the edge of BCR 29 in Alabama.

Yellow-billed Cuckoo/Alan Schmierer

Upland Hardwoods & Pine-Hardwood Woodlands and Forests currently occupy 7.0 million ac in high or moderate site quality in either an intact or fragmented landscape. The BCR 29 portion of Alabama is the only State-by-BCR area which currently meets its 10-year habitat objective (Table 18). For species not sensitive to fragmentation or edge, an additional 4.0 million ac of habitat can be found in very fragmented landscapes of high or moderate site quality (Table 19). For edge- and area-sensitive species, enhancing low quality habitat in intact landscapes (1.2 million ac) may accelerate population recovery. Much of this enhancement opportunity occurs in Alabama, Mississippi, and Tennessee.

For edge- and area-sensitive species, enhancing low quality habitat in intact landscapes (1.2 million ac) may accelerate population recovery, particularly in AL, MS, and TN.

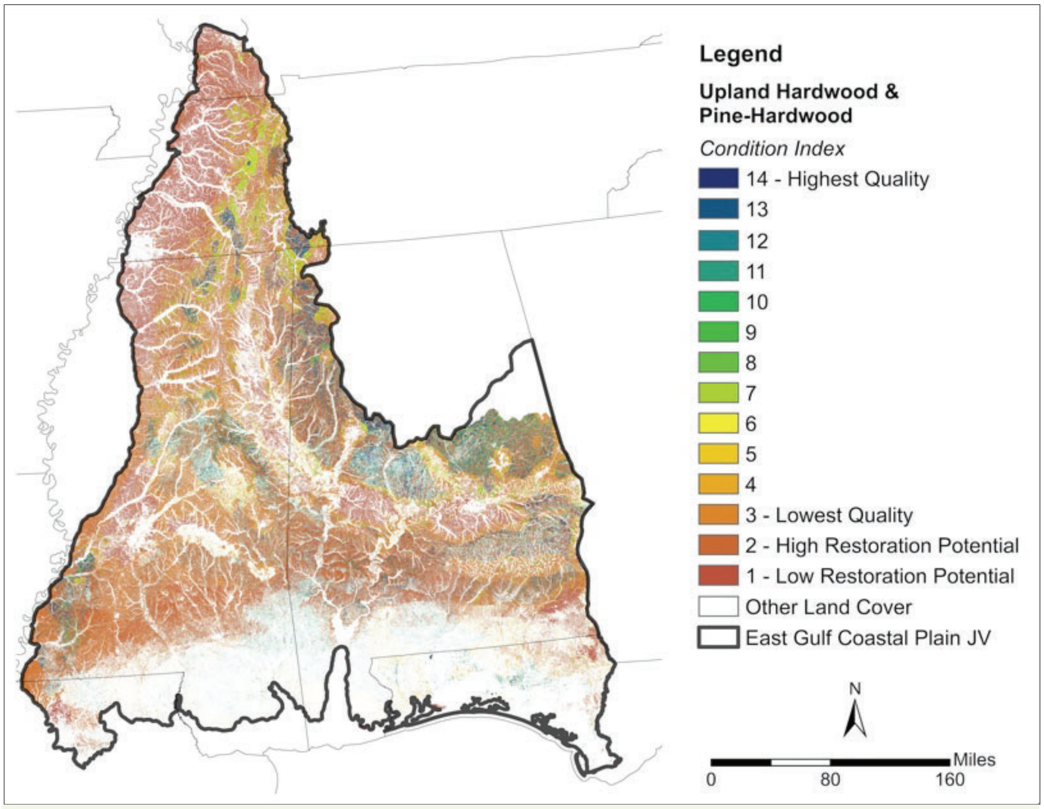

Figure 9. Condition summary of Upland Hardwood & Pine-Hardwood Woodlands and Forests in the East Gulf Coastal Plain (Gray and Jones-Farrand 2019).

Table 18. Upland Hardwood & Pine-Hardwood Woodlands and Forests current available habitat (ac) for high or moderate quality, intact or fragmented Upland Hardwood & Pine-Hardwood Woodlands and Forests for each State-by-BCR area within the East Gulf Coastal Plain as determined by Yellow-billed Cuckoo.

Habitat Objectives for each State-by-BCR							
	AL		FL	KY	LA	MS	TN
	BCR 27	BCR 29					
Upland Hardwood & Pine-Hardwood: High or Moderate Site Quality in Intact or Fragmented Landscapes[1]							
Current	3,072,160	770,973	101,086	36,436	82,498	2,539,814	373,917
10-year Objective	3,839,500-4,863,300	593,500-751,800	159,300-201,800	270,600-342,700	130,900-165,800	4,545,400-5,757,500	1,371,500-1,737,200
Habitat Needed to Meet Objective	767,300-1,791,100	Maintain current levels	58,200-100,700	234,200-306,300	48,400 83,300	2,005,600-3,217,700	997,600-1,363,300

[1] Upland Hardwoods Condition Index scores of 7,8,10,11,13, or 14

Table 19. Upland Hardwood & Pine-Hardwood Woodlands and Forests habitat availability (ac) as determined by the percentage of current or restorable Upland Hardwood & Pine-Hardwood Woodlands and Forests in the East Gulf Coastal Plain at the State-by-BCR level.

Habitat Objectives for each State-by-BCR							
	AL		FL	KY	LA	MS	TN
	BCR 27	BCR 29					
Upland Hardwood & Pine-Hardwood: High or Moderate Quality in Intact or Fragmented Landscapes[1]							
Current Habitat	3,072,160	770,973	101,086	36,436	82,498	2,539,814	373,917
Upland Hardwood & Pine-Hardwood: High or Moderate Quality in Very Fragmented Landscapes[2]							
Current Habitat	1,173,714	144,168	162,990	81,787	23,947	1,947,889	490,214
Upland Hardwood & Pine-Hardwood: Low Quality in Intact Landscapes[3]							
Current Habitat	754,933	26,816	4,749	0	9,420	295,268	127,872

[1] Upland Hardwoods Condition Index scores of 7,8,10,11,13, or 14

[2] Upland Hardwoods Condition Index scores of 4 or 5

[3] Upland Hardwoods Condition Index scores of 12

Worm-eating Warbler/Vern Wilkins, Indiana University, bugwooddotorg

State-level Habitat Objectives Summary

An important message for conservation partners working at the state-level includes identification of habitat objectives and summary of additional habitat needed within each priority JV habitat type. Table 20 below summarizes the aforementioned information across habitat types. This information may be useful in state-level planning efforts, as well as a means to measure successes in conservation and restoration efforts.

Table 20. Ten-year habitat objectives (ac) and shortages by priority habitat and state in the East Gulf Coastal Plain.

State-Level Habitat Objectives							
		Eastern Interior Grasslands-Prairie	Eastern Interior Grasslands-Improved Agriculture	Eastern Shrub-Scrub	Freshwater Forested Wetlands	Pine-dominated Woodlands and Savannas	Upland Hardwood & Pine Hardwood
Alabama[1]	10-year Habitat Objective	43,000 - 204,000	1,011,600 - 3,661,000	37,300 - 62,500	431,500 - 863,000	230,600	4,433,000 - 5,615,100
	Habitat Needed to Meet Objective	3,100 - 150,700	0 - 898,600	Maintain current levels	1,000 - 22,800	61,800	767,300 - 1,791,100
Florida	10-year Habitat Objective	16,500 - 78,600	389,700 - 1,410,400	15,000 - 25,200	133,500 - 266,900	128,400	159,300 - 201,800
	Habitat Needed to Meet Objective	Maintain current levels	0 - 350,200	Maintain current levels	Maintain current levels	Maintain current levels	58,200 - 100,700
Kentucky	10-year Habitat Objective	2,600 - 12,400	61,400 - 222,000	50 - 100	31,500 - 63,100	Maintain current levels	270,600 - 342,700
	Habitat Needed to Meet Objective	2,600 - 12,400	0 - 43,800	Maintain current levels	20,400 - 52,000	Maintain current levels	234,200 - 306,300

State-Level Habitat Objectives (Continued)

		Eastern Interior Grasslands-Prairie	Eastern Interior Grasslands-Improved Agriculture	Eastern Shrub-Scrub	Freshwater Forested Wetlands	Pine-dominated Woodlands and Savannas	Upland Hardwood & Pine Hardwood
Louisiana	10-year Habitat Objective	5,200 - 24,900	123,400 - 446,600	3,600 - 6,000	61,400 - 122,900	42,000	130,900 - 165,800
	Habitat Needed to Meet Objective	5,100 - 24,800	0 - 79,900	Maintain current levels	Maintain current levels	14,000	48,400 - 83,300
Mississippi	10-year Habitat Objective	67,900 - 322,600	1,600,000 - 5,790,500	31,500 - 52,800	551,900 - 1,103,800	207,600	4,545,400 - 5,757,500
	Habitat Needed to Meet Objective	0 - 188,200	0 - 1,798,500	Maintain current levels	Maintain current levels	64,900	2,005,600 - 3,217,700
Tennessee	10-year Habitat Objective	12,700 - 60,400	299,800 - 1,084,900	2,900 - 4,900	149,000 - 298,200	1,400	1,371,500 - 1,737,200
	Habitat Needed to Meet Objective	11,900 - 59,600	0 - 227,200	Maintain current levels	0 - 167,700	1,300	997,600 - 1,363,300

1 BCR 27 and 29 are combined for Alabama's habitat objectives

2 Prairie & Improved Agriculture combined totals

Swainson's Warbler/Alan Schmierer

Conservation Delivery, Measuring Success, and Outlook

This Plan presents priority bird species for the East Gulf Coastal Plain Joint Venture and presents population and habitat objectives for these species by habitat. Objective setting plays a critical role in supporting successful conservation efforts by our partners. Conservation delivery includes actions taken to protect, restore, and enhance habitat. It is vital to any successful conservation initiative and a central tenet of the EGCPJV's mission (EGCPJV 2008). Defining measurable population objectives is an important step in meeting our ultimate goal of sustaining populations by addressing ecological requirements of the birds (USFWS 2008). While science planning efforts are critical to defining priorities and objectives, conservation delivery translates objectives into tangible habitat improvements (both quantity and quality) to support bird populations. The role of population objectives in bird conservation is explained in a PIF technical series document (Andres et al. 2020). Population objectives can be used to:

Support conservation delivery by serving as biological targets (Andres et al. 2020). These targets support efficient and effective conservation delivery by providing a biological foundation for strategic planning and often entail additional conservation design efforts and development of products such as decision support tools.

Communicate and market the demonstrated needs for conservation (Andres et al. 2020). Audiences include internal and external JV partners, the general public, funding entities, and other organizations making decisions about the amount of funding available for bird conservation.

Measure success by serving as a performance metric for assessing conservation accomplishments (Andres et al. 2020). Measuring success is critical in evaluating conservation implementation and adapting methods and processes as needed. Within partnerships, population objectives allow partners to determine their responsibility and measure their contributions to the larger JV's objectives.

In recent years, there has been an increased focus by many entities on accountability and measuring conservation success (USFWS 2008). Setting objectives with transparent and defensible methods and delivering results is critical and maintains confidence in the ability to communicate likely outcomes (USFWS 2008). A solid scientific foundation provides measurable objectives, focuses conservation delivery, communicates likely and actual conservation outcomes, and measures success. The objectives presented in this Plan serve as a foundation for measuring success, increasing our partnership's ability to contribute meaningfully to the efforts of the larger bird conservation community.

Chuck-will's-widow/Alan Schmierer

Supporting Conservation Delivery

This Plan provides a list of prioritized species and 10- and 30-year population and habitat objectives. Species prioritization efforts result in broad agreement across the EGCP geography for organizations, including state wildlife agencies, which have approved State Wildlife Action Plans. For example, priority species can be central to single or multi-state proposals for habitat management and can also serve as target species for monitoring and research programs addressing information gaps or assumptions made during planning (see Chapter 3, Critical Assumptions). Species monitoring is a way to evaluate the effectiveness of habitat delivery and other conservation actions.

Cerulean Warbler, top left; Henslow's Sparrow, right; Eastern Whip-poor-will bottom left/Alan Schmierer

Population objectives are foundational to conservation planning and the development of decision support tools. While we have developed broad habitat objectives to meet population objectives, both of these objectives can be refined and improved. Future needs include more detailed identification of population-limiting factors for priority species and the application of population-habitat relationship models to facilitate the development of tools directing the 'what' and the 'where' of conservation delivery (USFWS 2008). Decision support tools often identify priority conservation areas and support decisions through:

1. Identification of focal areas where conservation can be directed by funding through State Wildlife Grants, the National Fish and Wildlife Foundation, and Farm Bill programs
2. Development of geographic-based criteria, which can be used to rank projects against each other ensuring implementation of the most beneficial projects
3. Justification of funds requested in proposals by indicating how restoration or management of a certain number of acres will support a number of birds and contribute to population objectives
4. Prioritized work planning to ensure efficient use of resources including work capacity and monetary funding tied to specific conservation outcomes (USFWS 2008)
5. Provision of targets allowing multiple partners to 'own' their portion of objectives, develop plans to meet them, and roll up successes across agencies and the geography to measure success.

Implementation of on-the-ground actions based on biological planning and conservation design results in the implementation of specific conservation actions on identified parts of the landscape (USFWS 2008). Managers constantly make decisions about what conservation treatments to apply and where to apply them, and conservation design can assist in focusing implementation. Managers have access to a variety of tools developed from the best available data and information to make those decisions.

“The partnership relies on the expertise and local knowledge of land managers to implement needed conservation action at the local scale, which roles up to effective, landscape-scale conservation.”

Managers are familiar with conservation issues on lands that they manage and are often best suited to develop appropriate conservation strategies. Depending on the habitat, current land ownership, and management history, land managers might consider myriad conservation delivery actions: land acquisition or easements, restoration and stewardship (e.g., tree or grassland planting, tree thinning, prescribed burning, mowing or haying, or invasive species removal [see Zenzal et al. 2019]). The partnership relies on the expertise and local knowledge of land managers to implement needed conservation action at the local scale, which roles up to effective, landscape-scale conservation.

Jeremy French and Brittney Viers (left) of the Southeastern Grasslands Initiative and Zach Tinkle of Paris Landing State Park, after seeding a grassland restoration project

Lastly, broad habitat objectives presented in the Plan indicate the number of acres needed to support bird population objectives. These habitat objectives can be used to assess the ability and desire of conservation partners and the public to achieve objectives as they are stated. Communicating the objectives with internal and external partners is also useful and provides an opportunity for feedback about feasibility and potential tradeoffs inherent in achieving these goals (USFWS 2008).

Marketing and Communicating Conservation Goals

JV partners must agree on priorities, objectives, and ultimately on how partners contribute individually to collective goals. Partners use objectives to gauge the ability, willingness, and openness of their organization to making decisions in ways to help meet objectives. Open dialogue at the management board level among organizations is critical, because a commitment and understanding of how each partner can contribute to collective goals is important. For example, a state or county agency may be better prepared to provide education programs to engage the public, whereas a federal agency like the Natural Resources Conservation Service generally has far more resources to work on private lands in collaboration with landowners.

“Joint Venture partners must agree on priorities, objectives, and ultimately on how partners contribute individually to collective goals.”

This plan provides the critical first step by developing objectives which answer the question “how much is needed.” How to actually achieve those objectives requires both planning and clear, open communication. Accountability, agreement, and buy-in to organizational contributions also requires transparent communication among and within partner agencies, among JV partners, and among the conservation community and the public.

Measuring Success

Success inherently depends on the mission, goals, organizational structure, metrics used to evaluate outcomes, and the spatial and temporal scales of interest. The goal of the EGCPJV and its partners is the restoration and maintenance of healthy bird populations. Here, we define success relative to the population and habitat objectives in the Plan and aspirational goals outlined in the Implementation Plan (EGCPJV 2008).

This EGCPJV Landbird Conservation Plan provides the first quantitative bird population and habitat objectives for the EGCPJV. Success will require a commitment to tracking habitat and population changes to determine if the objectives presented in this Plan are sufficient to meet the EGCPJV's and PIF's bird population targets. Ultimately, the EGCPJV will evaluate its success by determining how conservation action affects the ability of our landscapes to sustain species (USFWS 2008). Delivering a certain number of acres on the landscape is only a means for achieving success. However, to meet biological outcomes linked to the partnership's mission, conservation delivery must result in positive biological outcomes as expressed by population objectives set in this Plan. Successful landbird conservation is achieved when habitat in the EGCP geography is no longer limiting priority species from reaching population objectives and when habitat gains meet or exceed habitat losses.

> "Successful landbird conservation is achieved when habitat in the EGCP geography is no longer limiting priority species from reaching population objectives and when habitat gains meet or exceed habitat losses."

This Plan was developed with the expectation that individual EGCPJV partners use objectives to plan and implement programs and projects that contribute to the larger partnership's biological objectives. Self-monitoring by partners allows for an evaluation of how contributions of acquired, managed, and restored acres support biological population objectives. Monitoring can also allow evaluation of assumptions made during biological planning and assessing management impacts on bird populations.

Annual BBS data, field studies, and feedback from managing agencies are central to tracking bird populations. Advances in satellite imagery can track additional metrics related to habitat condition and bird migration patterns. Further, tracking habitat gains and losses will be central to assessing and refining future objectives. While the EGCPJV Technical Advisory Team calls for this Plan to be revisited every 10 years, progress toward achieving population and habitat objectives should be tracked at shorter intervals, at minimum every 5 years.

The Plan provides population and habitat objectives to sustain populations of priority landbird species within the EGCP. This Plan will be re-evaluated every 10 years, and it will include additional conservation considerations in subsequent iterations. The LWG will evaluate the success of the EGCPJV and its partners in meeting population and habitat objectives and will adjust objectives as needed to meet the

30-year step-down PIF population goal for the EGCP. Three areas of particular focus in subsequent iterations are: (1) addressing critical assumptions within this Plan; (2) evaluating habitat needs of wintering landbird species; and (3) assessing the overall challenges to conservation delivery. Population and habitat objectives are the product of years-long discussions and multi-step calculations. Inherent in these discussions and calculations are many assumptions, outlined in Chapter 3, Critical Assumptions. This list of 12 assumptions (and/or potential biases) will be addressed in Plan updates as new information from scientific studies, managing agencies, and evaluations of Plan outcomes become available. Three critical assumptions rise to the top of research and monitoring priorities:

1. The Plan will be used and result in improvements in conservation decisions and implementation and thereby lead to improvements in habitat quantity and/or quality.
2. Condition indices and their use in this Plan accurately reflect habitat conditions required by priority species.
3. Increasing habitat availability will result in positive population responses.

Indigo Bunting/Steve Maslowski

Outcome-based monitoring efforts are central to the evaluation of the first and third research priorities. As remote sensing technology and its derivative datasets improve and increase in diversity, condition indices of priority habitat types may be adjusted. In addition, ground-truthing exercises, continued measurements by the U.S. Forest Service Forest Inventory and Analysis Program, and feedback from managing agencies can address knowledge gaps and verify the effectiveness of using condition indices to estimate habitat types and potential or real habitat shortages.

The LWG anticipates future iterations of this Plan to address needs of wintering species and species requiring migratory stopover habitat in this geography. Additionally, monitoring efficacy associated with conservation delivery efforts is a critical information need. Datasets used in this Plan do not address wintering species in the geography, making stepped-down PIF population goals incalculable for this critical season. The LWG, partners, and other experts must determine if current habitat objectives are likely to meet population goals and habitat needs of wintering species (e.g., Henslow's Sparrow, Rusty Blackbird).

Bird populations are under increasing pressures from habitat loss and fragmentation, degradation and conversion to other land cover types and uses, in addition to a myriad of other stressors. Updates to the Landbird Conservation Plan will identify conservation challenges and system-specific threats, including those the partnership can influence to conserve landbirds in the EGCP. This geography continues to face many challenges, and the EGCPJV will continue to act as a resource and forum for its partners to assess the efficacy of conservation delivery methods and coordinate conservation action to address the myriad conservation challenges facing priority landbird species.

Painted Bunting/Alan Schmierer

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Appendix A

Determining Priority Landbird Species

Table A.1. List of landbird species eligible for priority species designation in the East Gulf Coastal Plain. The 29 priority species (emboldened) have a score of at least 0.5 (or, if the score is less than 0.5, the species is a priority if a significant 10-year decline is evident in the North American Breeding Bird Survey [Sauer et al. 2017], can be associated with a primary habitat type (i.e., not a generalist species), and has a core range within the EGCPJV). Scores are calculated via an average weighting process that assigns weight to priority species in the following plans and lists:

- 20% to PIF Landbird Conservation Plan (Rosenberg et al. 2016);
- 2.5% to the EGCPJV Implementation Plan (IP) 2008 (EGCPJV 2008);
- 5% each to PIF's Avian Conservation Assessment Database (ACAD; Panjabi et al. 2019) Area Importance (AI) and Regional Concern (RC);
- 10% each to State Wildlife Action Plans from Alabama (AL; ADCNR et al. 2015), Florida (FL; FFWCC 2012), Kentucky (KY; Kentucky's Comprehensive Wildlife Conservation Strategy 2013), Louisiana (LA; Holcomb et al. 2015), Mississippi (MS, Mississippi Museum of Natural Science 2015), and Tennessee (TN; Tennessee SWAP Team 2015);
- 2.5% to USFWS Birds of Management Concern and Focal Species (FWS BMC; USFWS 2011);
- 1.9% each to Atlantic Coast JV (ACJV; unpubl. report) and Lower Mississippi Valley JV Landbird Plan (LMVJV; Twedt et al. 1999); and
- 0.4% each to Gulf Coast JV (GCJV; Gulf Coast JV Landbird Conservation Plan (Vermillion et al. 2012), Central Hardwoods JV (CHJV; Jones-Farrand et al. 2009, Bonnet et al. 2011, 2013), and Appalachian Mountains JV (AMJV; unpubl. report).

The table below (Table A.1) includes binary values, with "1" indicating a species' inclusion in a plan or list, and a "0" indicating that a species is not included.

Table A.1. List of landbird species eligible for priority species designation in the East Gulf Coastal Plain.

Species	Score	PIF	EGCPJV IP 2008	ACAD		State Wildlife Action Plans						FWS	Joint Venture Plan				
				AI	RC	AL	FL	KY	LA	MS	TN	BMC	GCJV	CHJV	ACJV	LMVJV	AMJV
Bachman's Sparrow	0.977	1	1	1	1	1	1	1	1	1	1	1	0	1	1	0	1
Cerulean Warbler	0.950	1	1	0	1	1	1	1	1	1	1	1	1	1	1	1	1
Henslow's Sparrow	0.927	1	1	1	0	1	1	1	1	1	1	1	0	1	1	0	1
Wood Thrush	0.921	1	0	0	1	1	1	1	1	1	1	1	0	1	1	1	1
Prothonotary Warbler	0.896	1	1	1	1	0	1	1	1	1	1	1	0	1	1	1	1
Red-cockaded Woodpecker	0.877	1	1	1	1	1	1	1	1	1	0	1	0	1	1	0	1
Kentucky Warbler	0.871	1	0	0	0	1	1	1	1	1	1	1	0	1	1	1	1
Northern Bobwhite	0.85	1	1	0	1	0	1	1	1	1	1	1	1	1	1	1	1
Loggerhead Shrike	0.85	1	1	0	1	0	1	1	1	1	1	1	1	1	1	1	1
Short-eared Owl	0.848	1	0	0	0	1	1	1	1	1	1	1	0	1	1	0	0
Red-headed Woodpecker	0.821	1	0	1	0	0	1	1	1	1	1	1	0	1	1	1	1
Prairie Warbler	0.821	1	0	0	1	0	1	1	1	1	1	1	0	1	1	1	1
Rusty Blackbird	0.819	1	1	1	0	0	1	1	1	1	1	1	0	0	1	0	0
Chuck-will's-widow	0.817	1	0	0	1	0	1	1	1	1	1	1	0	0	1	1	1
Grasshopper Sparrow	0.752	1	0	0	0	0	1	1	1	1	1	1	0	1	1	0	1
Swainson's Warbler	0.750	0	1	0	1	1	1	1	1	1	1	1	1	1	1	1	1
Worm-eating Warbler	0.671	0	0	0	0	1	1	1	1	1	1	1	0	1	1	1	1
LeConte's Sparrow	0.648	1	0	0	0	0	1	1	0	1	1	1	1	0	1	0	0
American Woodcock	0.648	0	1	0	0	1	1	1	1	1	1	0	0	1	1	0	0
Golden-winged Warbler	0.633	1	0	0	0	0	1	1	1	0	1	1	1	0	0	0	1
Swallow-tailed Kite	0.592	0	1	0	0	1	1	1	1	1	0	1	0	1	1	1	0

Species	Score	PIF	EGCPJV IP 2008	ACAD		State Wildlife Action Plans						FWS BMC	Joint Venture Plan				
				AI	RC	AL	FL	KY	LA	MS	TN		GCJV	CHJV	ACJV	LMVJV	AMJV
American Kestrel (SE)	0.575	0	0	0	1	1	1	1	1	1	0	1	0	0	0	0	0
Chimney Swift	0.573	1	0	0	1	0	1	1	0	0	1	0	0	0	1	0	1
Peregrine Falcon	0.548	0	0	0	0	0	1	1	1	1	1	1	0	0	1	0	1
Louisiana Waterthrush	0.548	0	0	0	0	0	1	1	1	1	1	1	0	0	1	0	1
Eastern Whip-poor-will	0.533	1	0	0	0	0	1	0	1	0	1	1	0	1	0	0	1
Canada Warbler	0.529	1	0	0	0	0	1	0	1	0	1	1	0	0	0	0	1
Painted Bunting	0.517	0	0	0	1	0	1	1	0	1	1	1	0	1	1	1	0
Bank Swallow	0.500	1	0	0	0	0	1	0	1	0	1	0	0	0	0	0	0
BeWick's Wren	0.483	0	0	0	1	1	0	0	1	1	1	1	0	1	0	0	1
Brown-headed Nuthatch	0.452	0	0	0	0	0	1	1	0	1	1	1	0	1	1	0	1
Sedge Wren	0.448	0	0	0	0	0	1	1	1	0	1	1	0	1	1	0	0
Bobolink	0.444	1	0	0	0	0	1	0	1	0	0	1	0	0	1	0	0
Greater-Prairie-Chicken	0.429	1	0	0	0	0	0	0	1	0	1	1	0	1	0	0	0
Field Sparrow	0.421	1	0	0	1	0	0	1	0	0	0	1	0	1	1	1	1
Barn Owl	0.419	0	0	0	0	0	0	1	1	1	1	0	0	0	1	0	0
Common Nighthawk	0.400	1	0	0	0	0	1	0	0	0	1	0	0	0	0	0	0
Least Flycatcher	0.400	1	0	0	0	0	0	0	1	0	1	0	0	0	0	0	0
Common Ground Dove	0.394	0	0	0	1	0	1	1	0	1	0	1	0	0	1	0	0
Eastern Meadowlark	0.377	1	0	0	1	0	0	0	0	0	1	0	0	1	1	0	1
Mississippi Kite	0.363	0	0	0	0	0	1	0	1	0	1	1	0	0	1	1	0
Bell's Vireo	0.348	0	0	0	0	0	0	1	1	0	1	1	0	1	0	1	0
Yellow-billed Cuckoo	0.342	1	1	0	1	0	0	0	0	0	0	1	0	1	1	1	0
Blue-winged Warbler	0.333	0	0	0	0	0	1	0	1	0	1	1	0	1	0	0	1

Species	Score	PIF	EGCPJV IP 2008	ACAD		State Wildlife Action Plans						FWS BMC	Joint Venture Plan				
				AI	RC	AL	FL	KY	LA	MS	TN		GCJV	CHJV	ACJV	LMVJV	AMJV
Olive-sided Flycatcher	0.329	1	0	0	0	0	0	0	0	0	1	1	0	0	0	0	1
Northern Harrier	0.323	0	0	0	0	1	0	0	1	0	1	0	0	0	1	0	1
Brewer's Blackbird	0.300	1	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0
Black-throated Green Warbler	0.294	0	0	0	1	0	1	0	1	0	0	1	0	0	1	0	0
Yellow-throated Warbler	0.292	0	0	0	1	0	0	1	0	0	1	0	0	0	1	1	1
Common Grackle	0.269	1	0	1	0	0	0	0	0	0	0	0	0	0	0	1	0
Dickcissel	0.244	0	0	0	0	0	0	1	1	0	0	1	0	0	0	1	0
Willow Flycatcher	0.229	0	0	0	0	0	0	0	1	0	1	1	0	0	0	0	1
Sharp-shinned Hawk	0.225	0	0	0	0	0	0	0	1	0	1	1	0	0	0	0	0
Lark Sparrow	0.208	0	0	0	0	0	0	1	1	0	0	0	0	1	0	0	1
Ruffed Grouse	0.208	0	0	0	0	0	0	0	1	0	1	0	0	1	0	0	1
Blackburnian Warbler	0.204	0	0	0	0	0	0	0	1	0	1	0	0	0	0	0	1
Northern Flicker	0.202	0	0	0	1	0	1	0	0	0	0	1	0	1	1	0	1
Brown Creeper	0.200	0	0	0	0	0	0	0	1	0	1	0	0	0	0	0	0
Common Raven	0.200	0	0	0	0	1	0	0	1	0	0	0	0	0	0	0	0
White-breasted Nuthatch	0.200	0	0	0	0	0	1	1	0	0	0	0	0	0	0	0	0
White-tailed Kite	0.200	0	0	0	0	0	1	1	0	0	0	0	0	0	0	0	0
Broad-winged Hawk	0.179	0	0	0	1	0	1	0	0	0	0	1	0	0	0	0	1
Orchard Oriole	0.167	0	0	0	0	0	0	0	0	0	1	1	0	1	1	1	0
Burrowing Owl	0.144	0	0	0	0	0	1	0	0	0	0	1	0	0	1	0	0
Hooded Warbler	0.142	0	0	0	0	0	0	1	0	0	0	0	0	0	1	1	1
Yellow-throated Vireo	0.142	0	0	0	0	0	0	1	0	0	0	0	0	0	1	1	1
Golden Eagle	0.129	0	0	0	0	0	0	0	0	1	0	1	0	0	0	0	1
Northern Saw-whet Owl	0.129	0	0	0	0	0	0	0	0	0	1	1	0	0	0	0	1

Species	Score	PIF	EGCPJV IP 2008	ACAD		State Wildlife Action Plans						FWS BMC	Joint Venture Plan				
				AI	RC	AL	FL	KY	LA	MS	TN		GCJV	CHJV	ACJV	LMVJV	AMJV
Yellow-breasted Chat	0.127	0	0	0	0	0	0	0	0	0	1	0	0	1	0	1	1
Black-capped Chickadee	0.125	0	0	0	0	0	0	0	0	0	1	1	0	0	0	0	0
Vesper Sparrow	0.125	0	0	0	0	0	1	0	0	0	0	1	0	0	0	0	0
Snail Kite	0.125	0	0	0	0	0	1	0	0	0	0	1	0	0	0	0	0
White-crowned Pigeon	0.125	0	0	0	0	0	1	0	0	0	0	1	0	0	0	0	0
Yellow-bellied Sapsucker	0.125	0	0	0	0	0	0	0	0	0	1	1	0	0	0	0	0
Purple Martin	0.123	0	0	0	0	0	1	0	0	0	0	0	0	0	0	1	1
American Redstart	0.119	0	0	0	0	0	1	0	0	0	0	0	0	0	0	1	0
Black-throated Blue Warbler	0.119	0	0	0	0	0	0	0	0	0	1	0	0	0	1	0	0
Scarlet Tanager	0.104	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	1
Alder Flycatcher	0.100	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0
Barn Swallow	0.100	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0
Eastern Screech Owl	0.100	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0
Hairy Woodpecker	0.100	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0
Long-eared Owl	0.100	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0
Merlin	0.100	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0
Red-breasted Nuthatch	0.100	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0
Rose-breasted Grosbeak	0.100	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0
Savannah Sparrow	0.100	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0
Warbling Vireo	0.100	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0
Winter Wren	0.100	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0
Eastern Wood-peewee	0.096	0	0	0	1	0	0	0	0	0	0	0	0	1	1	1	1
Eastern Towhee	0.077	0	0	0	1	0	0	0	0	0	0	0	0	1	1	0	1
Eastern Kingbird	0.073	0	0	0	1	0	0	0	0	0	0	0	0	1	1	0	0
Acadian Flycatcher	0.067	0	0	0	0	0	0	0	0	0	0	1	0	0	1	1	1

Species	Score	PIF	EGCPJV IP 2008	ACAD		State Wildlife Action Plans						FWS BMC	Joint Venture Plan				
				AI	RC	AL	FL	KY	LA	MS	TN		GCJV	CHJV	ACJV	LMVJV	AMJV
Summer Tanager	0.063	0	0	0	0	0	0	0	0	0	0	1	0	0	1	1	0
Brown Thrasher	0.052	0	0	0	0	0	0	0	0	0	0	1	0	1	1	0	1
Mourning Dove	0.044	0	0	0	0	0	0	0	0	0	0	1	0	0	0	1	0
White-eyed Vireo	0.042	0	0	0	0	0	0	0	0	0	0	0	0	1	1	1	0
Northern Parula	0.042	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	1
Indigo Bunting	0.042	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	1
Red-shouldered Hawk	0.038	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	0
Red-bellied Woodpecker	0.038	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	0
Black Vulture	0.038	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	0
Black-and-white Warbler	0.029	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	1
Blue-gray Gnatcatcher	0.023	0	0	0	0	0	0	0	0	0	0	0	0	1	0	1	0
White-throated Sparrow	0.023	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	1
Pine Warbler	0.019	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0
Cooper's Hawk	0.019	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0
Carolina Chickadee	0.019	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0
Baltimore Oriole	0.019	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0
Ruby-throated Hummingbird	0.019	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0
Northern Mockingbird	0.019	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0
Carolina Wren	0.019	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0
Barred Owl	0.019	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0
Northern Cardinal	0.019	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0
Pileated Woodpecker	0.019	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0
Wild Turkey	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Appendix B

Population Estimates of Priority Landbird Species

Table B.1. Population estimates of priority landbird species in the EGCPJV. Note that population estimates listed below are exact numbers, calculated across the entirety of BCR 27, BCR 29, and the EGCP geography based on the proportion of each BCR within the JV boundary. Population estimates have been rounded in the Landbird Plan. Please see Table 6 in the Landbird Plan for more detail.

POPULATION ESTIMATES FOR PRIORITY LANDBIRD SPECIES			
	BCR 27	BCR 29	EGCPJV
American Kestrel (SE)	920	7,360	700
American Woodcock	Not applicable[1]		
Bachman's Sparrow	111,639	1,190	56,329
Cerulean Warbler	2,544	10,123	1,680
Chuck-will's-widow	2,093,610	278,160	1,196,732
Eastern Kingbird	2,579,200	520,000	1,201,204
Eastern Meadowlark	928,700	740,000	439,698
Eastern Towhee	11,750,800	3,190,000	6,368,276
Eastern Whip-poor-will[2]	261,180	238,680	---
Eastern Wood-Peewee	793,000	---	389,266
Field Sparrow	695,640	601,710	435,495
Grasshopper Sparrow	129,200	496,400	110,894
Henslow's Sparrow	2,009	492	59
Indigo Bunting	12,885,600	5,678,400	6,456,514
Kentucky Warbler	468,780	85,800	252,053
Loggerhead Shrike	245,700	18,200	138,246
Louisiana Waterthrush	53,505	33,570	25,033
Northern Bobwhite	543,460	80,620	273,511
Painted Bunting	244,500	---	99,738
Prairie Warbler	1,128,240	622,080	618,107
Prothonotary Warbler	1,053,990	21,000	424,778
Red-cockaded Woodpecker	9,909	156	6,150
Red-headed Woodpecker	343,260	42,480	136,530
Rusty Blackbird	Not applicable[1]		
Swainson's Warbler	73,760	2,400	53,087
Swallow-tailed Kite	8,450	---	5,085
Wood Thrush	1,854,000	1,185,600	1,096,986
Worm-eating Warbler	42,978	42,900	35,310
Yellow-billed Cuckoo	1,656,960	396,480	780,533

[1] Population estimates were not available from Breeding Bird Survey

[2] GAP does not have species distribution data available for Eastern whip-poor-will

Appendix C

Density Estimates of Priority Landbirds with PIF Designations

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Table C.1. Densities, given in birds/ac, used to calculate habitat objectives for 18 Partners in Flight species included in continental concern groups. Densities are based on a literature review of published density estimates for BCR 27 and neighboring BCRs in the Eastern U.S. For species assigned to more than one primary habitat type, the Landbird Working Group specified densities for each habitat type if published density estimates varied by habitat types. In addition, more than one density is given if land cover and land use show significant variation within a single habitat type (e.g., prairie and agriculture within Eastern Interior Grasslands).

Densities for Priority Landbird Species in a PIF Continental Concern Group			
	Density Range used for EGCPJV Objectives (birds/ac)	Densities for BCR 27 (n = publications) (birds/ac)	Densities for Neighboring BCRs (n = publications) (birds/ac)
American Woodcock	Not applicable: Population and habitat objectives defined by conservation plan (Kelley et al. 2008)		
Bachman's Sparrow	0.162-0.243	0.174-0.851 (7)	0.049-0.097 (1)
Cerulean Warbler			
All Habitat Types	0.101-0.364	Not available	0.031-0.365 (6)
Chuck-will's-widow	Insufficient data: Habitat objectives were not calculated		
Eastern Meadowlark[1]			
All Habitat Types		0.101-0.207 (2)	0.016-0.324 (20)
Prairie	0.081-0.304		
Agriculture	0.040-0.202		
Eastern Whip-poor-will	0.097	0.003-0.097 (3)	0.002-0.050 (3)
Field Sparrow[1]			
All Habitat Types		0.028-0.196 (2)	0.002-1.737 (11)
Prairie	0.101-0.405		
Agriculture	0.028-0.081		
Grasshopper Sparrow[1]			
All Habitat Types		0-0.207 (2)	0.008-0.608 (36)
Prairie	0.081-0.405		
Agriculture	0.081-0.202		
Henslow's Sparrow[1]			
All habitat types	0.243-0.405	0.243-1.54 (3)	0-5.589 (18)
Kentucky Warbler[1]			
All habitat types	0.024-0.283	0.025 (1)	0.016-1.215 (17)

DENSITIES FOR PRIORITY LANDBIRD SPECIES IN A PIF CONTINENTAL CONCERN GROUP (CONTINUED)

	Density Range used for EGCPJV Objectives (birds/ac)	Densities for BCR 27 (n = publications) (birds/ac)	Densities for Neighboring BCRs (n = publications) (birds/ac)
Loggerhead Shrike[1] All habitat types	 0.040-0.243	0.006-0.275 (2)	0.049-0.006 (1)
Northern Bobwhite[1] All Habitat Types Prairie Agriculture Pine Woodland	0.081-0.283 0.040-0.202 0.202-0.364	0.009-0.051 (4)	0.0004-0.304 (30)
Prairie Warbler All Habitat Types Climax Shrub-Scrub Regenerating Pine	1.214-1.619 0.040-0.202	0.203-2.029 (3)	0.0004-4.257 (20)
Prothonotary Warbler	0.202-0.647	Not available	0.190-0.652 (4)
Red-cockaded Woodpecker	Not applicable: Population and habitat objectives defined by recovery plan (USFWS 2003)		
Red-headed Woodpecker	0.040-0.324	0.041 (1)	0.012-0.608 (7)
Rusty Blackbird	Insufficient data: Habitat objectives were not calculated		
Wood Thrush	0.040-0.405	Not available	0.002-0.506 (9)
Yellow-billed Cuckoo All Habitat Types Forested Wetlands Upland Hardwoods	0.121-0.283 0.040	0.051 (1)	0.024-0.741 (5)

[1] Most studies of grassland birds provide density estimates for two or more land uses or management types (e.g., hay fields, improved pasture, fields enrolled in Conservation Reserve Program, row crop fields with and without borders, prairie managed with burning or grazing). As such, densities (in the second column) used to calculate habitat objectives for prairie and agricultural land use often originate from the same set of published papers.

Appendix D

Habitat Objectives by Habitat Type and State-by-BCR Areas

Eastern Interior Grasslands

Table D.1. 10-year habitat objectives (ac) given by population objective and species density scenarios for achieving PIF population goals (Rosenberg et al. 2016) in the East Gulf Coastal Plain for priority species associated with Eastern Interior Grasslands. The target representative species (i.e., the priority species which demands the greatest area) are Eastern Meadowlark (for prairie) and Field Sparrow (for improved agriculture). Please see Table 7 in the Landbird Plan for more detail.

		Species Density	
		Lower	Upper
Population Objective	Lower	554,919 (prairie) 9,959,636 (improved ag)	147,978 (prairie) 3,485,873 (improved ag)
	Upper	702,897 (prairie) 12,615,539 (improved ag)	187,439 (prairie) 4,415,439 (improved ag)

Table D.2. 10-year habitat objectives (ac) given by population objective and species density scenarios for achieving PIF population goals (Rosenberg et al. 2016) for each State-by-BCR area in the EGCPJV for priority species associated with Eastern Interior Grasslands. The target representative species (i.e., the priority species which demands the greatest area) are Eastern Meadowlark (for prairie) and Field Sparrow (for improved agriculture). Please see Table 8 in the Landbird Plan for more detail.

	Population Objective-by-Species Density Scenarios			
	Low Pop. Obj. at Low Density	Low Pop. Obj. at High Density	High Pop. Obj. at Low Density	High Pop. Obj. at High Density
Alabama				
BCR 27	149,551 (prairie) 2,684,122 (ag)	39,880 (prairie) 939,443 (ag)	189,431 (prairie) 3,399,888 (ag)	50,515 (prairie) 1,189,961 (ag)
BCR 29	11,487 (prairie) 206,164 (ag)	3,063 (prairie) 72,158 (ag)	14,550 (prairie) 261,142 (ag)	3,880 (prairie) 91,400(ag)
Florida	62,040 (prairie) 1,113,487 (ag)	16,544(prairie) 389,721 (ag)	78,584 (prairie) 1,410,417 (ag)	20,956 (prairie) 493,646 (ag)
Kentucky	9,767 (prairie) 175,290 (ag)	2,604 (prairie) 61,351 (ag)	12,371 (prairie) 222,033 (ag)	3,299 (prairie) 77,712 (ag)
Louisiana	19,644 (prairie) 352,571 (ag)	5,238 (prairie) 123,400 (ag)	24,883 (prairie) 446,590 (ag)	6,635 (prairie) 156,307 (ag)
Mississippi	254,708 (prairie) 4,571,473 (ag)	67,922 (prairie) 1,600,016 (ag)	322,630 (prairie) 5,790,532 (ag)	86,035 (prairie) 2,026,686 (ag)
Tennessee	47,723 (prairie) 856,529 (ag)	12,726 (prairie) 299,785 (ag)	60,449 (prairie) 1,084,936 (ag)	16,120 (prairie) 379,728 (ag)

Table D.3. 10-year habitat objectives (ac) given by population objective and species density scenarios for achieving PIF population goals (Rosenberg et al. 2016) in the East Gulf Coastal Plain for priority species associated with Eastern Shrub-Scrub. The target representative species (i.e., the priority species which demands the greatest area) is Prairie Warbler.

		Species Density	
		Lower	Upper
Population Objective	Lower	120,527	90,395
	Upper	151,432	113,574

Table D.4. 10-year habitat objectives (ac) given by population objective and species density scenarios for achieving PIF population goals (Rosenberg et al. 2016) for each State-by-BCR area in the East Gulf Coastal Plain for priority species associated with Eastern Shrub-Scrub. The target representative species (i.e., the priority species which demands the greatest area) is Prairie Warbler.

	Population Objective-by-Species Density Scenarios			
	Low Pop. Obj. at Low Density	Low Pop. Obj. at High Density	High Pop. Obj. at Low Density	High Pop. Obj. at High Density
Alabama				
BCR 27	45,065	33,799	56,620	42,465
BCR 29	4,689	3,516	5,891	4,418
Florida	20,080	15,060	25,228	18,921
Kentucky	72	54	91	68
Louisiana	4,737	3,553	5,951	4,463
Mississippi	41,992	31,494	52,759	39,569
Tennessee	3,893	2,920	4,891	3,668

Table D.5. 10-year habitat objectives (ac) given by population objective and species density scenarios for achieving PIF population goals (Rosenberg et al. 2016) in the East Gulf Coastal Plain for priority species associated with Freshwater Forested Wetlands. The target representative species (i.e., the priority species which demands the greatest area) is American Woodcock. American Woodcock has a single population objective, rather than a range, as established by its Conservation Plan (Kelley et al. 2008). Please see Table 11 in the Landbird Plan for more detail.

		SPECIES DENSITY	
		Lower	Upper
POPULATION OBJECTIVE	Lower	2,718,155	1,359,078
	Upper	2,718,155	1,359,078

Table D.6. 10-year habitat objectives (ac) given by population objective and species density scenarios for achieving PIF population goals (Rosenberg et al. 2016) for each State-by-BCR area in the East Gulf Coastal Plain for priority species associated with Freshwater Forested Wetlands. The target representative species (i.e., the priority species which demands the greatest area) is American Woodcock. American Woodcock has a single population objective, rather than a range, as established by its Conservation Plan (Kelley et al. 2008). Please see Table 12 in the Landbird Plan for more detail.

	POPULATION OBJECTIVE-BY-SPECIES DENSITY SCENARIOS			
	Low Pop. Obj. at Low Density	Low Pop. Obj. at High Density	High Pop. Obj. at Low Density	High Pop. Obj. at High Density
Alabama				
BCR 27	819,524	409,762	819,524	409,762
BCR 29	43,490	21,745	43,490	21,745
Florida	266,923	133,461	266,923	133,461
Kentucky	63,061	31,531	63,061	31,531
Louisiana	122,861	61,430	122,861	61,430
Mississippi	1,103,843	551,921	1,103,843	551,921
Tennessee	298,182	149,091	298,182	149,091

Table D.7. 10-year habitat objective (ac) for Pine-Dominated Woodlands & Savannas. The target representative species (i.e., the priority species which demands the greatest area) is Red-cockaded Woodpecker. Red-cockaded Woodpecker has a single population objective, rather than a range, and a prescribed density target as established by the Recovery Plan (USFWS 2003). Please see Table 14 in the Landbird Plan for more detail.

		Species Density
Population Objective		610,003

Table D.8. 10-year habitat objective (ac) for each State-by-BCR area in the East Gulf Coastal Plain for priority species associated with Pine-Dominated Woodlands & Savannas. The target representative species (i.e., the priority species which demands the greatest area) is Red-cockaded Woodpecker. Red-cockaded Woodpecker has a single population objective, rather than a range, and a prescribed density target as established by the Recovery Plan (USFWS 2003). Please see Table 15 in the Landbird Plan for more detail.

	Population Objective-by-Species Density Scenarios
	Based on JV-wide population objective and target density (USFWS 2003)
Alabama	
BCR 27	226,128
BCR 29	4,453
Florida	128,406
Kentucky	0
Louisiana	41,968
Mississippi	207,645
Tennessee	1,403

Table D.9. 10-year habitat objectives (ac) given by population objective and species density scenarios for achieving PIF population goals (Rosenberg et al. 2016) in the East Gulf Coastal Plain for priority species associated with Upland Hardwood & Pine-Hardwood Woodlands & Forests. The target representative species (i.e., the priority species which demands the greatest area) is Yellow-billed Cuckoo. Yellow-billed Cuckoo has a single value for species density, rather than a range of density estimates. Please see Table 17 in the Landbird Plan for more detail.

		Species Density
		Single density estimate of 0.1 birds/ha
Population Objective	Lower	10,910,648
	Upper	13,820,154

Table D.10. 10-year habitat objectives (ac) given by population objective and species density scenarios for achieving PIF population goals (Rosenberg et al. 2016) for each State-by-BCR area in the East Gulf Coastal Plain for priority species associated with Upland Hardwood & Pine-Hardwood Woodlands & Forests. The target representative species (i.e., the priority species which demands the greatest area) is Yellow-billed Cuckoo. Please see Table 18 in the Landbird Plan for more detail.

	Population Objective-by-Species Density Scenarios	
	Low Pop. Obj.	High Pop. Obj.
Alabama		
BCR 27	3,839,457	4,863,312
BCR 29	593,539	751,816
Florida	159,295	201,774
Kentucky	270,584	342,740
Louisiana	130,928	165,842
Mississippi	4,545,376	5,757,476
Tennessee	1,371,468	1,737,193

Appendix E
Methodology: Condition Indices Associated with the GCPO LCC Blueprint

The LWG assessed current habitat availability, total current and restorable habitat, and management options associated with site quality and landscape intactness using Terrestrial Broadly Defined Habitat Condition Index scores for the Middle Southeast. These spatially-explicit condition indices can be described as follows:

> This set of spatial data products refines and improves the Conservation Blueprint 1.0 product developed by the Gulf Coastal Plains and Ozarks Landscape Conservation Cooperative. The principal improvement is the elimination of spatially contradictory information about the distribution of habitat for targeted wildlife species across the landscape. Each of the ecological assessments for terrestrial broadly defined habitats was reproduced using a single integrated map based on ecological systems and measurable landscape attributes. For each terrestrial broadly defined habitat, an independent assessment was produced using two large landscape targets, two measures of habitat condition, and two measures of potential to generate a condition index score, standardized to range from 0 – 14 across all habitat types. Each individual habitat assessment data layer includes a bar code descriptor field that explains which measures contributed to the index for each cell in the grid. These individual condition index layers were combined into a unified assessment of all habitat types in a single map. A simple analysis of potential corridors linking core areas of highest quality habitat was produced by identifying core areas, splitting core areas into classes based on size, creating cost distance surface grids for each class, and linking each individual patch in each class to its least cost "nearest" neighbor from each of the other three classes. The Condition Index scores have been incorporated into a 2019 project developing draft Conservation Opportunity Areas for the state of Arkansas. Products from this project have potential to be a key input into the next iteration of the Southeastern Conservation Adaptation Strategy (SECAS) regional assessment of lands and waters having high conservation value (Gray and Jones-Farrand 2019).

The condition indices are grounded in several input data layers including:

- LANDFIRE Biophysical Settings, which describes the vegetative communities expected to occupy the landscape if human influence were removed,
- LANDFIRE Existing Vegetation Type, which describes current land cover conditions,
- basal area inventories from the USFS Forest Inventory & Analysis (FIA) program,
- percent canopy cover derived from satellite imagery processed for National Land Cover Database 2011 (Yang et al. 2018), and
- known prairie patches, obtained from state agencies.

The LWG used condition index scores of 0-14 in the application of habitat objectives for the JV and each State-by-BCR area. Scores greater than 0 designate total current and restorable habitat. These scores were used to apportion habitat objectives based on the proportion of habitat restorability residing in a State-by-BCR area relative to the restorability of the entire EGCP. Assessments of current habitat, from which habitat deficits were calculated, were tailored to each habitat type. For Eastern Interior Grasslands, prairie was defined as Grassland Condition Index scores of nine and greater, and improved agriculture was defined as scores of 3-8. For Freshwater Forested Wetlands, the LWG defined current habitat as having moderate or high site quality within fragmented or intact landscapes (Forested Wetlands Condition Index scores of 7, 8, 10, 11, 13, and 14). The same was applied to Upland Hardwood & Pine-Hardwood Woodlands & Forests using Mixed Forests, Upland Hardwood Forests, and Upland Hardwood Woodlands Condition Indices. Pine-Dominated Woodlands & Savannas were defined differently because the representative target species, the Red-cockaded Woodpecker, inhabits a more niche set of conditions. In this case, only high site quality in intact landscapes (score of 14) from Longleaf Pine Flatwoods, Longleaf Pine Woodlands, and Shortleaf-Loblolly Woodland Condition Indices defined current habitat availability. Because the Pine-Dominated habitat type includes priority species that inhabit a wider range of conditions than Red-cockaded Woodpecker, additional estimations of current habitat availability were included in Table 13 (Chapter 4).

The technical report describing detailed methodology and application of condition indices is permanently stored at https://www.sciencebase.gov/catalog/item/5ccb0cfce4b09b8c0b780433.

Table E.1. Area (ac) of Eastern Interior Grassland Condition Index scores for each State-by-BCR area in the East Gulf Coastal Plain.

EASTERN INTERIOR GRASSLAND CONDITION INDEX							
Score	AL-27	AL-29	FL-27	KY-27	LA-27	MS-27	TN-27
1	195,087	0	4,043	4,040	442	584,821	33,816
2	642	0	771	0	0	52,198	0
3	1,292,006	144,991	225,370	147,242	160,907	2,094,450	613,945
4	447,534	8,997	34,602	343	52,762	411,333	48,769
5	32,929	0	3,395	0	2,449	18,360	227
6	525,587	54,961	127,133	30,332	114,358	1,192,684	177,241
7	227,132	5,661	34,476	287	32,297	259,342	17,359
8	22,642	0	4,050	0	3,882	15,815	124
9	36,982	0	16,922	52	47	77,136	667
10	8,298	0	6,672	0	37	10,349	119
11	430	0	521	0	0	163	0
12	5,315	0	7,057	2	0	40,570	40
13	2,016	0	4,166	0	0	6,069	5
14	262	0	363	0	0	49	0
Total	2,796,863	214,611	469,542	182,299	367,181	4,763,339	892,311

Table E.2. Area (ac) of Forested Wetland Condition Index scores for each State-by-BCR area in the East Gulf Coastal Plain.

FORESTED WETLAND CONDITION INDEX							
Score	AL-27	AL-29	FL-27	KY-27	LA-27	MS-27	TN-27
1	225,543	6,407	18,360	189,085	7,855	871,732	581,964
2	2,380,133	216,911	775,280	141,529	74,574	3,136,313	808,827
3	242,459	3,316	51,956	19,499	79,775	342,053	123,108
4	218,389	3,509	37,718	11,468	54,427	291,875	96,077
5	16,969	235	5,024	1,448	4,537	21,978	9,472
6	36,132	3,996	9,205	0	10,289	72,113	561
7	37,693	4,552	5,093	0	7,890	78,060	593
8	2,795	240	741	0	899	6,244	72
9	202,443	1,082	117,748	15,372	98,988	312,664	75,416
10	205,974	1,421	90,391	9,583	75,693	310,445	94,827
11	15,078	64	9,840	1,371	5,389	19,635	9,887
12	681,402	11,354	325,815	378	178,897	625,087	13,764
13	742,681	13,875	183,819	106	147,497	678,953	23,033
14	47,736	563	16,346	12	11,523	43,313	2,068
Total	5,055,427	267,526	1,647,335	389,853	758,234	6,810,466	1,839,667

Table E.3. Area (ac) of Longleaf Pine Flatwoods Condition Index scores for each State-by-BCR area in the East Gulf Coastal Plain.

LONGLEAF PINE FLATWOODS CONDITION INDEX							
Score	AL-27	AL-29	FL-27	KY-27	LA-27	MS-27	TN-27
1	19,526	0	22,936	0	20,673	7,623	0
2	115,351	0	451,330	0	46,401	35,027	0
3	106	0	1,539	0	726	82	0
4	882	0	6,778	0	3,183	976	0
5	455	0	3,682	0	1,700	588	0
6	413	0	7,818	0	2,600	346	0
7	1,918	0	44,007	0	11,510	4,957	0
8	633	0	15,965	0	3,709	2,002	0
9	0	0	7	0	5	0	0
10	22	0	20	0	52	210	0
11	10	0	0	0	2	163	0
12	161	0	12,938	0	870	200	0
13	1,858	0	110,725	0	4,240	2,686	0
14	546	0	18,081	0	1,228	862	0
Total	141,880	0	695,828	0	96,900	55,722	0

Table E.4. Area (ac) of Longleaf Pine Woodland Condition Index scores for each State-by-BCR area in the East Gulf Coastal Plain.

LONGLEAF PINE WOODLAND CONDITION INDEX							
Score	AL-27	AL-29	FL-27	KY-27	LA-27	MS-27	TN-27
1	1,683,388	74,245	229,835	0	183,611	726,602	2
2	1,671,124	10,719	1,335,929	0	340,740	1,246,422	2
3	44,232	2,901	1,310	0	5,310	57,170	47
4	202,159	4,858	8,105	0	33,362	187,128	277
5	83,887	526	3,884	0	14,535	43,752	27
6	51,581	600	7,846	0	16,951	119,742	37
7	273,659	1,045	54,546	0	94,691	497,262	119
8	111,222	138	36,794	0	33,688	174,501	40
9	1,930	126	40	0	215	3,484	0
10	9,205	185	423	0	1,485	12,513	0
11	2,271	17	22	0	450	1,974	0
12	45,638	22	16,709	0	13,714	124,020	69
13	399,883	30	225,268	0	63,980	445,491	151
14	164,379	0	268,635	0	26,077	130,590	52
Total	4,744,557	95,415	2,189,345	0	828,810	3,770,652	823

Table E.5. Area (ac) of Shortleaf-Loblolly Woodland Condition Index scores for each State-by-BCR area in the East Gulf Coastal Plain.

SHORTLEAF-LOBLOLLY WOODLAND CONDITION INDEX							
Score	AL-27	AL-29	FL-27	KY-27	LA-27	MS-27	TN-27
1	3,015	0	0	0	0	133	37
2	0	0	0	0	0	0	0
3	7,569	558	0	2	499	51,185	2,155
4	66,118	2,493	0	12	2,263	306,596	17,537
5	34,773	509	0	12	1,465	76,516	6,252
6	4,119	89	0	0	1,599	39,221	415
7	30,105	423	0	0	6,010	175,277	2,674
8	11,881	173	0	0	2,318	29,793	981
9	432	15	0	0	10	2,113	109
10	3,289	37	0	0	40	11,137	462
11	1,455	5	0	0	5	2,634	171
12	2,422	0	0	0	494	32,917	5
13	25,425	5	0	0	2,323	100,792	52
14	3,736	0	0	0	722	11,268	10
Total	194,338	4,307	0	27	17,747	839,581	30,858

Table E.6. Area (ac) of Mixed Forest Condition Index scores for each State-by-BCR area in the East Gulf Coastal Plain.

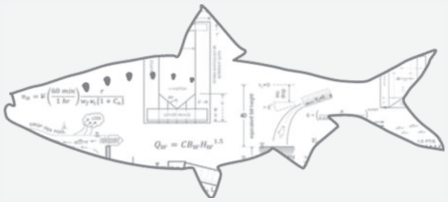
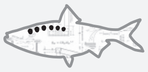
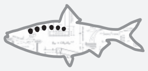
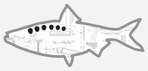
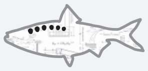
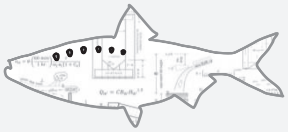
MIXED FOREST CONDITION INDEX							
Score	AL-27	AL-29	FL-27	KY-27	LA-27	MS-27	TN-27
1	245,726	175,284	15,355	0	16,131	2,078,492	190,239
2	440,119	585,019	2,938	0	20,421	755,383	29,181
3	43,293	3,993	14,883	13,401	2,078	45,242	30,799
4	490,894	43,231	80,396	22,706	12,111	730,625	191,205
5	652,315	61,789	76,783	8,224	10,517	999,962	171,298
6	4,386	40	47	269	0	1,678	282
7	97,987	1,685	1,144	6,044	0	37,847	4,394
8	157,942	2,711	855	1,925	0	58,796	4,500
9	55,940	11,199	4,848	0	1,900	37,575	1,448
10	802,520	152,780	42,717	0	17,478	664,194	20,102
11	1,193,487	247,886	31,538	0	19,662	876,862	24,199
12	12,936	395	133	0	0	3,474	5
13	248,904	8,280	3,761	0	0	89,383	430
14	372,535	13,956	1,989	0	0	119,735	596
Total	4,818,985	1,308,248	277,388	52,569	100,297	6,499,247	668,676

Table E.7. Area (ac) of Upland Hardwood Forest Condition Index scores for each State-by-BCR area in the East Gulf Coastal Plain.

UPLAND HARDWOOD FOREST CONDITION INDEX							
Score	AL-27	AL-29	FL-27	KY-27	LA-27	MS-27	TN-27
1	298,849	175	29,722	2,115	67	180,513	881,169
2	5,135,082	21,283	89,076	0	3,210	2,405,612	809,321
3	7,794	6,936	8,933	101,306	519	29,386	99,774
4	16,640	38,964	5,807	49,080	1,258	209,585	88,963
5	94	141	0	0	0	94	111
6	3,714	4,890	6,402	21,975	368	20,821	104,782
7	15,335	38,583	10,579	28,113	9,504	224,433	194,437
8	161	121	0	62	0	69	269
9	2,202	8,310	875	0	59	3,291	1,161
10	4,732	58,643	497	0	267	25,773	756
11	7	101	0	0	0	0	5
12	13,242	26,418	4,023	0	1,349	25,585	20,483
13	54,613	245,711	6,116	0	34,990	405,460	69,231
14	141	497	0	0	0	15	153
Total	5,552,605	450,774	162,029	202,651	51,591	3,530,636	2,270,616

Table E.8. Area (ac) of Upland Hardwood Woodland Condition Index scores for each State-by-BCR area in the East Gulf Coastal Plain.

UPLAND HARDWOOD WOODLAND CONDITION INDEX							
Score	AL-27	AL-29	FL-27	KY-27	LA-27	MS-27	TN-27
1	677,554	4,099	80,111	700,814	72,384	990,501	1,362,349
2	1,407,562	338,564	41,793	0	229,237	4,563,424	161,263
3	64,974	321	27	1,030	222	55,198	91,987
4	13,771	44	5	1,777	59	7,626	38,637
5	0	0	0	0	0	0	0
6	150,855	116	427	353	1,589	130,051	200,256
7	20,122	20	109	292	106	12,560	42,030
8	0	0	0	0	0	0	0
9	64,680	0	0	0	91	23,811	4,072
10	11,513	0	0	0	10	3,450	860
11	0	0	0	0	0	0	0
12	728,755	2	593	0	8,070	266,209	107,384
13	92,158	0	1,782	0	484	21,236	11,955
14	0	0	0	0	0	0	0
Total	3,231,943	343,167	124,847	704,267	312,254	6,074,066	2,020,795

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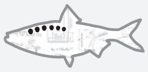
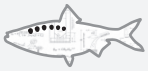
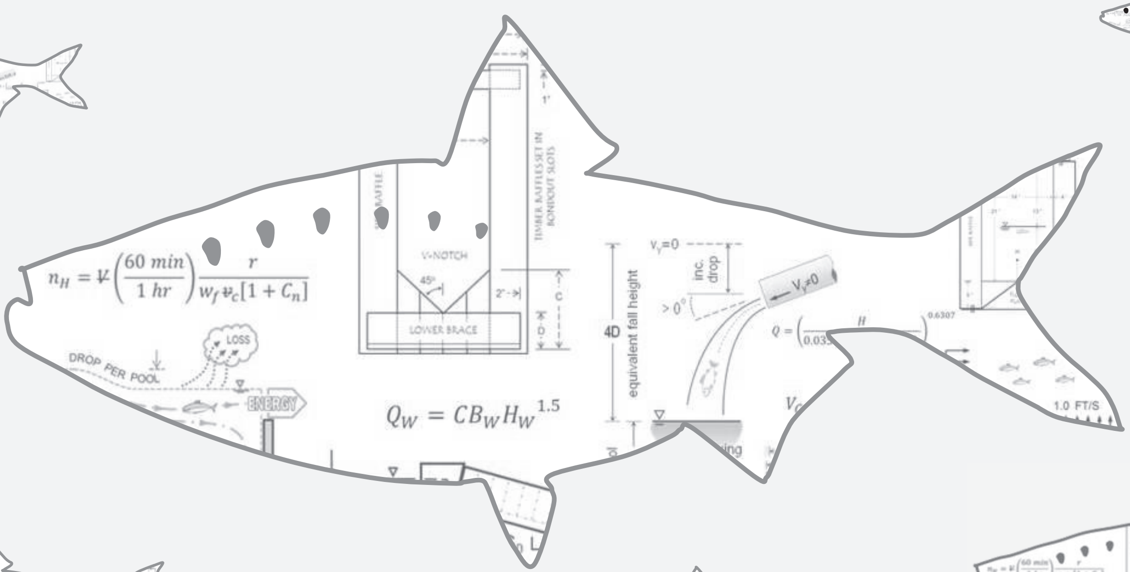
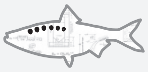
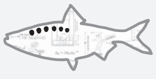


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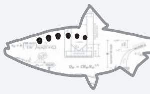
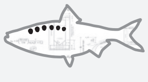

United States Fish and Wildlife Service
Region 5

FISH PASSAGE ENGINEERING DESIGN CRITERIA

February 2017

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1 Scope of this Document

1.1 Role of the USFWS Region 5 Fish Passage Engineering

The U.S. Fish and Wildlife Service (Service) Region 5 (R5) Fish Passage Engineering (Engineering) team provides technical and engineering assistance to the Fish and Aquatic Conservation program, Service biologists, and other federal, state, tribal, and non-governmental partners working to improve passage for migratory fish and other aquatic organisms. For hydroelectric projects under the jurisdiction of the Federal Energy Regulatory Commission (FERC), Engineering coordinates and consults with R5 Ecological Services' Conservation Planning Assistance program.

1.2 Purpose of This Document

Anthropogenic activities in rivers may introduce undue hazards to many aquatic organisms and contribute to overall habitat fragmentation. Fragmentation may negatively alter the structure and diversity of both diadromous and resident fish populations. These adverse impacts can be mitigated through dam removal, and a variety of technical and nature-like fish passage and protection technologies. Fish passage and protection (hereafter simply "fish passage") requires the integration of numerous scientific and engineering disciplines including fish behavior, ichthyomechanics, hydraulics, hydrology, geomorphology, and hydropower. This document is intended to: 1) establish Engineering's "baseline" design criteria for technical and nature-like fishways; 2) serve as a resource for training in these disciplines; and 3) support the implementation of the Service's statutory authorities related to the conservation and protection of aquatic resources (e.g., Section 18 of the Federal Power Act, Endangered Species Act, Fish and Wildlife Coordination Act, and the Anadromous Fish Conservation Act).

1.3 Limitation of Criteria and Consultation

The efficacy of any fish passage structure, device, facility, operation, or measure is highly dependent on local hydrology, target species and life stage, dam orientation, turbine operation, and myriad other site-specific considerations. The information provided herein should be regarded as generic guidance for the design, operation, and maintenance of fishways throughout the northeastern U.S. The criteria described in this document are not universally applicable and should not replace site-specific recommendations, limitations, or protocols. This document provides generic guidance only and is not intended as an alternative to active consultation with Engineering. Application of these criteria in the absence of consultation does not imply approval by Engineering.

1.4 Acknowledgements

This document was written and developed by the U.S. Fish and Wildlife Service Region 5 Fish Passage Engineering team. The editor and corresponding author of this manual is Brett Towler, Ph.D., P.E., P.H. Co-authors were Kevin Mulligan, Ph.D., Curt Orvis, P.E. (retired), and Bryan Sojkowski, P.E. Valuable contributions were provided by other Engineering staff including Jesus Morales, P.E., Jessica Pica, P.E., Ben Rizzo (retired), and Richard Quinn (retired).

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2 Fishway Implementation and Performance

2.1 Definition of a Fishway

A fishway is the combination of elements (structures, facilities, devices, project operations, and measures) necessary to ensure the safe, timely, and effective movement of fish past a barrier. Examples include, but are not limited to, volitional fish ladders, fish lifts, bypasses, guidance devices, zones of passage, operational flows, and unit shutdowns.

The terms "fishway," "fish pass," or "fish passageway" (and similarly "eelway," "eel pass," or "eel passageway") are interchangeable. However, Engineering recommends use of the terms "fishway" or "eelway" as they are consistent with 16 U.S.C. § 811 (1994), which reads:

> *"That the items which may constitute a 'fishway' under section 18 for the safe and timely upstream and downstream passage of fish shall be limited to physical structures, facilities, or devices necessary to maintain all life stages of such fish, and project operations and measures related to such structures, facilities, or devices which are necessary to ensure the effectiveness of such structures, facilities, or devices for such fish.''*

The term "fish passage" (or "eel passage") refers to the act, process, or science of moving fish (or eels) over a stream barrier (e.g., dam).

2.2 Zone of Passage

The zone of passage (ZOP) refers to the contiguous area of sufficient lateral, longitudinal, and vertical extent in which adequate hydraulic and environmental conditions are maintained to provide a route of passage through a stream reach influenced by a dam (or stream barrier).

2.3 Safe, Timely, and Effective

The elements of a fishway are designed and implemented to provide safe, timely, and effective fish passage. These three key species-specific passage characteristics are defined below:

- *Safe Passage:* The movement of fish through the ZOP that does not result in unacceptable stress, incremental injury, or death of the fish (e.g., by turbine entrainment, impingement, and increased predation). If movement past a barrier results in delayed mortality or a physical condition that impairs subsequent migratory behavior, growth, or reproduction, it should not be considered safe passage.

- *Timely Passage:* The movement of fish through the ZOP that proceeds without materially significant delay or impact to essential behavior patterns or life history requirements.
- *Effective Passage:* The successful movement of target species through the ZOP resulting from a favorable alignment of structural design, project operations, and environmental conditions during one or more key periods. Effectiveness includes both qualitative and quantitative components; efficiency, and the hyponyms passage efficiency and attraction efficiency, are typically reserved for quantitative evaluations.
    - *Efficiency:* A quantitative measure of the proportion of the population motivated to pass a barrier (i.e., motivated population) that successfully moves through the entire ZOP; typically expressed as the product of attraction and passage efficiencies.
    - *Attraction Efficiency:* A measure of the proportion of the (motivated) population that is successfully attracted to the fishway; typically measured as a percentage of the motivated population that enters the fishway.
    - *Passage Efficiency:* A measure of the proportion of fish entering the fishway that also successfully pass through the fishway; successful passage through the fishway is typically measured at the fishway exit; also referred to as "internal fishway efficiency."

2.4 Performance Standards

A performance standard establishes a measurable level of success needed to ensure safe, timely, and effective passage for fish migrating through (or within) the ZOP. These three characteristics may be evaluated quantitatively through a site-specific framework agreed upon by the Service and the licensee, although the specific standard may take many forms. For example, a performance standard established for upstream-migrating adult American shad may include a passage efficiency of 85%, an attraction efficiency of 90%, and a maximum migration delay of 4 days.

Other, more stringent performance standards that emphasize short and long-term survivability may apply. For example, the following performance standards have been established by NOAA (2012) for the passage of Atlantic salmon in the Gulf of Maine; the Distinct Population Segment of Atlantic salmon are protected under the Endangered Species Act and these standards have been codified in project-specific species protection plans and biological opinions:

- *Example Atlantic Salmon Downstream Passage Performance Standard*: The downstream migrant successfully locates and uses the downstream fish passage system within 24 hours of encountering the project dam or fishway. In addition, the downstream migrant does not exhibit any trauma, loss of equilibrium, or descaling greater than 20% of the body surface (Black Bear Hydro Partners, 2012).
- *Example Atlantic Salmon Upstream Passage Performance Standard*: The upstream migrant enters the project tailrace (defined as 200 meters downstream of the lowermost water discharge structure), locates the fishway entrance, and passes within 48 hours. In addition, the upstream migrant does not exhibit any trauma, loss of equilibrium, or descaling greater than 20% of the body surface (Black Bear Hydro Partners, 2012).

Generally, the performance standard is informed by state and federal agency biologists with expertise in the life history requirements of the region's fish populations. Factors to consider include the impact of all barriers within the watershed and the minimum number of fish required to sustain a population's long-term health and achieve identified management plan objectives and goals. In cases where a single waterway is impacted by multiple barriers, a "cumulative efficiency" performance standard may apply (i.e., the proportion of the stock that has successfully passed through the composite zone of passage spanning multiple barriers).

2.5 Project Phases

In general, the life of a fishway can be partitioned into distinct stages or phases. The phases in this sequence are listed, along with Engineering's typical support activities, in Table 1. While this sequence is followed in most fish passage projects, certain activities in Table 1 may only be appropriate for work performed in a regulatory environment.

Table 1. Typical fishway project phases and related Engineering activities

Phase	Engineering Activities
Fisheries Management	stream barrier assessment; fishway facility/device needs; FERC re-licensing support; study plan development and review
Planning	fishway capacity and sizing; hydrologic/hydraulic analyses; determination of fishway design flows and operating range; alternatives analyses; conceptual designs; cost estimates; establishment of appropriate fish passage criteria
Design	preliminary (i.e., 30%) design review and input; final (i.e., 90%) design review and input; liaison with owner/consultant on design issues
Construction	construction review and inspection; photo documentation and survey; quality control (QC); post-construction engineering evaluation; commissioning; review/author fishway operation and maintenance (O&M) plan
Operation	Development of a data collection protocol; annual fishway inspection; support FERC compliance activities; troubleshoot known fishway performance issues; evaluation of fishway compliance with criteria; revision of O&M plan; general engineering and technical support

2.6 Trial Operation, Evaluation, and Commissioning of a New Fishway

A newly constructed (or significantly modified) fishway should undergo a period of testing and trial operation to verify proper functioning of the facilities. This trial operation, or "shakedown period," focuses on final adaptations to the facility that optimize hydraulic conditions for fish passage. The shakedown period typically lasts one year and warrants regular consultation with the dam owner(s) by Engineering. In a regulatory environment, completion of the trial operation period often ends in a formal commissioning of the fishway, whereupon the Service certifies that the facilities were built as prescribed (or intended).

Biological evaluation of the fishway typically follows the shakedown period. Evaluation may take many forms including video observation, sample collection, hydro-acoustics, telemetry, or passive integrated transponder (PIT) studies. The evaluation periods typically last 1 to 3 years. Information gleaned from these studies may be used to verify the efficacy of the new fish passage facilities or, if applicable, determine whether or not a formal performance standard has been met. Failure to meet performance expectation(s) may necessitate structural or operational changes, followed by additional evaluation.

2.7 Fishway Operations and Maintenance Plan

An operations and maintenance (O&M) plan is a best-management practice that formally establishes the protocols and procedures necessary to keep a fishway in proper working order. An O&M plan may contain:

- Schedules for routine maintenance, pre-season testing, and the procedures for routine fishway operations, including seasonal and daily periods of operation;
- Standard operating procedures for counting fish;
- Plans for post-season maintenance, protection, and, where applicable, winterizing the fishways;
- Details on how the fishway, spillway, powerhouse and other project components shall be operated, inspected, and maintained during the migration season to provide for adequate fish passage conditions, including, as appropriate:
    - pre-season preparation and testing;
    - sequence of turbine start-up and operation under various flow regimes to enhance fishway operation and effectiveness;
    - surface and underwater debris management at the fishway entrance, guidance channels, the fishway exit, attraction water intakes, and other water supply points;
    - water surface elevations at the fishway entrance and exit, and attraction water flow rate/range.

Engineering recommends that dam owners develop an O&M plan at least three months prior to the commissioning of the fishway and submit it to the Service and other stakeholders for review. The owner should update the O&M plan annually to reflect any changes in fishway operation and maintenance planned for the year. For any FERC jurisdictional fishway, any modifications to the O&M plan by the licensee should require approval by the Service and, if necessary, FERC prior to implementation.

2.8 Fishway Inspections

For a FERC jurisdictional fishway, annual inspections by Engineering are recommended. While daily operation, inspection, and routine maintenance of a FERC project's fishway are the responsibility of the owner and licensee, annual inspections by Service staff allow for documentation of changing site conditions, updated assessment of component design life, and verification of operational settings. Fishway inspections are a critical element of long-term successful passage at any site. In the absence of pre-existing, site-specific, robust inspection protocols, Engineering recommends the implementation of procedures described in Appendix B, "Fishway Inspection Guidelines" by Towler et al. (2013).

2.9 Data Collection and Reporting

As a complement to the annual inspection, Engineering recommends collection of hydraulic conditions in the fishway (e.g., river flows, unit operations, head differential at the fishway entrance, velocities, water temperature, dissolved oxygen levels, tailwater (TW) and headwater (HW) elevations) during the migration season throughout the entirety of the project life. Data collection should be collected at short time intervals (e.g., hourly) via automated systems such as programmable logic controllers. Daily data should be collected manually at projects where automated data collection is not feasible. The hydraulic data collection can help to identify conditions that are: 1) not conducive to passage that may result from improper operations, changing site conditions, malfunctioning of a fishway component, and/or some other unforeseen circumstance; and 2) advantageous to passage that may be useful in updating fishway criteria and informing future designs.

3 Populations

By necessity, the flow through a fishway is only a fraction of the total river flow. Consequently, the design engineer of a fishway must estimate the maximum number of fish that can safely, timely, and effectively pass through the fishway (the biological capacity) versus the total passage goal (the design population) in a given time duration. Each component of the fishway should be designed such that the biological capacity is equal to or greater than the design population within a specified time interval. Typically, the design population is developed by the state, Service or other federal agency biologists, or other local experts.

3.1 Estimating Design Populations

The design population is often estimated as the product of the amount of estimated upstream habitat area (e.g., 10,000 acres) the regional carrying capacity of fish per unit habitat area (e.g., 100 American shad per acre). In other instances, the design population can be an estimate of the number of fish required to support a restoration target or a fisheries management goal. Four examples from the Northeast U.S.A. are provided below:

- *Connecticut Department of Energy & Environmental Protection (CT DEEP):* The CT DEEP uses the common species specific carrying capacity of the habitat to determine the design population for a fishway. The approach is based on the quantity of available upstream habitat and the amount of fish per acre which that habitat type can typically support to determine the design population for a fishway. For American shad, their estimates use a minimum of 50 fish per acre of riverine habitat and are based on the St. Pierre (1979) study. For Blueback Herring in large rivers, their estimate is 90 fish per acre and is based on data prior to 1986 at the Holyoke Dam in Massachusetts. For alewives in coastal streams, the estimate is 900 to 1,000 fish per acre of lake habitat, although data collected from 2012-2013 showed values as high as 5,036 and low as 324 alewives per acre. More recently, the Connecticut River Atlantic Salmon Commission (CRASC) has proposed adult target levels of 82 fish per acre in the main stem. This standard, developed by cooperating agencies, has been incorporated into an updated draft of the CRASC Shad Management Plan.

- *U.S. Fish and Wildlife Service, Maine Department of Inland Fisheries and Wildlife (ME IFW), Maine Atlantic Sea Run Salmon Commission, Maine Department of Marine Resources (ME DMR):* These agencies jointly authored a management plan for the Saco River in Maine (McLaughlin et al., 1987). The plan, which estimates production and escapement based on habitat and fishway efficiencies, assumes a shad production of 2.3 adults per 100 square yards of riverine habitat.
- *Maryland Department of Natural Resources (MDNR):* The MDNR also applied the work of St. Pierre (1979) in the development of a restoration target for the Susquehanna River. The target, or design population in this context, was determined using the area-density estimate of 48 American shad per acre in the free-flowing reaches of the river upstream of York Haven, Pennsylvania.
- *New Hampshire Fish and Game Department (NH Fish and Game):* The NH Fish and Game developed a sustainability plan in 2011 which established a restoration target of 350 river herring per acre of available spawning habitat in the state's smaller coastal river basins. This target was based on a percentage of the mean annual return of river herring in the prior 20 years.

4 Design Flows

Upstream fish passage design flows define the range of flow over which timely, safe, and effective passage can be achieved. As such, these design flows correlate to specific river flow conditions and do not generally represent the discharge through the fish passage devices themselves. Timely passage relates to seasonal hydrology; the spawning migrations of many East Coast diadromous fishes are typically linked to elevated flow events and water temperature (the latter, in turn, often being influenced by the former). Safe passage may become an issue under extreme flow conditions when low flows may strand migrants in disconnected pools or when high flows may force fish over emergency spillways under supercritical conditions impacting on chute blocks or natural ledge outcroppings. Effective passage can be compromised by high flows in numerous ways including the development of adverse hydraulic conditions in the fishway, the presence of competing flows over adjacent spillways, and generally impassible conditions which encourage fish to temporarily suspend their migration until river conditions improve. The relationship between hydrology, design flows, project discharge, and operating range is illustrated in Appendix A, Reference Plate 4-1 “Fishway Operating Range.”

4.1 Streamflow Data

Fish passage design flows for new or retrofitted projects are based on estimates of predicted (i.e., future) daily average streamflow conditions. Though influenced by upstream man-made barriers and driven by well-known seasonal trends, future daily streamflow cannot generally be predicted with certainty. Consequently, Engineering often applies the concept of stationarity by relying on trends demonstrated in historical hydrologic records to estimate future streamflow. In this context, a time series of historical streamflow data is assumed to have the same temporal distribution as future streamflow.

Contrary to the concept of stationarity, the frequency of storm events (i.e., high flow events) have been increasing within the Northeast (Collins, 2009). Engineering acknowledges that the use of calibrated hydrology and climate models may be the best approach to estimate future streamflow. However, these models are often nonexistent at a site, require extensive effort to create, and may still possess a high degree of uncertainty. Thus, in most cases site stationarity remains the basis for the development of design flows and flood flows as described in the following subsections.

4.1.1 Period of Record

The period of record (POR) is defined as the continuous record of historical streamflow data that is of sufficient length to adequately characterize daily and seasonal variations in flow.

- Where possible, the POR should include 30 years of data to demonstrate hydrologic stationarity for all flood flow events up to and including the 100-year flood. The U.S. Water Resources Council (1981) recommends the use of the log-Pearson Type III method for a flood flow frequency analysis.
- Based on climatic trends in the Northeast established by Collins (2009), Engineering recommends using post-1970 data only. Where older data is needed to establish design flows, watershed specific pre- and post-1970 data trends should be investigated before proceeding.
- Under certain circumstances, it is advisable to use a shorter POR (of no less than 10 years) even when 30 years of data are available. For example, a truncated POR should be used when recent construction or changes in operations upstream have significantly altered the temporal distributions of streamflow.

Calculation of the design flows requires a refinement to the POR based on the migration season of one or more target species, referred to as the migratory POR (MPOR). The MPOR is the truncated streamflow data set comprised of only the dates within the migration season of one or more target species. Although the spawning migrations of East Coast anadromous species typically correlate to elevated flow events and water temperature, the migration season tends to vary regionally throughout each species' geographical range, between adjacent watersheds, and even across years. This variation is locally influenced by environmental factors such as (Turek et al., 2016):

- Precipitation and other weather events and patterns;
- Freshwater, estuarine or oceanic conditions;
- River flows including the effects of storage impoundment releases or water withdrawals;

- In-stream turbidity, dissolved oxygen levels and water temperatures, and in particular short-term fluctuations in air and water temperatures;
- Time of day and in particular, ambient light conditions;
- The specific passage site location within a watershed.

In consideration, Engineering employs conservative estimates for a target species migration season. Typically, the migration season for a particular species in a particular location is provided to Engineering by Service or state biologists or other local experts. Generally, the fishway should be operational during the defined migration period.

4.1.2 Streamflow Data Sources

Historical streamflow data are used to establish fish passage design flows. As such, the data influence many of the design parameters (e.g., pool depth and length) that are linked to hydraulic conditions (e.g., water depth and velocity) fish will encounter within the ZOP. This hydrologic information can come from a variety of sources; however, any streamflow data used in the design of a FERC jurisdictional fishway should be reviewed and approved by Engineering.

In general, Engineering recommends the use of U.S. Geological Survey (USGS) streamflow gage data where possible. The USGS National Streamflow Information Program maintains the largest network of stream gages in the U.S. and provides access to a comprehensive online database of historical streamflow (http://water.usgs.gov/nsip/). While many USGS stream gages are located at existing dams (and fishway sites), most are not. Therefore a method of estimating flow at ungaged sites is required. The most common method to estimate streamflow at an ungaged site is linear proration by drainage area of a nearby gaged site in the watershed. The ungaged target site streamflow, Q_u, is calculated by:

$$Q_u = Q_g \left(\frac{A_u}{A_g}\right) \qquad \text{Eq. (1)}$$

where Q_g is the streamflow at the gaged reference site, A_g is the watershed area at the gaged site, and A_u is the watershed area at the ungaged target site. The reference gage should be of similar watershed size, land use, geology, and exposed to the same precipitation events as the target site.

If no adequate reference gages exist, other methods of estimating streamflow at an ungaged site may be available. These include, but are not limited to, regional regression equations and rainfall-runoff modeling (e.g., HEC-HMS), and more complex stochastic methods of generating synthetic hydrology. Engineering strongly recommends any method for developing streamflows at ungaged sites be both locally calibrated and of sufficient accuracy to capture the daily variation in flow.

4.2 Flow Duration Analysis

A flow duration analysis is a method commonly used by both states and federal agencies to estimate hydrologic extremes and fish passage design flows. A flow-duration curve (FDC) is a cumulative frequency curve that shows the percent of time a specified variable (e.g., daily average streamflow, 7-day average flow) was equaled or exceeded during a given period.

To develop a FDC, the independent variables (or observations) are arranged in descending order. The largest observation is ranked m = 1 and the smallest observation is ranked m = N, where N is the number of observations. These ranked observations are plotted on the y-axis against the plotting position, P_m, on the x-axis. P_m is considered an estimate of the exceedance probability of the associated ordered observation and is calculated by the Weibull plotting position formula:

$$P_m = \frac{m}{N+1} \qquad \text{Eq. (2)}$$

4.3 Operating Range

The operating range over which safe, timely and effective passage can be achieved is bounded by the low and high design flows. In establishing these two design flows for specific fishways, site hydrologic data and the timing of local migrations are paramount. Engineering presumes that for flow rates outside of the operating range (e.g., during storm events), fish may either: 1) pass the barrier without the use of the fishway; or 2) not be actively migrating.

4.3.1 Low Design Flow

The low design flow (Q_L) defines the nominal lower limit of river flow that can achieve safe, timely, and effective fish passage. Engineering defines the design low flow as the mean daily average river flow that is equaled or exceeded 95% of the time during the MPOR for target species normally present in the river basin and at the fish passage site. The low design flow is interpolated from a FDC (defined in Section 4.2) where P_m equals 0.95. In other terms, the low design flow, Q_L can be defined as:

$$Q_L = Q_{95} \qquad \text{Eq. (3)}$$

Competing demands for water under low design flows are particularly important. River flows should be apportioned to the fishway before generation, process water, irrigation or other consumptive use. On sites where the minimum environmental bypass flows are required, this requirement should be met, where possible, by the fishway discharge (i.e., attraction flow).

4.3.2 High Design Flow

The high design flow (Q_H) defines the nominal upper limit of river flow that can achieve safe, timely, and effective fish passage. Engineering defines the design high flow as the mean daily average river flow that is equaled or exceeded 5% of the time during the MPOR for target species normally present in the river basin and at the fish passage site. The high design flow is interpolated from a FDC where P_m equals 0.05. In other terms, the high design flow, Q_H can be defined as:

$$Q_H = Q_5 \qquad \text{Eq. (4)}$$

4.3.3 Constraints on Design Flows

Design flows (i.e., operating ranges) are based upon myriad site conditions and hydrologic analyses. Post-construction operating ranges are sometimes modified (through effectiveness studies and adaptive management) to ensure compliance with performance standards or fishery management goals. However, once prescriptions for specific projects are made and incorporated into license articles, they may not be changed without adequate justification and a written waiver from the Service. If a fishway operator perceives a need to revise the operational period and design flow range, documentation should be provided for Engineering and Service biologists to review.

4.3.4 Alternate Methods

Alternate methods, some of which are listed below, may be used to determine fishway design flows but should be reviewed by Engineering.

4.3.4.1 Three Day Delay Discharge Frequency Analysis

An alternate method to compute a fishway high design flow is through a three day delay flow duration analysis, proposed by Katopodis (1992). In this method, a flow duration analysis is performed using Q_{3d} (the largest daily average streamflow value that is equaled or exceeded three times in three consecutive days over the fish migration period during a particular year) as the independent variable. The high design flow is set equal to the Q_{3d} value which corresponds to an exceedance probability of 0.1 (or a 10-year return period). This return period is chosen assuming that a delay period of greater than three days is acceptable if occurring at a frequency of once every ten years (or more).

4.3.4.2 USGS Regression Analysis

The USGS has developed regional regression equations to estimate flow duration events based on watershed area, annual precipitation, and regional variables (Natural Resource Conservation Service (NRCS), 2007). The USGS StreamStats tool (http://water.usgs.gov/osw/streamstats/) offers a simple way to access some of these regression equations.

4.3.4.3 Mean Flow Indices

The mean flow indices method computes the high design flow based on a multiple (e.g., three to four) of annual or monthly average streamflow. In the case of using monthly average streamflow, the month in which the peak of the migration season occurs is normally selected. In most situations, the Service recommends against using this technique because it provides no estimate of frequency or duration of passable conditions.

4.3.4.4 Regional flow-duration curves for ungaged sites

Methods to create regional flow-duration curves for ungaged sites have been developed in New Hampshire (Dingman, 1978) and Massachusetts (Fennessey and Vogel, 1990).

4.4 Flood Flow Considerations

The following list describes how flood flow events should be considered within the design of a fishway:

- Overtopping of the fishway should not occur for flood flow events with a recurrence interval of 50 years or less.
- Flood flow events with a recurrence interval greater than 50 years may require a shutdown of the fishway. Following such flood events, the fishway should be inoperable

- or operating outside of the design criteria for a maximum of one week during the migration season.
- The fishway must be designed with enough structural integrity to withstand an appropriately infrequent hydrologic loading or design storm.

The U.S. Water Resources Council (1981) recommended that the log-Pearson Type III be used as the standard method for flood flow frequency analysis.

5 Hydraulic Design Considerations

Many anadromous species make tremendous journeys over the course of their lives. The freshwater portion of the "sea to source" path is an arduous one characterized by an energetically demanding migration upstream to reach spawning habitat, relying on stored energy reserves (Glebe and Leggett, 1981; Leonard and McCormick, 1999). . For iteroparous fishes, their post-spawning return journey to the ocean is equally challenging and often initiated under the stress of greatly reduced energy reserves in less favorable environmental conditions (e.g., elevated water temperatures). These challenges are compounded by the presence of hydropower projects which create impoundments, bypass natural river reaches via canals, and channel significant portions of the river flow through hydroelectric turbines including into pumped storage reservoirs. Technical fishways provide a corridor for migrants to pass stream barriers, but in doing so can create complex hydraulic conditions such as turbulence and plunging flow. The following subsections provide an overview of the key hydraulic concepts associated with a fishway and how fish biology informs hydraulic design. Each of these concepts must be evaluated over the full operating range of the fishway.

5.1 Depth

Providing sufficient depth allows fish to swim normally (i.e., fully submerged, including dorsal fin) and may alleviate any adverse behavioral reaction to shallow water. In general, Engineering recommends that the depth of flow be greater than or equal to two times the largest fish's body depth. Greater depth criteria may apply to various fishway components to meet the needs of certain species or to address site-specific concerns.

5.2 Width

In a natural environment, fish are accustomed to moving in an open river. Fishways, by necessity, concentrate flow and narrow openings accelerate velocity. These conditions may inhibit swimming ability, injure fish or elicit an avoidance response. These factors must be taken into consideration within the fishway design process. Table 2 below displays typical ranges of fishway entrance widths and minimum entrance depths for several technical fishway types. Note that specific site conditions may warrant values outside of these ranges.

Table 2: Typical fishway entrance widths and minimum depths.

Fishway Type	Entrance Widths (ft)	Minimum Entrance Depth (ft)
Standard Denil	2 - 4	2
Model A/A40 Steeppass	1.17	1.08
Ice Harbor	4 - 10	4
Vertical Slot	4 - 10	4
Fish Lift	4 - 10	4

5.3 Velocity

By design, fishways create spatially and temporally variable water velocities (e.g., low speed in a quiescent pool and high speed over a weir crest). The desired range is dependent upon: 1) the swim speed abilities; and 2) the endurance of the target fish species (the duration in which the swim speed can be sustained), Δt (Larinier et al., 2002).

5.3.1 Swimming Performance Model

Species and site specific data and models are preferred in estimating the swimming abilities of fish. In the absence of such information, a three-tiered model, described below, is a suitable method for describing the swimming abilities (swim speed and endurance) of fish. However, the existing literature contains inconsistent usage of terms to describe each of the three swimming modes (Beamish, 1978; Bell, 1991; Katopodis, 1992). For the purposes of this manual, the swimming modes will be referred to as cruising, prolonged, and burst (Bell, 1991). Further details are below and can also be found on Appendix A, Reference Plate 5-1 “Swim Speed Categories.”

- *Cruising speed, V_c*
    - The swim speed a fish can maintain for hours without causing any major physiological changes.
    - An aerobic muscle activity (“red” muscle tissue).
    - Influenced by temperature and oxygen; Bell (1991) suggests swim speeds reduced by 50% at extreme temperatures.

  - For fishway design, V_C should be used for transport flumes, holding pools, etc.
- *Prolonged speed, V_P*
  - The swim speed a fish can maintain for minutes; tires the fish.
  - An aerobic and anaerobic ("white" muscle tissue) muscle activity, in variable proportions.
  - Bain and Stevenson (1999) suggests speed can be maintained for 5-8 minutes; Beamish (1978) suggests 20 seconds to 200 minutes.
  - $4 \text{ BL/s} \leq V_P \leq 7 \text{ BL/s}$ (BL/s → body lengths per second).
  - For fishway design, V_P can be used in conjunction with the duration of the swim speed, Δt, to estimate travel distance, D, before fatigue.
- *Burst speed, V_B*
  - The swim speed a fish can maintain for seconds.
  - Species specific, with correlation among similar species (e.g., salmonids)
  - Primarily an anaerobic muscle activity.
  - Bell (1991) suggests speed can be maintained for 5-10 seconds; Bain and Stevenson (1999) 2-3 seconds; Beamish (1978) < 20 seconds.
  - Decreases at extreme water temperature (high or low)
  - Increases with length of fish; Speed used for predator avoidance or feeding; in fishways, use to ascend weir crests.
  - For fishway design, velocities should be kept below V_B for the weakest target species at all times.

Eq. (5) below relates each of the swim speeds:

$$V_C \approx \frac{1}{3}V_P \approx \frac{1}{6}V_B \qquad \text{Eq. (5)}$$

The following are examples of how the swimming performance is considered in the design of a fishway:

- 200 foot (ft) long roughened rock ramp nature like fishway might be designed to allow prolonged speed for an alewife, 3 feet per second (fps);
- A pool-and-weir ladder for alewife might be designed for the combination of burst speed (over weirs) followed by prolonged speed (in pools), 6 fps vs 1 fps.

5.3.2 Fatigue

A fishway must be designed such that no velocity barriers impede safe, timely, and effective passage. Water velocity becomes a barrier when: 1) the water velocity is greater than the burst speed of the fish; or 2) the fish fatigues prior to passing an area of high velocity. Engineering recommends the use of one or more of the following methods to estimate the level of fatigue a fish will incur during an attempt to pass the barrier:

- *Fatigue – Distance Model;* A concept based in the knowledge of the swimming performance model. For an example in its simplest form, the distance a fish can swim at a prolonged speed prior to fatigue, D, can be calculated by the following set of equations:
    - $V_g = V_w - V_P$, where V_g is the speed of the fish relative to the ground and V_w is the water velocity;
    - $D = V_g \Delta t$, given Δt for V_P is 5 minutes $\leq \Delta t \leq$ 8 minutes.

  A more sophisticated Fatigue – Distance approach was proposed by Castro-Santos (2004).
- *Work – Energy Model;* Utilizes fluid mechanics to estimate the virtual mass force, non-Archimedean buoyant force, and profile drag on fish in order to estimate the net propulsive power and net energy required by a fish to pass a fishway (Behlke, 1991).
- *Survival Analysis Model;* The survivorship function describes the proportion of fish successfully passing a velocity barrier of distance, D. The equation is a function of six species-specific variables including: shape and scale parameters, temperature, fork length, velocity coefficients, and a regression intercept (Haro et al., 2004).

5.4 Turbulence, Air Entrainment, and the Energy Dissipation Factor

Turbulence has been shown to influence both swimming behavior and performance of fish (Lupandin, 2005; Enders et al., 2003; Pavlov et al., 2000). A phenomenon common to the natural river environment, turbulence is often exacerbated by the dissipation of energy that is characteristic of dams and other anthropogenic in-stream structures. In many cases, the dissipation is the result of a rapid conversion of potential energy to kinetic energy (e.g., high velocity flow over a spillway impounding a quiescent reservoir). Fishways overcome these barriers by providing continuous hydraulic pathways over or around dams. Kinetic energy in these pathways must be dissipated to ensure flow velocities do not exceed the swimming ability of fish. Dissipation can be effected through increased roughness (form or surface) or through the momentum exchange that occurs when high speed jets discharge into larger quiescent pools. However, excessive power dissipation or energy dissipation rates can also lead to unwanted turbulence and air entrainment. Thus, the challenge is to design a fishway that simultaneously reduces flow velocities to speeds below maximum fish swimming speeds while maintaining acceptably low levels of turbulence (Towler et al., 2015). Engineering's preferred metric of turbulence in the design of fishways is the energy dissipation factor (EDF).

- The EDF is a measure of the volumetric power (or rate of energy) dissipation in a pool, chute or stream reach.
- The EDF is particularly useful because it correlates well to meso-scale turbulence (e.g., eddies the size of fish) and aeration.
- Eq. (6) expresses the potential energy loss (or dissipation) rate per unit length of fishway (Towler et al., 2015) and is the basis for the EDF:

$$loss_{1-2} = \gamma_w Q \frac{dh}{d\ell} \qquad \text{Eq. (6)}$$

where dh/dℓ is the effective hydraulic gradient, γ_w is the unit weight of water in pound per cubic feet (lbf/ft^3), Q is the flow rate in cubic feet per second (cfs), and loss$_{1\text{-}2}$ is the energy loss rate per unit length of fishway from cross section 1 (upstream) to cross section 2 (downstream).

Specific forms of the EDF equation and criteria values are discussed in Section 6.7. Criteria and threshold EDF values are presented on Appendix A, Reference Plate 5-2 "Power Dissipation Rates."

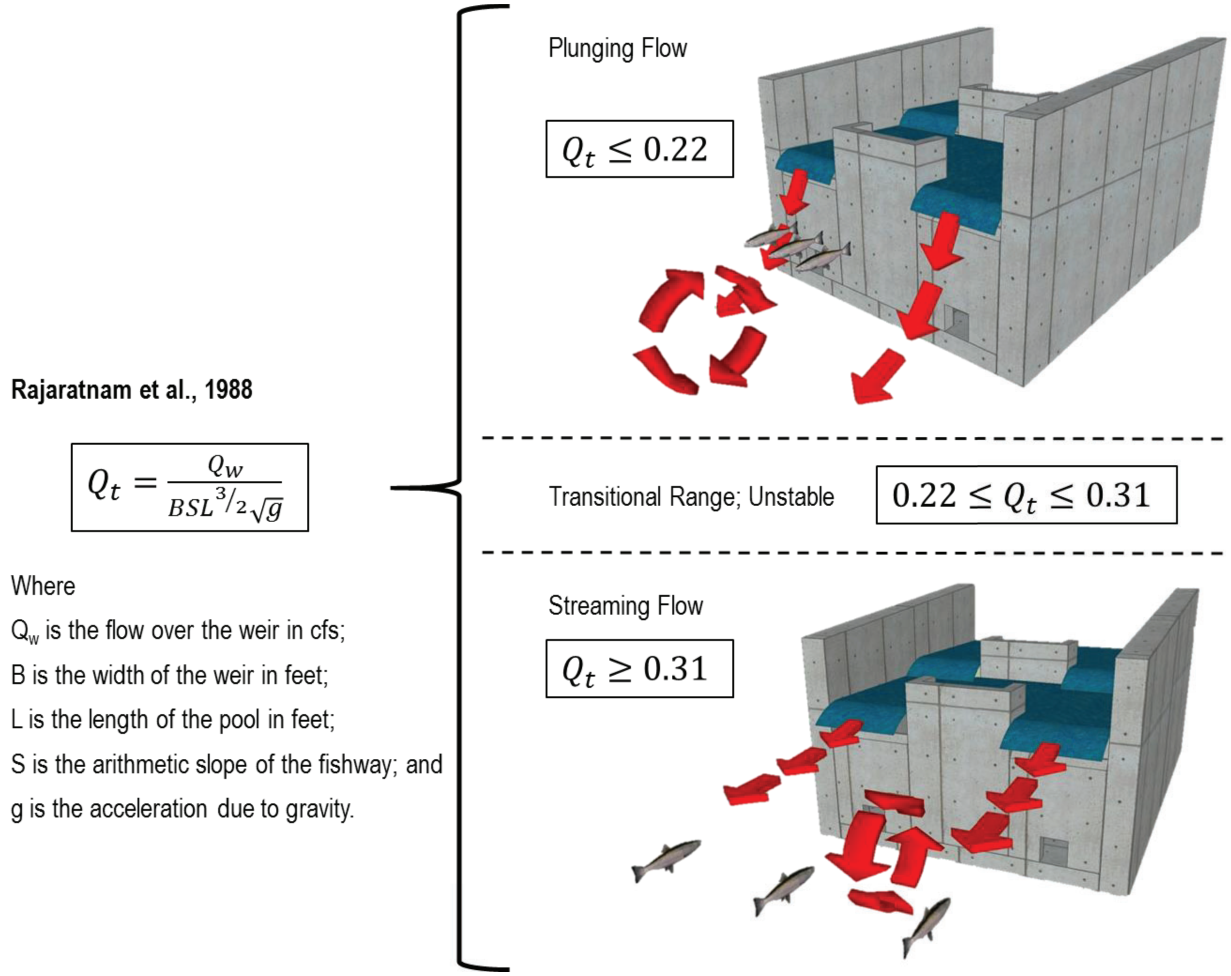
5.5 Streaming and Plunging Flow

In pool-type fish ladders, the hydraulic jet formed over the upstream control (e.g., weir, low flow notch) typically either plunges downwards into the pool (referred to as "plunging flow") or skims across the pool surface toward the downstream control (referred to as "streaming flow"). At lower flow rates, plunging flow conditions develop producing two counter-rotating hydraulics or rollers. These rollers are efficient at dissipating energy due to the rapid momentum transfer between the submerged jet and the surrounding water. At higher flow rates, streaming flow conditions develop creating a lesser forward hydraulic and a pronounced jet which skims across the pool surfaces and weir crests. These regimes have been shown to correlate with a dimensionless transitional flow term, Q_t:

$$Q_t = \frac{Q_w}{BSL^{3/2}\sqrt{g}} \qquad \text{Eq. (7)}$$

where Q_w is the flow over the weir in cfs, B is the width of the weir in ft, L is the length of the pool in ft, S is the arithmetic slope of the fishway, and g is the acceleration due to gravity.

The transition from plunging flow to streaming flow has been shown to occur in the range of $0.22 \leq Q_t \leq 0.31$ (Rajaratnam et al., 1988). As implied by the range, the transition from plunging to streaming flow is difficult to predict precisely. From a design standpoint, this transitional regime should be avoided because of its inherent instability (i.e., the flow regime may change between streaming and plunging when within this range). Furthermore, significant anadromous target species for the East Coast (e.g., American shad and alewife) have difficulty leaping over or ascending plunging flow nappes. For these reasons, Engineering recommends that pool-type fish ladders meet or exceed a transition discharge parameter of $Q_t = 0.31$ to ensure operation in the streaming flow regime. Figure 1 further illustrates plunging and streaming flow conditions in a pool-type fish ladder.



Rajaratnam et al., 1988

$$\boxed{Q_t = \frac{Q_w}{BSL^{3/2}\sqrt{g}}}$$

Where

Q_w is the flow over the weir in cfs;

B is the width of the weir in feet;

L is the length of the pool in feet;

S is the arithmetic slope of the fishway; and

g is the acceleration due to gravity.

Figure 1: Plunging versus streaming flow conditions.

Plunging versus streaming flow conditions illustrated within an Ice Harbor fishway.

5.6 Other Considerations

Fish size, physiological/spawning state, and environmental conditions (particularly water temperature) are additional factors influencing fish movement, behavior (e.g., propensity to pass in schools or groups), passage efficiency, and ultimately passage restoration effectiveness described in Appendix C, "Federal Interagency Nature-like Fishway Passage Design Guidelines for Atlantic Coast Diadromous Fishes" (Turek et al., 2016).

6 General Upstream Fish Passage

As described in Section 2.1, the term “fishway” has a comprehensive definition that encompasses many different technologies. Appendix A, Reference Plate 6-1 “Fishway Types,” relates common fishway types and their broader categories. This section provides information related to many different upstream fishways.

6.1 Site Considerations

A myriad of site-specific factors must be considered prior to the design of a fishway. These include, but are not limited to, the following:

- Topography and bathymetry data;
- Details of existing barrier (plan view map, elevations, etc.);
- Project operational information (powerhouse capacity, period of operation, etc.);
- Project forebay and tailwater rating curves;
- River morphology trends;
- Soil conditions;
- Accessibility;
- Target and non-target species at the site that require passage;
- Predatory species at the site.

6.2 Zone of Passage for Upstream Migration

The ZOP (defined in Section 2.2), as it pertains to upstream migration, encompasses a far-field attraction zone, a near-field attraction zone, the fish passage facility, and the impoundment upstream of the barrier.

Numerous other conceptual models have been developed to describe the regions influenced by a hydroelectric project beyond the fishway entrance and exit. For example, Castro-Santos and Perry (2012) and Castro-Santos (2012) partition this area into three regions: an approach zone, an entry zone, and a passage zone; the former two regions describing areas downstream of the fish passage facility entrance, the latter zone referring to movement within the fish pass (e.g., ladder, lift).

6.3 Fishway Attraction

6.3.1 Competing Flows

At typical hydroelectric facilities, river flows are passed over, through, and around various machines and water-control structures. The resulting flows are often complex and spatially separated. The flow fields created by these project elements (i.e., turbines, spillways, flood gates, and trash/log sluices), may attract (or dissuade) fish and thus, compete with the directional cues created by fishways. Figure 2 displays an example of the competing flows created by various project elements at a hydroelectric facility.

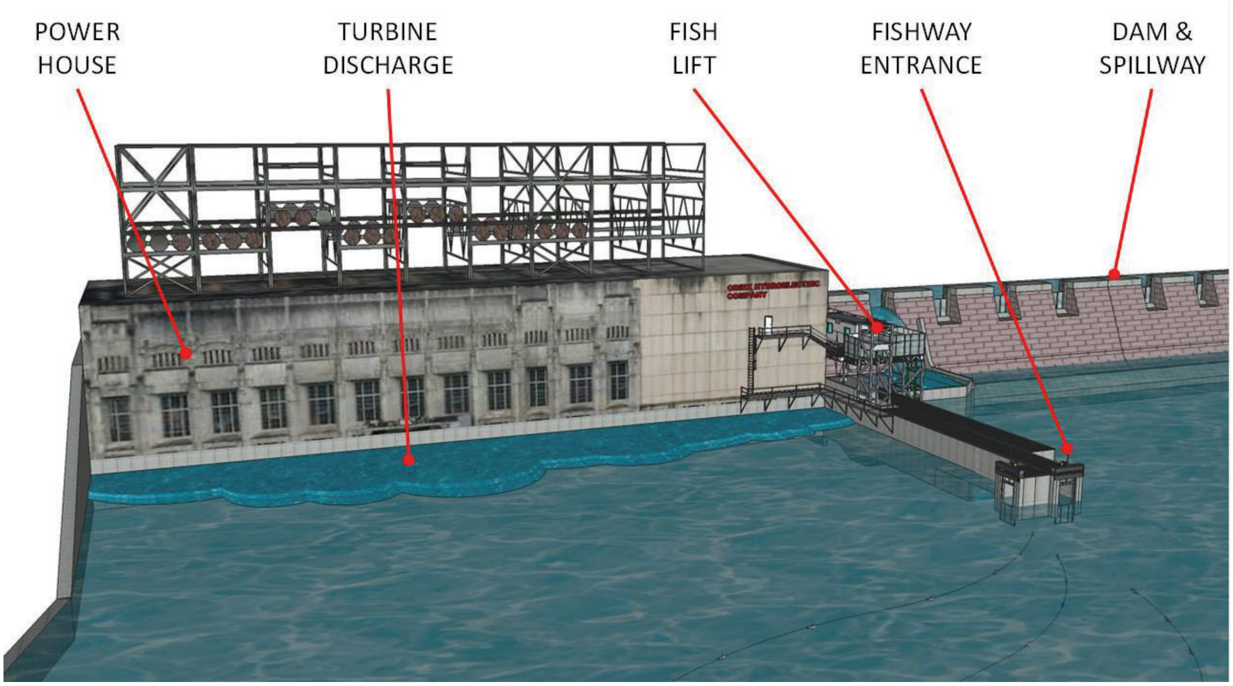


Figure 2: An example of competing flow fields at a hydroelectric facility.

In this illustration, the turbine discharge acts as the primary competing flow field to the attraction flow from the fishway entrances. The flood gates, when opened, act as another competing flow field.

6.3.2 Attraction Flow

Successful fishways must create hydraulic signals strong enough to attract fish to one or multiple entrances in the presence of competing flows (i.e., false attraction). Under most operating conditions, fishways do not directly discharge sufficient attraction flow. Therefore, to create adequate attraction flow, fishways must be supplemented by auxiliary water. The terms fishway "attraction water" or "attraction flow" refer to the combination of discharges from an operating fishway and associated auxiliary water systems (AWS).

In a survey of the literature, the following two approaches for determining adequate attraction flow were identified:

- *Statistical Hydrology:* This approach sets the attraction flow equal to a percentage of a hydrologic statistical measure (e.g., 5% of the mean annual river flow).
- *Percentage of Competing Flows:* This approach expresses attraction flow as a percentage of the sum of other competing flows. Recognizing that powerhouse discharge is typically the most dominant and predictable competing flow (especially at run-of-river projects), this method is often simplified to express attraction flow as a percentage of powerhouse hydraulic capacity.

In general, the higher the percentage of total river flow used for attraction into the fishway, the more effective the facilities will be in providing upstream passage (National Marine Fisheries Service (NMFS), 2011). For non-hydropower sites, NMFS' Northwest Region recommends an attraction flow between 5% and 10% of the high design flow (see Section 4.3.2) for streams with mean annual flows greater than 1,000 cfs; for smaller streams, a larger percentage is recommended. For hydropower sites, Engineering expresses the attraction flow requirement as a fraction of the competing flows (e.g., turbine discharge). Specifically, Engineering recommends that fishways be designed for a minimum attraction flow per fishway equal to 5% of the total station hydraulic capacity or a flow rate of 50 cfs, whichever is greater. In addition, Engineering's preference is that the entirety of the attraction flow be discharged through, or at, the fishway entrance(s). While adjacent turbine units can often be sequenced to attract fish to the fishway entrance, the discharge from the turbine is not generally used to meet, in whole or in part, the Service's attraction flow requirement.

6.4 Entrance

The fishway entrance for upstream passage is the structure through which: 1) fish access the facility; and 2) attraction flow is discharged into the tailrace and/or surrounding river channel. A properly designed and operated entrance is critical to passage success. The entrance is typically constructed as a flap gate or slot with fully submerged weir boards and may also be comprised of an entrance channel and a collection gallery. Figure 3 illustrates an example of an entrance gate and channel in the lower section of a fish lift.

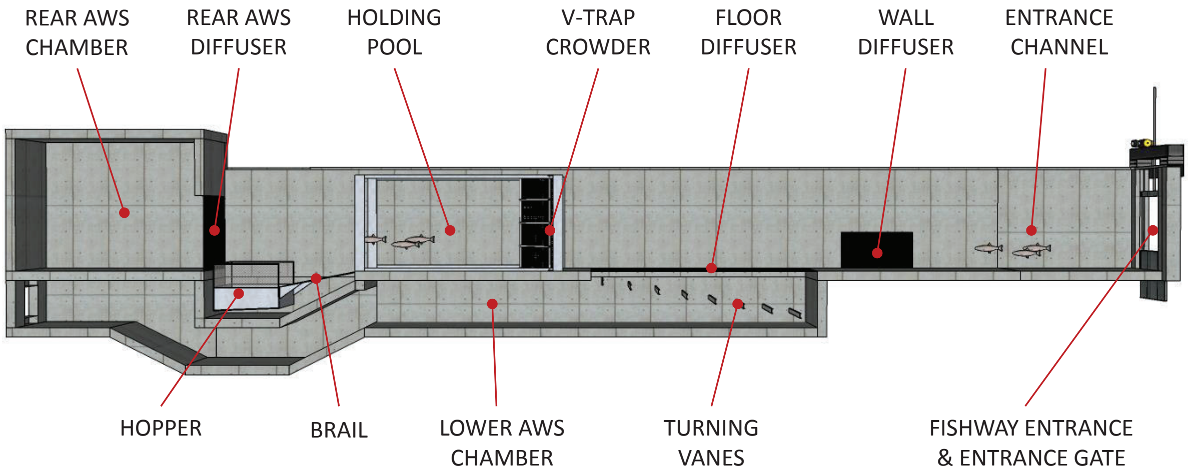


Figure 3: Cross-sectional view of the lower section of a fish lift.

A cross-sectional view of the lower section of a fish lift, including the entrance gate, entrance channel, AWS chamber, and hopper

6.4.1 <u>Location</u>

Fishway entrances must be located where upstream migrating fish will be lured in a timely manner to the entrance through the discharge of attraction flow. Target species migration patterns downstream of the barrier can help to inform the ideal entrance location. Generally, the entrance should be located near either the most upstream point immediately downstream of the barrier or the dominant attraction flow (e.g., powerhouse discharge). The comparatively slow velocity and low turbulence zones found adjacent to the powerhouse and spillway can create favorable entranceway conditions. In some cases, excavation to create a deeper, slower, and less turbulent region at the fishway entrance and/or additional entrances is required. In other cases, locating the fishway entrance (or one of multiple entrances) downstream of, or laterally separated from, a highly turbulent area or other source of false attraction may be necessary. The combined discharge of the fishway and AWS should create an attraction jet that migrating fish will sense as they approach the fishway entrance. In general, the design should minimize the impacts on the direction, magnitude, and character of the attraction jet to ensure the resulting hydraulic signal reaches as far downstream (from the entrance) as possible.

6.4.2 Orientation

The attraction jet discharged from the fishway entrance is directly influenced by both the orientation of the entrance structure and the competing flow fields (e.g., turbine discharge). Generally, Engineering recommends that fishway entrances adjacent to appreciable competing flows be oriented parallel to the direction of the surrounding flow field to project the jet longitudinally and maximize the influence of the jet's hydraulic cue downstream; entrances without competing flows should be oriented perpendicular to the dam to project the jet laterally in front of the barrier. However, fishway entrance orientation should be selected in consultation with Engineering and after careful consideration. Hydraulic modeling may be required due to complex site-specific factors.

6.4.3 Entrance Width

Fishway entrance width is influenced largely by: 1) the attraction discharge flow rate; and 2) the behavioral tendencies (e.g., schooling or shoaling) of target species.

- At hydroelectric projects, fishway entrances should be 4.0 feet wide or greater; exceptions may include minor projects with small baffled chute fishways (i.e., 3-foot-wide Denil ladders, or steeppasses).
- Additional width (greater than 4 feet), may be required to ensure entrance jet velocity criteria are maintained (see Section 6.4.5).
- Where adjustable contractions at the entrance are necessary to accelerate flow, an automated gate is preferred or a manual gate or stop logs.
- Where permanent contractions at the entrance to accelerate flow are appropriate, the contraction should be lateral not horizontal. To avoid adverse hydraulics, the entrance width should be greater than or equal to 62.5% (5/8) of the entrance channel width. Additionally, the lateral contraction should be beveled or rounded to promote favorable hydraulics.

6.4.4 Entrance Depth

Operationally, the entrance should always maintain a minimum of 2 feet of depth above the vertical constriction (does not apply to Steeppass Model A or A40); adjustable entrance gates and weir boards should never constrict flow depth to less than 2 feet even under the low design flow conditions. The entrance gates and weir boards should be fully submerged when the fishway is operating.

6.4.5 Entrance Jet Velocity

The entrance jet refers to the influence of the velocity field created by the attraction flow immediately downstream of the (upstream) fishway entrance. The influence of the jet persists until the attraction flow becomes fully mixed with the tailwater and the jet velocity is indistinguishable from the surrounding flow field. For a fishway to be effective, the velocity of the jet and quantity of attraction flow must produce enough momentum to penetrate the receiving waters to a point where fish are commonly present; this will create the opportunity for fish to detect the hydraulic cue created by the jet. Concurrently, the jet velocity must not be so high that it creates a velocity barrier to migrating fish.

The relationship between entrance gate settings and entrance velocity are based on specified channel geometry, width of the entrance gate, inclined angle of the gate measured from the horizontal axis (e.g., 90 degrees is a vertical lift gate), tailwater elevations, level of gate submergence, and attraction flow. Gate positions must be adjusted in response to varying tailwater elevations in order to maintain favorable fish passage conditions.

For East Coast projects, Engineering recommends that the entrance jet velocity (measured at the entrance) be within a range of 4 to 6 fps at any site where American shad and/or river herring are present. If only the stronger swimming Atlantic salmon is present, then an entrance jet velocity of 4 to 8 fps is permissible. General recommendations from other sources are below:

- Larinier et al. (2002) states that "for most species, a speed of the order of 1 m/s (3.28 fps) would normally be the minimum…The optimal speed for salmonids and large migrants is of the order of 2 m/s to 2.4 m/s (6.56 fps to 7.87 fps)."
- Clay (1995) states that the entrance jet velocity for salmon should be a minimum of 4 fps. The author also states that it "is doubtful if 8 fps may be safely exceeded even for the strongest fish, and velocities approaching this value should be maintained for only a short distance at the entrance of the fishway."

6.4.6 Entrance Channels

The entrance channel is the section of the fishway that hydraulically connects the most downstream baffle/weir of a ladder or the crowder of a fish lift to the entrance gate/weir boards. Water enters the entrance channel through either the upstream ladder or the AWS diffusers and discharges into the tailrace or surrounding flow field through the fishway entrance. The location and size of AWS horizontal and vertical attraction flow diffusers will influence the entrance channel geometry. In ladders, vertical (wall) diffusers and horizontal (floor) diffusers are incorporated downstream of the last baffle or weir. In lifts, a portion of the AWS diffusers are incorporated upstream of the hopper; the remaining portion are built into the entrance channel downstream of the crowder.

- Velocities within the entrance channel should be within the range of 1.5 to 4 fps and be as close to a uniform velocity distribution as possible; however, the upper end of this range (i.e., 4 fps) is intended to accommodate the accumulation of flow discharged by internal wall and floor diffusers and should never occur within the holding pool.
- The entrance channel should be void of high turbulent and aeration zones.
- Generally, the entrance channel in large technical fishways should be designed for a depth of 6 feet below normal tailwater; though in operation, actual depth may be adjusted (via gate or weir boards) to meet the attraction flow and entrance velocity jet requirements.

6.4.7 Collection Galleries

A collection gallery is a type of manifold fishway entrance constructed on the downstream face of the powerhouse above the turbine outlets (i.e., draft tubes). The gallery provides multiple entrances to a common conveyance channel connected to the fishway (Clay, 1995; FAO/DVWK, 2002). Velocity within the collection gallery should be maintained between 1.5 fps to 4.0 fps.

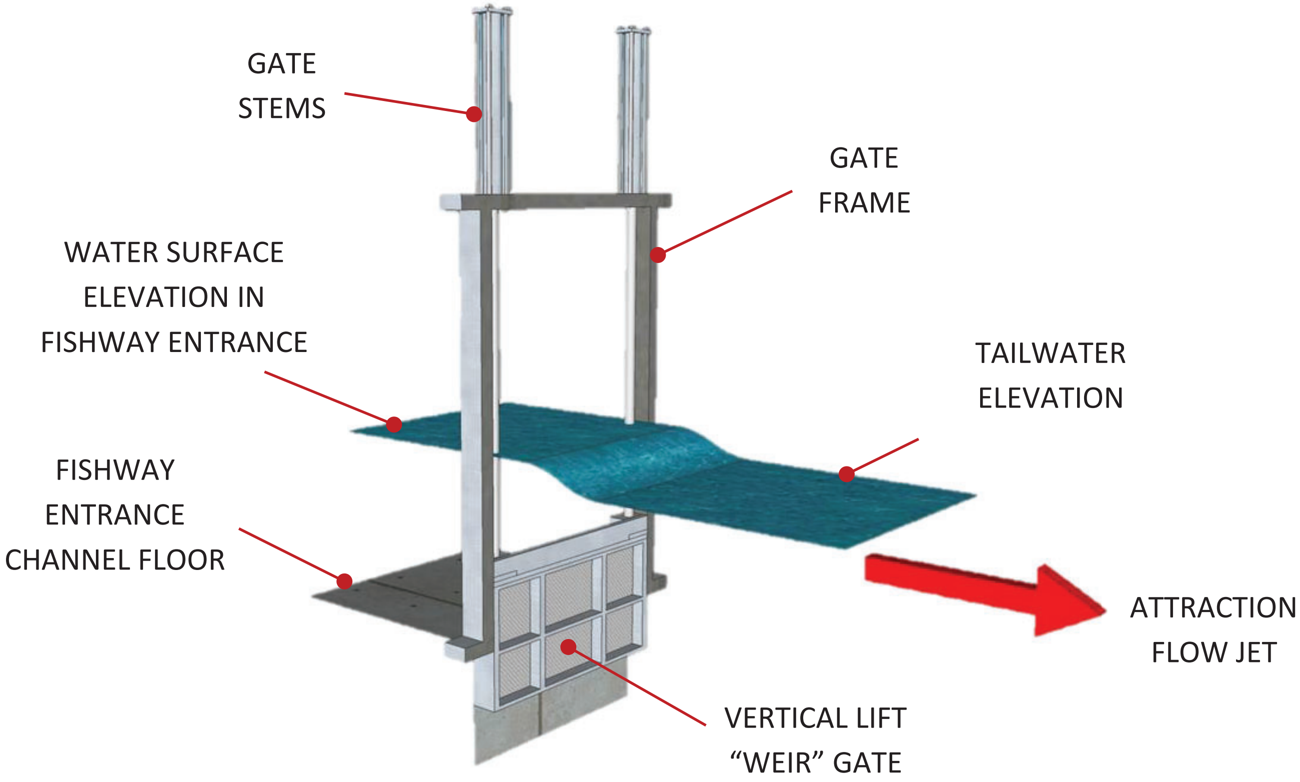


Figure 4: A typical entrance gate at a large technical fishway.

The hydraulic drop across the gate is a function of the inclined gate angle (here shown as vertical, e.g., 90 degrees), attraction flow rate, entrance channel geometry, gate width, and tailwater elevations.

6.4.8 General Considerations

- The hydraulic drop across the entrance (Figure 4) should not produce plunging flow.
- A fishway entrance located on or adjacent to a spillway should be protected by a non-overflow section; non-overflow sections can be created using flashboards.
- The non-overflow structure will reduce spill into the fishway and hydraulically separate the entrance jet from spill.

6.5 Exit

The fishway exit for upstream passage is the structure through which: 1) fish exit the facility; 2) water enters the fishway; and in some cases, 3) water enters the AWS. The exit refers to both the actual exit immediately downstream of the exit trash rack and the exit channel immediately downstream of the actual exit and upstream of the ladder or lift. The fishway exit diminishes the effect of headwater fluctuations and creates adequate hydraulic conditions as the flow enters the downstream sections of the fishway (e.g., pool-and-weirs). Figure 5 displays an example of a fishway exit at a lift, including the exit flume, crowder for a counting facility, and exit trash rack.

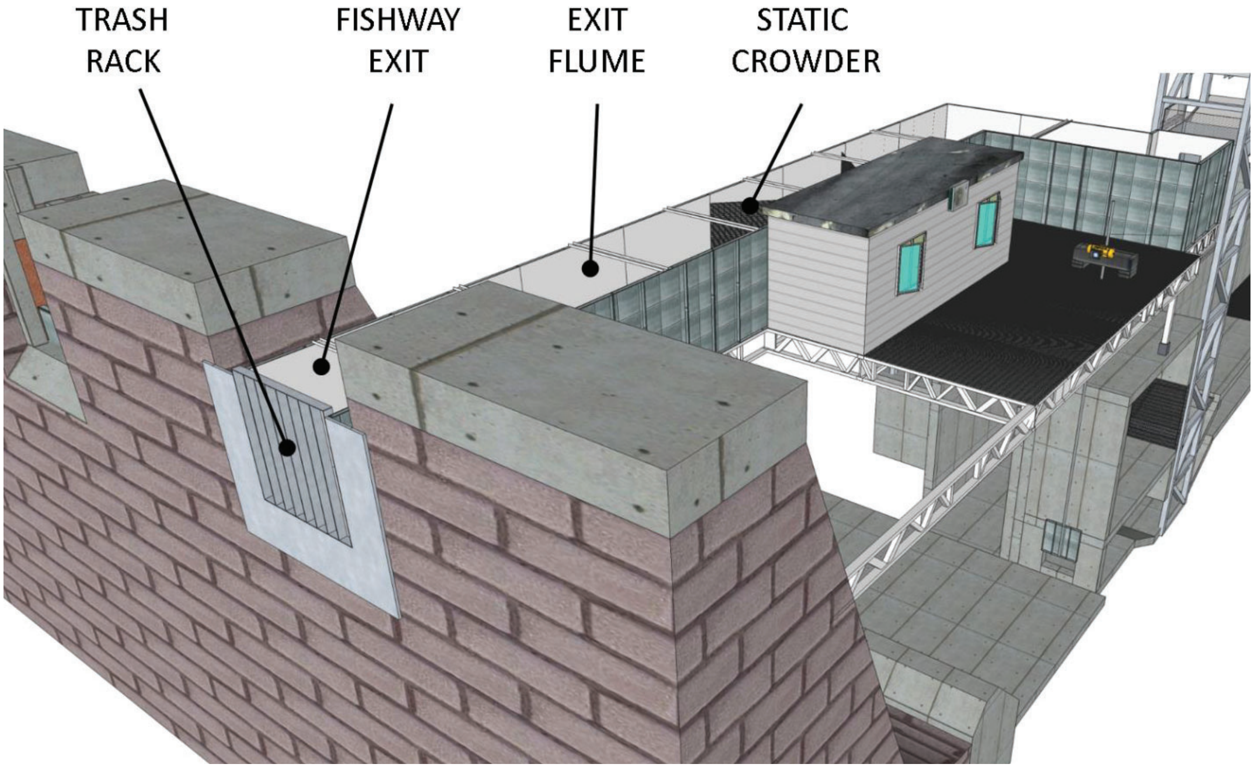


Figure 5: Example of a fish lift exit.

Example of a fish lift exit, including the exit trash rack and flume.

6.5.1 Location

The location of a fishway exit must consider: 1) the risk for the fish to be overwhelmed by the surrounding flow field and either fall back downstream of the barrier or be entrained into the turbines; and 2) the potential for debris accumulation.

- Engineering recommends the fishway exit be placed along the bank of the river channel in a region where water velocities are less than or equal to 4 fps.

6.5.2 Orientation

The fishway exit should be oriented such that the flow entering the exit is at an angle of 0 (parallel) to 45 degrees from the main river flow surrounding the exit.

6.5.3 Depth of Flow

The depth of flow within the exit flume should be a minimum of 4.0 feet for any lift or large pool-type fishway. The depth of flow in any exit flume connected to a baffled chute ladder is determined by the minimum operating depth of the baffled chute. No fishway should operate with flow depth less than two fish body depths at all times and locations.

6.5.4 Velocity at Exit

Velocities within an exit section should be less than 1.5 fps so that fish can enter the forebay without undue difficulty or exertion.

6.5.5 Trash (Grizzly) Racks

Coarse trash racks should be installed immediately upstream of the fishway exit to stop large debris (e.g., trees) from entering the fishway. If large debris enters the fishway, it may partially block passage, result in unintended velocity barriers, or cause injury to fish.

- The bottom of the coarse trash rack should be set at the invert of the fishway exit.
- The rack should extend above the elevation corresponding to the high design flow or, if present, to the top of the working deck.
- The rack should be installed at a maximum slope of 1:5 Horizontal/Vertical (H:V) to enable cleaning.
- To avoid an adverse behavioral reaction from the fish, the exit trash rack should have a 12-inch (in.) minimum clear space between the vertical bars. Common designs use 3/8 in. thick, 3-4 in. wide flat stock for vertical bars.
- Horizontal structural support bars may impact fish movement and are not recommended. Where necessary, horizontal bars must be kept as distant as possible above the free surface. Increasing vertical bar thickness (or otherwise increasing section modulus) may reduce the need for horizontal supports.
- The gross velocity through a clean coarse trash rack, Eq. (8), should be less than 1.5 fps:

$$V_g = \frac{Q}{A_g} \qquad \text{Eq. (8)}$$

where Q is the flow through the exit in cfs, A_g is the trash rack gross area (the projected vertical surface area of the unobstructed opening) in square feet (ft^2), and V_g is the gross velocity in fps.

- On sites where debris loading is expected to be high, the fishway design should include debris booms, curtain walls, and an automated mechanical debris removal system.

6.5.6 Exit Gates

An exit gate is the mechanism used for dewatering a fishway. Most importantly, the design of an exit gate must ensure that it in no way affects fish passage. The gate must be fully open during fish passage operations (unless for dewatering). Creating an orifice flow condition to capture debris or reduce flow entering the exit channel is not acceptable. Gate stems, bolts, and other protrusions should not be in the flow path.

6.6 Fishway Capacity

In general, fishway capacity is a measure of the quantity of fish that the facility can successfully convey, upstream or downstream, in a given period. Timing and space constraints inherent in upstream passage are generally not critical in downstream passage design. Therefore, the criteria and methods presented in this section are limited to upstream technology.

6.6.1 Population and Loading

Migratory runs of anadromous fish on the East Coast tend to be of a highly compressed duration. A properly designed fishway will limit the effect of crowding and minimize delay caused by the barrier during these migratory runs. The quantity of fish that the fishway can safely, timely, and effectively convey over a barrier in a given time period is referred to as the fishway (or biological) capacity. Biological capacity of a fishway may be expressed as the number or pounds of fish per unit of time. Typical time periods include annual, daily, and hourly.

The annual biological capacity, n_T, is defined as the total annual count of fish designed to pass a barrier through the fishway. In the design of a new fishway, this value is set equal to the annual design population (refer to Section 3.0).

The peak day, n_D, is defined as the largest number of fish designed to pass during a 24-hour period. One approach to calculate the peak day is to use the following regression equation:

$$n_D = n_T[0.4193 - 0.026 \ln n_T] \qquad \text{Eq. (9)}$$

where n_T is the annual biological capacity of the fishway. Eq. (9) is based on a regression analysis of fish counts of American shad passing the Bonneville and The Dalles dams on the Columbia River during the periods 1938-1966 (Bonneville) and 1957-1966 (The Dalles) (Rizzo, 2008). Eq. (9) is valid over a range of n_T from 2,800 to 1,250,000.

The peak hour, n_H, is defined as the largest number of fish designed to pass in a 1-hour period during the peak day. For existing, well-performing facilities, n_H is estimated using historical count data. For new facilities, Engineering's approach is to develop fish count regression analyses on similar facilities, in similar locations, that pass the same target species (or a reasonable surrogate fish). In the absence of better data, the following relationship between peak day and peak hour may be used for screening-level estimates:

$$n_H = \beta n_D \qquad \text{Eq. (10)}$$

Where β is a coefficient ranging from 0.10 to 0.20.

In addition, it is convenient to define the average number of fish passed per minute during the peak hour:

$$n_M = n_H \left(\frac{1\,hr}{60\,m}\right) \qquad \text{Eq. (11)}$$

In a typical design process, these values are provided by, or developed in consultation with, the fisheries agency or project biologist.

6.6.2 Fish Lifts and Pool-Type Fishways Capacity Parameters

In order to convert the peak hour rate, n_H, into an expression of volume per unit time (required for fishway capacity calculations of pool-type fishways and fish lifts), the following parameters must first be estimated.

6.6.2.1 Design Adult Weight for Selected Species

For the purposes of the fishway capacity calculation, a design weight must be selected for the target species at a specified life stage. Engineering recommends the use of the following design weights, w_f, for prevalent adult anadromous fish species on the East Coast.

Table 3 Design adult weight for selected species, w_f.

Species	Design Adult Weight, w_f (lb)
American shad	4.0
Alewives	0.5
Blueback herring	0.5
Atlantic salmon	8.0

6.6.2.2 Non-Target Species Allowance

The fishway capacity calculation must also take into account allowances for non-usable space (e.g., sharp corners in a lift hopper) and for the presence of other species that may be in the fishway. Migratory fish runs in the same watershed rarely peak simultaneously; however, the peak day of one species may partially overlap with the start or end of another species run (e.g., alewife and blueback herring). As a consequence, one must assume some percentage of non-target species is in the fishway and increase volume accordingly.

Engineering employs a lumped coefficient, C, to represent the additional volume requirements of unusable space and non-target species. A reasonable range for C is 0.10 to 0.15 (10% to 15%); 0.15 is recommended. However, this is a site specific parameter. For example, very large migrations of non-target species may require the volume of a fishway component (e.g., lift hopper, lift holding pool, pool in a pool-type fishway) to be increased by as much as an order of magnitude or more.

6.6.2.3 Crowding Limit

It has been shown that fishway capacity is constrained by crowding within pools (Lander, 1959). To minimize this effect, a permissible level of crowding in each different fishway component (e.g., lift hopper, lift holding pool, pool in a pool-type fishway) must be selected. Engineering applies the following crowding limit, v_c, for the following fishway components:

- Ladder pools: $v_c = 0.50$ ft^3/lbf
- Lift holding pools: $v_c = 0.25$ ft^3/lbf
- Lift hopper: $v_c = 0.10$ ft^3/lbf

Note that the lift hopper crowding limit is only valid for lift cycle times equal to or less than 15 minutes. For cycle times greater than this, the crowing limit should be increased beyond 0.10 ft^3/lbf. Bell (1991) recommends a crowding limit of 0.13 ft^3/lbf for long hauls.

6.6.2.4 Pass Rate

The pass rate, r, for the fishway must also be estimated to calculate the fishway capacity of a pool-type fish ladder or fish lift. For pool-type fishways, the pass rate is the rate of ascent, a measure of how quickly fish of different species can traverse the fishway and is expressed in pools per minute (Table 4). This parameter reflects both behavioral characteristics and the swimming speed of the fish. Conceptually, the inverse of r can be regarded as a residence time.

Table 4. Rates of ascent for pool-type fishways

Source	Species	Rate of ascent, r (pools/min)
Bell (1991)	general	0.250 – 0.400
Clay (1995)	chinook salmon	0.200
Elling & Raymond (1956)	general	0.172 – 0.303
USFWS R5 Recommendation	Atlantic salmon	0.250
	American shad	0.250
	river herring	0.250

For fish lifts, the pass rate, r, is the design cycle time. The cycle time of a lift represents the time required to perform the steps outlined in Section 7.8. For all but the tallest of lifts, one may assume a cycle time of 15 minutes or less. Ultimately, the cycle time is a function of the mechanical design of the various lift elements. Prolonged time in the hopper induces stress in the fish and should be avoided.

6.6.3 Capacity of Fish Lifts and Pool-Type Fishways

To calculate the required volume for the pools, V, within a pool-type fishway, fish lift holding pools, and fish lift hoppers, Eq. (12) is used:

$$V = n_M \frac{w_f v_c}{r}[1 + C] \qquad \text{Eq. (12)}$$

For a pool-type fishway, this is required to be less than or equal to the volume of water held in the pool under normal operating conditions. For a lift holding pool, this is required to be less than or equal to the volume of water (used by fish) between the downstream edge of the hopper brail (or leading edge of the hopper) and the closed mechanical crowder. For a lift hopper, this is required to be less than or equal to the water-retaining volume of the bucket.

Other important considerations are below:

- The volume of a pool in a pool-type fishway must also consider the effects of hydraulic parameters such as the energy dissipation factor and streaming versus plunging flow;
- Biological capacity of the fish lift holding pool must be equal to or exceed the capacity of the hopper(s) for proper functioning.

6.6.4 Capacity of Baffled Chute Fishways

Based on research by Slatick (1975), Slatick and Basham (1985), Haro et al. (1999), and monitoring studies, the USFWS has estimated capacities of Standard Denil ladder fishways (described in Section 7.6) and Model A Steeppasses (described in Section 7.7). The values reported in Table 5 assume that there is no overlap in the timing of the migration run for each of the reported species. In the event of overlapping migrations, the capacity can be expressed in terms of an equivalent biomass using the design weights presented in Table 3.

Table 5. Fishway capacity for baffled chute fishways

Fishway Type	Species	Annual Biological Capacity, n_T
Standard 4 ft Wide Denil Ladder	adult American shad	25,000
	adult Atlantic salmon	12,000
	adult river herring	200,000
Model A Steeppass	adult river herring	50,000
	adult Atlantic salmon	3,125

6.7 Energy Dissipation in Upstream Fishways

The energy dissipation factor (EDF), introduced in Section 5.4, is a measure of the volumetric energy dissipation rate (or power dissipation) in a pool, chute or stream reach.

6.7.1 Sizing Step Pools

Eq. (6) in Section 5.4 expresses the potential energy loss (or dissipation) rate per unit length of fishway. The well-known EDF equation for fishway step pools, illustrated in Figure 6, is derived from Eq. (6) by: 1) dividing both sides by the mean cross-sectional area of the fishway pool; and 2) recognizing that the term $dh/d\ell$ is equivalent to the (hydraulic) drop per pool over the length of the pool.

$$EDF = \frac{\gamma QD}{\forall_P} \qquad \text{Eq. (13)}$$

where D is the hydraulic drop per pool in ft, $\forall_P$ is the volume of the pool in cubic feet (ft^3), γ is the unit weight of water in lbf/ft^3, and EDF is the energy dissipation factor in ft-lbf/s-ft^3.

Multiplying both sides of Eq. (13) by the pool volume and dividing both sides by the EDF results in Eq. (14), used for the sizing of fishway step pools:

$$\forall_P = \frac{\gamma QD}{EDF} \qquad \text{Eq. (14)}$$

In Eq. (14), the EDF is considered a species-specific criterion. Section 6.7.3 provides Engineering's recommended values for selected anadromous fish species.

It is important to note that a proper aspect ratio and depth must be selected in the design of the step pool. Engineering should be consulted in the design process to ensure that the step pool acts as both an energy dissipation zone and a resting zone. Further details on the EDF can be found on Appendix A, Reference Plate 5-2, "Power Dissipation Rates."

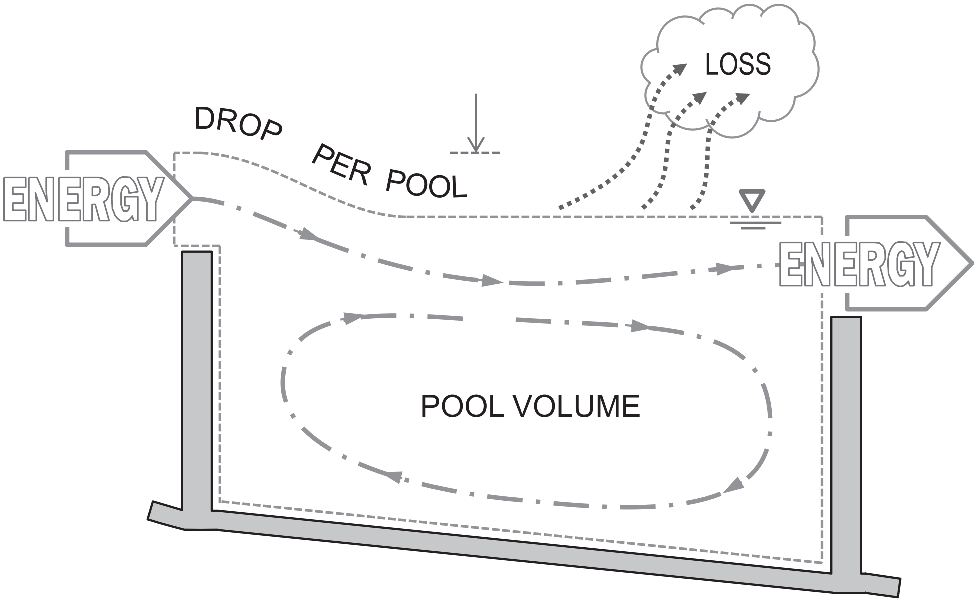


Figure 6: Sizing step pools in a ladder type fishway based on the EDF.

6.7.2 Sizing Denil Resting Pools

A transferable energy dissipation function, based on energy loss rate from a Standard Denil resting pool, was developed by Towler et al. (2015):

$$EDF = \left[\frac{\alpha_1 Q_1^2}{2A_1} - \frac{\alpha_2 Q_2^2}{2A_2} + g(z_1 - z_2)\right]\frac{Q\gamma}{HWL_p} \qquad \text{Eq. (15)}$$

where H is the mean water surface elevation in the resting pool in ft, W is the width of the Denil channel in ft, L_P is the length of the resting pool in ft, α is the Coriolis coefficient (also referred to as the kinetic energy correction coefficient), Q is the flow rate in cfs, A is the cross-sectional area in ft^2, g is the gravitational constant in ft/s^2, γ is the unit weight of water in lbf/ft^3, z is the elevation of the inlet and outlet sections, and EDF is the energy dissipation factor in ft-lbf/s-ft^3.

Shown in Figure 7, the upstream cross section 1 is located at the upstream interface between the sloped, baffled section and the horizontal pool and the downstream cross section 2 is located at a point close to the end of the resting pool where conditions are nearly uniform. At cross section 1, the area of flow is given by the following discontinuous function that accounts for the transition between the v-notched and vertical sections of the baffle:

$$A_1 = \begin{cases} \dfrac{bc}{2} + \left(\dfrac{H}{\sin\left(\dfrac{\pi}{4}\right)} - 2c\right)b & H > 2c\sin\left(\dfrac{\pi}{4}\right) \\ \dfrac{b}{2c}\left(\dfrac{H}{\sin\left(\dfrac{\pi}{4}\right)} - c\right)^2 & c\sin\left(\dfrac{\pi}{4}\right) < H \le 2c\sin\left(\dfrac{\pi}{4}\right) \end{cases} \qquad \text{Eq. (16)}$$

where b and c are the geometric scaling parameters for the Standard Denil baffle as shown in Figure 7. For Standard Denil designs, resting pools are generally prismatic, horizontal extensions of the sloped channel. Thus, the flow area at downstream cross section 2 in Figure 7 is simply the product of H and W. Translating the head above the baffle notch at cross section 1 to the common resting pool floor datum yields:

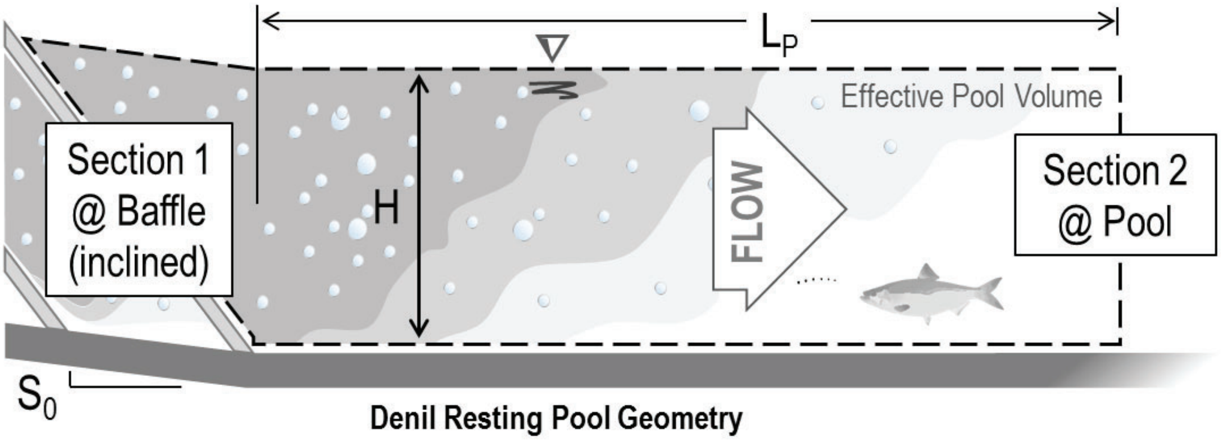
$$z_1 = H\sqrt{2}\cos\left(\frac{-\pi + 4\tan^{-1}(S_0)}{4}\right) \qquad \text{Eq. (17)}$$

Towler et al. (2015) provides an in-depth analysis of the effect of α on the Eq. (15). When used in open channel flow calculations, Coriolis values typically range from α = 1 (uniform velocity distribution) to α = 2. Despite the large range, values above 1.15 rarely occur in regular channels (Henderson, 1966). However, Denil baffles generate more intense turbulence and irregular velocity distributions than ordinary open channel flows. To account for this uncertainty, Engineering recommends the proposed range of acceptable deviations be incorporated into the design equation. Substituting Eq. (17) into Eq. (15) and replacing α with a ± 5% error bound results in the following expression for EDF in Standard Denil resting pools:

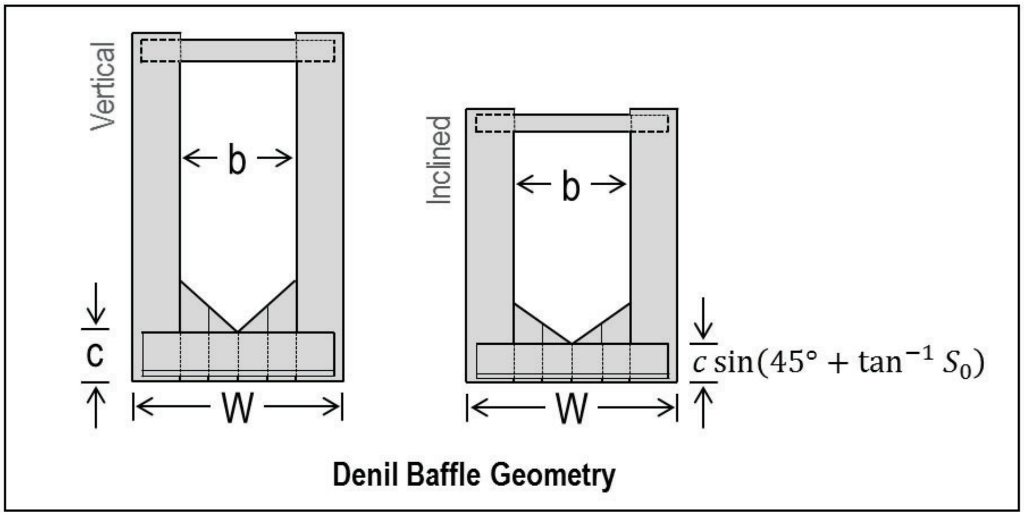
$$EDF = \left[\frac{Q}{2}\left(\frac{1}{A_1}-\frac{1}{HW}\right)+gH\left(\sqrt{2}\cos\left(\frac{-\pi+4\tan^{-1}(S_0)}{4}\right)-1\right)\right]\frac{Q\gamma}{HWL_p}\pm 5\% \qquad \text{Eq. (18)}$$

Recognizing that HWL_P is equal to the volume of the pool, $\forall_P$, and dividing each side of Eq. (18) by the EDF and multiplying each side by $\forall_P$, the generalized equation to size Denil resting pools is developed:

$$\forall_P = \left[\frac{Q}{2}\left(\frac{1}{A_1}-\frac{1}{HW}\right)+gH\left(\sqrt{2}\cos\left(\frac{-\pi+4\tan^{-1}(S_0)}{4}\right)-1\right)\right]\frac{Q\gamma}{EDF}\pm 5\% \qquad \text{Eq. (19)}$$



Denil Resting Pool Geometry



Denil Baffle Geometry

Figure 7: A cross-sectional view of a Denil fishway resting pool and baffle.

On the east coast of the U.S., Standard Denil fishways typically employ horizontal prismatic resting pools that are as wide as the sloped baffled section (e.g., 3 ft, 4 ft). From a design standpoint, the goal is to select a resting pool length adequate to reduce the EDF to a level acceptable for the target species. For clarity and application to these standard designs, regression equations were fit to Eq. (18) for both the 3-foot wide and 4-foot wide Standard Denil fishways at three common channel slopes. These equations, couched in the form of energy dissipation rate per unit area, take the form:

$$EDF \times L_P = K_1(H - h_v)^{K_2} \quad \text{Eq. (20)}$$

where H is the head above the channel invert in ft, h_v is vertical height of the baffle notch in ft, EDF–L_p is the energy dissipation rate per unit area in ft-lbf/s/ft^2 and the regression coefficients K_1 and K_2 depend on the width as shown in Table 6.

Additional details on the development of EDF for Denil resting pools can be found on Appendix A, Reference Plate 6-2 "Denil Resting Pool."

Table 6: Standard Denil Fishway regression coefficients.

Regression coefficients for energy dissipation rate per unit area for 3-foot and 4-foot wide Standard Denil fishways at three common channel slopes (V:H).

Fishway	Parameter	1:6	1:8	1:10
3-foot Wide	h_v (ft)	0.6103	0.592	0.5805
	K_1	13.523855	9.728355	7.697128
	K_2	1.774059	1.802865	1.773244
4-foot Wide	h_v (ft)	0.8137	0.7894	0.774
	K_1	12.483282	9.166344	7.160788
	K_2	1.772447	1.779516	1.765067

6.7.3 Species Specific Criteria

Table 7 displays species specific EDF criteria. The rows in bold are the criteria adopted by Engineering.

Table 7: Species specific EDF criteria

Species	EDF (ft-lb/s-ft^3)	Source
Salmonids, juvenile	2.0	NMFS, 2011
Non-salmonids	2.09	Armstrong et al., 2010
Trout	3.13	Armstrong et al., 2010
Salmonids, adult	3.13	NMFS, 2011
American shad	**3.15**	**Engineering**
Atlantic salmon	**4.0**	**Engineering**
Salmonids	5.0	Maine DOT, 2008

6.8 Supplemental Attraction Water

Auxiliary water is defined as the portion of attraction flow (see Section 6.3.2) that is diverted through the AWS prior to flowing out of the fishway entrance. An AWS typically consists of an intake screen, hydraulic control gate, and energy dissipating pools, baffles, and diffusers. Not only may the AWS be used to provide additional attraction flow through the fishway entrance, but it also may be used to add water depth at various locations through the fishway. Figure 3 in Section 6.4 displays an example of a gravity-fed AWS supplying flow to a fish lift. Attraction flow is routed through the exit flume via a conduit to the rear AWS chamber and lower AWS chamber. The flow enters the hopper through a rear diffuser and flow enters the entrance channel via wall and floor diffusers.

6.8.1 Free Surface (Gravity) AWS

A gravity-fed AWS is a conduit hydraulically connecting the headwater (or forebay) to the fishway entrance by converting significant potential energy into kinetic energy.

6.8.2 Pressurized AWS

A pressurized AWS is the most common type on the East Coast. The auxiliary water is transported from the forebay via a closed pipe. The type of valve used within the pipe must be able to minimize debris entry and any entrained air. Three common valve types are the butterfly, knife, and bladder valve. The bladder valve is the preferred option as it reduces both debris and air entering into the system. A bladder valve is made of an inflatable material; when closed, the bladder valve is filled with air and it effectively seals off the pipe from flow. The knife valve is effective at reducing air entrainment but can have problems closing when debris is present, unlike the bladder valve which has been shown to close even around debris. A butterfly valve should not be used as it is subject to problems with both air entrainment and debris.

6.8.3 Pump AWS

A pump-fed AWS converts mechanical energy into kinetic energy by pumping water from the tailrace to the fishway.

6.8.4 Intakes

Racks or screens at the flow entrance of an AWS are used to reduce the amount of debris and prevent fish from entering the system. Engineering recommends:

- Juvenile downstream migrants should not be entrained or impinged by the AWS intake screen (for a gravity-fed system). Screening or other protection measures are assessed by Engineering on a site-by-site basis.

- A clear space between the vertical flat bars of 3/8 inch or less is required; this criterion is based on the exclusion of adult river herring.
- Flow velocities should be as close to uniform as possible as the water passes through the rack or screen.
- The gross maximum velocity through the fine trash rack should be less than 1.0 fps as calculated by Eq. (8).
- To facilitate cleaning, the trash rack should be installed at a horizontal to vertical slope of 1:5 or greater and the overall trash rack design should allow for personnel access and maintain clearance for manual or automated raking.
- Occlusion or blockage creates a hydrostatic and hydrodynamic load on a rack. This load manifests itself, in part, as a head differential across the intake and fine trash rack. The head differential across a rack should be minimal.
- AWS trash racks should be of sufficient structural integrity to minimize deformation.

6.8.5 Diffusers

Both wall and floor diffusers are commonly included in an AWS design. The diffusers provide a means to reduce excess energy and entrained air as the flow passes from the AWS conduit to directly within the flow path of the fishway. Wall diffusers consist of vertically-oriented grating of galvanized steel or aluminum, whereas floor diffusers consist of horizontally-oriented grating. The following are general recommendations by Engineering pertaining to AWS diffusers:

- Diffuser grating panels are typically constructed of 1”x3” or 1”x4” galvanized steel or aluminum grating. To minimize movement of small fish (e.g., alewife) through a diffuser panel, the grating should always be installed with the longer dimension (i.e., 3 in. or 4 in.) aligned to the horizontal plane. However, tighter spacing may be required depending upon the species present at the site.
- The screen size of the AWS intake must be less than or equal to the screen size of the diffuser screen to prevent fish from being trapped within the AWS.
- Vertical (wall) diffusers are preferred over horizontal (floor) diffusers due to the maintenance, de-watering, and performance issues associated with horizontal diffusers.

- AWS vertical (wall) diffuser velocities should be less than or equal to 0.5 fps; this criterion is based on Engineering's observations that, above 0.5 fps, AWS discharge can attract and delay fish at the wall diffuser.
- Based on the poor performance of high-velocity floor diffusers installed throughout the region in years past, Engineering has adopted the National Marine Fisheries Service, Northwest Region horizontal (floor) diffuser velocity criterion of 0.5 fps (NMFS, 2011).
- AWS diffusers installed upstream of a hopper in a fish lift may produce acceptable velocities as high as 1.5 fps.
- AWS diffuser velocity calculations should be based on Eq. (8).
- The velocity distribution exiting the diffuser should be as close to uniform as possible.
- Wall and floor diffusers should be submerged during normal operation of the fishway.
- Orientation of the grating should maximize the open area of the diffuser.
- All bar edges and surfaces exposed to fish should be rounded or smooth.
- Diffuser panels are susceptible to leaves and woody debris. Access for debris removal from each diffuser should be included within the design.
- AWS pits below diffusers must be clear of debris.

6.8.6 Turning Vanes

Turning vanes, illustrated in Figure 3 of Section 6.4, are designed to turn the flow in such a way that the flow field will quickly approximate a uniform velocity distribution in a desired direction. These vanes are typically located below horizontal diffusers and direct the flow up through the diffuser. Criteria regarding spacing and angle of the turning vanes remain under development.

6.8.7 Sizing Dissipation Pools

An energy dissipation pool is an important component of an AWS that is designed for the sole purpose of dissipating energy from the attraction water (unlike fishway pools which also require resting zones within the pools). The pool(s) must have sufficient volume to properly dissipate the incoming kinetic energy. For gravity-fed pools, Engineering recommends a minimum water volume established by the following formula (similar to Eq. (13)):

$$V = \frac{\gamma Q H}{16.0 {}^{ft\cdot lbf}/_{s\cdot ft^3}} \qquad \text{Eq. (21)}$$

where V is the dissipation pool volume in cubic feet, γ is the unit weight of water in pounds per cubic feet, Q is the flow through the fish ladder in cfs, H is the differential energy head on the pool in feet, and 16 ft-lbf/s-ft^3 is the acceptable maximum EDF (notably greater than the maximum EDF within fishway pools). Note: in AWS that convey water to the dissipation pool via closed conduit, the differential energy is significantly reduced by frictional and minor losses within the pipe; in such systems, H is rarely more than a few feet of head.

6.8.8 Air Entrainment

Generally, air entrainment should be as low as possible within an AWS to reduce the total amount of entrained air passed on through the fishway. Engineering recommends the following techniques to reduce aeration within the AWS system:

- Proper sizing of the dissipation pools;
- Submerging the intake; if this cannot be achieved, Engineering recommends the use of anti-vortex plates;
- Submerge the outlet.

7 Technical Upstream Fishways

Technical fishways employ engineering designs that are typically concrete, aluminum, polymer, and wood, with standardized dimensions, using common construction techniques. Technical upstream fish passage systems can be categorized as volitional or non-volitional as illustrated in Figure 8 (also refer to Appendix A, Reference Plate 6-1 “Fishway Types”). The distinction refers to whether passage relies upon motivation, performance, and behavior of the fish to ascend over the barrier. Generally, volitional fishways include specific pool-type and chute-type designs such as the pool-and-weir, Ice Harbor, vertical slot, Denil, and steeppass. Non-volitional passage facilities include fish lifts (i.e., elevators), fish locks, and trap-and-transport systems. The following subsections describe each of these fishway designs and any applicable Engineering criteria. Note that the criteria for the serpentine, pool-and-chute, and trap-and-transport systems (listed in Figure 8) remain under development. Fishways specific to American eel passage are discussed in Section 13.

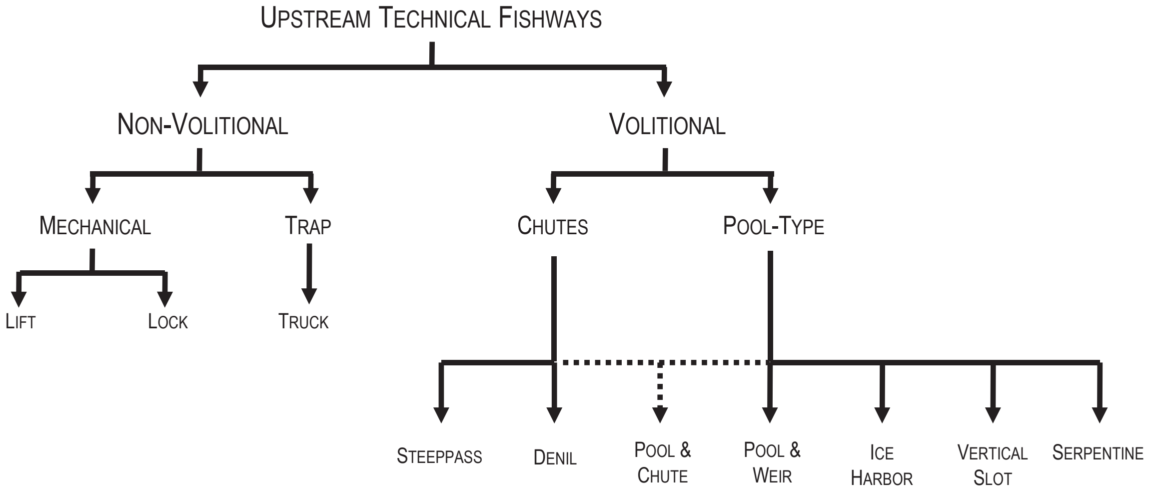


Figure 8: Technical upstream fishway types

7.1 Pool-and-Weir Fishways

Pool-and-weir fishways are characterized by a series of pools separated by overflow weirs that break the total head into discrete, passable increments.

7.1.1 Slope

The slope of a pool-and-weir fishway is calculated by dividing the (exterior) length of the pool by the hydraulic drop per pool.

- The slope of a pool-and-weir fishway should be less than or equal to 10%.
- Pool-and-weir fishways are designed for "uniform-in-the-mean" conditions (Towler et al., 2015). That is, each successive pool maintains the same hydraulic characteristics at the inlet and outlet. Therefore, the slope of the fishway is approximately equal to the friction slope (slope of the energy grade line).

7.1.2 Pool Geometry

Resting pools create hydraulic conditions that promote fish recovery from energy demanding high speed swimming before ascending the next step pool section.

- Typically, a resting pool is rectangular in shape. The specific geometry is dependent upon velocity, flow, depth, streaming/plunging conditions, and EDF criteria. In addition, a biological capacity requirement must be met.
- For large streams or rivers, biological capacity and EDF criteria often require pools 8-feet long or greater.

7.1.3 Weirs

The design of the weir must take into account both the flow depth and the velocity of the jet over the weir crest in relation to the size of the target species and any ability to leap over obstructions.

- To safely pass fish, weirs should be designed to provide a minimum of two body depths of flow depth over the weir crest with a minimum submergence of the crest that promotes streaming flow conditions.
- The velocity of the jet over the weir crest must be low enough to permit passage of all target fish species at the site. The velocity of the jet is proportional to the square root of the hydraulic head on the crest. Thus, knowledge of the target fish species swimming

capabilities is required to determine the maximum flow depth over the weir in which passage can occur.

- The weir-to-weir alignment of the low flow notch must be designed to reduce momentum loss in the jet through the interstitial pool.

7.1.4 Hydraulic Drop

The hydraulic drop from pool to pool is a function of several factors, including the water surface elevation of the downstream pool, flow rate and velocity over the weir, and weir width. The maximum hydraulic drop between pools should be approximately 1.0 foot; however, actual drop is determined by ensuring the fishway meets all other hydraulic criteria including velocity and streaming flow.

7.1.5 Orifices

Submerged orifices are often included as an alternate route of passage (for salmonids) and may also promote streaming flow under threshold conditions.

- Orifices can be aligned on one side or alternating side-to-side.
- Often built with a deflecting baffle design immediately downstream to redirect the flow towards the center of the pool.
- The dimensions of orifices should be sized to maintain streaming flow and adequate fish passage conditions (e.g., velocities, width).
- The top and sides should be chamfered 0.75 inches on the upstream side and chamfered 1.5 inches on the downstream side of the orifice.
- The orifices must be void of debris at all times during the migration season. Blockages can create high velocities at the orifice and other complex hydraulic conditions which can reduce the efficacy of the fishway.

7.1.6 Turning Pools

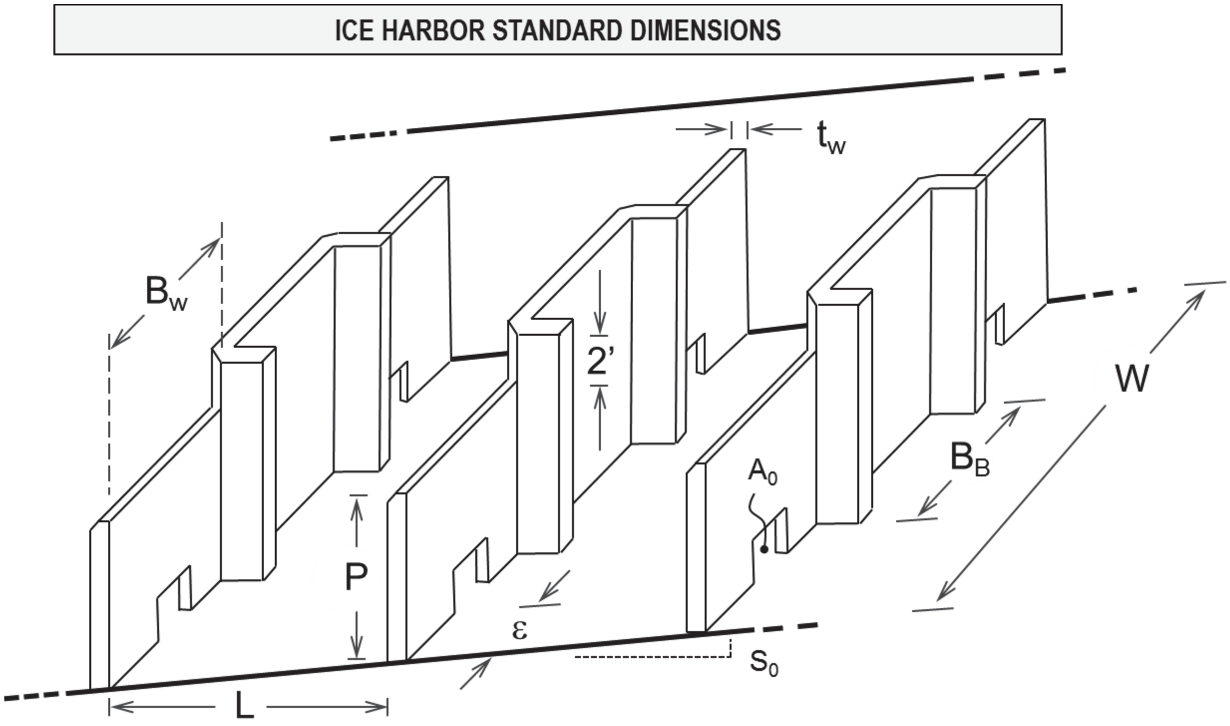
Turning pools are locations within the fishway where bends are required. These pools are often curved in shape or rectangular with chamfered walls. This shape differs from linear resting pools and, consequently, can create much more complex hydraulic conditions. Turning pools often also act as a resting pool.

- The design of the fishway should limit the number of turning pools to a feasible minimum.
- The hydraulic conditions within a turning pool must be designed to elicit a rheotactic response from the upstream migrating fish.
- The flow field should be nearly uniform throughout the turning pool.
- Turning pools should be designed to minimize flow separation and turbulence. The walls should be chamfered (ideally circular).
- The upstream pool width should be maintained throughout the entirety of the bend.
- Ideally, turning pools should have bends of 90 degrees or less. Greater than 90 degrees increases risk for poor hydraulic conditions and can cause confusion to fish, especially American shad, as they attempt to migrate upstream through the fishway.
- For turning pools which require a bend greater than 90 degrees, a weir should be placed at the midpoint of the pool creating a jet of water designed to motivate fish to continue ascending the fishway.

7.2 Ice Harbor Fishways

An Ice Harbor fishway is a modified pool-and-weir ladder that has two weir crests separated by a non-overflow central baffle and two submerged orifices centered below the crests.

The Appendix A, Reference Plate 7-1 “Ice Harbor Fishway” illustrates design schematic and provides a list of standard dimensions. Figure 9 displays the Ice Harbor standard dimension parameters, pertinent geometric ratios, and design criteria.



$$L \geq 9\,ft \qquad S_0 \leq \frac{1}{10} \qquad B_B = 0.375W \qquad B_W = 0.625\frac{W}{2}$$

Figure 9: Ice Harbor fishway standard dimensions.

Ice Harbor fishway standard dimensions; where B_W is the overflow weir crest width, B_B is the non-overflow baffle width, A_0 is the area of the orifice opening, S_0 is the floor slope, L is the pool length, W is the pool width, P is the overflow weir crest height, t_W is the overflow weir crest thickness, and ε is the distance from the center of the orifice to the side wall.

7.2.1 Slope

The slope of a pool-type fishway is calculated by dividing the length of the pool by the hydraulic drop per pool.

- The slope of an Ice Harbor fishway should be less than or equal to 10%.
- Ice Harbor fishways are designed for "uniform-in-the-mean" conditions (Towler et al., 2015). That is, each successive pool maintains the same hydraulic characteristics at the inlet and outlet. Therefore, the slope of the fishway is approximately equal to the friction slope (slope of the energy grade line).

7.2.2 Pool & Central Baffle Geometry

- The pool width, W, typically ranges from 10 to 25 feet. The pool length, L, must be greater than or equal to 9 feet. However, the specific pool geometry is dependent upon velocity, flow, depth, streaming/plunging conditions, and EDF criteria.
- The difference in height between the top of the non-overflow central baffle and the weir crest is typically 2 feet.
- Typically, the width of the central baffle, B_B, is 37.5% of the pool width, W.
- The central baffle is equipped with flow stabilizers which take the form of stub walls facing upstream at each end. Typically, the length of the two stub walls is 1.5 feet.

7.2.3 Weirs

An Ice Harbor fishway has two symmetrical weir crests, separated by a central baffle.

- The width of each weir crest, B_W, is typically 31.25% of the pool width, W. This results in an effective weir width of 62.5% of W.

7.2.4 Orifices

Similar to weirs, the Ice Harbor fishway has two symmetrical orifices, rectangular in shape, below the weir crests. The bottom of the orifice is the fishway floor. The two orifices provide an alternate route for upstream movement through the structure, although most fish swim over the weirs.

- The size of the orifice opening typically varies from 12 in. x 12 in. for a 10 foot wide pool to 18 in. x 18 in. for a 25 foot wide pool.

7.2.5 Turning Pools

Refer to Section 7.1.6, Turning Pools of Pool-and-Weir Fishways.

7.3 Alternating Ice Harbors

The Alternating Ice Harbor is a low flow variant of the Ice Harbor fishway. In each pool, one of the weirs and one of the orifices is blocked, in alternating arrangement. This effectively reduces the flow, increasing the relative volume available for energy dissipation.

Alternating Ice Harbors are not designed as such; they are post-construction modifications to (poorly performing) Ice Harbor fishways.

7.3.1 Slope

The slope of a pool-type fishway is calculated by dividing the length of the pool by the hydraulic drop per pool.

- The slope of an Alternating Ice Harbor fishway should be less than or equal to 10%.
- Alternating Ice Harbor fishways are designed for "uniform-in-the-mean" conditions (Towler et al., 2015). That is, each successive pool maintains the same hydraulic characteristics at the inlet and outlet. Therefore, the slope of the fishway will approximate the friction slope (slope of the energy grade line).

7.3.2 Pool & Central Baffle Geometry

Criteria in development.

7.3.3 Weir and Weir Arrangement

Criteria in development.

7.3.4 Orifice and Orifice Arrangement

Criteria in development.

7.3.5 Turning Pools

Criteria in development.

7.4 Half Ice Harbor Fishways

The Half Ice Harbor is a low flow variant of the Ice Harbor fishway. The geometry of a Half Ice Harbor is, as the name implies, equivalent to a lateral section of the full Ice Harbor cut along a plane of symmetry defined by its central axis. Accordingly, the low flow fishway consists of one weir crest, one orifice, and a non-overflow baffle between fishway pools.

Engineering's experience is that it is challenging to maintain streaming flow conditions in a Half Ice Harbor fishway. For this reason, Half Ice Harbor fishways are not recommended for American shad.

7.4.1 Slope

The slope of a pool-type fishway is calculated by dividing the length of the pool by the hydraulic drop per pool.

- The slope of a Half Ice Harbor fishway should be less than or equal to 10%.
- Half Ice Harbor fishways are designed for "uniform-in-the-mean" conditions (Towler et al., 2015). That is, each successive pool maintains the same hydraulic characteristics at the inlet and outlet. Therefore, the slope of the fishway will approximate the friction slope (slope of the energy grade line). Engineering's experience is that the typical geometry of the Half Ice Harbor (e.g., 1 foot drop, 10% slope) does not adequately dissipate energy. As a result, high approach velocities at the weir often inhibit the ascent of American shad and river herring.

7.4.2 Pool & Central Baffle Geometry

Criteria in development.

7.4.3 Weir and Weir Arrangement

Criteria in development.

7.4.4 Orifice and Orifice Arrangement

To reduce the turbulence and air entrainment in Half Ice Harbors, Engineering recommends blocking the orifice. American shad, river herring, and American eel do not generally pass through submerged orifices. Closing the orifice significantly reduces fishway flow, and consequently the EDF.

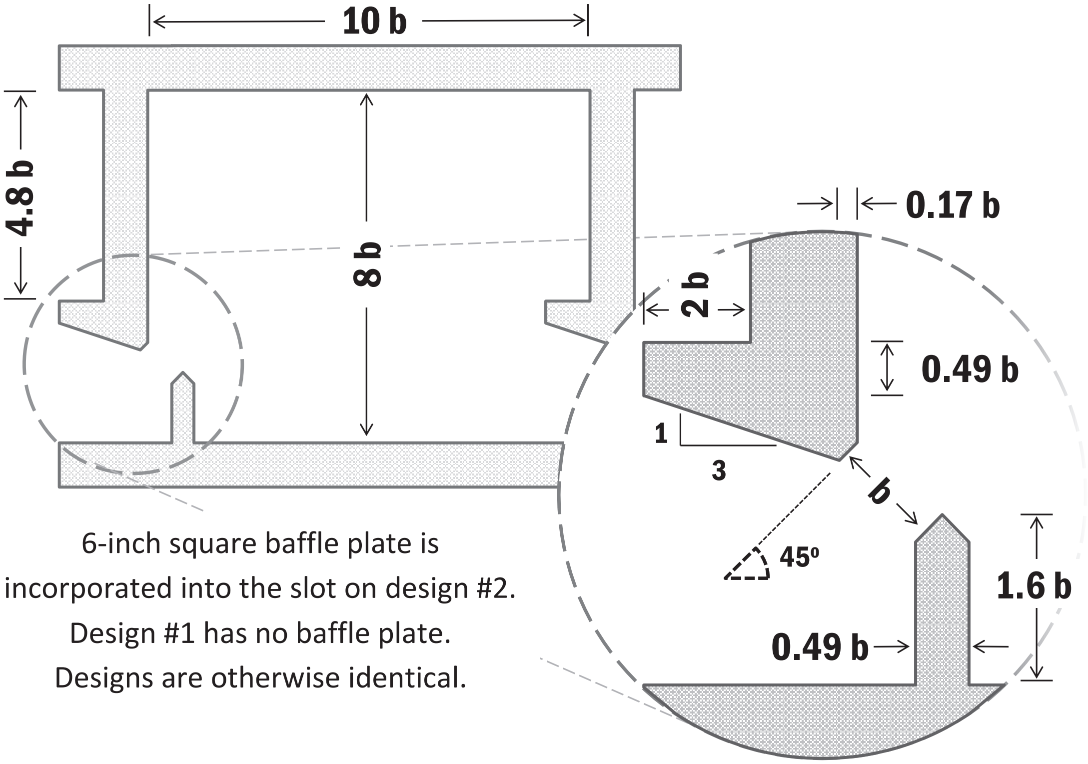
7.4.5 Turning Pools

Refer to Section 7.1.6.

7.5 Vertical Slot Fishways

A vertical slot fishway is a pool-type fish ladder characterized by a rectangular channel with a sloping floor in which a series of regularly spaced baffles separate the pools. Water flows from pool to pool via a vertical slot at each baffle. These designs are applicable to medium head dams and, unlike pool-and-weir fishways, may accommodate large fluctuations in headwater and tailwater levels. Another advantage of the vertical slot is that it offers passage along the full depth of the slot, thus it theoretically provides passage to a wider variety of species.

Engineering recommends vertical slot Design #1 (Rajaratnam et al., 1986) as the standard vertical slot fishway design. Figure 10 and Appendix A, Reference Plate 7-2 “Vertical Slot Fishway” illustrate this design with its dimensions as a function of slot width, b. Vertical slot fishways produce complex hydraulics; refer to studies by Rajaratnam et al. (1986), Rajaratnam et al. (1992), and Wu et al. (1999) for a view of the flow field within multiple vertical slot configurations.



6-inch square baffle plate is
incorporated into the slot on design #2.
Design #1 has no baffle plate.
Designs are otherwise identical.

Figure 10: Geometric ratios for the vertical slot fishway designs #1 and #2.

(Rajaratnam et al., 1986)

7.5.1 Slope

The slope of a vertical slot fishway is calculated by dividing the length of the pool by the hydraulic drop per pool.

- The fishway slope typically ranges between 4% and 10%.

- In the case of a vertical slot, the maximum hydraulic drop (typically corresponding to low river flows) is used to establish the design water surface profile and friction slope which, in the absence of flow development, is equivalent to the friction slope.

7.5.2 Pool Geometry

The design and dimensions of a standard vertical slot fishway (with one slot per baffle) are shown in Figure 10 (Rajaratnam et al., 1986). The dimensions are given in relation to the slot width, b. At each site, the sizing and arrangement of the slot and walls is influenced by hydraulics, discharge, and the biological needs of fish. The design is intended to redirect the water into the center of the pool rather than allowing it to pass down from slot to slot. This allows the flow to stabilize and creates a zone where energy is dissipated.

7.5.3 Slot Width Requirements

The slot width, b, is often based upon a biological (width) criterion that is typically proportional to the fish size.

- In general, the slot width should be significantly wider than the width of the target species in order to avoid injury and/or abrasion along the wall.
- Velocities through slots should be less than burst speeds of target species.
- The slots for a vertical slot fishway should be no less than 18 inches wide.

7.5.4 Baffle Plates

Baffle plates, when used, are suspended within the slot and provide additional control of the water surface elevation within the pool. It is critical that the baffle plate is suspended high enough in the slot to provide safe passage for fish to exit the fishway during any fishway shutdown. Rajaratnam et al. (1986) provides a discharge equation for the inclusion of a 6 inch square baffle plate, designated “Design #2”. Appendix A, Reference Plate 7-2 “Vertical Slot Fishway” provides additional details. Note that baffle plates may inadvertently exacerbate the collection of debris and create blockages at the vertical slot; for this reason Engineering recommends against the use of baffle plates where possible.

7.5.5 Turning Pools

Refer to Section 7.1.6, Turning Pools of Pool-and-Weir Fishways.

7.6 Standard Denil Fishways

Denil designs are a family of baffled-chute ladders that utilize roughness elements (i.e., baffles) to dissipate the kinetic energy of water moving through a flume to create a low velocity zone of passage for migratory fish. The baffles turn a portion of the flow to oppose the main current in the flume. This change in inertia results in a decrease in flume velocity but also generates considerable turbulence that can reduce passage efficiency. Though limited in biological capacity, Denil fishways have demonstrated an efficacy in the passage of salmonids, alosines, and other species at relatively steep slopes.

A Standard Denil, displayed in Figure 11, is typically composed of a 2-4 feet wide prismatic concrete, steel or wood channel. The Denil fishway can operate over a moderate range of impoundment water level fluctuation. A minimum flow depth of 2 feet or two body depths (whichever is greater) should be maintained throughout the entirety of the fishway. The maximum operating water depth must remain 3.0 inches below any cross-support members (on the upper portion of the baffles).

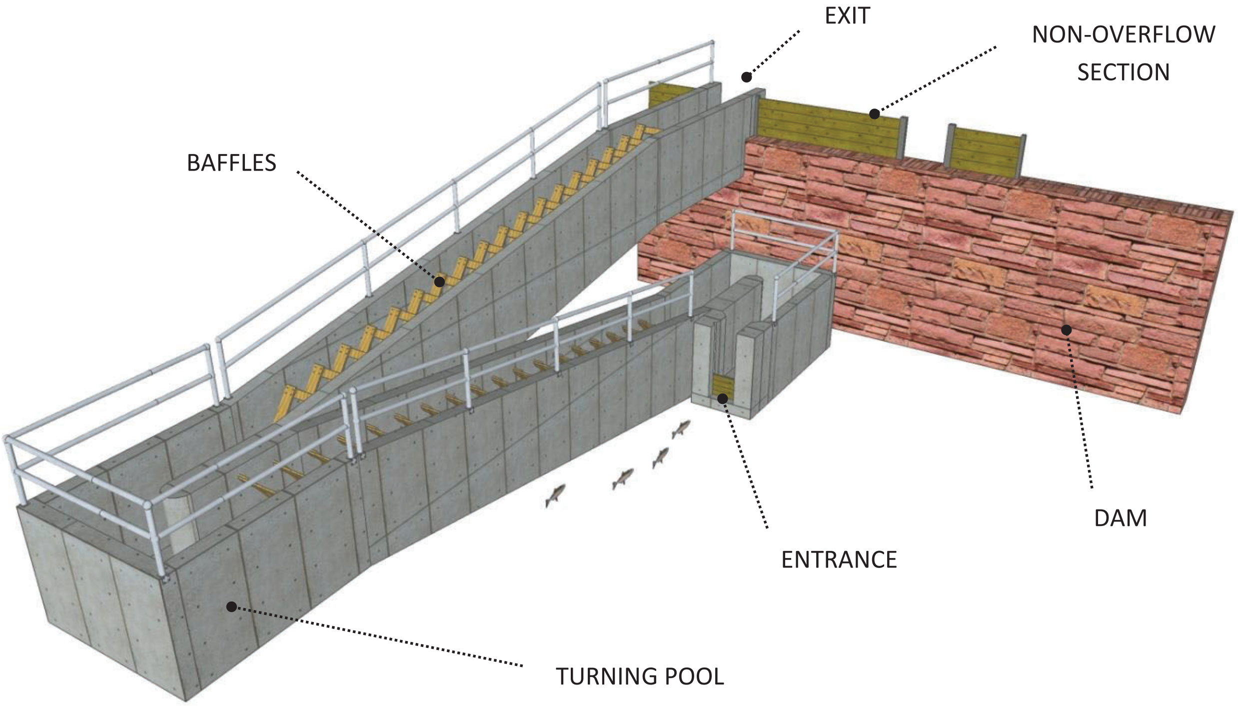


Figure 11: A Standard Denil fishway illustration.

7.6.1 Entrance

- At all times, the flow depth at the entrance (measured above the channel floor, gate lip, or weir boards) must be at least 2 feet or two body depths (whichever is greater). In practice, this typically requires a fishway be designed to maintain this depth during low operating TW (i.e., tailwater elevation at the low design flow).
- Fully submerged stop-logs at the most downstream point of the fishway (the actual entrance) should be used to maintain depth in the entrance.
- Entrances, particularly those without significant flow contributions from an AWS, should be laterally contracted at the entrance to promote a strong entrance jet. The contracted entrance should be 62.5% (5/8th) of the channel width.

7.6.2 Slope

Recommended slopes for a Denil vary by target species.

- The slope of a Denil designed to pass only salmonids can be up to 16.7% (1:6).
- The slope of a Denil designed to pass American shad should not be steeper than 12.5% (1:8); a slope of 10% (1:10) is preferred.
- Ignoring the effect of flow development in the upper reach of baffled chutes and conceptualizing the energy-dissipating baffles in steeppasses and Standard Denil fishways as roughness elements, one may treat flow in baffled chutes as essentially uniform between any two sections. Therefore, the slope of the fishway will approximate the friction slope (slope of the energy grade line).

7.6.3 Channel Width

Similar to the fishway slope, recommended widths for Denils vary by target species.

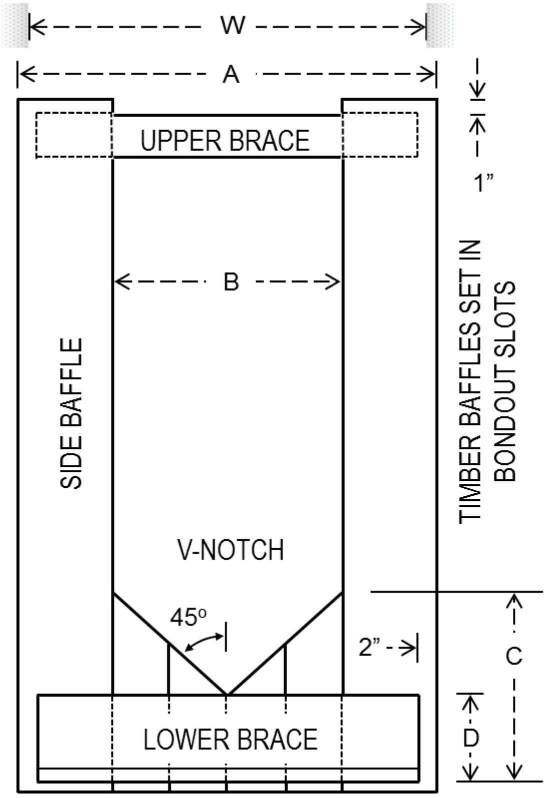
- Standard Denil ladders designed to pass only salmonids are typically 3-feet wide.
- Standard Denil ladders designed to pass American shad should have a width of 4 feet.

7.6.4 Baffle Geometry and Spacing

Figure 12 and Appendix A, Reference Plate 7-3 “Standard Denil Geometry” display the baffle geometry and the horizontal (longitudinal) spacing of baffles in the channel.

- Baffles are typically set at a 45 degree angle to the sloped floor.

- The baffle height is typically 1 foot greater than the high design flow water surface elevation.



STANDARD DENIL GEOMETRY					
W	A	B	C	D	S
4’ - 0”	4’ - 3”	2’ - 4”	2’ - 0”	1’ - 0”	2’ - 6”
3’ - 6”	3’ - 9”	2’ - 0”	1’ - 9”	10½”	2’ - 4”
3’ - 0”	3’ - 3”	1’ - 9”	1’ - 6”	9”	2’ - 0”
2’ - 6”	2’ - 9”	1’ - 5½”	1’ - 3”	7½”	1’ - 8”
2’ - 0”	2’ - 3”	1’ - 2”	1’ - 0”	6”	1’ - 4”

Figure 12: A Standard Denil baffle geometry.

A Standard Denil baffle geometry, where W is the Denil channel width (typically the inside width of the concrete channel) and S is the horizontal (longitudinal) spacing of baffles in channel.

7.6.5 Baffle Material

The baffles are typically built from dimensional lumber (e.g., 2 x 6, 2 x 8). The lumber is often assembled with stainless carriage bolts. A top cross beam lends support and should remain above the water surface through the operational range. Acceptable lumber material includes oak, white pine, ash, cypress and marine-grade high-density polyethylene (HDPE).

7.6.6 Turning and Resting Pools

Unlike pool-type fishways, baffled-chute designs do not necessarily incorporate resting pools for migrants ascending the ladder. Therefore, Denil fishways must be designed with resting pools at appropriate intervals. Resting pools can be placed between two chute sections or incorporated as turning pools at switchbacks or other directional changes.

- A resting pool should be incorporated every 6 to 9 feet of vertical rise.
- Resting pool volumes must adhere to volume requirements specified in Section 6.7.1.
- Refer to Section 6.7.2 for the sizing of Standard Denil resting pools.
- Refer to Section 7.1.6 for more recommendations regarding turning pools.

7.6.7 Operating Range

The operating range of a Denil is bracketed by the lowest and highest depths over which the fishway may safely pass fish. These depths are measured from the bottom of the exit channel, the effective hydraulic control of a Denil. Ideally, the lowest and highest depths correlate to headpond elevations at the low design flow and high design flow, respectively. Practically, this range is influenced, and often limited, by the width of the channel, the height of the baffle, and size and swimming ability of the target species. If operating levels cannot be set to encompass the entire design flow range, set the exit channel bottom to optimize passage at the site.

Appendix A, Reference Plate 7-4, “Standard Denil Operating Range” provides criteria for the operating range of a Standard Denil fishway. The low operating (water) level was based on providing two body depths of water in the rectangular section of the Denil baffle. A nominal adult body depth of 4 inches was used for river herring; 6 inches for American shad; and 8 inches for Atlantic Salmon. The horizontal projection of C, as shown of Figure 12, was used to identify the starting elevation of the rectangular section of 5 to 8 foot long baffles. The high operating level was based on the horizontal projection of the supporting cross member (located approximately 6 inches below the projected top of all baffles).

It is important to note that the high operating water level may be further limited by the swimming capability of the target species. For example, the high operating level in a 4-foot wide, 8-foot long baffle set in a Denil fishway at a 1:8 slope is approximately 5.75 feet above the exit channel bottom; however, the average velocity in the baffle may exceed the swimming ability of river herring (e.g., 4 ft/s) when the water level reaches 4.7 feet above the exit channel bottom. Limitations due to river herring (and weaker resident fish) swimming capabilities typically occur when the depth of flow exceeds 4.5 feet in any 3 or 4-foot wide Denil built at a 1:8 or 1:10 slope. Other combinations of baffle width, channel slope and target species should be considered in the design process, as appropriate.

7.6.8 Other Considerations

- Denil fishways must be inspected and cleaned on a regular basis and should not be used where debris loading is particularly heavy.
- A Standard Denil is susceptible to variations in headwater levels. Removable, flow-reducing baffles at the upstream section can be used to help overcome this limitation and extend the headpond level operating range.

7.7 Steeppass Fishways

A Denil variant, the steeppass is a baffled-chute type fishway designed to be highly portable and is applicable to low head dams. Typically, this fishway is prefabricated in 10-foot sections made of sheet aluminum or steel and bolted together on site. Compared to a Standard Denil fishway, a steeppass has a lower flow capacity and greater form roughness. It’s widely used in the state of Alaska and is commonly used on the East Coast for salmonids and river herring.

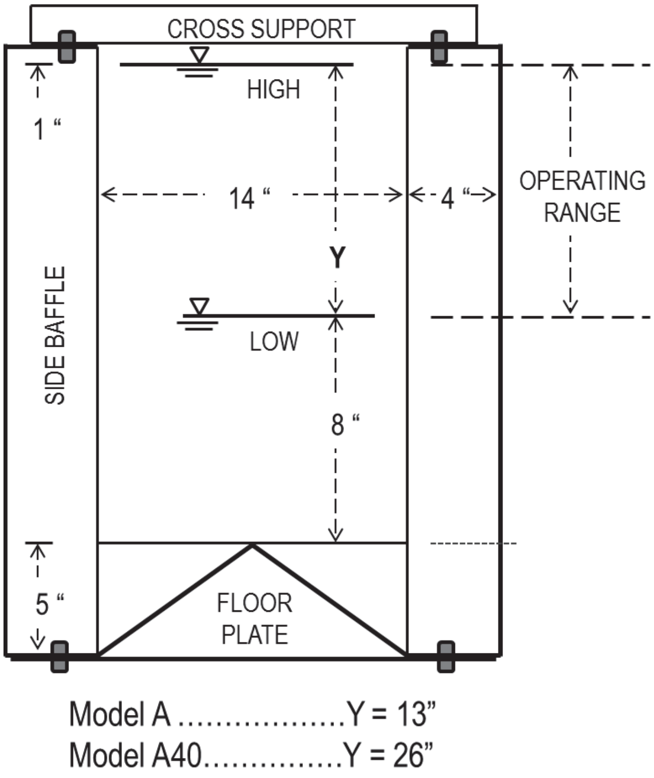


Figure 13: Steeppass fishway baffle geometry.

7.7.1 Slope

The standard slope of a steeppass fishway ranges between 10 and 33%; Engineering recommends steeppasses be installed at a slope of 20% (1V:5H) or milder.

- NMFS (2011) recommends the slope be less than or equal to 28%.
- Larinier et al. (2002) recommends a slope of 23-33%.
- NRCS (2007) recommends a slope of up to 35%.

Ignoring the effect of flow development in the upper reach of baffled chutes and conceptualizing the energy-dissipating baffles in steeppasses and Denil fishways as roughness elements, one may treat flow in baffled chutes as essentially uniform between any two sections. Therefore, the slope of the fishway will be equal to the friction slope (slope of the energy grade line).

7.7.2 Model A Steeppass

A Model A Steeppass (refer to Figure 13 and Appendix A, Reference Plate 7-5 "Model A Steeppass") is a 21-inch wide, 27-inch tall, baffled aluminum (or steel) channel. The effective zone of passage is the area between the side baffles, above the top of the floor "V" plate (8 inches below the minimum water level for the operating range), and 1 inch below the cross struts. As depicted in Appendix A, Reference Plate 7-5 "Model A Steeppass," a Model A Steeppass can only accommodate a 10-inch fluctuation in headwater level.

7.7.3 Model A40 Steeppass

The Model A40 Steeppass is a 40-inch tall, deepened version of the Model A Steeppass. Consequently, the Model A40 Steeppass can accommodate a 23 inch fluctuation in headwater level, 13 inches greater than the Model A Steeppass. The Model A40 ladder is also known as a "deepened steeppass".

7.7.4 Turning and Resting Pools

Similar to Denil ladders, a steeppass fishway does not necessarily incorporate resting pools. In most cases, the length of the steeppass is short enough such that no resting pools are required. A resting pool should be incorporated every 6 to 9 feet of vertical rise and be a minimum of 6 feet long.

7.7.5 Other Considerations

- A steeppass fishway is limited by its low flow capacity. As a result, steeppasses are only applicable to small (coastal) watersheds; the Model A is limited to locations with a drainage area of 20 square miles or less, whereas the Model A40 is limited to locations with a drainage area of 30 square miles or less.
- The direction of the V-plate within the baffle is critical to the functioning of a steeppass fishway. The apex of the V must be pointed upstream.
- In many cases an entrance structure (concrete, wood, aluminum) is used to maintain adequate flow conditions within the steeppass and at the entrance.
- A critical component of a properly operating steeppass is that the invert of the entrance be submerged a minimum of 13 inches at low tailwater.

7.8 Fish Lifts

Fish lifts or elevators, illustrated in Figure 14 (alternative views are in Figures 2, 3, and 5), are non-volitional upstream fishways that are comprised of numerous mechanical, hydraulic, and electrical components. Generally, fish lifts have a smaller footprint than large volitional passage designs. The cycle of a fish lift consists of the following sequences:

1. Fishing: Fish, attracted to the fishway entrance, enter the fishway through the entrance structure (e.g., gate). Fish swim upstream within the fishway to the holding pool through a V-gate designed to retain the fish within the pool.
2. Crowding: The V-gate (or similar mechanism) is then used to mechanically crowd the fish above the hopper.
3. Lifting: Fish are lifted within the hopper to the exit channel or impoundment.
4. Releasing: Fish are released from the hopper to the exit channel.
5. Returning: The hopper, empty of fish, is returned to the fishing position.

Further information on fish lifts is provided in the Appendix A, Reference Plate 7-6 “Fish Lift Velocities” and Reference Plate 7-7 “Fish Lift Sequence.”

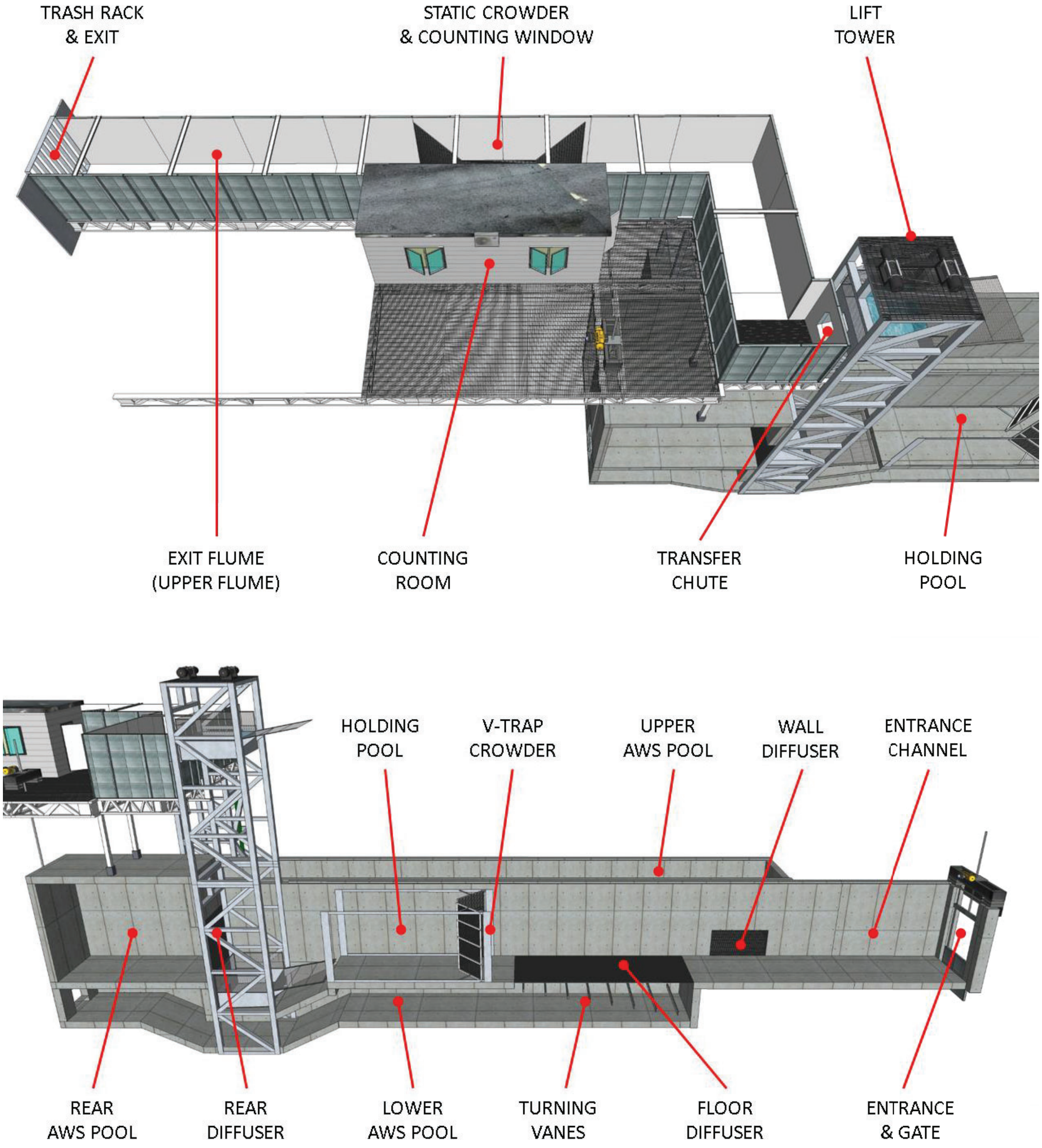


Figure 14: Multiple cross-sectional views of a fish lift.

7.8.1 Hopper

The hopper, displayed in Figure 15 (alternative views are in Figures 3 and 14), is a water retaining vessel that lifts the fish from the lower channel to the upper flume.

- While set in the fishing position, the velocities over the hopper should be within the cruising speed range (1 to 1.5 fps) to allow fish to hold without fatigue.
- Hinged flap valves in the floor of the hopper should be included to facilitate submergence after the lift cycle; it is important to ensure flap gates remain closed during the lift to prevent loss of water.
- The hopper should be free of any sharp corners or protrusions that may injure fish at any stage within the fish lift cycle.
- Fish must be prevented from leaping over the hopper sidewalls at all times. Engineering recommends a minimum of 1 foot of freeboard on the hopper sidewalls and/or an automated cover. The freeboard height need not be water-retaining; grating can be used to ensure fish do not leap from the hopper (as shown in Figure 15).
- Side clearances between the hopper and pit sidewalls should not exceed one inch.

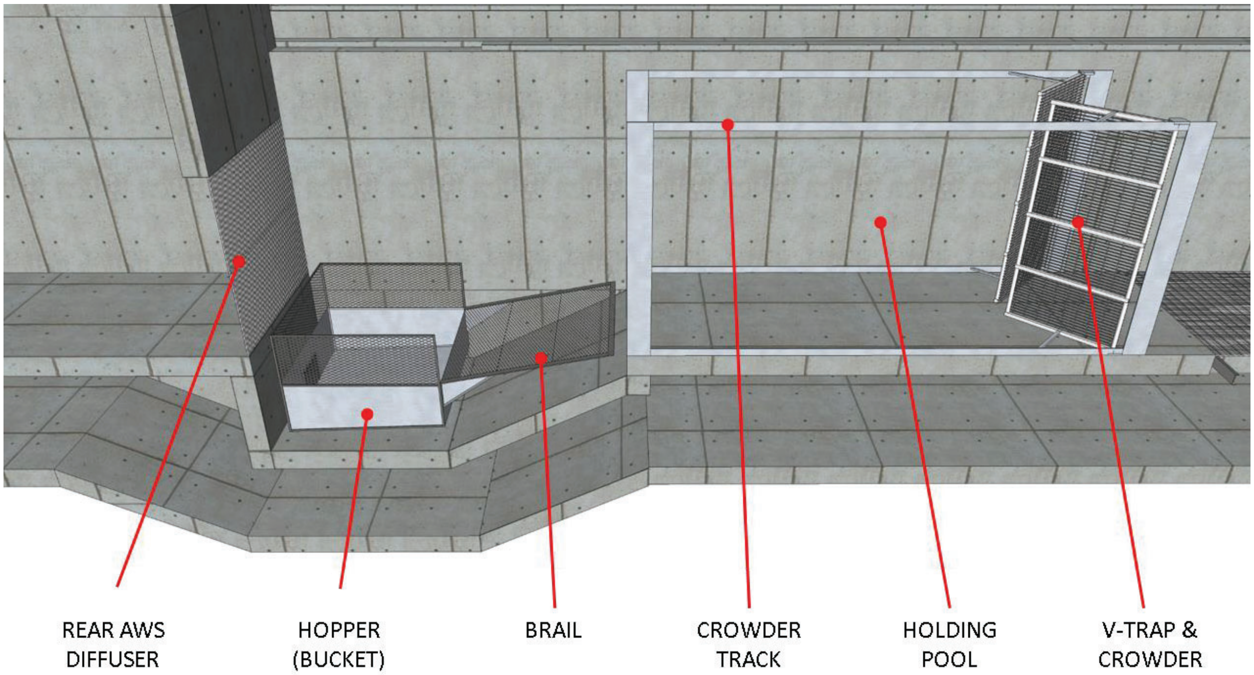


Figure 15: Illustration of fish lift components.

Fish lift components including a fish lift hopper, mechanical crowder track, holding pool, and V-trap mechanical crowder in the fishing position.

7.8.2 Holding Pool

A fish lift's holding pool, illustrated in Figure 15 (alternative views are in Figures 3 and 14), is a section in the lower channel that is downstream of the hopper and bound by the (open) mechanical crowder. The purpose of the holding pool is to retain migrants prior to crowding them into the hopper.

- Section 6.6.3 provides guidance on the proper sizing of holding pools.
- The velocities within the holding pool should be within the cruising speed range (1 to 1.5 fps for most East Coast anadromous species) to allow fish to hold without fatigue.

7.8.3 Crowder

A crowder is a mechanical device designed to move fish from the holding pool into the hopper prior to the lifting sequence. The components of a crowder typically include: 1) a trolley supported V-gate screen; 2) a hoist; and 3) the supporting crowder track on which the V-gate is moved from the entrance of the holding pool to immediately downstream of the hopper and brailling system. In the fishing position (i.e., collecting fish from the entrance), the V-gate is parked at the entrance of the holding pool (as shown in Figure 15) and acts to discourage fish within the holding pool from moving back out into the entrance channel. In this position, the V-gate is open 6 to 24 inches, although specific settings should be adjusted in response to fish behavior and implemented through adaptive management. Prior to lifting, the V-gate is closed and moves linearly toward the holding pool, effectively crowding the fish into the space above the submerged hopper.

Alternatively, the mechanical V-gate crowder can be replaced by an angled screen (or floor brail) that extends from the downstream end of the hopper to a static V-gate. The hopper and angled screen are then lifted simultaneously, forcing fish into the hopper.

- The floor screen (brail) from the hopper to the V-gate is typically set at an angle of 10 to 20 degrees.
- The dimensions of the screens used in the V-gate and floor brail must be sized to retain fish in the holding pool and avoid injury.
- In the case of a rectangular mesh screen, the openings should be sized at a ratio of 3:1 (H:V) to reduce the chance of fish injury.
- The screens must be clear of debris at all times during operation, although the AWS trash racks should prevent most debris from entering the fishway.
- The V-gate should extend at least 12 inches above the high fish passage design flow elevation.
- A typical V-gate installation has a gap between the gate and the location in which it hinges to the inside wall of the entrance flume. Rubber seals should be installed to eliminate a potential avenue around the V-gate and reduce the risk of injury.

7.8.4 Exit Flume

The exit flume is the steel or concrete channel connecting the hopper discharge chute and the fishway exit.

- Flow velocities in the exit channel should be low enough to prevent fatigue, yet high enough to motivate fish to move out of the channel and into the impoundment. Engineering recommends velocities are maintained in the range of 1.0 to 1.5 fps in this channel.

- It is important to note that velocity in the exit channel is typically created by a screened intake to a return pipe which conveys the water to the lower fishway and contributes to the attraction flow. Engineering recommends that this return pipe be outfitted with a gate or bladder valve; the valve can be used to adjust the exit flume velocity to optimize movement of fish through the exit.
- Where possible, the exit flume design should avoid sudden transitions in lighting or hydraulics that could induce an adverse behavioral reaction in fish leaving the fishway.

7.8.5 Cycle Time

Lift cycle time is defined in Section 6.6.2.4. Refer to Appendix A, Reference Plate 7-7 "Fish Lift Sequence" for a detailed view of the standard fish lift cycle sequence of events.

7.8.6 Hopper to Flume Transfer

The hopper discharge chute (i.e., the chute through which fish are emptied into the exit channel) should be large enough to empty the hopper rapidly (about 15 to 20 seconds). The discharge chute, shown in Figure 16, should also have rounded corners or a bell mouth to provide a gradual hydraulic transition to promote fish movement from the hopper to the exit channel. The transfer must provide safe passage into the receiving water of the exit flume. Engineering prefers that the fish always remain in an adequate depth of water during the transfer. In the event that trapping is required, the hopper may be configured with a secondary discharge to trapping and holding facilities.

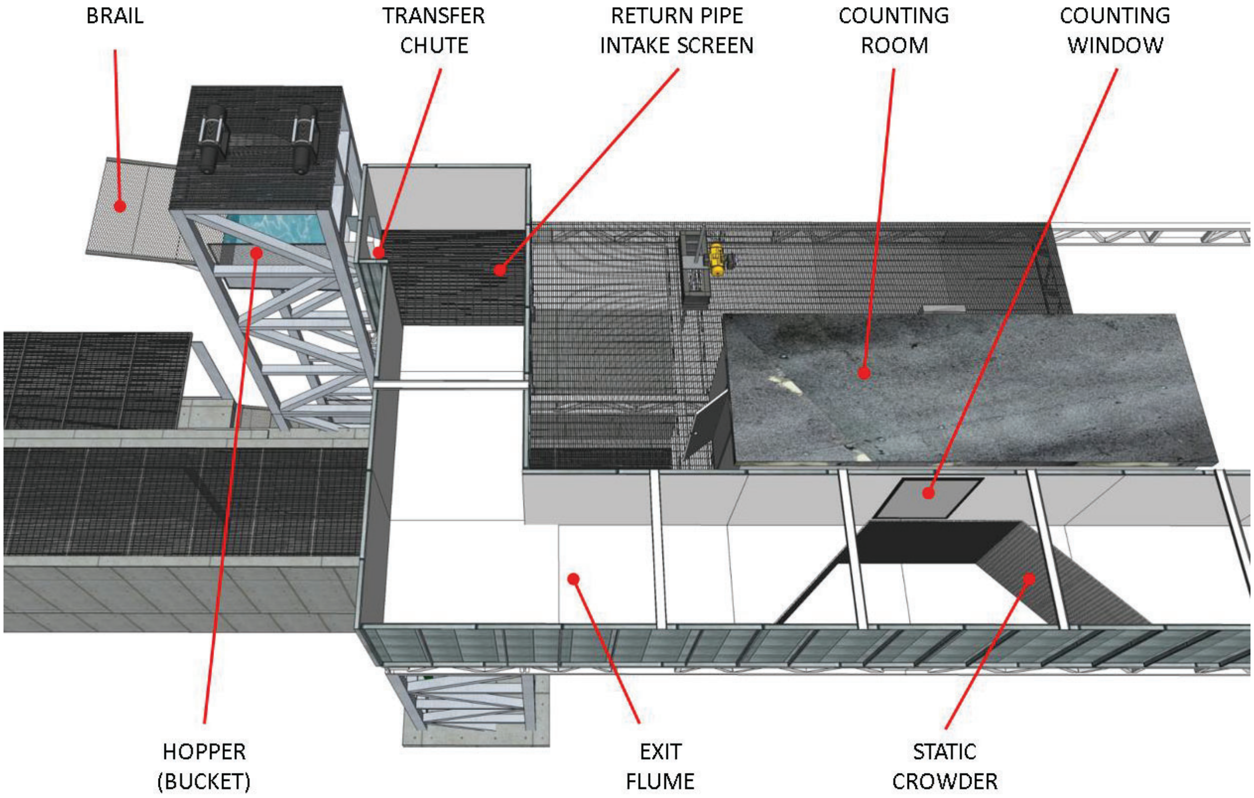


Figure 16: An illustration of fish lift transfer of fish components.

7.8.7 Lift Velocity

Engineering's recommendations for velocities within each lift component are as follows:

- Entrance weir/gate: 4 to 6 fps;
- Entrance channel: 1.5 to 4 fps;
- Wall diffuser (part of AWS): 0.5 fps;
- Floor diffuser (part of AWS): 0.5 fps;
- Holding pool and mechanical crowder: 1 to 1.5 fps;
- Hopper pit: 1 to 1.5 fps;
- Rear diffuser (part of AWS): 1 to 3 fps;
- Exit channel: 1 to 1.5 fps.

For more information, refer to Appendix A, Reference Plate 7-6 "Fish Lift Velocities."

7.8.8 Other Considerations

- An entrance attraction jet (combined fishway and AWS discharge) is created by acceleration due to entrance (lift) gate operations; the jet typically results in a 0.5 – 2.0 foot hydraulic drop into the TW. The drop must not impede fish passage and should produce streaming flow. Actual site-specific settings should be based on total attraction flow, tailwater fluctuations, fish behavior and attraction efficiency.
- Flood walls and other lift components should be designed to protect against a 50-year flood event.
- Flow in the entrance channel, downstream of the diffusers, should be streamlined and relatively free of eddies and aeration.
- Diffuser velocities are maximum point velocities; localized upwelling and aeration from the AWS should be minimal.
- Water depth in the lower flume should be greater than 4 feet at all times.
- Flow above hopper and in holding pool should be free of aeration (i.e., visible bubbles).
- As much AWS flow as possible should be discharged behind the hopper through the rear diffuser, without exceeding maximum water velocity at the hopper pit or the holding pool.
- AWS dissipaters should be designed to remove excess energy from flow.

7.9 Fish Locks

A fish lock is a non-volitional fishway consisting of a columnar structure that, when filled with water, acts as a passage route for migrating fish. The design principle of the columnar structure within a fish lock is similar to the hopper and lift tower within a fish lift. Controllable gates at the headwater and tailwater openings are used to fill the structure with water. Locks are characterized by particularly long cycle times. Fish locks are rare on the East Coast and are not typically endorsed by Engineering.

8 Counting and Trapping

A minority of fishways are equipped with counting rooms and trapping facilities. While not integral to the passage of fish, these elements may support critical monitoring and research programs. It is critical that counting and trapping facilities are designed to minimize any interference with fish passage operations.

8.1 Counting Facilities

A counting station, illustrated in Figure 16 and 17, is a section of a technical fishway constructed with the purpose of tallying fish (by species and life stage) as they ascend or descend the fishway. Typically, fish are counted as they pass a window located in the fishway exit channel. The viewing room is equipped with a counting window and camera. In some instances, the camera is replaced by a fish count technician and/or a fish count software.

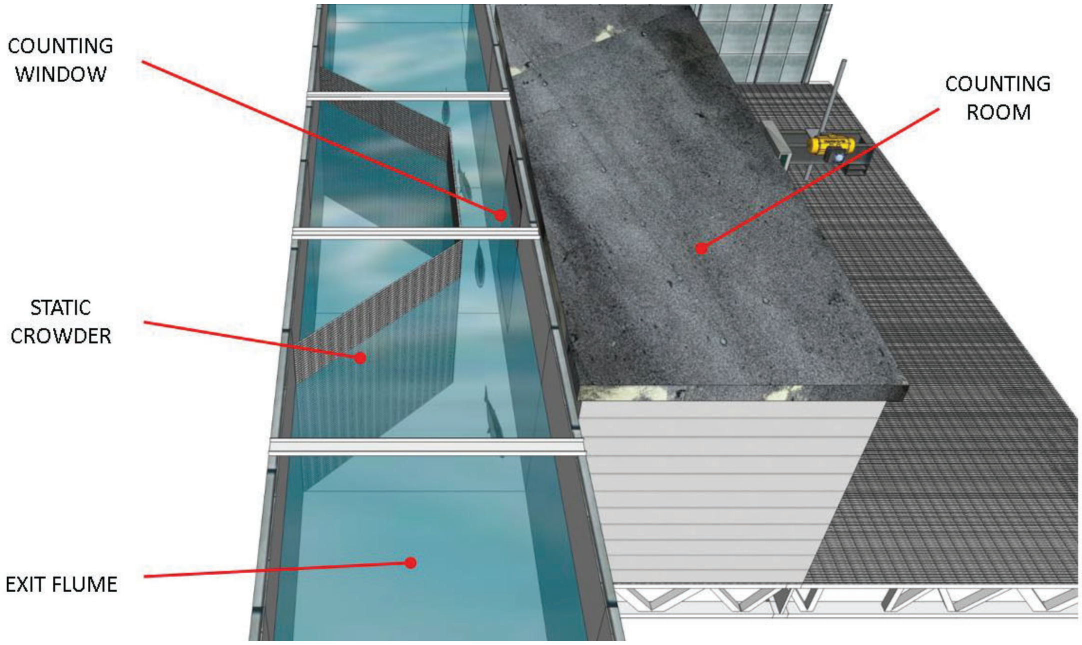


Figure 17: Illustration of fish lift counting facilities.

8.1.1 Location

The viewing room should be built alongside a section of the fishway (most often the fishway exit channel) where velocities are less than 1.5 fps.

8.1.2 Windows

- The counting window must be clean at all hours of operation. The window should be designed with adequate abrasion resistance to permit recurrent cleaning.
- The counting window must be properly lit at all hours of operation. If artificial lighting is included in the design, it must not affect passage.
- The window must be vertically oriented to allow for lateral observation.
- The observable area through the window should be a minimum of 5 feet wide and cover the full depth of the water column for manually counted facilities. For facilities where only video counts will occur, the window should be sized such that adequate field of view for the camera is provided.

8.1.3 Counting Panel

A counting panel, or observation plate, should be placed within the fishway, oriented vertically and extending from above the water surface to the fishway floor. The counting panel should be parallel to the counting window. The panel should be designed to create a strong contrast between the background and the fish when viewed through the window from the viewing room. The distance from the window to the counting panel depends upon site-specific factors (e.g., turbidity); although the typical range is 12 to 30 inches. The clarity of the counting plate can be enhanced through the use of reflective tape.

8.1.4 Static Crowder

Static crowders, or deflectors, should be installed to ensure fish pass within the observable space through the window.

- A vertically oriented static crowder that is angled from the fishway wall opposite the counting window to the counting panel is designed to guide fish to in front of the window.
- A static crowder acting as a ramp from the fishway floor is designed to guide fish into the observable space of the window.
- Crowders must be frequently cleaned of debris. When there is too much debris buildup, velocities are higher through the static crowder (possibly causing impingement) and

flows can be increased in front of the window (increasing velocities above the design velocity). Cleaning the crowder should not necessitate shutting down the fishway.

- Static crowder panels are typically constructed of 1”x3” or 1”x4” galvanized steel or aluminum grating. To minimize movement of small fish (e.g., alewife) through a static crowder panel, the grating should always be installed with the longer dimension (i.e., 3 in. or 4 in.) aligned to the horizontal plane.

8.1.5 Gates

A gate within a counting facility is typically used to temporarily halt the movement of fish through the fishway as needed by a fish count technician. A gate should never remain closed for long durations while fish are migrating. If installed, a gate should follow the same protocols as trapping facilities gates (see Section 8.3.4).

8.1.6 Video

The use of a video camera and/or other recording technology enables continuous, long-term recordings of fish.

- Motion detection software is recommended to reduce review times of the video recordings.
- Any use of light should not alter fish behavior. For night time recordings, Engineering recommends specialized low-light cameras or infrared illumination systems.
- If water turbidity is high through the fishway, imaging technologies (e.g., hydroacoustic monitoring, sonar imaging cameras) may be required.
- Frequent checks must be made to ensure that the quality of recordings is high.

8.2 Biotelemetry Installations

Biotelemetry is defined as the remote monitoring of individual fish or other organisms through space and time with electronic identification tags (e.g., radio tags, acoustic tags, passive integrated transponder, or PIT tags).

- Selection of the biotelemetry technology for a site must consider both hydraulic conditions (e.g., water depth, conductivity) and other constraints such as detection range.

- The electronic identification tags should be carefully selected such that they do not alter behaviors or survival of the monitored fish.
- The design of the biotelemetry study must ensure that the flow field within the fishway is not altered. For instance, antennas should always be recessed 2-4 inches into the wall of the fishway (new designs should include bond-outs for this purpose) or installed someplace else outside of the flow path (e.g., above the upper cross member of a Denil).
- Antennas should not be placed on or around steel structures due to the increased likelihood of impaired signal detection (PIT tags) or unwanted signal transmission (radio telemetry).

8.3 Trapping Facilities

A trapping facility is a section of a technical fishway constructed with the purpose of trapping select fish as they ascend the fishway. Typically, a trapping facility is built to also operate as a counting station (see Section 8.1).

8.3.1 Location

The trapping facility must be built alongside a section of the fishway where velocities are low (less than 1.5 fps), often within the fishway exit channel. Trapping facilities at lifts should be located at the primary hopper discharge. Secondary lifts to a trapping facility should be avoided.

8.3.2 Windows

Trapping facility windows require the same protocols as counting facilities (see Section 8.1.2).

8.3.3 Static Crowder

If installed, trapping facility static crowders require the same protocols as counting facilities (see Section 8.1.4).

8.3.4 Gates

Design considerations for gates within the trapping facility (installed on both the trap and bypass) largely pertain to safety concerns for the fish.

- The opening/closing speed of the gate must be slow enough such that it does not injure fish in its path.

- The amount of pressure applied at the pinch point (i.e., the point of contact between the gate and the opposing surface) should be low enough to minimize fish injury if a gate is closed directly on a fish.
- Neoprene padding (or equivalent) should be used on sharp edges, protuberances, and pinch points that may injure fish.
- The gate, when closed, should have no gap between it and the opposing surface.
- When closed, the gate is designed to exclude fish, not water. The gate mesh should be sized to reduce the chance of impingement and fish injury by maintaining velocities through mesh of less than 1.5 fps. The rectangular mesh openings should be sized at a ratio of 3:1 (H:V) to reduce the chance of fish injury.

8.3.5 Bypass and Trap Design

The bypass and trap are the two routes for a fish to move through a trapping facility. Engineering recommends the following:

- Installing a series of traps and bypasses to provide for redundant control/capture
- Locating the trap within the main flow path of the fishway.
- Installing the counting window within the wall of the trap.
- Properly sizing the bypass to ensure velocities remain low enough to allow for fish to pass within the constricted area if the bypass gates are open.
- To the degree possible, “water-to-water” transfers are preferable; handling and netting should be minimized.

8.3.6 False Weirs

False weirs are used, often at the exit of a steeppass fishway, to volitionally capture fish in a trap or bypass.

- Depth over the crest of the false weir should be maintained at least 6 inches.
- Streaming (rather than plunging) conditions should be maintained over the weir to minimize leaping/jumping behavior.
- Where feasible, a gravity driven water supply should be used for false weirs; pumps may create noise and vibration that could induce an adverse behavioral reaction in fish that leads to injury or rejection.

- Due to the confined space within a false weir, neoprene padding (or equivalent) should be used on any metal edges in the flow path to prevent injury from leaping/jumping.

9 Downstream Passage

9.1 Site Considerations

At a typical hydropower facility there are three primary routes of downstream passage for a fish. These three routes, ordered by typical proportion of average annual river flow, are: 1) through the turbine intakes; 2) over a spillway; and 3) through a fish bypass system. In the absence of better information (i.e., site-specific studies), Engineering does not recognize passage through the turbine intakes as an acceptable downstream route for fish. Fish injuries and mortalities may occur within this route as a result of rapid pressure changes, cavitation, turbine blade strikes, grinding, shear, and excessive turbulence. Fish may pass safely over the spillway and through gates, but generally only during high flow events and the degree to such passage is “safe” will vary with several factors (e.g., height, velocity, landing area). Conversely, the fish bypass system is designed to provide safe, timely, and effective passage to out-migrating fish throughout the entire migration season.

Design of downstream fish passage facilities varies with site-specific characteristics and the timing and movement of the migratory fish of interest. Typically, these systems consist of four primary components (Towler ed., 2014):

- Physical/behavioral guidance screen or rack;
- One or more bypass openings (e.g., weir, chute, sluice, or orifice);
- Conveyance structure (i.e., open channel or pressurized conduit);
- Receiving pool (e.g., plunge pool).

9.2 Zone of Passage for Downstream Migration

The ZOP (defined in Section 2.2) for downstream migration encompasses a far-field attraction zone, a near-field attraction zone (within the impoundment and/or power canal), the fish bypass system, and the tailrace (or surrounding river channel) downstream of the barrier. Numerous other conceptual models have been developed to describe the regions influenced by a hydroelectric project. For example, Johnson and Dauble (2006) classified the flow upstream of a typical hydroelectric facility as consisting of three separate zones; the approach, discovery, and decision zone. The first zone an out-migrating fish will enter is the approach zone, located about

100-10,000 meters upstream of the dam. Next is the discovery zone, located about 10-100 meters from the dam, where the fish are expected to encounter the flow field of the fish bypass system and turbine intakes. Last is the decision zone, located about 1-10 meters from the dam. Key features here that impact fish behavior are velocity, acceleration, turbulence, sound, light, structures, other fish (Larinier, 1998), and total hydraulic strain (Nestler et al., 2008).

9.3 Attraction, False Attraction and Bypasses

The fish bypass system is intended to function as a safe outlet for fish migrating downstream beyond the barrier. For this to occur, the bypass must be designed to provide sufficient attraction flow such that fish will sense the bypass route and pass through it in a timely manner to avoid undue delay, fatigue, injury, and/or mortality.

9.3.1 Attraction Flow Requirement

The flow fields created by project elements (i.e., turbine intakes, spillways, gatehouses, flood gates, and trash/log sluices) may attract (or dissuade) out-migrating fish and thus, compete with the directional cues created by the fish bypass system. Successful fish bypass systems must create hydraulic signals strong enough to attract fish to one or multiple entrances in the presence of these competing flows (i.e., false attraction), in particular the turbine intakes. Therefore, the downstream fish bypass flow requirement is based on a fraction of the maximum station hydraulic capacity.

- The downstream bypass should be designed to pass a minimum of 5% of station hydraulic capacity or 25 cfs, whichever is larger. For example, a new powerhouse with a hydraulic capacity of 7,800 cfs should be designed to provide a downstream bypass flow of at least 312 cfs.
- The bypass should be designed to pass this flow under all headpond levels and station operating conditions that occur during the migration season.

9.3.2 Flow Recapture Systems

Generally, flow recapture systems introduce an increased hazard potential for fish and are not recommended. A proposal for such a device or configuration should be reviewed by Engineering.

9.4 Conveyance to Receiving Waters

A conveyance structure (i.e., open channel or pressurized conduit) creates a safe passage route hydraulically connecting the bypass opening to the receiving pool (when directly discharging from the bypass opening to the receiving pool is not possible).

9.4.1 Conveyance by Flume

Downstream migrating fish may be conveyed to the plunge pool through a flume.

- Bypass channels should be non-pressurized (i.e., open channel flow).
- The spatial velocity acceleration within the bypass channel should be within the range of 0 to 0.2 fps per foot of travel.
- Bypass flumes should maintain a flow depth of 1 foot or two body depths of the largest fish, whichever is greater.
- Fish are often conveyed though bypass channels at relatively high speed. It is therefore critically important that the wetted perimeter of a bypass channel be smooth and free of protuberances (e.g., sharp corners, exposed bolts).

9.4.2 Conveyance by Conduit

Downstream migrating fish may be conveyed to the plunge pool via a conduit, particularly when the bypass route must penetrate a power canal wall or other structure. Engineering recommends the following:

- For conduits discharging into tailraces, a horizontal outlet 6 to 10 feet above normal tailwater is desirable; where the outlet is not horizontal, the plunge pool depth must account for the vertical component of (outlet) velocity.
- For outflows of less than 40 cfs, the conveyance pipe must be a minimum of 2 feet in diameter. Conduit diameters of 3 feet or larger are advisable for flow rates greater than 40 cfs.
- Bypass conduits should be designed to have free surface flow conditions within the pipe (i.e., non-pressurized). The flow depth should be greater than or equal to 40% of the pipe diameter at all points within the conduit. If required by site-specific conditions, pressurized bypass conduits should be evaluated by Engineering prior to installation. Sub-atmospheric pressures are not permitted within the conduit in this case.

- Bypass conduits should be designed at the smallest feasible length. If the bypass conduit is long (e.g., greater than 150 feet) it should include multiple access points to allow for inspection and debris removal.
- Fish should never free fall or be pumped within the conduit.
- To reduce the potential for debris clogging and excessive turbulence, bends in the pipe should be at a minimum of a 10 foot radius and the ratio of bend radius to pipe diameter should be five or greater.
- No hydraulic jump should exist at any location or during any time within the conduit.
- The bypass conduit must be smooth and free of protuberances that may injure fish.
- The conduit design should avoid the use of valves and/or gates. If required by site-specific conditions, valves and/or gates should be evaluated by Engineering prior to installation.
- Bypass conduits should be designed to allow trapped air to escape.

9.4.3 General Considerations

- The conveyance structure design must take measures to minimize any debris or sediment build-up.

9.5 Receiving Waters

9.5.1 Location

The receiving water, often referred to as the “plunge pool,” is the body of water downstream of the barrier where the conveyance outlet discharges both fish and water.

- Bypass conduits/flumes must discharge into safe receiving waters that minimize exposure to predation.
- Transition from the conveyance outlet to the receiving water may temporarily stun fish creating a higher risk of predation. To reduce this increased risk of predation, Engineering recommends that bypass outfalls be located at the thalweg or where the receiving waters are moving in excess of 4 fps.

9.5.2 Plunge Pool Requirements

Whether natural or engineered, the conveyance structure outfall must discharge into a pool of adequate depth and volume to provide a safe transfer for fish from the bypass system to the waters downstream of the barrier.

- Plunge pools depth should be equal to 25% of the fall height or 4 feet, whichever is greater. For sloped outlets, the equivalent fall height is measured from the height of 0 initial vertical velocity (V_y).
- The impact velocity (V_i) must be less than or equal to 25 fps to avoid any injury to fish as they hit the surface of the plunge pool.

These Engineering criteria are illustrated in Figure 18.

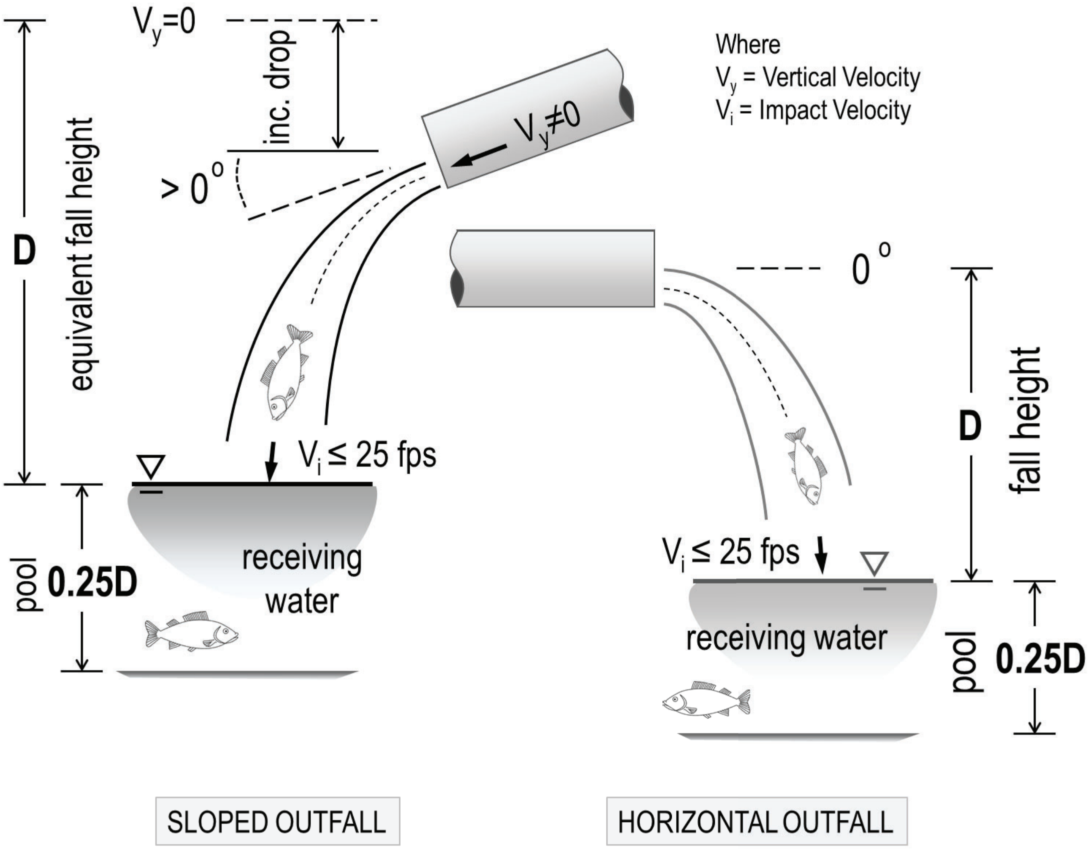


Figure 18: Fall height and plunge pool requirements

9.6 Guidance Technologies

Guidance technologies rely on the rheotactic response of fish, among other factors, to improve downstream passage efficiency and reduce migration delay. Rheotaxis is defined as a fish's behavioral orientation to the water current (Montgomery et al., 1997). A fish's movement with (or against) the water current is referred to as a negative (or positive) rheotaxis, respectively. If guidance is successful, the fish will avoid entrainment in a dangerous intake structure (i.e., turbine intakes) while passing from the headpond to the tailwater of a hydroelectric facility through a safer passage route (i.e., the bypass). The following sub-sections provide Engineering's recommendations for each guidance device.

9.6.1 Angled Bar Screen

An angled bar screen (or bar rack) is constructed of a series of vertical slats, placed along a diagonal line within a power canal terminating at the bypass (illustrated in Figure 19). The broad faces of the slats are generally oriented at 45 degrees to the approach flow.

9.6.1.1 Velocity Considerations

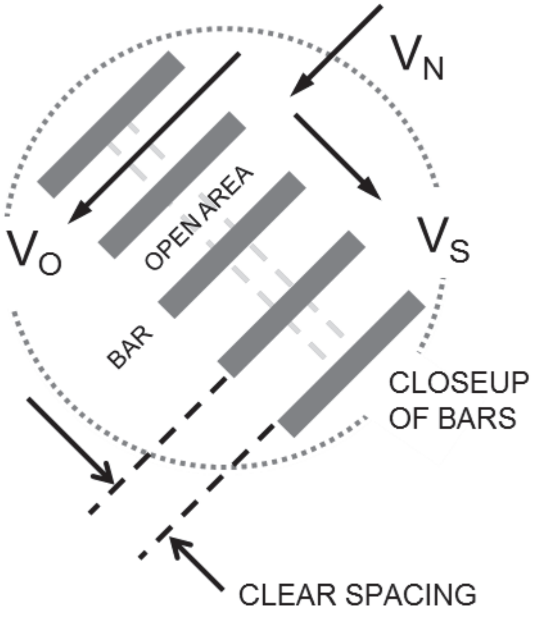
In the case of a full-depth guidance structure (e.g., louvers and angled bar screen), a 2-dimensional velocity vector is often used to inform the design. These two velocity components, displayed in Figure 19, are referred to as the sweeping velocity (velocity component parallel to the guidance structure pointing in the direction of the bypass) and the normal velocity (velocity component perpendicular to the guidance structure pointing directly at the face of the structure). Normal velocities should not exceed 2 fps measured at an upstream location where velocities are not influenced by the local acceleration around the guidance structural members. This criterion was established to minimize or eliminate fatigue in weaker species (e.g., riverine species, American eel) and allow fish to escape entrainment/impingement without resorting to burst swimming speed. Typically, the normal velocity is measured 1 foot upstream and at a right angle to the guidance structure. The spacing and the normal velocity influence the head loss through an angled bar screen. Appendix A, Reference Plate 9-1 “Angled Bar Screens” provides a nomograph-based method for estimating these losses.

9.6.1.2 Angle

A guidance structure installed at 45 degrees or less to the upstream flow field will result in a sweeping velocity greater than or equal to the normal velocity, thereby reducing the likelihood of impingement and entrainment. For this reason, guidance technologies are typically set at a maximum angle of 45 degrees to the flow field, thus creating a hydraulic cue designed to elicit a negative rheotactic response from migrating fish (encouraging their movement downstream towards the bypass). In the case of angled bar screen, Engineering recommends an angle to flow between 30 and 45 degrees.

9.6.1.3 Bar Spacing

Engineering recommends a clear spacing between bars (illustrated in Figure 19) of 1 in. for adult Atlantic salmon smolts. For American eels, 3/4 in. (20 mm) clear spacing is recommended based on the findings of Travade et al. (2005).



<u>Velocity components at the screen:</u>

- Sweeping velocity, V_S
- Normal Velocity, V_N

$$V_S \geq V_N$$

- Open Velocity, V_O

Clear spacing between bars:

- smolts: less than or equal to 1 inch
- eels: less than or equal to ¾ inch

Figure 19: Spacing and velocity components at angled bar screen.

9.6.2 <u>Louvers</u>

A louver system is constructed of a series of vertical slats placed along a diagonal line within a power canal terminating at the bypass. As fish approach the louvers, the turbulence and flow field that is created by the bars tend to elicit an avoidance response resulting in lateral movement away from the louvers and guiding fish toward a bypass.

9.6.2.1 Angle

In the case of louvers, Engineering recommends an angle to flow between 10 and 20 degrees. A study by Bates and Vinsonhaler (1957) recommends louvers to be set at an angle between 10 and 16 degrees.

9.6.2.2 Louver Geometry

- The vertical slats of louvers are typically full-depth.
- The broad face of the slat is at a right angle to the approach flow.
- The slat width is 2.5 inches and thickness is 3/16 inches.
- The spacing between slats should be 1 inch.

9.6.2.3 Velocity Considerations

Refer to Section 9.6.1.1.

9.6.3 Floating Guidance Systems and Booms

A floating guidance system for downstream fish passage is constructed as a series of partial-depth panels or screens anchored across a river channel, reservoir, or power canal. These structures are designed for pelagic fish which commonly approach the guidance system near the upper levels of the water column. While full-depth guidance systems are strongly preferred, partial-depth guidance systems may be acceptable at some sites (e.g., for protection of salmonids, but not eels). Site-specific considerations will influence the selection and design of guidance systems and booms. The use of such downstream passage systems should be done in consultation with Engineering.

9.6.3.1 Velocity Considerations

In the case of a partial-depth floating guidance system, a strong downward vertical velocity component may be present upstream of the wall (Mulligan et al., 2017). The vertical velocity component may compete with, or even overwhelm, hydraulic cues created by the sweeping and normal velocities (defined in Section 9.6.1.1). The downward velocity component upstream of the guidance system is increased as the permeability of the wall is reduced. However, increasing the permeability (through the use of perforated plates or screens as the guidance panels) can exacerbate impingement potential.

9.6.3.2 Depth & Angle

A floating guidance system should be installed at a depth and angle such that sweeping-flow dominant conditions (i.e., greater sweeping velocities than both downward vertical velocities and normal velocities) prevail within the expected vertical distribution of fish approaching the structure.

9.6.4 Behavioral Barriers

A behavioral barrier is any device, structure or operation that requires response, or reaction (volitional taxis) on the part of the fish to avoid entrainment. The following subsections include examples of behavioral barriers.

9.6.4.1 Acoustic

The use of acoustics to guide or create a barrier to fish is considered experimental. Any use of such device should be done in consultation with Engineering. Criteria are in development.

9.6.4.2 Electric

The use of electricity to guide or create a barrier to fish is considered experimental. Any use of such device should be done in consultation with Engineering. Criteria are in development.

9.6.4.3 Lights

The use of light to guide or create a barrier to fish is considered experimental. Any use of such device should be done in consultation with Engineering. Criteria are in development.

9.7 Surface Bypasses

A surface level bypass targets surface-oriented out-migrating fish species, such as Atlantic salmon, blueback herring, alewife, and American shad. However, potential diel movements in deeper water areas around intakes and in the forebay areas should be considered and examined. Appendix A, Reference Plate 9-2 "Bypass and Plunge Pool" provides numerous details on downstream bypass systems.

9.7.1 Location and Orientation

Downstream bypass flow must be discernable in the presence of unit intakes (a competing flow). Typically, the bypass is located in close proximity to the turbine intakes and oriented in line with the flow field. Where possible, the bypass should be located such that the downstream migrants will likely encounter the bypass before exposure to the intake racks.

9.7.2 Bypass Geometry

Surface bypasses operate as overflow weirs. Bypasses should be a minimum of 3-feet wide and 2-feet deep. Depth and width may be increased to meet other design criteria specified in this document. Further, Engineering recommends uniform acceleration weirs over sharp-crested weirs to minimize regions of high acceleration. As described by Haro et al. (1998), Kemp et al. (2005), Johnson et al. (2000), and Taft (2000), several surface-oriented juvenile fish species prefer to avoid regions of high acceleration. Therefore, the geometry of a surface level bypass weir should create a uniform spatial flow velocity increase (1 m/s per m of linear distance), similar to the NU-Alden weir as tested in Haro et al. (1998). Figure 20 displays the uniform acceleration weir in comparison to a sharp-crested weir.

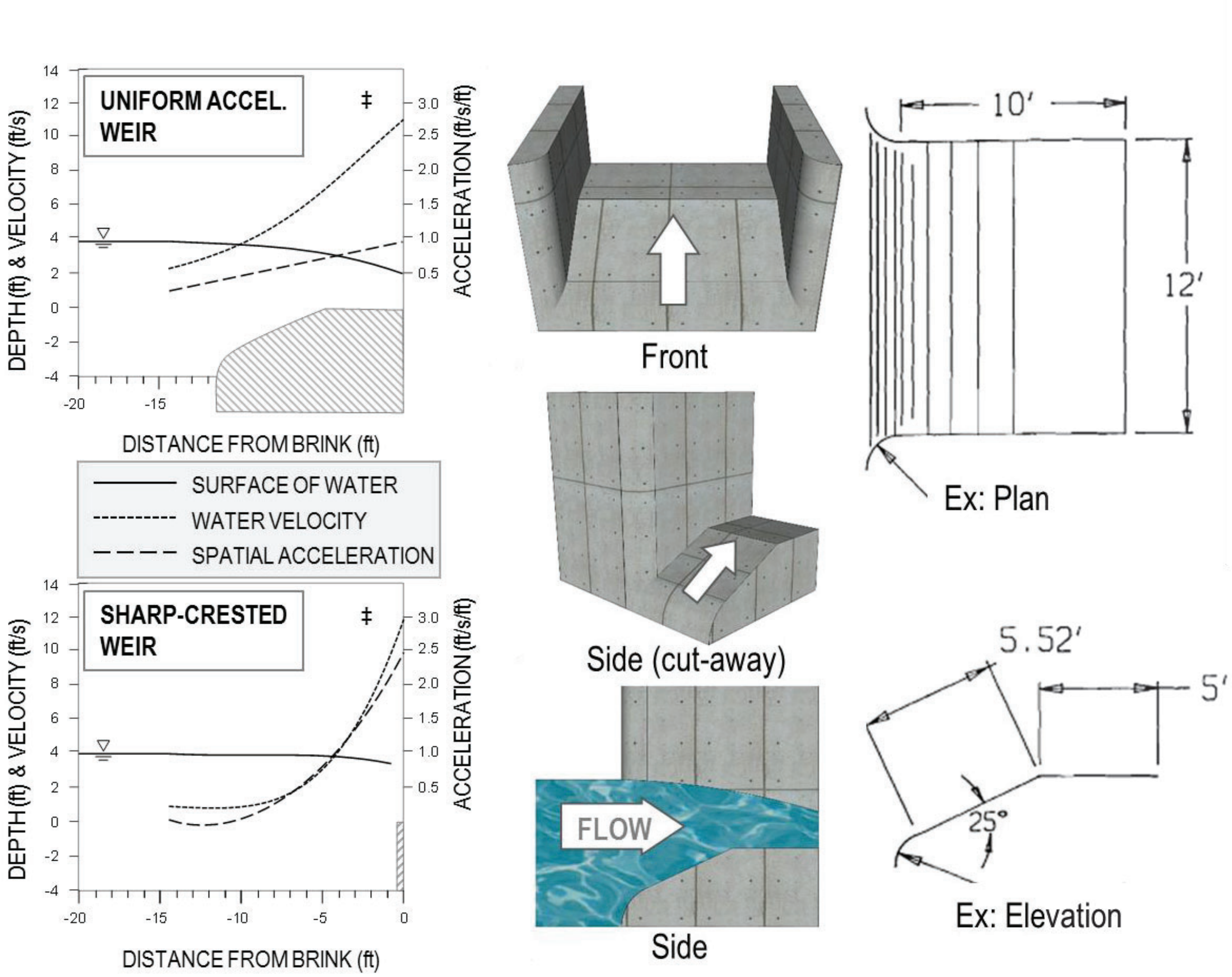


Figure 20: Comparison of uniform acceleration and sharp-crested weirs.

The left column displays the depth, velocity, and acceleration versus the distance from the brink of the weir for both a sharp-crested weir (bottom) and uniform acceleration weir (top). The center column shows a sketch of the uniform acceleration weir from the front (top), side cut-away (middle), and side (bottom). The right column displays a plan (top) and elevation (bottom) view of the uniform acceleration weir with example dimensions in ft.

9.7.3 Hydraulic Considerations

The bypass must generate velocities higher than the ambient flow to attract and capture fish without eliciting an avoidance response in fish.

9.7.4 Trash Racks

Coarse trash racks, if required, should not disrupt downstream passage of fish through the bypass. If trash racks are not used, then conduits should be designed with large diameter, straight runs and rounded corners in order to pass large trash.

9.8 Low Level Bypasses

A low level bypass targets benthic-oriented out-migrating fish species, such as American eel and shortnose sturgeon.

9.8.1 Location and Orientation

Criteria in development.

9.8.2 Bypass Geometry

Criteria in development.

9.8.3 Hydraulic Considerations

Criteria in development.

9.8.4 Trash Racks

Criteria in development.

10 Nature-Like Fishways

Nature-like fishways (NLFs) are artificial instream structures that span stream barriers. NLFs are constructed of boulders, cobble, and other natural materials to create diverse physical structures and hydraulic conditions that dissipate energy and provide efficient passage to multiple species including migratory and resident fish assemblages, refer to Appendix C, “Federal Interagency Nature-like Fishway Passage Design Guidelines for Atlantic Coast Diadromous Fishes” (Turek et al. 2016). They typically consist of a wide, low gradient channel (usually less than 1:20 slope) with a concave stream channel cross section (Haro et al. 2008). NLFs represent a new fish passage technology, on which, relatively little evaluation has been performed. While many of the concepts are similar, Engineering does not categorically support application of technical fishway criteria presented in Chapters 6, 7 and 9 to the design of NLFs.

10.1 Layout and Function

In terms of layout and function, nature-like fishways may be categorized as:

- Rock ramp: sloped watercourse that links two pools of different elevation (e.g., headwater and tailwater of a dam) constructed in the existing channel and spanning the entire river. The entire stream flows through a (full width) rock ramp, thus eliminating competing flows and reducing concerns related to attraction. Where possible, Engineering recommends rock ramps over partial rock ramps and bypasses.
- Partial-width rock ramp: constructed in the existing channel and similar in composition to a (full-width) rock ramp, a partial-width rock ramp does not span the entire river width. As a result, the partial rock ramp is subject to false attraction from gates, spill, and other adjacent watercourses. Detailed analyses that estimate flow distribution through all paths (e.g., spill, gates, NLF) under varying hydrologic conditions (e.g., low design flow, high design flow) should be performed to evaluate the magnitude, persistence and location of competing and attraction flows.
- Bypass: channels designed to convey water and pass fish around a dam or other barrier. The primary distinction is that this fishway is constructed outside of the exiting river channel. Assuming flow continues to pass over the adjacent stream barrier, bypasses are prone to attraction problems. Detailed analyses that estimate flow distribution through all

paths (e.g., spill, gates, NLF) under varying hydrologic conditions (e.g., low design flow, high design flow) should be performed to evaluate the magnitude, persistence and location of competing and attraction flows.

10.2 Hydraulic Design

The hydraulic design of NLFs can be categorized as:

- Roughened channel: hydraulically functions as gravity-driven, free-surface flow under uniform or gradually varied conditions. Depending on the complexity of design, roughened channel NLFs are designed using a 1-D hydraulic software (e.g., HEC-RAS) or 2-D/3-D computational fluid dynamics software. Accurate estimates of channel roughness (e.g., Manning's n, Nikuradse's k_s) are critical to this hydraulic design.
- Step-pool: hydraulically functions as a series of pools and control structures (e.g., rock weirs) under rapidly varied conditions. Accurate estimates of weir coefficients are critical to this hydraulic design.
- Hybrid: may function as a roughened channel or step-pool depending on depth, approach velocity and flow conditions (e.g., pool and riffle structure). Hybrid NLFs are complex and should be analyzed accordingly.

10.3 Roughened Channel NLF

In general, the slopes of roughened channels are milder than step-pool structures. Consequently, this type has a larger construction footprint requiring more space. Under uniform and gradually varied flows conditions, roughened channels with steep slopes produce higher velocities that cannot be mitigated by larger roughness elements (e.g., boulders) without producing unacceptable levels of turbulence and air entrainment. While final approval of any fishway should be based on parameters that directly influence passage (e.g., velocity), Engineering recommends that roughened channels are designed at slopes less than 3%.

10.4 Step-Pool NLF

Step-pool designs approximate pool-and-weir technical fishways. Notionally, fish move through these structures by bursting over a weir then momentarily resting in the upstream pool.

10.4.1 Slope

Suitable fish passage conditions (e.g., flow velocity) can often be created in step-pools with slopes of 5% or less. Species-specific recommendations on slope for step-pool NLFs are provided by Turek et al. (2016), Appendix C. At grades steeper than 5%, NLFs are generally not recommended.

10.4.2 Pool width

Full-width rock ramps (i.e., full-width pools) are preferred. For partial width rock ramps and bypasses, species-specific recommendations for step pools are provided by Turek et al. (2016), Appendix C.

10.4.3 Weir Geometry

Rock weir geometry is dictated by stability, hydraulic, and biological considerations. Rock weirs used to partition pools are typically braced upon footer stones and sized to ensure stability under flood flow conditions (e.g., 50-year flood event). Hydraulically, these rocks should be of sufficient longitudinal thickness to function as broad-crested weirs. Refer to Appendix A, Reference Plate 10-1 “Rock Weir Hydraulics” for additional details. Species-specific recommendations for weir depths and widths are provided by Turek et al. (2016), Appendix C.

11 Dam Removal and Channel Design

A significant number of aging dams in the U.S. are beyond their designed life span and may no longer provide any societal value. In such cases, dam removal is Engineering's preferred method of restoring fish passage to an impacted watershed.

11.1 Channel Adjustments

Dam removal often leads to temporary increases in sediment transport and, over time, channel adjustments (widening, bed profile changes, alterations in grain size distribution). The Shields Number provides a method of predicting the initial of motion of sediment. Appendix A, Reference Plate 11-1 "Initiation of Motion" serves as a convenient screening tool for such predictions. For detailed predictions that account for the influence of grain angularity, embedment, and periphyton cover, more complex sediment-transport models are warranted.

12 Road-Stream Crossings

Road-stream crossings act as critical infrastructure for multiple purposes such as protection of embankments, roadways, and property. Yet, if these crossings are not designed with aquatic organism passage (AOP) in mind, they can cause a break in the continuity of vital ecosystems that rely on the habitat within our streams and rivers. Fragmentation of this habitat can have detrimental effects on the life cycles, population dynamics, and overall survival of numerous species.

There is a multitude of ways in which road-stream crossings can hinder successful passage of critical species; some of the most common are listed below:

1. High Velocity – road-stream crossings that constrict the natural width of the river induce velocities that are higher than those witnessed within the natural reaches of the stream or river. Most crossing structures do not maintain an appropriate roughness within the structure to dissipate the energy of the constricted flow and therefore can produce velocities that exceed the swimming capabilities of various species.
2. Perched Culvert – over time, higher than natural velocities (especially during flood events) can promote scour downstream of the culvert. Depending on the composition of the streambed, this degradation can become extensive and the crossing can become perched (i.e., a drop in water surface elevation from the outlet of the crossing to the stream).
3. Outlet Pool Too Shallow – in cases where culverts do become perched, it is important that the outlet pool is deep enough for the species to generate the momentum necessary to make the jump into the culvert. It is important to note, that once perched, the crossing will hinder successful passage of any species that does not naturally leap, especially juveniles.
4. Shallow Water Depth – if the crossing is set at an elevation that does not meet the natural grade of the streambed, depths within the crossing can become too shallow for successful fish passage.

5. Debris Accumulation – an undersized culvert that constricts the river flow becomes a high risk location for debris accumulation. Debris accumulation can cause hydraulic conditions, such as a drop in water surface elevation that may hinder fish passage.

12.1 Design Methods

There are three common design methods for providing AOP at road-stream crossings that seek to overcome the aforementioned issues for successful fish passage:

- Hydraulic Design: This approach is analogous to the development of technical fishways and the criteria in Chapters 4 and 5 may inform design methods. Through careful selection of culvert diameter, slope, material (and in-culvert baffles and weirs), the designer seeks to create hydraulic conditions that meet fish passage criteria (e.g., velocity, depth, EDF) for one or more target species. The scale and prismatic geometry of a culvert, make it challenging to achieve hydraulic conditions that pass all species (especially weaker, resident fish). Hydraulic design is typically used to retro-fit existing culverts where site conditions or economics prohibit other options.
- “No Slope” Method: This technique, described by the Washington Department of Fish and Wildlife (2003), involves counter-sinking a culvert such that the bed within is at least as wide as the channel bank-full width. It represents a relatively low cost replacement for impassable culverts, but its application is limited to mild slopes and, over time, may suffer from head-cutting at the inlet.
- Stream Simulation: These structures have a continuous bed that approximates the natural streambed (or reference reach) up to bank full flows. In so doing, aquatic species generally experience no greater difficulty moving through the structure than through the adjacent stream channel.

Engineering’s preferred method for providing passage at road-stream crossings is stream simulation. Forest Service Stream-Simulation Working Group (2008) developed the stream simulation method for a national audience working on forested lands using unimpaired reference reaches. In Region 5, many watersheds are heavily urbanized and restoration priorities focus on coastal, diadromous species. In consideration of these regional challenges, Engineering offers the following additional guidance:

- *Criteria in development.*

13 American Eel Passage

Eel migratory biology is characterized by the following (Towler ed., 2014):

- Demersal, moderate swimmers (strong sprint swimming); non-schooling but aggregating;
- Panmictic, no river-specific populations (no homing to natal stream);
- Small eels can climb wet surfaces and pass through some technical fishways;
- Ascend structures during day or night, but primarily at night;
- Upstream migration spring through fall; for several years after entering freshwater;
- Specific upstream migration timing at latitudes from South America to Canada is related to water temperature;
- Juvenile eels may move repeatedly, irregularly or seasonally, between freshwater and marine habitat;
- Late summer, fall, and possibly spring movements of silver phase; primarily during rain events/high flows.

13.1 Upstream Eel Passes

Eel passes (or eelways) are upstream passage structures that provide a path over the dam for elvers and juvenile eels (Towler ed., 2014).

13.1.1 Location

Typically, Engineering consults with Service, state, and other federal agency biologists to determine the best location of the eel pass. Suitable locations may be found at spillways, dam abutments, or other locations where leakage and rock outcrops can concentrate eels attempting to move upstream. Locations in deep water or at spillways may also pass upstream migrating eels. If possible, installing temporary eel passes in a variety of locations along the barrier is recommended in order to determine which of the locations attracts the most eels. Nighttime surveys for migrating eels below dams can also be effective at identifying areas where eels are congregating, thereby identifying potential eelway locations. Odors from conspecifics in a fishway may attract eels and improve fishway efficacy.

13.1.2 Volitional Ramps

Generally, eel passes consist of a volitional ramp (lined with various wetted substrate) and an attraction water delivery system. Eels utilize the wetted substrate to propel themselves up the ramp. Engineering endorses the following design guidelines for volitional ramps (Towler ed., 2014):

- Construction: metal or plastic ramp channel (typically aluminum); wood or other materials for temporary ramp passes;
- Ramp geometry: 8 in. to 18 in. wide, 4 in. to 6 in. high;
- Cover: full opaque cover for entire width/length of ramp, except open below high water level at entrance (uncovered ramps may be susceptible to predation);
- Flow depth in ramp channel dependent on design, typically 1/16 in. to 1/8 in. for flat ramps;
- Ramp design should accommodate fluctuation in headpond levels (e.g., pumped water discharge above the maximum headpond elevation);
- Length: dependent on slope; sloped runs of ramp should not exceed 10 foot total vertical height; total length technically unlimited but preferably less than 100 feet;
- Slope: ramp section slopes 45 degrees maximum;
- Resting/turning pools: minimum of one horizontal resting pool per 10 feet vertical height; pool width equal to ramp width; pool length at least pool width; water depth of at least 1 in.;
- Climbing substrate: typically specialized formed plastic substrates (vertical cylinders, mesh, inverted brushes); sizing of substrates is dependent on eel size distribution. Various substrates have been recommended and tried with variable success. The science on the eelway design continues to progress; therefore, Engineering recommends that the selection of substrate on every eel ramp be made in close consultation with Service biologists.
- Ramp exits should be located away from turbine intakes, gates, and spillways that may entrain eels;
- Ramp capacity: maximum 5,000 eels/day per inch of ramp width (mean eel size 150 millimeter (mm) TL);

- Attraction flows: required for larger rivers or high flow tailraces; minimum 50 gallons per minute (gpm) for 8 in. wide ramp; additional 5 gpm for each addition inch of ramp width; typically 80-300 gpm;
- Substrate should be clean of debris.

13.1.3 Traps/Buckets

Volitional ramps may terminate in a trap depending upon the height of the barrier and the need to enumerate migrants for monitoring and evaluation. Generally, a barrier higher than 3-5 meters will require a trap or lift. Engineering endorses the following design guidelines for traps (Towler ed., 2014):

- Trap box volume: minimum 2 ft^3 (15 gallons); maximum capacity 350 eels/gallon (~1 eel per 10 ml)
- Trap box flow: minimum 1 gpm; 0.5 gpm per additional ft^3 of box volume (minimum 2 ft^3 volume); adequate flow to maintain sufficient oxygen for maximum capacity and ambient water temperatures
- Trap clearing frequency: daily if possible; no longer than every 2-3 days. Mandatory clearing when trap reaches > 50% capacity; eels should be released at night, if possible
- Trap should be designed such that eels cannot escape (e.g., adequate wall height, interior lip, dry walls to inhibit climbing)
-

13.1.4 Eel Lifts

Volitional ramps may terminate in a lift depending upon the height of the barrier. Generally, a barrier higher than 5 meters will require a trap or lift that is specialized for eels. However, trap systems remain more common than eel lifts for high head barriers.

13.1.5 Eel Movement through Ladders

Eels may move through fish ladders, though generally not in large numbers. Engineering does not regard fish ladders as a primary method of passing eels.

13.2 Downstream Eel Passage

Duration and timing of migration may vary in different parts of a watershed. In addition, a latitudinal trend persists in emigration dates of American eels (Haro, 2003). General downstream migratory behaviors are listed below (Towler ed., 2014):

- Movements primarily at night;
- Occupy all depths during migration;
- Selective tidal stream transport in tidal reaches;
- Tend to follow dominant flows;
- Reactive to some physical, visual, chemical, and sound stimuli;
- Environmental conditions can initiate, suspend or terminate downstream migration.

13.2.1 Physical Barriers and Guidance

Angled bar screens may be used as a guidance device to a safe passage route (i.e., bypass) for downstream migrating eels. The bar screen should be installed at no greater than 45 degrees to the flow field and spacing should be a maximum of ¾ inches for adult American eels. The racks must be designed and maintained so there are no voids between rack panels and adjacent forebay structures. Structural members comprising the rack should not easily bend (as seen with some plastic materials); bent or damaged bars can create wider gaps in the rack. Angled bar screens must be frequently checked and cleaned of debris. Other physical barriers include screens and louvers (with and without bottom overlays).

13.2.2 Surface Bypass

Criteria in development.

13.2.3 Low-Level Bypass

At depth, a downstream (low-level) bypass acts as a pressurized intake and water is subject to rapid spatial accelerations around the inlet. To prevent injuries to adult silver eels entering the bypass, the intake opening should be approximately one half the maximum body length of an adult silver eel, 18 inches, or larger.

13.2.4 Behavioral Barriers and Guidance

Behavioral barriers such as light, sound, and bubble screens are considered experimental and have not shown consistent performance in guiding American eels.

13.2.5 Operational Measures

Operational alternatives such as nightly project shutdowns can be effective at passing eels provided an alternative egress (e.g., spillway, bypass) is available.

14 Hydroelectric Facilities

14.1 Flow Management

River flows should always be prioritized to meet fishway requirements before any other project element (i.e., spill, generation, consumptive withdrawal).

14.1.1 Spill

Criteria in development.

14.1.2 Turbine Efficiency

Criteria in development.

14.1.3 Bypassed Reach

Criteria in development.

15 Experimental Technologies

Applied and theoretical research provides valuable insight into the refinement of existing methods and the development of new fish passage technologies. Engineering encourages the development of technologies that further minimize the ecological impact of anthropogenic in-stream activities and structures. Until new technologies are proven *in-situ* to be safe, timely and effective (see Section 2.3), Engineering refers to them as “experimental.”

The purpose of the experimental designation is to communicate to the proponent (e.g., researcher, developer, owner, licensee) that upon implementation, the Service may require a higher level of evaluation than it would for a conventional fish passage device or method. To avoid delays in implementation of fish passage at a project site, proponents of experimental technologies are encouraged to consider, in advance, alternative (conventional) options. The experimental designation is not intended to: 1) initiate any specific regulatory action; 2) label the technology as categorically unacceptable under any policy or statute; nor 3) suggest the technology is known to be deficient in any way.

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Appendix A

Reference Plates

Reference Plate	Page Reference
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5-2 “Power Dissipation Rates”	5-5, 6-16
6-1 “Fishway Types”	6-1, 7-1
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7-6 “Fish Lift Velocities”	7-17, 7-23
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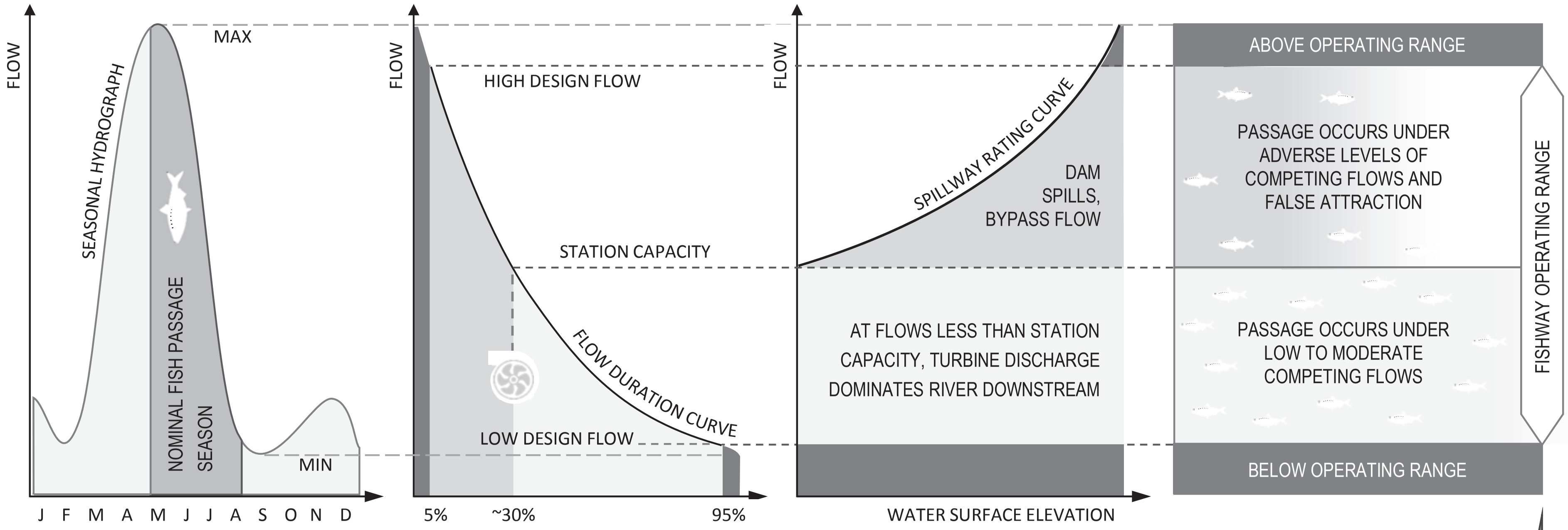

LINEAR PRORATION OF DRAINAGE AREA

Daily average river flows at ungaged project sites can be linearly prorated from hydrologically similar gaged sites.

$$Q_u = Q_g \left({A_u}/{A_g} \right)$$

where: Q_u is the ungaged flow (cfs)
Q_g is the gaged flow (cfs)
A_u is the site drainage (mi^2)
A_g is the gage drainage (mi^2)

Note: the linear relationship is valid only when the drainage area of the ungaged project site is of **comparable size** to the drainage of the gage site.

WEIBULL EXCEEDANCE PROBABILITY

Fish passage design flows, and associated **exceedance probabilities**, are developed using daily average river flows recorded during the fish passage season over a sufficiently long period of record (i.e., 10 to 30 years). High (5%) and low (95%) design flows can be compared to station capacity (~30%).

$$P_m = {m}/{(n+1)}$$

where: P is the probability of rank m
m is the rank of the flow event
n is the number of flow events

HEAD-DISCHARGE RELATIONSHIP

The spillway rating curve can be related to fish passage design flows (and station capacity). For simple, uncontrolled spill, the weir equation relates **water surface elevation (or head above crest) to discharge**.

$$Q_S = CLH^{3/2}$$

where: Q_s is the total spillway flow (cfs)
L is the length of spillway crest (ft)
C is the weir coefficient (-)
H is the head above crest (ft)

Note: head is **offset** from the water surface elevation by the crest elevation

FISH PASSAGE OPERATING RANGE

The **operating range describes the river flows and associated water surface elevations under which the fish passage facility is safe, timely, and effective**. Additionally, it illustrates when the fishway discharge competes with false attraction created by the power station and spillway. To mitigate adverse effects of competing flows, the **Service recommends total fishway discharge**:

$$Q_T \geq Q_P\,(3-5\%)$$

where: Q_T is the total fishway flow (cfs)
Q_P is the station capacity (cfs)

USFWS Northeast Region (R5), FAC
Fish Passage Engineering, B. Towler, K. Mulligan
Issued 1/6/2017; replaces “Fishway Operating Range” 11/12/2015

FISHWAY OPERATING RANGE

REFERENCE PLATE 4-1

BURST

Burst or Dart or Sprint Speed is the swim speed that a fish can maintain for mere seconds V_B

- Burst speed engages anaerobic white muscle tissues
- Bell (1990) suggests can be maintained for 5-10 sec.; Bain (1999) 2-3 sec.; Beamish (1978) < 20 sec.
- Speed used for predator avoidance or feeding; in fishways, use to ascend weir crests
- For fish passage design, velocities should be kept below V_B for the weakest target species at all times

Many published swimming speeds are derived from lab tests on handled fish; such values may underestimate *in situ* performance.

$$V_B = 2\,V_P$$

$$2\,sec \leq \Delta t \leq 10\,sec$$

PROLONGED

Prolonged (or Sustained Speed *) is the swim speed that a fish can maintain for minutes; V_P

- Prolonged speed engages both red and white muscle tissues
- Bain (1999) suggests speed can be maintained for 5-8 minutes; Beamish (1978) suggests 20 sec. to 200 min.
- Critical swim speed, U_{crit}, is a sub-category of prolonged speed measured by Brett (1964)
- For fish passage design, V_P can be used in conjunction with Δt to estimate travel distance, D, before fatigue

$$4BL\,sec^{-1} \leq V_P \leq 7BL\,sec^{-1}$$

$$V_g = V_w - V_P$$

$$D = V_g \Delta t$$

$$5\,min \leq \Delta t \leq 8\,min$$

CRUISING

Cruising or Sustained Speed is the swim speed that a fish can maintain for hours; V_C

- Cruising speed engages aerobic red muscle tissues
- Speed used for extended periods of travel at low speeds
- Influenced by temperature, oxygen; Bell (1990) suggested swim speeds reduced by 50% at temp. extremes
- For fish passage design, V_C should be used for transport flumes, holding pools, etc.

*** Literature on the definition of Sustained Speed is inconsistent. e.g., Bain (1999) refers to the speed that fish can maintain for minutes as "sustained"; contradicting Bell (1990) and others. For this reason, the cruising-prolonged-burst naming convention is used here.**

$$V_C = \frac{1}{3}\,V_P = \frac{1}{6}\,V_B$$

Bell, M. (1990) "Fisheries Handbook of Engineering Requirements and Biological Criteria"
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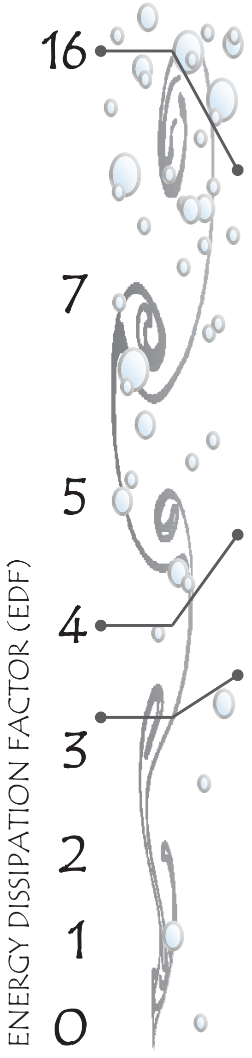
USFWS Northeast Region (R5), FAC
Fish Passage Engineering, B. Towler
Issued 1/6/2017; replaces "Swim Speeds" 7/23/2014

SWIM SPEED CATEGORIES

REFERENCE PLATE 5-1

FT-LB/S/FT³ RECOMMENDATIONS & REQUIREMENTS



AWS dissipation, max. (31.33 ft-lb/s/ft^3); EA UK (2010)

AWS dissipation, min. (20.89 ft-lb/s/ft^3); EA UK (2010)

AWS POOLS (16.0 ft-lb/s/ft^3) †

check weirs, salmon (10.44 ft-lb/s/ft^3); Larinier et al. (1999)

roughened culverts (7.0 ft-lb/s/ft^3); WA DFW (2003)

baffled culverts, max. (5.0 ft-lb/s/ft^3); CalTrans (2013)

salmonids (5.0 ft-lb/s/ft^3); Maine DOT (2008)

vertical slot pools (4.18 ft-lb/s/ft^3); FAO and DWVK (2002)

ATLANTIC SALMON (4.0 ft-lb/s/ft^3) †

salmonids, adult (3.13 ft-lb/s/ft^3); NOAA (2011)

AMERICAN SHAD (3.15 ft-lb/s/ft^3) †

trout (3.13 ft-lb/s/ft^3); EA UK (2010)

non-salmonids (2.09 ft-lb/s/ft^3); EA UK (2010)

step-pools at turns (2.09 ft-lb/s/ft^3); EA UK (2010)

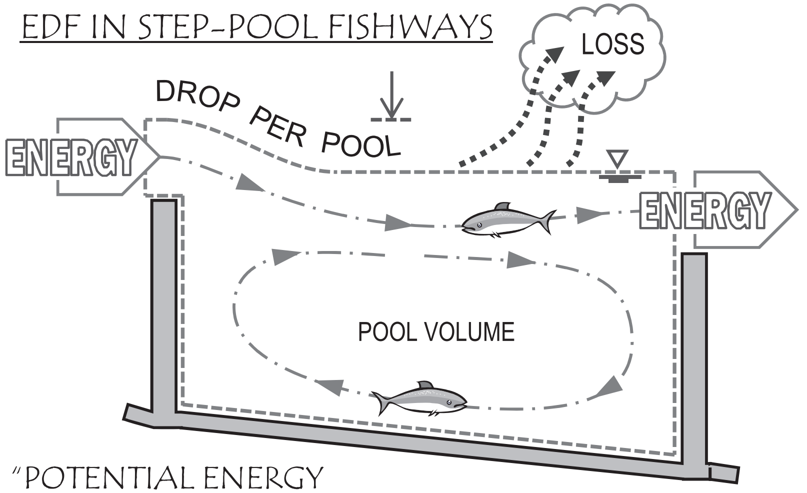
salmonids, juvenile (2.0 ft-lb/s/ft^3); NOAA (2011)

resting pools (1.04 ft-lb/s/ft^3); FAO and DWVK (2002)

Denil resting pools (0.52 ft-lb/s/ft^3); FAO and DWVK (2002)

† U.S. Fish and Wildlife Service criteria

EDF IN STEP-POOL FISHWAYS



"POTENTIAL ENERGY DISSIPATION RATE PER UNIT VOLUME"

DESIGN

$$\forall = \frac{\gamma Q D}{EDF}$$

EVALUATE

$$EDF = \frac{\gamma Q D}{\forall}$$

where:

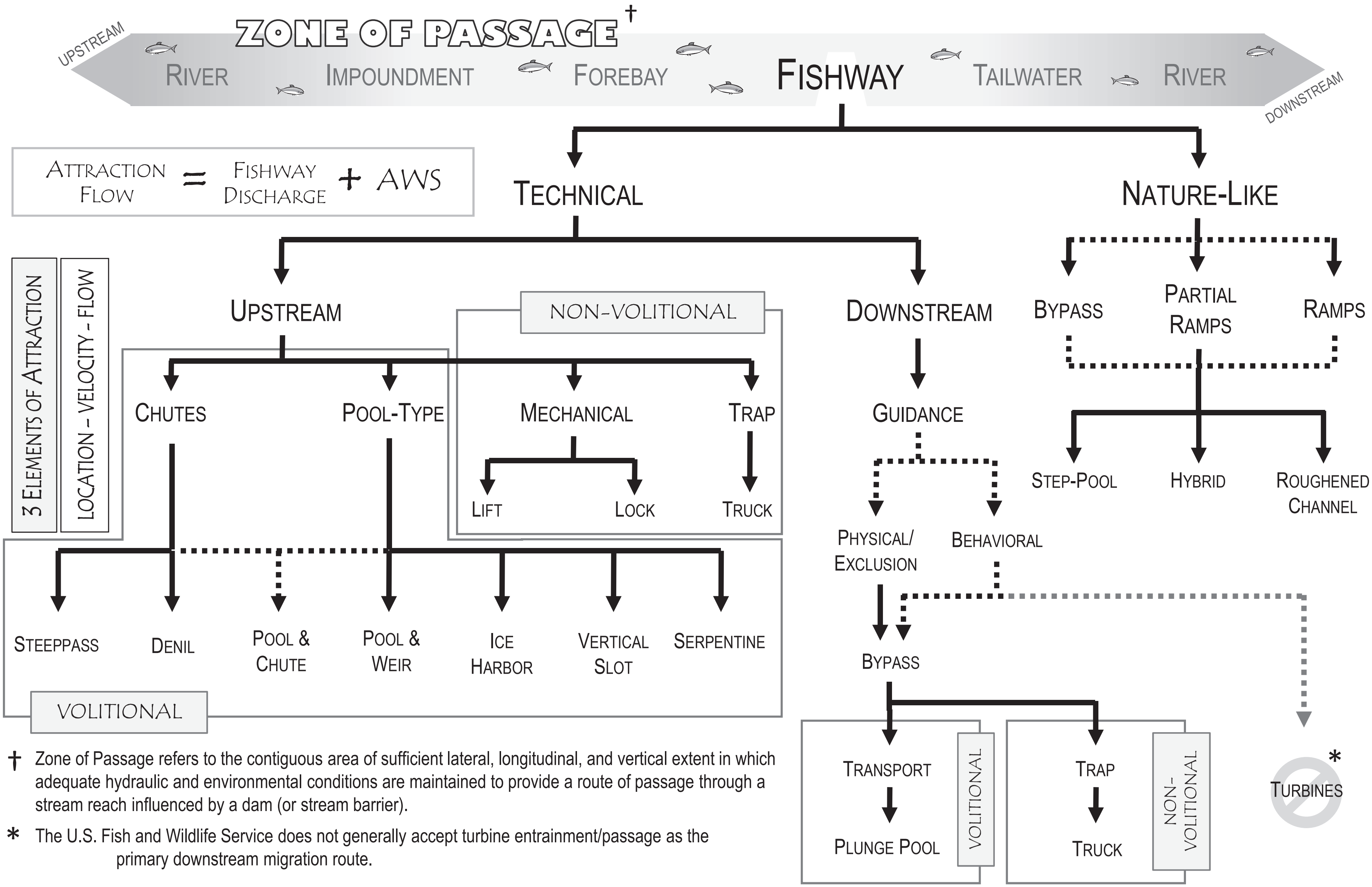
EDF is the volumetric power dissipation rate in ft-lb/s/ft^3
$\forall$ is the water volume in the fishway step pool in ft^3
D is the hydraulic drop from one pool to the next in ft
Q is the flow over the weir crests, through the fishway, in cfs
γ is the unit weight of water (62.4 lbs/ft^3)

- Larinier et al. (1999) "Passes a Poissons"
- WA DFW (2003) "Design of Road Culverts for Fish Passage"
- FAO and DWVK (2002) "Fish Passes"
- EA UK (2010) "Fish Pass Manual"
- NOAA (2011) "Anadromous Salmonid Passage Facility Design"
- CalTrans (2013) "Fish Passage Design for Road Crossings"
- Maine DOT (2008) "Waterway & Wildlife Crossing Policy & Design Guide"

USFWS Northeast Region (R5), FAC
Fish Passage Engineering, B. Towler
Issued 1/6/2017; replaces "Power Dissipation Rates" 7/26/2014

POWER DISSIPATION RATES

REFERENCE PLATE 5-2



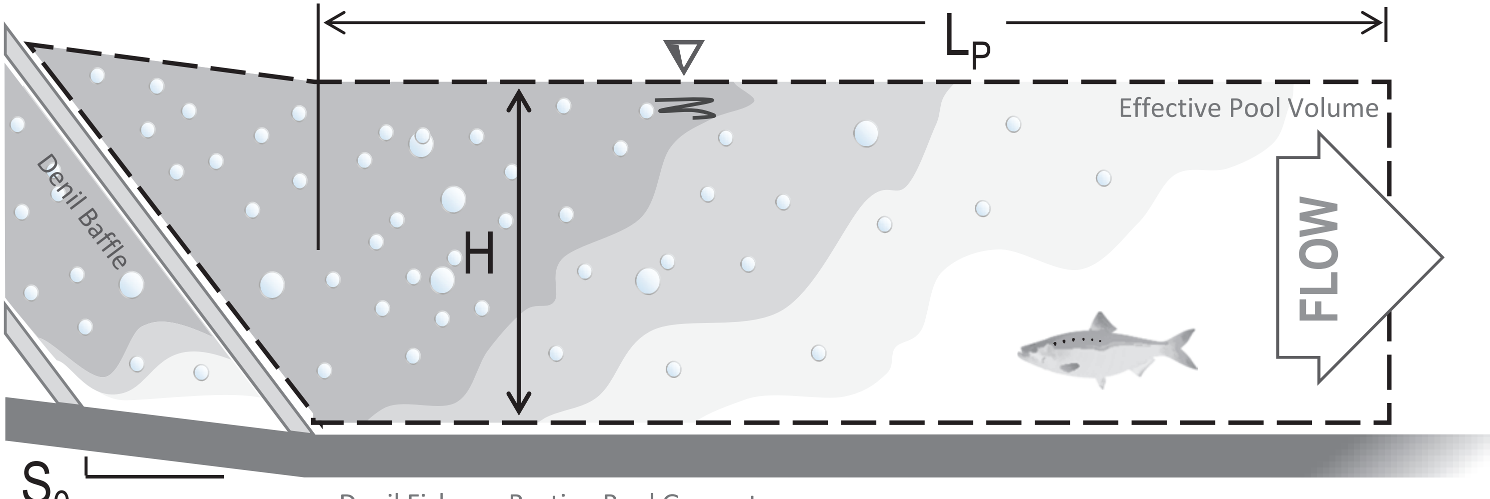
† Zone of Passage refers to the contiguous area of sufficient lateral, longitudinal, and vertical extent in which adequate hydraulic and environmental conditions are maintained to provide a route of passage through a stream reach influenced by a dam (or stream barrier).

* The U.S. Fish and Wildlife Service does not generally accept turbine entrainment/passage as the primary downstream migration route.

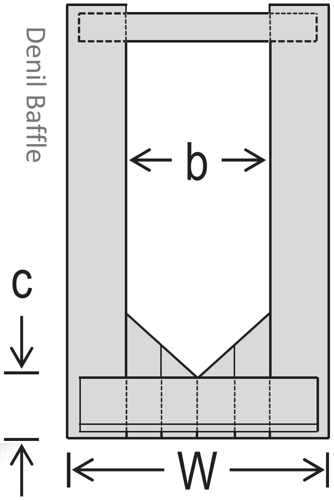
USFWS Northeast Region (R5), FAC
Fish Passage Engineering, B. Towler
Issued 1/6/2017; replaces “Fishway Types” 7/30/2014

FISHWAY TYPES

REFERENCE PLATE 6-1



Denil Fishway Resting Pool Geometry



Generalized Power Dissipation in Denil Resting Pools

$$EDF = \left[\frac{Q}{2}\left(\frac{1}{A_1} - \frac{1}{HW}\right) + gH\left(\sqrt{2}\,\cos\frac{-\pi + 4\tan^{-1} S_0}{4} - 1\right)\right]\frac{Q\gamma}{HWL_P}$$

$$A_1 = \begin{cases} \dfrac{bc}{2} + \left(\dfrac{H}{\sin\left(\frac{\pi}{4}\right)} - 2c\right)b & \blacktriangleleft \quad H > 2c\sin\left(\frac{\pi}{4}\right) \\ \dfrac{b}{2c}\left(\dfrac{H}{\sin\left(\frac{\pi}{4}\right)} - c\right)^2 & \blacktriangleleft \quad \sin\left(\frac{\pi}{4}\right) < H \le 2c\sin\left(\frac{\pi}{4}\right) \end{cases}$$

Energy Dissipation Factor is the volumetric power dissipation in foot-pounds per second per cubic feet

- "Derivation and Application of the Energy Dissipation Factor in the Design of Fishways" B. Towler, K. Mulligan and A. Haro. Ecological Engineering 83 (2015) 208-217

Pool Sizing for Standard Denil Fishways

$$EDF \times L_P = K_1(H - h_v)^{K_2}$$

Width		1:8 slope	1:10 slope
3 (ft)	h_v	0.592 (ft)	0.5805 (ft)
	K_1	9.728355	7.697128
	K_2	1.802865	1.773244
4 (ft)	h_v	0.7894 (ft)	0.774 (ft)
	K_1	9.166344	7.160788
	K_2	1.779516	1.765067

h_v is the vertical (installed) height of the notch in the Denil baffle

USFWS Northeast Region (R5), FAC
Fish Passage Engineering, B. Towler
Issued 1/6/2017; replaces "Denil Resting Pools" 10/27/2015

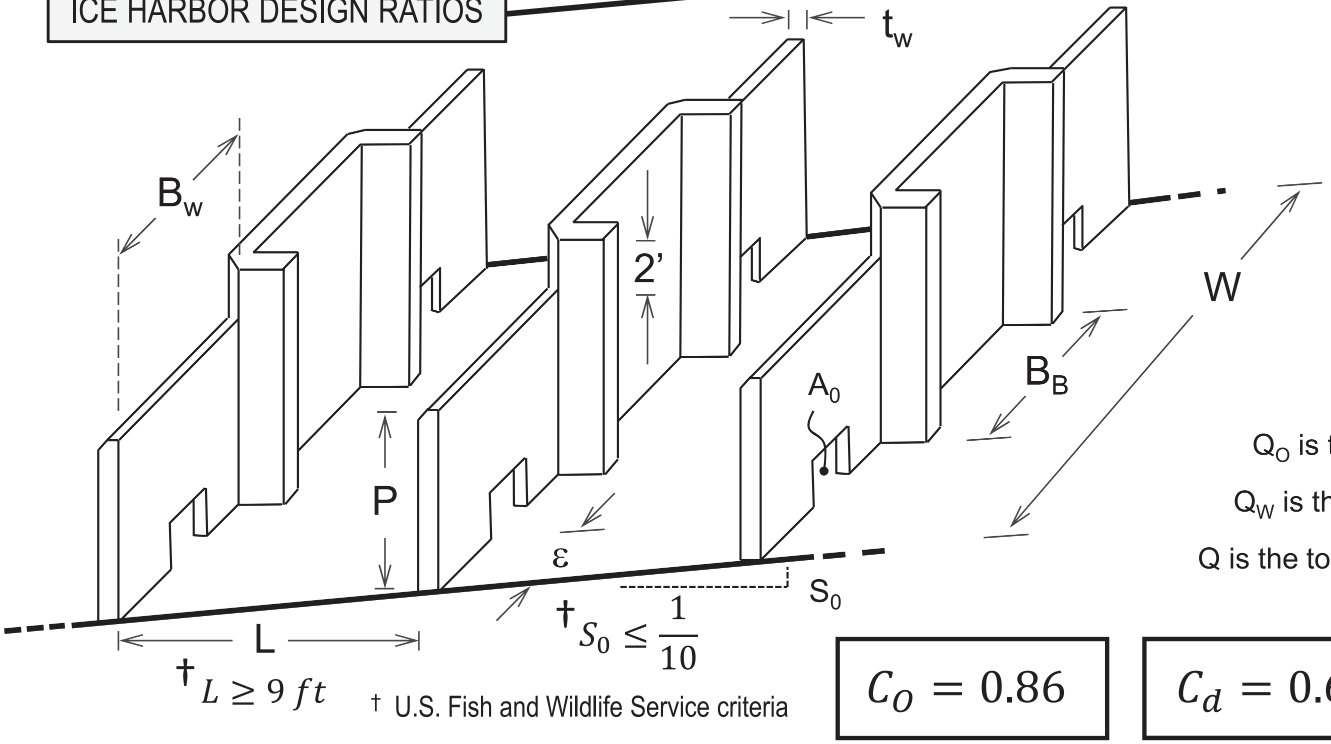
DENIL RESTING POOLS

REFERENCE PLATE 6-2

ICE HARBOR STANDARD DIMENSIONS

W	10’	11’	12’	13’	14’	16’	18’	20’	25’
B_W	3’ – 1”	3’ – 5”	3’ – 9”	4’ – 1”	4’ – 4”	5’ – 0”	5’ – 8”	6’ – 3”	7’ – 10”
B_B	3’ – 10”	4’ – 2”	4’ – 6”	4’ – 10”	5’ – 4”	6’ – 0”	6’ – 8”	7’ – 6”	9’ – 4”
ε	1’ – 10"	2’ – 0”	2’ – 3”	2’ – 5”	2’ – 7”	3’ – 0”	3’ – 0”	3’ – 0”	3’ – 0”
A_O	12” x 12”	13” x 13”	14” x 14”	15” x 15”	16” x 16”	18” x 18”	18” x 18”	18” x 18”	18” x 18”

ICE HARBOR DESIGN RATIOS



$$Q_W = CB_W H_W{}^{1.5}$$

$$Q_O = C_O A_O \sqrt{2gH_O}$$

$$Q = 2Q_W + 2Q_O$$

H_O is the head on the orifice in feet

H_W is the head on the weir crest in feet

Q_O is the discharge though each orifice in cfs

Q_W is the discharge over each weir crest in cfs

Q is the total discharge through the fishway in cfs

$$C_O = 0.86$$

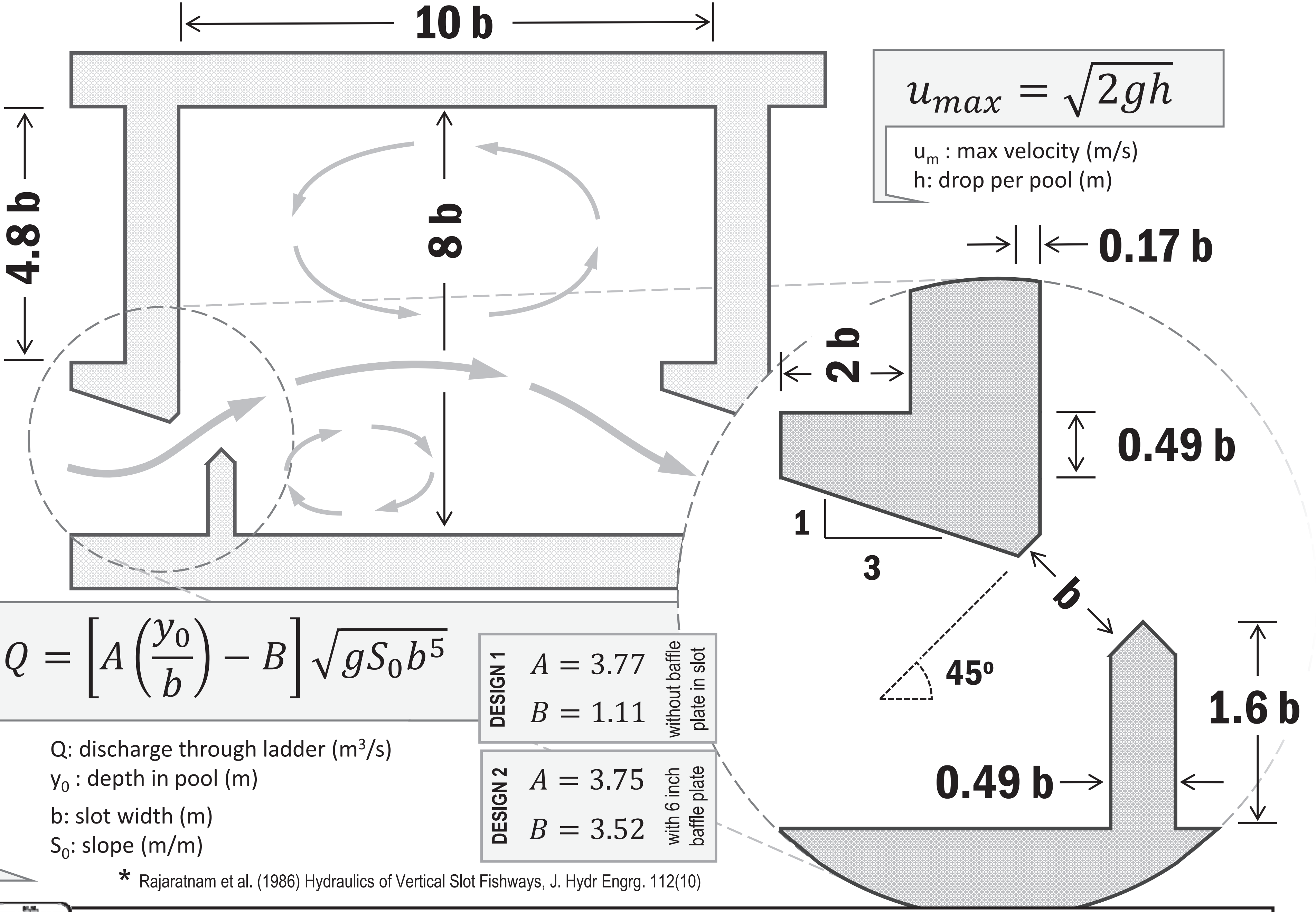
$$C_d = 0.68$$

$$C = \frac{2}{3}\sqrt{2g}\,C_d$$

USFWS Northeast Region (R5), FAC
Fish Passage Engineering, B. Towler
Issued 1/6/2017; replaces “Ice Harbor Fishway” 7/24/2014

ICE HARBOR FISHWAY

REFERENCE PLATE 7-1



$$u_{max} = \sqrt{2gh}$$

u_m : max velocity (m/s)
h: drop per pool (m)

*
$$Q = \left[A\left(\frac{y_0}{b}\right) - B\right]\sqrt{gS_0b^5}$$

DESIGN 1	$A = 3.77$ $B = 1.11$	without baffle plate in slot
DESIGN 2	$A = 3.75$ $B = 3.52$	with 6 inch baffle plate

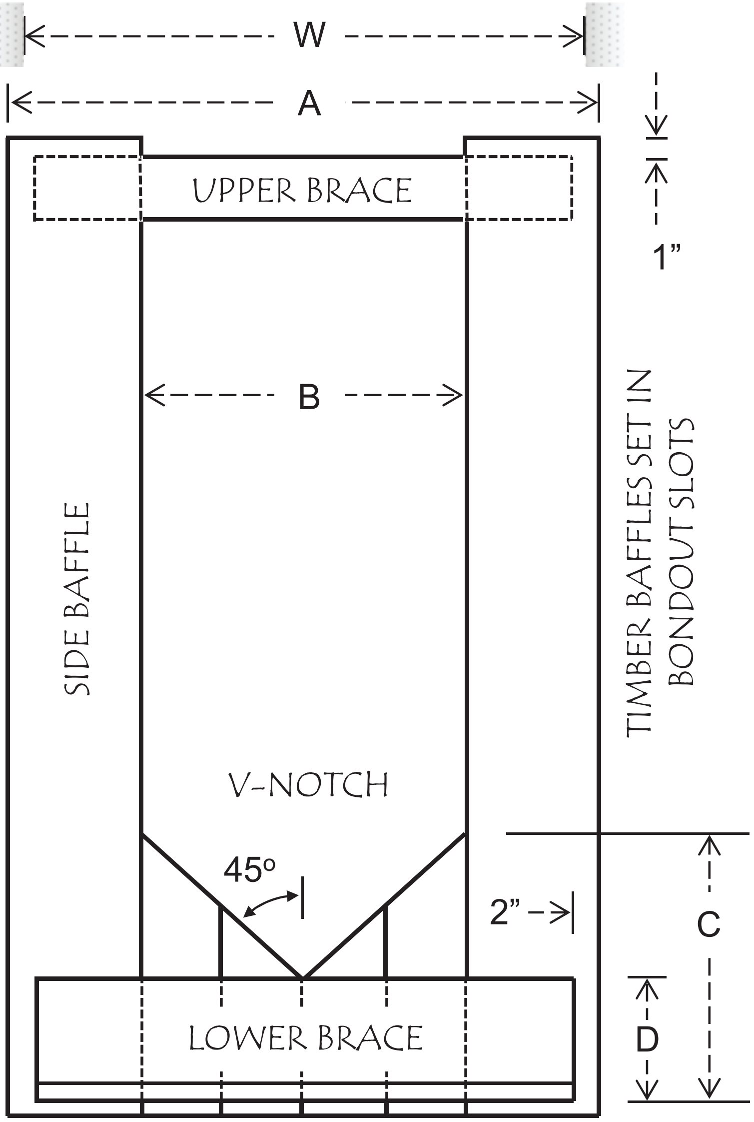
Q: discharge through ladder (m^3/s)
y_0 : depth in pool (m)
b: slot width (m)
S_0: slope (m/m)

* Rajaratnam et al. (1986) Hydraulics of Vertical Slot Fishways, J. Hydr Engrg. 112(10)

USFWS Northeast Region (R5), FAC
Fish Passage Engineering, B. Towler
Issued 1/6/2017; replaces "Vertical Slot Fishway" 10/27/2015

VERTICAL SLOT FISHWAY

REFERENCE PLATE 7-2



STANDARD DENIL GEOMETRY [*]

W [**]	A	B	C	D	S [***]
4’ - 0”	4’ - 3”	2’ - 4”	2’ - 0”	1’ - 0”	2’ - 6”
3’ - 6”	3’ - 9”	2’ - 0”	1’ - 9”	10½”	2’ - 4”
3’ - 0”	3’ - 3”	1’ - 9”	1’ - 6”	9”	2’ - 0”
2’ - 6”	2’ - 9”	1’ - 5½”	1’ - 3”	7½”	1’ - 8”
2’ - 0”	2’ - 3”	1’ - 2”	1’ - 0”	6”	1’ - 4”

[*] U.S. Fish and Wildlife Service criteria

[**] Denil channel width denoted by W; typically inside width of concrete channel

[***] Horizontal (longitudinal) spacing of baffles in channel denoted by S

$$Q = (1.34 - 1.84S_0){h_u}^{1.75}B^{0.75}\sqrt{g\,S_0}$$

$$h_u = H - Dsin[45^o + tan^{-1}(S_0)]$$ [†]

h_u is the vertical depth of water (or head) above the v-notch in the timber baffle in feet

H is the vertical depth of water (or head) above fishway channel bottom at exit in feet

[†] Odeh (2003) “Discharge Rating Equation and Hydraulic Characteristics of Standard Denil Fishways”

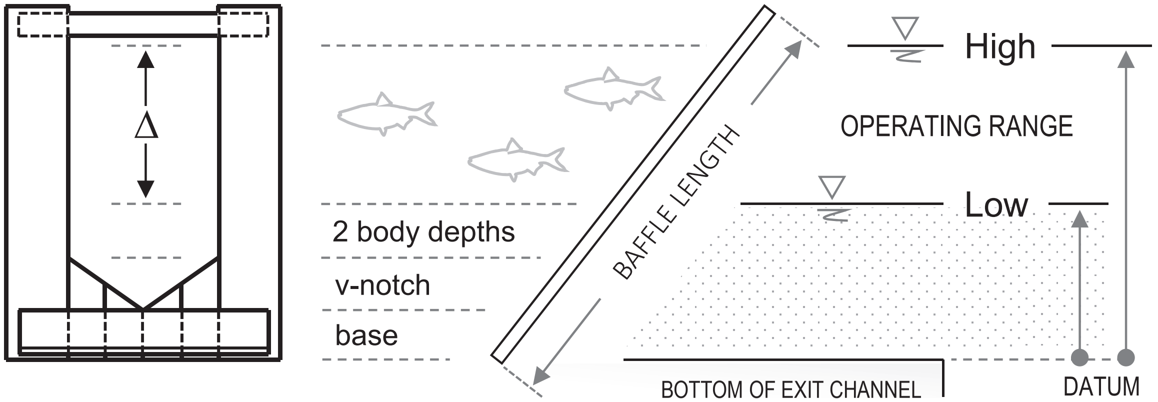
USFWS Northeast Region (R5), FAC
Fish Passage Engineering, B. Towler
Issued 1/6/2017; replaces “Standard Denil Ladder” 7/23/2014

STANDARD DENIL GEOMETRY

REFERENCE PLATE 7-3

OPERATING RANGES FOR 3 FT. AND 4 FT. DENIL FISHWAYS AT 1:8 OR 1:10 SLOPES

SPECIES	OPERATING RANGE	BAFFLE LENGTH (ft)			
		5	6	7	8
River Herring (nominal 4” body depth)	High (ft)	3.25	4.25	4.75*	4.75*
	Low (ft)	1.75	1.75	1.75	1.75
	Δ (ft)	1.5	2.5	3	3
American Shad (nominal 6” body depth)	High (ft)	3.25	4.25	5	5.75
	Low (ft)	2.25	2.25	2.25	2.25
	Δ (ft)	1	2	2.75	3.5
Atlantic Salmon (nominal 8” body depth)	High (ft)	3.25	4.25	5	5.75
	Low (ft)	2.5	2.5	2.5	2.5
	Δ (ft)	0.75	1.75	2.5	3.25



NOTES:

The uppermost Denil baffle is installed at the break in slope between the exit channel and the sloped channel.

Low and high operating levels are measured from the bottom of the exit channel.

High operating level is set 6 inches below the top of the baffle to avoid impact with the cross support.

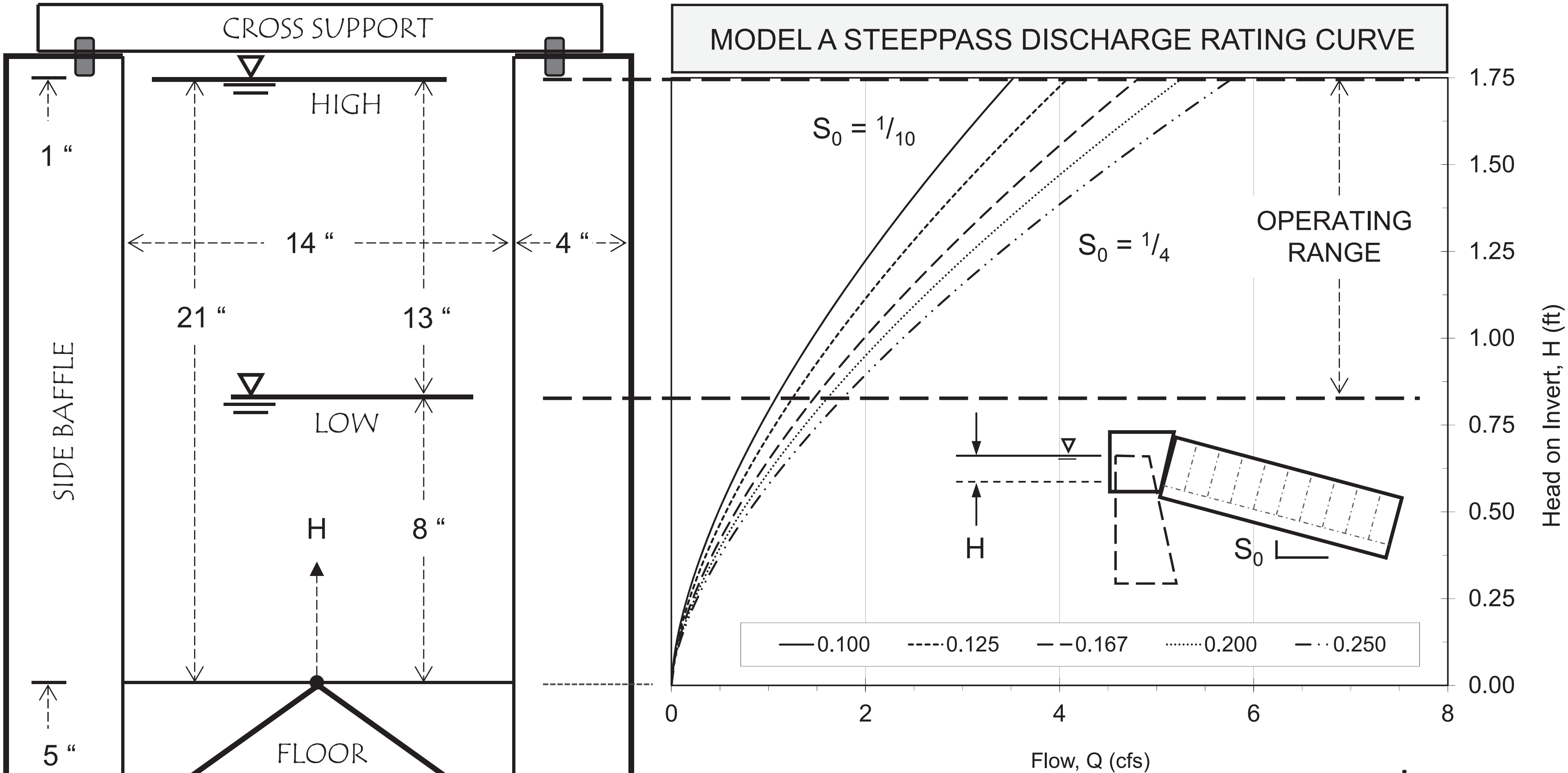
Ideally, the low and high operating levels correlate to headpond elevations at the low design flow and high design flow, respectively.

* OPERATING LEVEL IS BASED ON A MAXIMUM VELOCITY CRITERION FOR RIVER HERRING (4 FT/S)

USFWS Northeast Region (R5), FAC
Fish Passage Engineering, B. Towler
Issued 2/28/2017

STANDARD DENIL OPERATING RANGE

REFERENCE PLATE 7-4


MODEL A STEEPPASS DISCHARGE RATING CURVE

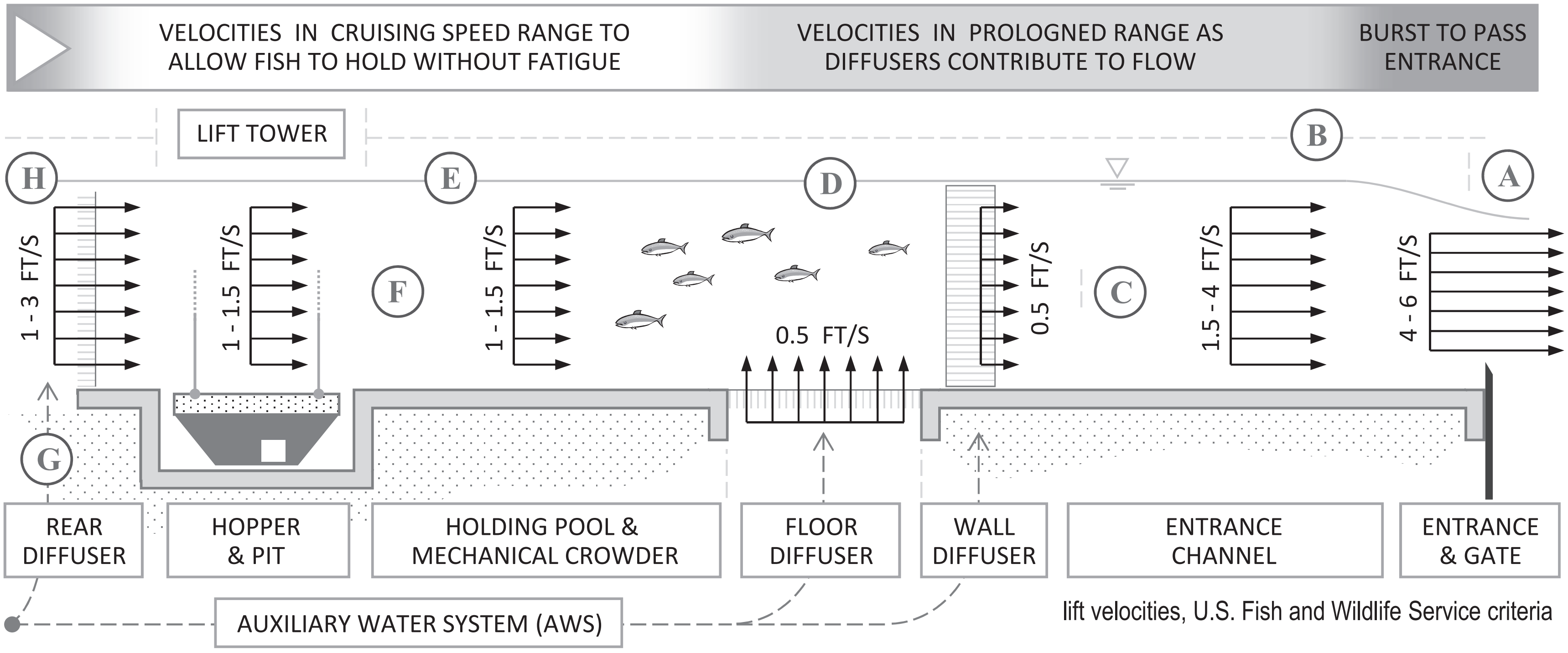
$$Q = \left(\frac{H}{0.0354\, S_0{}^{-1} + 0.4364} \right)^{\frac{1}{0.6307}}$$ †

† Odeh (1993) “Hydraulics of Alaska Steeppass Fishway Model A40”

USFWS Northeast Region (R5), FAC
Fish Passage Engineering, B. Towler
Issued 2/28/2017; replaces “Model A Steeppass” 7/23/2014

MODEL A STEEPPASS

REFERENCE PLATE 7-5



lift velocities, U.S. Fish and Wildlife Service criteria

BIOLOGICAL LIFT CAPACITY

$$n_H = \not{V}\left(\frac{60\ min}{1\ hr}\right)\frac{r}{w_f \not{v}_c[1 + C_n]}$$

n_H is the lift biological capacity in fish per hour
V is the volume of the component in ft^3
r is the cycle time in lifts per minute
w_f is the nominal weight of the target species in lbs
C_n is the non-target species allowance
$\not{v}_c$ is the crowding limit: hopper = 0.10 ft^3/lb †
holding pool = 0.25 ft^3/lb

† crowding limit is valid for lift cycle times of 15 m or less

A. Attraction jet is created by acceleration due to entrance (lift) gate operations; jet typically results in 0.5 – 2 foot hydraulic drop into TW.
B. Flood walls and other lift components should be design to protect against a 50-year flood event.
C. Flow in the entrance channel, downstream of the diffusers, should be streamlined and free of eddies and aeration.
D. Diffuser velocities are maximum point velocities; upwelling and aeration from the AWS should be minimal.
E. Depth in lower flume should be greater than 4 ft. at all times.
F. Flow above hopper and in holding pool should be free of aeration.
G. As much AWS flow as possible should be discharge behind the hopper.
H. AWS dissipators should be design to remove excess energy from flow.

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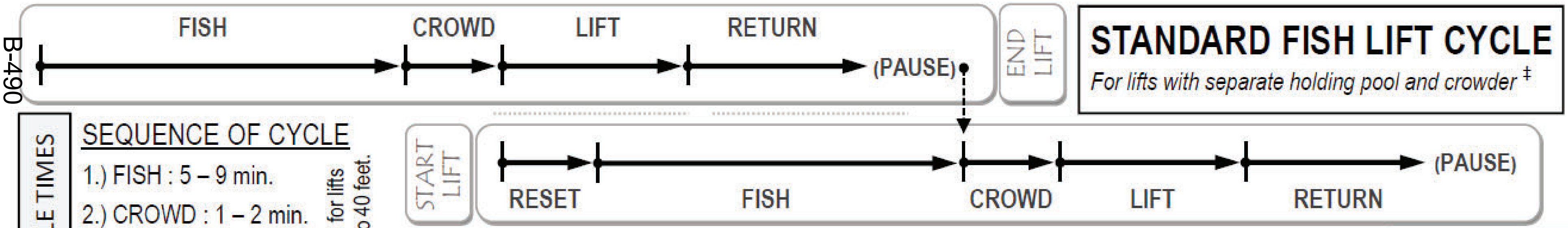
Fish Passage Engineering, B. Towler
Issued 2/28/2017; replaces “Fish Lift” 7/27/2014

FISH LIFT VELOCITIES

REFERENCE PLATE 7-6

STANDARD FISH LIFT CYCLE

For lifts with separate holding pool and crowder ‡

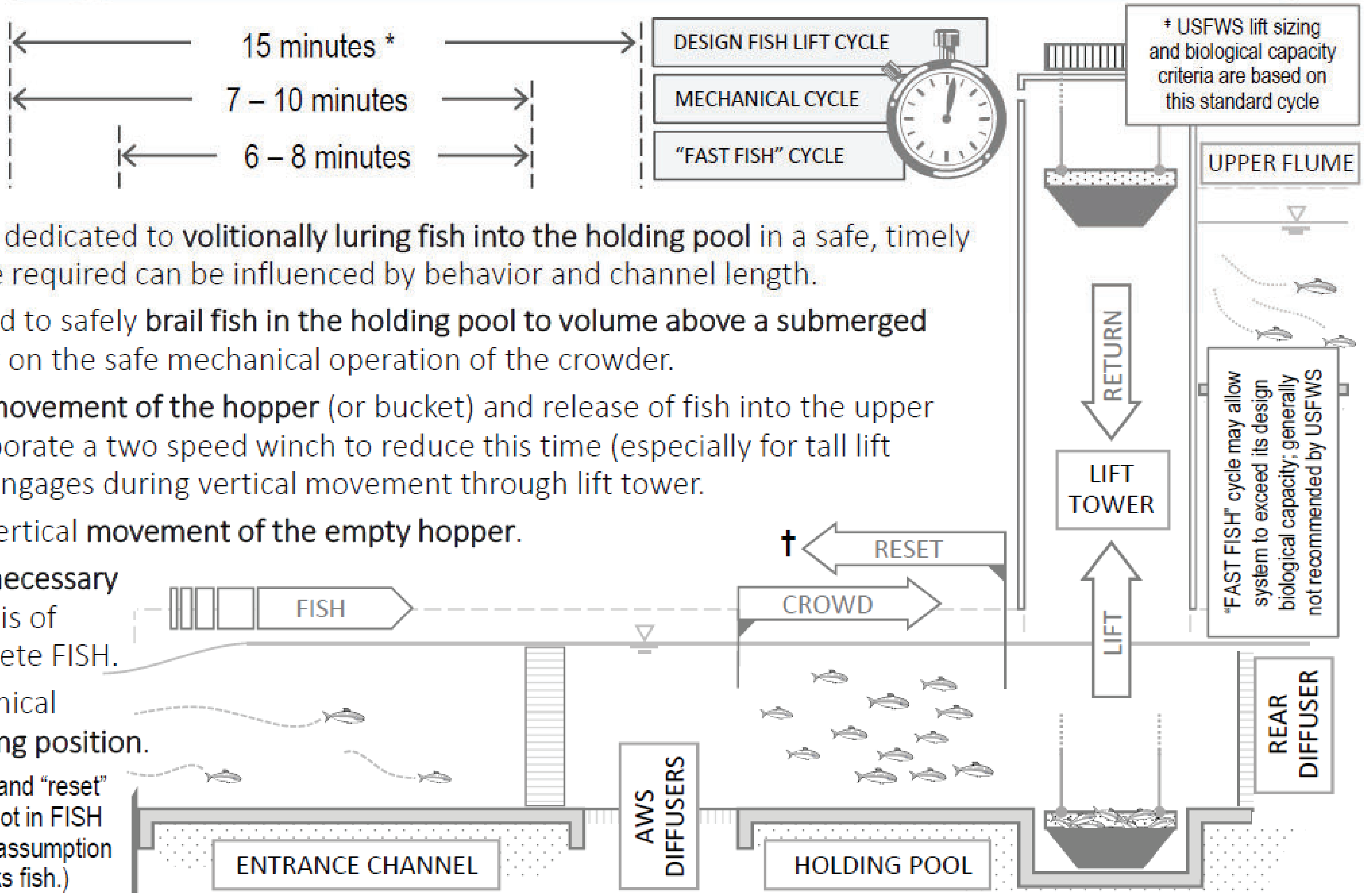


TYPICAL CYCLE TIMES

SEQUENCE OF CYCLE

1.) FISH : 5 – 9 min.
2.) CROWD : 1 – 2 min.
3.) LIFT : 3 – 4 min.
4.) RETURN : 3 – 4 min.
5.) PAUSE : 5 – 8 min.
6.) RESET : 1 – 2 min.

* times are typical for lifts less than or equal to 40 feet.



‡ USFWS lift sizing and biological capacity criteria are based on this standard cycle

"FAST FISH" cycle may allow system to exceed its design biological capacity; generally not recommended by USFWS

1. **FISH** is the part of the cycle dedicated to **volitionally luring fish into the holding pool** in a safe, timely and effective manner. Time required can be influenced by behavior and channel length.
2. **CROWD** is the time required to safely **brail fish in the holding pool to volume above a submerged hopper**. Time is dependent on the safe mechanical operation of the crowder.
3. **LIFT** is the **upward vertical movement of the hopper** (or bucket) and release of fish into the upper flume. Most designs incorporate a two speed winch to reduce this time (especially for tall lift towers); the higher speed engages during vertical movement through lift tower.
4. **RETURN** is the downward vertical **movement of the empty hopper**.
5. **PAUSE** in the cycle **may be necessary** when the mechanical cycle is of insufficient length to complete FISH.
6. **RESET** occurs as the mechanical crowder **returns to the fishing position**.

† NOTE: in standard designs, the "crowd" and "reset" steps are the only times when the lift is not in FISH mode (due to closed exclusion gate OR assumption that crowder movement spooks fish.)

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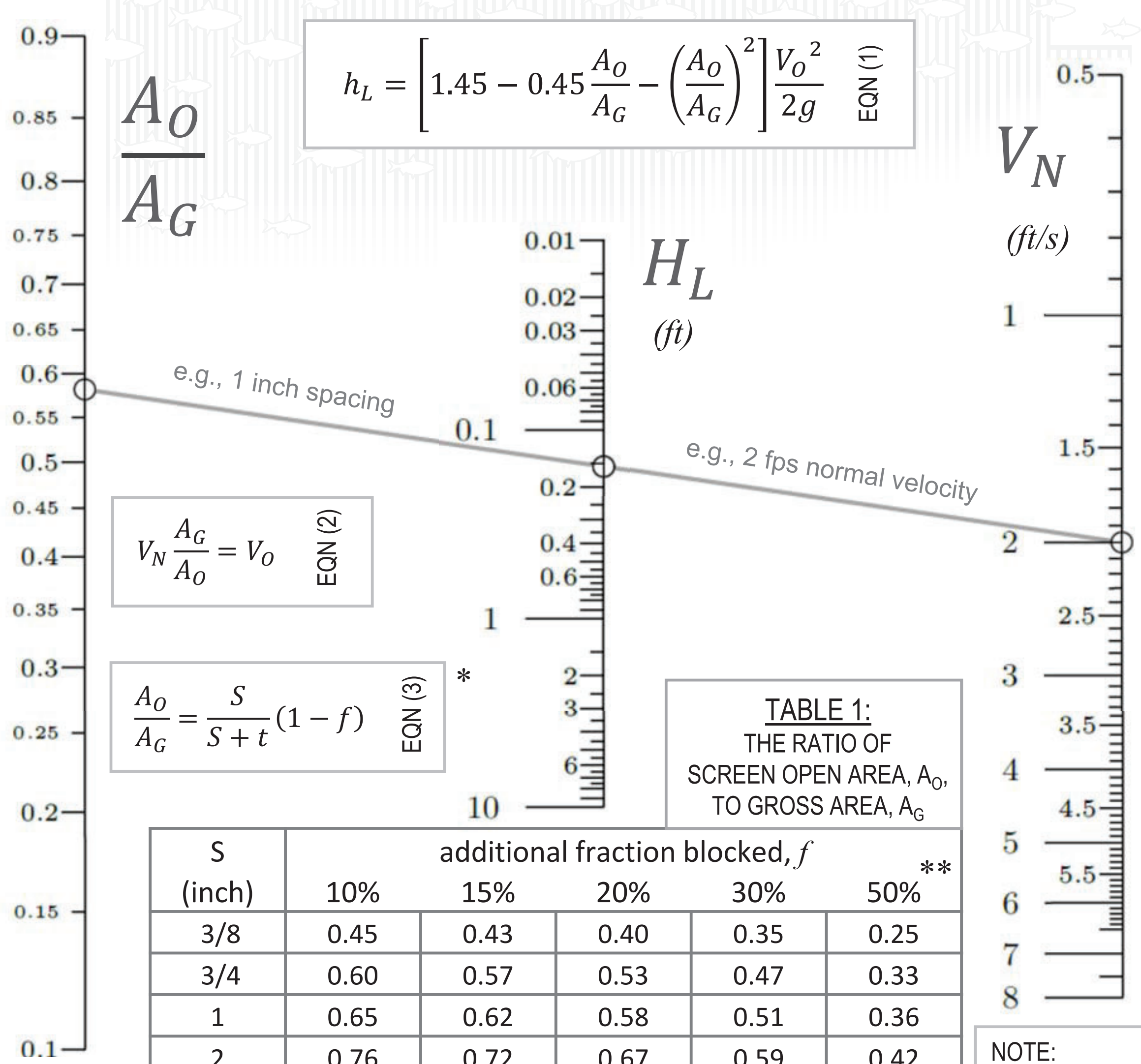
FISH LIFT SEQUENCE

REFERENCE PLATE 7-7

ANGLED BAR SCREEN HEADLOSS NOMOGRAPH



$$h_L = \left[1.45 - 0.45\frac{A_O}{A_G} - \left(\frac{A_O}{A_G}\right)^2\right]\frac{{V_O}^2}{2g} \quad \text{EQN (1)}$$

$$V_N\frac{A_G}{A_O} = V_O \quad \text{EQN (2)}$$

$$\frac{A_O}{A_G} = \frac{S}{S+t}(1-f) \quad \text{EQN (3)}$$ *

TABLE 1:

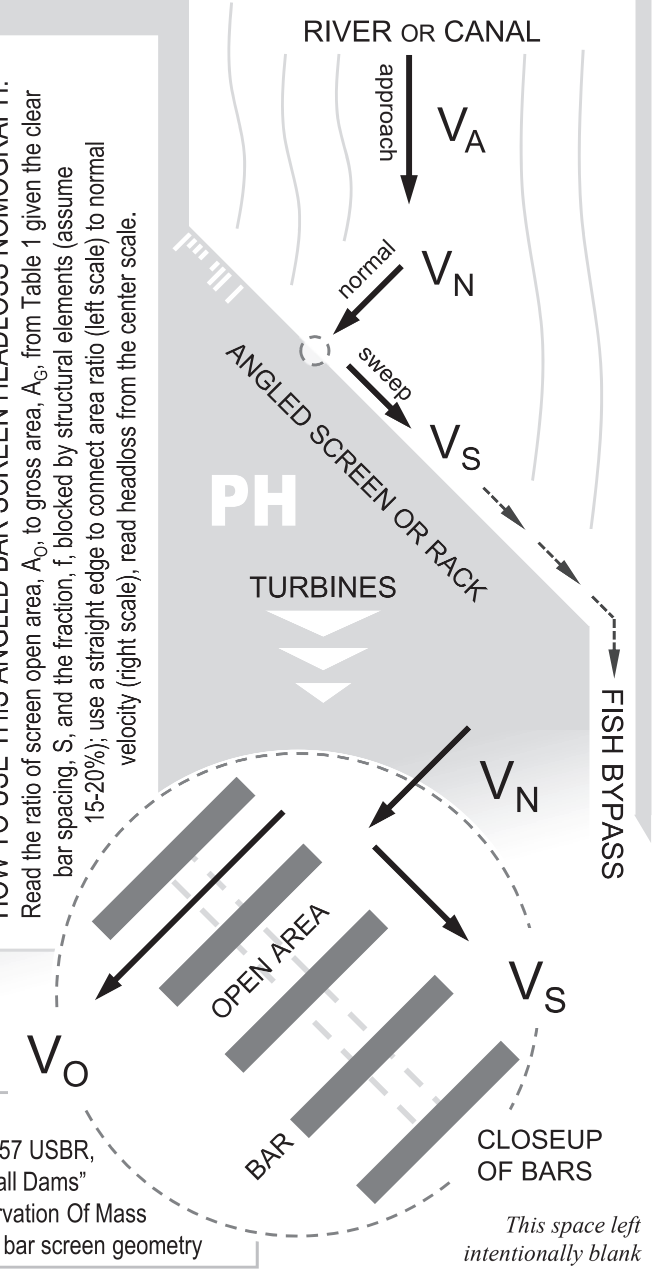
THE RATIO OF SCREEN OPEN AREA, A_O, TO GROSS AREA, A_G

S	additional fraction blocked, f				**
(inch)	10%	15%	20%	30%	50%
3/8	0.45	0.43	0.40	0.35	0.25
3/4	0.60	0.57	0.53	0.47	0.33
1	0.65	0.62	0.58	0.51	0.36
2	0.76	0.72	0.67	0.59	0.42
4	0.82	0.78	0.73	0.64	0.46
6	0.85	0.80	0.75	0.66	0.47

** bar thickness, t = 3/8 inch; ** f = 50% blockage typical of heavy debris*

HOW TO USE THIS ANGLED BAR SCREEN HEADLOSS NOMOGRAPH:

Read the ratio of screen open area, A_O, to gross area, A_G, from Table 1 given the clear bar spacing, S, and the fraction, f, blocked by structural elements (assume 15-20%); use a straight edge to connect area ratio (left scale) to normal velocity (right scale), read headloss from the center scale.



NOTE:
EQN (1) from page 457 USBR, 1987, “Design of Small Dams”
EQN (2) from Conservation Of Mass
EQN (3) from angled bar screen geometry

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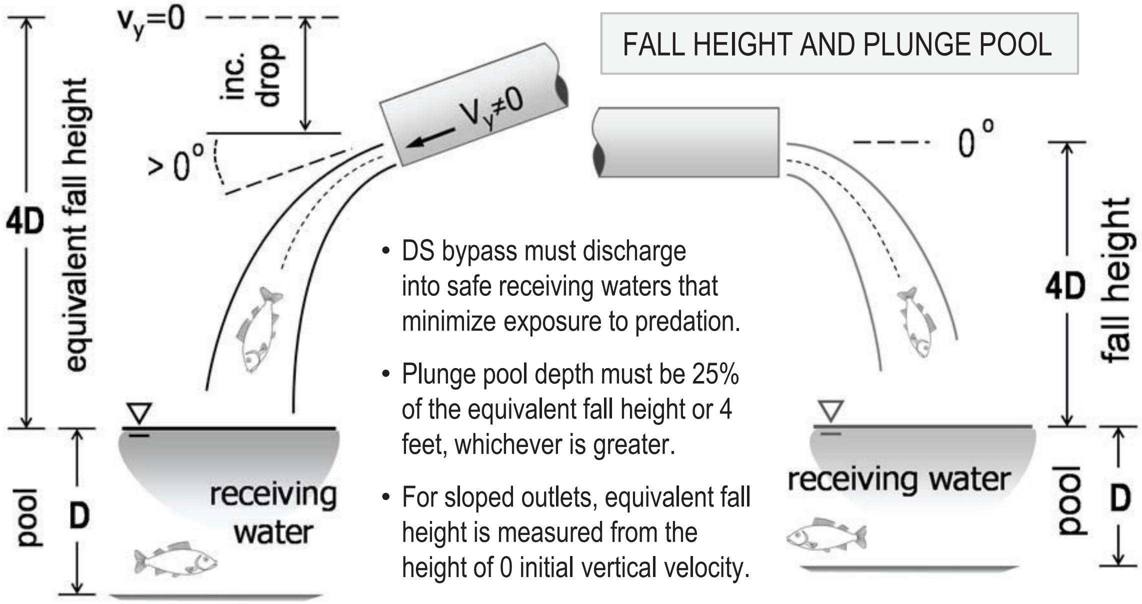
ANGLED BAR SCREENS

REFERENCE PLATE 9-1

FALL HEIGHT AND PLUNGE POOL



- DS bypass must discharge into safe receiving waters that minimize exposure to predation.
- Plunge pool depth must be 25% of the equivalent fall height or 4 feet, whichever is greater.
- For sloped outlets, equivalent fall height is measured from the height of 0 initial vertical velocity.

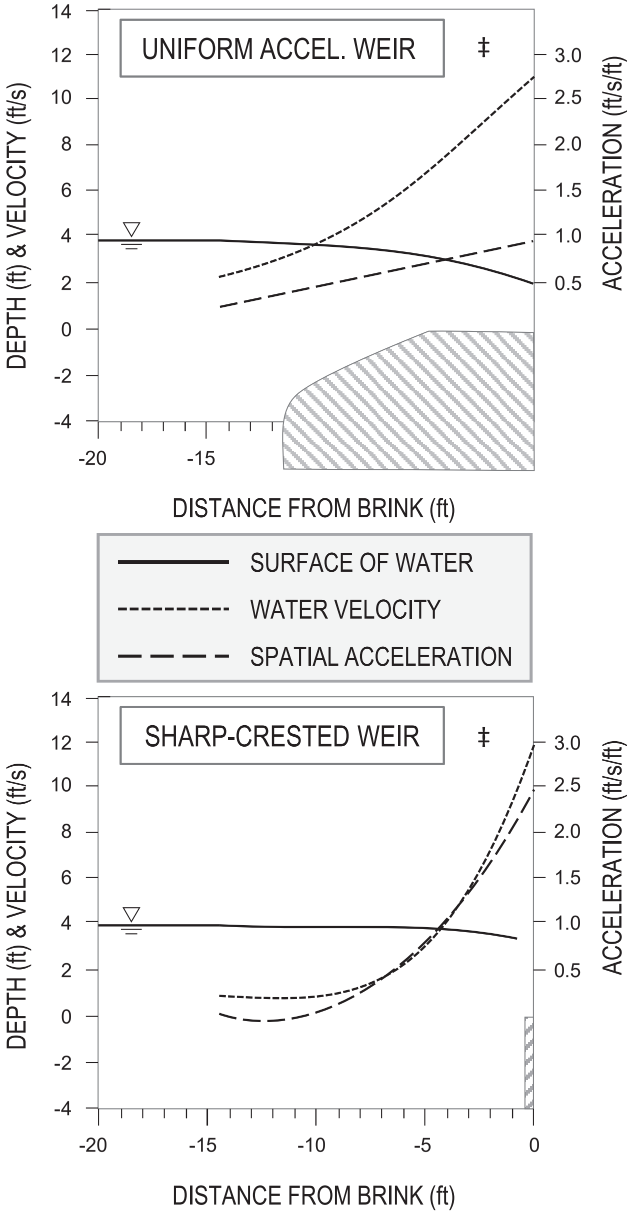
DOWNSTREAM BYPASSES SHOULD BE DESIGNED TO DISCHARGE A MINIMUM OF 5% OF STATION CAPACITY

†

$$\boxed{Q_W = CB_W{H_W}^{1.5}}$$

$$\boxed{3.14 \leq C \leq 3.34}\ ^*$$

- Q_W is flow over weir in cfs
- B_W is the width of the weir in ft
- H_W is head on weir in ft
- C is the weir coefficient



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* Uniform acceleration weir coefficient based on Johnson et al. (1995)

‡ Johnson et al. (1995) “Development of a Downstream Fish Passage Weir”

† U.S. Fish and Wildlife Service criteria

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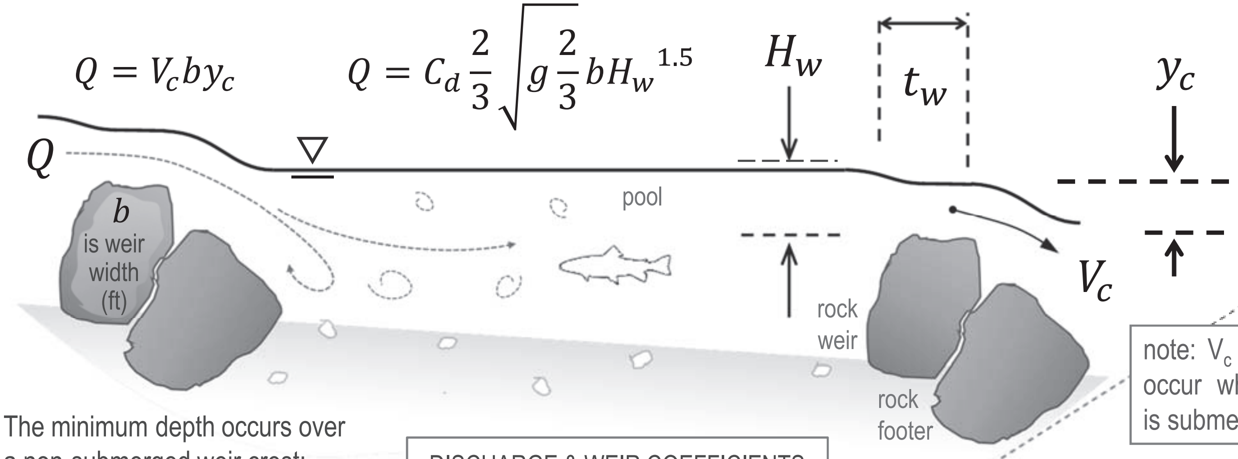
BYPASS AND PLUNGE POOL

REFERENCE PLATE 9-2

HYDRAULICS OF STEP-POOL TYPE, NATURE-LIKE FISHWAYS CAN BE APPROXIMATED AS BROAD-CRESTED WEIRS.

$$Q = V_c b y_c \qquad Q = C_d \frac{2}{3}\sqrt{g\frac{2}{3}}bH_w{}^{1.5}$$



note: V_c may not occur when weir is submerged

The minimum depth occurs over a non-submerged weir crest:

$$y_c = \sqrt[3]{Q^2/gb^2}$$

The maximum velocity occurs at this minimum depth:

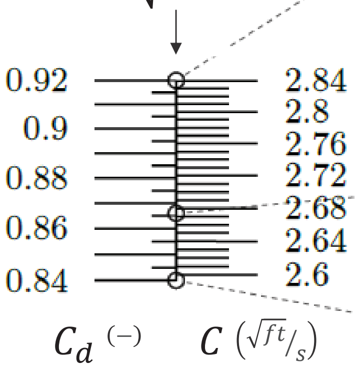
$$V_c = \sqrt{gy_c}$$

Expressed in terms of the discharge coefficient and head:

$$V_c = \sqrt[3]{C_d}\sqrt{\tfrac{2}{3}gH_w}$$

DISCHARGE & WEIR COEFFICIENTS

$$C_d \frac{2}{3}\sqrt{g\frac{2}{3}} = C$$

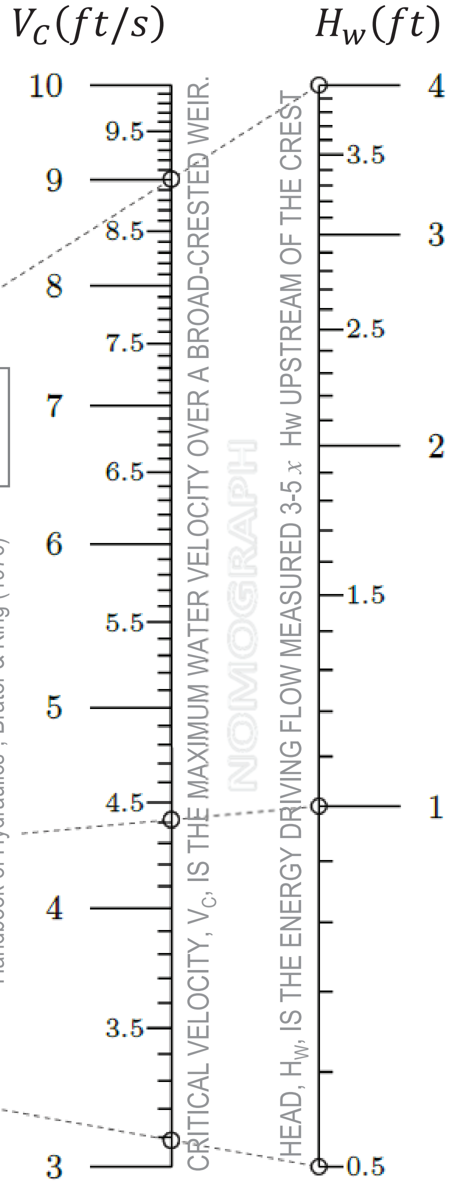


Weir Thickness, t_w (ft)

Head Over Weir Crest, H_w (ft)	5	4	3	2.5	2
0.6	2.7	2.69	2.68	2.6	2.61
0.8	2.68	2.68	2.67	2.6	2.6
1	2.68	2.67	2.65	2.64	2.66
1.2	2.66	2.67	2.64	2.65	2.7
1.4	2.65	2.65	2.64	2.68	2.77
1.6	2.65	2.66	2.68	2.75	2.89
1.8	2.65	2.66	2.68	2.74	2.88
2	2.65	2.68	2.72	2.76	2.85
2.5	2.67	2.72	2.81	2.89	
3	2.66	2.73	2.92		
3.5	2.68	2.76			
4	2.7	2.79			

C $(\sqrt{ft}/_s)$

* "Handbook of Hydraulics", Brater & King (1976)



CRITICAL VELOCITY, V_C, IS THE MAXIMUM WATER VELOCITY OVER A BROAD-CRESTED WEIR.

HEAD, H_W, IS THE ENERGY DRIVING FLOW MEASURED 3-5 x Hw UPSTREAM OF THE CREST

NOMOGRAPH EXAMPLE

With the aid of this nomograph, table, and a straight edge, one can quickly estimate the maximum velocity over a rock weir. Given a weir thickness of 4 feet and a head of 1 foot, the table indicates C = 2.67. Aligning the straight edge from C = 2.67 on the left scale to H_w = 1 foot on the right scale indicates V_c = 4.4 feet per second on the center scale (values shown on dotted line).

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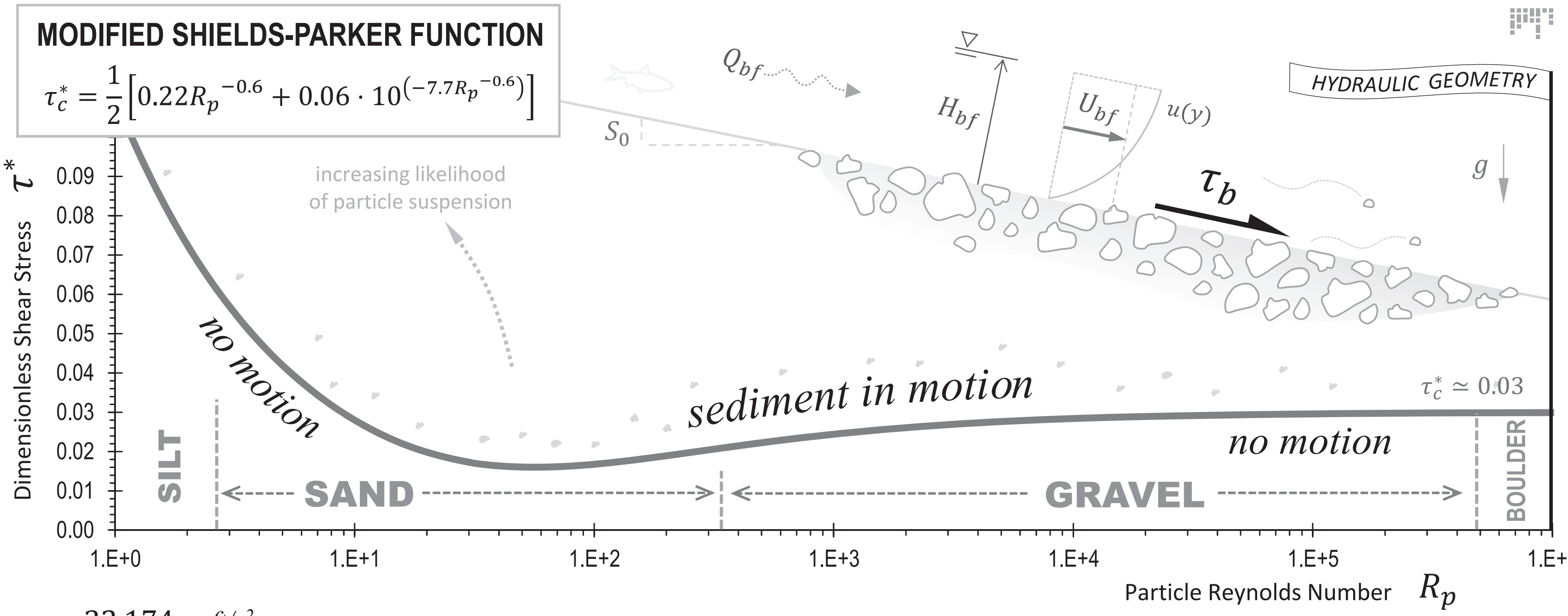
ROCK WEIR HYDRAULICS

REFERENCE PLATE 10-1

MODIFIED SHIELDS-PARKER FUNCTION

$$\tau_c^* = \frac{1}{2}\left[0.22R_p^{-0.6} + 0.06 \cdot 10^{\left(-7.7R_p^{-0.6}\right)}\right]$$



$g = 32.174 \quad ft/s^2$

$\nu = 1.13 \cdot 10^{-5} \quad ft^2/s$ { water at 65F

$R = \frac{\rho_s}{\rho_w} - 1 \cong 1.65$ { for silica

$$\tau^* = \frac{\tau_b}{\rho g R D_{50}} = \frac{H_{bf} S_0}{1.65 D_{50}}$$

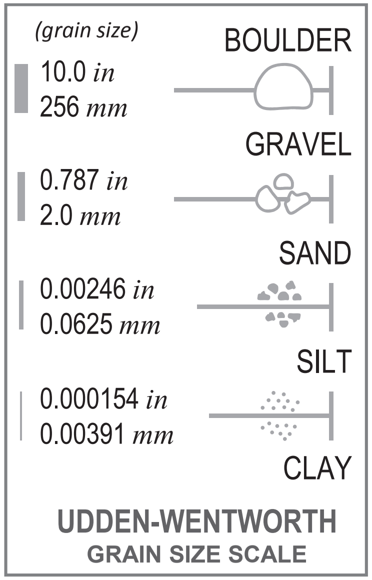
$$R_p = \frac{\sqrt{RgD_{50}}D_{50}}{\nu} \cong \frac{\sqrt{1.65\ gD_{50}}D_{50}}{\nu}$$

Shields (1936) “Appl. of Similarity Princ. & Turb. Res. to Bed Load Movement”
Parker et al, (2003) “Effect of Floodwater Extr. on Mountain Stream Morphology”

The **Shields Diagram** is a graphical representation of the Shields Criterion, a critical shear stress parameter used to calculate the **initiation of motion of sediment** in fluid flow (Shields, 1936). Initiation of motion can be predicted through the relationship between the Shields Criterion, or **Shields Number**, and the particle **Reynolds Number**. Brownlie (1981) and Parker et al. (2003) provided analytical forms of this shear stress-grain size relationship that can be expressed in terms of the hydraulic geometry of rivers.

EXAMPLE: A small stream, with a mean bank-full depth of 4 feet, falls 2 vertical feet for every 1000 horizontal feet. Water temperature is 65 degrees F. Determine if a median grain size of 1 inch meets the Shields Criterion for threshold of motion.

$R_p = 1.57 \cdot 10^4 \;\; ; \;\; \tau^* = 0.0577 \;\; \Longrightarrow$ *motion!*



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Issued 1/6/2017

INITIATION OF MOTION
REFERENCE PLATE 11-1

Appendix B

Fishway Inspection Guidelines

FISHWAY INSPECTION GUIDELINES

TR-2013-01
June 5, 2013

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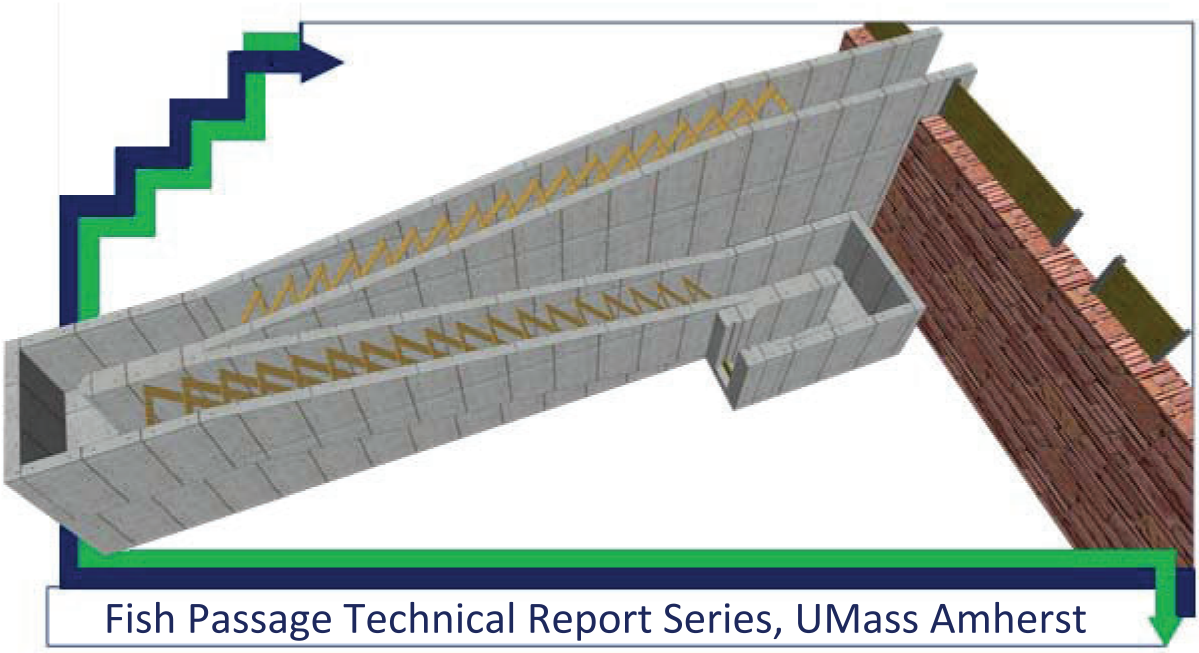

Fish Passage Technical Report Series, UMass Amherst

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Available at: http://scholarworks.umass.edu/fishpassage/

1.0 General

This technical report provides guidance for engineers, biologists, operators, regulators and dam owners involved in the inspection of fishways at dams. Volitional fish ladders, fish lifts, and other fish passage and protection facilities are devices of varying complexity frequently integrated into sophisticated reservoir management and hydropower installations. As with any device, maintenance of fish passage facilities is necessary to ensure their proper operation. Improper operation of fishways may limit or eliminate entire year classes of diadromous fish. Routine fishway inspections are a critical component of an overall fish passage operation and maintenance plan.

2.0 Definition of a Fishway

Fishway (or fish pass) is a generic term for those structures and measures which provide for safe, timely, and effective upstream and downstream fish passage. Fishways include physical structures, facilities, or devices necessary to maintain all life stages of fish, and operations and measures related to such structures, facilities, or devices which are necessary to ensure their effectiveness. Examples include, but are not limited to, volitional fish ladders, fish lifts, bypasses, guidance devices, and operational shutdowns.

3.0 Types of Fishways

Fish passes can be broadly categorized as either technical fishways or nature-like fishways. Nature-like fishways include bypass channels, rock ramps and other passage structures that approximate (either functionally or aesthetically) natural river reaches. Technical fishways employ engineering designs that are typically concrete, aluminum, polymer, and wood, with standardized dimensions, using common engineering construction techniques. The physical and hydraulic structure of nature-like fishways is markedly different from technical fishways, and the inspection of nature-like fishways is beyond the scope of this report. Technical fishways (hereafter, simply fishways) can be further categorized as upstream or downstream passes. Figure 1 shows these categories and common types of fishways.

Baffled-Chute Fishways: Baffled chutes are a subset of upstream volitional ladders designed to reduce velocities in a sloping channel to levels against which fish can easily ascend. Baffled chutes common to the Eastern United States include:

• Steeppass Model A	21-inch wide, 27-inch tall, baffled aluminum channel
• Steeppass Model A40	40-inch tall, deepened version of the Model A steeppass
• Standard Denil	2-to-4 foot-wide (typically concrete) channel with wooden baffles

Pool-Type Fishways: Pool-type upstream fishways are designed to link headwater and tailwater through a series of (typically concrete) pools through and over which water cascades slowly. Pool-types include:

• Pool-and-Weir	pools often separated by rectangular weirs; may also include orifices
• Ice Harbor	variant of the pool-and-weir type; characterized by two weirs separated by central C-shaped vertical baffle

Half Ice Harbor	modified Ice Harbor; characterized by one weir opposite an L-shaped vertical baffle
Vertical Slot	flow through pools via deep, narrow, full-depth slots rather than an overflow weir
Serpentine	similar to a vertical slot with a winding, tortuous horizontal flow path

Fish Lifts/Locks: Fish lifts or elevators are non-volitional upstream fishways that attract fish into an entrance channel and mechanically crowd them above a hopper before lifting them into an impoundment (or alternatively, into an exit channel hydraulically linked to an impoundment). Fish lifts differ from volitional ladders in that they usually possess numerous mechanical, hydraulic, and electrical components. A fish lock is similar to a lift where the hopper and lift tower is replaced with a full-height, columnar structure (i.e., lock) that can be filled with water. Fish locks are rare on Atlantic coast and are therefore not addressed directly in this document.

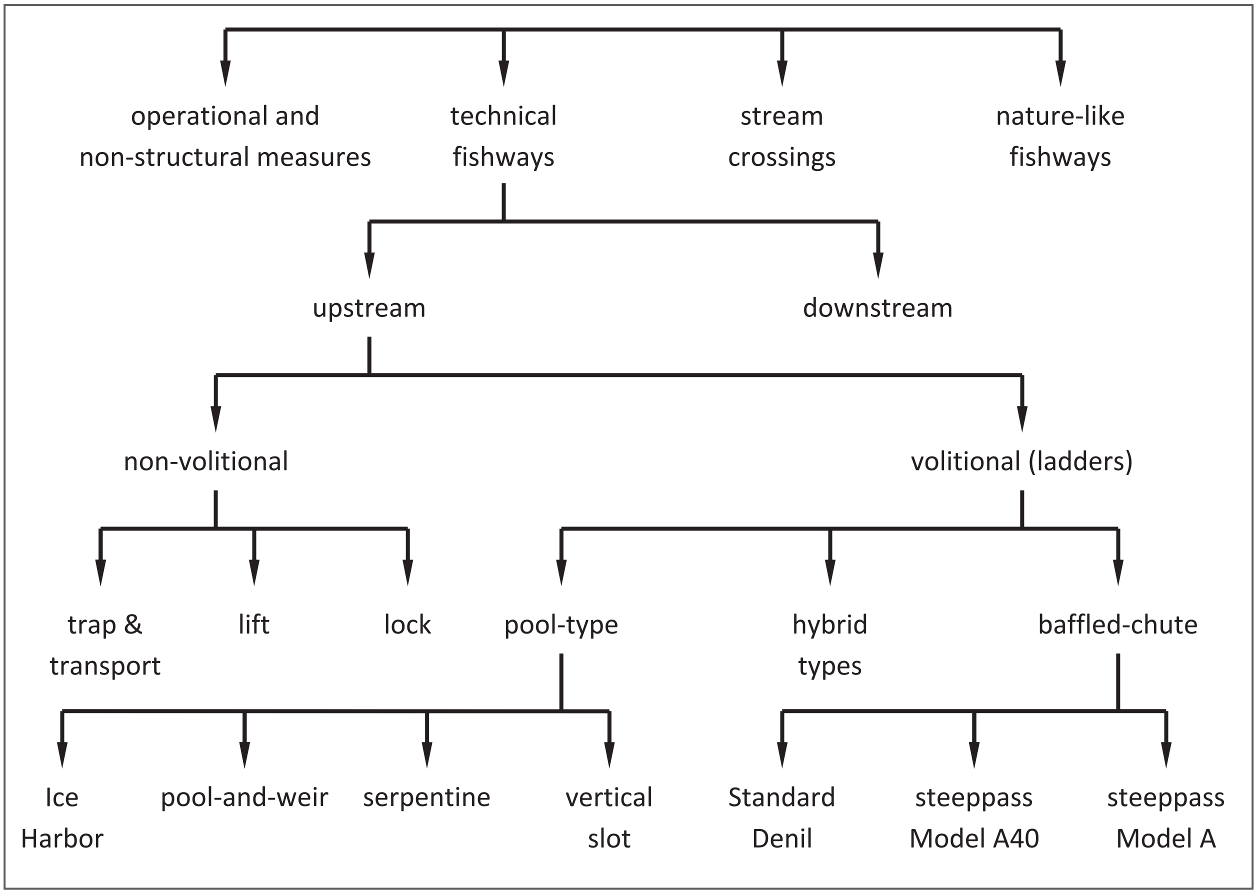

Figure 1. Common fishway types in the eastern U.S.

Downstream Passage: Facilities designed to protect and pass out-migrating fish are varied and diverse ranging from simple overflow weirs to highly complex guidance screens with attraction water recycling systems, bypasses, plunge pools, and fish sampling systems. Typically, these systems consist of four primary components:

- Physical/behavioral guidance screen or bar rack
- Bypass opening (e.g., weir, chute, sluice, or orifice)
- Conveyance structure (i.e., open channel or pressurized conduit)
- Receiving pool

The bypass opening is intended to function as a safe outlet for fish migrating downstream past the dam. Exclusion screens or behavioral guidance screens (or racks) are designed to create physical and/or hydraulic cues that encourage fish to move towards and pass through the bypass opening. Receiving waters or plunge pools are typically necessary to safely transition fish to waters below the dam. Receiving waters generally refer to the existing tailrace or tailwater below the dam; plunge pools are separately excavated pits, or built-up basins, which provide adequate depth to prevent plunging fish from impacting the channel bottom, concrete apron, or other submerged feature.

Eel Pass: Eel passes (or eelways) are upstream passage structures that provide a path over the dam for catadromous elvers and juvenile eels. These structures typically consist of an attraction water delivery system incorporated into ramp lined with various wetted media which eels use to propel themselves up the ramp. They may provide a full volitional pathway for up-migrating eels or terminate in a trap or lift.

The above list represents some of the more common fishways used to mitigate the impacts of stream barriers on the east coast of the United States. However, the reader should be aware that there are numerous other types, variations of these technologies, and auxiliary components not described herein.

4.0 An Approach to Fishway Inspection

The holistic definition of a fishway (as described in Section 2.0) should convey the importance of assessing fishway conditions in a comprehensive manner that considers a) the path of fish past a barrier, and b) the aggregate passage conditions and timing due to the interaction of numerous (non-fishway) structures and operations. Unfortunately, such myriad interactions cannot be enumerated or described in a generalized way. Consider these examples:

- the strength of the hydraulic cue created by a fishway entrance jet may be influenced by tailwater elevation (which, in turn, may be affected by turbine discharge);
- salmonids may ascend over weirs under plunging flow conditions, clupeids may not;
- the efficacy of fishway attraction flow may be compromised by the sequence of turbine operations resulting in delays in upstream migration;
- sweeping velocities in front of a downstream bypass guidance screen may be influenced by generation, trash loading, or spill; and

- water surface elevations throughout a ladder may be influenced by flashboard failure at the upstream spillway.

Therefore, the reader is strongly encouraged to keep the broadest definition of a fishway in mind when performing inspections so as to avoid a myopic view of individual fishway components that may obscure the integrated functionality critical to the proper operation of these facilities.

Certain anomalous conditions or occurrences are seen at more frequently fishways. Inspectors should be keenly aware of, and document, these issues:

- Damage to, or degradation of, structural components
- Visual or auditory evidence of poorly functioning mechanical components
- Leaf litter, large woody debris, or sediment in the fishway
- Adverse water levels in and adjacent to the fishway
- Eddies, jumps, aeration and other unusual hydraulic phenomena
- Evidence of fish delay, entrainment, impingement, injury, or mortality
- Original design deficiencies

5.0 Equipment

Inspectors should anticipate the equipment needed to properly perform the inspection. Furthermore, ensuring the equipment is in proper working order is a prudent step in pre-inspection planning. Battery operated electronic equipment (e.g., total station, camera) should be charged. Digital instruments (e.g., acoustic Doppler velocity meter) may require calibration. In general, all equipment should be checked prior to traveling to the site of the dam or barrier.

The following is a list of items which may prove useful during inspection:

• Inspection checklist	Suggested checklist attached to this document
• Pencil and field book	Checklist may be insufficient to document anomalous conditions
• Voice recorder	Digital recordings can augment notes
• Digital camera	Photographs and video of field conditions are essential to inspection
• Staff gage	Gage (e.g. survey rod) used to measure water surface elevations
• Tape measure	Allows measurement of relevant fishway geometry
• Flashlight	Covered channels and transitions may not be lit
• Lumber crayon	Inspector may wish to mark water levels during operational changes
• Watertight boots	Recommended for inspecting de-watered fishways
• Velocity meter	Useful in assessing velocity barriers and impingement “hot spots”
• Survey/hand level	For precise measurement of HGL or elevation changes

Given the proximity to moving water, heavy equipment, and the steep terrain associated with dams, fishways are potentially hazardous sites. Safety equipment is always recommended. Moreover, fishways are often located at large hydroelectric facilities where rigorous safety programs have been implemented. Safety plans which identify anticipated risks and possible hazards are becoming a more common practice and should be reviewed prior to assessing the facilities. If you are unfamiliar with the site, be sure to contact the dam owner to ensure proper safety protocols are met.

Standard safety equipment may include:

- Hard hat
- Steel-toed boots
- Safety glasses
- Hearing protection (if entrance to the powerhouse is necessary)
- Harness and fall protection
- Personal floatation device (PFD)
- High-visibility orange safety vest
- First-aid kit (equipped bee sting treatment)

6.0 Performing an Inspection

Fishway inspections are best performed in a systematic fashion. The inspection checklist included with this document is intended to guide the reader through a logical sequence from exit to entrance. However, the checklist is intended only as a guide and should not replace good observational skills, adequate record keeping, or site-specific experience. The inspector is strongly encouraged to review any standard operating procedures (SOP) and as-built drawings of the fish passage structures prior to arriving on site. Figures 2 and 3, which illustrate major components of fishways, may help orient the novice inspector.

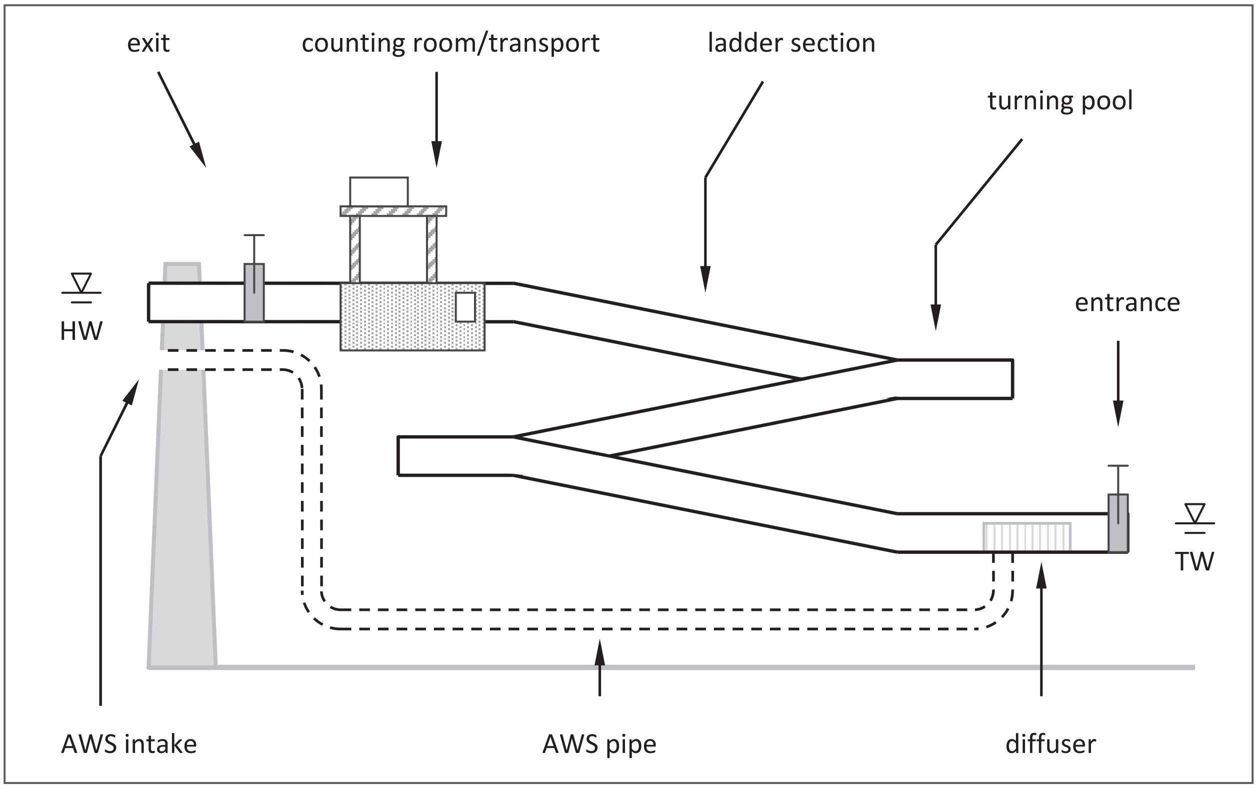

Figure 2. Major components in typical volitional fish ladders

Information gathered on anomalous conditions (either on this checklist or in supplemental records) should include these three important elements:

1. **Location**: Record the location where conditions are of interest. If the location is a standard fishway component then identify it as such:
    - “fishway entrance gate”
    - “3rd turning pool upstream of the entrance”
    - “downstream bypass plunge pool”

    If the location possesses no standard name, describe it in relation to a clearly identifiable, datum or nearby feature:
    - “… 7 feet upstream of the antenna array bond-out”
    - “… overflow pool at elevation 110.5 feet USGS”
    - “… on intake rack 30 feet out from right abutment”
2. **Extent**: Measure or estimate the dimension(s) of the problem or condition:
    - “2-foot by 3-foot section of the wedge-wire screen”
    - “overtopping of 3-feet of water”
    - “6 inches of sediment”
3. **Detail**: A brief description of the condition should be included:
    - “a swirling horizontal eddy forms in the turning pool during operation”
    - “an impassable hydraulic drop forms over the weir crest”
    - “fish trapped behind skimmer wall

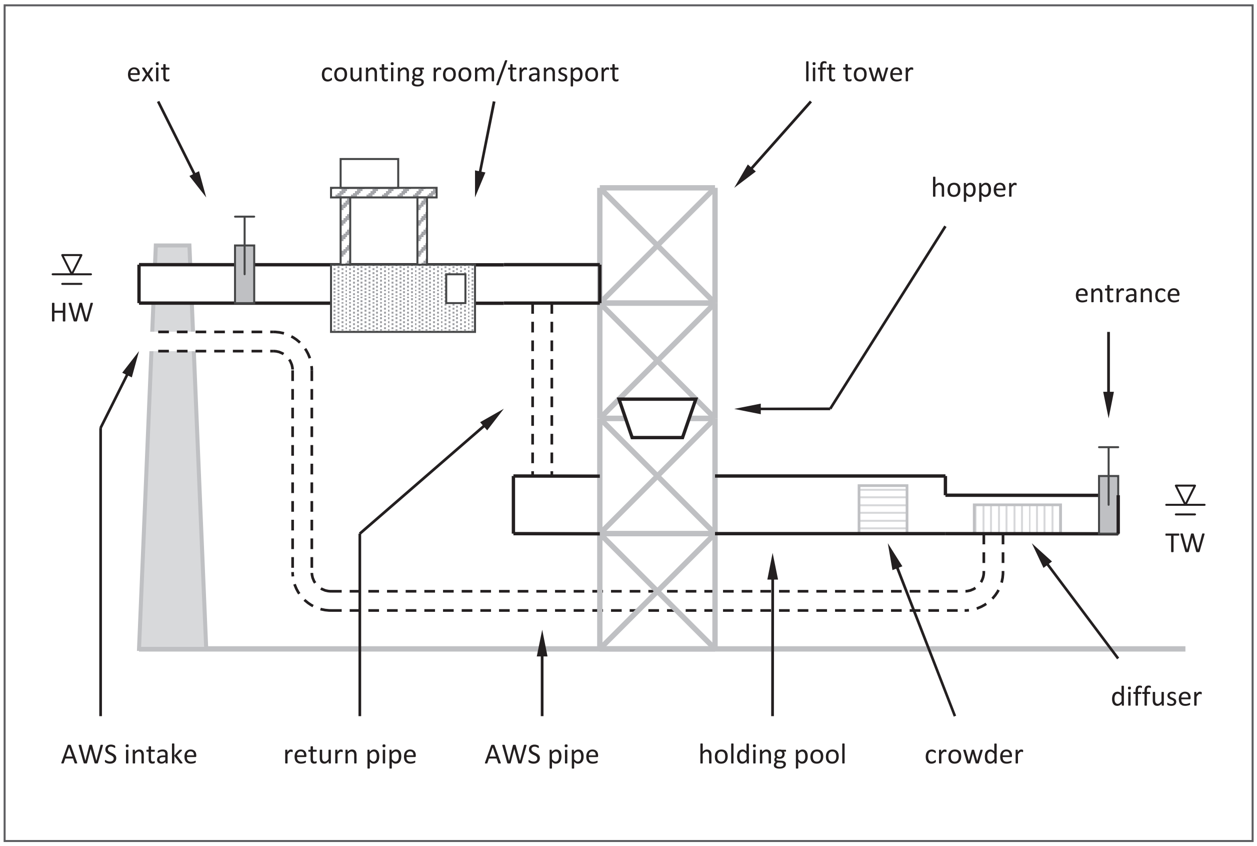

Figure 3. Major components in typical non-volitional fish lifts

7.0 Checklist

The FISHWAY INSPECTION CHECKLIST included in this technical report is formatted to guide the inspector in a sequential manner moving down-gradient from the fishway exit to the fishway entrance. Numbered checklist items are written as questions requiring the user to verify the structural, hydraulic, or operational functionality of fishway components. Comment space is provided at the end of each major section. These major sections are:

<u>Reason for Inspection</u>: Fishways are often inspected during the peak of a migratory fish run to evaluate the facility while operating at design capacity. However, they may be inspected at opening (i.e., start of the season), shut-down, or post-flood to assess damage. Recording the reason for the inspection provides important context for the subsequent notes.

<u>Fishway Status</u>: It is equally important to note whether or not the fishway is de-watered and whether or not it is operating at the time of the site visit. For pre- (or post-) season inspections, the need to examine specific components may dictate the status of the fishway. For instance, a watered, operating fishway may allow for an assessment of the hydraulics, but will also obscure potential problems below the waterline.

Hydrology & Ecology: Fishways vary according to site hydrology and the target species for which they were designed. The inspector should note the target species and mark the approximate migration periods on the upstream (U/S) and downstream (D/S) migration scales. Comments on fish health issues (i.e. VHS, descaling, parasitism) and noting the presence of invasive species may prove useful to resource agencies.

The river flow influences numerous operational aspects of fishway operation including the headpond and tailwater elevation, adjustable gate settings, and entrance jet velocities. The USGS is the principal agency tasked with maintaining stream gages in the U.S. If the dam owner/operator cannot provide the current river flow, the USGS stream gage network should be used:

http://waterdata.usgs.gov/nwis

Additionally, the inspector may consider recording the water temperature at the fishway entrance channel and in the headpond. The movement of many migratory species is linked to water temperature. Surface water temperatures in the impoundment are typically higher than the river and may be further influenced municipal treatment plants and industrial cooling water. A significant difference in fishway temperature versus headpond temperature could indicate undue solar warming in the AWS or fishway pools.

Hydropower Operations: It is well known that dams are barriers to the passage of riverine and migratory aquatic species. Hydroelectric facilities present additional fishway operational challenges and represent a significant hazard to down-migrating fish. Inspectors should document powerhouse capacity, unit type, methods of remote operation, and any operational links between the fishway and turbine sequencing. For example, turbines adjacent to the fishway entrance may be prioritized to enhance attraction flow. Similarly, Kaplan units (which may be less harmful to some species than comparable Francis units) may be preferentially operated during the downstream migration period. Turbine rotational speed often correlates to mortality, and could be documented if the information is available on site. For estimates of approach velocity (in the forebay), inspectors may choose to estimate the turbine intake dimensions. For inspections of dams without powerhouses, users may strike through this section.

Upstream Fishway Exit: The exit typically refers to those components that connect the ladder or lift to the headpond or river upstream of the barrier. It is important to note that the upstream fishway exit is also the hydraulic intake to the fishway (and these seemingly contradictive definitions can cause confusion). The inspector should look for conditions that may prevent or delay fish from quickly exiting the fishway such as debris accumulation, partially opened gates, dark shadows, bright lights and noise-inducing structures. One should also document any evidence that fish are not quickly moving up into the impoundment (and beyond the immediate hydraulic influence of adjacent flood gates, turbines, or other water intakes). If possible, record the headpond water surface elevation.

Ladder: The chute, channel, or pools connecting the entrance to exit are commonly called the ladder. Debris, sediment and failure of wooden water-retaining structures (e.g., blocking boards, weir crests) are the most common causes of operational failure in otherwise-effective fishways. Though time-consuming, the entire ladder can be rigorously inspected for problems in a de-watered state. In an operating and watered state, blockages and board failures can be more quickly identified by the anomalous water surface elevations and flow patterns these problems create. For inspections of lifts, users may strike through this section.

Fishlift: The lift includes the lift tower, holding pool, hopper (i.e., bucket), crowder, brail, and any associated electrical, hydraulic and mechanical components. It also includes any water conveyance between the exit and the entrance (e.g., transfer from hopper to exit flume). Grating on the crowder and exclusion gate behind the hopper are particularly susceptible to debris blockage. Debris can lead to altered flow patterns and velocities, but sharp woody debris lodged in the grating may also injure fish. It is recommended that the inspector observe a complete lift cycle while on site; if possible, the lift cycle should be timed to ensure it is operating within design parameters. Unusual sounds, binding, and vibration during operation are indicators of a problem. Where possible, the operators should accompany the inspectors; operators can provide invaluable insight into the condition of the equipment. For inspections of ladders, users may strike through this section.

Upstream Fishway Entrance: For both lifts and ladders, the entrance consists of a channel of varying length leading fish into the ladder/lift from the tailwater below the dam. Larger hydropower facilities may include collection galleries that consist of a flume with manifold gated entrances. Regulating the attraction jet velocity is perhaps the most critical aspect influencing the effectiveness of the entrance. In the presence of varying tailwater, velocities are controlled through installation of (overflow) weir boards in a slot at the entrance. Alternatively, larger facilities may be equipped with an (overflow) lift gate. Regardless, the gate or boards serve as submerged weirs that locally accelerate the flow to create an attraction jet. The water surface elevations between the entrance channel and the tailwater correlate to the strength of the attraction jet and should be diligently recorded by the inspector. If possible, record the tailwater elevation.

Auxiliary Water System: The fishway must produce a sufficiently strong attraction jet at the entrance often in the presence of other competing flows (e.g., spill, powerhouse discharge). Lifts generate no flow by themselves, and ladders may not discharge enough flow to create an adequate attraction signal. Auxiliary Water Systems (AWS) provide an additional source of water to augment the attraction flow. AWS commonly consist of an intake at the headpond, anti-vortex devices, a headgate, a conveyance pipe, valves, a diffuser chamber, and diffuser outlets. Most of these components are underground or underwater; however the inspector should examine the intake screen for blockages and, if possible, verify the current AWS discharge (with the dam owner or operator).

Downstream Passage Facilities: Access to much of the downstream passage system (e.g., floating boom, intake racks) may be problematic. At a minimum, fishway inspectors should examine the accessible racks/screens, downstream bypass, bypass weir, any fish sampling systems, conveyance structures, and plunge pool. For rack or screens that cannot be measured directly, inspectors may estimate depths and widths (or inquire of the dam owner and/or operator). Unfavorable hydraulic conditions (e.g., lack of guidance, excessive velocities, impinging jets), debris blockages, partially open gates which obstruct fish movement, and incorrectly installed bypass weirs are among the more common deficiencies.

Counting & Trapping: A minority of fishways are equipped with counting rooms and trapping facilities. While not integral to the passage of fish, these elements may support critical monitoring and research programs. Where appropriate, trap gates and lift mechanisms should be operated and examined for serviceability and fish safety. A courtesy engineering assessment of the counting room may be welcomed by the operator and/or resource agency biologist.

Eel Pass: This section is intended to capture elements related to upstream eel passage. Downstream eel passage (if it exists) can be addressed in the “Downstream Passage Facilities” section. Critical elements of the eelway include ensuring the ramp is sufficiently wet and that the media is clean of debris. If the ramp terminates in a trap, check to ensure the trap box receives adequate flow and that eels cannot escape. If the trap box appears overcrowded, notify the project or agency biologist immediately. Uncovered ramps may be susceptible to predation. Additionally, make observations on the attraction water supply system (e.g., water source, approximate flow, flow conditions at the base of the ramp, leakages)

Inspections are time-consuming and demand one’s full attention. Advance preparation will enhance the quality of the inspection. Therefore, it is recommended that the inspector fill out as much of the form as possible prior to arriving on site. As discussed in Section 6.0, fishway SOPs and as-built drawings are valuable sources of information that should be reviewed in advance.

8.0 Disclaimer

These fishway inspection guidelines were developed by the authors with input from other subject-matter experts. They are intended for use by persons who have the appropriate degree of experience and expertise. The recommendations contained in these guidelines are not universally applicable and should not replace site-specific recommendations, limitations, or protocols.

The authors have made considerable effort to ensure the information upon which these guidelines are based is accurate. Users of these guidelines are strongly recommended to independently confirm the information and recommendations contained within this document. The authors accept no responsibility for any inaccuracies or information perceived as misleading. The findings and conclusions in these guidelines are those of the authors and do not necessarily represent the views of the University of Massachusetts Amherst, Integrated Statistics, the U.S. Fish and Wildlife Service, the National Oceanic and Atmospheric Administration, or the United States Geological Survey.

9.0 Acknowledgements

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The authors thank these individuals for their thoughtful contributions.

FISHWAY INSPECTION CHECKLIST

Dam/Project Name: ______________________ Waterway: ______________________

Owner (Organization): ______________________ Date/Time: ______________________

Inspector(s): ____

Owner's Representative(s) On-site: ____

Comments: ____

STATUS

Reason for inspection: ☐ opening ☐ during season/run ☐ shutdown ☐ construction
☐ other ____

Fishway Status:
☐ de-watered/non-operational
☐ watered or underwater/non-operational
☐ unknown damaged/non-operational
☐ watered/operational
☐ damaged/operational

HYDROLOGY & ECOLOGY

1. Target species for fishway: ____

2. U/S migration period:
J F M A M J J A S O N D

3. U/S fish passage design flow:
HIGH ▶ (cfs)
LOW ▶ (cfs)

4. D/S migration period:
J F M A M J J A S O N D

5. Drainage & current river flow (if known): ▶ (mi^2) ▶ (cfs)

Comments on Hydrology & Ecology: ____
____

HYDROPOWER OPERATIONS

6. Is the fishway and dam part of a hydroelectric project? ☐ YES ☐ NO

7. Is there a powerhouse at this location? ☐ YES ☐ NO

8. Powerhouse hydraulic capacity: ▶ (cfs)

9. Project generating capacity: ▶ (MW)

10. Number and type of hydroelectric turbines:

Francis:	Kaplan:	Bulb:	Other:

11. Are units sequenced on/off to enhance fish passage? ☐ YES ☐ NO
If YES, describe operations: ____
____

Comments on Hydropower Operations: ____
____

Dam/Project Name: ____

UPSTREAM FISHWAY EXIT

12. Waterway upstream of the exit is clear of debris: ☐ YES ☐ NO
13. Headgate and/or headboards are in good condition ☐ YES ☐ NO ☐ n/a
14. If operational, have headboards been removed or gates raised? ☐ YES ☐ NO ☐ n/a
15. Are adjustable weirs/baffles set to track HW? ☐ YES ☐ NO ☐ n/a
16. Trashrack is in place and clean? ☐ YES ☐ NO ☐ n/a
17. Trashbooms are in place? ☐ YES ☐ NO ☐ n/a
18. Is a staff gage installed in the fishway exit channel? ☐ YES ☐ NO
19. Is a staff gage installed in the headpond? ☐ YES ☐ NO
20. Differential head measured between exit and headpond: ▶ (ft.)

Comments on Exit: ____

____

LADDER (Not Applicable for Lifts or Locks)

21. Ladder type: ☐▸ Vertical Slot ☐▸ Ice Harbor ☐▸ Pool&Weir ☐▸ Denil ☐▸ Steeppass
☐▸ other: ____
22. Fishway is free of trash and large woody debris: ☐ YES ☐ NO
23. Was the fishway de-watered during inspection? ☐ YES ☐ NO ☐ n/a
24. Concrete walls/floors are free of cracks, erosion, leaks, spalling: ☐ YES ☐ NO ☐ n/a
If NO, describe extent and location: ____

____

25. Pools are free of sand, rocks, and other material: ☐ YES ☐ NO ☐ n/a
If NO, describe accumulations, locations and plan to remove: ______________________

____

26. Baffles, baffles plates, and/or or weirs are installed properly, installed at the correct elevation, and were found in good condition: ☐ YES ☐ NO ☐ n/a
If NO, describe problems and locations (e.g., number from entrance): ______________________

____

27. Has the fishway been inspected for damage that created sharp edges, formed wooden splinters, or resulted in new obstacles (in the flow field) that could injure fish? ☐ YES ☐ NO ☐ n/a
Comments: ____
28. Is the protective grating cover in place and structurally sound? ☐ YES ☐ NO ☐ n/a
29. Representative head measurement (over weir crest, through vertical slot): ▶ (ft.)

If measured, describe location and method (e.g., pool number from entrance, with staff gage):

____

____

Comments on Ladder: ____

____

____

____

____

____

FISHLIFT (Not applicable for Ladders)

30. Was the lift cycled (operated) during this inspection? ☐ YES ☐ NO
31. Holding pool is relatively free of debris: ☐ YES ☐ NO
32. Hopper raises smoothly without binding or vibrating: ☐ YES ☐ NO ☐ n/a
33. Mechanical crowder opens/closes/operates properly: ☐ YES ☐ NO ☐ n/a
34. Crowding proceeds in a manner consistent with design: ☐ YES ☐ NO

If NO, describe problems and locations: ____

____

35. Hopper properly aligns with chute during exit channel transfer: ☐ YES ☐ NO ☐ n/a
36. Is the exit channel (between lift and exit) free of debris? ☐ YES ☐ NO ☐ n/a
37. Other mechanical components appear in good working order: ☐ YES ☐ NO

If NO, describe problems and locations: ____

____

38. Lift appears free of sharp corners that could injure fish: ☐ YES ☐ NO
39. Lift cycles manually or automatically: ☐ Manual ☐ Automatically
40. Cycle time of lift (fishing to fishing): ▶ (min.)
41. Hopper volume (if known): ▶ (ft^3)

Comments on Lift: ____

____

____

UPSTREAM FISHWAY ENTRANCE

42. Is the approach to the entrance(s) free of debris and obstructions? ☐ YES ☐ NO
43. Are boards properly installed in the entrance? ☐ YES ☐ NO ☐ n/a
44. Are adjustable gates tracking TW? ☐ YES ☐ NO ☐ n/a
45. If operational, does the entrance jet appear appropriate? ☐ YES ☐ NO ☐ n/a
46. Is a staff gage installed in the fishway entrance channel? ☐ YES ☐ NO
47. Is a staff gage installed in the tailwater area? ☐ YES ☐ NO
48. Differential head measured between entrance and tailwater: ▶ (ft.)

Comments on Entrance: ____

____

____

AUXILLIARY WATER SYSTEM

49. If the fishway is operational, is the AWS operating? ☐ YES ☐ NO ☐ n/a
50. AWS flow is driven by: ☐ Gravity ☐ Pump ☐ Other
51. The AWS intake screen is undamaged and free of debris: ☐ YES ☐ NO ☐ n/a
52. AWS appears free of debris or other blockages: ☐ YES ☐ NO
53. AWS flow (in cfs or % of turbine discharge) ▶
54. Has this flow been verified? ☐ YES ☐ NO ☐ n/a

If YES, by whom and/or how? ____

Comments on AWS: ____

____

Dam/Project Name: ______________________________

DOWNSTREAM PASSAGE FACILITIES

55. Are there facilities specifically design for d/s passage on site? ☐ YES ☐ NO

56. If so, are d/s facilities open and operational? ☐ YES ☐ NO ☐ n/a

57. Identify all possible SAFE routes for d/s passage at this site:

☐ d/s bypass ☐ spillway ☐ floodgate ☐ logsluice ☐ surface collect.

If other routes, describe: ______________________________

58. Flow field in impoundment appears conducive to d/s passage: ☐ YES ☐ NO ☐ n/a

If NO, describe problems and locations: ______________________________

____

59. If appropriate, are overlays in place on trash racks? ☐ YES ☐ NO ☐ n/a

60. Are screens (or overlays on trashracks) relatively free of debris? ☐ YES ☐ NO ☐ n/a

61. Is there any evidence of fish impingement on racks or screens? ☐ YES ☐ NO

If YES, describe problems and locations: ______________________________

____

62. Is the d/s bypass intake adequately lit and free of debris? ☐ YES ☐ NO ☐ n/a

63. Is the d/s conveyance free of debris and obstructions? ☐ YES ☐ NO ☐ n/a

64. Are sharp corners evident in the bypass which could injure fish? ☐ YES ☐ NO ☐ n/a

65. Approximate depth of flow over bypass crest: ▶ ______ (ft.)

66. Does d/s bypass discharge into sufficiently deep pool/water? ☐ YES ☐ NO ☐ n/a

67. Approximate plunge height from d/s bypass crest to receiving pool/water: ▶ ______ (ft.)

68. Is there evidence of significant predation at receiving pool/water? ☐ YES ☐ NO

If YES, describe: ______________________________

69. D/S Bypass flow (in cfs or % of turbine discharge) ▶ ______ $(^{cfs}/_{\%})$

Comments on D/S Passage: ______________________________

____

____

____

COUNTING & TRAPPING

70. Is the facility equipped for trapping & sorting? ☐ YES ☐ NO

71. Systems for transfer from tank to truck appear in order? ☐ YES ☐ NO ☐ n/a

72. Do mech. components (e.g., winches, gates) appear serviceable? ☐ YES ☐ NO ☐ n/a

73. Were gates/winches tested during inspection? ☐ YES ☐ NO

Note any concerns: ______________________________

____

74. Is there a counting house/room at the site? ☐ YES ☐ NO

75. Is the counting window clean and properly lit? ☐ YES ☐ NO ☐ n/a

76. Is CCTV and camera system operating properly? ☐ YES ☐ NO ☐ n/a

77. If counts are automated (e.g. resistance), is it functioning? ☐ YES ☐ NO ☐ n/a

Comments on Counting & Trapping: ______________________________

Dam/Project Name: ____

78. Is there an eel pass on site? ☐ YES ☐ NO ☐ n/a

79. If YES, what is the type of eel pass:

☐ volitional ramp (TW to HW) ☐ permanent ramp & trap/lift ☐ temporary ramp & bucket

80. Describe the eel pass substrate media type:

☐ stud (peg) ☐ bristle ☐ geotextile mat ☐ other: ________________________

81. Is the eel pass currently operating (i.e., wetted and installed)? ☐ YES ☐ NO ☐ n/a

Identify the water source (i.e., gravity, pump): ____

82. Is the media clean of debris and watered throughout? ☐ YES ☐ NO ☐ n/a

Describe depth of flow and adequacy of attraction: ____

Comments on Eel Pass: ____

____

EEL PASS

OBSERVATIONS ON THE PRESENCE AND/OR MOVEMENT OF FISH DURING INSPECTION:

GENERAL COMMENTS:

RECOMMENDATIONS:

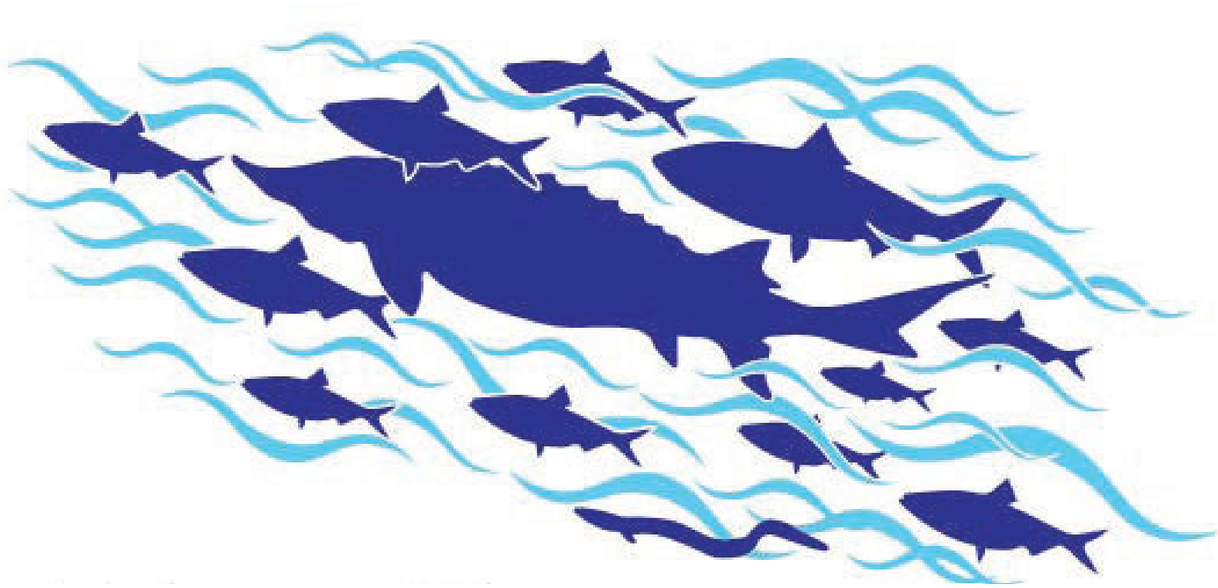
Appendix C

Federal Interagency Nature-like Fishway

Passage Design Guidelines for Atlantic Coast Diadromous Fishes

Technical Memorandum

Federal Interagency Nature-like Fishway Passage Design Guidelines for Atlantic Coast Diadromous Fishes



May 2016

B-515

Technical Memorandum
Federal Interagency Nature-like Fishway Passage Design Guidelines for Atlantic Coast Diadromous Fishes

May 2016

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Abstract: The National Marine Fisheries Service (NMFS), the U.S. Geological Survey (USGS) and the U.S. Fish and Wildlife Service (USFWS) have collaborated to develop passage design guidance for use by engineers and other restoration practitioners considering and designing nature-like fishways (NLFs). The primary purpose of these guidelines is to provide a summary of existing fish swimming and leaping performance data and the best available scientific information on safe, timely and effective passage for 14 diadromous fish species using Atlantic Coast rivers and streams. These guidelines apply to passage sites where complete barrier removal is not possible. This technical memorandum presents seven key physical design parameters based on the biometrics and swimming mode and performance of each target fishes for application in the design of NLFs addressing passage of a species or an assemblage of these species. The passage parameters include six dimensional guidelines recommended for minimum weir opening width and depth, minimum pool length, width and depth, and maximum channel slope, along with a maximum flow velocity guideline for each species. While these guidelines are targeted for the design of step-pool NLFs, the information may also have application in the design of other NLF types being considered at passage restoration sites and grade control necessary for infrastructure protection upstream of some dam removals, and in considering passage performance at sites such as natural bedrock features.

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Disclaimer: The efficacy of any fish passage structure, device, facility, operation or measure is highly dependent on local hydrology, target species and life history stage, barrier orientation, and a myriad of other site-specific considerations. The information provided herein should be regarded as generic guidance for the design of NLFs for the Atlantic Coast of the U.S. The guidelines described are not universally applicable and should not replace site-specific recommendations, limitations, or protocols. This document provides generic guidance only and is not intended as an alternative to proactive consultation with any regulatory authorities. The use of these guidelines is not required by NMFS, USFWS or USGS, and their application does not necessarily imply approval by the agencies of any site-specific design.

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Introduction

Diadromous fishes spend portions of their lives in marine, estuarine and freshwater environments and migrate great distances throughout their life cycles. All diadromous fish species require unimpeded access between their rearing and spawning habitats. Diadromous fishes that use freshwater rivers and streams of the Atlantic Coast of the U.S. as spawning habitats include a diverse anadromous species assemblage, and the catadromous American eel (*Anguilla rostrata*) which spends much of its life in freshwater rearing habitat with adults out-migrating to spawn in the Sargasso Sea. These fishes deliver important ecosystem functions and services by serving as forage for higher trophic-level species in both marine and freshwater food webs (Collette and Klein-MacPhee 2002; Ames 2004; McDermott et al. 2015) and providing an alternative prey resource (i.e., prey buffer benefitting other species) to predators in estuaries and the ocean (Saunders et al. 2006). In rivers and streams, services provided by this diadromous fish assemblage include relaying energy and nutrients from the marine environment (Guyette et al. 2013),transferring energy within intra-species life stages in streams (Weaver 2016), providing benthic habitat nutrient conditioning and beneficial habitat modification (Brown 1995; Nislow and Kynard 2009; West et al. 2010), serving as hosts to disperse and sustain populations of freshwater mussel species (Freeman et al. 2003; Nedeau 2008), and enhancing stream macro-invertebrate habitat (Hogg et al. 2014).

Diadromous fishes are also recognized in contributing significant societal values. Historically, Native Americans, European colonists, and post-settlement America relied heavily on these species as sources of food and for other uses (McPhee 2003). Many of these diadromous fish species are highly valued in supporting commercial and recreational fisheries, with some species prized as sportfish and/or food sources including culinary delicacies (Greenberg 2010). They also contribute to important passive recreational opportunities where people can observe spring fish runs, learn about their life histories, and appreciate these migratory fishes and their key roles in riverine, estuarine and marine ecosystems (Watts 2012).

Many populations of Atlantic Coast diadromous fishes have been in serious decline for decades due to multiple factors including hydro-electric dams and other river barriers preventing access to spawning and rearing habitats, water and sediment quality degradation, overharvesting, parasitic infestations and other fish health effects, body injuries due to boat strikes and other human-induced impacts (Limburg and Waldman 2009; Hall et al. 2011; Waldman 2014). Shortnose sturgeon (*Acipenser brevirostrum*), Atlantic salmon (*Salmo salar*), and Atlantic sturgeon (*Acipenser oxyrinchus oxyrinchus*) (NMFS 1998, 2009, 2013a) have been designated as endangered under the Endangered Species Act (ESA) (Atlantic sturgeon are currently listed as threatened in the Gulf of Maine). American eel were recently considered for listing under the ESA (USFWS 2011, 2015) and are currently designated as a Species of Concern. Both alewife (*Alosa pseudoharengus*) and blueback herring (*Alosa aestivalis*) were designated as Species of Concern in 2006 (NMFS 2006), and NMFS was petitioned in 2011 to list both as ESA species. NMFS completed its review for the candidate ESA listing in 2013 and determined that listing either river herring species was not warranted as either threatened or endangered. NMFS continues to collect and assess monitoring data on the status of populations and abundance trends of and threats to each river herring species (NMFS 2013b). Rainbow smelt (*Osmerus mordax*) were also previously designated by NMFS as a Species of Concern (NMFS 2007).

To address these precipitously declining diadromous fish populations, pro-active restoration has been implemented by many agencies and non-governmental organizations to help restore diadromous fish runs by removing dams and other barriers, installing technical and nature-like fishways, or a combination of these passage restoration alternatives. Improving habitat access through dam removal and other measures may also contribute to diadromous species recolonizing historic freshwater habitats and increasing abundance and distribution of target species locally (Pess et al. 2014). Federal regulatory programs also seek to minimize upstream and downstream mortality of diadromous fishes passing hydro-electric dams or other river and stream barriers by requiring mitigative passage measures.

The NMFS and USFWS have well-established programs to address diadromous restoration by providing funds for and/or technical assistance in the planning, design and implementation of fish passage restoration. Both NMFS and USFWS along with USGS seek to advance engineering design and technology in providing safe (from both physical injury and predator avoidance), timely, and effective upstream and downstream passage for all diadromous species targeted for restoration. At many passage barrier sites, complete removal of the obstruction presents the best alternative for restoring diadromous fish passage and watershed populations.

For sites where barriers cannot be fully removed or modified, other passage alternatives can be considered. Nature-like fishways (NLFs) include a wide variety of designs such as step-pools, roughened ramps, rock-arch rapids, rocky riffles, and cross vanes which are typically constructed of boulders, cobble, and other natural materials to create diverse physical and hydraulic conditions providing efficient passage to multiple species including migratory and resident fish assemblages. NLFs also provide greater surface roughness and flow complexity than typical technical (or structural) fishways (e.g., Denil, steep-pass fishways), creating attractive flow cues to passing fish. Interstitial spaces and surface irregularities associated with NLFs also provide cover and spawning microhabitats, which may be particularly important in watersheds where these specific habitats are limited. The use of natural materials in NLFs such as fieldstone boulders and cobble is also beneficial in lessening the likelihood of fish injury from sharp-edge structures such as those typically associated with structural fishways. NLF designs such as partial or full-river width or bypass channels around barriers can result in effective passage if appropriately designed and constructed for passing fish over a wide range of flows throughout the anticipated seasonal run period for a target species or run periods for targeted fish species assemblage.

Rationale for Passage Guidelines

Fish passage guidelines contribute to best design practices, promote design consistency, and facilitate time and cost-efficiency and quality in engineering design of NLFs and related passage supporting ecological restoration of river systems. NMFS, USGS and USFWS initiated a collaborative effort in 2010 to compile and review existing information from published journals, reports and other unpublished literature on body dimensions and the swimming and leaping capabilities of 14 Atlantic Coast diadromous fish species, and passage and hydraulic functioning of existing fishways. Published data on critical swim speed for each species were also secured, when available. NMFS subsequently organized and held a technical workshop including fish passage biologists and engineers from USGS, USFWS and state agencies experienced with diadromous fish passage in the Northeast region to discuss knowledge and experiences in species passage success and challenges. Subsequent federal agency meetings were held and follow-up consultations were made with professionals from state agencies, academia, and private industry to secure supplemental information on the biology of these target species and their experience with and data available for or analysis of fish swimming performance and/or passage evaluation of the Atlantic Coast diadromous fish species.

Compiling and assessing species data and information from expert knowledge and field and flume laboratory experiences, NMFS, USGS and USFWS applied the collective dataset in developing science-based guidelines when fish swimming and leaping data were available, or best professional judgment when scientific data were limited or unavailable. Compiled information includes the ranges in body length and depth for each of the 14 target diadromous species, to derive body depth-to-total length ratios. These data were then applied in developing a set of six dimensional guidelines for designing passage openings and resting pools. To date, swim speed data from controlled respirometer experiments are available for 10 of the 14 species. Swim data from controlled open-channel swimming flume experiments were available for 8 of the 14 species (data for shortnose sturgeon and Atlantic salmon from USGS Conte Laboratory open flume are forthcoming). Swimming performance data from both respirometer and open-channel swimming flume research was then used to derive maximum through-weir velocity guidelines for each species. Where performance data for a species are minimal, more conservative estimates have been applied in developing the guidelines. The rationales for the guidelines presented in this document include published references or other source of information, as indicated; otherwise, guidelines presented herein are based on best professional judgment.

These guidelines are primarily for purposes of informing the design of NLFs, and in particular, nature-like, step-pool fishways that include resting pools formed by boulder weirs with passage notches specifically designed for the intended target species. One or more of these passage guidelines may also have application to other types of NLFs. These guidelines may also be considered for application in evaluating potential passage alternatives at low-head dams and other barrier sites (e.g., flow diversion and gauging station weirs) and in designing grade control structures upstream of potential dam removals to improve fish passage and/or to protect upstream infrastructure (e.g., bridges and utilities buried in channel bed and bordering floodplain). At some dam removal sites, passage design features may be required upstream of barrier removals to take into account channel bed adjustments which may otherwise result in exposure of and damage to existing infrastructure and/or re-exposure of natural bedrock features. These guidelines may also have application for assessing the likelihood of safe, timely and effective passage at existing natural barriers considered in the context of passage restoration throughout a watershed. As additional studies on fish swimming performance and fish passage effectiveness are completed, these guidelines may be subject to further updates and revisions.

Existing Fish Passage Design Criteria and Guidance

During development of these guidelines, a thorough review was conducted to evaluate other efforts in establishing criteria for fish passage design. To date, a science-based application of fish body morphology, swimming and leaping capabilities, and behavior for passage design has been limited, with most early studies and publications focused on salmonid passage through culverts in the U.S. Pacific Northwest. Bell (1991) presents a synopsis of biological requirements of a limited number of fish species which are then applied to developing biological design guidance including swimming speeds of both juvenile and adult life stages; the published swimming speeds are based primarily on limited and non-standardized experimental methods. Clay (1995) provides an overview of fishway types and examples of installed technical fishways on the Atlantic Coast of North America and elsewhere, with passage guidance that targets hydraulics over weirs, through slots or orifices, and in resting pools which are related to varying fish swims speeds. Beach (1984) and Pavlov (1989) note that body length and water temperature influence swim speeds which in turn help to define passage design guidance.

The Food and Agriculture Organization (FAO 2002) released guidance on European upstream fish passage design, as a follow-up to a 1996 publication prepared by the German Association for Water Resources and Land Improvement (‘DVWK’). The FAO document addresses general fish body size and swim speed of a number of European species, along with designated river “fish zones” in which diadromous and resident fishes are found. The FAO guidance also addresses both nature-like and technical fishways, and general design and detailed guidelines for, and completed examples of (e.g., design dimensions, construction materials and fishway sizes) nature-like fishways. The FAO document is the first guidance for nature-like fishway design, taking into account the swimming and leaping capabilities of fishes.

The Maine DOT (2008) presents both a fish passage policy and design guidelines for passage of diadromous and freshwater fishes through culverts including a minimum-depth guideline applied to low flows, and a maximum-flow velocity guideline based primarily on body-length derived from sustained swimming speeds of target species. The Maine DOT guidance does not address design guidance for fishways. Similar culvert design guidance was released by the Vermont DFW (2009) discussing Atlantic salmon and resident freshwater species biometric and swimming information for passage design including maximum jump height, and a minimum passage water depth of 1.5 times the maximum body depth of the target species. Other states (Washington, California) have released guidance materials for anadromous fish passage design of culverts (Bates et al. 2003, California Department of Fish and Game 2009). The guidelines for velocity and jump height thresholds in these design documents are typically intended to provide passage conditions for the weakest fishes and smallest individuals of each species, while the minimum passage depth guideline for a species is based on the largest-sized fish expected to pass.

There are several sources of passage design for the construction of nature-like fishways. NMFS' Northwest Region provides guidance for passage specifically for Pacific salmonids (primarily genus *Oncorhynchus*) (NMFS 2008, updated 2011), with fish biological requirements and specific design guidelines (prescriptive unless site-specific, biological rationale is provided and accepted by NMFS) and general guidelines (specific values or range in values that may vary when site-specific conditions are taken into consideration) to address a variety of passage types including both technical fishways and nature-like ramps. Aadland (2010) addresses dam removal and nature-like structures for achieving fish passage targeting Mid-Western region warm and cool water fish assemblages, with nature-like fishways serving as features to emulate natural rapids and providing a range of passage conditions and in-fishway habitats benefitting diverse fish assemblages with varying species' swimming capabilities. The document also presents a review of engineering design practices for rock ramp, rock arch rapids and bypass channels. The U.S. Department of Interior's Bureau of Reclamation (Mooney et al. 2007) provides detailed guidelines for nature-like rock ramp design, although species-specific body metrics and swimming and leaping requirements are not addressed in detail.

This existing published passage guidance literature contributes valuable input on how criteria and guidelines have been developed for a number of fish species and variety of fish assemblages and river systems. Conversely, none of the guidelines are targeted specifically for Atlantic Coast diadromous fishes which each have specific body morphology and swimming and leaping capabilities. NMFS, USGS and USFWS thus seek to provide a set of guidelines addressing this diadromous fish assemblage for use by passage restoration practitioners.

Federal Interagency Guidance with Science-Based Application

As noted above, the federal interagency team reviewed and evaluated relevant published journal articles, reports and gray literature, summarized and selected more recent data gained through controlled experiments (e.g., USGS Conte Anadromous Fish Laboratory and other open channel flumes), utilized past performance data from constructed NLFs (primarily in the Northeast), and advanced hydraulic formulae pertinent to nature-like fishway design (e.g., SMath model; See Towler et al. 2014) to develop these science-based guidelines. These guidelines are intended to benefit passage design professionals with information to provide safe, timely and effective passage for Atlantic Coast diadromous fish species targeted in using step-pool and other NLFs.

Target Species

Biological information has been compiled and evaluated for fourteen diadromous species in developing these passage design guidelines. The species addressed in this memorandum include species endemic to the Atlantic Coast. The species are listed according to an evolutionary taxonomic hierarchy (**Table 1**). While not currently addressed by this document, other anadromous (e.g., sticklebacks), amphidromous, and/or potamodromous fish species may be added in future interagency updates, as more research-based swimming and leaping performance data become available and are evaluated.

Table 1. Atlantic Coast Diadromous Fish Species, Common and Scientific Names

Common Name	Scientific Name
Sea lamprey	*Petromyzon marinus*
Shortnose sturgeon	*Acipenser brevirostrum*
Atlantic sturgeon	*Acipenser oxyrinchus oxyrinchus*
American eel	*Anguilla rostrata*
Blueback herring	*Alosa aestivalis*
Alewife	*Alosa pseudoharengus*
Hickory shad	*Alosa mediocris*
American shad	*Alosa sapidissima*
Gizzard shad	*Dorosoma cepedianum*
Rainbow smelt	*Osmerus mordax*
Atlantic salmon	*Salmo salar*
Sea-run brook trout	*Salvelinus fontinalis*
Atlantic tom cod	*Microgadus tomcod*
Striped bass	*Morone saxatilis*

Fish passage engineers and other practitioners should consult with fishery biologists familiar with diadromous fish populations on a regional basis and with the watershed targeted for restoration to secure reliable species and meta-population-specific information on run timing and projected restored run size for each targeted species. Information should include the range of earliest to latest dates of passage, including documented or anticipated earlier season runs or truncated run periods due to climatic change effects on in-stream water temperatures and/or peak discharges. The identification and agreement on the target species to be restored in a watershed and passed at a proposed restoration site should be a principal project objective and central to the initial step in the design process (See Palmer et al. 2005).

Run Timing and Passage Flows

Seasonal timing of fish migrations is a key consideration in fishway design, and needs to be thoroughly considered in determining fish passage design flows and fishway discharge. Fish run timing is often highly variable throughout each species' geographical range, between watersheds, and over years. Run timing, encompassing the beginning, peak, and end of a fish species migratory run period (or spring and fall run periods), is influenced by multiple factors. These factors include genetics; environmental conditions such as precipitation and other weather events and patterns; freshwater, estuarine or oceanic conditions; river flows including the effects of hydro-electric impoundment releases or water withdrawals; in-stream turbidity, dissolved oxygen levels and water temperatures including short-term fluctuations in air and water temperatures; time of day and ambient light conditions; and the specific passage site location within a watershed. Changes in the timing (along with changes in species range and recruitment and habitat change due to sea-level rise) of Atlantic Coast migratory fish runs due to climate change have been identified in a number of locations (Huntington et al. 2003; Juanes et al. 2004; Fried and Schultz 2006; Ellis and Vokoun 2009; Wood and Austin 2009).

For purposes of this document, the federal agencies recommend that a NLF be designed to function in providing passable conditions over a range of flows from the 95% to 5% flow exceedance during the targeted species migratory run period or the collective run periods for multiple target species. The range of river flows used to inform the design of a fishway can be graphically represented by a flow duration curve (FDC). The FDC should be based on the historic probability of flows at the site, or scaled to the project site from an appropriately similar reference site. Active, continuously operated USGS stream gages typically provide the most reliable and complete record of flows for rivers and streams in the U.S. To reasonably estimate future conditions, a sufficiently long period of record (POR) is required. In general, a POR of 10 to 30 years is recommended. Furthermore, the use of post-1970 flow data is preferred to account for documented increasing peak flows over time due to climatic change (See Collins 2009). Additional considerations that influence the length of the POR may include, but are not limited to, gauge data availability, alterations in upstream water management, and changing trends in watershed hydrology.

Body Morphology, Swimming and Leaping Capabilities and Behaviors

Diadromous fishes vary greatly in body shape and size and swimming and leaping capabilities. General body size in fish populations may be affected by genetics, environmental conditions and other factors. Historic fishery catch data indicate decreasing trends in average body size of anadromous fishes that have resulted from overharvesting and natural mortality factors (ASMFC 2012; Waldman 2014; Waldman et al. 2016). Fish body shape and anatomy are determinants of how a fish moves, functions, and adapts to its river environment. Fish body size also affects swimming performance, and swimming ability is largely a function of fish biomechanics and hydrodynamics of its environment (Castro-Santos and Haro 2010). Larger fish have proportionally more propulsive area and a larger muscle mass, and are thus able to move at greater absolute speeds (i.e., the absolute distance through water covered over time). For example, a 10-cm long striped bass swimming at 5 body lengths per second will move through the water at 50 cm per second, while a 50 cm striped bass swimming at 5 body lengths per second will move through the water at 250 cm per second. Larger fish may also have a greater likelihood of injury from coming in contact with boulders or other structures. Fish age, physiological state, and environmental conditions such as water temperature, are additional factors influencing fish movement, behavior (e.g., propensity to pass in schools or groups), passage efficiency, and ultimately passage effectiveness.

In addition to swimming biomechanics, fish exhibit an equally important variety of behavioral responses to their physical and hydraulic environment such as motivation, attraction, avoidance, orientation, maneuvering, station-holding, depth selection, and schooling. In particular, schooling behavior occurs with some species and should be accommodated in fish passage design (e.g., passage opening dimensions and/or multiple openings within each boulder weir). Although basic behaviors of fish have been studied in both laboratory and field environments, only a modest number of behavioral studies have directly addressed fish passage. Most behavioral observations in reference to passageways have been a secondary outcome of passage evaluation studies, where study objectives or experimental designs were not focused on the evaluation of the causes of the behavioral responses.

Understanding the swimming capability of a target species is critical to designing fish passage sites. Swimming performance depends greatly on the relationship between swim speed and fatigue time. At slower speeds, fish can theoretically swim indefinitely using aerobic musculature. Once swim speed exceeds a certain threshold, fish begin to recruit different muscle fibers that function without using oxygen. This condition is noticeable by the onset of *burst-and-coast swimming* – a kinematic shift, whereby fish use both aerobic and anaerobic muscle fibers to power locomotion (Beamish 1978). Anaerobic muscle fibers can only perform for brief periods before running out of metabolic fuel; thus, high-speed swimming results in fatigue and is usually of very short duration. This physiological condition affects potential passage by a fish through high-velocity zones in rivers and fishways. In general, fish swim at speeds requiring anaerobic metabolism infrequently, given the energetic demands of this swimming mode.

Three operationally-defined swimming modes exist in fish: sustained, prolonged, and sprint speeds. Sustained swimming occurs at low or sustained speeds that are maintained for greater than 200 minutes (Beamish 1978). Prolonged swimming occurs at speeds that fish can maintain for 20 seconds to 200 minutes, and sprint swimming can only be maintained for periods of less than 20 seconds. Determining these swim modes and the critical swim speed – the threshold at which a fish changes from sustained to prolonged swim speeds (U_{crit}) is challenging. For many species, quantitative measures of these swimming modes are unknown, and only a few fish species have been comprehensively evaluated for all three modes.

Laboratory respirometer experiments are used to determine the thresholds for a species' swim speeds, but these tests tend to underestimate maximum swimming speed, and may therefore, be limited in accurately measuring burst-speed swimming. Determining burst swimming speeds is usually conducted in open channel flumes, but these experiments can also be biased by fish behavior, stress, or motivation (Webb 2006). Nonetheless, open channel flume studies usually provide better estimates of true swimming performance than results from studies of fish in respirometers, and are the preferred data source for determining fish swimming capabilities and for establishing passage guidelines presented in this document. Existing experimental swim data are also limited in terms of the size range of fish, species life history stage, and experimental water temperatures. Swimming capabilities of fish may also be significantly influenced by turbulence, air entrainment, or other hydraulic/physical factors that influence swimming efficiency and fish motivation.

Leaping (or "jumping") is another component of swimming performance that must be considered in designing and assessing fish passage sites. Leaping height is positively correlated with swimming speed and water depth of the pool from which fish leap. Larger or deeper pools allow higher swimming velocities (i.e., a "running start") to be attained before leaping. Larger fish tend to have greater absolute leaping heights, but also require corresponding increased depths from which to leap. Leaping behavior can be initiated by the fall or plunging flow into a pool creating strong submerged water jets which serve as a stimulus and orientation cue for the direction and speed of an ensuing leap. While salmonids are known to leap during their upstream passage, many non-salmonid fish species are poor leapers or do not leap at all, being physically restricted by body morphology or maximum swimming speed, or more commonly, being behaviorally reluctant to do so. Leaping increases the potential risk of injury or stranding. Typically, leaping or sprint swimming behavior are expressed only when other behaviors are ineffective in passing a velocity or structural barrier. The design of fishways should present conditions that minimize leaping behaviors.

Federal Interagency Passage Design Guidelines

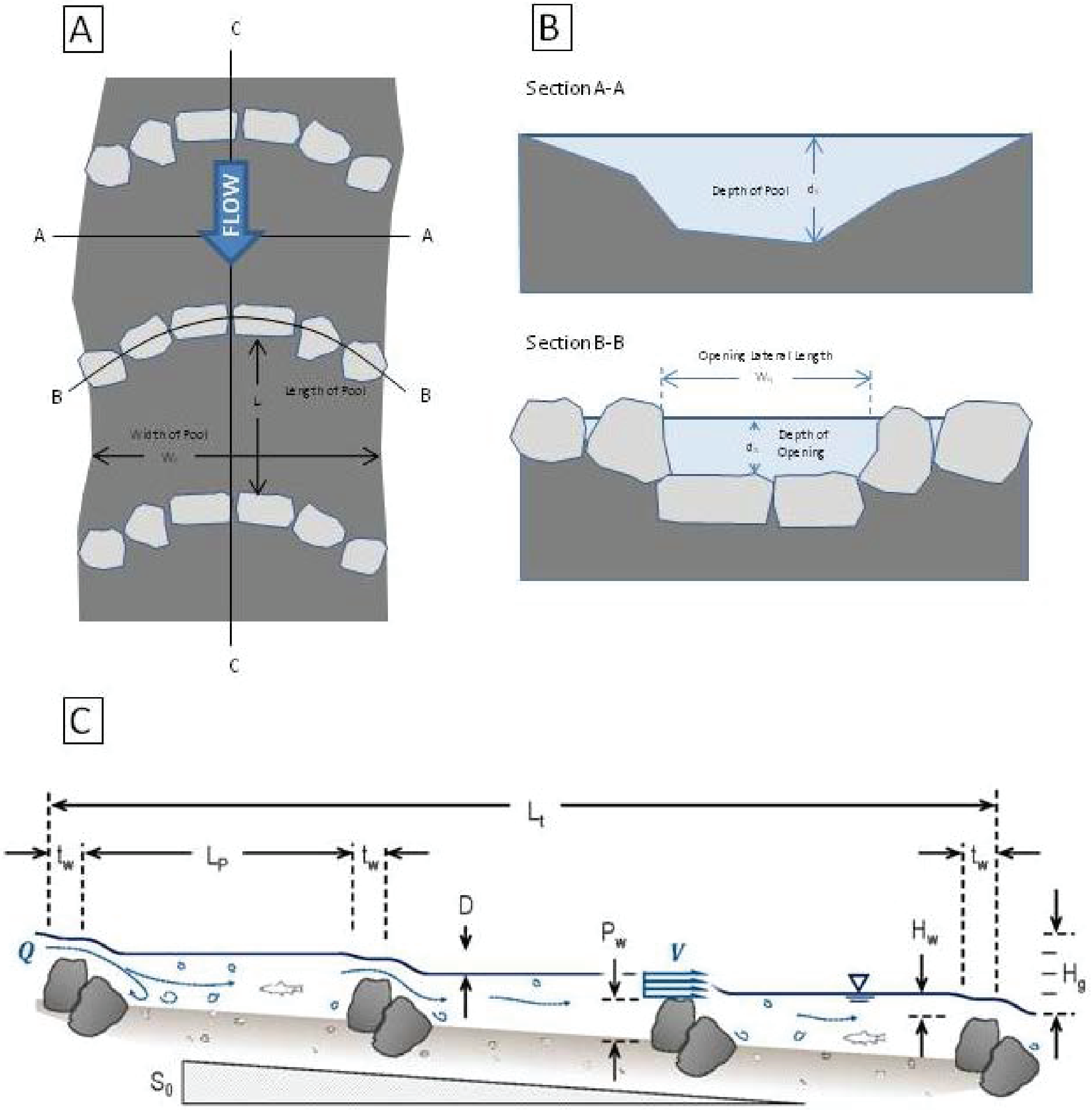
The following are key passage design guidelines that have been identified by the federal interagency team for application to passage of Atlantic Coast diadromous species, and for some species, more discrete guidelines according to life stage/body size categories for the species. These guidelines may be updated by the agencies as additional flume experiments, respirometer and other laboratory studies, and/or field research are completed and results become available that address the physiological and/or behavioral requirements, swimming and leaping capabilities, and passage efficiency of these diadromous fishes and/or other migratory species.

General Design Rationale

This section describes body morphologic dimensions which are determinants of passage, followed by a set of seven design guidelines for each species based on these fish biometrics, plus a maximum velocity criterion based on each species swimming capability. Schematic illustrations are provided in **Figure 1** to accompany and help explain the descriptions of these passage guidelines. Some variables labeled in the graphics are not passage guidelines, but relate to the guidelines. Following the set of passage guidelines descriptions, we present **Table 2** which summarizes the passage guidelines for each of the 14 Atlantic Coast diadromous species, including two length categories for American eel and smaller-sized salmonids; and the basis for, and rationales used in developing this set of guidelines for each of the 14 target fish species.

Figure 1. Plan view (A), cross section (B), and profile (C) illustrations of physical features and nominal measures relating to passage design guidelines for a typical boulder step-pool type fishway.

Note: Schematic profile includes variables that relate to passage guidelines including: Q= flow, t_w= thickness of boulder weir, D= hydraulic drop, P_w= height of rock weir crest, H_w= head over the rock weir, H_g= gross head between headpond and tailwater water surface elevations, and L_t= total length of fishway.



Fish Body Morphology (TL_{min}, TL_{max}, BD/TL Ratio): Maximum and minimum total lengths (TL_{max} and TL_{min}, respectively) and body depth (BD) to total length ratio (BD/TL) for each species were determined to the nearest cm from values published in the literature for diadromous fishes in the Atlantic Coast region. For species with limited or no published data available, unpublished data from recent field investigations were used (Refer to sources cited in species rationales section).

Pool Dimensions

Dimensions of a pool are based on the need to create full- or partial-width channels and pools or bypass channels with pools of sufficient size to serve as resting areas for the target fish species and provide for their protection from predators during passage. Larger fish or species that school in large numbers (hundreds to thousands) require wider, deeper, and longer pools.

The anticipated total run size of the target species and co-occurring species assemblages also need to be thoroughly considered in dimensioning pools.

As a guideline, pool dimensions should also be scaled relative to the size of the stream or river channel and existing pool conditions in nearby unaltered reach or reaches of the study river as a reference, and river flows for the specific design reach. This scaling guideline should be applied regardless of whether the design involves a full or partial width of the stream or river targeted for passage restoration, or is a nature-like bypass channel around a dam or other passage barrier that cannot be removed or modified. Each of the following dimensions should be considered in NLF design:

> ***Minimum Pool Width (W_P):*** For full river-width structures, minimum pool width will vary depending on the size of the river or stream channel. For bypass channels, pool width will depend on maximum design width of the bypass, taking into account the proportion of the river flows used to design safe, timely and effective passage through the bypass during the full range of fish run flows at the subject river reach. To maximize energy dissipation, pool volume, and available resting areas, pool widths should generally be made as wide as practicable.
>
> ***Minimum Pool Depth (d_P):*** In general, pools should be sufficiently deep to serve as resting areas, allow for maneuverability, accommodate deep-bodied and schooling species, and offer protection from terrestrial predators. For small streams (e.g., site with watershed area <5 mi^2), the stream/river channel scaling guideline may be difficult to achieve, and the project design team should assess normal pool depth range in nearby reference reach(es) during the fish passage season. For downstream passage, a minimum depth of pools is needed to provide safe passage of fish and prevent injury or stranding of fish passing over a weir or through a weir opening, especially during low-flow outmigration conditions. Height of the fall as well as body mass of each species needs to be taken into account to minimize the potential for injury to out-migrating fish. For all species, a formula for minimum pool depth was derived which includes a minimum depth of 1 ft, plus 3 body depths, plus one additional body depth as a bottom buffer (to accommodate bottom unconformities and roughness); thus, d_p = 1 ft + 4 BD. Final values of the d_p guideline have been rounded up from the calculated value to the nearest 0.25 ft.
>
> ***Minimum Pool Length (L_P):*** Pool length dimensions follow design guidelines similar to the pool widths, but also depths (i.e., maximize energy dissipation, pool volume and available resting areas; accommodate fish body size(s), run size(s), and resting and schooling behaviors). More importantly, pool length also determines overall slope of the fishway for a given drop per pool, so slope must be taken into account when determining minimum pool length (as well as the number of pools for a given design and overall drop). Refer to the Maximum Fishway Channel Slope (S_0) criterion which takes into account both pool length and drop-per-pool.

Minimum Weir Opening Width (W_N): The weir opening width (i.e., weir notch lateral length) relative to fish passage is based on providing a primary passage opening wide enough to accommodate fish body size and swimming mode and schools of upstream migrating target species adults. For sea lamprey and American eel (anguilliform swimmers), W_N equals 2 times the tailbeat amplitude (values from published literature) for the largest sized individual. For sturgeons, which possess a relatively wide body with broad pectoral fins, W_N equals 2 times the body width of the largest-sized individual, including maximum pectoral fin spread during passage. For all other target species, W_N equaled 2 times the maximum total body length. Final values of W_N were rounded up from the calculated value to the nearest 0.25 ft.

The opening width should also be designed for downstream migrating fish that may be oriented obliquely to the flow in a worst-case condition, to minimize potential body contact with (and subsequent injury) the weir-opening sidewall boulders. Wide weir openings also facilitate location of and attraction to the weir opening by fish in broader river reaches and passage sites by providing a flow jet that spans a larger proportion of the total pool width. Weirs will optimally have multiple passage openings, particularly on larger rivers, with varying invert elevations to function over a range of river flows during the passage season(s) and to benefit multiple species with varying swimming capabilities.

Conversely, the passage opening width needs to take into account the pool depth and hydraulics to accommodate the target species. For small streams with limited flows, the passage opening may need to be limited in width to maintain a minimum depth for passage due to very low flows over weirs, and in particular through a notch especially with lowest flows (e.g., flows <5 cfs) during the fish run period. Weirs should be properly designed such that modeled flows through a passage reach should result in submerged weirs or other grade control structures with passage openings, even during the lowest fish run flows. Such a design will result in streaming flow into a pool with water surface elevation at or above the upstream weir opening invert elevation, and preferably backwatering to the weir crest elevation.

Minimum Weir Opening Depth (d_N): Weir opening depths (i.e., weir notch) need to at least accommodate the full depth (vertical depth of body when swimming horizontally) of the body of the largest-sized target species, including extended dorsal and ventral fins to minimize potential for injury. We conservatively established d_N as 3 times the body depth of the largest-sized individual, rounded up to the nearest 0.25 ft. Minimum depths allow freedom of swimming movements and assurance that propulsion and maneuverability by the tail and fins will allow maximum generation of thrust and the ability of fish to maneuver. If limited river flows during the passage season(s) are not a concern, greater passage opening water depth is preferred at locations where schooling fish, like American shad, are passing simultaneously or passing fish are at high risk to predation. Sufficient water depths are also needed to create a low-velocity bottom zone to facilitate ascent by bottom-dwelling or smaller, weaker-swimming species.

The calculated low stream-flow for the target species run period is most critical to designing the weir opening dimensions and to ensure the minimum water depth guideline is attained. Thus, depths of weirs, openings and other passageway features should be designed to accommodate minimum fish-run period flows and low-flow depths. This passage design need is most critical on small streams and watersheds where normal stream flow is limited (e.g., <20 cfs) and flow through a weir opening would be very limited (e.g., <2 cfs).

Maximum Weir Opening Water Velocity (V_{max}): The ability of fish to traverse zones of higher water velocity, particularly through passage openings, is dependent on motivation, physiological capability (sprint swimming speed), and size range of the target species, and the overall distance that the fish must swim through a high-velocity passage zone. For most weir openings in typical fishway designs, the distances and durations that fish must swim to make upstream progress is relatively short (i.e., tens of feet), so fish may be able to swim over weirs or through these openings at prolonged or brief sprint speeds resulting in minimal fatigue. The probability of fish passing upstream through velocity barriers at prolonged or sprint speeds can be calculated for some species based on known high-speed swimming performance or empirical high-speed swimming model data, particularly the critical swim speed for a species (e.g., Weaver 1965, McAuley 1996, Haro et al. 2004). Sprint swimming data, if available, are usually the best data to use to infer maximum weir opening water velocity. However, sprint swimming research has not been conducted and/or sprint swimming curves have not been developed for most Atlantic Coast diadromous fish species, in which case, alternative methods for determining maximum weir opening velocity were used for developing this guideline.

The following rationale was used to determine V_{max} for each species:

1. When sprint swimming data are available, then U_{max} = the sprint swimming speed sustained for 60 sec, for fish of minimum size (TL_{min}).
2. When no sprint swimming data are available, but critical swimming speed (U_{crit}) values have been determined (i.e., from respirometer studies), then U_{max} = 2 times U_{crit} for fish of minimum size (TL_{min}).
3. When no swimming data are available, U_{max} is calculated for a nominal value of 5 BL/sec for subcarangiform swimmers or 3 BL/sec for anguilliform swimmers, for fish of minimum size (TL_{min}).
4. The initial value of U_{max} was adjusted (if necessary) by assessing calculated U_{max} values within the context of other direct fish swimming observations of each species and known velocity barriers (if available; i.e., observed ability to pass a velocity barrier with known water velocity, or best professional judgment, based on experience).
5. V_{max} = U_{max}, rounded down to the nearest 0.25 ft/sec.

The V_{max} applied in each project should be the value associated with the weakest swimming target species. The V_{max} values presented herein for each species are specifically provided for the targeted species expecting to pass over a weir, through a weir opening or other short-distance high velocity zone and into an effective resting area. A V_{max} value should not be misapplied as the guideline for the overall design or diagnostic evaluation of an entire fishway or fish passage reach, where passage length and time of passage would exceed the capability of the target species in sprint swimming mode to pass the site without available resting pools or sites. Such an example may include a rock ramp nature-like fishway constructed at too steep a slope for the target species, and which lacks resting pools, large boulders, or other features providing adequate resting areas.

Maximum Fishway Channel Slope (S_0): The channel slope, S_0, influences energy loss and water velocity over weirs, through weir notches, in pools, and around other in-stream features. In turn, velocity and energy dissipation influence fish behavior and passage efficiency. The friction slope, S_f, is the rate at which this energy is lost along the channel. In prismatic-shaped channels, uniform flow (i.e., flow that is unchanging in the longitudinal direction) occurs when $S_0 = S_f$. In step-pool fishway structures, the average friction slope is equal to the ratio of hydraulic drop-per-pool, D, to pool length plus weir thickness, $L_p + t_w$ (Figure 1). Thus, quasi-uniform or “uniform-in-the-mean” flow is achieved in step-pool fishways when S_0 and the average S_f are equal over the length of the fishway. In most cases, step-pool fishways are designed for this quasi-uniform condition to limit longitudinal flow development (e.g., accelerating flow) and ensure predictable hydraulic conditions in each pool and over each weir.

Quasi-uniform flow establishes a relationship between S_0 and S_f in step-pool structures; however, an additional constraint on S_0 is necessary to safeguard against unacceptably steep fishway designs. Both the pool length and drop-per-pool criteria are based on a species’ need for adequate resting space and swimming capability, respectively. Fishway channel slopes based solely on quasi-uniform flow and a friction slope established by the recommended maximum D and minimum L_p may still result in excessive energy dissipation, propagation of velocity from pool to pool, and/or other undesirable conditions. Therefore, a maximum fishway channel slope, S_0, is also recommended. These channel slopes presented herein (Table 1) are conservative estimates based on natural river gradients and sites known to be passable or populated by the target species.

The reader is cautioned that these slope relationships and associated pool and hydraulic drop criteria create an over-determined system (i.e., more equations than unknowns). To avoid conflicting slope constraints, the following procedure is recommended:

1. Based on a species’ V_{max} (Refer to Table 2, below), calculate an appropriate D;
2. Based on D and L_p (Table 2), estimate the friction slope, S_f;
3. If $S_f \leq$ channel slope S_0 (Table 2), then set $S_0 = S_f$ and proceed;
   If $S_f > S_0$, then lengthen L_p or add pools to the design to reduce D (while ensuring minimum depth of flow criterion is also met) until $S_f \leq S_0$, and proceed.

Consider the following example for the passage of alewife over a step-pool structure: For this target species, a V_{max} of 6 ft/sec is recommended (Table 2). To provide structural stability, a 3-ft wide rock weir is selected. Using this V_{max} and t_w, a hydraulic analysis results in a maximum drop-per-pool of D= 1.25 ft. For alewife as the target species, a minimum pool length of L_p = 10 ft is recommended (Table 2). This results in a friction slope, S_f = 0.092 which exceeds the specified maximum pool slope of S_0 = 0.05 or 1:20 (Table 2). Accordingly, the geometry needs to be revised to ensure the maximum channel slope criterion is met. The L_p must be increased, D must be decreased, or both until $S_f \leq S_0$.

In general, consistent pool geometry is preferred, but may not be feasible for some passage sites. When site constraints necessitate pools of varying geometry, the procedure above should be applied, iteratively, to each pool-and-weir combination to ensure S_0, S_f, and the other passage criteria are met.

The above methodology integrates species-specific biological criteria from Table 2 and engineering hydraulics. However, it is important to note that fishway geometry is also influenced by other site conditions and target fish species behavioral factors. Additional considerations include substrate stability, channel morphology, immovable boulders/ledge and other natural features that may further constrain the slope of the fishway. Excessively long pool length, which may otherwise meet slope criteria, may decrease motivation of a target species to pass, thus, compromising passage efficiency. As fish passage planning progresses from conceptual to final design, it is critical to verify these parameters with each design modification to ensure that criteria are still met for the weakest target species and over the greatest possible range of hydrologic conditions at the project site.

Other Design Considerations: For moderate and large-sized rivers, multiple weir openings should be provided for safe passage by multiple target species and schools of a species that behaviorally pass in groups (e.g., American shad). The design should consider the diversity of the fish community present in the stream or river. Large rivers with greater spatial habitat diversity typically support a greater number of both resident and anadromous species, with large numbers of fishes seasonally passing upriver often during coincidental, overlapping spawning run periods. A diverse fish assemblage and large numbers of fish passing necessitate multiple passage openings, and benefitting from varying invert elevations and locations along the weir to account for changes in river flow, especially in larger rivers with a diverse fish assemblage and/or widely varying fish run flow range. Weaker-swimming species will use passage openings closer to the river edge and inside river bends where lower flow velocities occur. Weak-swimming species (e.g., minnows, darters) and some species life-stages (e.g., American eel elvers and yellow-phase juveniles) seek out low-velocity, near-bottom conditions not only for passage sites but often as habitat (Aadland 1993).

Regarding passage at weirs, fish will preferentially pass through weir openings, rather than over weir crests. Fish preferentially use streaming flow through openings, as opposed to plunging flows passing over weirs and into resting pools which are often impassible for species with limited leaping capabilities. Although an in-line configuration of weir openings is preferred, primary openings along multiple weirs can be off-set in alignment to prevent propagation of increasing flow velocities through successive weirs or other grade control structures.

Channel size and flow (e.g., bypass channels) should be referenced to both river size and projected run size of the target fish species or fish community assemblage. For example, nature-like bypass fishways sited on large rivers would need to be appropriately sized for flow and run-size capacity. Fishways which are expected to support large runs of target species should include longer and deeper pools to provide sufficient resting areas to accommodate large numbers of fish during peak passage periods.

Figure 2 provides examples of photographed NLF sites in the Northeast region targeted for passage by Atlantic coast diadromous fish species.

Table 2. Summary of design guidelines for NLFs and related to swimming capabilities and safe, timely and efficient passage for Atlantic Coast diadromous fish species. Note: units are expressed in both metric (cm) and English units (feet or feet/sec). See text for informational sources.

Species	Minimum TL (cm)	Maximum TL (cm)	Body Depth/ TL Ratio	Maximum Body Depth (cm)	Minimum Pool/Channel Width (ft)	Minimum Pool/Channel Depth (ft)	Minimum Pool/Channel Length (ft)	Minimum Weir Opening Width (ft)	Minimum Weir Opening Depth (ft)	Maximum Weir Opening Water Velocity (ft/sec)	Maximum Fishway Channel Slope
	TL_{min}	**TL_{max}**	**BD/TL**	**BD_{max}**	**W_p**	**d_P**	**L_p**	**W_N**	**d_N**	**V_{max}**	**S_0**
Sea Lamprey	60	86	0.072	6.2	10.0	2.00	20.0	0.75	0.75	6.00	1:30
Shortnose Sturgeon	52	143	0.148	21.2	30.0	4.00	30.0	2.75	2.25	5.00	1:50
Atlantic Sturgeon	88	300	0.150	45.0	50.0	7.00	75.0	5.50	4.50	8.50	1:50
American Eel ≤ 15 cm TL	5	15	0.068	1.0	3.0	1.25	5.0	0.25	0.25	0.75	1:20
American Eel >15 cm TL	15	116	0.068	7.9	6.0	2.00	10.0	0.75	1.00	1.00	1:20
Blueback Herring	20	31	0.252	7.8	5.0	2.00	10.0	2.25	1.00	6.00	1:20
Alewife	22	38	0.233	8.9	5.0	2.25	10.0	2.50	1.00	6.00	1:20
Hickory Shad	28	60	0.221	13.3	20.0	2.75	40.0	4.00	1.50	4.50	1:30
American Shad	36	76	0.292	22.2	20.0	4.00	30.0	5.00	2.25	8.25	1:30
Gizzard Shad	25	50	0.323	16.2	20.0	3.25	40.0	3.50	1.75	4.00	1:30
Rainbow Smelt	12	28	0.129	3.6	5.0	1.50	10.0	1.00	0.50	3.25	1:30
Atlantic Salmon	70	95	0.215	20.4	20.0	3.75	40.0	6.25	2.25	13.75	1:20
Sea Run Brook Trout	10	45	0.255	11.5	5.0	2.50	10.0	1.50	1.25	3.25	1:20
Juvenile Salmonid ≤ 20 cm TL	5	20	0.250	5.0	5.0	1.75	10.0	1.25	0.50	2.25	1:20
Atlantic Tomcod	15	30	0.202	6.1	5.0	2.00	10.0	2.00	0.75	0.75	1:30
Striped Bass	40	140	0.225	31.5	20.0	5.25	30.0	9.25	3.25	5.25	1:30

Figure 2. Captioned photographs of nature-like fishways (NLFs) in the Northeast targeting passage of Atlantic coast diadromous fishes (Photo sources: J. Turek, M. Bernier)

Saw Mill Park step-pool fishway,
Acushnet River, Acushnet, MA

Fields Pond step-pool fishway,
Sedgeunkedunk Stream, Orrington, ME

Kenyon Mill step-pool fishway,
Pawcatuck River, Richmond, RI

Homestead dam removal and NLF cross-vanes,
Ashuelot River, West Swanzey, NH

Water Street tidal rock ramp,
Town Brook, Plymouth, MA

Lower Shannock Falls NLF weirs,
Pawcatuck River, Richmond, RI

Species-Specific Rationales

The following passage guidelines rationales for each species are based upon best professional judgment, unless otherwise noted by referenced published literature or other source(s). We applied our experiences with laboratory flume experiments and field observations, and queried other state and federal agency experts in fishery biology and/or fishway engineering design. We note that there is a general paucity of experimental research available, and substantial additional species information is required to verify or refine these guidelines.

Sea Lamprey

TL_{min} = 60 cm (Collette and Klein-MacPhee 2002)
TL_{max} = 86 cm (USFWS Connecticut River Coordinator's Office, unpub. data)
Body Depth/TL Ratio = 0.072 (A. Haro, USGS; unpub. data)

Minimum Pool/Channel Width: 10.0 ft
The guideline is based on creation of pools large enough to serve as resting areas and protection from terrestrial predators. Lamprey tends to rest in pool environments more so than other species, and often aggregate in large numbers while resting. Larger run sizes (hundreds to thousands) will require resting pools wider than this minimum dimension.

Minimum Pool/Channel Depth: 2.0 ft
The guideline is based on creation of pools large enough to serve as resting areas and protection from terrestrial predators. Minimum pool depth was calculated using the formula 1 ft + $4BD_{max}$: d_p = 1 ft + (4*(86 cm * 0.072)* 0.0328) = 1.8 ft. This value was rounded up to d_p = 2.0 ft. Lamprey tends to rest in pool environments more so than other species, and often aggregate in large numbers while resting. Larger run sizes (hundreds to thousands) will require pools deeper than this minimum dimension.

Minimum Pool/Channel Length: 20.0 ft
The guideline is based on creation of pools large enough to accommodate lamprey body size, run size, and resting and schooling behavior, as well as meeting minimum weir velocity and maximum energy dissipation and slope guidelines. Lampreys tend to rest in pool environments more than other species, and often aggregate in numbers while resting. Larger run sizes (hundreds to thousands) will require pools longer than this minimum dimension.

Minimum Weir Opening Width: 0.75 ft
The minimum opening width guideline is based on a dimension wide enough to accommodate the two times the tailbeat amplitude of the maximum total length (TL) of adult lamprey. Because adult sea lamprey die after spawning, there is no design consideration for downstream passage. Tailbeat amplitude for sea lamprey has been measured as 10% of total length (Bainbridge 1958). Therefore WN = 86 cm * 2 * 0.1 = 17.2 cm = 0.56 ft. This value was rounded up to WN = 0.75 ft.

Minimum Weir Opening Depth: **0.75 ft**
The guideline is based on provision of sufficient water depth over the weir to enable protection from terrestrial predators, lamprey maneuvering in low flows, and use of lower velocity zone in high flows; equivalent to 3 times BD_{max} =3 * 6.15 cm = 18.5 cm = 0.61 ft. This value was rounded up to d_N = 0.75 ft.

Maximum Weir Opening Water Velocity: **6.0 ft/sec**
The guideline takes into consideration laboratory sprint swimming studies in an open channel flume (McAuley 1996): approximately 1.0 m/sec swimming speed for a maximum of 60 sec duration for adult lamprey (TL_{min} = 60 cm; U=2 BL/sec). Therefore U_{max} = (2 * 60 cm) = 120 cm/sec = 3.94 ft/sec. However, adult sea lampreys are known to have the capability to free-swim ascend surface weirs in technical fishways at velocities of 8.0 ft/sec (Haro and Kynard 1997). Since laboratory studies and field observations suggest strong but varying swimming capabilities, V_{max} was conservatively established at 6.0 ft/sec.

Maximum Fishway/Channel Slope: **1:30**
This nominal slope guideline approximates the maximum slope at natural river sites known to be passable by sea lamprey, or is a conservative estimate of maximum slope based on known sea lamprey swimming behavior and river hydro-geomorphologies in which sea lamprey occurs.

Shortnose Sturgeon

TL_{min} = 52 cm (Collette and Klein-MacPhee 2002)
TL_{max} = 143 cm (Dadswell 1979)
Body Depth/TL Ratio = 0.148 (M. Kieffer, USGS; unpub. data)

Minimum Pool/Channel Width: **30.0 ft**
The guideline is based on pools large enough to serve as sturgeon resting areas and protection from terrestrial predators. Sturgeons typically require larger than average pools, especially if multiple sturgeon are migrating simultaneously through a passageway. While data are lacking for shortnose sturgeon, lake sturgeon are known to use and pass nature-like fishways in groups (L. Aadland, pers. commun.).

Minimum Pool/Channel Depth: **4.0 ft**
The guideline is based on creation of pools large enough to serve as resting areas and protection from terrestrial predators. Minimum pool depth was calculated using the formula 1 ft + $4BD_{max}$: d_p = 1 ft + (4*(143 cm * 0.148)* 0.0328) = 3.8 ft. This value was rounded up to d_p = 4.0 ft. Sturgeons typically require larger than average-sized pools, especially if multiple sturgeon are migrating simultaneously through a passageway.

Minimum Pool/Channel Length: **30.0 ft**
The guideline is based on pools large enough to accommodate sturgeon body size, run size, and resting and schooling behavior, as well as meeting minimum weir velocity and maximum energy

dissipation and slope guidelines. Shortnose sturgeon may aggregate in large numbers while resting in pools. Larger run sizes (hundreds or greater) will require pools longer than this minimum dimension.

Minimum Weir Opening Width: 2.75 ft
The minimum opening width guideline is based on a dimension wide enough to accommodate two times the total body width (including pectoral fin spread) of the maximum total length (TL) of adult shortnose sturgeon. Data are lacking for total body span (including pectoral fins) for shortnose sturgeon, but have been estimated as 27% of TL in lake sturgeon (L. Aadland, Minnesota Department of Natural Resources, pers. comm.). Therefore, W_N = 143 cm * 2 * 0.27 = 77.2 cm = 2.53 ft. This value was rounded up to W_N = 2.75 ft.

Minimum Weir Opening Depth: 2.25 ft
The guideline is based on provision of sufficient water depth over the weir to enable protection from terrestrial predators, sturgeon maneuvering in low flows, and use of lower velocity zone in high flows; equivalent to 3 times BD_{max} =3 *21.19 cm = 63.6 cm = 2.09 ft. This value was rounded up to d_N = 2.25 ft.

Maximum Weir Opening Water Velocity: 5.0 ft/sec
No sprint swimming data are available for adult shortnose sturgeon; U_{crit} for adult shortnose sturgeon is unknown. Based on maximum U=3 BL/sec for anguilliform swimmers and affording passage of smallest sized adults, U_{max} = 3 * 52 cm = 156 cm/sec = 5.12 ft/sec. This value was rounded down to V_{max} = 5.0 ft/sec.

Maximum Fishway/Channel Slope: 1:50
This nominal slope guideline approximates the maximum slope at natural river sites known to be passable by shortnose sturgeon, or is a conservative estimate of maximum slope based on known shortnose sturgeon swimming behavior and river hydro-geomorphologies in which this sturgeon species occurs.

Atlantic Sturgeon

TL_{min} = 88 cm (M. Kieffer, USGS, unpub.data)
TL_{max} = 300 cm (M. Kieffer, USGS, unpub.data)
Body Depth/TL Ratio = 0.150 (M. Kieffer, USGS, unpub.data)

Minimum Pool/Channel Width: 50.0 ft
The guideline is based on creation of pools large enough to serve as resting areas and protection from terrestrial predators. Sturgeons typically require larger than average pools, especially if multiple sturgeon are migrating simultaneously through a passageway.

Minimum Pool/Channel Depth: 7.0 ft
The guideline is based on creation of pools large enough to serve as resting areas and protection from terrestrial predators. Minimum pool depth was calculated using the formula 1

ft + $4BD_{max}$: d_p = 1 ft + (4*(300 cm * 0.150)* 0.0328) = 6.9 ft. This value was rounded up to d_p = 7.0 ft. Sturgeons typically require larger than average-sized pools, especially if multiple sturgeon are migrating simultaneously through a passageway.

Minimum Pool/Channel Length: 75.0 ft
The guideline is based on creation of pools large enough to accommodate sturgeon body size, run size, and resting and schooling behavior, as well as meeting minimum weir velocity and maximum energy dissipation and slope guidelines. Atlantic sturgeon may aggregate in large numbers while resting in pools. Larger run sizes (hundreds or greater) will require pools longer than this minimum dimension.

Minimum Weir Opening Width: 5.50 ft
The minimum opening width guideline is based on a dimension wide enough to accommodate two times the total body width (including pectoral fin spread) of the maximum total length (TL) of adult Atlantic sturgeon. Data are lacking for total body span (including pectoral fins) for Atlantic sturgeon, but have been estimated as 27% of TL in lake sturgeon (L. Aadland, Minnesota Department of Natural Resources, pers. comm.). Therefore, W_N = 300 cm * 2 * 0.27 = 162 cm = 5.31 ft. This value was rounded up to W_N = 5.50 ft.

Minimum Weir Opening Depth: 4.5 ft
The guideline is based on provision of sufficient water depth over the weir to enable protection from terrestrial predators, sturgeon maneuvering in low flows, and use of lower velocity zone in high flows; equivalent to 3 times BD_{max} = 3 * 45.00 cm = 135.0 cm = 4.43 ft. This value was rounded up to d_N = 4.5 ft.

Maximum Weir Opening Water Velocity: 8.5 ft/sec
No sprint swimming data are available for adult Atlantic sturgeon; U_{crit} for adult Atlantic sturgeon is unknown. Based on U=3 BL/sec for anguilliform swimmers; U_{max} = (3 * 88 cm) = 264 cm/sec = 8.66 ft/sec. This value was rounded down to V_{max} = 8.5 ft/sec.

Maximum Fishway/Channel Slope: 1:50
This nominal slope guideline approximates the maximum slope at natural river sites known to be passable by Atlantic sturgeon, or is a conservative estimate of maximum slope based on known Atlantic sturgeon swimming behavior and river hydro-geomorphologies in which sturgeon occur.

American Eel $\leq$ 15 cm ($\leq$6 inch) TL

TL_{min} = 5 cm (Haro and Krueger 1991)
TL_{max} = 15 cm (upper limit of specified range)
Body Depth/TL Ratio = 0.068 (A. Haro, USGS, unpub.data)

Small ($\leq$15 cm TL) American eels (elvers and small juveniles) are usually upstream migrants, passing through low-velocity flows along river edges and through openings, voids, and crevices in natural and man-made barriers and other riverside structures. Small eels can also climb wetted surfaces for significant distances, aided by water-surface tension. Small eels therefore may only require small openings or passageways, preferably along low-velocity river edges, where they commonly congregate. Design guidelines were developed for two eel size classes since eels continue upstream migration for multiple years and eels may not ascend to distant upstream sites during elver/small juvenile eel stage. These upstream sites are more likely to only pass larger, older eels; guidelines for elvers and small eels would therefore not apply. Size distribution of eels should be assessed at sites considered for nature-like fishway planning before guidelines for upstream eel passage are applied in design. Guidelines for this size range do not take into account downstream passage; see next Section (American Eel > 15 cm TL) for downstream passage guidelines relevant to adult ("silver" phase) or larger juvenile or downstream migrant ("yellow phase") American eel.

Minimum Pool/Channel Width: 3.0 ft
The guideline is based on creation of pools large enough to serve as resting areas and protection from terrestrial predators. American eels tend to rest in pool environments more so than other species, and young eels often aggregate in large numbers while resting, particularly within the substrate. Larger run sizes (hundreds to thousands) will require pools wider than this minimum dimension.

Minimum Pool/Channel Depth: 1.25 ft
The guideline is based on creation of pools large enough to serve as resting areas and protection from terrestrial predators. Minimum pool depth was calculated using the formula 1 ft + $4BD_{max}$: d_p = 1 ft + (4*(15 cm * 0.068)* 0.0328) = 1.1 ft. This value was rounded up to d_p = 1.25 ft. American eel tend to rest in pool environments more so than other species, and young eels often aggregate in large numbers while resting, particularly within the substrate. Larger run sizes (hundreds to thousands) will require pools deeper than this minimum dimension.

Minimum Pool/Channel Length: 5.0 ft
The guideline is based on creation of pools large enough to accommodate eel body size, run size, and resting and schooling behavior, as well as meeting minimum weir velocity and maximum energy dissipation and slope guidelines. American eel tend to rest in pool environments more so than other species, and young eels often aggregate in large numbers while resting in pools. Larger run sizes (thousands or greater) will require pools longer than this minimum dimension.

Minimum Weir Opening Width: 0.25 ft
The minimum opening width guideline is based on a dimension wide enough to accommodate the two times the tailbeat amplitude of the maximum total length (TL) of small American eels. Tailbeat amplitude for American eels has been measured as 8% of total length (Gillis 1998). Therefore W_N = 15 cm * 2 * 0.08 = 2.4 cm = 0.08 ft. This value was rounded up to W_N = 0.25 ft. However, as adults, eels may migrate downstream through weir openings, so a larger weir opening width may be required.

Minimum Weir Opening Depth: **0.25 ft**
The guideline is based on provision of sufficient water depth over the weir to enable protection from terrestrial predators, maneuvering in low flows, and use of lower velocity zone in high flows; equivalent to 3 times BD_{max} =3 *1.02 cm = 3.1 cm = 0.10 ft). This value was rounded up to d_N = 0.25 ft. However, as adults, eels may migrate downstream through weir openings, so a larger opening may be required (See *American Eel > 15 cm TL; Minimum Weir Opening Depth*).

Maximum Weir Opening Water Velocity: **0.75 ft/sec**
The guideline is based on laboratory sprint swimming studies (McCleave 1980): U=4.6 BL/sec swimming speed for maximum 60 sec duration for 5 cm TL elvers in an open channel test flume. Therefore, U_{max} = 4.6 * 5 cm = 23 cm/sec = 0.75 ft/sec. V_{max} was established at 0.75 ft/sec.

Maximum Fishway/Channel Slope: **1:20**
This nominal slope guideline approximates the maximum slope at natural river sites known to be passable by juvenile American eel, or is a conservative estimate of maximum slope based on known eel swimming behavior and river hydro-geomorphologies in which eel occur.

American Eel > 15 cm (>6 inch) TL

TL_{min} = 15 cm (lower limit of specified range)
TL_{max} = 116 cm (Tremblay 2009)
Body Depth/TL Ratio = 0.068 (A. Haro, USGS, unpub.data)

Minimum Pool/Channel Width: **6.0 ft**
The guideline is based on creation of pools large enough to serve as resting areas and protection from terrestrial predators. American eels tend to rest in pool environments more so than other species, and often aggregate in large numbers while resting, particularly within the substrate. Larger run sizes (hundreds to thousands) will require pools wider than this minimum dimension.

Minimum Pool/Channel Depth: **2.0 ft**
The guideline is based on creation of pools large enough to serve as resting areas and protection from terrestrial predators. Minimum pool depth was calculated using the formula 1 ft + $4BD_{max}$: d_p = 1 ft + (4*(116 cm * 0.068)* 0.0328) = 2.0 ft. American eels tend to rest in pool environments more so than other species, and often aggregate in large numbers while resting, particularly within the substrate. Larger run sizes (hundreds to thousands) will require pools deeper than this minimum dimension.

Minimum Pool/Channel Length: **10.0 ft**
The guideline is based on creation of pools large enough to accommodate fish size, run size, and resting and schooling behavior, as well as meeting minimum weir velocity and maximum energy dissipation and slope guidelines. American eel tend to rest in pool environments more so than other species, and often aggregate in large numbers while resting in pools. Larger run sizes (thousands or greater) will require pools longer than this minimum dimension.

Minimum Weir Opening Width: **0.75 ft**
The minimum opening width guideline is based on a dimension wide enough to accommodate the two times the tailbeat amplitude of the maximum total length (TL) of larger American eels. Tailbeat amplitude for American eels has been measured as 8% of total length (Gillis 1998). Therefore, W_N = 116 cm * 2 * 0.08 = 18.6 cm = 0.61 ft. This value was rounded up to W_N = 0.75 ft. However, as adults, eels may migrate downstream through weir openings, so a larger weir opening width may be required.

Minimum Weir Opening Depth: **1.0 ft**
The guideline is based on provision of sufficient water depth over the weir to enable protection from terrestrial predators, maneuvering in low flows, and use of lower velocity zone in high flows; equivalent to 3 times BD_{max} =3 * 7.9 cm = 23.4 cm = 0.76 ft. This value was rounded up to d_N = 1.0ft.

Maximum Weir Opening Water Velocity: **1.0 ft/sec**
The guideline is based on mean U_{crit} = 0.43 m/s for eels of mean length 44 cm eel; U= 0.97 BL/sec in respirometer experiments (Quintella et al. 2010). Therefore, U_{max} = 2 * 0.97 * 15 cm = 29.1 cm/sec = 0.95 ft/sec. This value was rounded up to V_{max} = 1.0 ft/sec.

Maximum Fishway/Channel Slope: **1:20**
This nominal slope guideline approximates the maximum slope at natural river sites known to be passable by American eel, although juvenile eels are capable of ascending substrates with steeper slopes having roughened surfaces and/or interstitial spaces within boulders, cobbles or other structures.

Blueback Herring

TL_{min} = 20 cm (Collette and Klein-MacPhee 2002)
TL_{max} = 31 cm (S. Turner, NMFS, unpub. data)
Body Depth/TL Ratio = 0.252 (A. Haro, USGS, unpub. data)

Minimum Pool/Channel Width: **5.0 ft**
The guideline is based on pools large enough to serve as resting areas and protection of adults from terrestrial predators. Blueback herring is a schooling species and often aggregates in large numbers while resting in pools. Larger run sizes (hundreds to thousands or more) will require pools wider than this minimum dimension.

Minimum Pool/Channel Depth: **2.0 ft**
The guideline is based on pools large enough to serve as resting areas and protection of adults from terrestrial predators. Minimum pool depth was calculated using the formula 1 ft + $4BD_{max}$: d_p = 1 ft + (4*(31 cm * 0.252)* 0.0328) = 2.0 ft. Blueback herring is a schooling species and often aggregates in large numbers while resting in pools. Larger run sizes (thousands or more) will require pools deeper than this minimum dimension. This depth guideline may not be

feasible on very small-sized, first- and second-order streams with small watersheds (e.g., <5 mi^2), limited stream flows, and smaller run sizes (hundreds of fish or less).

Minimum Pool/Channel Length: **10.0 ft**
The guideline is based on pools large enough to accommodate herring body size, run size, and resting and schooling behavior, as well as meeting minimum weir velocity and maximum energy dissipation and slope guidelines. Blueback herring is a schooling species and often aggregates in large numbers while resting in pools. Larger run sizes (thousands or greater) will require pools longer than this minimum dimension.

Minimum Weir Opening Width: **2.25 ft**
The guideline is based on a weir dimension wide enough to accommodate downstream movement of adult blueback herring oriented in "worst case" perpendicular orientation to the flow, equivalent to 2 times TL_{max} or 2 * 31 cm = 62 cm = 2.03 ft. This value was rounded up to W_N = 2.25 ft. In the case of larger populations (thousands or greater), entrance dimensions should be greater than 2.25 ft, or multiple openings of this minimal dimension should be constructed in weirs to accommodate multiple groups of fish simultaneously passing through the weir opening(s).

Minimum Weir Opening Depth: **1.0 ft**
The guideline is based on provision of sufficient water depth over the weir to enable protection from terrestrial predators, herring maneuvering in low flows, and use of lower velocity zone in high flows; equivalent to 3 times BD_{max} =3 * 7.81 cm = 23.4 cm = 0.77 ft. This value was rounded up to d_N = 1.0 ft.

Maximum Weir Opening Water Velocity: **6.0 ft/sec**
The guideline is based on laboratory sprint swimming studies in an open channel flume (Haro et al. 2004, Castro-Santos 2005): U=6 BL/sec swimming speed for a maximum 60 sec. Therefore U_{max} = (6 * 20 cm) = 120 cm/sec = 3.94 ft/sec. However, adult blueback herring are known to ascend surface weirs, natural ledge drops, and technical fishways at velocities of 8.0 ft/sec or higher (Reback et al. 2004). To address the varying data currently available, V_{max} was established at 6.0 ft/sec.

Maximum Fishway/Channel Slope: **1:20**
This nominal slope guideline approximates the maximum slope at natural river sites known to be passable by blueback herring (Franklin et al. 2012), or is a conservative estimate of maximum slope based on known blueback herring swimming behavior and river hydro-geomorphologies in which blueback herring occur.

Alewife

TL_{min} = 22 cm (Collette and Klein-MacPhee 2002)
TL_{max} = 38 cm (Collette and Klein-MacPhee 2002)
Body Depth/TL Ratio = 0.233 (G. Wippelhauser, Maine Div. Marine Fisheries, unpub. data)

Minimum Pool/Channel Width: 5.0 ft

The guideline is based on creation of pools large enough to serve as resting areas and protection from terrestrial predators. Alewife is a schooling species and often aggregates in large numbers while resting in pools. Larger run sizes (hundreds to thousands) will require pools wider than this minimum dimension.

Minimum Pool/Channel Depth: 2.25 ft

The guideline is based on creation of pools large enough to serve as resting areas and protection from terrestrial predators. Minimum pool depth was calculated using the formula 1 ft + 4BD_{max}: d_p = 1 ft + (4*(38 cm * 0.233)* 0.0328) = 2.2 ft. This value was rounded up to d_p = 2.25 ft. Alewife is a schooling species and often aggregates in large numbers while resting in pools. Larger run sizes (hundreds to thousands) will require pools deeper than this minimum dimension. This depth guideline may not be feasible on very small-sized, first- and second-order streams with small watersheds (e.g., <5 mi^2), limited stream flows, and smaller run sizes (hundreds of fish or less).

Minimum Pool/Channel Length: 10.0 ft

The guideline is based on creation of pools large enough to accommodate alewife body size, run size, and resting and schooling behavior, as well as meeting maximum weir opening velocity and maximum energy dissipation and slope guidelines. Alewife is a schooling species and often aggregates in large numbers while resting in pools. Larger run sizes (thousands or greater) will require pools longer than this minimum dimension.

Minimum Weir Opening Width: 2.50 ft

The guideline is based on a weir dimension wide enough to accommodate downstream movement of adult alewife oriented in a "worst case" perpendicular orientation to the flow, equivalent to 2 times TL_{max} or 2* 38 cm: = 76 cm = 2.49 ft. This value was rounded up to W_N = 2.50 ft. In the case of larger stream populations (thousands or greater), entrance dimensions should be increased above 2.5 ft or multiple openings should be constructed in weirs to accommodate large numbers of fish simultaneously passing through the weir opening(s).

Minimum Weir Opening Depth: 1.0 ft

The guideline is based on provision of sufficient water depth over the weir to enable protection from terrestrial predators, maneuvering in low flows, and use of lower velocity zone in high flows; equivalent to 3 times BD_{max}: 3 * 8.86 cm = 26.6 cm = 0.87 ft. This value was rounded up to d_N = 1.0 ft.

Maximum Weir Opening Water Velocity: 6.0 ft/sec

The guideline is based on laboratory sprint swimming studies in an open channel test flume (Haro et al. 2004, Castro-Santos 2005): U=5.5 BL/sec swimming speed for a maximum 60 sec. Therefore U_{max} = 5.5 * 22 cm = 121 cm/sec = 3.97 ft/sec. In contrast, field observations have revealed adult alewives may ascend surface weirs in technical fishways at velocities of 8.0 ft/sec or higher (Reback et al. 2004) . To address the varying test data available, V_{max} was established at 6.0 ft/sec.

Maximum Fishway/Channel Slope: 1:20

This nominal slope guideline approximates the maximum slope at natural river sites known to be passable by alewife (Franklin et al. 2012), or is a conservative estimate of maximum slope based on known alewife swimming behavior and river hydro-geomorphologies in which alewives occur.

Hickory Shad

TL_{min} = 28 cm (Collette and Klein-MacPhee 2002)
TL_{max} = 60 cm (Klauda et al. 1991)
Body Depth/TL Ratio = 0.221 (FishBase; www.fishbase.org; BD = 22.1% of TL)

Minimum Pool/Channel Width: 20.0 ft

The guideline is based on creation of pools large enough to serve as resting areas and protection from terrestrial predators. Hickory shad is a schooling species and often aggregates in large numbers while resting in pools. Larger run sizes (hundreds to thousands) will require pools wider than this minimum dimension.

Minimum Pool/Channel Depth: 2.75 ft

The guideline is based on creation of pools large enough to serve as resting areas and protection from terrestrial predators. Minimum pool depth was calculated using the formula 1 ft + $4BD_{max}$: d_p = 1 ft + (4*(60 cm * 0.221)* 0.0328) = 2.7 ft. This value was rounded up to d_p = 2.75 ft. Hickory shad is a schooling species and often aggregates in large numbers while resting in pools. Larger run sizes (hundreds to thousands) will require pools deeper than this minimum dimension.

Minimum Pool/Channel Length: 40.0 ft

The guideline is based on creation of pools large enough to accommodate shad body size, run size, and resting and schooling behavior, as well as meeting maximum weir opening velocity and maximum energy dissipation and slope guidelines. Hickory shad is a schooling species and often aggregates in large numbers while resting in pools. Larger run sizes (hundreds to thousands) will require pools longer than this minimum dimension.

Minimum Weir Opening Width: 4.0 ft

The guideline is based on a weir dimension wide enough to accommodate downstream movement of adult hickory shad oriented in a “worst case” perpendicular orientation to the flow, equivalent to 2 times TL_{max} or 2*60 cm = 120 cm = 3.94 ft. This value was rounded up to W_N = 4.00 ft. In the case of larger populations (thousands or greater), entrance dimensions should be greater than 4.00 ft, or multiple openings should be constructed in weirs to accommodate multiple shad simultaneously passing through weir opening(s).

Minimum Weir Opening Depth: 1.5 ft

The guideline is based on provision of sufficient water depth over the weir to enable protection from terrestrial predators, maneuvering in low flows, and use of lower velocity zone in high flows; equivalent to 3 times BD_{max} =3 * 13.3 cm = 39.8 cm = 1.31 ft. This value was rounded up to d_N = 1.50 ft.

Maximum Weir Opening Water Velocity: 4.5 ft/sec
No sprint swimming data are available for hickory shad. U_{crit} for hickory shad is unknown. Based on U=5 BL/sec for subcarangiform swimmers, U_{max} = 5 * 28 cm = 140 cm/sec = 4.59 ft/sec. This value was rounded down to V_{max} = 4.50 ft/sec.

Maximum Fishway/Channel Slope: 1:30
This nominal slope guideline approximates the maximum slope at natural river sites known to be passable by hickory shad, or is a conservative estimate of maximum slope based on known hickory shad swimming behavior and river hydro-geomorphologies in which hickory shad occur.

American Shad

TL_{min} = 36 cm (MacKenzie 1985)
TL_{max} = 76 cm (Klauda et al. 1991)
Body Depth/TL Ratio = 0.292 (A. Haro, USGS, unpub. data (Connecticut River fish))

Minimum Pool/Channel Width: 20.0 ft
The guideline is based on creation of pools large enough to serve as resting areas and protection from terrestrial predators. American shad is a schooling species and often aggregates in large numbers while resting in pools. Larger run sizes (hundreds to thousands) will require pools wider than this minimum dimension, typically on moderate to large-sized Atlantic Coast rivers (i.e., >200-1,000+ mi^2 watersheds).

Minimum Pool/Channel Depth: 4.0 ft
The guideline is based on creation of pools large enough to serve as resting areas and protection from terrestrial predators. Minimum pool depth was calculated using the formula 1 ft + $4BD_{max}$: d_p = 1 ft + (4*(76 cm * 0.292)* 0.0328) = 3.9 ft. This value was rounded up to d_p = 4.0 ft. American shad is a schooling species and often aggregates in large numbers while resting in pools. Larger run sizes (hundreds to thousands) will require pools deeper than this minimum dimension, typically on moderate to larger-sized rivers (i.e., >200-1,000+ mi^2 watersheds).

Minimum Pool/Channel Length: 30.0 ft
The guideline is based on creation of pools large enough to accommodate shad body size, run size, and resting and schooling behavior, as well as meeting maximum weir opening velocity and maximum energy dissipation and slope guidelines. American shad is a schooling species and often aggregates in large numbers while resting in pools. Larger run sizes (thousands or greater) will require pools longer than this minimum dimension, typically on moderate to large-sized rivers (i.e., >200-1,000+ mi^2 watersheds).

Minimum Weir Opening Width: **5.0 ft**
The guideline is based on a weir dimension wide enough to accommodate downstream movement of adult American shad oriented in a "worst case" perpendicular orientation to the flow, equivalent to 2 times TL_{max} or 2*76 cm: = 152 cm = 4.99 ft. This value was rounded up to W_N = 5.00 ft. In the case of larger populations (thousands or greater), entrance dimensions should be greater than 5.00 ft or multiple openings should be constructed. Multiple fish simultaneously passing through weir openings are frequently observed in passage structures designed for large runs of America shad (Haro and Kynard 1997).

Note, in the southern portion of its range, particularly from Florida north to North Carolina, mature American shad are somewhat smaller (lengths: 35-47 cm; 1.2-1.6 ft) and have a higher percentage of single-time spawners than adult shad comprising more northerly populations (Facey and Van Den Avyle 1986). South of Cape Hatteras, North Carolina, American shad die after spawning (termed, semelparous), with increasing repeat spawning (iteroparous) with increasing latitude north of Cape Hatteras (Leggett and Carscadden 1978).

Minimum Weir Opening Depth: **2.25 ft**
The guideline is based on provision of sufficient water depth over the weir to enable protection from terrestrial predators, maneuvering in low flows, and use of lower velocity zone in high flows; equivalent to 3 times BD_{max}: 3 * 22.2 cm= 66.6 cm = 2.18 ft. This value was rounded up to d_N = 2.25 ft. As noted above, smaller-sized adults in the southern Atlantic Coast populations may support a lesser passage opening depth based on the body depth of adults in these populations.

Maximum Weir Opening Water Velocity: **8.25 ft/sec**
The guideline is based on laboratory sprint swimming studies in an open channel test flume (Haro et al. 2004; Castro-Santos 2005): U=7.0 BL/sec swimming speed for a maximum 60 sec. Therefore U_{max} = 7.0 * 36 cm = 252 cm/sec = 8.27 ft/sec. This value was rounded down to V_{max} = 8.25 ft/sec.

Maximum Fishway/Channel Slope: **1:30**
This nominal slope guideline approximates the maximum slope at natural river sites known to be passable by American shad, or is a conservative estimate of maximum slope based on known American shad swimming behavior and river hydro-geomorphologies in which shad occur.

Gizzard Shad

TL_{min} = 25 cm (Miller 1960)
TL_{max} = 50 cm (Able and Fahay 2010)
Body Depth/TL Ratio = 0.323 (FishBase; www.fishbase.org; BD = 32.3% of TL)

Minimum Pool/Channel Width: **20.0 ft**
The guideline is based on creation of pools large enough to serve as resting areas and protection from terrestrial predators. Gizzard shad is a schooling species and often aggregates

in large numbers while resting in pools. Larger run sizes (hundreds to thousands) will require pools wider than this minimum dimension.

Minimum Pool/Channel Depth: **3.25 ft**
The guideline is based on creation of pools large enough to serve as resting areas and protection from terrestrial predators. Minimum pool depth was calculated using the formula 1 ft + $4BD_{max}$: d_p = 1 ft + (4*(50 cm * 0.323)* 0.0328) = 3.1 ft. This value was rounded up to d_p = 3.25 ft. Gizzard shad is a schooling species and often aggregates in large numbers while resting in pools. Larger run sizes (hundreds to thousands) will require pools deeper than this minimum dimension.

Minimum Pool/Channel Length: **40.0 ft**
The guideline is based on creation of pools large enough to accommodate shad body size, run size, and resting and schooling behavior, as well as meeting maximum weir opening velocity and maximum energy dissipation and slope guidelines. Gizzard shad is a schooling species and often aggregates in large numbers while resting in pools. Larger run sizes (thousands or greater) will require pools longer than this minimum dimension.

Minimum Weir Opening Width: **3.5 ft**
The guideline is based on a weir dimension wide enough to accommodate downstream movement of adult gizzard shad in a "worst case" perpendicular orientation to the flow, equivalent to 2 times TL_{max} or 2*50 cm: = 100 cm = 3.28 ft. This value was rounded up to W_N = 3.5 ft. In the case of larger populations (thousands or greater), entrance dimensions should be greater than 3.5 ft or multiple openings provided to accommodate multiple fish simultaneously passing through the weir opening(s).

Minimum Weir Opening Depth: **1.75 ft**
The guideline is based on provision of sufficient water depth over the weir to enable protection from terrestrial predators, maneuvering in low flows, and use of lower velocity zone in high flows; equivalent to 3 times BD_{max}: 3 * 16.2 = 48.5 cm = 1.59 ft, to provide additional depth for maneuvering, passage by shad schools, and use of lower velocity zone. This value was rounded up to d_N = 1.75 ft.

Maximum Weir Opening Water Velocity: **4.0 ft/sec**
No known sprint swimming data are available for gizzard shad; U_{crit} for gizzard shad is unknown. The guideline is therefore based on U= 5 BL/sec for subcarangiform swimmers; U_{max} = 5 * 25 cm = 125 cm/sec = 4.10 ft/sec. This value was rounded down to V_{max} = 4.0 ft/sec.

Maximum Fishway/Channel Slope: **1:30**
This nominal slope guideline approximates the maximum slope at natural river sites known to be passable by gizzard shad, or is a conservative estimate of maximum slope based on known gizzard shad swimming behavior and river hydro-geomorphologies in which gizzard shad occur.

Rainbow Smelt

TL_{min} = 12 cm (C. Enterline, Maine Department of Marine Resources, unpub. data)
TL_{max} = 28 cm (C. Enterline, Maine Department of Marine Resources, unpub. data; Data from O'Malley (2016) for anadromous smelt from four Maine rivers (2010-2014) indicate maximum length of 24 cm, perhaps suggesting a temporal trend in decreasing mean length in Northeast smelt populations)
Body Depth/TL Ratio = 0.129 (FishBase; www.fishbase.org; BD = 12.9% of TL)

Minimum Pool/Channel Width: **5.0 ft**
The guideline is based on creation of pools large enough to serve as resting areas and protection from terrestrial predators. Rainbow smelt is a schooling species and often aggregates in large numbers while resting in pools. Larger run sizes (hundreds to thousands) will require pools wider than this minimum dimension.

Minimum Pool/Channel Depth: **1.5 ft**
The guideline is based on creation of pools large enough to serve as resting areas and protection from terrestrial predators. Minimum pool depth was calculated using the formula 1 ft + $4BD_{max}$: d_p = 1 ft + (4*(28 cm * 0.129)* 0.0328) = 1.5 ft. Rainbow smelt is a schooling species and often aggregates in large numbers while resting in pools. Larger run sizes (hundreds to thousands) will require pools deeper than this minimum dimension.

Minimum Pool/Channel Length: **10.0 ft**
The guideline is based on creation of pools large enough to accommodate fish size, run size, and resting and schooling behavior, as well as meeting minimum weir velocity and maximum energy dissipation and slope guidelines. Rainbow smelt is a schooling species and often aggregates in large numbers while resting in pools. Larger run sizes (hundreds to thousands) will require pools longer than this minimum dimension.

Minimum Weir Opening Width: **1.0 ft**
The guideline is based on a weir dimension wide enough to accommodate downstream movement of adult rainbow smelt in a "worst case" perpendicular orientation to the flow, equivalent to 2 times TL_{max} or 2*28 cm = 56 cm = 1.84 ft . This value was reduced to W_N = 1.0 ft to offset potential flow limitations during low fish-run flow periods for passageways on small to very small (first or second-order) coastal streams where wider openings may result in shallow water depths not meeting the passage opening depth guideline (See minimum weir opening depth guideline, below) . In the case of larger populations (thousands or greater), entrance dimensions should be greater than1.0 ft to accommodate multiple fish simultaneously passing through the weir opening.

Minimum Weir Opening Depth: **0.50 ft**
The guideline is based on provision of sufficient water depth over the weir to enable protection from terrestrial predators, maneuvering in low flows, and use of lower velocity zone in high flows; equivalent to 3 times BD_{max}: 3 * 3.6 cm = 10.8 cm = 0.35 ft. This value was rounded up to d_N = 0.50 ft.

Maximum Weir Opening Water Velocity: **3.25 ft/sec**

The guideline is based on mean U_{crit} = 0.30 m/s for 7 cm, smaller-sized adult rainbow smelt in respirometer experiments (Griffiths 1979); U_{crit} = 4.29 BL/sec. Therefore U_{max} = 2 * 4.29 * 12 cm = 103.0 cm/sec = 3.38 ft/sec. Velocity barriers have been observed for rainbow smelt at water velocities greater than 3.9 ft/sec (B. Chase, MADMF, pers. comm., 8/30/2011). V_{max} was rounded down to 3.25 ft/sec.

Maximum Fishway/Channel Slope: **1:30**

Rainbow smelt spawning runs are typically associated with low-gradient streams and rivers near the head-of-tide. Slope guidelines have not been previously established for rainbow smelt, so a conservative slope was selected. This nominal slope guideline approximates the maximum slope at natural river sites known to be passable by rainbow smelt, or is a conservative estimate of maximum slope based on known rainbow smelt swimming behavior and river hydro-geomorphologies in which smelt occur.

Atlantic Salmon

TL_{min} = 70 cm (T. Sheehan, NMFS, unpub. data)
TL_{max} = 95 cm (T. Sheehan, NMFS, unpub. data)
Body Depth/TL Ratio = 0.215 (T. Sheehan, NMFS, unpub. data; these data were applied to best represent current Northeastern U.S. populations)

Minimum Pool/Channel Width: **20.0 ft**

The guideline is based on creation of pools large enough to serve as resting areas and protection from terrestrial predators.

Minimum Pool/Channel Depth: **3.75 ft**

The guideline is based on creating pools large enough to serve as resting areas and protection from terrestrial predators. Minimum pool depth was calculated using the formula 1 ft + $4BD_{max}$: d_p = 1 ft + (4*(95 cm * 0.215)* 0.0328) = 3.7 ft. This value was rounded up to d_p = 3.75 ft.

Minimum Pool/Channel Length: **40.0 ft**

The guideline is based on creation of pools large enough to accommodate salmon body size, run size, and resting and schooling behavior, as well as meeting maximum weir opening velocity and maximum energy dissipation and slope guidelines.

Minimum Weir Opening Width: **6.25 ft**

The guideline is based on a weir opening dimension wide enough to accommodate downstream movement of adult Atlantic salmon in a “worst case” perpendicular orientation to the flow, equivalent to 2 times TL_{max} or 2*95 cm = 190 cm = 6.23 ft. This value was rounded up to W_N = 6.25 ft. This width dimension may be reduced to offset potential flow limitations not meeting the minimum weir opening water depth guideline (See water depth guideline, below) associated with low-flow (e.g., autumn post-spawn downstream passage) conditions during the passage season.

Minimum Weir Opening Depth: **2.25 ft**

The guideline is based on provision of sufficient water depth over the weir to enable protection from terrestrial predators, maneuvering in low flows, and use of lower velocity zone in high flows; equivalent to 3 times BD_{max}: 3 * 20.41 cm = 61.2 cm = 2.01 ft. This value was rounded up to d_N = 2.25 ft.

Maximum Weir Opening Water Velocity: **13.75 ft/sec**

The guideline is based initially on mean U_{crit} = 1.70 m/s for 57 cm adult Atlantic salmon in respirometer experiments (Booth et al. 1997). The 57 cm body length approximates the smallest-sized, sea-run adult salmon (grilse) and is not based on smaller-sized spawning adult landlocked salmon; U_{crit}= 3.0 BL/sec. Therefore, U_{max} = 2 * 3.0 * 70 cm = 420 cm/sec = 13.78 ft/sec. This value was rounded down to V_{max} = 13.75 ft/sec.

Maximum Fishway/Channel Slope: **1:20**

This nominal slope guideline approximates the maximum slope at natural river sites known to be passable by Atlantic salmon, or is a conservative estimate of maximum slope based on known Atlantic salmon swimming and leaping behavior and river hydro-geomorphologies in which Atlantic salmon occur.

Sea-Run Brook Trout

TL_{min} = 10 cm (M. Gallagher, Maine Department of Inland Fisheries, unpub. data)
TL_{max} = 45 cm (M. Gallagher, Maine Department of Inland Fisheries, unpub. data)
Body Depth/TL Ratio = 0.255 (M. Gallagher, Maine Dept. Inland Fisheries, unpub. data)

Minimum Pool/Channel Width: **5.0 ft**

The guideline is based on creating pools large enough to serve as resting areas and protection from terrestrial predators. Streams and rivers with larger runs (hundreds or more) will require greater passage widths.

Minimum Pool/Channel Depth: **2.5 ft**

The guideline is based on creating pools large enough to serve as resting areas and protection from terrestrial predators, as well as accommodating trout leaping capabilities and needs for passing over weirs or through openings. Minimum pool depth was calculated using the formula 1 ft + $4BD_{max}$: d_p = 1 ft + (4*(45 cm * 0.255)* 0.0328) = 2.5 ft.

Minimum Pool/Channel Length: **10.0 ft**

The guideline is based on creation of pools large enough to accommodate trout body size, run size, and resting and schooling behavior, as well as meeting maximum weir opening velocity and maximum energy dissipation and slope guidelines.

Minimum Weir Opening Width: **1.5 ft**

The guideline is based on a weir dimension wide enough to accommodate downstream movement of adult sea-run brook trout in a “worst case” perpendicular orientation to the flow, equivalent to 2 times TL_{max} or 2*45 cm: = 90 cm = 2.95 ft. However, this dimension was reduced to W_N = 1.5 ft. to offset potential flow limitations not meeting the minimum weir opening water depth guideline (See minimum weir opening water depth guideline, below) associated with low-flow (e.g., autumn post-spawn downstream passage) conditions during the passage season for passages on small or very small (first or second-order) coastal streams.

Minimum Weir Opening Depth: **1.25 ft**
The guideline is based on provision of sufficient water depth through the weir opening to enable protection from terrestrial predators, maneuvering in low flows, and use of lower velocity zone in high flows; equivalent to 3 times BD_{max}: 3 * 11.5 cm = 34.4 cm = 1.12 ft. This value was rounded up to d_N = 1.25 ft.

Maximum Weir Opening Water Velocity: **3.25 ft/sec**
The guideline is based initially on laboratory sprint swimming studies in an open channel flume (Castro-Santos et al. 2013): U=10.0 BL/sec swimming speed for a maximum 60 sec. Therefore, U_{max} = 10.0 * 10 cm = 100 cm/sec = 3.28 ft/sec. This value was rounded down to V_{max} = 3.25 ft/sec.

Maximum Fishway/Channel Slope: **1:20**
This nominal slope guideline approximates the maximum slope at natural river sites known to be passable by sea-run brook trout, or is a conservative estimate of maximum slope based on known brook trout swimming behavior and river hydro-geomorphologies in which brook trout occur.

Smaller-sized Salmonids $\leq$20 cm ($\leq$8 inch) TL

TL_{min} = 5 cm (lower limit of specified range)
TL_{max} = 20 cm (upper limit of specified range)
Body Depth/TL Ratio = 0.250 (generalized BD/TL ratio)

We present guidelines for smaller-sized salmonids which may include both non-migratory phase Atlantic salmon parr (juveniles) using low-order, high-gradient streams with limited seasonal flows; and native sea-run brook trout which may mature as adults as small as 8.5-cm length, and are typically found in Northeast streams and rivers at smaller-size lengths.

Minimum Pool/Channel Width: **5.0 ft**
The guideline is based on creating pools large enough to serve as resting areas and protection from terrestrial predators.

Minimum Pool/Channel Depth: **1.75 ft**
The guideline is based on creating pools large enough to serve as resting areas and protection from terrestrial predators, as well as accommodating leaping capabilities and needs of juvenile salmonids. Minimum pool depth was calculated using the formula 1 ft + $4BD_{max}$: d_p = 1 ft + (4*(20 cm * 0.250)* 0.0328) = 1.7 ft. This value was rounded up to d_p = 1.75 ft.

Minimum Pool/Channel Length: 10.0 ft

The guideline is based on creation of pools large enough to accommodate fish size, run size, and resting and schooling behavior, as well as meeting maximum weir opening velocity and maximum energy dissipation and slope guidelines.

Minimum Weir Opening Width: 1.25 ft

The guideline is based on a weir dimension wide enough to accommodate downstream movement of upstream passage by a larger juvenile or young adult, and the downstream movement of juvenile salmonids and smolts in a "worst case" perpendicular orientation to the flow, equivalent to 2 times TL_{max} of 20 cm: = 40 cm = 1.31 ft. However this value was rounded down to W_N = 1.25 ft to offset potential flow limitations not meeting the minimum weir opening water depth guideline (See minimum weir opening water depth guideline, below) associated with low fish-run flow conditions for passageways on small or very small (first or second-order) coastal streams and streams with substantially varying ("flashy") seasonal flow conditions.

Minimum Weir Opening Depth: 0.50 ft

The guideline is based on provision of sufficient water depth through the weir opening to enable protection from terrestrial predators, maneuvering in low flows, and use of lower velocity zone in high flows; equivalent to 3 times BD_{max}: 3 * 5.0 cm = 15.0 cm = 0.49 ft. This value was rounded up to d_N = 0.50 ft.

Maximum Weir Opening Water Velocity: 2.25 ft/sec

The guideline is based on mean U_{crit} = 0.62 m/s for 8.5 cm brook trout in respirometer experiments (McDonald et al. 1998); U= 7.3 BL/sec. This guideline is based on the approximate smallest body length for adult brook trout. Therefore, U_{max} = 2 * 7.3 * 5.0 cm = 73.0 cm/sec = 2.40 ft/sec. This value was rounded down to V_{max} = 2.25 ft/sec.

Maximum Fishway/Channel Slope: 1:20

This nominal slope guideline approximates the maximum slope at natural river sites known to be passable by juvenile salmonids, or is a conservative estimate of maximum slope based on known salmonid swimming and leaping behavior and river hydro-geomorphologies in which salmonids occur.

Atlantic Tomcod

TL_{min} = 15 cm (Collette and Klein-MacPhee 2002)
TL_{max} = 30 cm (Collette and Klein-MacPhee 2002, Stevens et al., 2016)
Body Depth/TL Ratio = 0.202 (FishBase; www.fishbase.org; BD = 20.2% of TL)

Minimum Pool/Channel Width: 5.0 ft

The guideline is based on creating pools large enough to serve as resting areas and protection from terrestrial predators.

Minimum Pool/Channel Depth: 2.0 ft

The guideline is based on creating pools large enough to serve as resting areas and protection from terrestrial predators. Minimum pool depth was calculated using the formula 1 ft + $4BD_{max}$: d_p = 1 ft + (4*(30 cm * 0.202)* 0.0328) = 1.8 ft. This value was rounded up to d_p = 2.0 ft.

Minimum Pool/Channel Length: 10.0 ft

The guideline is based on creation of pools large enough to accommodate tomcod body size, run size, and resting and schooling behavior, as well as meeting maximum weir opening velocity and maximum energy dissipation and slope guidelines.

Minimum Weir Opening Width: 2.0 ft

The guideline is based on a weir dimension wide enough to accommodate upstream passage by multiple adult Atlantic tomcod migrating upstream in small tidal, coastal streams, including during ebbing-tide periods in tidal streams; as well as downstream movement of adult Atlantic tomcod in a "worst case" perpendicular orientation to the flow; equivalent to 2 times TL_{max} or 2*30 cm: = 60 cm = 1.97 ft. This value was rounded up to W_N = 2.0 ft.

Minimum Weir Opening Depth: 0.75 ft

The guideline is based on provision of sufficient water depth through the weir opening to enable protection from terrestrial predators, maneuvering in low flows, and use of lower velocity zone in high flows; equivalent to 3 times BD_{max}: 3 * 6.06 cm = 18.2 cm = 0.60 ft. This value was rounded up to d_N = 0.75 ft.

Maximum Weir Opening Water Velocity: 0.75 ft/sec

No sprint swimming data are available for Atlantic tomcod. U_{crit} for Atlantic tomcod is unknown. Water velocities in excess of 30 cm/sec are known to be barriers for Atlantic tomcod (Bergeron et al. 1998); therefore, U_{max} = 30 cm/sec = 0.98 ft/sec. This value was rounded down to V_{max} = 0.75 ft/sec. If a passage site is affected by tidal flooding, tom cod may alternatively passively move over project site weirs or through weir openings or other hydraulic features during diurnal flood tide events.

Maximum Fishway/Channel Slope: 1:30

This nominal slope guideline approximates the maximum slope at natural river sites known to be passable by tom cod, or is a conservative estimate of maximum slope based on known tom cod swimming behavior and river hydro-geomorphologies in which tom cod occur.

Striped Bass

TL_{min} = 15 cm (Fay et al. 1983)
TL_{max} = 30 cm (Collette and Klein-MacPhee 2002)
Body Depth/TL Ratio = 0.225 (FishBase; www.fishbase.org; BD = 22.5% of TL)

Minimum Pool/Channel Width: **20.0 ft**
The guideline is based on creating pools large enough to serve as resting areas and protection from terrestrial predators.

Minimum Pool/Channel Depth: **5.25 ft**
The guideline is based on creating pools large enough to serve as resting areas and protection from terrestrial predators. Minimum pool depth was calculated using the formula 1 ft + 4BD_{max}: d_p = 1 ft + (4*(140 cm * 0.225)* 0.0328) = 5.1 ft. This value was rounded up to d_p = 5.25 ft.

Minimum Pool/Channel Length: **30.0 ft**
The guideline is based on creation of pools large enough to accommodate bass body size, run size, and resting and schooling behavior, as well as meeting maximum weir opening velocity and maximum energy dissipation and slope guidelines.

Minimum Weir Opening Width: **9.25 ft**
The guideline is based on a weir dimension wide enough to accommodate upstream migration by adult striped bass on migratory spawning runs (principally tidal rivers with varying tidal prism, or larger (fourth+-order) non-tidal rivers); and downstream movement of adult striped bass in a “worst case” perpendicular orientation to the flow; equivalent to at least 2 times TL_{max} or 2*140 cm: = 280 cm = 9.19 ft. This value was rounded up to W_N = 9.25 ft.

Minimum Weir Opening Depth: **3.25 ft**
The guideline is based on provision of sufficient water depth over the weir to enable protection from terrestrial predators, maneuvering in low flows, and use of lower velocity zone in high flows; equivalent to 3 times BD_{max}: 3 * 31.5 cm= 94.5 cm = 3.10 ft. This value was rounded up to d_N = 3.25 ft.

Maximum Weir Opening Water Velocity: **5.25 ft/sec**
The guideline is based on laboratory sprint swimming studies in an open channel test flume (Haro et al. 2004; Castro-Santos 2005): U=4.0 BL/sec swimming speed for a maximum 60 sec. Therefore U_{max} = 4.0 * 40 cm = 160 cm/sec = 5.25 ft/sec. V_{max} was therefore established as 5.25 ft/sec for smaller-sized striped bass.

Maximum Fishway/Channel Slope: **1:30**
This nominal slope guideline approximates the maximum slope at natural river sites known to be passable by striped bass, or is a conservative estimate of maximum slope based on known striped bass swimming behavior and river hydro-geomorphologies in which striped bass occur.

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Appendix D

Glossary of Terms

List of Unit Abbreviations

List of Acronyms

Glossary of Terms

Aeration	Process by which air is mixed into water. Typically used in reservoirs, tailraces, and turbines to mitigate low dissolved oxygen conditions.
Anadromous	A fish life history strategy whereby fish are born in fresh water, spends most of life at sea, and returns to freshwater to spawn.
Approach velocity	The prevailing free stream velocity in a river or channel; typically parallel to the longitudinal direction of the waterway.
Aquatic organism passage	The ability for fish and other aquatic fish and other aquatic creatures to move up or downstream under road crossings.
Attraction flow	The flow that emanates from a fishway entrance with sufficient velocity and in sufficient quantity and location to attract upstream migrants in the fishway. Attraction flow consists of gravity flow from the fish ladder, plus any auxiliary water system flow added at points within the lower fish ladder.
Auxiliary water	Portion of attraction flow that is diverted through the auxiliary water system (AWS) prior to flowing out of the fishway entrance.
Auxiliary water system	A hydraulic system that augments fish ladder flow at various points in the upstream passage facility. Typically, large amounts of auxiliary water flow are added in the fishway entrance pool in order to increase the attraction of the fishway entrance.
Behavioral barrier	Any device, structure, or operation that requires response, or reaction (volitional taxis) on the part of the fish to avoid entrainment. Examples include acoustic, electric, and light.
Behavioral devices	Requires a decision, response, or reaction (volitional taxis) on the part of the fish to avoid entrainment.
Benthic-oriented	Fish that live and feed on or near the bottom of oceans or lakes (the benthic zone). Lower than demersal zone.
Biological capacity	Maximum number of fish that can safely, timely, and effectively pass through the fishway.
Biomass	The total mass of organisms in a given area or volume.

Biotelemetry	Remote monitoring of individual fish or other organisms through space and time with electronic identification tags.
Brail	A device that moves upward (vertically) through the water column, crowding fish into an area for collection.
Burst speed	Swim speed a fish can maintain for seconds, primarily an anaerobic muscle activity.
Bypassed reach	The portion of the river between the point of flow diversion and the point of flow return to the river.
Catadromous	A fish life history strategy whereby a fish spawn at sea and move to and spend most of their lives in fresh water.
Channel roughness	Measure of the amount of frictional resistance water experiences when passing over land and channel features.
Crowder	A combination of static and/or movable picketed and/or solid leads installed in a fishway for the purpose of moving fish into a specific area for sampling, counting, broodstock collection, or other purposes.
Cruising speed	The swim speed a fish can maintain for hours without causing any major physiological changes, an aerobic muscle activity ("red" muscle tissue).
Degradation	Erosion of sediment in a river channel.
Demersal fish	Fish that live and feed on or near the bottom of seas or lakes (the demersal zone).
Denil fishway	Family of baffled-chute ladders that utilize roughness elements (i.e., baffles) to dissipate the kinetic energy of water moving through a flume to create a low velocity zone of passage for migratory fish.
Design flow, high	Nominal upper limit of river flow that can achieve safe, timely, and effective fish passage.
Design flow, low	Nominal lower limit of river flow that can achieve safe, timely, and effective fish passage.
Diadromous	A fish life history strategy whereby fish spend parts of their life cycle in fresh water and other parts in salt water.

Diffuser	Typically, a set of horizontal or vertical bars designed to introduce flow into a fishway in a nearly uniform fashion. Other means are also available that may accomplish this objective.
Discharge	The volume of water per unit time flowing through a structure, a turbine, or a channel cross-section.
Downstream bypass	The component of a downstream passage facility that transport fish from the diverted water back into the body of water from which they originated, usually consisting of a bypass entrance, a bypass conveyance, and a bypass outfall.
Downstream passage	The act of moving from upstream of a dam or other hydropower facility to downstream of a dam or other hydropower facility. This can be accomplished through unmitigated passage through turbines or spill gates, or mitigated passage through locks, elevators, sluiceways or channels that bypass turbines or other structures.
Eelway	A fishway specifically designed for eel.
Elvers	A young eel, especially when undergoing mass migration upriver from the sea.
EDF	The energy dissipation factor (EDF) is the measurement of energy in a bypass downwell to assist in providing enough water volume in the downwell to dissipate the energy entering the downwell and to limit turbulence and circulation patterns that may trap debris and/or fish.
Energy grade line	A line that represents the elevation of energy head (in feet or meters) of water flowing in a pipe, conduit, or channel. The line is drawn above the hydraulic grade line (gradient) a distance equal to the velocity head of the water flowing at each section or point along the pipe or channel.
Entrainment	The unintended diversion of fish into an unsafe passage route.
Exclusion barriers	Upstream passage facilities that prevent upstream migrants from entering areas with no upstream egress, or areas that may lead to fish injury.
FERC	The Federal Energy Regulatory Commission (FERC) is an independent agency that regulates the interstate transmission of natural gas, oil, and electricity.

Fish ladder	The structural component of an upstream passage facility that dissipates the potential energy into discrete pools, or uniformly dissipates energy with a single baffled chute place between an entrance pool and an exit pool or with a series of baffled chutes and resting pools.
Fish lift	A mechanical component of an upstream passage system that provides fish passage by lifting fish in a water-filled hopper or other lifting device into a conveyance structure that delivers upstream migrants past the impediment.
Fish lock	A mechanical and hydraulic component of an upstream passage system that provides fish passage by attracting or crowding fish into the lock chamber, activating a closure device to prevent fish from escaping, introducing flow into the enclosed lock, and raising the water surface to forebay level, and then opening a gate to allow the fish to exit.
Fish passage system	The range of dates when a species migrates to the site of an existing or proposed fishway, based on either available data collected for a site, or consistent with the opinion of an assigned NMFS/USFWS biologist when no data is available.
Fishway	Combination of elements (structures, facilities, devices, project operations, and measures) necessary to ensure the safe, timely, and effective movement of fish past a barrier.
Fishway capacity	A measure of the quantity of fish that the facility can successfully convey, upstream or downstream, in a given period.
Fishway entrance	The component of an upstream passage facility that discharges attraction flow into the tailrace, where upstream migrating fish enter (and flow exits) the fishway.
Fishway exit	The component of an upstream passage facility where flow from the forebay enters the fishway, and where fish exit into the forebay upstream of the passage impediment.
Flashboards	Temporary structures installed at the top of dams, gates, or spillways for the purpose of temporarily raising the pool elevation, and hence, the gross head of a hydroelectric generating plant, thus increasing power output. Normally, flashboards are removed either at the end of the water storage season, or during periods of high stream flow.

FDC	The flow-duration curve (FDC) is the plot of the relationship between the magnitude of the daily flow and the percentage of the time period for which that flow is likely to be equaled or exceeded. Other time units can be used as well, depending on the intended application of the data.
Forebay	The impoundment immediately above a dam or hydroelectric plant intake structure. The term is applicable to all types of hydroelectric developments (i.e., storage, run-of-river, and pumped storage).
Fork length	A measurement used frequently for fish length when the tail has a fork shape. Projected straight distance between the tip of the snout and the fork of the tail.
Francis turbine	A reaction turbine typically installed at medium head projects characterized fixed blades on a runner (wheel) and paired with an external generator.
Freeboard	The height of a structure that extends above the maximum water surface elevation.
Head loss	The loss of energy through a hydraulic structure, device or from one known point to another.
Headwater	Waters located immediately upstream from a hydraulic structure, such as a dam (excluding minimum release such as for fish water), bridge or culvert.
Holding pools	Section in the lower channel that is downstream of the hopper and bound by the (open) mechanical crowder in a fish lift. The purpose of the holding pool is to retain migrants prior to crowding them into the hopper.
Hopper (bucket)	Water retaining vessel used to lift fish (in water) from a collection or holding area, for release at a higher elevation.
Hydraulic jump	A hydraulic jump happens when a higher velocity supercritical flow upstream is met by a subcritical downstream flow with a decreased velocity and sufficient depth.
Impingement	A fish’s injurious contact with a screen or bar rack.
Impoundment	A lake formed or enlarged through use of a dam or lock built to store water.

Kaplan turbine	A propeller turbine in which the angle of the blades to the flow can be adjusted.
Life history	The series of changes over the life of an organism including such events as birth, death and reproduction. Also known as life cycle.
Louver	A louver system is constructed of a series of vertical slats placed along a diagonal line within a power canal terminating at the bypass.
Migration	Seasonal or annual movement of organisms from one area to another.
Migratory run	Seasonal migration undertaken by fish, usually as part of their life history; for example, spawning run of salmon, upstream migration of shad.
Mortality	Measures the rate of death of fish. Mortality occurs at all life stage of the population and tends to decrease with age.
Nature-like fishway (NLF)	Fishway constructed of boulders, cobble, and other natural materials to create diverse physical and hydraulic conditions providing efficient passage to multiple species including migratory and resident fish assemblages (Turek et al. 2016)..
Non-volitional passage	Fish passage facilities that include fish lifts (i.e., elevators), fish locks, and trap-and-transport systems.
Normal velocity	Velocity component perpendicular to the guidance structure pointing directly at the face of the structure.
Orifice	An opening through which something may pass.
Pass rate	The rate of ascent, a measure of how quickly fish of different species can traverse the fishway. This parameter reflects both behavioral characteristics and the swimming speed of the fish.
Passive screens	Juvenile fish screens without an automated cleaning system.
Peak day	Largest number of fish designed to pass during a 24-hour period.
Peak hour	Largest number of fish designed to pass in a 1-hour period during the peak day.
Peak minute	Average number of fish passed per minute during the peak hour.

Pelagic fish	Fish that live in the pelagic zone of ocean or lake waters – being neither close to the bottom nor near the shore.
Periphyton cover	Complex mixture of algae, cyanobacteria, heterotrophic microbes, and detritus that is attached to submerged surfaces in most aquatic ecosystems.
Picket leads or pickets	A set of vertically inclined flat bars or circular slender columns (pickets), design to exclude fish from a specific point of passage (also, see fish weir).
PIT –tag detector	A device that passively scans a fish for the presence of a passive integrated transponder (PIT) tag that is implanted in a fish and read when activated by an electro-magnetic field generated by the detector.
Plunge pool	Body of water downstream of the barrier where the conveyance outlet discharges both fish and water.
Plunging flow	Flow over a weir that falls into the receiving pool with a water surface elevation below the weir crest elevation.
Pool-type fishway	A volitional type of fishway that include pool-and-weir, Ice Harbor, and vertical slot.
Potamodromous	A fish life history strategy whereby fish are migrate entirely within freshwater.
Powerhouse	A structure at a hydroelectric plant site that contains the turbine and generator. (FERC 2016) .
Predation	The act of killing and eating other animals.
Radio telemetry	The use of radio waves for transmitting information from a distant instrument to a device that indicates or records the measurements.
Reservoir	A storage space for water that may be created in multiple ways, such as (1) damming a valley to create an impoundment, (2) siphoning water into bank-side areas lined with impermeable material, or (3) constructing above ground water towers or below ground cisterns known as service reservoirs.
Residence time	The average length of time during which a substance, a portion of material, or an object is in a given location or condition. Also can be regarded as the inverse of pass rate.

Rheotaxis	A form of taxis seen in many aquatic organisms, e.g., fish, whereby they will (generally) turn to face into an oncoming current. In a flowing stream, this behavior leads them to hold position in a stream rather than being swept downstream by the current.
Rheotropism	Movement stimulated by a current of water.
Riffle	An area of a stream or river flowing over cobbles, boulders and gravel where characterized as being relatively shallow and having relatively rapid current velocities generally located downstream of a run. Because riffles have high turbulence, they are areas that provide a good deal of oxygen to the stream or river.
Rock ramp	A sloped watercourse that links two pools of different elevation (e.g., headwater and tailwater of a dam) constructed in the existing channel and spanning the entire river. The entire stream flows through a (full width) rock ramp, thus eliminating competing flows and reducing concerns related to attraction.
Run	An area of a stream or river characterized as having relatively rapid current velocities generally located downstream of a pool. Runs generally have relatively greater depths than riffles, but relatively shallower depths than pools.
Scour	The removal of sediment particles by water potentially in the river channel bed or along the shoreline.
Scroll case	A spiral waterway normally made of either reinforced concrete or steel that guides water to the runner of a reaction turbine.
Spillway	An outlet from a reservoir or section of a dam designed to release surplus water that is not discharged through a turbine or other outlet works.
Step pool	A fishway designs approximate pool-and-weir technical fishways. Notionally, fish move through these structures by bursting over a weir then momentarily resting in the upstream pool.
Stop log/bulkhead gate	A gate installed at the entrance of a fluid passage and used to dewater the passage for inspection and maintenance. Almost always opened or closed under balanced pressure.
Streaming flow	Flow over a weir which falls into a receiving pool with water surface elevation above the weir crest elevation. Generally,

	surface flow in the receiving pool is in the downstream direction, downstream from the point of entry into the receiving pool.
Sustained swimming speed	A fish swimming speed that fish can maintain for minutes (see prolonged).
Sweeping velocity	The vector component of canal flow velocity that is parallel and adjacent to the screen face measured 1 foot in front of the screen.
Tailrace	The stream immediately downstream of an instream structure.
Tailwater	Waters located immediately downstream from a hydraulic structure, such as a dam (excluding minimum release such as for fish water), bridge or culvert.
Thalweg	The longitudinal line connecting the lowest points in a streambed.
Total length (TL)	The length of a fish defined as the straight-line distance from the tip of the snout to the tip of the tail (caudal fin) while the fish is lying on its side, normally extended.
Transport channel	A hydraulic conveyance designed to pass fish between different sections of a fish passage facility.
Trap and haul	A fish passage facility designed to trap fish for upstream or downstream transport to continue their migration (AKA trap and transport).
Trash (grizzly) rack	A rack of vertical bars with spacing designed to catch large debris and preclude it from passing. When used on a fishway exit, it must have enough clear spacing for fish to pass in the upstream direction.
Turbidity	Cloudiness or haziness of water created by dissolved or suspended solids. Turbidity upstream and downstream of hydropower facilities is generally reduced relative to free-flowing reaches of river; however, turbidity downstream of the dam is generally reduced compared to that upstream of the dam.
Turbine	A machine which, in the case of a hydroelectric plant, converts energy of water to mechanical energy.
Uniform-in-the-mean	Each successive pool maintains the same hydraulic characteristics at the inlet and outlet. Therefore, the slope of the fishway is approximately equal to the friction slope (slope of the energy grade line) (Towler et al., 2015).

Upstream passage	The act of moving from downstream of a dam or other hydropower facility to upstream of a dam or other hydropower facility. This can be accomplished through a variety of means including lifts, locks or elevators, fishways, or trapping target organisms on the downstream side of the dam or other hydropower facility and transporting them to the upstream side of the dam or other hydropower facility where they are released.
Vertical slot fishway	A pool-type fish ladder characterized by a rectangular channel with a sloping floor in which a series of regularly spaced baffles separate the pools. Water flows from pool to pool via a vertical slot at each baffle. These designs are applicable to medium head dams and, unlike pool-and-weir fishways, may accommodate large fluctuations in headwater and tailwater levels. Another advantage of the vertical slot is that it offers passage along the full depth of the slot, thus it theoretically provides passage to a wider variety of species.
Volitional passage	Fish passage facilities that include specific pool-type and chute-type designs such as the pool-and-weir, Ice Harbor, vertical slot, Denil, and steeppass.
Weir	An obstruction over which water flows.
Wicket gate	Adjustable vanes that surround a reaction turbine runner and control the area available for water to enter the turbine.

List of Unit Abbreviations

Unit	**Unit Abbreviation**
cubic foot	ft^3
cubic foot per second	cfs
foot	ft
foot per second	fps
foot pound per second per cubic foot	$ft\text{-}lbf/s\text{-}ft^3$
gallon per minute	gpm
inch	in.
millimeter	mm
pound	lb
pound per cubic foot	lbf/ft^3
square foot	ft^2

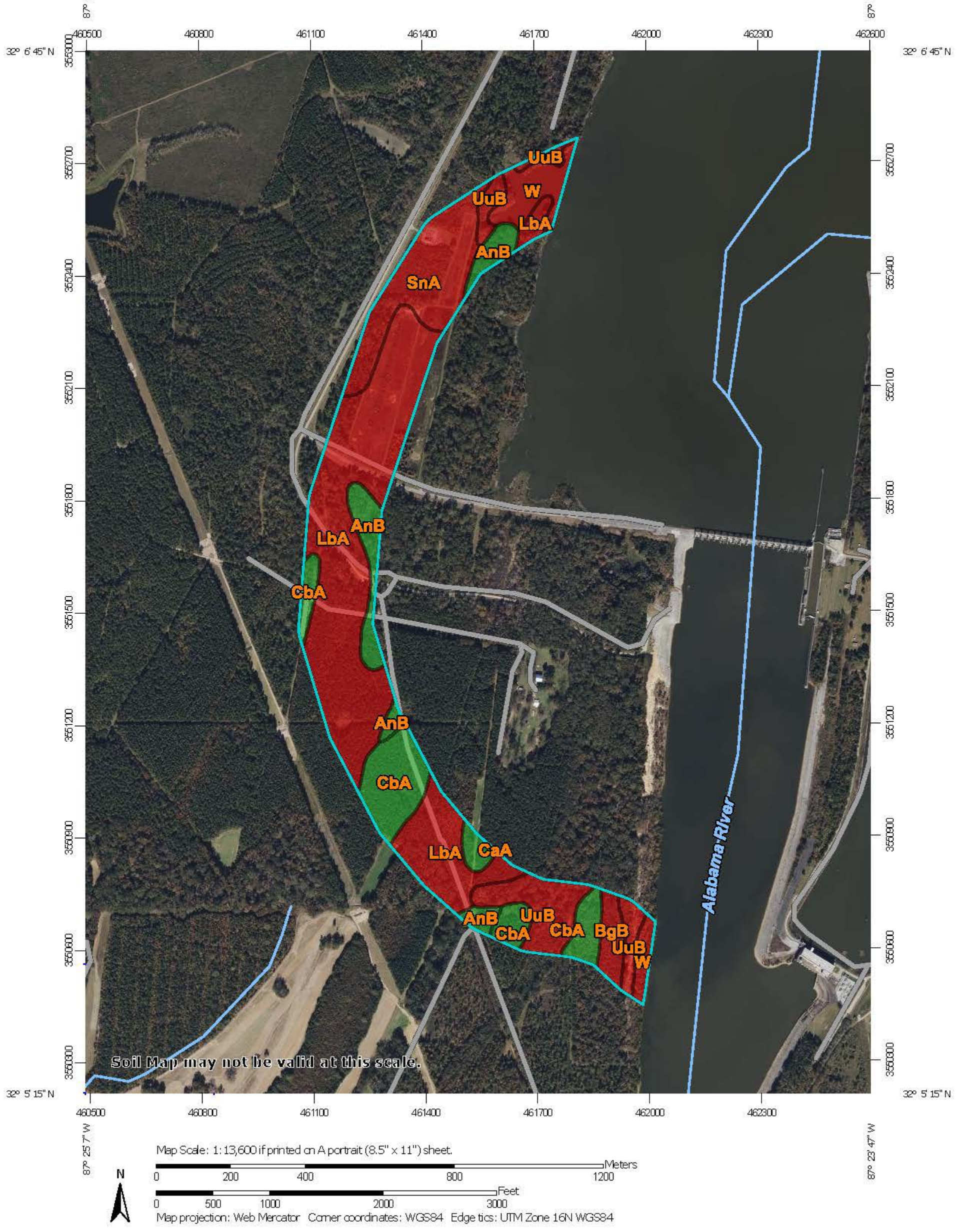
List of Acronyms

Acronym	
AOP	Aquatic organism passage
AWS	Auxiliary water system
CT DEEP	Connecticut Department of Energy & Environmental Protection
EDF	Energy dissipation factor
Engineering	Fish Passage Engineering
FAC	Fish and Aquatic Conservation program
FDC	Flow-duration curve
FERC	Federal Energy Regulatory Commission
HW	Headwater
MDNR	Maryland Department of Natural Resources
ME DMR	Maine Department of Marine Resources
ME IFW	Maine Department of Inland Fisheries and Wildlife
MPOR	Migratory period of record
NH DFG	New Hampshire Department of Fish and Game
NLF	Nature-like fishway
NMFS	National Marine Fisheries Service
NRCS	Natural Resource Conservation Service
O&M Plan	Operation and maintenance plan
PIT	Passive integrated transponder
POR	Period of record
R5	Region 5 (also Northeast Region)
Service	U.S. Fish and Wildlife Service
TW	Tailwater
USGS	U.S. Geological Survey
ZOP	Zone of Passage

B.1.6. *The Farmland Protection Policy Act*

B.1.6.1. *Millers Ferry*

Farmland Classification—Wilcox County, Alabama
(Miller's Ferry Bypass)



Natural Resources Conservation Service Web Soil Survey
National Cooperative Soil Survey

3/16/2023
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MAP LEGEND

Area of Interest (AOI)

- □ Area of Interest (AOI)

Soils

Soil Rating Polygons

- 🟥 Not prime farmland
- 🟩 All areas are prime farmland
- 🟩 Prime farmland if drained
- 🟩 Prime farmland if protected from flooding or not frequently flooded during the growing season
- 🟨 Prime farmland if irrigated
- 🟨 Prime farmland if drained and either protected from flooding or not frequently flooded during the growing season
- 🟫 Prime farmland if irrigated and drained
- ⬜ Prime farmland if irrigated and either protected from flooding or not frequently flooded during the growing season
- ⬜ Prime farmland if subsoiled, completely removing the root inhibiting soil layer
- 🟦 Prime farmland if irrigated and the product of I (soil erodibility) x C (climate factor) does not exceed 60
- 🟦 Prime farmland if irrigated and reclaimed of excess salts and sodium
- 🟦 Farmland of statewide importance
- 🟦 Farmland of statewide importance, if drained
- 🟪 Farmland of statewide importance, if protected from flooding or not frequently flooded during the growing season
- 🟧 Farmland of statewide importance, if irrigated
- 🟩 Farmland of statewide importance, if drained and either protected from flooding or not frequently flooded during the growing season
- 🟩 Farmland of statewide importance, if irrigated and drained
- 🟫 Farmland of statewide importance, if irrigated and either protected from flooding or not frequently flooded during the growing season
- ⬜ Farmland of statewide importance, if subsoiled, completely removing the root inhibiting soil layer
- ⬜ Farmland of statewide importance, if irrigated and the product of I (soil erodibility) x C (climate factor) does not exceed 60
- 🟪 Farmland of statewide importance, if irrigated and reclaimed of excess salts and sodium
- 🟨 Farmland of statewide importance, if drained or either protected from flooding or not frequently flooded during the growing season
- 🟦 Farmland of statewide importance, if warm enough, and either drained or either protected from flooding or not frequently flooded during the growing season
- 🟫 Farmland of statewide importance, if warm enough
- 🟥 Farmland of statewide importance, if thawed
- 🟦 Farmland of local importance
- 🟧 Farmland of local importance, if irrigated
- 🟦 Farmland of unique importance
- ⬜ Not rated or not available

Soil Rating Lines

- 〰 Not prime farmland
- 〰 All areas are prime farmland
- 〰 Prime farmland if drained
- 〰 Prime farmland if protected from flooding or not frequently flooded during the growing season
- 〰 Prime farmland if irrigated
- 〰 Prime farmland if drained and either protected from flooding or not frequently flooded during the growing season
- 〰 Prime farmland if irrigated and drained
- 〰 Prime farmland if irrigated and either protected from flooding or not frequently flooded during the growing season

- 〰 Prime farmland if subsoiled, completely removing the root inhibiting soil layer
- 〰 Prime farmland if irrigated and the product of I (soil erodibility) x C (climate factor) does not exceed 60
- 〰 Prime farmland if irrigated and reclaimed of excess salts and sodium
- 〰 Farmland of statewide importance
- 〰 Farmland of statewide importance, if drained
- 〰 Farmland of statewide importance, if protected from flooding or not frequently flooded during the growing season
- 〰 Farmland of statewide importance, if irrigated
- 〰 Farmland of statewide importance, if drained and either protected from flooding or not frequently flooded during the growing season
- 〰 Farmland of statewide importance, if irrigated and drained
- 〰 Farmland of statewide importance, if irrigated and either protected from flooding or not frequently flooded during the growing season
- 〰 Farmland of statewide importance, if subsoiled, completely removing the root inhibiting soil layer
- 〰 Farmland of statewide importance, if irrigated and the product of I (soil erodibility) x C (climate factor) does not exceed 60
- 〰 Farmland of statewide importance, if irrigated and reclaimed of excess salts and sodium
- 〰 Farmland of statewide importance, if drained or either protected from flooding or not frequently flooded during the growing season
- 〰 Farmland of statewide importance, if warm enough, and either drained or either protected from flooding or not frequently flooded during the growing season
- 〰 Farmland of statewide importance, if warm enough
- 〰 Farmland of statewide importance, if thawed
- 〰 Farmland of local importance
- 〰 Farmland of local importance, if irrigated
- 〰 Farmland of unique importance
- 〰 Not rated or not available

Soil Rating Points

- ■ Not prime farmland
- ■ All areas are prime farmland
- ■ Prime farmland if drained
- ■ Prime farmland if protected from flooding or not frequently flooded during the growing season
- ■ Prime farmland if irrigated
- ■ Prime farmland if drained and either protected from flooding or not frequently flooded during the growing season
- ■ Prime farmland if irrigated and drained
- ■ Prime farmland if irrigated and either protected from flooding or not frequently flooded during the growing season
- ■ Prime farmland if subsoiled, completely removing the root inhibiting soil layer
- ■ Prime farmland if irrigated and the product of I (soil erodibility) x C (climate factor) does not exceed 60
- ■ Prime farmland if irrigated and reclaimed of excess salts and sodium
- ■ Farmland of statewide importance
- ■ Farmland of statewide importance, if drained
- ■ Farmland of statewide importance, if protected from flooding or not frequently flooded during the growing season
- ■ Farmland of statewide importance, if irrigated

- 🟩 Farmland of statewide importance, if drained and either protected from flooding or not frequently flooded during the growing season
- 🟩 Farmland of statewide importance, if irrigated and drained
- 🟥 Farmland of statewide importance, if irrigated and either protected from flooding or not frequently flooded during the growing season
- 🟦 Farmland of statewide importance, if subsoiled, completely removing the root inhibiting soil layer
- 🟪 Farmland of statewide importance, if irrigated and the product of I (soil erodibility) x C (climate factor) does not exceed 60
- 🟪 Farmland of statewide importance, if irrigated and reclaimed of excess salts and sodium
- 🟨 Farmland of statewide importance, if drained or either protected from flooding or not frequently flooded during the growing season
- 🟩 Farmland of statewide importance, if warm enough, and either drained or either protected from flooding or not frequently flooded during the growing season
- 🟫 Farmland of statewide importance, if warm enough
- 🟥 Farmland of statewide importance, if thawed
- 🟦 Farmland of local importance
- 🟧 Farmland of local importance, if irrigated
- 🟦 Farmland of unique importance
- ⬜ Not rated or not available

Water Features

- ~ Streams and Canals

Transportation

- +++ Rails
- ~ Interstate Highways
- ~ US Routes
- ~ Major Roads
- ~ Local Roads

Background

- ▨ Aerial Photography

The soil surveys that comprise your AOI were mapped at 1:24,000.

Warning: Soil Map may not be valid at this scale.

Enlargement of maps beyond the scale of mapping can cause misunderstanding of the detail of mapping and accuracy of soil line placement. The maps do not show the small areas of contrasting soils that could have been shown at a more detailed scale.

Please rely on the bar scale on each map sheet for map measurements.

Source of Map: Natural Resources Conservation Service
Web Soil Survey URL:
Coordinate System: Web Mercator (EPSG:3857)

Maps from the Web Soil Survey are based on the Web Mercator projection, which preserves direction and shape but distorts distance and area. A projection that preserves area, such as the Albers equal-area conic projection, should be used if more accurate calculations of distance or area are required.

This product is generated from the USDA-NRCS certified data as of the version date(s) listed below.

Soil Survey Area: Wilcox County, Alabama
Survey Area Data: Version 16, Sep 14, 2022

Soil map units are labeled (as space allows) for map scales 1:50,000 or larger.

Date(s) aerial images were photographed: Nov 2, 2021—Dec 23, 2021

The orthophoto or other base map on which the soil lines were compiled and digitized probably differs from the background imagery displayed on these maps. As a result, some minor shifting of map unit boundaries may be evident.

Farmland Classification

Map unit symbol	Map unit name	Rating	Acres in AOI	Percent of AOI
AnB	Annemaine fine sandy loam, 2 to 5 percent slopes, occasionally flooded	All areas are prime farmland	10.1	7.5%
BgB	Bigbee loamy sand, 0 to 5 percent slopes, occasionally flooded	Not prime farmland	3.5	2.6%
CaA	Cahaba fine sandy loam, 0 to 2 percent slopes, rarely flooded	All areas are prime farmland	1.8	1.4%
CbA	Canton Bend loam, 0 to 2 percent slopes, occasionally flooded	All areas are prime farmland	17.1	12.7%
LbA	Lenoir silt loam, 0 to 2 percent slopes, occasionally flooded	Not prime farmland	61.8	46.0%
SnA	Sucarnoochee silty clay, 0 to 2 percent slopes, frequently flooded	Not prime farmland	17.8	13.2%
UuB	Urbo-Mooreville-Una complex, 0 to 3 percent slopes, frequently flooded	Not prime farmland	14.1	10.5%
W	Water	Not prime farmland	8.2	6.1%
Totals for Area of Interest			**134.5**	**100.0%**

Description

Farmland classification identifies map units as prime farmland, farmland of statewide importance, farmland of local importance, or unique farmland. It identifies the location and extent of the soils that are best suited to food, feed, fiber, forage, and oilseed crops. NRCS policy and procedures on prime and unique farmlands are published in the "Federal Register," Vol. 43, No. 21, January 31, 1978.

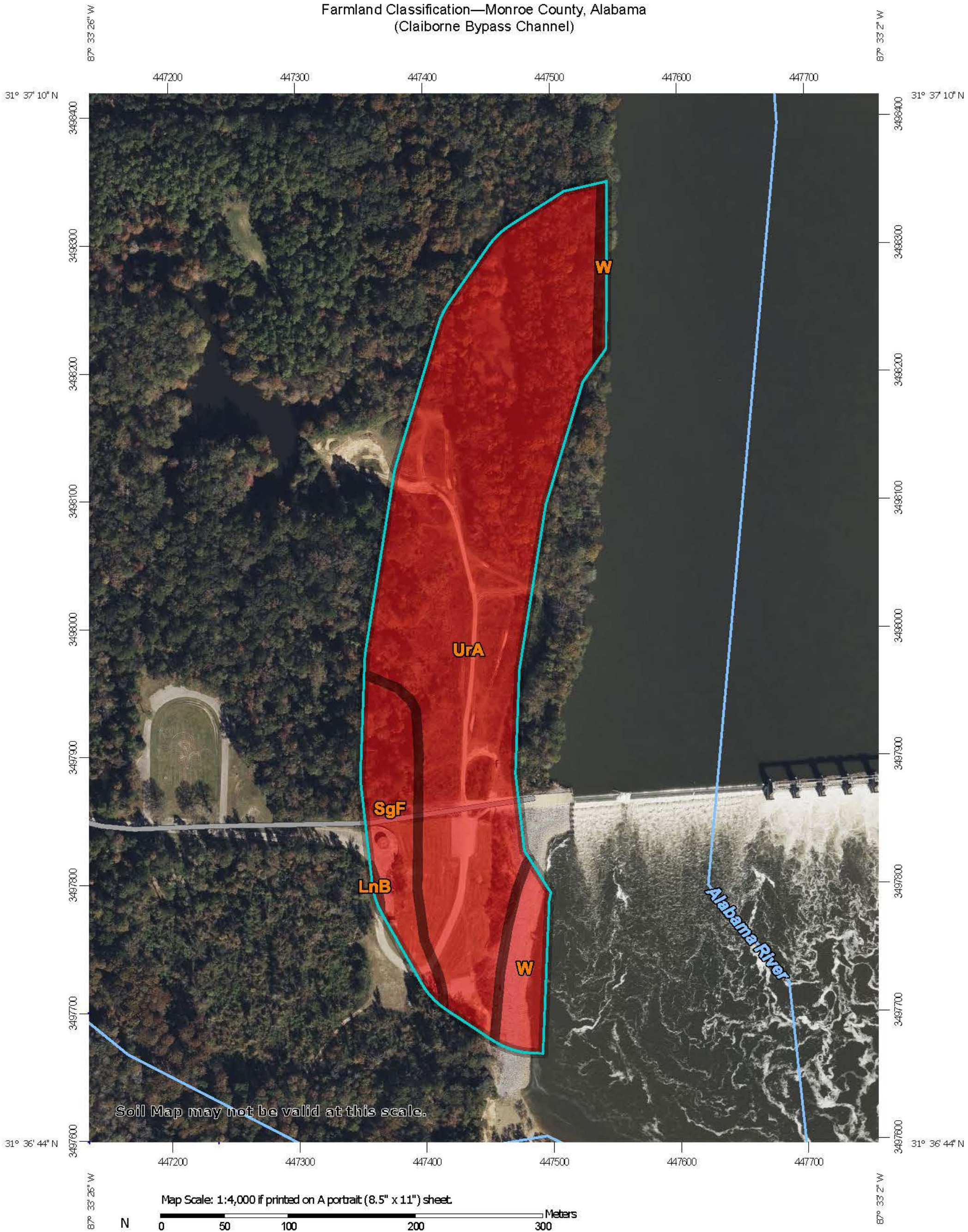
Rating Options

Aggregation Method: No Aggregation Necessary

Tie-break Rule: Lower

B.1.6.2. *Claiborne*

Farmland Classification—Monroe County, Alabama
(Claiborne Bypass Channel)



Map Scale: 1:4,000 if printed on A portrait (8.5" x 11") sheet.

0	50	100	200	300	Meters
0	150	300	600	900	Feet

Map projection: Web Mercator Corner coordinates: WGS84 Edge tics: UTM Zone 16N WGS84

Natural Resources
Conservation Service

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National Cooperative Soil Survey

3/16/2023
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MAP LEGEND

Area of Interest (AOI)

- ⬜ Area of Interest (AOI)

Soils

Soil Rating Polygons

- 🟥 Not prime farmland
- 🟩 All areas are prime farmland
- 🟩 Prime farmland if drained
- 🟩 Prime farmland if protected from flooding or not frequently flooded during the growing season
- 🟨 Prime farmland if irrigated
- 🟨 Prime farmland if drained and either protected from flooding or not frequently flooded during the growing season
- 🟫 Prime farmland if irrigated and drained
- ⬜ Prime farmland if irrigated and either protected from flooding or not frequently flooded during the growing season
- ⬜ Prime farmland if subsoiled, completely removing the root inhibiting soil layer
- 🟦 Prime farmland if irrigated and the product of I (soil erodibility) x C (climate factor) does not exceed 60
- 🟦 Prime farmland if irrigated and reclaimed of excess salts and sodium
- 🟦 Farmland of statewide importance
- 🟦 Farmland of statewide importance, if drained
- 🟪 Farmland of statewide importance, if protected from flooding or not frequently flooded during the growing season
- 🟧 Farmland of statewide importance, if irrigated
- 🟩 Farmland of statewide importance, if drained and either protected from flooding or not frequently flooded during the growing season
- 🟩 Farmland of statewide importance, if irrigated and drained
- 🟫 Farmland of statewide importance, if irrigated and either protected from flooding or not frequently flooded during the growing season
- ⬜ Farmland of statewide importance, if subsoiled, completely removing the root inhibiting soil layer
- 🟪 Farmland of statewide importance, if irrigated and the product of I (soil erodibility) x C (climate factor) does not exceed 60
- 🟪 Farmland of statewide importance, if irrigated and reclaimed of excess salts and sodium
- 🟨 Farmland of statewide importance, if drained or either protected from flooding or not frequently flooded during the growing season
- 🟦 Farmland of statewide importance, if warm enough, and either drained or either protected from flooding or not frequently flooded during the growing season
- 🟫 Farmland of statewide importance, if warm enough
- 🟥 Farmland of statewide importance, if thawed
- 🟦 Farmland of local importance
- 🟧 Farmland of local importance, if irrigated
- 🟦 Farmland of unique importance
- ⬜ Not rated or not available

Soil Rating Lines

- 〰 Not prime farmland
- 〰 All areas are prime farmland
- 〰 Prime farmland if drained
- 〰 Prime farmland if protected from flooding or not frequently flooded during the growing season
- 〰 Prime farmland if irrigated
- 〰 Prime farmland if drained and either protected from flooding or not frequently flooded during the growing season
- 〰 Prime farmland if irrigated and drained
- 〰 Prime farmland if irrigated and either protected from flooding or not frequently flooded during the growing season

- 〰 Prime farmland if subsoiled, completely removing the root inhibiting soil layer
- 〰 Prime farmland if irrigated and the product of I (soil erodibility) x C (climate factor) does not exceed 60
- 〰 Prime farmland if irrigated and reclaimed of excess salts and sodium
- 〰 Farmland of statewide importance
- 〰 Farmland of statewide importance, if drained
- 〰 Farmland of statewide importance, if protected from flooding or not frequently flooded during the growing season
- 〰 Farmland of statewide importance, if irrigated
- 〰 Farmland of statewide importance, if drained and either protected from flooding or not frequently flooded during the growing season
- 〰 Farmland of statewide importance, if irrigated and drained
- 〰 Farmland of statewide importance, if irrigated and either protected from flooding or not frequently flooded during the growing season
- 〰 Farmland of statewide importance, if subsoiled, completely removing the root inhibiting soil layer
- 〰 Farmland of statewide importance, if irrigated and the product of I (soil erodibility) x C (climate factor) does not exceed 60
- 〰 Farmland of statewide importance, if irrigated and reclaimed of excess salts and sodium
- 〰 Farmland of statewide importance, if drained or either protected from flooding or not frequently flooded during the growing season
- 〰 Farmland of statewide importance, if warm enough, and either drained or either protected from flooding or not frequently flooded during the growing season
- 〰 Farmland of statewide importance, if warm enough
- 〰 Farmland of statewide importance, if thawed
- 〰 Farmland of local importance
- 〰 Farmland of local importance, if irrigated
- 〰 Farmland of unique importance
- 〰 Not rated or not available

Soil Rating Points

- 🟥 Not prime farmland
- 🟩 All areas are prime farmland
- 🟩 Prime farmland if drained
- 🟩 Prime farmland if protected from flooding or not frequently flooded during the growing season
- 🟨 Prime farmland if irrigated
- 🟨 Prime farmland if drained and either protected from flooding or not frequently flooded during the growing season
- 🟫 Prime farmland if irrigated and drained
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- 🟦 Farmland of statewide importance, if drained
- 🟪 Farmland of statewide importance, if protected from flooding or not frequently flooded during the growing season
- 🟧 Farmland of statewide importance, if irrigated

- 🟩 Farmland of statewide importance, if drained and either protected from flooding or not frequently flooded during the growing season
- 🟩 Farmland of statewide importance, if irrigated and drained
- 🟥 Farmland of statewide importance, if irrigated and either protected from flooding or not frequently flooded during the growing season
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- 🟪 Farmland of statewide importance, if irrigated and the product of I (soil erodibility) x C (climate factor) does not exceed 60
- 🟪 Farmland of statewide importance, if irrigated and reclaimed of excess salts and sodium
- 🟨 Farmland of statewide importance, if drained or either protected from flooding or not frequently flooded during the growing season
- 🟩 Farmland of statewide importance, if warm enough, and either drained or either protected from flooding or not frequently flooded during the growing season
- 🟫 Farmland of statewide importance, if warm enough
- 🟥 Farmland of statewide importance, if thawed
- 🟦 Farmland of local importance
- 🟧 Farmland of local importance, if irrigated
- 🟦 Farmland of unique importance
- ⬜ Not rated or not available

Water Features

- 〰 Streams and Canals

Transportation

- +++ Rails
- 〰 Interstate Highways
- 〰 US Routes
- 〰 Major Roads
- 〰 Local Roads

Background

- ▨ Aerial Photography

The soil surveys that comprise your AOI were mapped at 1:20,000.

Warning: Soil Map may not be valid at this scale.

Enlargement of maps beyond the scale of mapping can cause misunderstanding of the detail of mapping and accuracy of soil line placement. The maps do not show the small areas of contrasting soils that could have been shown at a more detailed scale.

Please rely on the bar scale on each map sheet for map measurements.

Source of Map: Natural Resources Conservation Service
Web Soil Survey URL:
Coordinate System: Web Mercator (EPSG:3857)

Maps from the Web Soil Survey are based on the Web Mercator projection, which preserves direction and shape but distorts distance and area. A projection that preserves area, such as the Albers equal-area conic projection, should be used if more accurate calculations of distance or area are required.

This product is generated from the USDA-NRCS certified data as of the version date(s) listed below.

Soil Survey Area: Monroe County, Alabama
Survey Area Data: Version 17, Sep 14, 2022

Soil map units are labeled (as space allows) for map scales 1:50,000 or larger.

Date(s) aerial images were photographed: Nov 2, 2021—Dec 23, 2021

The orthophoto or other base map on which the soil lines were compiled and digitized probably differs from the background imagery displayed on these maps. As a result, some minor shifting of map unit boundaries may be evident.

Farmland Classification

Map unit symbol	Map unit name	Rating	Acres in AOI	Percent of AOI
LnB	Lucy loamy sand, 1 to 5 percent slopes	Not prime farmland	0.0	0.1%
SgF	Saffell-Lucy (flomaton) complex, 15 to 35 percent slopes	Not prime farmland	2.1	11.0%
UrA	Urbo silty clay loam, 0 to 1 percent slopes, frequently flooded	Not prime farmland	15.8	82.0%
W	Water	Not prime farmland	1.3	6.9%
Totals for Area of Interest			**19.2**	**100.0%**

Description

Farmland classification identifies map units as prime farmland, farmland of statewide importance, farmland of local importance, or unique farmland. It identifies the location and extent of the soils that are best suited to food, feed, fiber, forage, and oilseed crops. NRCS policy and procedures on prime and unique farmlands are published in the "Federal Register," Vol. 43, No. 21, January 31, 1978.

Rating Options

Aggregation Method: No Aggregation Necessary

Tie-break Rule: Lower

B.2. Public and Agency Comments and Responses

The Draft Feasibility Report with Integrated Environmental Assessment will be made available for public review for 30-days. Comments from the public, state, tribal, local, and federal agencies will be evaluated and responded to by the Project Delivery Team.