Green Power

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Via eFiling

September 28, 2018

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

Re: Lowell Hydroelectric Project (FERC No. 2790-072); Filing of Proposed Study Plan

Dear Secretary Bose:

Boott Hydropower, LLC (Boott), a subsidiary of Enel Green Power North America, Inc. (Enel), is the Licensee and operator of the 22.4 megawatt (MW) Lowell Hydroelectric Project (FERC Project No. 2790) (Project or Lowell Project). The Lowell Project is located on the Merrimack River in Middlesex County, Massachusetts and in Hillsborough County, New Hampshire. The existing license for the Project was issued by the Federal Energy Regulatory Commission (FERC or Commission) with an effective date of May 1, 1973. The existing license expires on April 30, 2023. Accordingly, Boott is pursuing a new license for the Project pursuant to the Commission's Integrated Licensing Process (ILP), as described at 18 Code of Federal Regulations (CFR) Part 5. In accordance with 18 CFR §5.11 of the Commission's regulations, Boott is filing the Proposed Study Plan (PSP) with the Commission describing the studies that the Licensee is proposing to conduct in support of relicensing the Project.

Boott filed a Pre-Application Document and associated Notice of Intent with the Commission on April 30, 2018, to initiate the ILP. The Commission issued Scoping Document 1 (SD1) for the Project on June 15, 2018. SD1 was intended to advise resource agencies, Indian tribes, non-governmental organizations, and other stakeholders as to the proposed scope of FERC's Environmental Assessment (EA) for the Project and to seek additional information pertinent to the Commission's analysis.

On July 17, 2018, the Commission held public scoping meetings in Lowell, Massachusetts. During these meetings, FERC staff presented information regarding the ILP and details regarding the study scoping process and how to request a relicensing study, including the Commission's study criteria. In addition, FERC staff solicited comments regarding the scope of issues and analyses for the EA. Pursuant to 18 CFR §5.8(d), a public site visit of the Project was conducted on July 18, 2018.

Resource agencies, Indian tribes, and other interested parties were afforded a 60-day period to request studies and provide comments on the PAD and SD1. The comment period was initiated with the Commission's June 15, 2018 notice and concluded on August 14, 2018. During the comment period, a total of seven stakeholders filed letters with the Commission providing general comments, comments regarding the PAD, comments regarding SD1, and/or study requests.

Proposed Study Plan

Boott has evaluated all the study requests submitted by the stakeholders, with a focus on the requests that specifically addressed the seven criteria for study requests as set forth at 18 CFR §5.9(b) of the Commission's ILP regulations. For the study requests that did not attempt to address the seven study criteria, where appropriate, Boott considered the study in the context of providing the requested information in conjunction with one of Boott's proposed studies.

The purpose of the PSP is to present the studies that are being proposed by Boott and to address the comments and study requests submitted by resource agencies and other stakeholders. The PSP also provides FERC, regulatory agencies, Indian tribes, and other stakeholders with the methodology and details of Boott's proposed studies. At this time, Boott is proposing to conduct the following studies as described in detail in the PSP:

1. Downstream American Eel Passage Assessment;
2. Juvenile Alosine Downstream Passage Assessment;
3. Upstream and Downstream Adult Alosine Passage Assessment;
4. Fish Passage Survival Study;
5. Three-Dimensional Computational Fluid Dynamics Modeling;
6. Instream Flow Habitat Assessment and Zone of Passage Study in the Bypassed Reach;
7. Fish Assemblage Study;
8. Recreation and Aesthetics Study;
9. Resources, Ownership, Boundaries, and Land Rights Study;
10. Water Level and Flow Effects on Historic Resources Study;
11. Operation Analysis of the Lowell Canal Study;
12. Historically Significant Waterpower Equipment Study; and
13. Whitewater Boating and Access Study.

Boott is filing the PSP with the Commission electronically and is distributing this letter to the parties listed on the distribution list in Appendix A of the PSP. For parties listed in Appendix A who have provided an email address, the Boott is distributing this letter via email; otherwise, Boott is distributing this letter via U.S. mail. All parties interested in the relicensing process may obtain a copy of the PSP electronically through FERC's eLibrary system at https://elibrary.ferc.gov/idmws/search/fercgensearch.asp under docket number P-2790. If any party would like to request a CD containing an electronic copy of the PSP, please contact Kevin Webb, Hydro Licensing Manager for Enel, at the information listed below.

Comments on the PSP, including any additional or revised study requests, must be filed within 90 days of the filing date of this PSP (i.e., no later than December 27, 2018). Comments must include an explanation of any study plan concerns, and any accommodations reached with Boott regarding those concerns (18 CFR §5.12). Any proposed modifications to this PSP must address the Commission's criteria as presented in 18 CFR §5.9(b).

As necessary, after the comment period closes, Boott will prepare a Revised Study Plan (RSP) that will address interested parties' comments to the extent practicable. Pursuant to the ILP, Boott will file the RSP with the Commission on or before January 26, 2019, and the Commission will issue a final Study Plan Determination by February 25, 2019.

Initial Proposed Study Plan Meeting

In accordance with 18 CFR §5.11(e) of the Commission's regulations, Boott intends to hold a two-day initial Proposed Study Plan Meeting (PSP Meeting) to describe the background, concepts, and study methods described in the PSP. The PSP Meeting will be held from 9:00 AM – 4:00 PM on October 18 and 19, 2018, at the DoubleTree by Hilton Boston Andover, located at 123 Old River Road, Andover, MA 01810. Boott is proposing to discuss Studies 1 – 7 on October 18, 2018, and Studies 8 – 13 on October 19, 2018.

To assist with meeting planning and logistics, Boott respectfully requests that individuals or organizations who plan to attend the meeting please RSVP by sending an email to Kevin Webb at Kevin.Webb@enel.com on or before October 5, 2018.

If there are any questions regarding the PSP or PSP Meeting, please do not hesitate to contact Kevin Webb at (978) 935-6039 or at the email address above.

Sincerely,
Boott Hydropower, LLC

Conrad E. St. Pierre, P.E.
Senior Director of Hydro North America

cc: K. Webb, Boott
M. Beauregard, Esq., Boott
M. Donahue, Boott
J. Gibson, HDR
R. Quiggle, HDR

Proposed Study Plan

Lowell Hydroelectric Project

(FERC No. 2790)

September 28, 2018

Prepared by:

HDR and NORMANDEAU ASSOCIATES ENVIRONMENTAL CONSULTANTS

Prepared for:

Boott Hydropower, LLC
Andover, Massachusetts

enel Green Power

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List of Acronyms

1D	One-dimensional
2D	Two-dimensional
A	area
ADA	Americans with Disabilities Act
ADCP	Acoustic Doppler Current Profiler
ADV	Acoustic Doppler Velocimeter
AIC	Akaike's Information Criterion
ArcGIS	Aeronautical Reconnaissance Coverage Geographic Information System
AW	American Whitewater
Boott	Boott Hydropower, LLC
CAD	Computer aided drawing
CFD	Computational Fluid Dynamics
CFR	Code of Federal Regulations
cfs	cubic feet-per-second
CJS	Cormack-Jolly-Seber
DEM	digital elevation model
EA	Environmental Assessment
FERC	Federal Energy Regulatory Commission (or Commission)
ft	feet
GIS	Geographic Information System
GPS	Global Positioning System
HAER	Historic American Engineering Record
HPMP	Historic Properties Management Plan
HSC or HSI	Habitat suitability curves
IFIM	Instream Flow Incremental Methodology
ILP	Integrated Licensing Process
ISR	Initial Study Report
LiDAR	Light Detection and Ranging

LMRLAC	Lower Merrimack River Local Advisory Committee
MADCR	Massachusetts Department of Conservation and Recreation
MADFW	Massachusetts Department of Fish and Wildlife
MHz	megahertz
mm	millimeters
MW	megawatt
NEPA	National Environmental Policy Act of 1969
NGOs	non-governmental organizations
NGVD 29	National Geodetic Vertical Datum 1929
NHFGD	New Hampshire Fish and Game Department
NHL	National Historic Landmark
NMFS	National Marine Fisheries Service
NOI	Notice of Intent
NPS	National Park Service
NRHP	National Register of Historic Places
PAD	Pre-Application Document
PHABSIM	Physical habitat model
PIT	passive-integrated transponder
PM&E	protection, mitigation, and enhancement
Project	Lowell Hydroelectric Project (or Lowell Project)
PSP	Proposed Study Plan
RSP	Revised Study Plan
RTK	Real Time Kinematic
SCORP	Massachusetts Statewide Comprehensive Outdoor Recreation Plan
SD1	Scoping Document 1
TL	total length
USEPA	U.S. Environmental Protection Agency
USFWS	U.S. Fish and Wildlife Service
USR	Updated Study Report

V	velocity
Working Group	Recreation Whitewater Boating and Access Study Working Group
WUA	weighted usable area
YOY	young-of-year

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1 Introduction and Background

Boott Hydropower, LLC (Boott), a subsidiary of Enel Green Power North America, Inc., is the Licensee and operator of the 22.4 megawatt (MW) Lowell Hydroelectric Project (FERC Project No. 2790) (Project or Lowell Project). The Project is located along the Merrimack River in Middlesex County, Massachusetts and in Hillsborough County, New Hampshire. Boott operates the Project for the generation and sale of electrical energy.

The existing license for the Project was issued by the Federal Energy Regulatory Commission's (FERC or Commission) with an effective date of May 1, 1973, for a term of 50 years. The existing license expires on April 30, 2023. Accordingly, Boott is pursuing a new license for the Project pursuant to the Commission's Integrated Licensing Process (ILP), as described at 18 Code of Federal Regulations (CFR) Part 5 of the Commission's regulations. In accordance with 18 CFR §5.11 of the Commission's regulations, Boott is filing this Proposed Study Plan (PSP) describing the studies that the Licensee is proposing to conduct in support of relicensing the Project.

1.1 Study Plan Overview

Boott filed a Pre-Application Document (PAD) and associated Notice of Intent (NOI) with the Commission on April 30, 2018, to initiate the ILP. The PAD provides a description of the Project and summarizes the existing, relevant, and reasonably available information to assist the Commission, resource agencies, Indian tribes, non-governmental organizations (NGOs), and other stakeholders to identify issues, determine information needs, and prepare study requests.

The National Environmental Policy Act of 1969 (NEPA), the Commission's regulations, and other applicable statutes require the Commission to independently evaluate the environmental effects of issuing new licenses for the Project, and to consider reasonable alternatives to relicensing. At this time, the Commission has expressed its intent to prepare an Environmental Assessment (EA) that describes and evaluates the site-specific and cumulative potential effects (if any) of issuing the new license, as well as potential alternatives to relicensing. The EA is being supported by a scoping process to identify issues, concerns, and opportunities for resource enhancement associated with the proposed action. Accordingly, the Commission issued Scoping Document 1 (SD1) for the Project on June 15, 2018. SD1 was intended to advise resource agencies, Indian tribes, NGOs, and other stakeholders as to the proposed scope of the EA and to seek additional information pertinent to the Commission's analysis. As provided in 18 CFR §5.8(a) and §5.18(b), the Commission issued a notice of commencement of the relicensing proceeding concomitant with SD1.

On July 17, 2018, the Commission held public scoping meetings in Lowell, Massachusetts. During these meetings, FERC staff presented information regarding the ILP and details regarding the study scoping process and how to request a relicensing study, including the Commission's study criteria. In addition, FERC staff solicited comments regarding the scope of issues and analyses for the EA. Pursuant to 18 CFR §5.8(d), a public site visit of the Project was conducted on July 18, 2018.

Resource agencies, Indian tribes, and other interested parties were afforded a 60-day period to request studies and provide comments on the PAD and SD1. The comment period was initiated with the Commission's June 15, 2018 notice and concluded on August 14, 2018.

During the comment period, a total of seven stakeholders filed letters with the Commission providing general comments, comments regarding the PAD, comments regarding SD1, and/or study requests. Six stakeholders filed timely study requests during the comment period including U.S. Fish and Wildlife Service (USFWS), National Park Service (NPS), New Hampshire Fish and Game Department (NHFGD), Massachusetts Department of Fish and Wildlife (MADFW), National Marine Fisheries Service (NMFS), and American Whitewater (AW). In addition, Massachusetts Department of Conservation and Recreation (MADCR) filed general information, statements, and/or informal study requests related to the Projects and/or relicensing process. Copies of the letters filed with the Commission are provided in Appendix B of this document. The ILP requires Boott to file this PSP within 45 days from the close of the August 14, 2018 comment period (i.e., on or before September 28, 2018).

FERC's ILP regulations require that stakeholders who provide study requests include specific information in the request in order to allow the Licensee, as well as Commission staff, to determine a requested study's appropriateness and relevancy to the Project and proposed action. As described in 18 CFR §5.9(b) of the Commission's ILP regulations, and as presented by FERC staff during the July 17, 2018 scoping meetings, the required information to be included in a study request is as follows:

(1) Describe the goals and objectives of each study and the information to be obtained (§5.9(b)(1));

> This section describes why the study is being requested and what the study is intended to accomplish, including the goals, objectives, and specific information to be obtained. The goals of the study must clearly relate to the need to evaluate the effects of the Project on a particular resource. The objectives are the specific information that needs to be gathered to allow achievement of the study goals.

(2) If applicable, explain the relevant resource management goals of the agencies or Indian tribes with jurisdiction over the resource to be studied (§5.9(b)(2));

> This section must clearly establish the connection between the study request and management goals or resource of interest. A statement by an agency connecting its

study request to a legal, regulatory, or policy mandate needs to be included that thoroughly explains how the mandate relates to the study request, as well as the Project's potential impacts.

(3) If the requester is not a resource agency, explain any relevant public interest considerations in regard to the proposed study (§5.9(b)(3));

This section is for non-agency or Indian tribes to establish the relationship between the study request and the relevant public or tribal interest considerations.

(4) Describe existing information concerning the subject of the study proposal and the need for additional information (§5.9(b)(4));

This section must discuss any gaps in existing data by reviewing the available information presented in the PAD or information relative to the Project that is known from other sources. This section must explain the need for additional information and why the existing information is inadequate.

(5) Explain any nexus between project operation and effects (direct, indirect, and/or cumulative) on the resource to be studied and how the study results would inform the development of license requirements (§5.9(b)(5));

This section must clearly connect Project operations and Project effects on the applicable resource. This section can also explain how the study results would be used to develop protection, mitigation, and enhancement (PM&E) measures that could be implemented under a new FERC license. The PM&E measures can include those related to any mandatory conditioning authority under Section 401 of the Clean Water Act[1] or Sections 4(e) and 18 of the Federal Power Act, as applicable.

(6) Explain how any proposed study methodology is consistent with generally accepted practices in the scientific community or, as appropriate, considers relevant tribal values and knowledge. This includes any preferred data collection and analysis techniques, or objectively quantified information, and a schedule including appropriate field season(s) and the duration (§5.9(b)(6));

This section must provide a detailed explanation of the study methodology. The methodology may be described by outlining specific methods to be implemented or by referencing an approved and established study protocol and methodology.

(7) Describe considerations of level of effort and cost, as applicable, and why any proposed alternative studies would not be sufficient to meet the stated information needs (§5.9(b)(7));

This section must describe the expected level of cost and effort to conduct the study. If there are proposed alternative studies, this section can address why the alternatives would not meet the stated information needs.

[1] 33 U.S.C. §1251 *et seq.*

The purpose of this PSP is to present the studies that are being proposed by Boott and to address the comments and study requests submitted by resource agencies and other stakeholders. This PSP also provides FERC, regulatory agencies, Indian tribes, and other stakeholders with the methodology and details of Boott's proposed studies. As necessary, after the comment period closes, Boott will prepare a Revised Study Plan (RSP) that will address interested parties' comments to the extent practicable. Pursuant to the ILP, Boott will file the RSP with the Commission on or before January 26, 2019, and the Commission will issue a final Study Plan Determination by February 25, 2019.

1.2 Boott's Proposed Study Plan

Boott has evaluated all the study requests submitted by the stakeholders, with a focus on the requests that specifically addressed the seven criteria set forth in §5.9(b) of the Commission's ILP regulations, as discussed above. For the study requests that did not attempt to address the seven study criteria, where appropriate, Boott considered the study in the context of providing the requested information in conjunction with one of Boott's proposed studies.

Based on Boott's review of the requested studies, FERC criteria for study requests under the ILP, and available information (e.g., associated with the previous licensing effort or resulting from ongoing monitoring activities), Boott is proposing 13 studies to be performed in support of issuing a new license for the Project. Information regarding each of these studies is provided in Sections 5 through 14 of this PSP. For each of Boott's proposed studies, this PSP describes:

1. The goals and objectives of the study;
2. The defined study area;
3. A summary of background and existing information pertaining to the study;
4. The nexus between Project operations and potential effects on the resources to be studied;
5. The proposed study methodology;
6. Level of effort, cost, and schedules for conducting the study.

1.2.1 Comments on the Proposed Study Plan

Comments on this PSP, including any additional or revised study requests, must be filed within 90 days of the filing date of this PSP (i.e., no later than December 27, 2018) Comments must include an explanation of any study plan concerns, and any accommodations reached with Boott regarding those concerns (18 CFR §5.12). Any proposed modifications to this PSP must address the Commission's criteria as presented in 18 CFR §5.9(b).

1.2.2 PSP Meeting

In accordance with 18 CFR §5.11(e), Boott plans to hold a PSP Meeting on October 18 and 19, 2018 in Andover, Massachusetts. The purpose of the PSP Meeting will be to clarify the intent and contents of this PSP, explain information gathering needs, and resolve outstanding issues associated with the proposed studies. Additional details regarding the meeting are presented in Section 4 of this document.

1.3 Project Description and Location

The Project consists of: (1) a 1,093-foot-long, 15-foot-high masonry gravity dam (Pawtucket Dam) that includes a 980.5-foot-long spillway with a crest elevation of 92.2 feet National Geodetic Vertical Datum 1929 (NGVD 29) and five 5-foot-high pneumatically-operated crest gates; (2) a 720-acre impoundment with a normal maximum water surface elevation of 92.2 feet NGVD 29; (3) a 5.5-mile-long canal system (Northern and Pawtucket Canal System) that includes several small dams and a gatehouse; (4) two intake facilities; (5) a powerhouse (E.L Field) that uses water from the Northern Canal and contains two turbine-generator units with a total installed capacity of 17.3 MW; (6) a 1,000-foot-long tailrace channel; (7) four powerhouses (Assets, Bridge Street, Hamilton, and John Street) housed in nineteenth century mill buildings along the Northern and Pawtucket Canal System containing fifteen turbine-generator units with a total installed capacity of 5.2 MW; (8) a 4.5-mile-long, 13.8-kilovolt transmission line connecting the powerhouses to the regional distribution grid; (9) upstream and downstream fish passage facilities, including a fish elevator and downstream fish bypass at the E.L. Field powerhouse, and a vertical-slot fish ladder at the Pawtucket dam; and (10) appurtenant facilities (HDR, 2018)[2].

The Project is located on the Merrimack River in the City of Lowell, Middlesex County, Massachusetts, with an impoundment extending into Hillsborough County, New Hampshire (Figure 1-1).

[2] The Project description reflects the Commission’s Order Amending License By Deleting Four Generating Units from the Bridge Street Station and Revising Annual Charges, 164 FERC ¶ 62,035, July 19, 2018.

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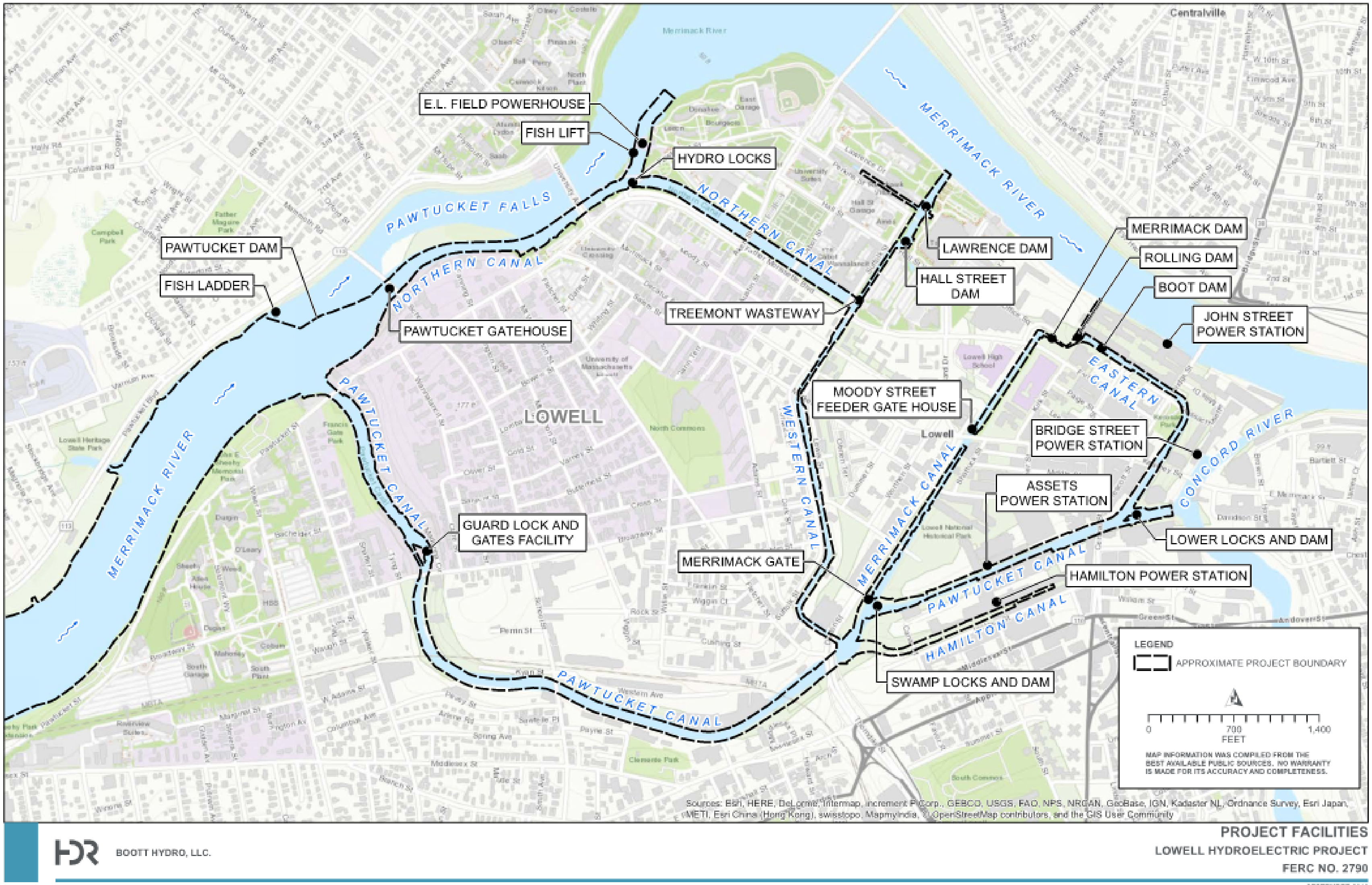
Figure 1-1. Lowell Hydroelectric Project Facilities



2 Execution of the Study Plan

As required by Section 5.15 of FERC's ILP regulations, Boott will prepare progress reports on a quarterly basis, file an Initial Study Report (ISR), hold a meeting with stakeholders and FERC staff to discuss the initial study results (ISR Meeting), and prepare and file an Updated Study Report (USR) and convene an associated USR Meeting, as appropriate. Boott will submit all study documents that must be filed with the Commission via FERC's eFiling system.

2.1 Process Plan and Schedule

The Process Plan and Schedule is presented in Table 2-1. Shaded milestones are unnecessary if there are no study disputes. If the due date falls on a weekend or holiday, the due date is the following business day. Early filings or issuances will not result in changes to these deadlines.

Table 2-1. Process Plan and Schedule

Milestone	Responsible Party	Time Frame	Estimated Date
File PAD and NOI PAD (18 CFR §5.5(d))	Boott	As early as five and one half years but no later than five years prior to license expiration	April 30, 2018
Initial Tribal Consultation Meeting (18 CFR §5.7)	FERC	No later than 30 days of filing PAD/NOI	May 30, 2018
Issue Notice of PAD/NOI and SD1 (18 CFR §5.8(a))	FERC	Within 60 days of filing PAD/NOI	June 15, 2018
Conduct Scoping Meetings and Site Visit (18 CFR §5.8(b) (viii))	FERC	Within 30 days of PAD/NOI notice and SD1 issuance	July 17-18, 2018
Comments on PAD, SD1, and Study Requests (18 CFR §5.9(a))	Stakeholders	Within 60 days of PAD/NOI notice and issuance of SD1	August 14, 2018
Issuance of Scoping Document 2 (SD2) (18 CFR §5.10) (if necessary)	FERC	Within 45 days of deadline for filing comments on SD1	September 27, 2018
File Proposed Study Plan (PSP) (18 CFR §5.11)	Boott	Within 45 days of deadline for filing comments on PAD	September 28, 2018
Study Plan Meeting(s) (18 CFR §5.11(e))	Boott	Meeting to be held within 30 days of filing PSP	October 18 and 19, 2018
Comments on PSP (18 CFR §5.12)	Stakeholders	Within 90 days of filing PSP	December 27, 2018

Milestone	Responsible Party	Time Frame	Estimated Date
File Revised Study Plan (RSP) (18 CFR §5.13(a))	Boott	Within 30 days of deadline for comments on PSP	January 26, 2019
Comments on RSP (18 CFR §5.13(b))	Stakeholders	Within 15 days following RSP	February 10, 2019
Issuance of Study Plan Determination (18 CFR §5.13(c))	FERC Director	Within 30 days of RSP	February 25, 2019
Formal Study Dispute Resolution Process (18 CFR §5.14(a)) (if necessary)	Agencies and Tribes with mandatory conditioning authority	Within 20 days of study plan determination	March 17, 2019
Third Panel Member Selection Due (18 CFR §5.14(d)(3)) (if necessary)	Dispute Resolution Panel	Within 15 days of when Dispute Resolution Panel convenes	April 1, 2019
Dispute Resolution Panel Convenes (18 CFR §5.14(d)) (if necessary)	Dispute Resolution Panel	Within 20 days of a notice of study dispute	April 6, 2019
Comments on Study Plan Disputes (18 CFR §5.14(i)) (if necessary)	Boott	Within 25 days of notice of study dispute	April 11, 2019
Dispute Resolution Panel Technical Conference (18 CFR §5.14(j)) (if necessary)	Dispute Resolution Panel, Boott, Stakeholders	-	April 16, 2019
Dispute Resolution Panel Findings and Recommendations (18 CFR §5.14(k)) (if necessary)	Dispute Resolution Panel	No later than 50 days after notice of dispute	May 6, 2019
Study Dispute Determination (18 CFR §5.14(1)) (if necessary)	FERC Director	No later than 70 days after notice of dispute	May 26, 2019
Conduct First Season of Studies (18 CFR §5.15)	Boott	-	Summer/Fall 2019
Study Progress Report (18 CFR §5.15(b))	Boott	Boott will provide summary updates every three months	Quarterly, beginning in Quarter 2 of 2019 through filing of the USR

Milestone	Responsible Party	Time Frame	Estimated Date
Initial Study Report (18 CFR §5.15(c))	Boott	Pursuant to the Commission-approved study plan or no later than 1 year after Commission approval of the study plan, whichever comes first	February 25, 2020
Initial Study Report Meeting (18 CFR §5.15(c)(2))	Boott and Stakeholders	Within 15 days of filing the initial study report	March 11, 2020
File Initial Study Report Meeting Summary (18 CFR §5.15(c)(3))	Boott	Within 15 days of initial study report meeting	March 26, 2020
File Disputes/Requests to Amend Study Plan (18 CFR §5.15(c)(4))	Stakeholders	Within 30 days of study results meeting summary	April 25, 2020
File Responses to Meeting Summary Disagreements (18 CFR §5.15(c)(5))	Boott	Within 30 days of filing meeting summary disagreements	May 25, 2020
Resolution of Disagreements (18 CFR §5.15(c)(6)) (if necessary)	FERC Director	Within 30 days of filing responses to disagreements	June 24, 2020
Conduct Second Season of Studies (if necessary)	Boott	-	Summer/Fall 2020
File Preliminary Licensing Proposal or Draft License Application (18 CFR §5.16(a))	Boott	No later than 150 days prior to the deadline for filing the Final License Application	December 1, 2020
File Updated Study Report (18 CFR §5.15(f)) (if necessary)	Boott	Pursuant to the approved study plan or no later than two years after Commission approval, whichever comes first	February 24, 2021
Comments on Preliminary Licensing Proposal or Draft License Application Due (18 CFR §5.16(e))	Stakeholders	Within 90 days of filing Preliminary Licensing Proposal or Draft License Application	March 1, 2021
Updated Study Report Meeting (18 CFR §5.15(f)) (if necessary)	Boott and Stakeholders	Within 15 days of updated study report	March 11, 2021

Milestone	Responsible Party	Time Frame	Estimated Date
File Updated Study Report Meeting Summary (18 CFR §5.15(f)) (if necessary)	Boott	Within 15 days of study report meeting	March 26, 2021
File Disputes/Requests to Amend Study Plan (18 CFR §5.15(f))	Stakeholders	Within 30 days of study results meeting summary	April 25, 2021
File Responses to Meeting Summary Disagreements (18 CFR §(f))	Boott	Within 30 days of filing meeting summary disagreements	May 25, 2021
Resolution of Disagreements (18 CFR §5.15(f) (if necessary)	FERC Director	Within 30 days of filing responses to disagreements	June 24, 2021
File License Application (18 CFR §5.17)	Boott	By April 30, 2021 – No later than 24 months before the existing license expires	April 30, 2021

3 Requested Studies Not Adopted

In general, Boott is proposing to adopt all studies requested by stakeholders. In some instances, Boott has consolidated study requests or elements/objectives of study requests into one study to increase efficiencies in how data is collected and analyzed. For example, AW, the MADCR, and NPS requested that Boott conduct a study of recreation use and needs in the Project. The NPS also requested that Boott conduct a study of vegetation and waterborne trash management. Consistent with the NPS study request, Boott believes that recreational visitor use data will inform a study of vegetation and waterborne trash management, and that issues related to waterborne trash also have the potential to affect aesthetic resources. Accordingly, Boott has consolidated these (and other) studies into a single Recreation and Aesthetics Study.

While Boott is proposing to conduct studies requested by stakeholders, in some instances, Boott has proposed modifications to the specific study methods. Boott discusses the reasons for proposing alternative methods in the individual study methodology section for each proposed study.

4 Study Reports

Boott expects to report on the progress and results of studies within the framework afforded by the ISR and associated ISR Meeting as well as the USR and associated USR Meeting. Based on exact timing of completion of work under for each study, Boott may issue draft products between the ISR and USR to the extent practicable. At this time, Boott is proposing to file technical study reports with the Commission and to provide stakeholders access to the study reports consistent with the schedule presented in Table 4-1. Boott notes that adverse weather conditions or other circumstances may necessitate modifications to this schedule. As necessary, Boott will update stakeholders of changes in the schedule in quarterly study progress reports.

Table 4-1. Preliminary Schedule for Study Reporting

Study	Anticipated Date of Study Report
1. Downstream American Eel Passage Assessment	February, 25, 2020 (Concurrent with ISR)
2. Juvenile Alosine Downstream Passage Assessment	February, 25, 2020 (Concurrent with ISR)
3. Upstream and Downstream Adult Alosine Passage Assessment	February 24, 2021 (Concurrent with USR)
4. Fish Passage Survival Study	February 24, 2021 (Concurrent with USR)
5. Three-Dimensional Computational Fluid Dynamics (CFD) Modeling	February 24, 2021 (Concurrent with USR)
6. Instream Flow Habitat Assessment and Zone of Passage Study in the Bypassed Reach	February 24, 2021 (Concurrent with USR)
7. Fish Assemblage Study	February, 25, 2020 (Concurrent with ISR)
8. Recreation and Aesthetics Study	February 24, 2021 (Concurrent with USR)
9. Resources, Ownership, Boundaries, and Land Rights Study	February 24, 2021 (Concurrent with USR)
10. Water Level and Flow Effects on Historic Resources Study	February, 25, 2020 (Concurrent with ISR)
11. Operation Analysis of the Lowell Canal Study	February, 25, 2020 (Concurrent with ISR)
12. Historically Significant Waterpower Equipment Study	February 24, 2021 (Concurrent with USR)
13. Whitewater Boating and Access Study	February, 25, 2020 (Concurrent with ISR)

5 Proposal for the PSP Meeting

Pursuant to 18 CFR §5.11(e) of the Commission's ILP regulations, Boott is providing information regarding the PSP Meeting that will be held for the purposes of clarifying the PSP, explaining information gathering needs, and resolving outstanding issues associated with the proposed studies. The Commission's regulations and the approved Process Plan and Schedule require Boott to conduct the PSP Meeting within 30 days of the filing of this PSP. Accordingly, Boott will hold the PSP Meeting on October 18 and 19, 2018 at the DoubleTree by Hilton Boston Andover, 123 Old River Road in Andover, Massachusetts.

Additional details regarding the meeting are presented below.

- Date: October 18 and 19, 2018
- Time: 9:00 AM to 4:00 PM
- Location:
  DoubleTree by Hilton Boston Andover
  123 Old River Road
  Andover, MA 01810

For additional information, please contact:
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6 Downstream American Eel Passage Assessment

6.1 Study Requests

The Commission's June 15, 2018 SD1 identified the following environmental resource issues to be analyzed in the EA for the Project relicensing:

- Effects of continued project operation on resident and migratory fisheries resources in the impoundment, canal system, bypassed reach and Merrimack River.
- Effectiveness of the existing fish passage facilities at passing migratory fish, including American shad, river herring and American eel.

The USFWS, NMFS, MADFW, and NHFGD submitted formal requests for a Downstream American Eel Passage Assessment, as shown in Table 6-1.

Table 6-1. Aquatic Resource Study Request

Requestor	Requested Study	Date
USFWS	Downstream American Eel Passage Assessment (USFWS Letter Request #5)	August 14, 2018
NMFS	American Eel Passage Downstream Study (NMFS Letter Request #1)	August 14, 2018
MADFW	Downstream American Eel Passage Assessment (MADFW Letter Request #5)	August 10, 2018
NHFGD	Downstream American Eel Passage Assessment (NHFGD Letter Request #5)	August 13, 2018

6.2 Goals and Objectives

The goal of this study is to determine the Project's impact on the outmigration of adult silver-phase American eels (*Anguilla rostrata*; silver eels). The specific objectives of this study are as follows:

- Quantify the movement rates and relative proportion of eels passing via various routes at the project (i.e., turbines, downstream bypass, and spill).
- Evaluate mortality of eels passed via each potential route.

6.3 Study Area

The study area includes the mainstem Merrimack River from the upper extent of the Project's impoundment located approximately 23 river miles upstream from the Pawtucket Dam in Litchfield, New Hampshire, to the Lawrence Hydroelectric Project (FERC No. 2800), located approximately 11 river miles downstream of the Pawtucket Dam. The Upper Pawtucket Canal and Guard Locks facility are also considered as part of the study area.

6.4 Background and Existing Information

Existing relevant and reasonably available information regarding silver eel passage at the Project was summarized in Section 5.4 of the PAD (HDR, 2018). Downstream passage of silver eels at the Lowell Hydroelectric Project was evaluated during fall 2017 and the study focused on Project approach and residence. A total of fourteen radio-tagged eels were detected approaching the upstream face of Pawtucket Dam. Approach durations for radio-tagged eels to move downstream from passage at the Amoskeag Dam (owned and operated by Eversource Energy) to Lowell (including the 23 mile project impoundment) ranged between 10.0 – 243.7 (median = 33.0 hours) hours, whereas upstream residence durations following initial detection at the upstream side of Pawtucket Dam were relatively short (range = 0.1-75.6; median = 0.3 hours) . Passage events occurred primarily during the period between sunset and sunrise with the majority of individuals passing via the turbines (n=8) and the remainder passing by spill (n=5). A single eel detected approaching the dam, but not recorded on any of the downstream bypass stationary receivers, was later detected at Lawrence Dam, indicating it either passed the entire stationary receiver set up at Lowell or used the canal system that originates upstream of the Pawtucket Dam. Following detection and passage at Lowell, thirteen of the fourteen radio-tagged eels were detected at the Lawrence Project's headpond.

6.5 Project Nexus

As American eels are known to occur upstream of the Project, the potential exists for Project operations to affect passage route selection, usage of the downstream bypass facility, entrainment at Project turbines, and to create delays prior to downstream passage.

6.6 Study Methodology

Agency study requests related to understanding downstream passage of silver eels at the Project involved a two-part approach which incorporated radio- and passive-integrated transponder (PIT) telemetry to evaluate movement rates and the distribution among available passage routes, and a HI-Z balloon tag study to evaluate mortality and injury of eels passed via each potential route. Boott proposes to evaluate downstream silver eel passage using radio-telemetry. Silver eels will be radio-tagged, and movements and passage at each route through the Project area will be monitored via a series of stationary receivers. The design of the monitoring array will permit the determination of: (1) Project residence duration above the dam and prior to downstream passage; (2) route of passage selection: (a) the proportion entering the canal system or remaining within the mainstem river and; (b) the distribution of mainstem eels passing via the turbines, downstream bypass, or spill); and (3) total Project and route-specific passage survival.

The methodology described herein does not include the use of PIT tags, as they would provide little additional information for determining downstream passage route selection or passage survival. The antennas associated with PIT readers offer limited range and would be restricted to installation at the downstream bypass. Each of the remaining downstream routes (i.e., Project turbines or spillways) are impractical for coverage using PIT antennas. Downstream bypasses can be readily covered for passage of radio-tagged eels using a broadband radio-receiver capable of monitoring multiple frequencies simultaneously.

With regard to the study request to evaluate each downstream potential turbine passage route using the HI-Z balloon tag, per FERC's study plan criteria, a proposed study plan must be consistent with generally accepted scientific practice and must be done at a higher level of effort only if a lower level of effort would not be sufficient to meet the information needs. At present, it is unknown if a significant portion of outmigrating silver eels enter the canal system and might be exposed to units in operation. The radio-telemetry study described in this plan will address that current information gap. As a large number of radio-tagged silver eels are proposed for release into the Merrimack River upstream of Lowell, the overall Project survival, as well as route-specific survival for the most frequently used downstream passage routes, will be estimated for a much lower cost than a HI-Z balloon tag study. In addition, estimates of turbine survival passage for silver eels at each Project turbine type will be generated as part of the Fish Passage Survival Study (Section 9, below) to assess fish mortality from turbines. As such, Boott has not adopted the study request related to field based direct turbine injection (HI-Z balloon) studies.

6.6.1 Radio-Telemetry Equipment

Installed radio telemetry equipment will include Orion receivers, manufactured by Sigma Eight, as well as SRX receivers manufactured by Lotek. Receivers will be installed following consideration of the detection requirements for the specific area of coverage, as well as the attributes of the receiver model. The Orion receiver is a broadband receiver capable of monitoring multiple frequencies simultaneously within a 1-megahertz (MHz) band; it will be most useful for monitoring tagged fish in areas where movement through the monitoring zone can occur quickly (e.g., for downstream passage through a turbine unit intake or a downstream bypass). Although Lotek receivers have a greater detection range than Orion receivers, they can only monitor a single frequency at a time and require frequency switching, which decreases detection efficiency in areas where fish may pass at high rates of speed. As part of monitoring silver eel passage at the Project, Lotek receivers will be used at locations requiring longer range and where the intended detection areas can be characterized by relatively slow transit speeds for tagged fish. Antenna types will include Yagi aerial antennas and underwater drop antennas custom built on site with RG58 coaxial cable.

Adult silver-phase eels will be tagged using transmitters manufactured by Sigma-Eight (model TX-PSC-I-450, or equivalent). The TX-PSC-I-450 measures approximately 12 x 12 x 46 mm, weighs 8.5 g, and has an estimated battery life of 357 days when set at a 2.0 second burst rate. This model has been successfully used by Normandeau in adult American eel studies on the Kennebec (Normandeau, 2012), Connecticut (Normandeau, 2017a) and Merrimack (Normandeau, 2017b) Rivers.

6.6.2 Monitoring Stations

Radio telemetry antennas and receivers will be set up at a number of predefined locations at Lowell as well as at points upstream and downstream of the Project and within the associated canal system. Each monitoring station will consist of a data-logging receiver, one or more antennas, and a power source. Each will be configured to receive transmitter signals from a designated area continuously throughout the study period. During installation of each station, range testing will be conducted to configure the antennas and receivers in a manner which maximizes detection efficiency at each location. The operation of the system as a whole will be confirmed during installation and throughout the study period by using beacon tags. These beacon tags will be stationed at strategic locations within the detection range of either multiple or single antennas and will emit a signal at a programmed time interval. These signals will be detected and logged by the receivers and used to record the functionality of the system throughout the study period. Although each monitoring station will be installed in a manner which limits the ability to detect transmitters from unwanted areas, the possibility of such detections does still exist. As a result, behavioral data collected in this study (i.e., duration at a specific location or passage route) will be inferred based on the signal strength and the duration and pattern of contacts documented across the entire detection array.

The locations of proposed monitoring stations for downstream passage of adult American eels at the Project are outlined below and presented visually in Figure 1-1. As with any telemetry study, monitoring station locations described here will be evaluated in the field prior to initialization of the study and, if necessary, may be modified to enhance the collection of passage information. Landowner permissions will be required for the installation of a number of the remote monitoring locations.

Monitoring Station M1: This station will be installed at a location in the vicinity of the upper end of the Project impoundment and is intended to detect eels following their initial movement downstream and away from the release location and upon entry into the project area. Station M1 will consist of a single receiver and aerial antenna oriented perpendicular to the river channel.

Monitoring Station M2: This station will consist of a single radio-receiver and an aerial antenna and will be located at the Project’s compressor building. Station M2 will be installed and calibrated in a manner to provide detection information for radio-tagged eels as they approach the upstream face of Pawtucket Dam. Detections at this location will be used to inform on arrival of eels at the project.

Monitoring Station M3: Station M3 will consist of a single radio-receiver and aerial antenna. It will be installed and calibrated to provide detection information for radio-tagged eels that have passed through the Pawtucket gatehouse, have entered the E.L. Field Powerhouse forebay (the Northern Canal) and are in the vicinity of the entrances to the downstream bypass and intake racks.

Monitoring Station M4: This station will consist of a single radio-receiver and underwater drop antenna. It will be installed and calibrated to provide detection information for radio-tagged eels which are exiting the forebay via the downstream bypass.

Monitoring Station M5: Station M5 will consist of a single radio-receiver and aerial antenna. It will be installed to scan across the bypassed reach at a point downstream of where the surge gate enters from the power canal and upstream from the downstream bypass. Detections at this location will be used to confirm the downstream passage of individuals using the spillway or surge gate.

Monitoring Station M6: This station will consist of a single radio-receiver and aerial antenna and will be installed at a location overlooking the E.L. Field Powerhouse tailrace. Detections at this location will be used to confirm the downstream passage of individuals via the Project turbine units.

Monitoring Station M7: This station will be installed at a point along the mainstem of the Merrimack River downstream of both the E.L. Field Powerhouse tailrace and the confluence with the Concord River. Station M7 will consist of a single receiver and aerial antenna oriented perpendicular to the river channel.

Monitoring Station M8: Station M8 will be installed at a point midway between the Lowell and Lawrence projects and detection information at this location will be collected to inform on continued downstream movement following passage at the Lowell Project. The exact location will be determined in the field and will be based on proximity to the river, property access, and equipment security. Station M8 will consist of a single receiver and aerial coverage oriented perpendicular to the river channel.

Monitoring Station M9: This station will be installed along the upstream side of the Essex Dam in Lawrence, and detection information at this location will be collected to inform on continued downstream movement following passage at the Lowell Project. Station M9 will consist of a single receiver and aerial antenna oriented perpendicular to the river channel.

Monitoring Station C1: This station will be installed to detect eels which may enter the Pawtucket canal system rather than pass the Project via one of the mainstem passage routes. The entrance to the Pawtucket Canal sits at a point upstream of the Pawtucket Dam and the Northern Canal. Station C1 will be located at the Guard Locks, approximately 1,700 feet (ft) downstream from the entrance to the canal. The monitoring zone for Station C1 will be focused downstream of the Guard Locks facility to ensure any detections recorded at that location are of fish which have definitively entered the Pawtucket Canal system.

6.6.3 Tagging and Release Procedures

Adult silver-phase American eels will be obtained from commercial trapping operations on the St. Croix River, Maine and transported to a temporary tank facility established at the Project. Following a 24-hour holding period, individuals will be visually examined and if they appear healthy will be anesthetized in a clove oil and ethanol solution. Eels will be held and visually monitored in the anesthesia bath until sufficiently sedated. Once sedated, eels will be removed from the bath and placed on a clean, wet towel. The total length and eye diameter (horizontal and vertical; nearest 0.1 mm) will be measured. A previously described correlation between eye size, body length and gonad development will be used to confirm whether individuals are mature and can be considered as active outmigrants (Pankhurst, 1982). This eye index relationship (I) was described using the formula:

$$I = [((A+B)/4)2\pi/L]*100$$

where A = horizontal eye diameter, B = vertical eye diameter, and L = total body length. Silver-phase American eels typically have an eye index between 6.0 and 13.5, with a bronze coloration along the lateral line that separates the dark, silver back from the white belly. Eels meeting these characteristics will be selected for surgical tagging.

For tagging, an incision will be made off-center on the ventral surface of the individual. A hollow needle will be inserted into the incision and pushed through the body wall just off the ventral mid-line and at a point posterior to the incision. The antenna will be fed through the needle and gently pulled so that the transmitter enters the body cavity. The needle will then be fully pulled through the body wall and removed from the antenna. The transmitter will be positioned by pulling the antenna so that it lies directly under the incision. The incision will then be closed with two or three interrupted sutures. A small amount of an antibacterial ointment will be applied to the incision site to prevent infection. Following tagging, each individual will be transferred to a second holding tank supplied with ambient river water for an additional 24-hour observation/recovery period.

A total of 100 radio-tagged adult American eels will be transported via stocking truck from the tagging location and released into the Merrimack River at a point several kilometers upstream of the upper extent of the project impoundment. A minimum of five separate release events will be conducted during mid-October with each event consisting of approximately 20 radio-tagged individuals. Releases will be conducted during the evening hours.

A total of ten freshly dead adult silver eels will be radio-tagged and released downstream of the E.L. Field Powerhouse during the release period to simulate “movements” of adult eels killed during downstream passage. The downstream progression of these known mortalities will be recorded via both the stationary receivers as well as during manual tracking events and will help inform on the probability that downstream receivers may record false positive detections associated with dead study fish drifting passed the receiver (this would result in biased estimates of downstream passage survival). The observed rates of downstream drift as well as final resting location relative to downstream stationary receivers will be considered during evaluation of Project survival.

6.6.4 Project Data Collection

6.6.4.1 Active Radio-transmitters

Data will be offloaded from the receivers at each monitoring station using a laptop computer and will be stored on removable memory sticks. Data downloads will occur at least twice weekly during the period from the initial tag and release date until the last week of November. Backup copies of all telemetry data will be made prior to receiver initialization. Field tests to ensure data integrity and receiver performance will include confirmation of file integrity, confirmation that the last record is consistent with the downloaded data (beacon tags will be critical to this step), and lastly, to confirm that the receiver is operational upon restart and actively collecting data post download. Within a data file, transmitter detections will be stored as a single event (i.e., single data line). Each event will include the date and time of detection, frequency, ID code, and signal strength.

Supplemental detection information will be collected during manual tracking events. Manual tracking will target the reaches between stationary antenna coverage to determine if and where any radio-tagged eels may become stationary. These tracking events will be conducted on an as needed basis up to once per week from the initial tag and release date until the end of November.

6.6.4.2 River and Project Operational Data

In addition to the manual and stationary radio telemetry data, river and project operations data (mainstem and canal system) will be reported for the duration of the evaluation period. Mainstem river temperature will be recorded via a thermal logger installed at the Project. Project discharge (generation and spill), unit operations, downstream bypass operation, and extent and location of spill will be obtained from Boott at the completion of the study period.

6.7 Analysis and Reporting

6.7.1 Data Processing

Tag detections in each downloaded stationary telemetry data file will be validated through a series of site-specific and logical criteria: These criteria will include:

1. Signal strength threshold level of the detection,

2. Frequency of the radio tag signals per unit of time, and
3. Spatial and temporal characteristics of each individual detection with respect to the full series of detections at monitoring stations within the entire detection array.

To determine the signal strength threshold for a valid tag signal, power levels associated with background noise will be recorded at each monitoring station prior to the release of radio-tagged fish. These “false” signals are typically received at relatively low power levels, and they will be removed from the analysis using a series of data filters. The frequency of the signal detections for an individual radio tag will be examined at each monitoring station, such that over a set period of time, there are an adequate number of detections to rule out an isolated false detection (e.g., at least 3 detections within 1 minute). Finally, the spatial and temporal distribution of detections across multiple monitoring stations will be examined to verify that the pattern of detections is not occurring in a manner that is unreasonable (i.e., time for a fish to have relocated within the time between the detections).

6.7.2 Data Analysis

A complete record of all valid detections for each uniquely coded radio-tagged silver eel will be generated and the pattern and timing of detections in these individual records will be reviewed. For the full set of radio-tagged eels released into the mainstem, the proportion entering the canal system will be determined. For the subset of radio-tagged silver eels remaining in the mainstem and approaching the Pawtucket Dam and E.L. Field Powerhouse, the arrival and passage times and downstream route of passage (i.e., turbine, bypass, and spill) will be determined. In instances where a specific passage route is not clearly defined by the available data, the passage route for that individual will be classified as unknown. For the subset of mainstem eels the date and time of entry into the Pawtucket Canal and the final time of entry back into the Merrimack River will be determined.

The stationary telemetry dataset collected using the monitoring stations described above will also permit the evaluation of residence time for radio-tagged silver eels between any two adjacent monitoring stations both prior to and following downstream passage. Passage duration through any defined reach will be calculated as the duration from initial detection at the stationary receiver on the upstream end of the reach until initial detection at the stationary receiver on the downstream end of the reach. For radio-tagged eels which approach Pawtucket Dam and the E.L. Field Powerhouse, Project residence duration will be defined as the duration of time from initial detection at the dam (i.e., detection at Monitoring Station M2) until successful downstream passage at the Project. For radio-tagged eels entering the canal system, canal residence duration will be defined as the duration of time from the confirmed entry into the canal system (i.e., detection at Monitoring Station C1) until confirmed outmigration and detection back in the Merrimack River at Monitoring Station M7.

Duration of passage attempt will be assessed with a Cox regression or proportional hazards model (Castro-Santos, 2012). The regression model describes the unit change in variables on the log-hazard function or instantaneous rate. The hazard function can describe the approach rate, entry rate or rejection rate (Castro-Santos, 2012).

Downstream passage survival at the project will be estimated for adult silver-phase American eels using a series of standard Cormack-Jolly-Seber (CJS) model run for a set of individual encounter histories (i.e., the series of detection/no detection through the linear sequence of receivers from upstream to downstream). For eels remaining in the mainstem Merrimack, this approach will provide a series of reach-specific survival estimates for:

- Reach A: Release location to Monitoring Station M1;
- Reach B: Monitoring Station M1 to Monitoring Station M2 (i.e., project impoundment);
- Reach C: Monitoring Station M2 to Passage;
- Reach D: Passage to Monitoring Station M7; and
- Reach E: Monitoring Station M7 to Monitoring Station M8.

Standard error and confidence bounds for each estimate will be generated. The joint probability of the three survival estimates for reaches C, D, and E will be used as the estimate of passage survival for mainstem eels at the Project. This approach will result in mortality estimates that include both background mortality (i.e., natural mortality such as predation) and mortality due to project effects for radio-tagged silver eels in the section immediately upstream of the Pawtucket Dam and E.L. Field Powerhouse as well as in the reach downstream of the dam extending to Monitoring Station M8. Thus, the results will reflect a minimum estimate of mainstem survival attributable to project effects for adult silver eels.

Dependent on the distribution of downstream passage events among potential mainstem passage routes (i.e., turbine, bypass, and spill), route-specific estimates of passage survival may be available. The availability of these estimates will be driven by sample size and will be a function of passage route selection at Pawtucket Dam and the E.L. Field powerhouse by the radio-tagged eels.

To evaluate passage survival using CJS models, a suite of candidate models will be developed in Program MARK (WhiteandBurnham, 1999) or other appropriate software based on whether survival, recapture (i.e., detection), or both vary or are constant among stations. Models will include:

- Phi(t)p(t): survival and recapture may vary between receiver stations;
- Phi(t)p(.): survival may vary between stations; recapture is constant between stations;
- Phi(.)p(t): survival is constant between stations; recapture may vary between stations;
- Phi(.)p(.): survival and recapture are constant between stations;

Where;

- Phi = probability of survival
- p = probability of detection
- (t) = parameter varies
- (.) = parameter is constant

Prior to comparison among models, goodness of fit testing will be conducted for the "starting model" (i.e., the fully parameterized model). To accommodate for a lack of fit, a measure of how much extra binomial noise (i.e., variation) exists in the data may be needed. This value, the variance inflation factor ($\hat{c}$), can be estimated and used to correct for any minor over-dispersion. Akaike's Information Criterion (AIC) will be used to rank the models as to how well they fit the observed mark-recapture data. Assuming the assumptions of the model with the lowest AIC value are reasonable with regards to this study, it will be selected for the purposes of generating survival estimates.

6.7.3 Reporting

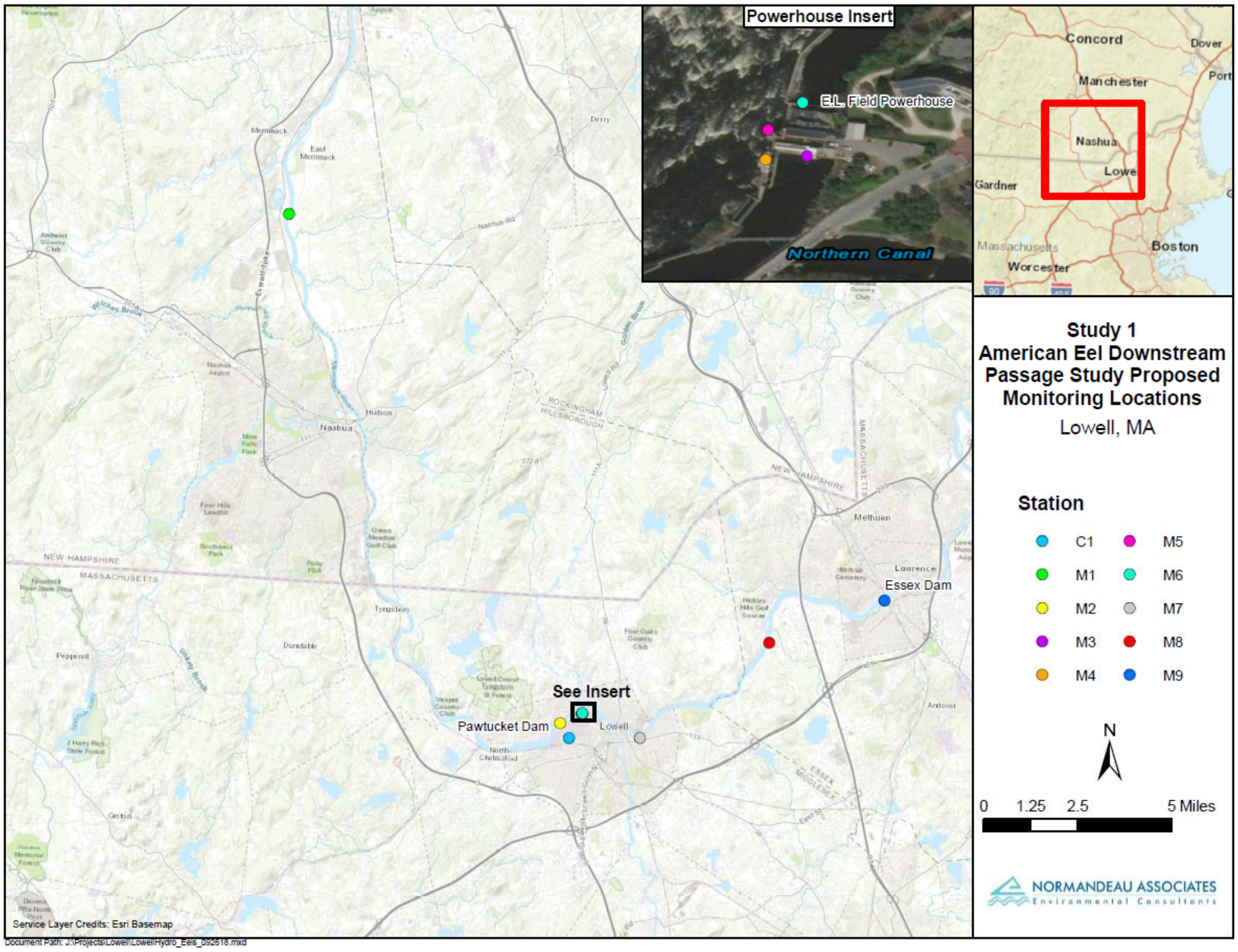
A report describing the methodologies and study results related to movement and passage of silver-phase American eels will be prepared. The report will include details related to the acquisition, tagging and release of silver eels at the mainstem and canal release locations as well as tabular and graphical summaries of downstream passage route selection, residence durations and survival estimates. Project operations at the time of arrival and passage for radio-tagged eels will be examined and summarized in both tabular and graphical format. Boott anticipates that the Downstream American Eel Passage Assessment study report will include the following elements:

- Project information and background
- Study area
- Methodology
- Study results
- Analysis and discussion
- Any agency correspondence and or consultation
- Literature cited

6.8 Schedule and Level of Effort

This study will require a substantial effort and cost to obtain, tag/monitor, and analyze collected data for a sufficient number of eels to evaluate downstream passage at the Proejct. Cost for the tagging, monitoring and analysis described in this plan is estimated at $140,000. A single year of evaluation is scheduled for 2019 and recently conducted evaluations of silver eel outmigration (2017 and 2018) will also be considered. If during the 2019 study, an inadequate sample size of fish is obtained or river conditions are unusual then Boott will consider discussing a second year of study.

Figure 6-1. Proposed radio-telemetry monitoring stations to evaluate downstream passage of adult silver-phase American eels at Lowell.



7 Juvenile Alosine Downstream Passage Assessment

7.1 Study Requests

The Commission's June 15, 2018 SD1 identified the following environmental resource issues to be analyzed in the EA for the Project relicensing:

- Effects of continued Project operation on resident and migratory fisheries resources in the impoundment, canal system, bypassed reach and Merrimack River.
- Effectiveness of the existing fish passage facilities at passing migratory fish, including American shad, river herring and American eel.

The USFWS, NMFS, MADFW, and NHFGD submitted formal requests for a Downstream Juvenile Alosine Passage Assessment, as shown in Table 7-1.

Table 7-1. Aquatic Resource Study Request

Requestor	Requested Study	Date
USFWS	Impact of Project Operations on Downstream Migration of Juvenile Alosines (USFWS Letter Request #4)	August 14, 2018
NMFS	Juvenile Alosine Downstream Study (NMFS Letter Request #2)	August 14, 2018
MADFW	Impact of Project Operations on Downstream Migration of Juvenile Alosines (MADFW Letter Request #4)	August 10, 2018
NHFGD	Impact of Project Operations on Downstream Migration of Juvenile Alosines (NHFGD Letter Request #4)	August 13, 2018

7.2 Goals and Objectives

The goals of this study are: (1) conduct a field study of juvenile alewife outmigration in the Lowell impoundment, the power canal, and at the Pawtucket Dam, to determine if Project operations negatively impact juvenile alosine survival and production; and (2) determine if Project operations affect juvenile alosine outmigration survival, recruitment, and production. The specific objectives of this study are as follows:

- Assess the effects of the Pawtucket Dam on the timing, orientation, passage routes, and migration rates of juvenile alewife;

- Determine the proportion of juvenile alewife that select the Pawtucket Canal versus the E.L. Field Powerhouse, downstream bypass facility, or dam spill as a downstream passage route, under varied operational conditions; and
- Determine if there are any delays associated with downstream movement related to either dam spill or the E.L. Field Powerhouse due to operations.

7.3 Study Area

The study area includes the mainstem Merrimack River from the upper extent of the Project's impoundment located approximately 23 river miles upstream from the Pawtucket Dam in Litchfield, New Hampshire, to the Lawrence Hydroelectric Project, located approximately 11 river miles downstream of the Pawtucket Dam. The Upper Pawtucket Canal and Guard Locks facility are also considered as part of the study area.

7.4 Background and Existing Information

Existing relevant and reasonably available information regarding juvenile alosine passage at the project was summarized in Section 5.4 of the PAD. Previously conducted studies related to downstream passage of juvenile alosines focused on assessing the effectiveness of the downstream bypass (Normandeau, 2015) (Normandeau, 2017c) (Normandeau, 2017d). A mark-recapture study was conducted during the fall of 1990 and estimated bypass effectiveness at 7 percent. Following modification to the downstream bypass entrance, passage effectiveness was evaluated again during the fall season in 1993 and 1994 and was estimated at 31percent and 37 percent, respectively.

7.5 Project Nexus

Alosine species (i.e., American shad [*Alosa sapidissima*], alewife [*Alosa pseudoharengus*] and blueback herring [*Alosa aestivalis*]) are known to pass upstream of the Project and spawn. In addition, river herring are presently being stocked into the upper Merrimack River watershed to enhance reproductive success within the system. As a result, juvenile alosines will encounter the Project during their outmigration from the Merrimack River system. The potential exists for Project operations to affect passage route selection, usage of the downstream bypass facility, entrainment at Project turbines, and to create delays prior to downstream passage for these fish.

7.6 Study Methodology

Agency study requests related to understanding downstream passage of juvenile alosines at Lowell involved a two-part approach which incorporated radio-telemetry to evaluate movement rates as well as the distribution among available passage routes (i.e., turbines at E.L. Field, downstream bypass, spill over Pawtucket Dam or entry into the canal system) as well as a HI-Z balloon tag study to evaluate mortality and injury of juvenile alosines passed via each potential route. As detailed in this study plan, Boott proposes to radio-tag juvenile alosines and monitor movements and passage at each route via a series of stationary telemetry receivers. The study design described herein will permit the determination of (1) Project residence durations above the dam and prior to downstream passage, (2) canal residence duration following passage through the Gate Locks structure, and (3) route of passage selection as it relates to (a) the proportion entering the canal system or remaining within the mainstem river, and (b) the distribution of mainstem fish passing via the turbines, downstream bypass or spill. The methodology described herein does not include the use of a HI-Z balloon tag study to evaluate mortality and injury of juvenile alosines passed via each potential project route. Following FERC's study plan criteria, a proposed study plan must be consistent with generally accepted scientific practice and must be done at a higher level of effort only if a lower level of effort would not be sufficient to meet the information needs. Use of desktop entrainment, impingement, and turbine survival studies has long been a standard practice as part of FERC relicensing processes. The desktop analysis will provide reasonable estimates of entrainment, impingement and turbine survival at the Project at a much lower cost. Imposition of the costs associated with a field based study would be unnecessary since the study results can be achieved through alternative and less costly means. As such, Boott has not adopted the study request related to field-based direct turbine injection (HI-Z balloon) studies for juvenile alosines. A study plan for the Fish Passage Survival Study to assess fish mortality from turbines (i.e., desktop analysis) can be found in Section 9.

7.6.1 Radio-Telemetry Equipment

Installed radio telemetry equipment will include Orion receivers, manufactured by Sigma Eight, as well as SRX receivers manufactured by Lotek. Receivers will be installed following consideration of the detection requirements for the specific area of coverage, as well as the attributes of the receiver model. The Orion receiver is a broadband receiver capable of monitoring multiple frequencies simultaneously within a 1-MHz band; it will be most useful for monitoring tagged fish in areas where movement through the monitoring zone can occur quickly (e.g., for downstream passage through a turbine unit intake or a downstream bypass). Although Lotek receivers have a greater detection range than Orion receivers, they can only monitor a single frequency at a time and require frequency switching, which decreases detection efficiency in areas where fish may pass at high rates of speed. As part of monitoring juvenile alosine passage at the Project, Lotek receivers will be used at locations requiring longer range and where the intended detection areas can be characterized by relatively slow transit speeds for tagged fish. Antenna types will include Yagi aerial antennas and underwater drop antennas custom built on site with RG58 coaxial cable.

Juvenile alosines will be tagged using Lotek NTQ-1 transmitters. The NTQ-1 transmitter measures approximately 5 x 3 x 10 mm, weights 0.25 g and has an estimated battery life of 10 days when set at a 2.0 second burst rate. This model has been successfully used in juvenile alosine studies on the Connecticut (Normandeau, 2017a) (Normandeau, 2017b) and Merrimack (Normandeau, 2015) rivers.

7.6.2 Monitoring Stations

Radio telemetry antennas and receivers will be set up at a number of predefined locations at Lowell as well as at points upstream and downstream of the Project and within the associated canal system. Each monitoring station will consist of a data-logging receiver, one or more antennas, and a power source. Each will be configured to receive transmitter signals from a designated area continuously throughout the study period. During installation of each station, range testing will be conducted to configure the antennas and receivers in a manner which maximizes detection efficiency at each location. The operation of the system as a whole will be confirmed during installation and throughout the study period by using beacon tags. These beacon tags will be stationed at strategic locations within the detection range of either multiple or single antennas and will emit a signal at a programmed time interval. These signals will be detected and logged by the receivers and used to record the functionality of the system throughout the study period. Although each monitoring station will be installed in a manner which limits the ability to detect transmitters from unwanted areas, the possibility of such detections does still exist. As a result, behavioral data collected in this study (i.e., duration at a specific location or passage route) will be inferred based on the signal strength and the duration and pattern of contacts documented across the entire detection array.

The locations of proposed monitoring stations for downstream passage of juvenile alosines at the Project are outlined below and presented visually in Figure 7-1. As with any telemetry study, monitoring station locations described here will be evaluated in the field prior to initialization of the study and, if necessary, may be modified to enhance the collection of passage information. Landowner permissions will be required for the installation of a number of the remote monitoring locations.

Monitoring Station M1: This station will be installed at a location approximately midway between the release site and Pawtucket Dam and is intended to detect radio-tagged juvenile alewives following their initial movement downstream and away from the release location and prior to entry into the Project area. Station M1 will consist of a single receiver and aerial antenna oriented perpendicular to the river channel.

Monitoring Station M2: This station will consist of a single radio-receiver and an aerial antenna and will be located at the Project compressor building. Station M2 will be installed and calibrated in a manner to provide detection information for radio-tagged juvenile alewives as they approach the upstream face of Pawtucket Dam. Detections at this location will be used to inform on arrival of juvenile alewives at the Project.

Monitoring Station M3: Station M3 will consist of a single radio-receiver and aerial antenna. It will be installed and calibrated to provide detection information for radio-tagged juvenile alewives that have passed through the Pawtucket gatehouse, have entered the forebay and are in the vicinity of the entrances to the downstream bypass and intake racks.

Monitoring Station M4: This station will consist of a single radio-receiver and underwater drop antenna. It will be installed and calibrated to provide detection information for radio-tagged juvenile alewives which are exiting the forebay via the downstream bypass.

Monitoring Station M5: Station M5 will consist of a single radio-receiver and aerial antenna and it will be installed to scan across the bypassed reach at a point downstream of where the surge gate enters from the power canal and upstream from the downstream bypass. Detections at this location will be used to confirm the downstream passage of radio-tagged juvenile alewives using the spillway or surge gate.

Monitoring Station M6: This station will consist of a single radio-receiver and aerial antenna and will be installed at a location overlooking the project tailrace. Detections at this location will be used to confirm the downstream passage of radio-tagged juvenile alewives via the E.L. Field powerhouse turbine units.

Monitoring Station M7: This station will be installed at a point along the mainstem of the Merrimack River downstream of both the E.L. Field powerhouse tailrace and the confluence with the Concord River. Station M7 will consist of a single receiver and aerial antenna oriented perpendicular to the river channel.

Monitoring Station C1: This station will be installed to detect radio-tagged juvenile alewives which may enter the Pawtucket Canal system rather than pass the Lowell Project via one of the mainstem passage routes. The entrance to the Pawtucket Canal sits at a point upstream of the Pawtucket Dam and the Northern Canal. Station C1 will be located at the Guard Locks, approximately 1,700 ft downstream from the entrance to the canal. The monitoring zone for Station C1 will be focused downstream of the Guard Locks facility to ensure any detections recorded at that location are of fish which have definitively entered the Pawtucket Canal system.

7.6.3 Tagging and Release Procedures:

Resource agencies have been stocking adult alewives into the upper Merrimack River watershed for the past several years and as a result, large numbers of juvenile alewife emigrate on a yearly basis. Boott proposes to collect Merrimack River watershed reared juvenile alewives and will consult with the resource agencies to identify a consistently reliable collection location. Potential collection techniques may include cast nets, beach seine or boat electrofishing. Following capture, juvenile alosines will be transported by truck to a temporary tank facility established at the project. Prior to tagging, fish will be lightly anesthetized using diluted soda water (10:1 river water: soda water ratio) and each individual will be quickly measured for total length. Previous experience with radio-tagging of juvenile alosines has demonstrated that a total body length of at least 100 millimeters (mm) is the minimum length required for a tagged individual to swim upright and maintain position among other untagged fish. NTQ-1 transmitters will be attached to a dry fly hook using bonding cement. The hook will be inserted posterior to the dorsal fin with the majority of the tag and antenna trailing behind the insertion point (Figure 6-2). After tagging, fish will be held in holding cans and maintained in ambient Merrimack River water until they are transported to the release site.

For testing, 10 groups of 15 alewives (150 total individuals) will be externally radio-tagged, transported by boat, and released approximately 1 mile upstream of the Lowell Project over the course of the downstream migration season. Each release group of 15 tagged individuals will be split into half with one set of tagged juvenile alewives (n≈7) released in the eastern third of the river and the other half of tagged juvenile alewives (n≈8) released in the western third of the river to reduce bias potentially associated with release on a single side of the river. A number of untagged juvenile alosines will be released in conjunction with tagged fish during each release event to provide a "schooling" feel for the tagged fish. It is expected that this release strategy will allow for monitoring over a range of environmental and Project operating conditions. Releases will be conducted during the evening hours.

It is anticipated that all releases will occur during October to ensure that (1) juvenile alewives are actively outmigrating from the system and (2) individuals have achieved the body size necessary to support the NTQ-1 transmitter.

7.6.4 Project Data Collection:

7.6.4.1 Active Radio-transmitters

Data will be offloaded from the receivers at each monitoring station using a laptop computer and will be stored on removable memory sticks. Data downloads will occur at least twice weekly during the period from the initial tag and release date until the last week of November. Backup copies of all telemetry data will be made prior to receiver initialization. Field tests to ensure data integrity and receiver performance will include confirmation of file integrity, confirmation that the last record is consistent with the downloaded data (beacon tags will be critical to this step), and lastly, to confirm that the receiver is operational upon restart and actively collecting data post download. Within a data file, transmitter detections will be stored as a single event (i.e., single data line). Each event will include the date and time of detection, frequency, ID code, and signal strength.

Supplemental detection information will be collected during manual tracking events. Manual tracking will target the reaches between stationary antenna coverage to determine if and where any radio-tagged juvenile alosines may become stationary. These tracking events will be conducted on an as needed basis up to once per week from the initial tag and release date until the end of November.

7.6.4.2 River and Project Operational Data

In addition to the manual and stationary radio telemetry data, river and Project operations data (mainstem and canal system) will be reported for the duration of the evaluation period. Mainstem river temperature will be recorded via a thermal logger installed at the Project. Project discharge (generation and spill), unit operations, downstream bypass operation, and extent and location of spill will be obtained from Boott at the completion of the study period.

7.7 Analysis and Reporting:

7.7.1 Data Processing

Tag detections in each downloaded stationary telemetry data file will be validated through a series of site-specific and logical criteria: These criteria will include:

1. Signal strength threshold level of the detection,
2. Frequency of the radio tag signals per unit of time, and
3. Spatial and temporal characteristics of each individual detection with respect to the full series of detections at monitoring stations within the entire detection array.

To determine the signal strength threshold for a valid tag signal, power levels associated with background noise will be recorded at each monitoring station prior to the release of radio-tagged fish. These “false” signals are typically received at relatively low power levels, and they will be removed from the analysis using a series of data filters. The frequency of the signal detections for an individual radio tag will be examined at each monitoring station, such that over a set period of time, there are an adequate number of detections to rule out an isolated false detection (e.g., at least 3 detections within 1 minute). Finally, the spatial and temporal distribution of detections across multiple monitoring stations will be examined to verify that the pattern of detections is not occurring in a manner that is unreasonable (i.e., time for a fish to have relocated within the time between the detections).

7.7.2 Data Analysis

A complete record of all valid detections for each uniquely coded radio-tagged juvenile alewife will be generated and the pattern and timing of detections in these individual records will be reviewed. For radio-tagged juveniles released into the mainstem, the proportion entering the canal system will be determined. For the subset of radio-tagged juvenile alewives remaining in the mainstem and approaching the Pawtucket Dam and E.L. Field Powerhouse, the arrival and passage times and downstream route of passage (i.e., turbine, bypass, and spill) will be determined. In instances where a specific passage route is not clearly defined by the available data, the passage route for that individual will be classified as unknown. For the subset of mainstem alewife the date and time of entry into the Pawtucket Canal and the final time of entry back into the Merrimack River will be determined.

The stationary telemetry dataset collected using the monitoring stations described above will also permit the evaluation of residence time for radio-tagged juveniles between any two adjacent monitoring stations both prior to and following downstream passage. Passage duration through any defined reach will be calculated as the duration from initial detection at the stationary receiver on the upstream end of the reach until initial detection at the stationary receiver on the downstream end of the reach. For radio-tagged juvenile alewives which approach Pawtucket Dam and the E.L. Field Powerhouse, Project residence duration will be defined as the duration of time from initial detection at the dam (i.e., detection at Monitoring Station M2) until successful downstream passage at the Project.

Duration of passage attempt will be assessed with a Cox regression or proportional hazards model (Castro-Santos, 2012). The regression model describes the unit change in variables on the log-hazard function or instantaneous rate. The hazard function can describe the approach rate, entry rate or rejection rate (Castro-Santos, 2012).

7.7.3 Reporting

A report describing the methodologies and study results related to movement and passage of radio-tagged juvenile alewives will be prepared. The report will include details related to the acquisition, tagging and release of tagged individuals at the mainstem release locations as well as tabular and graphical summaries of downstream passage route selection and residence durations. Project operations at the time of arrival and passage for radio-tagged juvenile alewives will be examined and summarized in both tabular and graphical format. Boott anticipates that the downstream juvenile alosine passage assessment study report will include the following elements:

- Project information and background
- Study area
- Methodology
- Study results
- Analysis and discussion
- Any agency correspondence and or consultation
- Literature cited

7.8 Schedule, Level of Effort, and Estimated Cost

This study will require a substantial effort and cost to obtain, tag/monitor, and analyze collected data for a sufficient number of juvenile alosines to evaluate downstream passage at the Project. Cost for the tagging, monitoring and analysis described in this plan is estimated at $150,000. A single year of evaluation is scheduled for 2019. If during the 2019 study, an inadequate sample size of fish is obtained or river conditions are unusual, then Boott will consider discussing a second year of study.

Figure 7-1. Proposed radio-telemetry monitoring stations to evaluate downstream passage of juvenile alosines at Lowell.

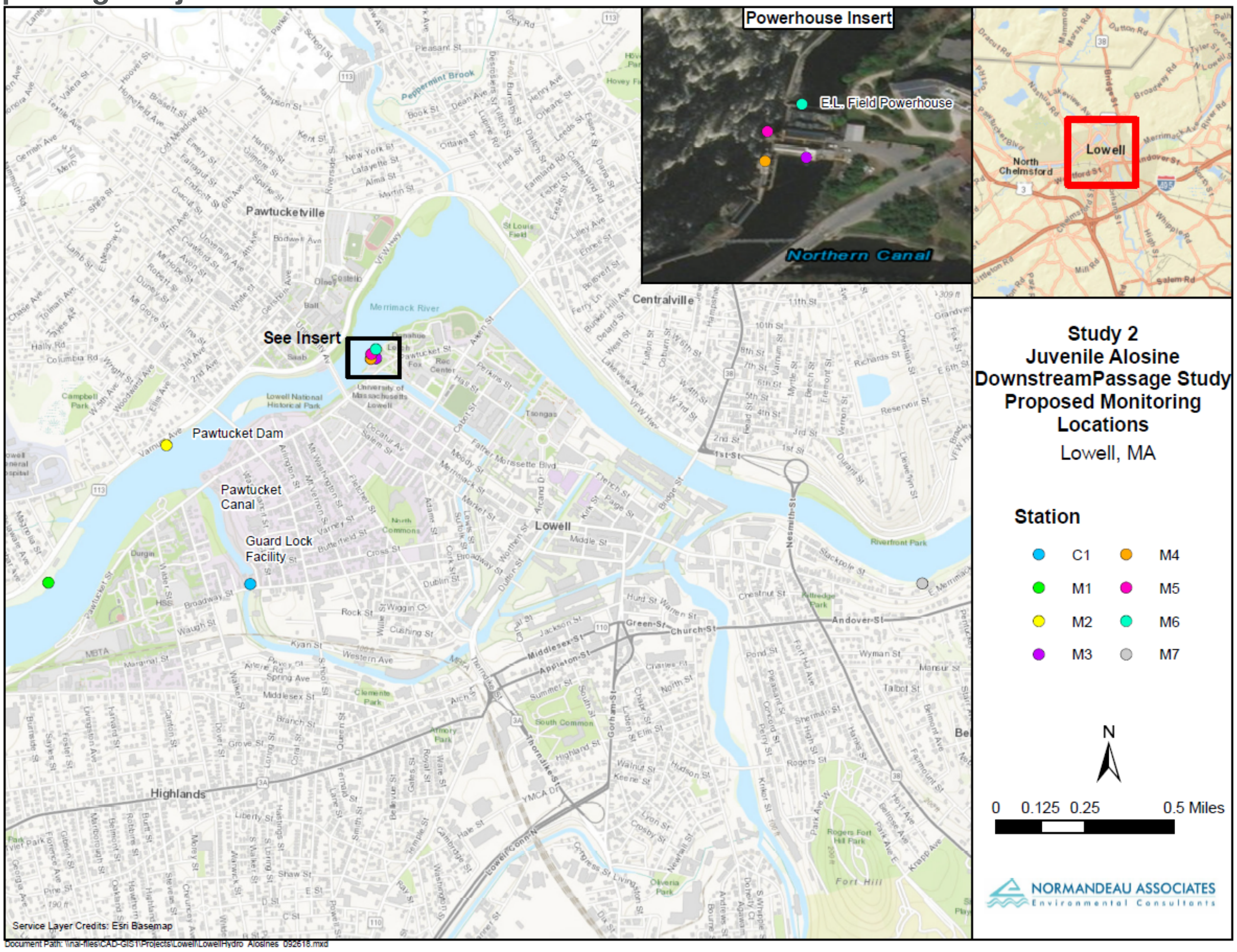


Figure 7-2. Externally radio-tagged juvenile alosines.

8 Upstream and Downstream Adult Alosine Passage Assessment

8.1 Study Requests

The Commission's June 15, 2018 SD1 identified the following environmental resource issues to be analyzed in the EA for the Project relicensing:

- Effects of continued Project operation on resident and migratory fisheries resources in the impoundment, canal system, bypassed reach and Merrimack River.
- Effectiveness of the existing fish passage facilities at passing migratory fish, including American shad, river herring and American eel.

The USFWS, NMFS, MADFW, and NHFGD submitted formal requests for an Upstream and Downstream Adult Alosine Passage Assessment, as shown in Table 8-1.

Table 8-1. Aquatic Resource Study Request

Requestor	Requested Study	Date
USFWS	Telemetry Study of Upstream and Downstream Migrating Adult American Shad and River Herring to Assess Passage Routes, Effectiveness, and Delay (USFWS Letter Request #3)	August 14, 2018
NMFS	Upstream and Downstream Adult Alosine Passage Study (NMFS Letter Request #3)	August 14, 2018
MADFW	Telemetry Study of Upstream and Downstream Migrating Adult American Shad and River Herring to Assess Passage Routes, Effectiveness, and Delay (MADFW Letter Request #3)	August 10, 2018
NHFGD	Telemetry Study of Upstream and Downstream Migrating Adult American Shad and River Herring to Assess Passage Routes, Effectiveness, and Delay (NHFGD Letter Request #3)	August 13, 2018

8.2 Goals and Objectives

The goal of this study is to assess the behavior, approach routes, passage success, survival, and residence duration of adult American shad and river herring as they encounter the Lowell Project during their upstream and downstream migrations to determine if Project operations negatively impact their survival and production. The specific objectives of this study are as follows:

- Assess the effects of Project operations on the timing, orientation, routes and migration rates of shad and river herring;
- Determine route selection and behavior of upstream migrating shad and river herring at the Project under varied operational conditions, including a range of spill conditions;
- Determine residence duration or fallback associated with the Northern canal;
- Assess near field attraction to, and entrance efficiency of, the fish lift under a range of spill conditions and with the river-side entrance and street-side entrances open;
- Assess near field attraction to, and entrance efficiency of, the Pawtucket Dam ladder under a range of spill conditions;
- Evaluate the internal efficiency of the Pawtucket Dam ladder;
- Collect ladder and lift efficiency data, to include rates of approach to fishway entrances, entry into fishways, and passage under varied operational conditions, including a range of spill conditions;
- Determine the proportion of post-spawned adults that select the power canal as a downstream passage route under varied operational conditions, including a range of spill conditions up to full spill
- Determine post-spawned adult downstream migration route selection, passage efficiency, and residence duration associated with the power canal under various operational conditions, including a range of spill conditions; and
- Compare rates and measures of residence duration and movement among Project areas and routes utilized (e.g., spill at dam versus power canal) under the range of permitted and proposed spill and operational conditions.

8.3 Study Area

The study area includes the mainstem Merrimack River from the upper extent of the Project's impoundment located approximately 23 river miles upstream from the Pawtucket Dam in Litchfield, New Hampshire, to the Lawrence Hydroelectric Project, located approximately 11 river miles downstream of the Pawtucket Dam. The Project's canal system and the Hamilton, Assets, Bridge Street and John Street Power Stations are also considered as part of the study area.

8.4 Background and Existing Information

Existing relevant and reasonably available information regarding adult American shad and river herring passage at the Project was summarized in Section 5.4 of the PAD, and Table 5.4-3 in the PAD summarizes the results of previous adult alosine studies (HDR, 2018).

8.5 Project Nexus

Alosine species (i.e., American shad, alewife and blueback herring) are known to approach and pass upstream of the Project and spawn. In addition, river herring are presently being stocked into the upper Merrimack River watershed to enhance reproductive success within the system. As a result, adult alosines will encounter the Project during both their upstream and downstream migration to upper reaches of the Merrimack River system. Project operations may affect passage route selection, entry into the Project upstream and downstream fishways, entrainment at Project turbines, and create delays prior to passage for these fish. The Project's fish passage facilities should be designed and operated to provide effective upstream and downstream passage.

8.6 Study Methodology

Agency study requests related to understanding the upstream and downstream passage of adult American shad and river herring at the Lowell Project incorporated radio- and PIT-telemetry to evaluate movement and behavior at the project, the nearfield and entrance efficiency of the Project lift and ladder, internal efficiency of the Project ladder, downstream passage routes and rate of passage as well as what proportion, if any, of outmigrants utilize the canal system. Boott proposes to adopt the recommended approach, and specifics related to the proposed study design are presented in the following sections of this plan.

8.6.1 Sample Size

An adequate sample size will be essential to meet the objectives of the study. Telemetry studies on movements of adult alosines must consider multiple factors including handling and transportation effects, fish condition, regurgitation of transmitters as well as site-specific factors such as rates of movement from the release location and the expected proportions of fish approaching upstream passage structures. When considering adult alosines, these factors can all increase the number of test fish required but also must be weighed against the functional limitations of effectively monitoring large numbers of fish within any one detection zone due to collisions among tag signals.

8.6.1.1 Upstream Passage Evaluation

Adult American shad and river herring tagged and released for evaluation of upstream passage effectiveness at Lowell will be either dual-tagged (i.e., radio and PIT) or PIT-tagged. The use of additional PIT-tagged fish will provide an inexpensive safeguard in the event of radio transmitter regurgitation and will also allow for precise tracking within the two Project fishways. During a recent field study of upstream passage for adult American shad at Holyoke, it was recommended that a total of 60 adult fish should ascend into the project area and be available to evaluate effectiveness for an upstream passage structure (Normandeau, 2017e). Considering this guidance, a sample size for both alosine species was developed which considered the factors listed above and should provide a sample size of 60 dual-tagged individuals approaching both the Lowell Project fish lift and ladder.

Adult alosine species typically experience an elevated rate of fallback (i.e., test fish moving downstream) and away from the target study area following handling and tagging. Observations during tagging of adult shad at the Lawrence Hydroelectric Project during 2002 (Sprankle, 2005) classified 10% of tagged fish as nonviable due to immediate downstream movement or lack of movement post release. Of the remaining fish, approximately 66% reached the pool area downstream of the project. When corrected for handling and post release losses, a total of 61% of tagged adult shad reached the base of the Lowell Project area (~39% fallback). The estimated fallback in the Sprankle (2005) study is near the middle of the range of rates observed for adult American shad downstream of Cataract [Saco River, 25%, (Normandeau, 2014)], Lockwood [Kennebec River, 42%, (Normandeau, 2016a); 42%, (ASA, 2010)] and Vernon [Connecticut River, 60%, (Normandeau, 2017f)]. Recent evaluations for upstream movements of adult river herring at the West Buxton [Saco River; (Normandeau, 2016b)] and Shawmut (Normandeau, 2016c) hydroelectric projects indicated that arrival at the project tailrace was generally higher for those species than observed for shad with only 27% and 21% fallback located at those two locations, respectively.

Upon arrival at a point immediately downstream of Lowell, tagged fish have the option to either (1) move upstream into the bypass reach and approach the Pawtucket Dam fish ladder or (2) move upstream into the tailrace channel and approach the E.L. Field fish lift. To examine the rates for alosines approaching the two passage structures we examined results from a comparative evaluation of shad counts at the Pawtucket Dam fish lift and E.L. Field fish lift for a 10 day period during June, 2015. During that period roughly 54% of adult shad passing upstream of the Project did so via the fish ladder (conversely 46% passed via the fish lift). Although these percentages may be influenced by a number of factors including river discharge, Project spill, generation, specific entrance efficiencies, etc., they represent the best available estimate for the proportional split of fish moving upstream via the tailrace channel or bypass reach. As a result a 1:1 ratio was assumed during sample size determination for adult alosines approaching the two potential routes of upstream passage.

Based on the lower end of anticipated fallback and the assumed ratio of approach between the two fishways, a total of 160 dual-tagged American shad and 150 dual-tagged river herring are proposed to achieve the target number of 60 adults for both species at each passage structure. Those numbers will be supplemented with an additional 80 PIT-tagged adult shad and 75 PIT-tagged adult river herring.

8.6.1.2 Downstream Passage Evaluation

Adult American shad and river herring tagged and released for evaluation of downstream passage at the Lowell Project will be radio-tagged. A total of 100 adult American shad and 100 adult river herring will be tagged and released into the mainstem Merrimack upstream of the Project. As it is not known if a significant portion of adult alosines moving down the mainstem Merrimack enter the Lowell canal system, an additional 50 radio-tagged individuals of both species will be released directly into the canal system at a point downstream of the Guard Locks to evaluate dispersal and passage of individuals among available routes. In addition to the adult alosines radio-tagged and released upstream of the project, downstream passage of any dual-tagged individuals which successfully pass upstream via the fish lift or fish ladder will also be monitored.

8.6.2 Telemetry Equipment

Adult alosine passage at Lowell will be monitored using a series of radio- and PIT-receivers. Installed radio telemetry equipment will include Orion receivers, manufactured by Sigma Eight, as well as SRX receivers manufactured by Lotek. Receivers will be installed following consideration of the detection requirements for the specific area of coverage, as well as the attributes of the receiver model. The Orion receiver is a broadband receiver capable of monitoring multiple frequencies simultaneously within a 1-MHz band; it will be most useful for monitoring tagged fish in areas where movement through the monitoring zone can occur quickly (e.g., for downstream passage through a turbine unit intake or a downstream bypass). Although Lotek receivers have a greater detection range than Orion receivers, they can only monitor a single frequency at a time and require frequency switching, which decreases detection efficiency in areas where fish may pass at high rates of speed. As part of monitoring fish passage at the Project, Lotek receivers will be used at locations requiring longer range and where the intended detection areas can be characterized by relatively slow transit speeds. Antenna types will include Yagi aerial antennas and underwater drop antennas custom built on site with RG58 coaxial cable.

Adult American shad and river herring will be tagged using transmitters manufactured by Sigma-Eight (model TX-PSC-I-80 or TX-PSC-I-80D) or equivalent. The TX-PSC-I-80 measures approximately 10 x 10 x 27 mm, weighs 4.2 g, and has an estimated battery life of 64 days when set at a 2.0 second burst rate. The TX-PSC-I-80D measures approximately 10 x 10 x 22 mm, weighs 3.3 g and has an estimated battery life of 64 days when set at a 2.0 second burst rate. These transmitter models have been successfully used in adult American shad on the Kennebec (Normandeau, 2016a), Connecticut (Normandeau, 2017f), and Penobscot (Normandeau, 2018a) Rivers and in adult river herring on the Kennebec (Normandeau, 2016d), Saco (Normandeau, 2016e) and Penobscot (Normandeau, 2018a) Rivers.

A series of PIT receivers will complement the radio-telemetry array and will be installed at locations intended to allow for precise tracking of shad and herring within the Project fishways. The PIT receivers and tags will be half-duplex (HDX) and supplied by Oregon RFID. Each antenna loop will be customized per monitoring site specifics, and equipped with a set of capacitors to properly tune the antenna loop inductance. During the study period, the PIT receivers will collect the signals transmitted by the PIT tags via the antenna, and then filter, amplify, decode, and format the unique tag information. The HDX PIT tags will be encoded by the manufacturer and will read only with a 64 bit unique ID. Each cylindrical PIT tag will measure 3.65 mm in diameter, 32 mm long, and weigh 0.8g.

8.6.3 Monitoring Stations

Prior to the release of study fish, stationary monitoring receivers (radio and PIT) will be installed at predefined locations at the Lowell Project, at points upstream and downstream of the Project and within the associated canal system. Each monitoring station will consist of a data-logging receiver, one or more antennas, and a power source. Each will be configured to receive transmitter signals from a designated area continuously throughout the study period. During installation of each station, range testing will be conducted to configure the antennas and receivers in a manner which maximizes detection. The operation of each stationary radio receiver will be confirmed during installation and throughout the study period by using beacon tags. These beacon tags will be stationed at strategic locations within the detection range of either multiple or single antennas and will emit a signal at a programmed time interval. These signals will be detected and logged by the receivers and used to record the functionality of the system throughout the study period. Although each monitoring station will be installed in a manner which limits the ability to detect transmitters from unwanted areas, the possibility of such detections does still exist. As a result, behavioral data collected in this study (i.e., duration at a specific location or passage route) will be inferred based on the signal strength and the duration and pattern of contacts documented across the entire detection array.

The locations of proposed monitoring stations for upstream and downstream passage of adult American shad and river herring at the project are outlined below and presented visually in Figure 8-3. As with any telemetry study, monitoring station locations described here will be evaluated in the field prior to initialization of the study and, if necessary, may be modified to enhance the collection of passage information. Landowner permissions will be required for the installation of a number of the remote monitoring locations.

Monitoring Station M1: This station will be installed at a location within the Lowell Project impoundment and is intended to detect radio-tagged alosines (1) originally released downstream as they move upstream following successful passage via the fish lift or ladder at the Project or (2) during their initial movement downstream and away from the release location. Station M1 will consist of a single radio-receiver and aerial antenna oriented perpendicular to the river channel.

Monitoring Station M2: This station will consist of a single radio-receiver and an aerial antenna and will be located at the project compressor building. Station M2 will be installed and calibrated in a manner to provide detection information for radio-tagged alosines (1) originally released downstream as they move upstream following successful passage via the fish lift or ladder at the Project (2) originally released upstream as they approach the upstream face of Pawtucket Dam. Detections at this location will be used to inform on arrival of outmigrants at the project.

Monitoring Station M3: Station M3 will consist of a single radio-receiver and aerial antenna. It will be installed and calibrated to provide coverage of the upstream side of the Pawtucket Gatehouse. This station will inform on (1) radio-tagged alosines originally released downstream which have ascended the Project fish lift and have successfully exited the Northern Canal via the Pawtucket Gatehouse, or (2) radio-tagged alosines which following a period of residence upstream of the Project have approached the upstream side of the Pawtucket Gatehouse.

Monitoring Station M4: Station M4 will consist of a single radio-receiver and aerial antenna. It will be installed and calibrated to provide coverage of the downstream side of the Pawtucket Gatehouse. This station will inform on (1) radio-tagged adult alosines originally released downstream which have ascended the Project fish lift and have approached the Pawtucket Gatehouse in an attempt to exit the Northern Canal, or (2) radio-tagged adult alosines which following a period of residence upstream of the Project have successfully passed the Pawtucket Gatehouse and entered the Northern Canal.

Monitoring Station M5: Station M5 will consist of a single radio-receiver and aerial antenna. It will be installed and calibrated to provide detection information for radio-tagged adult alosines which following a period of residence upstream of the Project have successfully passed the Pawtucket Gatehouse, entered the Northern Canal and forebay and are in the vicinity of the entrances to the downstream bypass and intake racks.

Monitoring Station M6: This station will consist of a single radio-receiver and underwater drop antenna. It will be installed and calibrated to provide detection information for radio-tagged adult alosines which following a period of residence upstream of the Project have successfully passed the Pawtucket Gatehouse, entered the Northern Canal and forebay, and passed downstream via the downstream bypass.

Monitoring Station M7: Station M7 will consist of a single radio-receiver and aerial antenna and will be installed to scan across the bypassed reach at a point downstream of where the surge gate enters from the power canal and upstream from the downstream bypass. Detections at this location will be used to (1) confirm the downstream passage of radio-tagged adult alosines which following a period of residence upstream of the Project passed downstream using the spillway or surge gate, or (2) identify radio-tagged adult alosines released at Lawrence which have initiated an ascent upstream into the bypassed reach.

Monitoring Station M8: Station M8 will consist of a single radio-receiver and aerial antenna and will be installed to scan across the bypassed reach at a location near to the midpoint of that section. Detections at this location will be used to identify radio-tagged adult alosines which have ascended upstream to near the midpoint of the bypassed reach.

Monitoring Station M9: Station M9 will consist of a single radio-receiver and aerial antenna and will be installed to scan the upper section of the bypassed reach in close proximity to the entrance to the upstream fishway. Detections at this location will be used to identify radio-tagged adult alosines which have ascended the full length of the bypassed reach and are within the nearfield area of the upstream fishway.

Monitoring Station M10: This station will consist of a single radio-receiver and aerial antenna and will be installed at a location overlooking the Project tailrace. Detections at this location will be used to (1) confirm the downstream passage of radio-tagged adult alosines which following a period of residence upstream of the Project passed downstream via the project turbine units, or (2) identify radio-tagged adult alosines which ascended into the Project tailrace and are within the nearfield area of the upstream fish lift.

Monitoring Station M11: This station will consist of a single half-duplex PIT reader and antenna and will be installed at the entrance to the Project fish ladder. It will provide fine scale detection information for PIT-tagged adult alosines which have ascended the Project bypass reach and entered the upstream fishway.

Monitoring Station M12: This station will consist of a single half-duplex PIT reader and antenna and will be installed at the turn pool of the Project fish ladder. It will provide fine scale detection information for PIT-tagged adult alosines which have ascended the Project bypass reach, entered the upstream fishway, and ascended the first leg.

Monitoring Station M13: This station will consist of a single half-duplex PIT reader and antenna and will be installed at the exit to the Project fish ladder. It will provide fine scale detection information for PIT-tagged adult alosines which have ascended the Project bypass reach, entered the upstream fishway and successfully navigated the upstream fishway structure.

Monitoring Station M14: This station will consist of a multi half-duplex PIT reader and antennas and will be installed to provide coverage of the two entrances to the Project fish lift (i.e., the river side and street side entrances). It will provide fine scale detection information for PIT-tagged adult alosines which have ascended into the E.L. Field Powerhouse tailrace and entered the upstream fish lift.

Monitoring Station M15: This station will consist of a single half-duplex PIT reader and antenna and will be installed at the exit to the Project fish lift. It will provide fine scale detection information for PIT-tagged adult alosines which have successfully navigated the fish lift structure.

Monitoring Station M16: Station M16 will be installed at a point just downstream of the convergence of flow from the bypassed reach and E.L. Field powerhouse tailrace channel. This station will provide detection information for (1) radio-tagged adult alosines released at the Lawrence Project as they approach the Lowell Project, and (2) outmigrating radio-tagged adult alosines following downstream passage or a period of residence within the tailrace or bypassed reach at the Lowell Project.

Monitoring Station M17: This station will be installed at a point along the mainstem of the Merrimack River downstream of both the E.L. Field Powerhouse tailrace and the confluence with the Concord River. Station M17 will consist of a single receiver and aerial antenna oriented perpendicular to the river channel. This station will provide detection information for (1) radio-tagged adult alosines released at the Lawrence Project as they approach the Lowell Project, and (2) outmigrating radio-tagged adult alosines following downstream passage or a period of residence within the tailrace or bypassed reach at the Lowell Project.

Monitoring Station M18: Station M18 will be installed at a point midway between the Lowell and Lawrence projects and detection information at this location will be collected to inform on (1) radio-tagged adult alosines released at the Lawrence Project as they approach the Lowell Project, and (2) outmigrating radio-tagged adult alosines following downstream passage or a period of residence within the tailrace or bypassed reach at the Lowell Project. The exact location will be determined in the field and will be based on proximity to the river, property access and equipment security. Station M18 will consist of a single receiver and aerial coverage oriented perpendicular to the river channel.

Monitoring Station M19: This station will be installed along the upstream side of the Essex Dam in Lawrence and detection information at this location will be collected to inform on outmigrating radio-tagged adult alosines following downstream passage at the Project. Station M19 will consist of a single receiver and aerial antenna oriented perpendicular to the river channel. This lowermost receiver station is required to provide detection data needed for modeling estimates of passage success.

Monitoring Station C1: This station will be installed to detect radio-tagged adult alosines which may enter the Pawtucket Canal system rather than pass the Lowell Project via one of the mainstem passage routes. The entrance to the Pawtucket Canal sits at a point upstream of the Pawtucket Dam and the Northern Canal. Station C1 will be located at the Guard Locks, approximately 1,700 ft downstream from the entrance to the canal. The monitoring zone for Station C1 will be focused downstream of the Guard Locks facility to ensure any detections recorded at that location are of fish which have definitively entered the Pawtucket Canal system.

Following detection at Monitoring Station C1, radio-tagged adult alosines are free to move downstream through the Pawtucket Canal until flow diverges and they can pass into the Western Canal, Merrimack Canal, or Hamilton Canal or continue in the Pawtucket Canal. Since the Western and Merrimack Canals are no longer in use and are essentially deadwater areas and the Assets Power Station (located on the Merrimack Canal) is non-functional and is planned to be eliminated from the new project license these sections will not be monitored for passage. Telemetry station coverage for outmigrating alosines within the canal system is focused on potential routes of egress where flow is present under generating conditions.

Monitoring Station C2: Station C2 will be installed to detect radio-tagged adult alosines which have moved from the Pawtucket Canal to the Hamilton Canal and reached the Hamilton Power Station. It will consist of a single receiver and antenna coverage at the Hamilton Power Station intake area upstream of the intake for Hamilton Unit 1.

Monitoring Station C3: Station C3 will consist of a single half-duplex PIT reader and antenna and will be installed at the Hamilton Wasteway located at the downstream end of the Hamilton Canal. During periods of canal generation it is occasionally necessary to route additional flow through the wasteway to supply accommodate the greater hydraulic capacity of units in the lower canal system (i.e., John Street and Bridge Street).

Following passage at Swamp Locks, the Hamilton Power Station (Monitoring Station C2) or the Hamilton Wasteway (C3), radio-tagged adult alosines are discharged into the lower Pawtucket Canal and then enter the Eastern Canal. Passage of fish into the Eastern Canal via Swamp Locks will be inferred based on a lack of detection information indicating entry into the Eastern Canal via the Hamilton Power Station or Hamilton Wasteway. From the Eastern Canal fish can pass into the Concord River via the Bridge Street Power Station (Station C4), or via the John Street Power Station (Station C5/C6) or Boott Gate (Station C7) to the Merrimack River. The Lower Locks is rarely used to pass flow other than for lockage, and therefore will not be monitored for passage.

Monitoring Station C4: This station will be installed to detect radio-tagged adult alosines which have entered the Eastern Canal and reached the Bridge Street Power Station (a.k.a. “Section 8”). It will consist of a single receiver and antenna coverage of the Bridge Street Power Station discharge area. Adult alosines successfully passing here can be subsequently detected downstream at Monitoring Stations M17, M18 and M19.

Monitoring Station C5: Station C5 will be installed to detect radio-tagged adult alosines which have entered the Eastern Canal and reached the John Street Power Station. It will consist of a single receiver and antenna coverage at the John Street Power Station intake area.

Monitoring Station C6: Station C6 will consist of a single radio receiver and antenna coverage of the John Street Power Station discharge. Adult alosines successfully passing here can be subsequently detected downstream at Monitoring Stations M17, M18 and M19.

Monitoring Station C7: Station C7 will consist of a single half-duplex PIT reader and antenna and will be installed at the sluice gate located at Boott Dam. This will provide coverage to detect any fish departing the Eastern Canal for the Merrimack River during periods of gate operation to flush debris from the lower canal system.

8.6.4 Tagging and Release Procedures

Adult American shad and river herring will be collected for tagging at either the E.L. Field or Essex Dam fish lift. Following collection methodology from a previous evaluation of shad movement in the lower Merrimack River (Sprankle, 2005), adult alosines will be collected from a net pen placed in the exit flume of the lift which receives fish directly from the hopper bucket. Following capture in the net pen, fish will be dip-netted out and visually assessed to ascertain their suitability for tagging. Any individuals exhibiting excessive scale loss or other signs of significant stress will not be considered for tagging. Individuals deemed acceptable for tagging will be quickly measured (total length, nearest mm), and gender will be determined (when possible) by gently expressing eggs or milt from running-ripe fish. Radio transmitters will be inserted gastrically. To facilitate gastric implantation, transmitters will be affixed to a flexible tube with their trailing antenna running through the hollow center. The transmitter and leading edge of the flexible tube will be pushed through the mouth and down to the stomach. Once in place, the tube will be removed leaving the transmitter antenna trailing from the mouth. PIT tags will be implanted into the peritoneal cavity through a small incision on the ventral side of the fish.

8.6.4.1 Upstream Passage Evaluation

Shad and river herring tagged for the evaluation of upstream passage at Lowell will be obtained at the Essex Dam fish lift in Lawrence, Massachusetts. As detailed in Section 3.6.1, a total of 240 adult American shad (160 dual-tagged and 80 PIT-tagged) and 225 adult river herring (150 dual-tagged and 75 PIT-tagged) will be tagged to evaluate upstream passage effectiveness at the Lowell Project. For each of five release events, 48 shad and 45 river herring will be collected at the Lawrence Project, half will be dual-tagged (i.e., 24 shad and 22 herring) and half will be PIT-tagged with all individuals being released at the boat launch located just upstream of Lawrence. The exact timing of the tagging effort will depend on the run timing for both species but is anticipated to begin at some point in early May.

8.6.4.2 Downstream Passage Evaluation

As detailed in Section 3.6.1, a total of 150 adult American shad and 150 adult river herring will be radio-tagged to evaluate downstream passage at Lowell. For each of five release events, 20 shad (100 total) and 20 river herring (100 total) will be collected at the Lawrence Project, radio-tagged and then transported by truck to a release location within the Lowell Project impoundment, several miles upstream of Lawrence. Preference will be given to a release location where tagged alosines can be sluiced directly from the truck into the Merrimack River to avoid any additional netting or handling of tagged individuals. A total of 50 adult shad and 50 adult river herring will be radio-tagged at Lawrence and transported to a release location within the Pawtucket Canal, downstream of the Guard Locks facility. Releases of radio-tagged adult alosines at this location will occur over three separate release events. The exact timing of the tagging effort will depend on the run timing for both species but is anticipated to begin at some point in early May.

A total of ten freshly dead adult American shad and adult river herring will be radio-tagged and released downstream of the E.L. Field powerhouse during the release period to simulate “movements” of adult alosines killed during downstream passage. The downstream progression of these known mortalities will be recorded via both the stationary receivers as well as during manual tracking events and will help inform on the probability that downstream receivers may record false positive detections associated with dead study fish drifting passed the receiver (this would result in biased estimates of downstream passage survival). The observed rates of downstream drift as well as final resting location relative to downstream stationary receivers will be considered during evaluation of Project survival.

8.6.5 Project Data Collection

8.6.5.1 Active radio- and PIT-tags

Data will be offloaded from the receivers at each monitoring station using a laptop computer and will be stored on removable memory sticks. Data downloads will occur at least twice weekly during the period from the initial tag and release date until the last week of June. Backup copies of all telemetry data will be made prior to receiver initialization. Field tests to ensure data integrity and receiver performance will include confirmation of file integrity, confirmation that the last record is consistent with the downloaded data, and lastly, to confirm that the receiver is operational upon restart and actively collecting data post download. Within a data file, tag detections will be stored as a single event (i.e., single data line). Each event will include the date and time of detection, frequency, ID code, and signal strength.

Supplemental detection information will be collected during manual tracking events. Manual tracking will target the reaches between stationary antenna coverage to determine if and where any radio-tagged adult alosines may become stationary. These tracking events will be conducted on an as needed basis up to once per week from the initial tag and release date until the end of June.

8.6.5.2 River and Project Operational Data

In addition to the manual and stationary radio- and PIT-tag data, river and Project operations data (mainstem and canal system) will be reported for the duration of the evaluation period. Mainstem river temperature will be recorded via a thermal logger installed at the Project. Project discharge (generation and spill), unit operations, downstream bypass operation, and extent and location of spill will be obtained from Boott at the completion of the study period.

8.7 Analysis and Reporting

8.7.1 Data Processing

Tag detections in each downloaded stationary radio-telemetry data file will be validated through a series of site-specific and logical criteria. These criteria will include:

1. Signal strength threshold level of the detection,

2. Frequency of the radio tag signals per unit of time, and

3. Spatial and temporal characteristics of each individual detection with respect to the full series of detections at monitoring stations within the entire detection array.

To determine the signal strength threshold for a valid tag signal, power levels associated with background noise will be recorded at each monitoring station prior to the release of radio-tagged fish. These “false” signals are typically received at relatively low power levels, and they will be removed from the analysis using a series of data filters. The frequency of the signal detections for an individual radio tag will be examined at each monitoring station, such that over a set period of time, there are an adequate number of detections to rule out an isolated false detection (e.g., at least 3 detections within 1 minute). Finally, the spatial and temporal distribution of detections across multiple monitoring stations will be examined to verify that the pattern of detections is not occurring in a manner that is unreasonable (i.e., time for a fish to have relocated within the time between the detections).

8.7.2 Data Analysis – Upstream Passage Evaluation

Radio and PIT telemetry data collected for tagged adult alosines migrating upstream towards the Lowell Project will be analyzed to:

- Evaluate route selection (i.e., movement of adult alosines either up the bypassed reach towards the Pawtucket Dam or towards the E.L. Field powerhouse discharge);
- Estimate nearfield attraction and entrance efficiency at the fish lift;
- Estimate nearfield attraction, entrance efficiency, and internal efficiency of the fish ladder;
- Estimate residence duration and passage success for fish to exit the Northern Canal; and
- Characterize project operational effects on timing, route and rate of shad and herring migration

Passage success and attraction/efficiency for tagged adult alosines at Lowell will be evaluated using one or more multi-state or standard CJS models run for a set of individual encounter histories (i.e., the series of detection/no detection through the linear sequence of receivers from upstream to downstream). Standard error and confidence bounds for each estimate will be generated. To evaluate passage success using CJS models, a suite of candidate models will be developed in Program MARK (WhiteandBurnham, 1999) or other appropriate software based on whether survival, recapture (i.e., detection), or both vary or are constant among stations. Models will include:

- Phi(t)p(t): survival and recapture may vary between receiver stations;
- Phi(t)p(.): survival may vary between stations; recapture is constant between stations;
- Phi(.)p(t): survival is constant between stations; recapture may vary between stations;
- Phi(.)p(.): survival and recapture are constant between stations;

Where;

- Phi = probability of survival
- p = probability of detection
- (t) = parameter varies
- (.) = parameter is constant

Prior to comparison among models, goodness of fit testing will be conducted for the "starting model" (i.e., the fully parameterized model). To accommodate for a lack of fit, a measure of how much extra binomial noise (i.e., variation) exists in the data may be needed. This value, the variance inflation factor (ĉ), can be estimated and used to correct for any minor over-dispersion. Akaike's Information Criterion (AIC) will be used to rank the models as to how well they fit the observed mark-recapture data. Assuming the assumptions of the model with the lowest AIC value are reasonable with regards to this study, it will be selected for the purposes of generating survival estimates.

The proportion of adult alosines passing upstream via the bypassed reach versus the powerhouse tailrace will be estimated as a transitional probability from a multi-state CJS model (Figure 8-3) and will be based on the split movements of dual-tagged adult alosines initially detected at Station M16 to either Station M10 (tailrace) or M7 (lower bypassed reach). Nearfield attraction for the project fish lift will be estimated as the survival probability for dual-tagged adult alosines to move upstream following an initial detection at Station M16 to Station M10. Nearfield attraction for the spillway fish ladder will be estimated as the survival probability for dual-tagged adult alosines to move upstream following an initial detection at Station M8 to Station M9. Entrance efficiency will be estimated as a survival probability within either a multi-state or standard CJS model for dual-tagged alosines to move from initial detection at Station M9 (for the fish ladder) or M10 (for the fish lift) to detection at the structure entrance (Station M11 for the fish ladder and Station M14 for the fish lift). Internal efficiency of the Project fish lift will be estimated as the survival probability for PIT tagged fish between Stations M14 and M15 and for the project fish ladder as the joint probability of survival for PIT-tagged fish moving between Stations M11 (entrance) to M12 (turn pool) and from M12 (turn pool) to M13 (exit). Passage success out of the Northern Canal will be estimated as the survival probability for dual-tagged fish between Stations M4 and M3.

Duration of passage attempt will be assessed with a Cox regression or proportional hazards model (Castro-Santos, 2012). The regression model describes the unit change in variables on the log-hazard function or instantaneous rate. The hazard function can describe the approach rate, entry rate or rejection rate (Castro-Santos, 2012).

8.7.3 Data Analysis – Downstream Passage Evaluation

Radio telemetry data collected for tagged adult alosines outmigrating past Lowell will be analyzed to:

- Determine the proportion of post-spawn adults which utilize the canal system versus remain within the mainstem;
- Evaluate downstream passage through the canal system to determine route selection, passage efficiency, and residence duration;
- Evaluate downstream passage past the E.L. Field Powerhouse and Pawtucket Dam to determine route selection, passage efficiency, and residence duration; and
- Compare rates and estimates of residence duration and movement between routes utilized (i.e., spill over Pawtucket Dam versus passage at power station).

A complete record of all valid detections for each uniquely coded outmigrating radio-tagged adult alosine will be generated and the pattern and timing of detections in these individual records will be reviewed. For radio-tagged fish released into the mainstem, the proportion entering the canal system will be determined. For the subset of radio-tagged adult alosines remaining in the mainstem and approaching the Pawtucket Dam and E.L. Field Powerhouse, the arrival and passage times and downstream route of passage (i.e., turbine, bypass, and spill) will be determined. In instances where a specific passage route is not clearly defined by the available data, the passage route for that individual will be classified as unknown. For the subset of mainstem adult alosines as well as the canal-specific release groups, the date and time of arrival and departure at each canal monitoring station will be reported and the final route of egress back into the Concord or Merrimack Rivers will be determined.

The stationary telemetry dataset collected using the monitoring stations described above will also permit the evaluation of residence time for radio-tagged alosines between any two adjacent monitoring stations both prior to and following downstream passage. Passage duration through any defined reach will be calculated as the duration from initial detection at the stationary receiver on the upstream end of the reach until initial detection at the stationary receiver on the downstream end of the reach. For radio-tagged adult alosines which approach Pawtucket Dam and the E.L. Field Powerhouse, Project residence duration will be defined as the duration of time from initial detection at the dam (i.e., detection at Monitoring Station M2) until successful downstream passage at the Project. For radio-tagged adult alosines entering the canal system, canal residence duration will be defined as the duration of time from the confirmed entry into the canal system (i.e., detection at Monitoring Station C1) until confirmed outmigration via one of the monitored exits at the Hamilton, Assets, Bridge Street or John Street Power Stations.

Duration of passage attempt will be assessed with a Cox regression or proportional hazards model (Castro-Santos, 2012). The regression model describes the unit change in variables on the log-hazard function or instantaneous rate. The hazard function can describe the approach rate, entry rate or rejection rate (Castro-Santos, 2012).

8.7.4 Reporting

A report describing the methodologies and study results related to movement and passage of adult American shad and river herring will be prepared. The report will include details related to the acquisition, tagging and release of test fish at the mainstem and canal release locations as well as tabular and graphical summaries of upstream and downstream passage route selection and effectiveness, residence duration and passage success. Project operations at the time of arrival and passage for radio-tagged adult alosines will be examined and summarized in both tabular and graphical format. Boott anticipates that the Upstream and Downstream Adult Alosine Passage Assessment study report will include the following elements:

- Project information and background
- Study area
- Methodology
- Study results
- Analysis and discussion
- Any agency correspondence and or consultation
- Literature cited

8.8 Schedule, Level of Effort, and Estimated Cost

This study will require a substantial effort and cost to capture, tag and monitor a sufficient number of adult American shad and river herring, and analyze collected data to evaluate upstream and downstream passage at Lowell. Cost for the tagging, monitoring and analysis described in this plan is expected to range from $315,000 to $365,000. Both the upstream and downstream components of the adult alosine passage assessment will be conducted during 2020 once the tailrace excavation work downstream of the E.L. Field Powerhouse has been completed.

Figure 8-1. Proposed radio-telemetry river monitoring stations to evaluate upstream and downstream passage of adult alosines at Lowell.

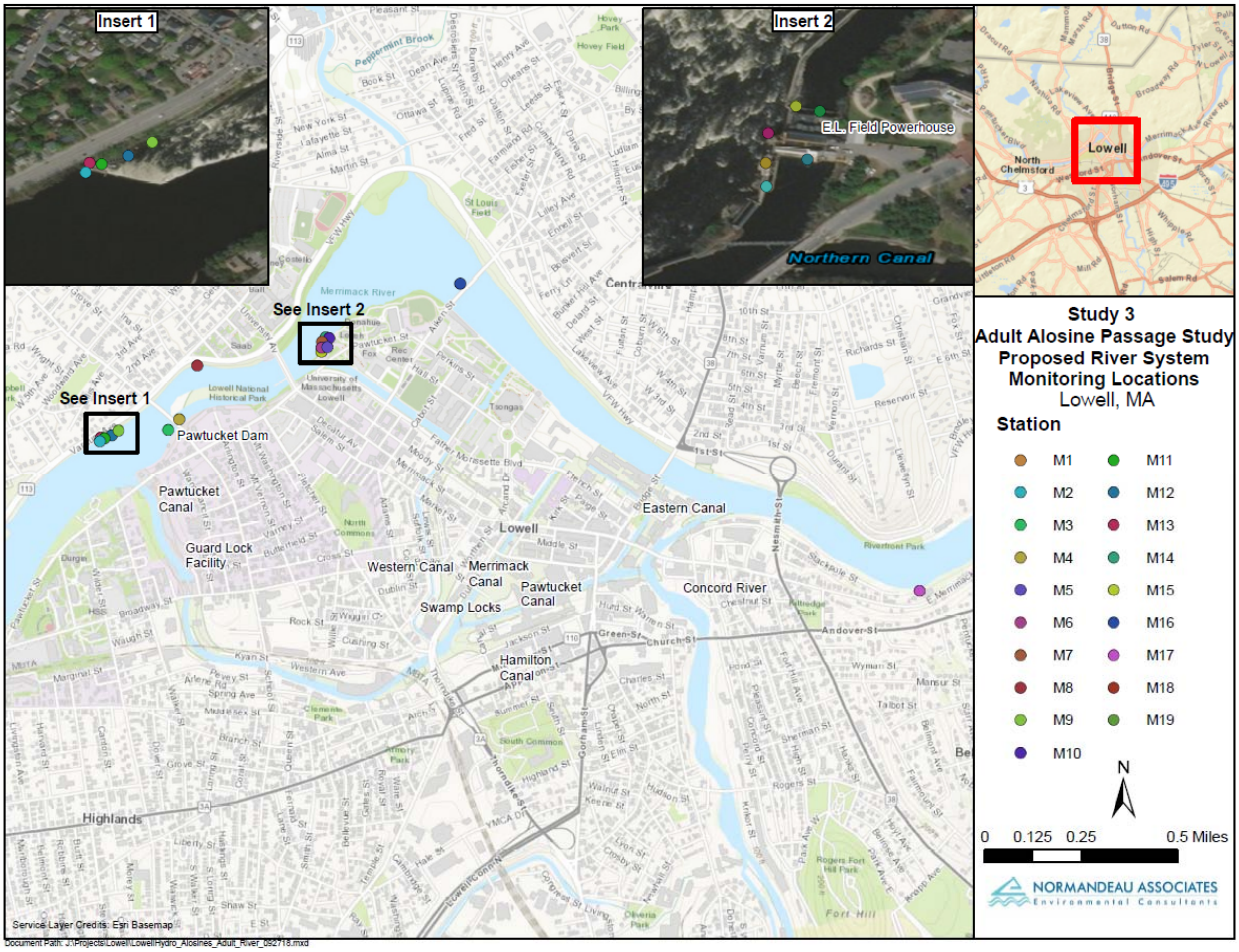


Figure 8-2. Proposed radio-telemetry canal monitoring stations to evaluate upstream and downstream passage of adult alosines at Lowell.

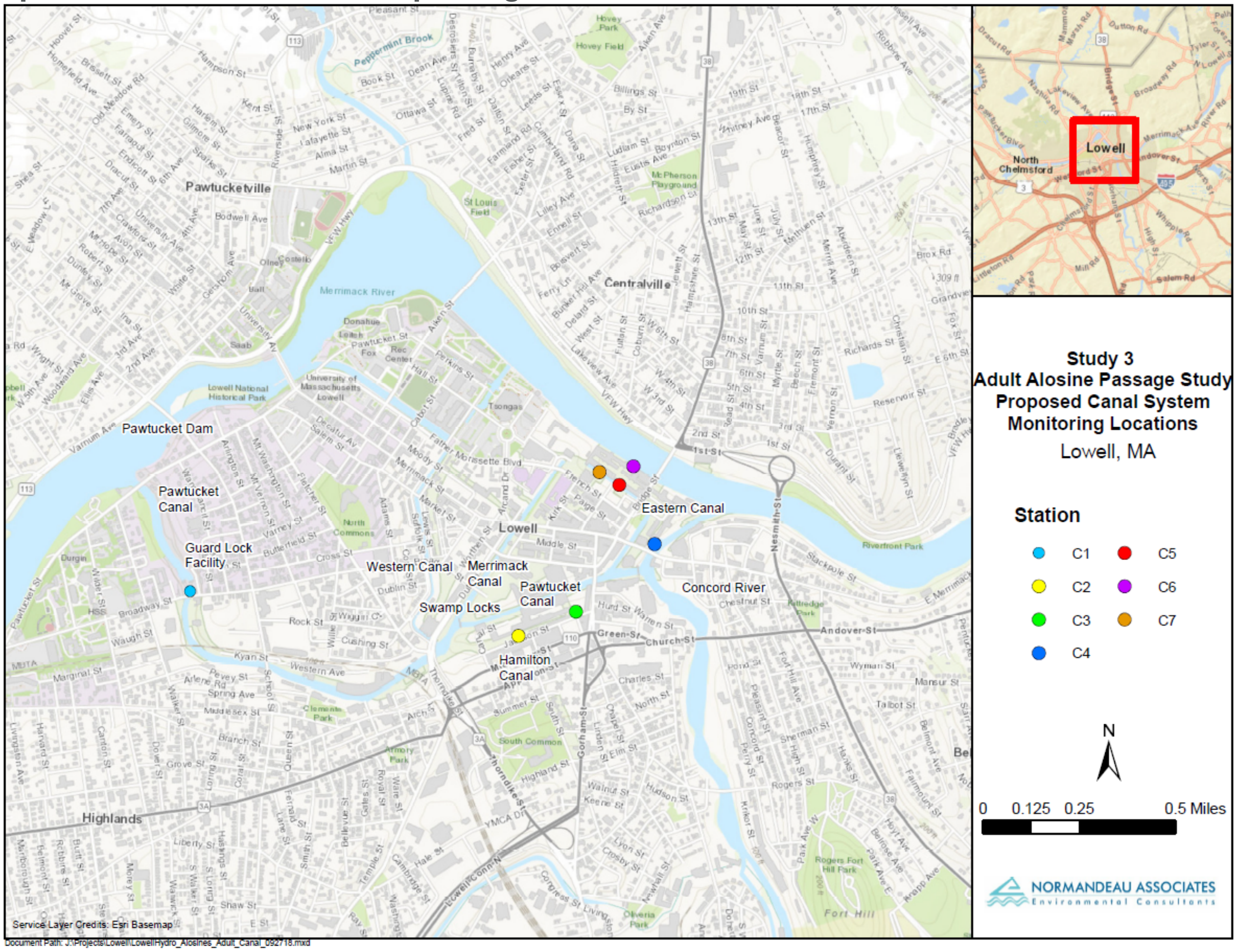
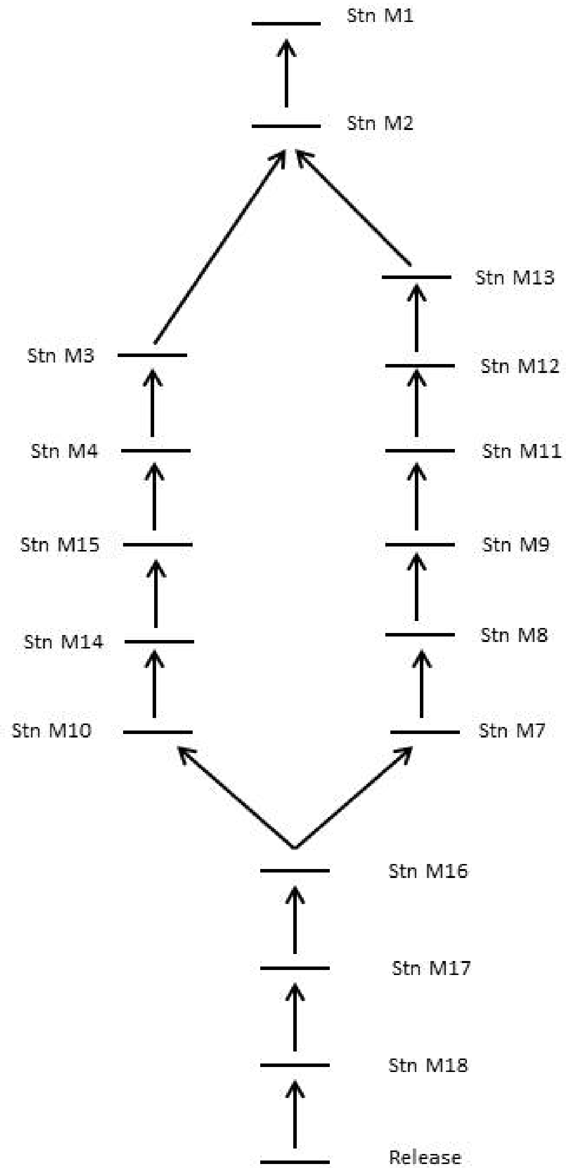


Figure 8-3. Sequence of monitoring stations to detect tagged adult alosines as they move upstream and pass Lowell via the tailrace, fish lift and Northern Canal (left side) and via the bypassed reach and fish ladder (right side).



9 Fish Passage Survival Study

9.1 Study Requests

The Commission's June 15, 2018 SD1 identified the following environmental resource issue to be analyzed in the EA for the Project relicensing:

- Effects of continued Project operation on resident and migratory fisheries resources in the impoundment, canal system, bypassed reach, and Merrimack River.
- Effectiveness of the existing fish passage facilities at passing migratory fish, including American shad, river herring, and American eel.

The USFWS, NMFS, MADFW, and NHFGD submitted formal requests either wholly or in part related to Project passage survival, as shown in Table 9-1.

Table 9-1. Aquatic Resource Study Request

Requestor	Requested Study	Date
NMFS	Project Survival Study (study request #4)	August 14, 2018
NMFS	Upstream And Downstream Adult Alosine Passage (Study Request #3, objective 3)	August 14, 2018
USFWS	Adult Alosine Downstream Passage Assessment and Protection Evaluation (study request #2, objectives 1, 2)	August 14, 2018
MADFW	Adult Alosine Downstream Passage Assessment and Protection Evaluation (study request #2, objectives 1, 2)	August 10, 2018
NHFGD	Adult Alosine Downstream Passage Assessment and Protection Evaluation (study request #2, objectives 1, 2)	August 13, 2018
NMFS	Juvenile Alosine Downstream Study (study request #2, objective 3)	August 14, 2018
USFWS	Impact of Project Operations on Downstream Migration of Juvenile Alosines (study request #4, objective 1)	August 14, 2018
MADFW	Impact of Project Operations on Downstream Migration of Juvenile Alosines (study request #4, objective 1)	August 10, 2018
NHFGD	Impact of Project Operations on Downstream Migration of Juvenile Alosines, (study request #4, objective 1)	August 13, 2018
NMFS	American Eel Passage Downstream Study (study request #1, objective 3)	August 14, 2018
USFWS	Downstream American Eel Passage Assessment (study request #5, objective 2)	August 14, 2018

Requestor	Requested Study	Date
MADFW	Downstream American Eel Passage Assessment (study request #5, objective 2)	August 10, 2018
NHFGD	Downstream American Eel Passage Assessment (study request #5, objective 2)	August 13, 2018

The following study requests included, in part, field evaluations using the HI-Z Turb'N-Tag (balloon tag, HI-Z Tag) technique to turbine, spill and bypass passage survival:

- NMFS – Project Survival Study, objective 1 (adult American Eels and American Shad);
- USFWS, MADFW, NHFGD- Adult Alosine Downstream Passage Assessment and Protection Evaluation, objectives 2 and 3 (adult American Shad and Alewife);
- NMFS - Juvenile Alosine Downstream Study, objective 3. Note that Turb'N-Tag method was not specifically proposed to address this objective. A radio-telemetry approach was inferred.
- USFWS, MADFW, NHFGD- Impact of Project Operations on Downstream Migration of Juvenile Alosines, objective 1 (juvenile alewife);
- NMFS - American Eel Passage Downstream Study, objective 3 (adult American Eel). Note that the Turb'N-Tag method was not specifically proposed to address this objective. A radio-telemetry approach was inferred; and
- USFWS, MADFW, NHFGD - Downstream American Eel Passage Assessment, objective 2 (adult American Eel).

9.2 Goals and Objectives

The goal of this study is to assess the potential survival of fish passing downstream through the E.L. Field, Bridge Street, Hamilton, and John Street turbines and to inform estimates of Project passage survival for emigrating diadromous species (adult and juvenile American Shad and Alewife and adult American Eel). The objectives of the study are to:

- Assess the potential for impingement and estimate survival rates for the target species and life stages;
- Assess the potential for entrainment and estimate survival rates for target species and life stages;
- Conduct a desktop survival analysis to estimate passage survival of target species and life stages for each active turbine type; and
- Assess total Project survival for the target species and life stages.

9.3 Study Area

This desktop assessment will examine fish impingement, entrainment, and passage survival probability through the E.L. Field, Bridge Street, Hamilton, and John Street units. Seven unique turbine designs will be assessed. E.L. Field units 1 and 2 are identical; Bridge Street units 4, 5, and 6 are identical and the Commission amended the Project's existing license in July 2018 to authorize Boott to remove Bridge Street units 1, 2, 3, and 12; Hamilton units 1, 4 and 5 are identical; John Street units 3, 4, and 5 are identical (PAD Table 4.3.-2). Boott has decommissioned the Assets units 1, 2, and 3.

9.4 Background and Existing Information

Existing relevant information regarding diadromous species presence and seasonality were summarized in Section 5.4 of the PAD (HDR, 2018). Passage count data for the Lowell Project (including Pawtucket Dam fish ladder) indicated seasonal river herring passage ranging from 0 to 432,599 over the ten year period 2008 through 2017. American Shad passage ranged from 490 to 20,937 during the same period. Surviving post-spawn adult alosines may encounter the Project turbines during outmigration in the late spring and summer, and juveniles during outmigration in the fall. Enumerated juvenile eel passage at the Lowell project ranged from 166 to 1,981 from 2014 through 2017. Unknown numbers of eels may emigrate the Project by various routes, however. Emigrating silver-phase adult eels may encounter the Project turbines during outmigration from late summer through fall.

Numerous studies documenting downstream passage behavior, route selection, and/or bypass effectiveness for juvenile alosines, adult American Shad, Atlantic salmon smolts, and adult American eels were summarized in the PAD. A comprehensive study of Atlantic salmon smolt passage route selection and turbine passage survival study of the E.L. Field turbines predicted 94% turbine passage survival and estimated 100% survival and injury free passage through direct passage estimates using the Turb'N-Tag method (Normandeau, 2003).

9.5 Project Nexus

Diadromous fish moving downstream in the Merrimack River as part of their life cycle encounter the Lowell Project. Potential effects of Project operations and facilities include fish impingement on the trash racks and entrainment through the generating units. This study will help establish a baseline condition to assist in evaluating entrainment and impingement potential and the expected passage survival of those at the Project. Information gained from this study will inform FERC's environmental assessment of the of the license application materials.

9.6 Study Methodology

Boott has not adopted the field based direct turbine survival approach, but instead proposes the desktop survival estimation approach to provide turbine-specific estimates for passage survival. Other studies address the requests for radio-telemetry based determinations of passage route selection and passage durations (e.g., Study 1 - American Eel Passage Downstream Study, Study 2 - Juvenile Alosine Downstream Study, and Study 3 - Adult Alosine Passage Study Upstream and Downstream). In addition, Boott proposes to calculate predicted survival using radio-telemetry data from those studies, which will address the estimated survival by bypass and spill as well as turbine routes of passage.

Agency study requests related to understanding downstream passage of adult and juvenile alosines and adult American eels at the Lowell Project incorporated Hi-Z Tag studies to evaluate mortality and injury of target species and life stages passed via each potential route. Boott proposes to evaluate downstream passage using radio-telemetry (see above studies). The design of the monitoring arrays will permit the determination of total project and route-specific passage survival. As described in the study requests, the HI-Z evaluations would entail the injection of adequate sample sizes of adult and juvenile alosines and adult eels into all 21 project turbines. Following FERC's study plan criteria, a proposed study plan must be consistent with generally accepted scientific practice and must be done at a higher level of effort only if a lower level of effort would not be sufficient to meet the information needs. Because the results of the radio telemetry studies and the desktop assessment of turbine passage survival will allow for analysis of Project effects, Boott has not adopted the study request related to HI-Z Tag studies. Boott believes that the results of this study, in conjunction with the results of other aquatic resources studies conducted in support of Project relicensing, will provide FERC with sufficient information for their EA.

The assessment of impingement, entrainment, and survival of diadromous species will be conducted as a desktop analysis. The potential for impingement or entrainment will be characterized based on the relationship of site-specific intake characteristics along with swim speed and life history characteristics of target fish species and guilds. Site-specific factors likely to influence the potential for entrainment include proportional flows to intake locations (e.g., E.L. Field Powerhouse, canal and canal powerhouses) intake location relative to shore and littoral habitat; depth of Project intakes; degree of water level fluctuations; hydraulic capacity; water quality; and intake velocities.

Each of the seven unique turbine designs (see Section 8.3) will be assessed for these site-specific intake characteristics. This assessment will rely on intake velocities calculated using the velocity equation Q = V*A where Q = flow rate [cubic feet-per-second (cfs)], V = velocity (feet per second) and A = area (square feet). Life history characteristics and species-specific swim speed information for target fish species and life stages will be obtained from peer-reviewed literature. The likelihood of impingement or entrainment for a particular species-life stage will be qualitatively assessed through the comparison of site-specific intake characteristics to literature reported swim speeds, body dimensions, and other life history characteristics. A review of entrainment studies conducted at other hydroelectric projects [i.e., (EPRI, 1997)] will be conducted to derive entrainment rates for target fish species. Following determination of appropriate project(s) for use as surrogates, available entrainment rate data will be summarized for the fish species-life stages of interest at the Lowell Project units. Literature-obtained entrainment rates will be combined with Project-specific discharge data to generate qualitative assessments of potential of entrainment for target species at each of the developments.

Entrainment survival of juvenile and adult alosines will be estimated using data from survival studies conducted at other hydroelectric facilities with similar characteristics [e.g., (EPRI, 1997); (Winchell, 2000)], and the Franke blade strike probability equation (Franke, 1997). Survival of adult eels will be estimated using the multiple linear regression models (Alden, 2017). They summarized laboratory and field studies demonstrating that turbine passage survival of American and European eels was higher than would typically be estimated with models used to predict blade strike probability and mortality. Thus, the Franke blade strike equation is not applicable to estimate turbine passage survival for eels. They parameterized multiple linear regression models for propeller turbines using data derived from direct turbine survival studies conducted at 56 projects and for Francis turbines at 5 projects.

Total Project downstream passage survival will be characterized for adult and juvenile American shad and alewife, and adult American eels considering the turbine passage survival estimated in this study and passage survival and proportional route selection data collected in the studies mentioned above (American Eel Downstream Passage Study, Juvenile Alosine Downstream Study and Adult Alosine Passage Study).

9.7 Analysis and Reporting

Results of this study, including probability of impingement, estimates of entrained fish survival through the project turbines, and predicted total Project survival will be summarized in tabular format. All data used in the development of those estimates will be provided in an appendix to the study report. Boott anticipates that the Fish Passage Survival study report will include the following elements:

- Project information and background
- Study area
- Methodology
- Study results
- Analysis and discussion
- Any agency correspondence and or consultation
- Literature cited

9.8 Schedule, Level of Effort, and Estimated Cost

This desktop assessment of impingement, entrainment, and turbine survival will be conducted during the second study year in the fall-winter of 2020. It will rely on results from the associated studies referenced above. The preliminary estimated cost for this study is $40,000 - $45,000. If the results from the field telemetry evaluations of fish passage (i.e., Study 1 - American Eel Downstream Passage Study, Study 2 - Juvenile Alosine Downstream Study, and Study 3 - Adult Alosine Upstream and Downstream Passage Study)and the desktop evaluation of turbine entrainment and survival (i.e., this study) suggest that additional operational or physical measures may be needed to increase passage success, Boott will consult with the resource agencies to evaluate potential alternatives.

10 Three-Dimensional Computational Fluid Dynamics (CFD) Modeling

10.1 Study Requests

The Commission's June 15, 2018 SD1 identified the following environmental resource issue to be analyzed in the EA for the Project relicensing:

- Effects of continued Project operation on resident and migratory fisheries resources in the impoundment, canal system, bypassed reach, and Merrimack River; and
- Effectiveness of the existing fish passage facilities at passing migratory fish, including American shad, river herring, and American eel.

The NMFS, USFWS, and MADFW submitted formal study requests for a three-dimensional computational fluid dynamics (CFD) modeling study of the project fish passage facilities and approaches as shown in Table 10-1.

Table 10-1. Aquatic Resource Study Request

Requestor	Requested Study	Date
NMFS	Three-Dimensional Hydraulic Modeling (study request #5)	August 14, 2018
USFWS	Three-Dimensional Computational Fluid Dynamics (CFD) Modeling in the Vicinity of Fishway Entrances and Powerhouse Forebays (study request #7)	August 14, 2018
MADFW	Three-Dimensional Computational Fluid Dynamics (CFD) Modeling in the Vicinity of Fishway Entrances and Powerhouse Forebays (study request #7)	August 10, 2018
NHFGD	Three-Dimensional Computational Fluid Dynamics (CFD) Modeling in the Vicinity of Fishway Entrances and Powerhouse Forebays (study request #7)	August 13, 2018

10.2 Goals and Objectives

The goal of this study is to determine the flow field conditions that exist in and around the Lowell Project's fish passage facilities, including around the fishway entrances, within fishway structures, and in the E.L. Field Powerhouse forebay. Information derived from this study may be used in conjunction with telemetry studies (American Eel Passage Downstream Study, Juvenile Alosine Downstream Study, and Adult Alosine Passage Study Upstream and Downstream) to analyze fish behavior in response to hydraulics. This is anticipated to aid in the interpretation of preferable conditions for the guidance of migrating fish to and through the fish passage facilities. The objectives of this study are to:

- Develop and calibrate three-dimensional models of areas pertinent to fish passage structure;
- Simulate various operational conditions using each model; and
- Produce a series of color contour maps depicting flow fields relating to fishway attraction, fishway hydraulics, and forebay and bypass approach.

10.3 Study Area

The study area includes the E.L. Field Powerhouse forebay, tailrace, and fish lift, the bypass reach in the vicinity of the Pawtucket Dam fish ladder entrance, and within the fish ladder.

10.4 Background and Existing Information

Existing relevant studies regarding project upstream and downstream diadromous fish passage were summarized in Section 5.4 of the PAD (HDR, 2018). A USFWS radio telemetry study suggested that American shad upstream passage effectiveness at the fish lift needs improvement (Sprankle, 2005), and recent studies have indicated upstream passage effectiveness and efficiency limitations for American shad that may be influenced by hydraulic conditions (Alden, 2011), (BlueLeaf, 2013). Of a small number (N=14) of silver-phase American eels monitored for emigration using radio telemetry, none used the E.L. Field Powerhouse bypass (Normandeau, 2018a). An assessment of Atlantic salmon smolt outmigration using radio telemetry techniques indicated a range of bypass effectiveness of 15% to 42% depending on the ratio of bypass to turbine discharge (Normandeau, 2003). No three-dimensional models exist for the Project fish passage facilities. In the northeast, CFD models have been used to address fish passage issues at the Holyoke, Turners Falls, Brunswick, Shawmut, Milford, and Orono projects.

10.5 Project Nexus

Diadromous fish migrating upstream and downstream in the Merrimack River as part of their life cycle encounter the Lowell Project. Potential effects of Project operations and facilities include upstream and downstream passage effectiveness and efficiency. The development of CFD models relative to the fish passage facilities will, in conjunction with fish behavior data, provide information regarding hydraulic conditions and behavioral responses. Information gained from this study will inform FERC's environmental assessment of the license application.

10.6 Study Methodology

CFD models will be developed and simulations of various operational conditions will be run to investigate the hydraulic conditions of the fish passage structures and their approach areas. In order to complete this study, several tasks will be completed: bathymetric survey and three-dimensional velocity data collection, model construction and calibration, and model simulation runs.

10.6.1 Bathymetric Survey

Boott preliminarily proposes to model four areas pertinent to fish passage, as described herein, but anticipates conducting a working group meeting(s) to discuss the appropriate domains and mesh size of areas to be surveyed and modeled. Surveys will be conducted using an Acoustic Doppler Current Profiler (ADCP) to collect bathymetry, depth, and three-dimensional flow data under low and high design flow conditions in the E.L. Field Powerhouse forebay and tailrace, and the bypass reach in the vicinity of the Pawtucket Dam fish ladder. Velocity data within the fish lift entrance channel structure and within the fish ladder will be collected with an ADCP or Acoustic Doppler Velocimeter (ADV). The surveys will be conducted after excavation of ledge material in the tailrace downstream of the fish lift entrance.

10.6.2 Model construction and Calibration

Boott proposes to construct three-dimensional models for three areas pertinent to fish passage:

- The E.L. Field Powerhouse forebay;
- The E.L. Field Powerhouse fish lift and tailrace; and
- The Pawtucket Dam fish ladder and approach and entrance area in the bypass reach.

The field collected bathymetry data (see Section 9.6.1) and Project elevation data will be used to construct three-dimensional surfaces of the river bed in the forebay, tailrace, and bypass reach study areas. Project drawings will be used to develop three-dimensional representation of the fish passage structures and other pertinent Project facilities and compiled into a full computer aided drawing (CAD) representation for each of the model areas. The CAD files will then be used to build three-dimensional hydraulic models. Then field collected water surface and flow data will be used to run calibration/validations scenarios.

10.6.3 Model Simulation Runs

The calibrated and validated models will be used to run simulations under various input operational scenarios. Boott has developed a suite of potential simulation runs based on stakeholder study requests, but anticipates conducting working group meeting(s) to discuss scenarios to be simulated. Proposed simulations include:

10.6.3.1 E.L. Field Powerhouse Forebay Model

With downstream bypass set at 5% of turbine discharge:

- Minimum flow, Unit 1;
- Minimum flow, Unit 2;
- 5% exceedance, both units; and
- 75% exceedance, typical unit setting.

10.6.3.2 E.L. Field Powerhouse Fish Lift and Tailrace Model

With auxiliary water supply at recommended settings:

- Minimum flow, Unit 1;
- Minimum flow, Unit 2;
- 5% exceedance, both units; and
- 50% exceedance, both units.

10.6.3.3 Pawtucket Dam Fish Ladder Model

With auxiliary water supply at recommended settings:

- Minimum flow, AWS from adjacent crest gate;
- Minimum flow, AWS from sluice gate; and
- 5% exceedance, typical spill settings.

10.7 Analysis and Reporting

A report will be developed to include maps, cross-sections and other representation of the simulation results that are relevant to the study objectives, as well as a summarization of findings relevant to the objectives of the study. Boott anticipates that the Three-Dimensional CFD Modeling study report will include the following elements:

- Project information and background
- Study area

- Methodology
- Study results
- Analysis and discussion
- Any agency correspondence and or consultation
- Literature cited

10.8 Schedule, Level of Effort, and Estimated Cost

Due to diverse locations and accessibility of the areas to be surveyed in the canal, forebay, tailrace, bypass reach and within the fish lift and fish ladder structures, four bathymetric and flow data collection surveys will be needed, and four separate CFD models will be constructed.

The preliminary estimated cost for this study is $130,000 – $200,000.

11 Instream Flow Habitat Assessment and Zone of Passage Study in the Bypassed Reach

11.1 Study Requests

The Commission's June 15, 2018 SD1 identified the following environmental resource issue to be analyzed in the EA for the Project relicensing:

- Effects of continued Project operation on resident and migratory fisheries resources in the impoundment, canal system, bypassed reach, and Merrimack River.
- Effects of continued Project operation on the aquatic macroinvertebrate community in the impoundment, canal system, bypassed reach, and Merrimack River.

The USFWS, NMFS, MADFW, and NHFGD submitted formal requests either wholly or in part related to aquatic habitat and fish passage in the bypassed reach, as shown in Table 11-1.

Table 11-1. Aquatic Resource Study Request

Requestor	Requested Study	Date
USFWS	Instream Flow Habitat Assessment of the Lowell Bypassed Reach (study request #1), objectives 1, 2)	August 14, 2018
MADFW	Instream Flow Habitat Assessment of the Lowell Bypassed Reach (study request #1), objectives 1, 2)	August 10, 2018
NHFGD	Instream Flow Habitat Assessment of the Lowell Bypassed Reach (study request #1), objectives 1, 2)	August 13, 2018
USFWS	Bypass Zone of Passage (study request #8, objectives 1)	August 14, 2018
MADFW	Bypass Reach Zone of Passage Study (study request #8, objectives 1)	August 10, 2018
NHFGD	Bypass Zone of Passage (study request #8, objectives 1)	August 13, 2018
NMFS	Bypass Zone-of-Passage Study (study request #6, objectives 1)	August 14, 2018

There are two separate study requests to evaluate the bypassed reach, one pertaining to aquatic habitat and one to fish passage:

- ***Instream Flow Habitat Assessment**:* determine impacts of a range of Project flows on wetted area and habitat for key aquatic species by conducting an instream flow study based on the Instream Flow Incremental Methodology (IFIM) process and one-dimensional (1D) modeling techniques. (Study request #1; USFWS, NHFGD, MADFW)
- ***Bypass Zone of Passage Assessment***: determine flows which facilitate fish passage through the bypass reach through the use of detailed elevation and bathymetry data and two-dimensional (2D) modeling techniques. (Study request #6; NMFS; Study request #8; USFWS, NHFGD, MADFW)

1D transects and modeling techniques could be applied to a portion of the bypassed reach to predict habitat suitability; however, they would not be able to effectively model the lower 2,000 ft of bedrock channels with highly variable flow angles, often perpendicular to the main flow. 2D models can be utilized to represent complex habitats with variable flow patterns such as transverse flow that 1D models are not able to capture.

A 2D model of the bypassed reach, specifically River2D, can be used to develop habitat-flow relationships using species specific habitat suitability curves (HSC, sometimes referred to as HSI), the same as a 1D physical habitat model (PHABSIM), and be used to evaluate passage in the bypassed reach.

Boott believes that the application of a 2D model of the bypassed reach will provide the results necessary to address both study requests and provide FERC with sufficient information to complete an environmental assessment.

11.2 Goals and Objectives

The goal of the Instream Flow Habitat Assessment study is to determine an appropriate flow regime that will protect and enhance the aquatic resources in the bypass reach between the Pawtucket Dam and the E.L. Field Powerhouse. Specifically, the objective of this study is to conduct an instream flow habitat study to assess the impacts of a range of Project discharges on the wetted area and optimal habitat for key species, including the quantity and location of suitable habitat.

The specific objectives of this study are to:

- Characterize and map wetted perimeter of the bypass reach over a range of bypass flows;
- Survey and evaluate the water depth and mean channel velocity at transects within the bypass reach over a range of flows; and
- Map and assess the value of aquatic habitat in the bypass reach over a range of flows, focusing on potential habitat for resident species, and spawning and migration habitat or rest/regrouping areas for migratory species.

The goal of the Zone of Passage study is to determine flows in the bypass reach that facilitate safe, timely, and effective fish passage through the Project.

Specifically, the objectives of this study are:

- Complete a detailed survey of the bypass reach;
- Develop a high-resolution, two-dimensional hydraulic model of the bypass reach;
- Release multiple flows from the dam to collect calibration data for the model;
- Simulate additional flows through the bypass reach with the calibrated model; and
- Determine minimum and optimal zone-of-passage flows for the Project.

11.3 Study Area

This study area is the Project's bypass reach from the Pawtucket Dam approximately 0.7 miles downstream to the E.L. Field Powerhouse tailrace.

11.4 Background and Existing Information

At present there is no minimum flow designated for the bypassed reach. When river flows exceed the hydraulic capacity of the E.L. Field units (approximately 4,000 cfs per unit, or 8,000 cfs for both units), excess flows up to approximately 2,000 cfs are routed through the downtown canal system and to the canal units. Any flows in excess of approximately 10,000 cfs (8,000 cfs at E.L. Field plus 2,000 cfs via canals) are passed over the Pawtucket Dam spillway. Pursuant to Article 37 of the Project's existing license, the Project maintains a minimum flow of 1,990 cfs or inflow, whichever is less, as measured immediately downstream from the Project (PAD Section 4.5.1.1).

The reinforced-concrete fish ladder at the base of Pawtucket Dam is designed to allow for controlled fish passage at river flows up to 25,000 cfs. The fishway operates at 500 cfs, including supplemental attraction flow. The fish ladder is a vertical-slot design with 13-foot-wide by 10-foot-long pools. A counting station and fish trap area is provided. Passage through the ladder is not part of the zone of passage study. Since 2013, Boott has worked cooperatively with USFWS and other fisheries agencies to assess and provide passage for eels moving upstream in the mainstem Merrimack River. The efforts have occurred primarily at the fish ladder at the Pawtucket Dam, from mid-July through September, annually.

Common freshwater game species currently found in the in the Lower Merrimack River include yellow perch, chain pickerel, northern pike, brown bullhead, smallmouth and largemouth bass, walleye, common carp and Centrarchid sunfishes [Lower Merrimack River Local Advisory Committee (LMRLAC, 2008)]. There are 43 fish species potentially residing in the Lowell Project reach of the Merrimack River. The fisheries and aquatic resources of the Merrimack River in the vicinity of Lowell Project are managed jointly by MADFW, NHDFG, and the USFWS. These agencies jointly manage the Merrimack

River, including the Lowell Project, as a warm water recreational fishery, as well as for conservation of diadromous species. Alewife, American eel, American shad, sea lamprey, and striped bass are currently managed diadromous species that are found at the Lowell Project during certain life stages [PAD Section 5.4.2 (HDR, 2018)].

Multiple studies have been conducted at the Lowell Project to assess the movement behavior, passage route use, and survival of migratory fish species during the past three decades [PAD Section 5.4.6 (HDR, 2018)]. However most have focused on downstream passage through the Project headgate and fish bypass system or upstream passage and effectiveness of the fish lift system. None have attempted to relate flow in the bypassed reach to upstream migration or aquatic habitat.

11.5 Project Nexus

Diadromous fish utilize the bypassed reach for upstream and downstream migration. In addition, native and non-native riverine species potentially use the reach for spawning and rearing. This study will evaluate the effect of Project operations and associated flow levels on passage, spawning and rearing habitat in the bypassed reach.

11.6 Study Methodology

A standard approach to instream flow analysis since 1980 has been the IFIM method. The IFIM is a structured habitat evaluation process initially developed by the Instream Flow Group of USFWS in the late 1970s to allow comparison of alternative flow regimes for water development projects (Bovee, 1998) (Milhous, 1984). The IFIM involves multiple scientific disciplines and stakeholders, in the context of which hydraulic habitat simulation studies are usually designed and implemented. Critical stakeholder concurrence on study design elements, and overall adequacy for decision-making is one of the principal objectives of IFIM scoping, one of the first identified steps of the methodology (Bovee, 1998). Depending on the desires of the participants, the IFIM can be completely comprehensive for all aquatic aspects of flow regulation or tightly focused on topics of specific concern. This study will utilize 2D hydraulic habitat modeling as one aspect of the IFIM process directed at the evaluation of instream flow needs as related to aquatic habitat. The primary data component of a 2D model is a detailed topographic map of the study area.

The ability of 2D hydrodynamic models to model flow characteristics and features of ecological importance has been well established over the last several years (Waddle, 2010). Depth-averaged 2D hydrodynamic models use a detailed topography of the study site to solve governing equations for conservation of mass and conservation of momentum in two horizontal directions to simulate water depths and velocities allowing for the modeling of complex flow patterns (WaddleEtAl, 2000). Model inputs are bed topography, channel roughness, as well as the upstream and downstream boundary conditions. The most important data requirements are detailed topographic measurements of the streambed at the site.

11.6.1 Study Site Topography

Specific data collection methods to collect detailed topography include:

1. Light Detection and Ranging (LiDAR) to capture out-of-water elevations and features.
2. Bathymetry in watered areas not captured by LiDAR will be surveyed by cataraft or other suitable water craft using Real Time Kinematic (RTK) Global Positioning Station (GPS) and multi-beam ADCP and/or single beam depth sounder.
3. In areas where use of a multi-beam or single-beam depth sounder is prohibitive, due to shallow water or non-navigable channels, an RTK survey will be conducted on foot.
4. In zones of poor GPS reception due to vegetation or other obstructions a total station (manual or robotic) will be used.

11.6.2 Field Calibration Data Collection

The upstream boundary requires an inflow amount, and the downstream boundary requires the corresponding water surface elevation for the given inflow. Water surface elevations at the upstream and downstream extent of the sites will be collected with a crew of two using RTK at a minimum of three to four different flows. Water's edge measurements will be taken on each bank along the length of the site for each flow. These water surface/edge measurements will be used for model calibration and evaluation.

Low calibration flow data collection will occur simultaneously with the topographic survey and should be between 300 cfs and 500 cfs. During low calibration flow substrate polygons, for use as a channel index (substrate) for fish habitat modeling, will be spatially surveyed using an RTK. Fish habitat cover components may also be spatially located if deemed important for habitat modeling. Additional calibration flows in the bypassed reach are anticipated to range between 2,000 cfs and 17,000 cfs.

NMFS suggests collecting depth and velocity using an ADCP at a number of cross sections and randomly throughout the reach at a high calibration flow. Though not a requirement for 2D model calibration, this type of validation data collection could be done at a flow level deemed safe for personnel and equipment. Because this type of data would have to be collected by watercraft, only a small area in the middle of the reach, and the downstream boundary could feasibly be measured, making the utility of the validation data open to discussion.

Considerable effort will be applied to maintaining strict quality control throughout all aspects of field data collection. Boott will also document each flow event with photographs and video which can assist in model calibration.

11.6.3 2D Model Calibration

Boott proposes to use River2D (StefflerandBlackburn, 2002), a two-dimensional depth-averaged model, to simulate depths and velocities, and habitat suitability for the study area over a range of flows determined during final study plan development and scoping. The topographic/bathymetric survey data will be processed in the bed topography editor of the River2D program. The resulting digital elevation model (DEM), or bed file, will then be used as the topographic input for the hydrodynamic model. Boundary conditions are also necessary inputs for the hydrodynamic model; they included the external computational boundary, the inflow discharge at the upstream boundary, and water surface elevations at the outflow boundary. The River2D model uses a finite-element method to perform numerical calculation of flow conditions. This method allows for a variable-density mesh where areas of hydrologic and/or biological significance can be represented in greater detail. Artificial channel extensions of approximately one channel width may be added upstream and downstream of the area of interest in order to minimize boundary condition effects on the modeled area.

Model calibration consists of adjusting the roughness values in the model until a reasonable match is obtained between the simulated water surface elevations and the surveyed water surface elevations and water's edge measurements taken along the study site at a given flow. Models may be calibrated at a single flow and then validated at other flows, or the model can be calibrated at each measured calibration flow.

Once calibrated, the downstream water surface elevation and the inflow of the model will be changed to simulate the flows of interest. Each modeled flow is run to a steady state solution. That is, for a constant inflow, the model is run until there is a constant outflow and the two flows are essentially equal. Typical convergence tolerance is 1% of the inflow

11.6.4 Aquatic Habitat

The fish habitat component of River2D is based on the weighted usable area (WUA) concept used in PHABSIM 1D models. The WUA for the entire site is calculated by expanding the composite suitability index for every point in the model domain with the area associated with that point, and then summing those values for all points. The composite suitability is calculated as the product of suitability values for depth, velocity and channel index (cover and substrate codes).

Target fish species include American shad, river herring (alewife and blueback herring), fallfish, white sucker, freshwater mussels and benthic macroinvertebrates. The final target species list and associated HSC would be developed in consultation with the fisheries agencies. The substrate coding system to be used is dependent on existing HSC.

11.7 Analysis and Reporting

Reports will be generated that include steps taken during field data collection and the resulting DEM for the site; steps taken during the development of the hydrodynamic model including model parameters and calibration results; the resulting depth and velocity maps for each modeled flow; and the results of the habitat modeling as stated above. Boott will produce nodal outputs of habitat suitability values for depth, velocity, channel index (substrate and/or cover), and combined parameters for a number of flows (determined during consultation with agencies) for each species and life stage of interest. Boott will also output image files of the plan view of each habitat parameter suitability and flows for each species/life stage. WUA plots and tables will be created for each species and life stage over a range of flows.

Boott anticipates that the Instream Flow Habitat Assessment and Zone of Passage Study in the Bypassed Reach study report will include the following elements:

- Project information and background
- Study area
- Methodology
- Study results
- Analysis and discussion
- Any agency correspondence and or consultation
- Literature cited

11.8 Schedule, Level of Effort, and Estimated Cost

LiDAR survey and topographic survey would take place in late fall at low flow (no spill). Estimated cost for LiDAR survey and post-processing is $5,000. The topographic survey would be conducted under no-spill conditions and is estimated to require 5 field days and includes one calibration flow. Two to three additional calibration flows would be accomplished when flows and conditions permit. The total estimated range of cost for this study is approximately $100,000 – $125,000.

12 Fish Assemblage Study

12.1 Study Requests

The Commission's June 15, 2018 SD1 identified the following environmental resource issue to be analyzed in the EA for the Project relicensing:

- Effects of continued Project operation on resident and migratory fisheries resources in the impoundment, canal system, bypassed reach, and Merrimack River.

In their study request letter, dated August 10, 2018, the MADFW submitted an informal study request for a fish assemblage assessment.

12.2 Goals and Objectives

The goal of this is study is to characterize the fish assemblage in areas affected by the Lowell Project, specifically the impoundment and bypass reach.

Specific objectives include:

- Conduct field sampling to describe fish assemblage structure, distribution, and abundance within the Project affected area along spatial and temporal gradients; and
- Compare historical records of fish species occurrence in the Project area to results of this study.

12.3 Study Area

The study area includes the mainstem Merrimack River from the Pawtucket Dam to the upper extent of the Project's impoundment located approximately 23 river miles upstream, and the Project's 0.7-mile-long bypass reach.

12.4 Background and Existing Information

Existing relevant information regarding diadromous species presence and seasonality were summarized in Section 5.4 of the PAD (HDR, 2018). The Merrimack River is home to a diverse assemblage of approximately 50 species of fishes, including cold water and warm water species, diadromous species, and introduced gamefish and non-gamefish species. There are 43 fish species potentially residing in the Lowell Project reach of the Merrimack River [see PAD Table 5.4-1 (HDR, 2018), (Hartel, 2002), (TechnicalCommittee, 1997)]. One resident freshwater species, bridle shiner, (*Notropis bifrenatus*), is listed as a Massachusetts species of special concern (CommMA, 2018), and is listed as state threatened in New Hampshire (NHDFG, 2018).

The MADFW, NHDFG, and USFWS jointly manage the Merrimack River, including the Lowell Project, as a warm water recreational fishery, as well as for conservation of diadromous species. The priority species for management at the Lowell Project are American eel, American shad, and blueback herring and alewife (collectively referred to as river herring). American eel and sea lamprey are listed as New Hampshire species of special concern, and river herring are federally listed as a species of concern and are currently in Status Review by NMFS. Boott collects information regarding the abundance of diadromous fishes using the upstream fishways annually [see PAD Table 5.4-2 (HDR, 2018)], and presented the breadth of fish passage studies that have been performed at and/or in the vicinity of the project [see PAD Table 5.4-3 (HDR, 2018)]. Resident fish assemblage data are limited and dated.

12.5 Project Nexus

Project operations have the potential to directly impact fish species life history requirements, biological interactions, and habitat quantity and quality. Because of the roles fish play in aquatic communities, and their ability to move to different environments based on changing conditions, the variety and diversity of fish species found at a given site serves as an indicator of biological integrity and water quality (USEPA, 2018). The results of this study will inform license application documents, FERC's environmental assessment, and the development of reasonable conservation, protection, mitigation and enhancement measures pursuant to the Fish and Wildlife Coordination Act, as amended (16 U.S.C. §661 *et seq*.), the Federal Power Act (16 U.S.C. §791a, *et seq*.), the Clean Water Act (33 U.S.C. §1251 *et seq*.), and the WPA.

12.6 Study Methodology

The study will employ a stratified-random sampling design and multi-gear approach to sample the fish assemblage over three seasons (spring, summer, and fall). Sampling will be preceded by a habitat mapping effort to inform the stratified-randomized sample site selection.

Preliminary aquatic habitat mapping of the impoundment will be conducted and used in conjunction with aquatic habitat data collected for the Bypass Zone-of-Passage Study and Bypass Flow Habitat Assessment to inform the stratified-random design. Aquatic habitat mapping of the impoundment is anticipated to occur during spring\summer 2019, flow dependent.

Impoundment habitat data will be collected on a reconnaissance level for the entire impoundment by boat. A GPS unit will be used to record real-time GPS positions and to delineate aquatic mesohabitat boundaries and to mark other features such as islands, split channels, and tributaries. Mesohabitat characterizations will include:

- riffle – shallow, moderate velocity, turbulent, high gradient, moderate to large substrates (cobble/gravel);

- rapid – shallow, moderate to high velocity, turbulent, chutes and eddies present, high gradient, large substrates or bedrock;
- run – moderately deep to deep, well defined non-turbulent laminar flow, low to moderate velocity, well defined thalweg, typically concave stream geometry, varying substrates, gentle slope
- glide – moderately shallow, well defined non-turbulent laminar flow, low velocity, well defined thalweg, typically flat stream geometry, typically finer substrates, transitional from pool
- pool – deep, low velocity, well defined hydraulic control at outlet
- backwater – varying depth, minimal or no velocity, long backwatered reaches
- impounded – varying depth, low velocity influenced by the presence of a dam
- Nearshore/Shallow: less than 8ft in depth
- Mid-Channel
- Deep water: depths greater than 20ft

12.6.1 Sample Site Selection – Impoundment

The 23-mile-long (37 kilometer) impoundment will be stratified based on mesohabitat characteristics. Each stratum will be delineated in 547-yard (500-meter) segments using Aeronautical Reconnaissance Coverage Geographic Information System (ArcGIS). Sampling locations will be randomly selected and weighted proportional to mesohabitat type frequency (e.g., if 50 percent of a particular geographic reach is shallow, riffle habitat, than 50 percent of the total number of sampling locations for that geographic reach would be randomly placed within that habitat type). As long as habitat is available, efforts will be made to ensure that a minimum of three sampling locations are placed within each strata (i.e., habitat type). A total of twelve, 547-yard (500-meter) segments will be randomly selected within the reach so that approximately 16% of the impoundment will be sampled. The randomized selection will be repeated to place alternative sites in the event that the primary site is inaccessible, or where personnel safety would be compromised by accessing it. The stratified-random site selection process will be repeated for each of three seasonal surveys (spring, summer, and fall).

12.6.2 Sample Site Selection – Bypass Reach

Access to the bypass reach will be by foot and only portable sampling gears will be used. Some areas may be inaccessible due to safety considerations. Delineation and stratified-random sample site selection will be scaled for the shorter, less accessible bypass reach. Each stratum will be delineated in 55-yard (50-meter) segments using ArcGIS. Sampling locations will be randomly selected and weighted proportional to mesohabitat type frequency. As long as habitat is available, efforts will be made to ensure that at least one sampling location is placed within each strata (i.e., habitat type) within the bypass reach. A total of 3 to 5 segments will be randomly selected within the bypass reach. The randomized selection will be repeated to place up to three alternative sites in the event that the primary site is inaccessible, or where personnel safety would be compromised by accessing it. The stratified-random site selection process will be repeated for each of three seasonal surveys (spring, summer, fall). Multiple alternative sampling locations will also be identified by mesohabitat in case a selected sampling station is inaccessible. Due to safety considerations, sampling will be limited to periods of minimum flow to the bypass reach.

12.6.3 Fish Assemblage Sampling Methodology

Sampling techniques for this study include electrofishing (boat, pram [barge], and backpack), gill netting with experimental mesh nets, beach seining, and minnow/eel traps. The gear to be used will be largely dictated by habitat type, but safe access will also be considered. To the extent practical, gear selection will be consistent within a reach (impoundment, bypass). For each sample site, where two general microhabitats [nearshore areas with shallow water and lower flow velocities and Mid-channel areas with deeper water and higher flow velocities (Bain.etAl, 1988)] occur, they will be sampled by applying a multiple gear approach. Standard fisheries techniques will be used for fish sampling [e.g., (Bonar, 2009); (Zale, 2012)].

In the impoundment, boat electrofishing, gillnet sampling, and minnow/eel traps will be the primary sampling techniques for all strata (i.e., habitat types) with adequate water depths and access. However, any randomly selected sites that are too shallow to operate or otherwise inaccessible to an electrofishing boat will be sampled with pram electrofishing and/or beach seining. In the bypass reach, it is anticipated that gear portability and large substrate (boulder, bedrock) will limit gear selection to portable (pram, backpack) electrofishing methods.

12.6.3.1 Boat Electrofishing

Boat electrofishing will be conducted at night to sample nearshore and shallow water microhabitats in the impoundment. Boat electrofishing will be done with a specially outfitted boat with variable voltage / variable pulse rate electrofisher operated to accommodate ambient conductivity. For each 547-yard (500-meter) sample site, the near-shore littoral habitat (< 10-feet deep) will be sampled at night in a general downstream direction (but maneuvering within the sample site to ensure thorough sampling (Yoder.etAl, 2015). Two netters stationed on the bow of the electrofishing boat will net and place stunned fish in an onboard, aerated or circulating ambient water live well for processing once the sample segment is complete. All fish captured will be identified to species, classified by life stage (adult, juvenile, or young-of-year), measured (total length, TL), enumerated, weighed, and released. Large numbers (N>25) of small fish [young-of-year (YOY) or cyprinids less than 100 mm] will be grouped, enumerated, batch-weighed, and representative samples of small and large individuals will be measured. Representative samples of fish that cannot be identified in the field will be retained for laboratory identification. For each sample the date, start and end time, sampling gear type, sampling effort (e.g., seconds fished), mesohabitat type, average depth, average velocity, river flow, water quality parameters (temperature, turbidity, DO, conductivity), predominant substrate, cover density and proportion of vegetation cover will be recorded to a field data sheet. The start point, end point, and boat track for each sampling station will be geo-referenced using a handheld GPS and uploaded to a Geographic Information System (GIS) database to produce geo-referenced maps of sampling effort.

12.6.3.2 Pram/Backpack Electrofish

For all strata (i.e., habitat types) where the use of boat electrofishing is inappropriate due to water depths or access, portable (pram or backpack) electrofishing sampling will be conducted. Preliminarily, it is assumed that all bypass reach sites will be sampled with portable electrofishing gear. Sampling will be conducted by anchoring a fine mesh seine at the downstream end of the sample station. A pram or backpack electrofishing unit and two to three technicians will move in a downstream direction towards the seine while actively netting stunned individuals and kicking the substrate to drive additional stunned individuals towards the collection net. To ensure crew safety while wading in moving water habitat, pram and backpack electrofishing sampling will be conducted during daylight hours. The electrofishing track for each sample will be geo-referenced, physical and habitat data will be recorded, fish catch will be processed as described above for boat electrofishing samples.

12.6.3.3 Seining

For any strata (i.e., habitat type) such as shallow shoreline locations where boat access is not feasible and the use of pram or backpack electrofishing methods are less effective (e.g., shallow flat habitat with limited cover) a seine net will be used to assess the fish assemblage. One end of a 100-ft long, 6-ft deep, 1/4-inch mesh seine net will be anchored on the shoreline and the net will be extended out and along the shoreline in an upstream direction, and then pulled 180 degrees pivoting around the anchored end in a downstream direction to return to the shoreline. Care will be taken to ensure that the lead line maintains contact with the bottom substrate to avoid fish escapement under the net. Seine sampling will be conducted during the daylight hours. Field crews will record the date and time and, start and end coordinates (of the unanchored end of the net) for each pull. Physical and habitat data will be recorded, and fish catch will be processed as described above for boat electrofishing samples.

12.6.3.4 Gillnetting

The use of experimental gill nets will supplement boat electrofishing within all strata (i.e., habitat types) with adequate water depths and flow conditions to allow for proper performance of the nets, specifically deep and mid-channel microhabitats. Gillnet sets will be made at a suitable location within or adjacent to the sample site selected. Gillnets will be an experimental design and will be constructed of 4 to 5 panels of increasing mesh size (e.g., 1.5, 2.0, 2.5, 3.0, and 3.5-inch stretch mesh). Gillnets will be set during evening/nighttime hours when fish species are most susceptible to the gear due to the reduced visual avoidance. Gillnets will be deployed perpendicular to the shoreline in areas where water depths are greater than the net height and capture area is maximized. Nets will be set and fished for an approximate four-hour period prior to retrieval to minimize netting mortality. Net set coordinates and the date and time of each set and pull will be recorded to a field datasheet. Physical and habitat data will also be recorded as described for boat electrofishing, and the fish catch will be processed following the same methods as described above for boat electrofishing samples.

12.6.3.5 Minnow traps/eel pots

The use of combination minnow trap/eel pots will supplement other gears in deeper habitats (>10 ft) where electrofishing will not be effective and small fish and eels will not be susceptible to gillnets. The traps will be standard 2.5 feet long galvanized wire mesh (0.25 square inch) cylinders with two entry fykes. Traps will be baited (e.g., herring, cat food, canned fish) and weighted to remain on station for the duration of their soak time. For each sample site (with appropriate depths), one to two traps will be deployed in depths >10 ft and fished simultaneously with gillnets for an approximate four-hour period. Trap set coordinates, type of bait, and the date and time of each set and pull will be recorded to a field datasheet. Physical and habitat data will also be recorded as described for boat electrofishing, and the fish catch will be processed following the same methods as described above for boat electrofishing samples.

12.7 Analysis Reporting

All data will be recorded on field data sheets. Upon return from the field, data sheets will be reviewed for quality assurance and archived. Results of this study will be presented in graphical and tabular format summarizing length, weight, and size class of catch. Species occurrence, distribution, and relative abundance will be displayed on maps of the sampled study areas. Abundance data in the form of catch standardized by unit of effort (seconds of electrofishing, net/trap-hours, and number of seine hauls seconds, CPUE) will be calculated for each species, sampling station, and sampling method, and descriptive statistics calculated by species, as well as by species classified by size groups. The Shannon-Weiner index of diversity will also be calculated. The report will include a comparison with available historical records for the reaches sampled.

Boott anticipates that the Fish Assemblage Study report will include the following elements:

- Project information and background
- Study area
- Methodology
- Study results
- Analysis and discussion
- Any agency correspondence and or consultation
- Literature cited

12.8 Schedule and Level of Effort

The study will require preliminary habitat mapping and three seasons of sampling under the assumption that river discharge conditions during sampling periods fall within the 25th to 75th percentile for weekly averages. Habitat mapping and stratified-random sample site selection will be conducted as early as possible in spring 2019. Provided appropriate flows and therefore timely mapping and site selection, all three seasonal sampling periods may occur during 2019, however if habitat mapping, including of the bypass reach (to be conducted in bypass zone-of-passage/bypass flow habitat assessment), cannot be completed in time for spring sampling, or if any of the seasonal sampling events cannot be completed due to anomalous physical characteristics, then sampling will continue in 2020. The preliminary estimated cost for this study is $75,000 – $100,000.

13 Recreation and Aesthetics Study

13.1 Study Requests

The Commission's June 15, 2018 SD1 identified the following environmental resource issues to be analyzed in the EA for the Project relicensing:

1. Effects of continued Project operation on recreational use in the Project area, including the adequacy of existing recreational access, and the adequacy and capacity of existing recreational facilities.

2. Effects of continued Project operation on aesthetic resources in the Project area, including the historic industrial context of the Project structures and features.

AW, MADCR, and NPS, submitted study requests related wholly or in part to recreation use and needs and aesthetics in the Project area as shown in Table 13-1, although neither the NPS nor MADCR requested specific study methodologies.

Table 13-1. Recreation Use and Needs Study Requests

Requestor	Requested Study	Date
AW	Recreation Facilities, Use, and Aesthetics Study	August 8, 2018
MADCR	Recreational Use Data	August 15, 2018
NPS	Water Level and Flow Effects on Recreation Study	August 14, 2018
NPS	Vegetation and Aquatic Trash Management Study	August 14, 2018

AW requested a Recreation Facilities, Use, and Aesthetics Study to meet a number of objectives including evaluating the condition of existing recreational facilities, access, and future demand. AW also requested that Boott develop a Recreation Management Plan for the Project.

The MADCR requested a study documenting how visitors currently use the Project areas and if the facilities are Americans with Disabilities Act (ADA) accessible. MADCR also requested Boott map protected recreational lands in the vicinity of the Project and identify locations where MADCR property needs to be accessed for routine or emergency maintenance.

The NPS requested a study to assess potential effects of water levels and flow rates on existing recreational facilities and evaluate expanded recreational access to and within the canals. The NPS also recommended that Boott collect information regarding cyclical vegetation and trash management and collect public feedback regarding vegetation growth on historic canal walls and waterborne trash to understand areas of particular concern.

13.2 Goals and Objectives

The goals of this study are to (a) document recreation resources and recreational activities that occur in the Project, (b) determine the adequacy and capacity of existing recreational facilities to accommodate existing recreational activities as well as proposed new recreational activities, (c) assess potential effects of water levels and flow rates on existing recreational facilities, (d) assess the potential for expanded access to the canal system for recreation, and (e) identify areas within the canal system where vegetation growth on historic canal walls and waterborne trash are a concern.

The specific objectives of the study are to:

- Identify existing recreation facilities in the Project area;
- Quantify current recreational use based on recent and new surveys and interviews and consultation with stakeholders, regional and statewide plans, and other available data (including NPS and MDCR planning documents);
- Identify proposed recreational uses based on surveys and interviews in consultation with stakeholders;
- Evaluate the potential effects of continued operation of the Project (including water levels and flow rates) on recreation resources and activities in the Project area;
- Assess the potential for expanded recreational access to the canal system in consultation with the NPS;
- Identify areas of concern related to waterborne trash and vegetation growth on historic canal walls; and
- Gather information on the condition of Boott's recreation facilities and identify any need for improvement.

13.3 Study Area

Boott proposes a general study area that includes the FERC Project Boundary and adjacent recreation facilities.

13.4 Background and Existing Information

The Merrimack River provides extensive recreational opportunities. Activities such as boating, canoeing, kayaking, rowing, fishing, and swimming take place on the river, including the Project's 23-mile-long impoundment. The surrounding vicinity is used for walking, hiking, cross-country skiing, picnicking, bird watching, nature study, and overall enjoyment of scenic views. Existing relevant and reasonably available information regarding recreation in the Project vicinity was summarized in Section 5.8 of the PAD (HDR, 2018).

There are a number of parks and conservation areas located in the vicinity of the Project and six boat access facilities that provide access to the Project impoundment. Most notably, the entire 5.5-mile-long canal system, supporting historic structures, and equipment, along with paved recreational trails constructed immediately adjacent to the canals are recreational resources within the Project area and within the boundary of the Lowell National Historical Park. The NPS offers seasonal ranger-guided canal and river boat tours which provide unprecedented access to the historic canals. Additionally, the canal system is located within the boundary of the Lowell Locks and Canals National Historic Landmark District, Lowell Water Power System National Historic Civil Engineering Landmark, and Lowell Power Canal System and Pawtucket Gatehouse National Historic Mechanical Engineering Landmark.

The Lowell Heritage State Park, established in 1974 as a precursor to the Lowell National Historical Park, is also located within the City of Lowell and is comprised of linear greenways along the Merrimack River and canal system and a collection of historic buildings and structures related to the industrial development of the city. The Lowell Heritage State Park is operated by the MADCR and features exhibits created in partnership with the NPS. The park also offers cycling, boating, field sports, fishing, a swimming pool, and other recreational activities.

There is one FERC-approved recreation facility at the Project, the E.L. Field Powerhouse Visitor Center. The Visitor Center offers a secured view of the interior of the turbine gallery and an interpretive display which provides information regarding the development, history, and operation of the Project, nearby historic, natural, cultural, recreational resources, and other items of interest.

Boott currently documents recreation use levels at the FERC-approved Project Visitor Center, and at recreation amenities adjacent to the Project including the facilities provided at the Lowell Heritage State Park. The E.L. Field Powerhouse Visitor Center had a capacity utilization of 5 percent, and the Lowell Heritage State Park amenities adjacent to the Project had a capacity utilization of 40 percent or below in 2014.

A significant component of a visitor’s experience to the Lowell National Historical Park is related to the unique aesthetic of the park unit. The intact canal system and large, red-bricked historic mill buildings create an “urban canyon” through the center of the city. The impacts of waterborne trash and vegetation can include the degradation of visual and aesthetic quality of the canals and park unit. The amount and type of vegetative growth and waterborne trash that accumulates within the Project Boundary can vary according to several factors including season, Project operations, and the magnitude and duration of the flow events. Accumulated waterborne trash includes material floating on the impoundment surface and/or found on the surface of the canal system.

13.5 Project Nexus

The principal facilities that comprise the Lowell Project are located in a largely urban area, and Project features are within the Lowell National Historical Park and Lowell Heritage State Park. Project facilities, including the canal system and historic infrastructure, attract tourists and feature prominently in recreational activities within both parks. Project operations have the potential affect recreational use and aesthetics within the National Historical Park, the Lowell Heritage State Park, the City of Lowell, and the region. The results of this study, in conjunction with existing information, can be used to inform resource discussions within the license application materials.

13.6 Methodology

Boott intends to conduct a Recreation and Aesthetics Study in accordance with the specific methods described below.

13.6.1 Literature Review

Prior to conducting a field inventory, Boott will conduct desktop research and a literature review to identify and describe recreational uses in the Project area, including (but not limited to) whitewater boating, canoeing, kayaking, fishing, swimming, walking, and architectural/historical tours. As a component of this research, Boott will review existing recreational uses, facilities management plans (as applicable), limitations, and regulations applicable to the Project area including, but not limited to:

- Annual use records and planning documents available from the NPS for the Lowell National Historical Park;
- Annual use records and planning documents available from the MADCR for the Lowell Heritage State Park;
- Qualitative data from AW related to whitewater boating in the vicinity of the Project;
- The Massachusetts Statewide Comprehensive Outdoor Recreation Plan (SCORP);
- The New Hampshire SCORP;
- The Massachusetts Recreational Trails Program Guide; and
- Applicable guidance documents from NPS related to the Lowell National Historical Park.

Additionally, Boott will conduct a records search and literature review on the historical and current practices regarding vegetation growth and waterborne trash. This information will be used to assess potential impacts related to recreation and aesthetic resources in the Project area.

13.6.2 Field Inventory

Boott will conduct a field inventory to document existing formal and informal recreation facilities, including the Project's FERC-approved recreation site. In support of this inventory, Boott will conduct informal interviews with recreationists to identify informal recreation and access areas at the Project. Boott will map and document popular access points to the Merrimack River, including formal and informal boat launches and angler access areas. Locations of recreational facilities will be recorded using GPS. Boott will also record other relevant and applicable information for each recreational facility including:

- A description of the type and location of existing recreation facilities;
- Ownership;
- The type of recreation provided (boat access, angler access, picnicking, etc.);
- Existing amenities and sanitation;
- The type of vehicular access and parking (if any);
- Suitability of facilities to provide recreational opportunities and access for persons with disabilities (i.e., compliance with current ADA standards for accessible design); and
- Photographic documentation of recreation facilities.

13.6.3 Collection of Visitor Use Data

Boott will collect visitor use regarding existing formal and informal recreation facilities through a combination of surveys, personal interviews, and field reconnaissance.

13.6.3.1 Personal Interviews and Field Reconnaissance

Boott will conduct field reconnaissance and visitor-intercept interviews with respondents at the following recreation facilities at or adjacent to the Project during the prime recreational season from May 1, 2019 through October 1, 2019. Boott will consult with the NPS, AW, and MADCR to identify specific locations for field reconnaissance and visitor-intercept surveys. Such locations may include:

- Lowell Heritage State Park
- Merrimack River Trail
- NPS Walkway Tours
- Riverwalk Ramble
- Waterpower Walk
- Heritage Hike
- Northern Canal Walkway

- Redevelopment Rove
- Boat access facilities on the Project impoundment
- Lowell Heritage State Park- Rourke Brothers Boat Ramp (Lowell, MA)
- Chelmsford Boat Access (Chelmsford, MA)
- Merrill Park (Hudson, NH)
- Greeley Boat Ramp (Nashua, NH)
- Depot St. Boat Ramp (Merrimack, NH)
- Moore’s Falls Conservation Area (Litchfield, NH)
- E.L. Field Powerhouse Visitor Center[3]

Following consultation with stakeholders, Boott will develop a list of reconnaissance and interview locations and will file the final list with the Commission and distribute to AW, NPS, and the MADCR.

Surveys will be conducted during normal daylight hours. Boott intends to conduct surveys on two random weekdays and two random weekend days on a monthly basis between May and October.

Boott expects that one team of two technicians will rotate between each of the recreation sites selected in consultation with stakeholders, and will spend approximately one hour at each site conducting interviews. Boott will conduct in-person surveys of individual recreationists and groups. Prior to rotating to the next site, technicians will record relevant conditions, including observed recreational activities, estimated number of vehicles, and number of recreational users. General information regarding date, time, and weather conditions will also be recorded by technicians. Interviews at informal recreation areas will be conducted if recreational users are observed at those locations.

Boott expects to develop an interview/survey using concepts from other germane relicensings. The interview/survey will address topics such as (but not necessarily limited to):

- General user information;
- Age group, resident/visitor;
- Purpose and duration of visit;
- Distance traveled;
- Day use/overnight lodging;
- History of visiting the site or area;

[3] The E.L. Field Powerhouse Visitor Center is located in the powerhouse, therefore tours are scheduled in advance. Boott will record visits, number of participants, and administer surveys.

- Types of recreational activities respondents participated in or plan to participate in during their visit; including primary and secondary recreation activities;
- Reasons for choosing the site or area;
- Areas of concern regarding vegetation growth on historic canal walls and waterborne trash;
- Prospective recreational enhancements or improvements, including access to the canal system for recreational uses; and
- Other recreational sites that respondents visited or intent to visit during their trip.

13.6.3.2 Online Survey

In addition to the personal interviews, Boott will develop an online version of the interview questions that will allow respondents to provide survey responses electronically. The online survey will allow respondents who do not wish to complete an interview or survey in the field to complete an online version of the survey at a later time or upon returning home from their visit.

To inform the recreating public about the availability of the online survey, Boott will provide handouts to recreationists with the relevant information on how to complete the online survey. Boott will also invite stakeholders such as AW, NPS, and MADCR, and river outfitters to share a link to the survey and instructions on their respective websites and to notify their constituents and customers about the survey.

13.6.4 Evaluation of Expanded Recreational Access in Project Canals

NPS and NPS partners have expressed interest in new, different, and expanded recreational access to and within the Project canals. Boott will consult with the NPS to determine which segments are most suitable for various recreational opportunities based on the NPS's plans for developing recreational access within the Lowell National Historical Park and the of visitor use data collected pursuant to Section 13.6 of this study plan.

Boott will conduct an evaluation of prospective recreation access at areas identified in consultation with the NPS. This evaluation will take into account:

- Potential options for improving canal system access, such as operational changes or other measures;
- Infrastructure enhancement that may be required to provide safe public access to the canal system and how such improvements may affect aesthetic and historic resources;
- Public safety concerns associated with canal access, including coordination with the NPS boat tours and lock operations; and

- Cost estimates for developing recreational access to the Project's canal system.

13.6.5 Documentation of Current Water Levels and Flows

Boott will document current water levels and flows by collecting photos, videos, and from direct observations of flows under varying flow conditions. Boott will use this information along with the results of the Operation Analysis of the Lowell Canal Study to analyze water levels and flows associated with Project operations to determine the number of days that canal walkways would be closed seasonally due to flows resulting from Project operations. This information will be used to assess how operations of the new crest gate system may potentially affect recreation facilities and activities, including the Northern Canal Walkway and NPS boat operations.

13.6.6 Visual Surveys for Vegetation and Waterborne Trash

Boott will survey the Lowell canal system on foot or by boat to visually inspect and document vegetation and waterborne trash within the study area. Observations will be recorded regarding vegetation type, depositional setting, and evidence and location of waterborne trash. Data collected during this portion of the survey will include detailed field notes, site sketch maps, and photographic documentation. Boott will map vegetation growth along the historic canal walls and concentrations of waterborne trash using GPS. Using the results of this task, Boott will develop maps showing locations of large accumulations of vegetation and waterborne trash present in the study area.

13.7 Analysis and Reporting

Boott will prepare a report summarizing the results of the Recreation and Aesthetics Study to include information presenting the results of the literature review, field inventory, personal interviews and field reconnaissance, online surveys, evaluation of expanded recreational access in Project canals, documentation of current water levels and flows, and visual surveys for vegetation and waterborne trash. Boott anticipates the Recreation and Aesthetics Study Report will include the following elements:

- Project Introduction and Background
- Study Area
- Methodology
- Study Results
- Analysis and Discussion
- Location maps, GIS analysis, and photos
- Any agency correspondence and consultation
- Literature cited

The results of the study will be used to evaluate the potential effects of continued operation of the Project on recreation and aesthetic resources and recreational activities in the Project area and form the framework for a Recreation Management Plan.

13.8 Schedule, Level of Effort, and Estimated Cost

Boott anticipates conducting background literature reviews, consultation with the NPS regarding canal access, and an evaluation of expanded canal access beginning in March 2019. Visitor use data collection, reconnaissance surveys, an inventory of recreation facilities, documentation of current water levels and flows, and visual surveys for vegetation and waterborne trash, will be conducted during the peak recreation season of 2019 (May 1 – October 1). Boott anticipates that this study will cost approximately $70,000 – $80,000 to complete.

14 Historically Significant Waterpower Equipment Study

14.1 Study Requests

The Commission's June 15, 2018 SD1 identified the following environmental resource issue to be analyzed in the EA for the Project relicensing:

- Effects of continued project operation and maintenance on historic resources, archaeological resources, and traditional cultural properties that are included or may be eligible for inclusion in the National Register of Historic Places.

The NPS subsequently submitted a formal request for a Historically Significant Waterpower Equipment Study on August 14, 2018.

14.2 Goals and Objectives

The goal of this study is to identify and document historically significant waterpower equipment in consultation with the NPS. The specific objectives of this study are as follows:

- Consult with the NPS and conduct a site visit to identify historically significant waterpower equipment of interest to the NPS for potential future interpretation, exhibition, or as scrap equipment to maintain and operate other historic machinery;
- Photo-document historically significant waterpower equipment identified in consultation with the NPS;
- Conduct background research on the history of identified waterpower equipment, including designer/engineer, dates of manufacture and use, and an explanation of how the equipment was or is used;
- Document current ownership of historically significant waterpower equipment; and
- Prepare a report summarizing the results of the Historically Significant Waterpower Equipment Study.

14.3 Study Area

The study area includes the Project's historic canal system, associated flow control structures and the Project's civil works within the Project Boundary.

14.4 Background and Existing Information

The Lowell Hydroelectric Project's primary features are located along the Merrimack River in the City of Lowell, Massachusetts. The City of Lowell was founded in the early 1820s by Boston merchant capitalists and became one of the most significant planned industrial cities in America (Hay, 1991). Lowell's factory system, which used the waterpower of the Merrimack River, incorporated new technologies to provide for the mass production of cotton cloth in mills throughout the city (LowellNationalHistoricalPark, 1981). Lowell established the pattern for large-scale waterpower development for the next 50 years (Hay, 1991).

Several Project facilities are located within overlapping locally, state, and nationally designated parks and historic properties/preservation districts. The Project's Pawtucket Dam and E.L. Field Powerhouse are located along the mainstem of the Merrimack River. The Project also includes a two-tiered network of man-made canals which extend throughout downtown Lowell. The 5.5-mile-long canal system provides flow to the Project's Hamilton, Assets, Bridge Street, and John Street developments. The Hamilton, Assets, Bridge Street, and John Street power stations and turbines are housed in large old mill buildings. The mill buildings are not included in the Project; the Project Boundary includes only the turbines and associated waterways and equipment at these downtown mill sites. In addition to the Pawtucket Dam and hydroelectric developments, the Project also includes miscellaneous civil works in the City of Lowell, including the Guard Lock and Gates, Moody Street Feeder Gatehouse, Lawrence Dam, Hall Street Dam, Tremont Wasteway, Lower Locks and Dam, Swamp Locks and Dam, Merrimack Dam and Merrimack Gate, Rolling Dam, and the Boott Dam.

The canal system, the downtown mill sites, and many of the Project's civil works, are contributing resources to Lowell Locks and Canals National Historic Landmark (NHL) District. The canal system and many Project facilities are also located within the Lowell National Historical Park and larger Lowell Historic Preservation District[4]. The Lowell National Historical Park was established by Congress in 1978 to "preserve and interpret the nationally significant historical and cultural sites, structures, and districts in Lowell, Massachusetts, for the benefit and inspiration of present and future generations." The park is by design a partnership park in which federal, state, and local governments as well as the private sector and local community carry out the legislative intent of the park unit. The Lowell National Historical Park is also listed on the National Register of Historic Places (NRHP), and certain properties within the park overlap with properties in the NHL District.

The Lowell Heritage State Park, established in 1974 as a precursor to the Lowell National Historical Park, is also located within the City of Lowell and is comprised of

[4] The Lowell Historic Preservation District surrounds the Park as a buffer zone and enables federal assistance in the preservation and revitalization of Lowell, while the Park consists of the areas intended for intensive visitor use in the interpretation of Lowell and its canal system (MADCR, 2014).

linear greenways along the Merrimack River and canal system and a collection of historic buildings and structures related to the industrial development of the city. These buildings and structures include Project features and properties located within the NHL District. The Lowell Heritage State Park is operated by the MADCR and features exhibits created in partnership with the NPS (MADCR, 2018). With the exception of the Rynne Bathhouse, all of the built resources within the Lowell Heritage State Park fall within the Lowell Historic District, designated by the City of Lowell to "…ensure that development activities within the district are consistent with the preservation of its 19th century setting" (MADCR, Resource Management Plan: Lowell/Great Brook Planning Unit, 2014). Portions of the Lowell Heritage State Park also overlap with the Lowell Locks and Canals NHL District and the Lowell National Historical Park.

Significant prior research and studies have been conducted to document historic buildings and structures within the City of Lowell, including Project facilities. In 1976, the Historic American Engineering Record (HAER) documented the history of the canal system in Lowell. The HAER study included detailed narratives, photographs, drawings, and maps of the historic canal system (NPS 2018). The Lowell National Historical Park and Historic Preservation District Cultural Resources Inventory (Shelpley, 1981) provides a comprehensive and detailed inventory of historic buildings and structures within the park unit and surrounding preservation area. Later studies, including the 1984 HAER documentation of the Boott Cotton Mills Complex, documented specific resources within the park unit. While these studies have documented historically significant buildings, structures, and some of the hydroelectric equipment associated with the Project, no systematic survey of historically significant waterpower equipment associated with the Project has been conducted.

14.5 Project Nexus

The Lowell Hydroelectric Project is an operating hydroelectric project that requires routine maintenance. Boott maintains, repairs, and replaces mechanical and control equipment at the Project on an as-needed basis. Additionally, Boott continuously evaluates the maintenance and operation of Project facilities to maximize operational efficiency and safety. Accordingly, Boott may occasionally identify historic waterpower equipment or facilities that are no longer necessary for normal or efficient Project operations or which require replacement.

As described above, several Project facilities are located within the Lowell National Historical Park. Activities such as replacing mechanical equipment or controls, decommissioning Project facilities, or discontinuing maintenance of equipment that is no longer required for safe and efficient Project operations may have an adverse effect on historically significant waterpower equipment. Such activities could unintentionally effect the NPS's ability to preserve and interpret the historic structures and stories of the Industrial Revolution and its legacies in Lowell (NPS, 2017).

14.6 Study Methodology

14.6.1 Site Visit and Consultation

Boott will coordinate with the NPS to conduct a site visit and visual inspection of Project facilities, including powerhouses and civil works. The purpose of the site visit will be to identify, in consultation with the NPS, historically significant Project waterpower equipment that is recommended for additional documentation. Based on consultation with the NPS, Boott will develop a list of equipment to document.

14.6.2 Photography and Documentation

14.6.2.1 Photography

Boott will digitally photo-document historically significant waterpower equipment identified in consultation with the NPS. For this task, Boott will retain an architectural historian or other professional experienced in photo-documenting historic industrial and mechanical equipment. While specific photos will depend on the nature and type of equipment, Boott intends to generally capture the following photographs for equipment identified in consultation with NPS:

- Any extant machinery and equipment, also capturing the spatial arrangements;
- Machinery details, such as the governor on a turbine, valves, or other details that reveal a machine's function;
- Power transmission systems, such as line shafting; and
- General views and details of structural framing systems.

14.6.2.2 Documentation

To the extent possible, Boott will research, document, and summarize relevant information of the history of significant waterpower equipment, including designer/engineer, dates of manufacture and use, and an explanation of how the equipment was or is used. This historical research and documentation will be conducted by a qualified architectural historian with experience conducting research and documentation of historic industrial equipment. Boott will also document current equipment ownership.

14.6.3 Analysis and Reporting

Boott will develop a Report on Historically Significant Waterpower Equipment that includes photographs and the historical documentation of waterpower equipment. The report will also summarize current equipment ownership. Boott anticipates the Recreation and Aesthetics Study Report will include the following elements:

- Project Information and Background
- Study Area
- Methodology
- Study Results
- Analysis and Discussion
- Location maps, GIS analysis, and photos
- Any agency correspondence and consultation
- Literature cited

Boott anticipates developing a Historic Properties Management Plan (HPMP) to describe how the licensee will consider and manage historic properties within the Project's area of potential effects during the term of the new license. Information presented in the Report on Historically Significant Waterpower Equipment will inform the development of the HPMP.

14.7 Schedule, Level of Effort, and Estimated Cost

Boott anticipates that a site visit and consultation with the NPS will take place in April and May of 2019. Photography and documentation of historically significant waterpower equipment is expected to be conducted between June and September of 2019, and Boott anticipates filing the Report on Historically Significant Waterpower Equipment with the Commission concurrent with the ISR in March 2020. Boott estimates the cost of the Historically Significant Waterpower Equipment Study to be approximately $25,000 – $35,000.

15 Resources, Ownership, Boundaries, and Land Rights Study

15.1 Study Requests

The study area will include the Project's canal system and associated infrastructure within the FERC Project Boundary in the City of Lowell. The Commission's June 15, 2018 SD1 identified the following environmental resource issue to be analyzed in the EA for the Project relicensing:

- Effects of continued Project operation on land use in the Project area.
- Effects of continued Project operation and maintenance on historic resources, archaeological resources, and traditional cultural properties that are included or may be eligible for inclusion in the National Register of Historic Places.

The NPS subsequently submitted a formal request for a Resources, Ownership, Boundaries, and Land Rights Study on August 14, 2018.

15.2 Goals and Objectives

Ownership and use of the canal system is complex. There are often several entities (e.g., Boott, MADCR, and NPS) with land rights or other entitlements granting authority to access, maintain, or utilize the canal system.

The goal of this study is to determine current ownership of resources within the canal system and Project Boundary, and document maintenance responsibilities, access rights, and FERC jurisdiction. The specific objectives of this study are as follows:

- Determine the current ownership of resources within the canal system in a comprehensive manner;
- Record maintenance responsibilities and obligations to resources within the canal system;
- Clarify FERC jurisdiction; and
- Document recreational, educational, or other land access rights to resources within the canal system.

The information collected through this study can be used to inform and define maintenance responsibilities in the Project Boundary.

15.3 Study Area

For Project land ownership and rights, the study area will include the Project's canal system and associated infrastructure within the FERC Project Boundary in the City of

Lowell, as well as relevant properties immediately adjoining the FERC Project Boundary necessary to define Boott's access rights.

15.4 Background and Existing Information

Ownership, boundaries, and land/access rights within the FERC Project Boundary in downtown Lowell are complex. The Project is situated within several different and overlapping parks, and preservation/conservation districts. The canal system, the downtown mill sites, and many of the Project's civil works, are contributing resources to Lowell Locks and Canals National Historic Landmark (NHL) District. The canal system and many Project facilities are also located within the Lowell National Historical Park and larger Lowell Historic Preservation District. The park is by design a partnership park in which federal, state, and local governments as well as the private sector and local community carry out the legislative intent of the park unit. The Project's Hamilton, Assets, Bridge Street, and John Street power stations and turbines are housed in large old mill buildings within the Lowell National Historical Park and Lowell Historic Preservation District. The mill buildings are not included in the Project; the Project Boundary includes only the turbines and associated equipment at these downtown mill sites.

The Lowell Heritage State Park, established in 1974 as a precursor to the Lowell National Historical Park, is also located within the City of Lowell and is comprised of linear greenways along the Merrimack River and canal system and a collection of historic buildings and structures related to the industrial development of the city. These buildings and structures include Project features and properties located within the NHL District and National Historical Park. The Lowell Heritage State Park is operated by the MADCR and features exhibits created in partnership with the NPS (MADCR, 2018). With the exception of the Rynne Bathhouse, all of the built resources within the Lowell Heritage State Park fall within the Lowell Historic District, designated by the City of Lowell to "…ensure that development activities within the district are consistent with the preservation of its 19th century setting" (MADCR, 2014).

15.5 Project Nexus

The Lowell Hydroelectric Project is an operating hydroelectric project situated within several different and overlapping parks and preservation/conservation districts that are managed by various federal and state entities. Continued operation of the Project has the potential to influence the management and maintenance of the structures associated with these parks and districts. In addition, the continued operation of the Project has the potential to effect the historic and archaeological resources managed by these various entities. Confirming which parties have authority to maintain and use and/or an obligation/right to maintain/use the canal system associated with the Project will inform the development of license requirements as well as roles and responsibilities with respect to maintenance of the historic canals.

15.6 Methodology

15.6.1 Review Existing Information

Boott will work with NPS, MADCR, City of Lowell, and private entities to compile and review available land rights documentation to obtain a better understanding of the rights and responsibilities related to resources within the Project Boundary. As feasible, this information will be obtained from title and land records, existing legislation, and other legal documents.

A summary of potential information Boott expects to review for the study area includes the following:

- Land ownership and mapped information in GIS;
- Property and land rights obtained by Boott, the NPS, MADCR, City of Lowell, and private entities;
- Property boundary survey information;
- Rights-of-way;
- Property title information;
- Land easements;
- Any existing maintenance agreements between entities;
- Any other relevant ownership and land rights information;

15.7 Schedule, Level of Effort, and Estimated Cost

Boott will initiate consultation with the NPS, MADCR, City of Lowell, and private entities regarding available property ownership and rights information in early 2019. Boott expects that this study will require the review of complex ownership and title information in coordination with the NPS, MADCR, City of Lowell, and private entities. As such, Boott anticipates that this study could take up to two years to complete. Boott estimates the approximate cost of this study as $150,000.

16 Water Level and Flow Effects on Historic Resources Study

16.1 Study Requests

The Commission's June 15, 2018 SD1 identified the following environmental resource issue to be analyzed in the EA for the Project relicensing:

- Effects of continued project operation and maintenance on historic resources, archaeological resources, and traditional cultural properties that are included or may be eligible for inclusion in the National Register of Historic Places.

The NPS subsequently submitted a formal request for a Water Level and Flow Effects on Historic Resources Study on August 14, 2018.

16.2 Goals and Objectives

The primary objective of this study is to evaluate potential Project effects to historic resources resulting from the operation of the new crest gate system at the Project.

Specific objectives of the study are:

- Evaluate how Project operations, including manipulation of the new crest gate system, canal headgates, spillways, locks, fish passage structures, and generating units will change water levels in any location within the canal;
- Determine the extent to which water flows or elevations are having an effect on historic resources; and
- Conduct a structural assessment of the Great River Wall.
- Identify potential impacts of current Project operations on nationally significant historic resources, including a structural assessment of the Great River Wall.

16.3 Study Area

The study area includes the Project's canal system and associated Project infrastructure within the FERC Project Boundary in the City of Lowell.

16.4 Background and Existing Information

The Lowell Hydroelectric Project's primary features are located along the Merrimack River in the City of Lowell, Massachusetts. The City of Lowell was founded in the early 1820s by Boston merchant capitalists and became one of the most significant planned industrial cities in America (Hay, 1991). Lowell's factory system, which used the waterpower of the Merrimack River, incorporated new technologies to provide for the mass production of cotton cloth in mills throughout the city (LowellNationalHistoricalPark, 1981). Lowell established the pattern for large-scale waterpower development for the next 50 years (Hay, 1991).

Several Project facilities are located within overlapping locally, state, and nationally designated parks and historic properties/preservation districts. The Project's Pawtucket Dam and E.L. Field Powerhouse are located along the mainstem of the Merrimack River. The Project also includes a two-tiered network of man-made canals which extend throughout downtown Lowell. The 5.5-mile-long canal system provides flow to the Project's Hamilton, Assets, Bridge Street, and John Street developments. The Hamilton, Assets, Bridge Street, and John Street power stations and turbines are housed in large old mill buildings. The mill buildings are not included in the Project; the Project Boundary includes only the turbines and associated equipment at these downtown mill sites. In addition to the Pawtucket Dam and hydroelectric developments, the Project also includes miscellaneous civil works in the City of Lowell, including the Guard Lock and Gates, Moody Street Feeder Gatehouse, Lawrence Dam, Hall Street Dam, Tremont Wasteway, Lower Locks and Dam, Swamp Locks and Dam, Merrimack Dam and Merrimack Gate, Rolling Dam, and the Boott Dam.

The canal system, the downtown mill sites, and many of the Project's civil works, are contributing resources to Lowell Locks and Canals National Historic Landmark (NHL) District. The canal system and many Project facilities are also located within the Lowell National Historical Park and larger Lowell Historic Preservation District. The Lowell National Historical Park was established by Congress in 1978 to "preserve and interpret the nationally significant historical and cultural sites, structures, and districts in Lowell, Massachusetts, for the benefit and inspiration of present and future generations." The park is by design a partnership park in which federal, state, and local governments as well as the private sector and local community carry out the legislative intent of the park unit. The Lowell National Historical Park is also listed on the NRHP, and certain properties within the park overlap with properties in the NHL District.

The Lowell Heritage State Park, established in 1974 as a precursor to the Lowell National Historical Park, is also located within the City of Lowell and is comprised of linear greenways along the Merrimack River and canal system and a collection of historic buildings and structures related to the industrial development of the city. These buildings and structures include Project features and properties located within the NHL District. The Lowell Heritage State Park is operated by the MADCR and features exhibits created in partnership with the NPS (MADCR, 2018). With the exception of the Rynne Bathhouse, all of the built resources within the Lowell Heritage State Park fall within the Lowell Historic District, designated by the City of Lowell to "…ensure that development activities within the district are consistent with the preservation of its 19th century setting" (MADCR, 2014). Portions of the Lowell Heritage State Park also overlap with the Lowell Locks and Canals NHL District and the Lowell National Historical Park.

16.5 Project Nexus

On April 18, 2013, FERC authorized Boott to replace the existing wooden flashboard system on the Project's Pawtucket Dam with a pneumatic crest gate system. FERC approved the amended crest gate system operation plan on March 30, 2015. Installation of the crest gate system is currently in progress.

Operation of the Project, including manipulation of the Pawtucket Dam crest gate, canal headgates, spillways, and other Project features affects water levels and flows in the historic canal system. This study would assess the impacts of Project operations on historic buildings and structures that comprise the canal system.

16.6 Study Methodology

16.6.1 Document Review of Existing Conditions

Boott will review available architectural and engineering evaluations of historic canal structures available from the NPS and other stakeholders, including documentation of previous maintenance and repairs to characterize existing conditions. As a component of this review, Boott will conduct a site visit to historic canal structures with the NPS to identify issues previously noted by the NPS related to the flow and water levels on historic structures. Based on this document review, Boott will identify properties that have previously been affected by water level or flow conditions. Boott will also document dimensions of significant structural features of these properties relative to the water levels in the canal system so that the effects of flow into the canal system and changes in water levels can be assessed. As part of this review of existing conditions, Boott will conduct a structural engineering assessment of the Great River Wall, including a visual inspection and review of available engineering and architectural drawings, maintenance records, and structural modifications.

16.6.2 Water Levels and Flows into the Canal System

Boott expects that the pneumatic crest gate system at the Pawtucket Dam will be operational in 2018. To assess water levels under a range of operating conditions, Boott will temporarily install pressure transducers (level loggers) at up to 10 locations within the canal system identified in consultation with the NPS. The level loggers will record water elevations in 15-minute increments from May 1, 2019 through May 1, 2020. The information collected by the level loggers can be compared to Project operational and flow data for the period of record to assess how Project operations (including operation of the new crest gate system) and flows into the canal system effect water levels.

16.6.3 Assessment of Water Levels, Flows, and Project Effects

Boott will compare the results of the document review of existing conditions and the water level, flow, and operational data collected in 2019 – 2020 to identify potential

Project-related effects on the historic canal system infrastructure. As part of this review, Boott will analyze if and when high flows into the canal system caused water levels to inundate wooden structural elements or if periods of low flows caused damage to historic turbines and waterwheels.

16.7 Analysis and Reporting

Boott will develop a Report on the Water Level and Flow Effects on Historic Resources Study that identifies any Project-related flow or water level effects on the historic canal system infrastructure. Boott anticipates the Water Level and Flow Effects on Historic Resources Study Report will include the following elements:

- Project Information and Background
- Study Area
- Methodology
- Study Results
- Analysis and Discussion
- Location maps, GIS analysis, and photos
- Any agency correspondence and consultation
- Literature cited

Boott anticipates developing an HPMP to describe how the licensee will consider and manage historic properties within the Project Boundary of potential effects during the term of the new license. Information presented in the Report on Water Level and Flow Effects on Historic Resources Study will inform the development of the HPMP, including measures to protect significant historic resources during high flow conditions.

16.8 Schedule, Level of Effort, and Estimated Cost

Boott anticipates that a review of existing documents and site conditions will be initiated in March 2019, and a site visit and consultation with the NPS will be conducted in March – April 2019. Level loggers will be installed in the canal system in April 2019, and an engineering assessment of the Great River Wall will be completed in the summer of 2019. Boott will conduct an assessment of the data in the spring and summer of 2020. Boott estimates the cost of the Water Level and Flow Effects on Historic Resources Study to be approximately $50,000 – $60,000.

17 Whitewater Boating and Access Study

17.1 Study Requests

The Commission's June 15, 2018 SD1 identified the following environmental resource issues to be analyzed in the EA for the Project relicensing:

- Effects of continued Project operation on recreational use in the Project area, including the adequacy of existing recreational access, and the adequacy and capacity of existing recreational facilities.

AW requested a Controlled-flow Whitewater Boating and Access Study.

17.2 Goals and Objectives

The goal of this study is to assess the Project's bypass reach for whitewater boating and access. The objectives of the study are as follows:

- Assess a range of flows on whitewater boating opportunities in the Project's bypass reach;
- Assess the frequency, timing, duration, and predictability of paddling flows under current and proposed Project operations;
- Define the need for put-in and take-out points for boaters; and
- Assess the flow information needs for whitewater boating and the current and potential flow information distribution system.

17.3 Study Area

Boott proposes a general study area of the Project's bypass reach extending downstream approximately two miles to the confluence of the Concord River.

17.4 Background and Existing Information

Existing relevant and reasonably available information regarding recreation in the Project vicinity was summarized in Section 5.8 of the PAD (HDR, 2018). Limited published information regarding whitewater boating in the Project area exists. AW reports a 1.25-mile run on the Concord River through downtown Lowell with a difficulty of class III and class IV under normal flows.

17.5 Project Nexus

The Lowell Project is a run-of-river facility. When river flows exceed the hydraulic capacity of the E.L. Field units (combined capacity of 8,000 cfs), excess flows up to approximately 2,000 cfs are routed through the downtown canal system and to the canal units. Flows in excess of 10,000 cfs are passed over the Pawtucket Dam spillway. The Project has the potential to affect whitewater boating opportunities in the bypass reach when flows are less than 10,000 cfs.

17.6 Study Methodology

Boott intends to conduct a Whitewater Boating and Access Study in accordance with the specific methods described below. The proposed study methods are based on the guidance provided in *Flows and Recreation: A Guide to Studies for River Professionals* (Whittaker, 2005).

17.6.1 Study Planning and Preparation

Primary planning and preparation activities for the Whitewater Boating and Access Study are: (1) formation of a Study Working Group and identification of volunteers to participate in controlled flow release evaluations; (2) identification of appropriate put-in and take-out locations for on-water evaluations; (3) development of a safety plan; (4) determine method for verifying flows in the Project's bypass reach; and (5) development of survey forms to be used in the execution of the flow evaluations.

17.6.1.1 Formation of a Study Working Group and Identification of Volunteer Boaters for Controlled Release Evaluations

Boott will contact representatives from AW and other stakeholders who express an interest in participating in this study to form the Recreation Whitewater Boating and Access Study Working Group (Working Group). The Working Group will meet in April and May of 2019 (as needed) to refine protocols specific to this study. Boott will also conduct a review of any existing online information if available, and anecdotal evidence regarding whitewater conditions under different bypass reach flows as a step in this study planning process.

The controlled release flow evaluation component of this study will require that volunteers from the Working Group, and other entities or individuals who request (in writing or via email) to Boott, to participate in the on-water observations and meet the criteria described below, paddle or raft the bypass reach under various flows to record what flows provide acceptable and optimal conditions for the desired use, and how changes in the flows alter the experience.

17.6.1.2 Identification of River Access Locations, Boating Feasibility, and Selection of Study Flows

The Working Group will conduct a site visit and meeting to discuss potential put-in and take-out locations along the Project's bypass reach. The put-in and take-out locations will be agreed upon by the Working Group and will be generally assessed for safety, and accessibility. Potential access areas will also be photographed and detailed on a map.

As part of this site visit, the Working Group will also evaluate the boating feasibility of the river reach by conducting a visual inspection from the shoreline. The focus of this feasibility assessment will be to identify safety issues associated with boating and accessing the river reach. If the group determines that the river reach cannot be safely or legally be accessed and boated, as well as access in a legal manner, the study will not be performed as proposed.

Boott will consult with the Working Group to identify appropriate study flows based on the feasibility assessment, visual inspection of the survey reach, and participants' previous whitewater boating experience. Boott anticipates up to three flows will be studied.

17.6.1.3 Development of Safety Plan

The volunteer boaters for the controlled release evaluations will be experienced, and will have the skills necessary to boat the reach. Participants may also be required to sign a liability waiver prior to taking part in on-water evaluations. Boott will develop a safety plan and will require that all study participants review and adhere to its requirements and applicable Boott safety policies, which will include, among other items, that participants be equipped with standard safety gear as required by the "Safety Code of American Whitewater."

17.6.1.4 Flow Verification Method

There is an active, existing USGS gage installed approximately 2.1 miles downstream of the Pawtucket Dam (USGS No. 01100000, Merrimack River BL Concord River at Lowell, MA). There is also an existing USGS gage installed on the Concord River (USGS No. 01099500, Concord R Below R Meadow Brook, at Lowell, MA). Flows from the USGS Gage No. 01099500 will be subtracted from the flows at USGS Gage No. 01100000 to account for flows entering the Merrimack River from the Concord River. Real-time data from the existing USGS gages is available online through USGS website. Boott will use Project operations data in combination with USGS real-time flow information to verify the controlled release flows in the bypass reach during this study. During the flow evaluation portions of this study, information on real-time flow conditions in the bypass reach will be made available by Boott to the Study Working Group and other whitewater boating participants.

17.6.1.5 Development of Survey Forms

Boott will develop the following Controlled Flow Release Study forms:

- A Pre-Run Information Form to be completed prior to the start of the study runs to determine each boater's experience level and preferred watercraft of the participants;
- A Single Flow Evaluation Form to be completed after each run to evaluate each boater's experience at that flow; and

- A Comparative Flow Evaluation Form, to be completed after all of the runs have been completed, to compare each of the flows that the boater participated in.

Draft survey forms have been developed and included in Appendices B through D of this PSP.

17.6.2 Controlled Whitewater Releases

Boott will consult with the Working Group to schedule the controlled flow releases. Each of the controlled releases will be provided for approximately 3 hours. This will afford participants the opportunity to boat the reach and make multiple passes at each flow so that participants are able to evaluate different lines through various portions of the study reach. Pre, post, and comparative surveys will be provided to controlled flow release participants for their completion during this portion of the study.

Following completion of the controlled flow releases, Boott will conduct an on-site meeting to discuss the results of the study and summarize opinions about the feasibility or quality of different types of boating opportunities at different flows.

17.6.3 Whitewater Recreational Access

Based on the results of the Recreation and Aesthetics Study, and in consultation with the Working Group and NPS, Boott will conduct an evaluation of prospective whitewater recreational access to the bypass reach. This evaluation will take into account:

- Public interest recreational access to the bypass reach;
- The feasibility of potential access areas;
- FERC public safety guidance documents;
- Enhancement that may be required to provide safe public access to the bypass reach, and how such improvements may affect aesthetic and historic resources;
- Public safety concerns associated with access to the bypass reach; and
- Cost estimates for developing recreational access to the Project’s canal system.

17.7 Analysis and Reporting

Boott will prepare a report summarizing the results of the Whitewater Boating and Access Study. Boott anticipates the Whitewater Boating and Access Study Report will include the following elements:

- Project Information and Background
- Study Area
- Methodology
- Study Results

- Analysis and Discussion
- Location maps, GIS analysis, and photos
- Any agency correspondence and consultation
- Literature cited

The results of the Whitewater Boating and Access Study will be used to identify potential PM&E measures that may be necessary to enhance recreation or mitigate Project effects on recreation in the Preliminary Licensing Proposal/Draft License Application and Final License Application, as appropriate.

17.8 Schedule, Level of Effort, and Estimated Cost

Boott anticipates initiating study planning and preparation in March 2019, and conducting controlled flow releases in the summer of 2019. Boott will consult with the Working Group and NPS regarding whitewater recreational access to the bypass reach subsequent to completion of the controlled flow releases. Boott estimates that this study will cost approximately $65,000 – $75,000 to complete.

18 Operation Analysis of the Lowell Canal Study

18.1 Study Requests

The Commission's June 15, 2018 SD1 identified the following environmental resource issue to be analyzed in the EA for the Project relicensing:

- Effects of continued Project operation on resident and migratory fisheries resources in the impoundment, canal system, bypassed reach, and Merrimack River.

The USFWS, MADFW, and NHFGD each subsequently requested studies related to an Operations Analysis of the Lowell Canal as shown in Table 18-1. The agencies requested this study to gain a better understanding of the operations associated with the canal system.

Table 18-1. Aquatic Resource Study Request

Requestor	Requested Study	Date
USFWS	Operation Analysis of the Lowell Canal	August 14, 2018
MADFW	Operation Analysis of the Lowell Canal	August 10, 2018
NHFGD	Operation Analysis of the Lowell Canal	August 13, 2018

18.2 Goals and Objectives

The goal of this study is to understand the operations of the Project's canal system. The specific objective of this study is to describe the operations of the canal system, which include, but are not limited to: how all of the canal units interact with the main units, how the canal units are sequenced, how often each of the units operate, the prioritization sequence of canal unit operations, the amount of time the units are operated during the downstream passage season, etc.

18.3 Study Area

The study area for this desktop study will be primarily focused on the Project's canal system and powerhouses

18.4 Background and Existing Information

Existing relevant and reasonably available information regarding current Project operations is summarized in Section 4.5 of the PAD (HDR, 2018). The Project is operated in a run-of-river mode using the automatic pond level control capability of the E.L. Field Powerhouse. Boott normally operates the Project to maximize flow through the available units at the E.L. Field Powerhouse, then routes any additional flows through the Pawtucket Canal system. The E.L. Field turbine-generator units are more efficient and operate at a higher head than the older canal units, and are therefore, the priority first-on, last-off units in the Project operations scheme. When river flows exceed the hydraulic capacity of the E.L. Field units (approximately 4,000 cfs per unit or 8,000 cfs for both units), excess flows up to approximately 2,000 cfs are routed through the downtown canal system and to the canal units. Any flows in excess of approximately 10,000 cfs (8,000 cfs at E.L. Field plus 2,000 cfs via canals) are passed over the Pawtucket Dam spillway. Pursuant to Article 37, the Project maintains a minimum flow of 1,990 cfs or inflow, whichever is less, as measured immediately downstream from the Project. The canal system operations are specifically described in Section 4.5.1.2 of the PAD (HDR, 2018).

18.5 Project Nexus

The Lowell Project consists of a two-tiered, 5.5-mile-long, network of man-made canals which include several small dams and 19 turbine units. Flows enter the canal system upstream of the Pawtucket dam via the Pawtucket canal. Currently there are no exclusionary measures in place for fish protection in the Lowell canal. Therefore, Project operations within the Lowell canal have the potential effect for safe, timely, and effective fish passage through the Project canal system. The PAD provides some operational information regarding the canal however, a more thorough analysis of canal operations would assist FERC and resource agencies in assessing potential impacts to fish moving through the canal.

18.6 Study Methodology

18.6.1 Current Project Operations

Boott will examine current Project operations, and develop a detailed description of the operational protocol used to determine when and how much water flows into the canal at a time scale relevant to the migratory fish species expected to potentially utilize the canal as a passage route (e.g., May, June, and July for spent alosines; August through November for adult eels and juvenile alosines).

Boott will describe how all of the canal units interact with the main units, how the canal units are sequenced, how often each of the units operate, the prioritization sequence of canal unit operations, the amount of time the units are operated during the downstream passage season, as well as other operations that may potentially affect fish passage in the Lowell canal.

Boott will compile and analyze historical operations data relative to historic hydrological data to determine the percent of time the canal units would be expected to operate during each passage month.

18.7 Analysis and Reporting

Boott will prepare an Operation Analysis of the Lowell Canal Study Report to summarize current and historic operations of the Project, with respect to the timeframes when the canal may potentially be utilized for fish passage. The results and analysis of this study will be used in conjunction with the results of the passage route and turbine mortality studies to estimate total through Project mortality for each target fish species/life stage. The results of this study will also be used in the analyses for several other studies to assess potential Project-related effects due to Project operations.

Boott anticipates the Operation Analysis of the Lowell Canal Study Report will include the following elements:

- Project Information and Background
- Study Area
- Methodology
- Study Results
- Analysis and Discussion
- Location maps, GIS analysis, and photos
- Any agency correspondence and consultation
- Literature cited

18.8 Schedule, Level of Effort, and Estimated Cost

This study will occur during the 2019 study year and is estimated to cost approximately $10,000 to complete.

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Appendix B. Comments and Study Requests

UNITED STATES OF AMERICA
FEDERAL ENERGY REGULATORY COMMISSION

Boott Hydropower, LLC	Lowell Hydroelectric Project
Application for New License	Project No. 2790-072 – Massachusetts

AMERICAN WHITEWATER COMMENTS & STUDY REQUESTS IN RESPONSE TO NOTICE OF INTENT TO FILE LICENSE APPLICATION, FILING OF PRE-APPLICATION DOCUMENT (PAD), COMMENCEMENT OF PRE-FILING PROCESS, AND SCOPING; REQUEST FOR COMMENTS ON THE PAD AND SCOPING DOCUMENT, AND IDENTIFICATION OF ISSUES AND ASSOCIATED STUDY REQUESTS REGARDING THE LOWELL HYDROELECTRIC PROJECT (FERC PROJECT NO 2790-072)

American Whitewater (AW) submits the following Comments and Study Requests in response to the filing of the Pre-Application Document (PAD) filed by Boott Hydropower, LLC for the Lowell Hydroelectric Project, FERC Project No. 2790, located in Lowell, Massachusetts. The project consists of the 1,093 long, 15-foot high Pawtucket Dam that impounds the Merrimack River and diverts flows into the Northern and Pawtucket canals leading to powerhouses with a total installed capacity of 24.8 MW. The 720-acre impoundment extends 23-miles upstream from the project. The project diverts nearly all flows from the Merrimack River into the canal system, bypassing approximately two miles of the natural river channel. Of particular concern is the 0.7-mile reach between the Pawtucket Dam and the E.L. Field Powerhouse that has been nearly completely dewatered by the project, destroying aquatic habitat and eliminating recreation opportunity that would otherwise provide a valuable whitewater boating opportunity under natural flow conditions.

American Whitewater is a national non-profit 501(c)(3) river conservation and recreation organization founded in 1954. With approximately 6,000 members and 100 affiliate clubs, representing tens of thousands of whitewater paddlers across the nation, American Whitewater's mission is to protect and restore our nation's whitewater resources and to enhance opportunities to enjoy them safely. Our members are primarily conservation-oriented kayakers and canoeists, many of whom live and/or engage in recreational boating in the New England region within easy proximity of the Merrimack River. Located in northeastern Massachusetts, the Lowell Hydroelectric Project is easily accessible to large population centers in and around the Boston area with the potential to provide a whitewater recreation experience unique to the area. American Whitewater has long been involved with the FERC licensed hydropower projects in the region, including hydropower projects located on the Deerfield and Connecticut rivers in Massachusetts, as well as other projects on the Kennebec, Rapid, Green, Moose, Black, Beaver, and Raquette rivers, and are party to settlement agreements that provide for whitewater boating opportunities that partially mitigate for project impacts.

Comments

From a recreation perspective, the Lowell Hydroelectric Project is problematic due to the lack of flow information, bypassed reach access, and flow alteration. These concerns are generally described below:

Issue 1: Flow Information

The Licensee states in the PAD that the project has a hydraulic capacity of 10,000 cfs with up to 8,000 cfs feeding the E.L. Field Powerhouse followed by the other canal units. Flows above the project hydraulic capacity are spilled into bypassed reach via the Pawtucket Dam spillway. There are no minimum flows into the bypassed reach other than the attraction flow for the fishway when operating plus leakage that Enel Green estimates at 300 cfs. For the recreating public, understanding the flow into the bypassed reach is impossible since the Licensee does not provide that information on its website or on Waterline. The Licensee states in the PAD, however, that the "estimated flow over the spillway is the flow at the Merrimack River (U.S. Geological Survey [USGS] gage No. 01100000) minus the flow at the Concord River (USGS gage No. 01099500) and minus any flow released through Boott's turbines and the downtown canal system." At best, flows into the bypassed reach could be estimated by subtracting flows from the Concord River from the Merrimack River below the project minus the hydraulic capacity of the project assuming that all units were operating and then adding the fishway flows and leakage. The Licensee needs to provide the recreating public with instantaneous and accessible information on flows into the bypassed reach.

Issue 2: Access & Navigability

Access into the natural river channel bypassed by the project is extremely limited. While there are several access points in the impoundment, access to the bypassed reach is only possible down steep, rugged and overgrown trails. There is no portage around the Pawtucket Dam that would allow a through paddler to navigate the Merrimack River through the project boundary. The Merrimack River is a navigable river subject to FERC jurisdiction, and the public right to navigation is protected under federal law. In addition, Massachusetts law protects the public's right to boat, fish, and fowl in navigable waters. [Opinion of the Justices, 383 Mass. 895 (1981)]. Even in non-navigable waters, the public still retains the right to "passage up and down the stream in boats or other craft, for purposes of business, convenience, or pleasure." Brosnan v. Gage, 240 Mass. 113 (1921). The Licensee cannot simply obstruct the river and divert all flow through its hydropower operation, eliminating nearly all public access. The FERC license to operate the project is granted subject to all applicable state laws and regulation. Under Massachusetts law and regulations, any water-dependent use project which interferes with the public's right to free passage over and through water, including "the right to float on, swim in, or otherwise move freely within the water column without touching the bottom," is required to provide "compensation to the public for interfering with its broad rights to use such lands for any lawful purpose … commensurate with the extent of interference caused, and shall take the form of measures deemed appropriate by the Department to promote public use and enjoyment of the water, at a location on or near the project site if feasible." [310 CMR 9.35]

Issue 3: Flow Alteration

The Licensee's hydropower operation diverts virtually all flow into the canal system for energy generation, eliminating practically all flow between the Pawtucket Dam and the E.L. Field Powerhouse. With no minimum aquatic base flow to sustain aquatic habitat for resident fish, macroinvertebrates, plants, and other aquatic dependent species, this portion of the bypassed reach is effectively a wasteland in the heart of Lowell. The current project license only requires a minimum flow of 1990 cfs below the project. While the Licensee maintains that the project is operated in run-of-river mode, its operations disrupt the natural flow regime in the bypassed reach, reducing the quantity of suitable aquatic habitat and the benefits of natural flow variability.

Fig. 1: Natural river channel dewatered by the Lowell Hydroelectric Project

The lack of a natural flow variability also eliminates the possibility recreational boating in the natural river channel, assuming access was provided, except during periods of spillage when inflows exceed 10,000 cfs, generally during the spring freshet in April and May. Other recreational uses of the bypassed reach are also impacted by the Licensee's operations including angling. There is evidence of multiple informal access point below the E.L. Field Powerhouse that are used for angling in the bypassed reach.

Fig. 1: Bypassed reach down river view from University Bridge at high water

Fig. 2: Merrimack River across from the outflow of E.L. Field tailrace at high water

Given the lack of portage and access into the bypassed reach below the Pawtucket Dam, little information is available about the quality of whitewater boating on the Merrimack River in the project boundary. The Licensee does cite to the American Whitewater Rivers Database for information on whitewater boating on the Concord River adjacent to the project, and whitewater boating is known to occur on other sections of the Merrimack River in New Hampshire. There is anecdotal information from whitewater boaters who have bushwhacked their way into the bypassed reach below the dam that there is a valuable whitewater boating resource in the bypassed reach when there is sufficient flow. In addition, a visual observation of the bypassed reach from the shoreline and bridges reveals a structure that is suitable for whitewater boating under certain conditions. With approximately 25 feet of gradient between the base of the Pawtucket dam and the E.L. Field Powerhouse tailrace and the presence of extensive rock formations that channelize the flow, it is likely that the Licensee's flow alteration eliminates whitewater boating in the bypassed reach.

Fig. 3: Kayaking the rapids in the bypass downstream of the university street bridge.

In addition, the E.L. Field Powerhouse tailrace releases up to 8,000 cfs into the natural river channel 0.7 miles below the Pawtucket Dam. The tailrace provides sufficient flows to create hydraulics that could be utilized by whitewater boaters for playboating under either current or enhanced conditions that are suitable for playboating, a style of whitewater boating that is frequently enjoyed by whitewater boaters where suitable hydraulic conditions are present.

Fig. 4: Whitewater boating feature in tailrace at Holtwood Hydroelectric Project (FERC Project No. P-1881)

<u>Study Requests</u>

- Study Request 1: Recreation Facilities, Use, and Aesthetics Study

Goals and Objectives
§5.9(b)(1)

The goals of the Recreation Facilities, Use, and Aesthetics Study are to:

1. Obtain information about the condition of existing recreation facilities and access to project lands and waters at the project; and existing recreation use, and demand at the project;
2. Evaluate the adequacy of existing access to the impoundment, canals, and

bypassed reaches in the project boundary, including formal and informal access areas that are utilized for boating, angling, hiking, and other recreational use;

3. Conduct an assessment of the need to enhance recreation opportunities and access in the project boundary;

4. Determine the minimum acceptable and optimal aesthetic flow in the bypassed reaches below the Pawtucket Dam sufficient to protect aesthetic values; and,

5. Develop a Recreation Management Plan for the implementation of any enhancement measures and long-term monitoring of recreation demand and adequacy of facilities at the project over the term of a new licenses.

§5.9(b)(2)

Not applicable.

§5.9(b)(3)

Sections 4(e) and 10(a) of the Federal Power Act require the Commission to give equal consideration to all uses of the waterway on which a project is located, and what conditions should be placed on any license that may be issued. In making its license decision, the Commission must equally consider the environmental, recreational, fish and wildlife, aesthetics, and other non-developmental values of the project, as well as power and developmental values. Any license issued shall be best adapted to a comprehensive plan for improving or developing a waterway or waterways for all beneficial public uses. Recreation and aesthetics have been identified as a legitimate project purpose by the Commission. The Lowell Hydroelectric Project reservoir, bypassed reach, and canals, have the potential to offer recreational opportunities unique to the region provided that sufficient flow and access are provided

Background and Existing Information
§5.9(b)(4)

Section 6.1.7 provides a general description of public recreation facilities, activities, and demand at the projects. However, the PAD provides no detailed information regarding the condition of existing facilities or type or location of various uses. The PAD provides no project-specific information regarding visitor perceptions and identified needs at the projects. Information on current use and whether existing access to facilities in the area are meeting recreation demand would inform a decision on whether additional designated public access at the projects is necessary to meet existing and future recreation demand at the projects.

Although the Licensee partially describes recreation uses in and near the project boundary, it does not fully describe the current and potential future use or adequacy of recreational opportunities and facilities. The Licensee does not propose to conduct any recreation studies as part of this relicensing process, and is silent on the impact of project operations on boating, angling, and hiking opportunities in the project area. Further, no information is provided in the PAD regarding the impact of project operations on aesthetic values in the bypassed reach.

While the PAD references American Whitewater's Rivers Database for information on whitewater boating opportunities on the Concord River, the PAD contains no information on the impact of the Licensee's flow diversion and power generating activities on potential whitewater boating use in the bypassed reach.

Project Nexus
§5.9(b)(5)

The project impounds the Merrimack River and diverts natural river inflows into two canal systems leading to a series of powerhouses. The Pawtucket Dam and the Licensee's hydropower operations have a significant impact on recreational opportunities on the Merrimack River in the project boundary including but not limited to whitewater boating by inundating rapids in the impoundment, dewatering the natural river channel, obstructing public access, and preventing the public from navigating the Merrimack River through the project boundary. An analysis of existing recreation use and access at the project would help form the basis for determining the projects' impacts upon, and ability to enhance, public recreation access opportunities. Flow over the dam and in the bypass reach directly impacts aesthetics. Also, an assessment of the current level of recreation use would provide information necessary to develop a Recreation Management Plan for efficient management of the recreational components of the project over the term of a new license.

Proposed Methodology
§5.8(b)(6)

1. Provide the methods and results of the investigation of the existing recreation facilities conditions, as referenced in the PAD.

2. The facility inventory will include characterization of the suitability of the bypassed reach below the Pawtucket Dam for whitewater boating (e.g., gradient, length, character of potential flows).

3. The use and needs assessment will include all recreation activity types known to occur or potentially occurring in the project area. Specific methods should include visitor observations; on-site visitor intercept surveys at formal and informal public recreation areas at the project reservoirs, bypassed reach, canals, tailraces, and riverine areas; and mail and/or internet surveys targeting unique stakeholder groups that may not be practically accessed through on-site surveys (e.g., adjacent residential land owners, residents of the counties in which the projects are located, rock climbers, whitewater boaters).

4. The needs assessment will include the demand for whitewater boating in the bypassed reach, existing boating opportunities within the project region, feasibility of providing additional public access at the project reservoir and riverine reaches (potential locations, type of facilities and access, and any associated costs), identifying visitor perceptions regarding the adequacy of recreation facilities, need for additional real-time flow information, access in the project area, and assessing future recreation demand and facility needs at the project under different modes of operation..

5. The aesthetic assessment will include a range of alternate spillages that should be videotaped and qualitatively analyzed, and a demonstration study should be arranged for direct observation of flows by a team for subjective grading. A rating form is employed to provide a structure for the individual observations.

6. Assess visitor perceptions of the effects of project operations and management on recreation and recreation opportunities at the project (including fluctuating reservoir levels, minimum flow releases, and anticipated changes) over a new license term. Identify potential measures to alleviate any negative effects as well as to enhance existing recreation opportunities and access.

7. A Recreation Management Plan for the projects should be included in the license application and should include, at a minimum:
(1) a description of any proposed protection, mitigation, and enhancement measures, including: location of any proposed facilities and/or access areas (including description and figure depicting the relationship of any proposed facilities to the existing project boundaries), proposed ownership and management of any proposed facilities, associated capital, and operation and maintenance costs; and a timeline for implementation;
(2) a description of operation and management measures associated with project-related recreation access and facilities; and
(3) a description of measures for future monitoring of recreation demand and adequacy of project-related facilities to meet this demand over the term of new licenses.

Level of Effort and Cost
§5.9(b)(7)

The estimated cost of the Recreation Facilities, Use, and Aesthetics Study for the Lowell Hydroelectric Project is about $60,000, including field studies, study report development, and drafting of a Recreation Management Plan. One field season should be sufficient to collect the required data and prepare the report.

- Study Request 2: Controlled-flow Whitewater Boating and Access Study

Goals and Objectives
§5.9(b)(1)

The goals of the Controlled-flow Whitewater Boating and Access Study are to:

(a) assess the presence, quality, access needs, flow information needs, and preferred flow ranges for river-based boating resources in a stepwise manner;
(b) assess the effects of a range of optimal and acceptable flows on whitewater recreation opportunities for whitewater paddling in the natural river channel between the Pawtucket Dam and the end of the project boundary;
(c) assess the frequency, timing, duration and predictability of optimal and acceptable paddling flows under current, proposed, and alternative modes of operation;
(d) identify the need for, and define adequate put-in and take-out points that promote car-top boating, and also identify the needs for parking areas;
(e) identify the location, challenge, and other recreational attributes associated with specific rapids and other river features;
(f) assess the flow information needs of whitewater boating and the current and potential flow information distribution system.
(g) evaluate the potential for whitewater playboating in the bypassed reach at various flow levels, including but not limited to assessing the potential for developing whitewater boating features below the tailrace of the E.F. Field Powerhouse.

§5.9(b)(2)

Not applicable.

§5.9(b)(3)

Sections 4(e) and 10(a) of the Federal Power Act require the Commission to give equal consideration to all uses of the waterway on which a project is located, and what conditions should be placed on any license that may be issued. In making its license decision, the Commission must equally consider the environmental, recreational, fish and wildlife, aesthetics, and other non-developmental values of the project, as well as power and developmental values. Any license issued shall be best adapted to a comprehensive plan for improving or developing a waterway or waterways for all beneficial public uses.

Conducting the necessary studies and implementing measures to ensure public access to outdoor recreation is in the public interest. It is widely accepted that outdoor recreation has significant benefits to participants including health, well-being, and quality-of-life. Outdoor recreation also has proven economic benefits for communities located near recreational resources. FERC has concluded elsewhere that to fully evaluate the project's effect on whitewater recreation opportunities and to balance potential enhancement opportunities with their cost, a controlled-flow whitewater boating study is relevant to Commission's public interest determination. The bypassed reach below the Pawtucket Dam has the potential to offer recreational opportunities unique to the region provided that sufficient flow and access are provided.

Background and Existing Information
§5.9(b)(4)

The Licensee acknowledges in the PAD that whitewater boating is currently an existing recreational use in the Project area, principally on the Concord River at its confluence with the Merrimack River. There is anecdotal information that whitewater boating has occurred in the bypassed reach when project inflows exceed the hydraulic capacity of the project. Beyond limited anecdotal information, little is known about the whitewater boating potential of the bypassed reach at various flow levels, necessitating a controlled-flow whitewater boating study. The PAD contains no information on whitewater boating use in the bypassed reach or the extent to which the Licensee's operations impact on the availability of sufficient flows for whitewater boating in the bypassed reach below the Pawtucket dam.

Project Nexus
§5.9(b)(5)

Lowell Hydroelectric Project diverts flows from the Merrimack River into the Northern and Pawtucket Canal System, destroying aquatic habitat and valuable whitewater boating opportunity between the Pawtucket Dam and the E.L. Field Powerhouse. There is currently no meaningful access into the bypassed reach below the Pawtucket Dam making whitewater boating nearly impossible even during periods of high spring flows that exceed the project hydraulic capacity. While the Licensee maintains that this is a run-of-river project, its assertion is inaccurate with respect to the bypassed reach where a large section of the river is effectively dewatered and all natural whitewater boating opportunity has been lost due to project operation. The diversion of natural flows through hydropower operations alters the landscape in the natural river channel, and reduces recreational opportunities that would otherwise be available.

Study Methodology
§5.9(b)(6)

The study we request on the Lowell Hydroelectric Projects should follow the standard methodology as described in Whittaker, et. al. (2005). This methodology is designed to assess the presence, quality, and preferred flow ranges for river-based boating resources in a step-wise manner. The process steps are generally 1) desktop analyses, 2) on-land feasibility assessment, 3) on-water single flow assessment, 4) on-water multiple flow assessment. We expect and request the full implementation of this methodology. Because the quality of the resource has not been fully analyzed with current metrics, we request that on-water multiple flow assessments be conducted. The study should focus on the 2-mile bypassed reach below the Pawtucket Dam. The Licensee should work with the boating groups to identify target flows for the evaluation.

Given the limited known information about the boating characteristics of the bypassed reach below the Pawtucket Dam, it will be necessary to conduct an on-land physical inspection of the reach to identify access points and potential hazards. An on-land observation of demonstration flows will also be required to identify a range of flows that should be evaluated, during an on-water controlled flow study following widely accepted protocols. A controlled-flow whitewater boating study will identify the minimum acceptable and optimal boating flows on identified whitewater and recreational boating reaches, analyze the frequency with which boating opportunities at various flow levels are available under current operations, and analyze the extent to which boating opportunities would be available under alternate modes of operation.

The Licensee should also assess the relationship between its discharge from the E.L. Field Powerhouse and the presence of hydraulic features that can be utilized for whitewater playboating, a style of whitewater boating that utilizes a different type of whitewater craft than are used for downriver boating. The Licensee should identify suitable consultants with experience in evaluating the potential for developing hydraulic features suitable for playboating in the bypassed reach, and in particular, in the tailrace of the E.L. Field Powerhouse.

We will work with the licensee to document the known information regarding the river. We will provide volunteers and technical support for the studies as appropriate. We hope to work collaboratively with the licensee on this study. The whitewater boating study methodology we have requested has been used on dozens of other FERC regulated reaches.

The Licensee PAD proposes no whitewater feasibility analysis. This no-action step would reveal nothing about the current project impacts on whitewater recreation or opportunities for protection, mitigation, or enhancement measures. We currently do not know the relationship between specific low and moderate flows and the paddling experiences they provide. A desktop analysis can't generate this information. Without this information we cannot fully define the project impacts, nor propose and consider provision of releases that provide targeted recreational experiences.

Level of Effort and Cost
§5.9(b)(7)

We are willing to work with the licensee on the whitewater paddling controlled-flow study to keep costs reasonable and the quality of information high. The study will need to integrate any known information with information from the controlled-flow flow study during which several flows are paddled by boaters. Consultants usually employ still image and video documentation, surveys of the boaters, a guided conversation among the boaters, and subsequently a written report. Given the collaborative approach sought by the paddling community, including in-kind contributions of time and expertise, a consultant should be able to complete this study on behalf of the licensee for a very reasonable cost. We estimate that the cost of conducting the controlled flow whitewater boating study will be approximately $50,000 including the field work and final report preparation.

Conclusion

We respectfully request that FERC require the Licensee to complete the above described (1) Recreation Facilities, Use, and Aesthetics Study, and, (2) Controlled-flow Whitewater Boating and Access Study, in order to provide FERC with sufficient information to complete its NEPA analysis of project impacts to determine appropriate license conditions that are protective of recreation values and mitigate project impacts. Thank you for considering these comments.

Respectfully submitted this 8th day of August, 2018.

/s/ Robert A Nasdor
Robert A. Nasdor
Northeast Stewardship and Legal Director
American Whitewater
365 Boston Post Road, Suite 250
Sudbury, MA 01776

UNITED STATES OF AMERICA
FEDERAL ENERGY REGULATORY COMMISSION

Boott Hydropower, LLC
Application for New License

Lowell Hydroelectric Project
Project No. 2790-072 – Massachusetts

CERTIFICATE OF SERVICE

I hereby certify that I have this day served the foregoing document upon each person designated on the official service list compiled by the Secretary in this proceeding.

Dated this 8th day of August 2018.

Carla Miner

Carla Miner
American Whitewater
Stewardship Assistant

Service List for P-2790-000 BOOTT HYDROPOWER, INC.

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August 10, 2018

Kimberly D. Bose, Secretary
Federal Energy Regulatory Commission
888 First Street, N.E., Room 1A
Washington, DC 20426

Lowell Hydropower Project, FERC No. 2790
Comments of the Massachusetts Division of Fisheries and Wildlife
Preliminary Application Document
Study Requests

Dear Secretary Bose:

The Massachusetts Division of Fisheries and Wildlife (MassWildlife) is the agency responsible for the protection and management of the fish and wildlife resources of the Commonwealth. The Division is also responsible for the regulatory protection of imperiled species and their habitats as codified under the Massachusetts Endangered Species Act (M.G.L. c.131A). The Massachusetts Endangered Species Act (MESA) was enacted in December 1990. Implementing regulations (321 CMR 10.00) were promulgated in 1992 and recently revised and implemented as of November 2010. The MESA provides a framework for review of projects or activities that occur within mapped areas of the state, called *Priority Habitat*, and published in the Natural Heritage Atlas. As such, we monitor operations at hydroelectric projects within the Commonwealth, as well as comment on proposed hydroelectric facilities. The Division offers the following comments on the Preliminary Application Document (PAD) for Lowell Hydropower Project (FERC No. 2790) submitted by Boott Hydropower, LLC, (Boott) on April 30, 2018.

PROJECT DESCRIPTION

The Lowell Project consists of a 1,093-foot-long, 15-foot-high masonry gravity dam (Pawtucket dam) topped by a 5-foot-high, pneumatic crest gate system, which creates a 720-acre impoundment extending approximately 23 miles upstream. The dam has a gross storage capacity of approximately 3,600 feet between the maximum normal water surface elevation of 92.2 feet National Geodetic Vertical Datum of 1929 (NGVD) and the minimum water surface elevation of 87.2 feet NGVD when all five pneumatic gates are fully lowered. The spillway is 980.5 feet long. The project includes a two-tiered network of man-made canals, totaling approximately 5.5 miles in length, which provide flow to 21 Boott-owned hydroelectric units. Nineteen of the units are located in four powerhouses (Assets, Bridge Street, Hamilton, and John Street) situated in the canal and have various runner speeds and diameters. The remaining two units are located in the main powerhouse (E.L. Field) on the Merrimack River, which uses water from the northern canal to generate power. The units in the E.L. Field powerhouse are identical, 8.6-MW horizontal Kaplan turbine-generator units, each with a maximum hydraulic capacity of 4,000 cfs.

Boott currently operates the project in a run-of-river mode. The current license requires an instantaneous minimum flow of 1,990 cfs or inflow, whichever is less, as measured immediately downstream of the project.

Boott operates both upstream and downstream fish passage facilities at the project. These include a lift at the E.L. Field powerhouse which conveys fish to the northern canal, an upstream anadromous vertical-slot fishway at the Pawtucket dam, and a downstream bypass facility at the E.L. Field powerhouse. The fish ladder has a total operating flow of 500 cfs and acts as the primary source of flow in the 0.7-mile-long bypass reach (other than spillage over the Pawtucket dam spillway when inflow exceeds the maximum hydraulic capacity of the project's stations). The current license contains no minimum bypass flow requirement.

In the PAD, Boott has proposed no additional protection, mitigation, or enhancement (PME) measures.

FISH AND WILDLIFE RESOURCES

The Merrimack River provides essential habitats and a migratory corridor for numerous species of fish and wildlife. As the second impassable barrier to upstream migration on the Merrimack River, the Pawtucket Dam has a significant impact on these resources, particularly anadromous and catadromous fish. These species require safe and effective passage past the dam on their upstream and downstream migrations. Likewise the bypass reach below the dam provides a unique riffle area for quality resident fish and macroinvertebrate habitat. Additionally, the dam acts as a passage barrier to resident fishes who act as host-fishes to freshwater mussels located both up and downstream of the dam.

COMMENTS

<u>Preliminary Application Document</u>

<u>General</u>
The PAD is comprehensive and provides most of the information necessary.

<u>Specific</u>

4.0 Project Location, Facilities, and Operations

Boott provided a detailed description of the project facilities; however, several important pieces of information are missing:

- the minimum hydraulic capacities, runner diameters and runner speeds of the turbines at the project (housed in the E.L. Field, Assets Station, Bridge Street, Hamilton Station, and John Street powerhouses);
- clear spacing of the trashracks at the intakes to all of the turbines; and
- the calculated approach velocity at the trashracks/intakes (based on the wetted trashrack area).

4.1 Civil Works

Tailrace

Telemetry studies in 2002, 2011, and 2013 showed emigrating American Shad which approach Lowell via the tailrace have difficulty using the entrance of the fishway (Sprankle 2005; Alden 2011; Blue Leaf Environmental 2013). In 2016, Gomez and Sullivan engineers performed an analysis of upstream passage at the lift and recommended Boott excavate the ledge outcropping in the tailrace channel to approximately 10 feet below normal tailwater level extending 50 to 100 feet downstream from the entrance (Gomez and Sullivan 2016). On July 18, 2017, Boott submitted design plans to the Merrimack River Technical Committee (MRTC; comprised of Federal and State agencies) for review prior to the start of construction. On July 26, 2017, the MRTC submitted their recommendations. On August, 18, 2017, at the request of Boott, the National Oceanic and Atmospheric Administration (NOAA) and the United States Fish and Wildlife Service (Service) provided additional information pertaining to the MRTC's recommendations (Attachment A). The PAD does not contain any information regarding the tailrace excavation project. We recommend Boott update the PAD to include the details we have provided here.

In the PAD, and the Commission's pre-filing milestone timetable included in the scoping document, the first study season is scheduled to begin during the spring of 2019. However, Boott plans to complete the tailrace excavation project during late summer of 2019 (Attachment B). The tailrace excavation project will change flow dynamics in the tailrace channel and therefore the hydraulic conditions fish will likely encounter as they migrate upstream. As such, we ask that the studies requested herein (related to upstream fish migration and flow in the tailrace area) occur after the excavation is complete so the natural resource agencies can properly assess the impacts project operations might have on migratory fish and develop adequate passage and protection measures if necessary.

4.5 Description of Project Operations

Fish Passage Operations

Boott states they have provided, and assessed the effectiveness of, American Eel passage at Lowell. The effort to pass eels at the project began in 2014 when temporary eel ramps were deployed near the ladder. However, the effectiveness of these structures has never been quantified. In 2018, Boott agreed to: (1) continue to operate the existing anadromous fish ladder for eels (releasing 30 cfs) until September 30; and (2) perform six, dewatered, visual inspections of the ladder. To date, there have been no siting surveys performed at Lowell. Therefore, it is unknown if eels congregate at other areas within the project boundary (e.g., the outfall of the canal power stations) or if passing eels at the ladder is the most appropriate technique. MassWildlife likely will include, in any fishway prescription issued for the project, a requirement that Boott conduct an upstream eel passage siting survey after a new bypass flow regime has been implemented, to determine areas of eel concertation so permanent upstream passage facilities can be properly sited.

National Park Service Requirements

In this section of the PAD, Boott states they maintain canal water levels "within appropriate limits during the May 15 to October 15 tour boat operating season," however no additional information is provided. We recommend Boott update the PAD to include further information regarding the water levels maintained in the canal and any additional, relevant, information regarding the operations agreement they have with the National Park Service.

5.4 Fish and Aquatic Resources

Overview

The fish ladder at the Pawtucket dam has a total operating flow of 500 cfs and is the primary source of flow in the 0.7-mile-long bypass reach which extends from the Pawtucket dam downstream to the E.L. Field powerhouse. However, there is no information provided in the PAD to support this flow release is adequate to meet the life history requirements of fish and wildlife (including invertebrates such as freshwater mussels). Therefore, MassWildlife recommends Boott undertake a study which evaluates habitat in the bypass reach at a range of flows, including the existing 500 cfs release. The study design should include habitat mapping of the entire bypass reach in addition to collecting hydraulic and habitat measurements (i.e., depth, velocity, wetted perimeter, substrate) along a number of transects to assess the existing flow release and alternative flows.

Boott states "fish are capable of bypassing the Project's entire canal system via the Merrimack River and can use the existing upstream and downstream fish passage facilities at the Pawtucket Dam and the E.L. Field Powerhouse." While fish can potentially avoid entering the canal, despite there being no exclusionary measures in place, a study by Normandeau Associates, Inc., found only 7 percent of juvenile alewives utilized the bypass (Normandeau 1991). A follow up study (Normandeau 1995) performed after the bypass was enlarged found of 1,779 marked fish, only 37 percent utilized the downstream fish passage facilities. While efficiency increased by approximately 30 percent from 1991 to 1995, the bypass remains over 60 percent ineffective at passing fish downstream.

Although bypass effectiveness studies were performed at Lowell in the early 1990s, it is still unclear as to which route American Shad, Alewife, Blueback Herring, and eel select as they move downstream (spillway, fish ladder, canal, turbines, existing bypass), the survival estimates associated with each route, the effect the Pawtucket gatehouse has on downstream movement, the effect the pneumatic crest gates have on emigration, etc. To fill these data gaps and better understand downstream passage at Lowell, especially in relation to the canal, MassWildlife recommends Boott conduct studies which assess: (1) the behavior, approach routes, passage success, survival and delay of adult American Shad and River Herring as they emigrate to the ocean; and (2) the impact project operations have on the downstream migration of juvenile Alewife (which can serve as a proxy for Blueback Herring and American Shad in this instance); and (3) downstream route of passage and survival of adult silver-phase American Eel.

Abundance

The Merrimack River supports a variety of migratory fish species, including American Shad, River Herring (Alewife and Blueback Herring), American Eel, and Sea Lamprey. Table 5.4-2 lists the number of river herring, shad, and eel that have passed the Lawrence Project (FERC No. 2800, the first hydroelectric dam on the Merrimack River), and Lowell since 1983. In 2017, Boott claims 177,738 eels swam upstream past Lawrence. However, our records indicate an estimated 8,645 elvers were lifted in the hopper and 17,691 passed the eelway at the dam (26,336 eels total). MassWildlife recommends Boott update Table 5.4-2 to: (1) ensure listed, annual, fish passage counts are accurate; and (2) include sea lamprey passage counts.

Other Site-Specific Fisheries Information

In this section of the PAD, Boott states American Shad studies were conducted in 1999 and 2000, which led to significant modifications and upgrades to the E.L. Field powerhouse fish lift, thereby improving passage efficiency. However, it is unclear as to which modifications Boott is referring.

According to our records, a lack of modifications and upgrades to the project coupled with poor fish passage led to a radio-telemetry study of shad migration in 2002 (Sprankle 2005). This study found 55 percent of the shad which passed upstream of Lawrence made their way into the Lowell tailrace near the fishway entrance. However, only 6.2 percent of the tagged shad were actually passed upstream of the project via the fish lift. This was consistent with fish passage counts taken at Lowell in 2002; only 9.7 percent of the shad which passed Lawrence subsequently passed Lowell. These data led to a dye test, also conducted by Ken Sprankle, in June 2003. During this qualitative evaluation, concentrated dye was released into the fishway entrance channel and observed. Results demonstrated the flow field extends downstream from the fishway and stalls approximately 35 feet from the entrance, effectively cutting off the progression of shad moving up the tailrace and into the fishway. Based on fish counts at Lawrence and Lowell, passage efficiencies for American shad have not improved at the project over the past 20 years. From 1996 to 2017, passage efficiency at the project has not exceeded 30 percent. Additionally, the internal fish lift efficiency has remained low. In 1996, fish lift efficiency ranged from 0.5 to 2.4 percent. In 2000, studies conducted by Boott suggested efficiency increased to 42 percent (Boott 2000). While this latest assessment does suggest an improvement in operations compared to previous years, an internal fish lift efficiency of 42 percent is still low as overall passage efficiency is based on the combined near/far field attraction efficiency and internal lift and ladder efficiency. Based on the information above, and considering the ledge removal improvements which will take place in 2019, MassWildlife recommends Boott perform a study assessing American shad upstream route selection passage effectiveness and migratory delay.

Boott goes on to state, “A 1988 acoustic telemetry study performed by RMC Environmental Services (RMC) of adult American shad movement through the Northern canal demonstrated successful passage through the Pawtucket Gatehouse, as well as incidental information regarding downstream passage routes for post-spawning individuals. In a follow-up study in 1991 by Normandeau Associates, Inc., found similar findings as the 1988 adult American shad telemetry study." While it is true that 80 percent of the fish successfully exited the canal, it should be noted: (1) the sample size was small, only 25 fish were used in the analysis; and (2) the delay caused by existing infrastructure was substantial, ranging from 1 to 5 days. Also, as a point of clarification, there were two studies conducted in 1991 by Normandeau Associates, Inc., which focused on downstream passage of river herring and shad. The scope and findings of these studies did not include upstream passage through the gatehouse, which was the focus of the RMC 1988 study. To date, the RMC study has been the only evaluation of upstream passage of shad in the northern canal and gatehouse. As a component of the studies provided herein, we recommend Boott track and monitor clupeid behavior in the canal.

Major Findings of Fish Passage Studies Since 1988

In the PAD, Boott provides an overview of the fish passage facilities at both projects, when they began operating, and studies which have been conducted to determine their effectiveness at passing target species. We would like to offer some points of clarification, specifically on the information listed in Table 5.4-3.

- 1988: Passage of Radio-Tagged American Shad through the Northern Canal Headgate Structure. Boott states "24 of 25 radio-tagged shad (96%) released at fish lift exit passed the Northern Canal headgate structure with little delay." However, 19 of the 24 shad (80 percent) which successfully passed did not pass through the headgate structure but rather the adjacent boat lock facility. When the boat lock was closed, delay ranged from 1 to 5 days. Since a majority of the shad were observed reaching the headgate structure within an hour, the delay in migration associated with closing the boat lock was approximately 23-119 hours. The study notes most fish approached the road bridge adjacent to the gatehouse but fell back downstream. The delay experienced by these shad is significant and, from the information provided by Boott, it is unclear how often the boat lock has been open during the upstream migratory season since the 1988 study was performed. We are concerned that the operation and management of the northern canal headgate may contribute to migratory delay and is an issue that will need to be resolved in order to successfully pass fish upstream and achieve a sustainable population of shad in the Merrimack River.

- 1991: An Assessment of the Effectiveness of a Fish Bypass for Passing Juvenile Alewives at the Lowell Hydroelectric Project. The findings listed in the table fail to include two critical results: (1) the bypass effectiveness for juvenile alewife was only percent, even when bypass flows reached 2 percent of the turbine flow; and (2) when the bypass flow was increased by 50 percent, due to the units shutting down, the number of fish using the bypass increased by a significant amount (4,250 alewives in 10 minutes versus 0 in the previous 4.5 hours).

- 1996: Lowell Hydroelectric Project Internal Fish Lift Efficiency Monitoring Program. The internal fish lift efficiencies should be included in the findings, as they were extremely low, ranging from 0.5 percent to 2.4 percent.

- 1999: An Assessment of Internal Fish Lift Efficiency at the Lowell Hydroelectric Project. The study findings section states "The ratio of total shad lifted at the Lowell Project to the total lifted at the downstream Lawrence facility was nearly doubled, reaching approximately 29% in 1999 compared to a historic ratio of 15% since 1986, and in the preceding two years." While this statistic may technically be correct, it actually represents a decrease from 1992 and 1995, when the ratios of total shad lifted at Lowell were 31 percent and 38 percent, respectively.

- Boott performed two fish lift internal efficiency studies and in the major findings column claims the crowder position has a beneficial impact on fish passage efficiency. However, this contradicts the study findings listed for the 1996 Normandeau Associates, Inc. study. As noted above, MassWildlife suggests Boott include information regarding modifications made to the fish lift which supports its contention of improved internal efficiency.

- A report by Gomez and Sullivan titled "Analysis of Upstream Fish Passage Facilities and Operations" was not included in the PAD. We recommend Boott update Table 5-4.3 to include this study, which identifies specific areas of improvement needed to increase the Lowell fishways reliability and upstream passage efficiency. Recommendations provided in the report include: (1) installing a pivot gate to update the existing vertical gate; (2) excavating the ledge outcrop downstream of the fishway entrance; (3) reopening the street side entrance; and (4) installing an entrance extension. The analysis also highlights the aging infrastructure at the project and the need to replace specific components, along with cost estimates.

6.0 Preliminary Issues, Project Effects, and Potential Studies

Fish and Aquatic Resources

Boott has not proposed any studies for relicensing at this time, but has identified potential resource issues which include: bypass flows, fish passage, historical resources, boating access, and inundation of upstream floodplains. Relevant to fish and aquatic resources, MassWildlife believes new studies need to be conducted, with sufficient fish sample sizes, to better understand upstream and downstream passage at the project as well as a complete instream flow study in the bypass reach.

Downstream Passage

MassWildlife recommends Boott conduct new studies to fully understand how post-spawned adult shad and river herring, juvenile shad and river herring, and adult silver phase eels move past the Pawtucket dam, through the canal system, turbine intakes, and the downstream bypass facility. In addition, turbine injury and mortality studies are needed and should be used in conjunction with the results of the passage routing studies, where applicable, to calculate total through-project survival rates. MassWildlife herein provides study requests in order to address these information needs.

Upstream Passage

Yearly site inspections, performed by MassWildlife, have identified a number of problems with respect to shad at the lift and ladder fishway entrances. MassWildlife believes that a comprehensive radiotelemetry study is needed to understand the relationship between project operations, including spill flows, and shad and river herring movement through the Merrimack River (including attraction to and passage through these facilities). Additionally, a study to define the relationship of the complex hydraulic conditions at the spillway fish ladder entrance and the tailrace fish lift entrance is needed in order to evaluate data on fish behavior and passage at those locations. Therefore, MassWildlife is providing herein study requests to address these information needs.

Instream Flows in the Lowell Bypass

The bypass reach is 0.7 mile long (from the Pawtucket dam to the E.L. Field powerhouse) and contains diverse habitat. There are approximately 11 miles of free-flowing river downstream of the Pawtucket dam which also contain a diversity of habitat, including important spawning and rearing habitat for migratory fish species such as American Shad. To date, there have not been any empirical studies which assess the adequacy of the existing flow protocols. MassWildlife herein submits study requests intended to address these information gaps.

ADDITIONAL INFORMATION

The following information is needed:

- the minimum hydraulic capacities, runner diameters and speeds of the turbines in each powerhouse associated with the project;
- a more thorough description of how project operations are monitored and recorded;
- hourly data (water surface elevations, dam discharge, generation) for the project in spreadsheet format for the past 5 years;
- a detailed description of modifications made to the existing fish passage facilities, including dates changes were made;
- a detailed description of canal operations; and
- a detailed description of modifications made to the bypass extending from the Pawtucket dam to the E.L. Field powerhouse (weir installation, excavation, etc.).

RECOMMENDED STUDIES

The pages below contain the studies requested by MassWildlife. They are presented in the format required pursuant to CFR §4.38(b)(5) and therefore each contain the rational for the request which will not be repeated here. Please note that MassWildlife also supports the study requests provided by the other agencies including, but not limited to, National Marine Fisheries Service, US Fish and Wildlife Service, and Massachusetts Department of Environmental Protection.

Massachusetts Division of Fisheries and Wildlife list of requested studies under P-2790

1. In-stream Flow Habitat Assessment
2. Adult Alosine Downstream Passage Assessment and Protection Evaluation
3. Telemetry Study of Upstream and Downstream Migrating Adult American Shad and River Herring
4. Impact of Project Operations on Downstream Migration of Juvenile Alosines
5. Downstream American Eel Passage Assessment
6. Operations Analysis of the Lowell Canal
7. CFD Modeling in the Vicinity of Fishway Entrances and Powerhouse Forebays
8. Bypass Reach Zone of Passage Study
9. Fish Assemblage Assessment

Thank you for this opportunity to comment.

Sincerely, Caleb Slater Caleb Slater, Ph.D. Anadromous Fish Project Leader	Sincerely, Thomas W. French Thomas W. French, Ph.D. Assistant Director for the Natural Heritage & Endangered Species Program

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Normandeau. 1991. An Assessment of the Effectiveness of a Fish Bypass for Passing Juvenile Alewives at the Lowell Hydroelectric Project, Lowell, Massachusetts. Submitted to Consolidated Hydro, Inc. Final Report. Normandeau Associates, Inc. Bedford, New Hampshire. 26 pp.

Normandeau. 1995. Use of the Fish Bypass by Juvenile Clupeids at the Lowell Hydroelectric Project During Fall 1994. Submitted to Consolidated Hydro, Inc. Final Report. Normandeau Associates, Inc. Bedford, New Hampshire. 18 pp.

Sprankle, K. 2005. Interdam movements and passage attraction of American shad in the lower Merrimack River main stem. North American Journal of Fisheries Management, 25, 1456-1466.

Boott Study Request # 1

Instream Flow Habitat Assessment of the Lowell Bypassed Reach
(Lowell, P-2790)

Goals and Objectives

The goal of this study is to determine an appropriate flow regime which will protect and enhance the aquatic resources in the bypass reach between the Pawtucket dam and the E.L. Field powerhouse. Specifically, the objective of this study is to conduct an instream flow habitat study to assess the impacts of a range of project discharges on the wetted area and optimal habitat for key species, including the quantity and location of suitable habitat.

The specific objectives of this field study, at a minimum, include:

1. characterize and map wetted perimeter of the bypass reach over a range of bypass flows;
2. survey and evaluate the water depth and mean channel velocity at transects within the bypass reach over a range of flows; and
3. map and assess the value of aquatic habitat in the bypass reach over a range of flows, focusing on potential habitat for resident species, and spawning and migration habitat or rest/regrouping areas for migratory species.

Target fish species should include American shad, river herring (alewife and blueback herring), fallfish, white sucker, freshwater mussels and benthic macroinvertebrates. The final target species list should be developed in consultation with the fisheries agencies and based on the results of the mesohabitat mapping.

Resource Management Goals

The U.S. Fish and Wildlife Service (Service) seeks the accomplishment of a number of resource goals and objectives through the relicensing process for the project. General goals include the following:

1. Ensure that protection, mitigation, and enhancement measures are commensurate with project effects and help meet regional fish and wildlife objectives for the basin.
2. Conserve, protect, and enhance the habitats for fish, wildlife, and plants that continue to be affected by the project.

Specific to aquatic resources within the Lowell bypassed reach, MassWildlife's goals are:

1. Protect, enhance, or restore diverse high quality aquatic and riparian habitats for plants, animals, food webs, and communities in the watershed and mitigate for loss or degradation of these habitats.
2. Provide a flow regime in the bypassed reach that meets the life history requirements of resident fish and wildlife (including invertebrates such as freshwater mussels) and diadromous fishes.
3. Minimize current and potential negative project operation effects on water quality and aquatic habitat.

Our study requests are intended to facilitate the collection of information necessary to conduct effects analyses and to develop reasonable and prudent conservation measures, and protection, mitigation, and enhancement measures pursuant to the Fish and Wildlife Coordination Act, as amended (16 U.S.C. §661, et seq.), and the Federal Power Act (16 U.S.C. §791a, et seq.).

Public Interest

The requester is a natural resource agency.

Existing Information

The Lowell Project bypasses a 0.7-mile-long section of the Merrimack River, from the Pawtucket dam to the E.L. Field powerhouse. There is presently no required minimum bypass flow. However, during the upstream fish passage season, the bypass reach receives 500 cfs through operation of the spillway fish ladder. In addition, the bypass reach receives flow whenever inflow exceeds the hydraulic capacity of all the project's stations. Pursuant to Article 37, Boott Hydropower, LLC, (Boott) maintains a minimum flow of 1,990 cfs or inflow, whichever is less, as measured immediately downstream of the project.

Available information in the PAD does not indicate how project operations have altered downstream hydrology, habitat quantity and quality, and water quality, which may affect resident and migratory fish, macroinvertebrates, aquatic plants and other biota and natural processes in the Merrimack River. The PAD provides no detailed description of the physical or biological characteristics of the bypassed reach.

An empirical study is needed to provide information on the relationship between flow and habitat in the bypassed reach for MassWildlife to use in determining a flow recommendation.

Nexus to Project Operations and Effects

Although the project license requires Boott to maintain a minimum flow of 1,990 cfs or inflow (if less), downstream of the project, Boott states in practice the project operates in a true run-of-river mode. The Department of the Interior is not recommending a below-project flow study based on the assumption that any new license issued for the project will require instantaneous run-of-river operation (essentially codifying current operations).

The project includes a 0.7-mile-long bypassed reach. The current license contains no minimum bypass flow requirement. During the upstream fish passage season, the bypass reach receives 500 cfs via operation of the spillway fish ladder; otherwise, the reach only receives flow when inflow exceeds the hydraulic capacity of the project's generating capacity. To our knowledge, the lack of a required bypass flow was not based on any quantitative, rigorous scientific studies.

This section of the Merrimack River contains habitat which supports native riverine species, including important spawning and rearing habitat for migratory species like American shad and river herring. While the existing license does not require a minimum bypass flow, MassWildlife believes one is needed to sufficiently protect the aquatic resources inhabiting the bypassed reach.

Results of the flow study will be used by MassWildlife to determine an appropriate flow recommendation which will protect and/or enhance the aquatic resources in the bypassed reach for the duration of any new license issued by the Federal Energy Regulatory Commission (Commission).

Methodology Consistent with Accepted Practice

Bypass flow habitat assessments are commonly employed in developing flow release protocols which will reduce impacts or enhance habitat conditions in reaches of river bypassed by hydroelectric projects.

Given the size of the bypassed reach (0.7 mile long) and the important resources known to inhabit the reach (i.e., diadromous fishes); we believe a study methodology which utilizes an instream flow incremental methodology (IFIM) approach is appropriate for this site. This same protocol was used during the relicensing of the Housatonic River Project (FERC No. 2576), and has been accepted by the Commission in other licensing proceedings.

The study should have two components. The first component entails mapping habitat within the bypass reach. The number, location, and size (area and linear distance) of each mesohabitat type in the reach should be documented, including qualitative characterizations (e.g., dominant substrate, average depth, overhead and instream cover, etc.). The second component consists of conducting an instream flow study.

At a minimum, the study design should involve collecting wetted perimeter, depth, velocity, and substrate data within a range of discharge levels along transects located in the reach of river between the dam and the E.L. Field powerhouse. The measurements should be taken over a range of test flows, to be agreed upon by the natural resource agencies. This information should then be synthesized to quantify habitat suitability (using mutually agreed upon Habitat Suitability Index curves) of each test flow for target species/life stages identified by the fisheries agencies. We recommend Boott perform habitat modeling using one dimensional modeling techniques to better characterize flows and velocities in this complex channel area.

Level of Effort/Cost, and Why Alternative Studies Will Not Suffice

Field work for flow studies can be reasonably extensive but will depend on consultation with Boott on study methodology and on-site decisions on locations for data collection and the number of collection locations. Post-field work data analysis would result in a moderate cost and effort. We anticipate that the level of effort and costs will be comparable to those experienced on similar Commission relicensing projects (e.g., the Glendale Project, FERC No. 2801).

Boott Study Request # 2

Adult Alosine Downstream Passage Assessment and Protection Evaluation
(Lowell, P-2790)

Goals and Objectives

The goal of this study is to assess the adequacy of the turbines at the E.L. Field, Assets, Bridge Street, Hamilton, and John Street powerhouses, to minimize injury, entrainment, and mortality of fishes residing in the Merrimack River, and to recommend appropriate mitigative measures as necessary.

The specific objectives of the field study, at a minimum, are: (1) assess the risk of adult American shad and alewife becoming injured, impinged, or entrained in the E.L. Field, Assets, Bridge Street, Hamilton, and John Street powerhouse units; (2) estimate turbine survival; (3) assess the risk of injury or mortality at the spillway and downstream bypass; and (4) evaluate potential passage and protection measures.

Resource Management Goals

The Atlantic States Marine Fisheries Commission has developed several documents related to the management of American shad and river herring:

1. Atlantic States Marine Fisheries Commission. 1999. Amendment 1 to the Interstate Fishery Management Plan for shad and river herring. (Report No. 35). April 1999.
2. Atlantic States Marine Fisheries Commission. 2000. Technical Addendum 1 to Amendment 1 of the Interstate Fishery Management Plan for shad and river herring. February 9, 2000.
3. Atlantic States Marine Fisheries Commission. 2009. Amendment 2 to the Interstate Fishery Management Plan for shad and river herring, Arlington, Virginia. May 2009.
4. Atlantic States Marine Fisheries Commission. 2010. Amendment 3 to the Interstate Fishery Management Plan for shad and river herring, Arlington, Virginia. February 2010.

Amendment 3 to the Interstate Fishery Management Plan for Shad and River Herring includes an objective of maximizing the number of juvenile recruits emigrating from freshwater stock complexes and recommends enhancing survival at dams during emigration by evaluating survival of post-spawned adults and juvenile fish passed via each route (e.g., turbines, spillage, bypass facilities, or a combination of the three) at any given facility, and implementing measures to pass fish via the route with the best survival rate.

Specific to resident riverine and migratory fish entrainment, MassWildlife's goals are:

1. Minimize current and potential negative project operation effects such as turbine entrainment that could hinder management goals and objectives.

2. Minimize project-related sources of mortality to resident and migratory fishes in order to restore natural food web interactions and ecosystem functions and values.

Our study requests are intended to facilitate the collection of information necessary to conduct effects analyses and to develop reasonable and prudent conservation measures, and protection, mitigation, and enhancement measures pursuant to the Fish and Wildlife Coordination Act, as amended (16 U.S.C. §661, et seq.), and the Federal Power Act (16 U.S.C. §791a, et seq.).

Public Interest

The requestor is a natural resource agency.

Existing Information and the Need for Additional Information

No project-specific information exists regarding risk of impingement and/or entrainment of adult alosines. In the PAD, Boott provided little information which would inform the relative risk of impingement or entrainment in any of the 21 units associated with the project. Moreover, information regarding fish mortality at the spillway and the downstream bypass was not discussed. While Normandeau Associates, Inc., performed a study in 2003 pertaining to the survival of Atlantic salmon smolts through the turbines, (1) the sample size was small (20 fish); (2) the study was not performed at a full range of gate settings; and (3) salmon are a robust fish species and cannot be used as a proxy for alosines. The 2003 study did shed light on a predation issue, however, in the project's tailrace. Of the salmon that passed downstream, 69 percent were suspected to be preyed upon after using the downstream bypass facility. As Normandeau Associates, Inc., noted in their study results, predators residing in the tailrace can have a large impact on emigrating migratory fish species that use the current bypass facility at the project.

To date, no directed studies of alosine injury, entrainment, or mortality have been conducted at the project's modified spillway, the downstream fish bypass facility, or through the turbines. These information gaps need to be filled so the natural resource agencies can assess the relative and cumulative impacts of project operations on outmigrating adult alosines and develop adequate passage and protection measures to meet management goals and objectives.

Nexus to Project Operations and Effects

Hydropower projects generate electricity by moving water through a turbine-generator system. Typically, there are trashracks in front of the intakes leading to the turbines. If the rack spacing is narrow and the velocities at the racks too high (relative to the swim speeds of fish species inhabiting or moving through the headpond), fish may become impinged against the racks and die. If the rack spacing is wide and the velocities too high (relative to the swim speeds of fish species inhabiting or moving through the headpond), fish may become entrained (i.e., pass through the racks) and get injured or die while passing through the turbines.

Lowell's configuration likely presents problems with respect to providing safe, timely, and effective passage for outmigrating alosines. Pre-spawned adult American shad and river herring pass upstream through the Lowell fishways and/or are stocked into upstream habitats. These fish need to be able to migrate back downstream because they are iteroparous in this region. Therefore, it is necessary to understand how alosines move through the project area and the level of injury or mortality caused by entrainment through the project's turbines and/or passage via the dam spillway and downstream bypass facility.

Methodology Consistent with Accepted Practice

MassWildlife proposes a phased approach to this study.

Phase 1:

Spill, bypass, and turbine mortality should be assessed using a balloon-tag method.

For spill mortality sites (dam spillway and downstream bypass), tagged alosines will be injected or released into spill flow at points where water velocity exceeds 10 ft/sec to minimize the possibility of the fish swimming upstream into the headpond or canal. Passed balloon-tagged alosines will be recovered below areas of spill and held for 48 hours in isolated tanks for observation of injury and latent mortality; unrecovered balloon-tagged alosines will be censored from the data.

For turbine mortality sites, tagged alosines will be injected into the intakes of units operating at or near full generation at points where intake water velocity exceeds 10 ft/sec to minimize the possibility of fish swimming back upstream through the intakes. Passed balloon-tagged alosines will be recovered in the tailrace and held for 48 hours in isolated tanks for observation of injury and latent mortality; unrecovered balloon-tagged alosines will be censored from the data.

Phase 2:

Boott should investigate existing or potential future operational and/or physical measures that would minimize injury or mortality to outmigrating adult alosines moving past the project. Based on the results of this investigation, we recommend Boott provide a range of potential alternatives (e.g., increasing attraction to the existing downstream bypass, installing exclusionary screening, etc.).

Project operations (flows, levels, gate openings, number of units operating, and operation level) and environmental conditions (river flow, temperature, turbidity, air temperature, precipitation) should be monitored regularly (hourly measurements if possible) throughout the duration of the study.

These methodologies are consistent with accepted practice.

Level of Effort/Cost, and Why Alternative Studies Will Not Suffice

The cost and effort of each individual phase of this study are expected to be moderate. Based on the scale and scope of the subject study, we estimate the cost to be $25,000 to $50,000. In the PAD, Boott proposes no studies to address this issue. MassWildlife is not aware of any previously conducted or ongoing studies related to impingement, entrainment or survival of adult alosines at the project.

REFERENCES

Normandeau. 2003. Passage Route Selection and Survival of Atlantic Salmon Smolts Passed through the Lowell Hydroelectric Project. Submitted to Boot Hydro, LLC. Final report. Normandeau Associates, Inc. Westmoreland, New Hampshire. 130 pp.

Boott Study Request # 3

Telemetry Study of Upstream and Downstream Migrating Adult American Shad and River Herring to Assess Passage Routes, Effectiveness, and Delay
(Lowell, P-2790)

Goals and Objectives

The goal of this study is to assess the behavior, approach routes, passage success, survival, and delay of adult American shad and river herring as they encounter the Lowell Project during their upstream and downstream migrations to determine if project operations negatively impact their survival and production.

The following objectives will address this request:

1. assess project operations effects on the timing, orientation, routes, and migration rates of shad and river herring;
2. determine route selection and behavior of upstream migrating shad and river herring at the project under varied operational conditions, including a range of spill conditions (e.g., movement to the dam, attraction to the E.L. Field station discharge, movement between locations, delay, timing, etc.);
3. determine delay/fallback associated with the northern canal;
4. assess near field attraction to, and entrance efficiency of, the fish lift under a range of spill conditions and with the river-side entrance and street-side entrances open;
5. assess near field attraction to, and entrance efficiency of, the spillway ladder under a range of spill conditions;
6. evaluate the internal efficiency of the Pawtucket dam ladder;
7. collect ladder and lift efficiency data, to include rates of approach to fishway entrances, entry into fishways, and passage under varied operational conditions, including a range of spill conditions;
8. determine the proportion of post-spawned adults that select the power canal as a downstream passage route under varied operation conditions, including a range of spill conditions up to full spill; determine post-spawned adult downstream migration route selection, passage efficiency, and delay associated with the power canal under various operational conditions, including a range of spill conditions; and
9. compare rates and measures of delay and movement among project areas and routes utilized (e.g., spill at dam vs. power canal) under the range of permitted and proposed spill and operational conditions.

If project operations are adversely affecting shad or river herring migration timing or are resulting in other deleterious population effects, we recommend Boott identify operational solutions or other passage measures that will reduce and minimize these impacts within the project area.

This study will require 3 years of field data due to the tailrace ledge excavation project which will be completed in 2019 and to capture inter-annual variability of river discharge, water temperatures, and variability in outmigration timing. We recommend Boott perform the downstream routing portion of the study in 2019 (pre-ledge excavation) and 2020 (post-ledge excavation). In 2020 and 2021, after the ledge has been excavated, we recommend Boott perform the upstream portion of this study.

Resource Management Goals

The Atlantic States Marine Fisheries Commission, Amendment 3 to the Interstate Fishery Management Plan for Shad and River Herring, approved in 2010, includes the following objectives:

Upstream Passage

1. Fish must be able to locate, enter, and pass the passage facility with little effort and without stress.
2. Where appropriate, upstream fish passage effectiveness should be improved through operational or structural modifications.
3. Fish which have ascended the passage facility should be guided to an appropriate area so they can continue their upstream migration and avoid being swept back downstream.

Downstream Passage

1. Enhance survival at dams during emigration.
2. Evaluate survival of post-spawned adults and juvenile fish passed via each project route (e.g., turbines, spillage, bypass facilities, or a combination of the three).
3. Implement measures to pass fish via the route with the least delay and best survival rate.

MassWildlife seeks the accomplishment of a number of resource goals and objectives through the relicensing process for the projects. General goals include the following:

1. Ensure that protection, mitigation and enhancement measures are commensurate with project effects and help meet regional fish and wildlife objectives for the basin.
2. Conserve, protect, and enhance the habitats for fish, wildlife, and plants that continue to be affected by the project.

Specific to American shad and river herring movement and migration, MassWildlife's goal is to minimize current and potential negative project operation effects on the safe, timely and effective upstream and downstream passage of adult American shad and river herring.

Our study requests are intended to facilitate the collection of information necessary to conduct effects analyses and to develop reasonable and prudent conservation measures, and protection, mitigation, and enhancement measures pursuant to the Fish and Wildlife Coordination Act, as amended (16 U.S.C. §661, et seq.), the Federal Power Act (16 U.S.C. §791a, et seq.), the Atlantic States Marine Fisheries Compact (P.L. 539, 77th Congress, as amended by P.L. 721, 81st Congress), and the Atlantic Coastal Fisheries Cooperative Management Act (16 U.S.C. 5107).

Public Interest

The requestor is a natural resource agency.

Existing Information and the Need for Additional Information

Several studies pertaining to the fish lift and downstream passage facilities at Lowell have been conducted for American shad. Studies of alewife passage are limited to a single downstream test performed in 1991. Previous studies pertaining to upstream shad migration (listed in Table 5.4-3 of the PAD) demonstrate passage through the existing lift at Lowell is relatively poor. Also, when analyzing annual passage counts for river herring and shad, the number of fish which utilize the Lowell lift versus those that pass at Lawrence is low (from 1996 to 2017 passage efficiency at Lowell has not exceeded 30 percent).

Until 2016, the fish lift has been the primary route of upstream passage at the project. The ladder, located at the Pawtucket dam, has typically only been operated during periods of high flow. Therefore, to date, studies performed at Lowell have not tested the nearfield attraction, entrance efficiency, or internal efficiency of the ladder. Moreover, past studies have had statistically low sample sizes (less than 60 fish) and were all performed prior to the ledge excavation project which will occur in August 2019. Future studies should have a robust sample size (at a minimum, 150 fish per species) and array system. Additionally, to obtain a comprehensive understanding of fish behavior at Lowell, for both upstream and downstream migration, studies are needed to: (1) determine if project operations affect pre-spawned and post-spawned river herring and shad migration timing; (2) assess fish movement to, and through, the ladder at the Pawtucket dam; and (3) assess passage success at the tailrace fish lift post-ledge removal.

Nexus to Project Operations and Effects

Lowell tailrace turbulence (potentially exacerbated by the existing ledge outcropping) creates attraction issues at the entrance of the fish lift. Moreover, a lack of effective protection at the 21 turbines associated with the project increases the risk of entrainment and mortality alosines may experience as they migrate downstream to the ocean. During the upstream fish passage season, the Lowell bypass reach receives 500 cfs during the day and 300 cfs at night via operation of the spillway fish ladder; otherwise, the reach only receives flow when inflow exceeds the hydraulic capacity of the project's generating capacity. The spillway ladder is, therefore, only partially effective due to lack of flow.

Existing project operations and limited bypass flows can have a direct impact on diadromous fish migration. Migration delays, increased predation, mortality during passage over the dam or through turbines, and changes in route selection under different flow conditions are potential influences of the project on shad and river herring populations in the Merrimack River. Effective upstream and downstream passage and successful spawning and juvenile production are necessary to help achieve shad and river herring management restoration goals for the Merrimack River, particularly in the upstream reaches.

Methodology Consistent with Accepted Practice

The movement of migratory shad and river herring would be best studied by using radio telemetry, including passive integrated transponder (PIT) tags. Radio telemetry is an accepted technology that has been used for a number of studies associated with hydropower projects, including at the Bellows Falls (FERC No. 1855), Wilder (FERC No. 1892), and Vernon (P-1904) projects.

The study design must specify sample sizes, as well as tag and receiver configurations, to ensure rates of entry and exit to the tailrace, fish lift and fish ladder, downstream bypass, the bypassed reach, and canal, can be calculated with sufficient precision. We recommend Boott capture shad and river herring below Lawrence and tag at least 150 individuals per species. Double-tagged (radio and PIT) shad and river herring should be released upstream of the Lawrence dam and upstream of the Lowell dam. Fish should also be released directly into the Pawtucket canal to adequately assess project conditions likely to be encountered during downstream migration. Additional, tagged, individuals may need to be released farther upstream to ensure enough fish encounter the dam during a sufficient range of turbine and operational conditions to test for project effects (especially in 2020 and 2021). A large array of stationary monitoring stations (radio and PIT) will be needed to provide an appropriate level of resolution for data analyses and to answer the natural resource agencies' questions regarding project operation effects. Additionally, since fish can drift a considerable distance downstream after they have died (Havn et al. 2017); a minimum of 25 dead river herring and 25 dead shad should also be released as a control group in this study. A plan and schedule for spill releases should be developed which provides sufficient periods of spill and various generating levels (treatments will require multiple days of consistent discharge).

Each component of this study will require 2 years of field data collection to attempt to account for inter-annual variability in river discharge, water temperatures, and the ledge excavation project which will be completed in 2019. We recommend Boott perform the downstream routing portion of the study in 2019 (pre-ledge excavation) and 2020 (post-ledge excavation). In 2020 and 2021, after the ledge has been excavated, the upstream portion of this study should be performed.

A related study request on computational fluid dynamics (CFD) modeling in the Lowell tailrace, in and around the fish lift and fish ladder entrances and powerhouse forebay, will complement this study and address related project operational effects.

These methodologies are consistent with accepted practice.

Level of Effort/Cost, and Why Alternative Studies Will Not Suffice

Estimated cost for this study is expected to range from $400,000 to $500,000, with the majority of costs associated with equipment (radio and PIT tags, radio receivers, and PIT readers) and related field work labor. Since tagged shad and river herring will move throughout the area, to varying degrees, there will be expected cost savings (e.g., radio tags) to Boott, provided cooperation in study planning and implementation occurs.

Boott did not propose any studies to meet this need in the PAD.

REFERENCES

Havn, T. B., F. Økland, M.A. Teichert, L. Heermann, J. Borcherding, S.A. Sæther, O.H. Tambets and E.B. Thorstad. 2017. Movements of dead fish in rivers. Animal Biotelemetry, 5: 7.

Boott Study Request # 4

Impact of Project Operations on Downstream Migration of Juvenile Alosines
(Lowell, P-2790)

Goals and Objectives

The goals of this study are: (1) conduct a field study of juvenile alewife outmigration in the Lowell impoundment, the power canal, and at the Pawtucket dam, to determine if project operations negatively impact juvenile alosine survival and production; and (2) determine if project operations affect juvenile alosine outmigration survival, recruitment, and production.

The following objectives will address this request:

1. assess project operations effects of the Pawtucket dam on the timing, orientation, passage routes, migration rates, and survival of juvenile alewife;
2. determine the proportion of juvenile alewife that select the Lowell canal versus the Pawtucket powerhouse, downstream bypass facility, or dam spill as a downstream passage route, under varied operational conditions;
3. determine if there are any delays associated with downstream movement related to either dam spill or the Pawtucket powerhouse due to operations;
4. determine the juvenile downstream passage timing and route selection in the Lowell canal, assess delays associated with the canal, and with project operations (e.g., stockpiling in the canal).

If it is determined the project operations are adversely affecting juvenile alosine survival, migration timing, or other deleterious population effects, identify operational solutions or other passage measures which will reduce and minimize these impacts within the project area. This study will require 2 years of field data to capture inter-annual variability of river discharge and water temperatures.

Resource Management Goals

The Atlantic States Marine Fisheries Commission Amendment 3 to the Interstate Fishery Management Plan for Shad and River Herring (American Shad Management), approved in 2010, includes the following objective:

Maximize the number of juvenile recruits emigrating from freshwater stock complexes.
To enhance survival at dams during emigration, evaluate survival of post spawning and juvenile fish passed via each route (e.g., turbines, spillage, bypass facilities, or a combination of the three) at any given facility, and implement measures to pass fish via the route with the best survival rate.

MassWildlife seeks the accomplishment of a number of resource goals and objectives through the relicensing process for the projects. General goals include the following:

1. Ensure that protection, mitigation, and enhancement measures are commensurate with project effects and help meet regional fish and wildlife objectives for the basin.
2. Conserve, protect, and enhance the habitats for fish, wildlife, and plants that continue to be affected by the project.

Specific to juvenile American shad and river herring movement and migration, MassWildlife’s goal is to minimize current and potential negative project operation effects on the safe, timely and effective downstream passage.

Our study requests are intended to facilitate the collection of information necessary to conduct effects analyses and to develop reasonable and prudent conservation measures, and protection, mitigation, and enhancement measures pursuant to the Fish and Wildlife Coordination Act, as amended (16 U.S.C. §661, et seq.), the Silvio O. Conte National Fish and Wildlife Refuge Act (P.L. 102-212; H.R. 794), the Federal Power Act (16 U.S.C. §791a, et seq.), the Atlantic States Marine Fisheries Compact (P.L. 539, 77th Congress, as amended by P.L. 721, 81st Congress), and the Atlantic Coastal Fisheries Cooperative Management Act (16 U.S.C. 5107).

Public Interest

The requestor is a natural resource agency.

Existing Information and the Need for Additional Information

The seaward migration of juvenile alosines is of great importance to the restoration of alewife, blueback herring, and American shad in the Merrimack River. However, data on the downstream migratory movements and rates of alosines past Lowell is sparse and relatively incomplete. In 1994 and 1995, Normandeau Associates, Inc., documented the use of the bypass facility by downstream migrating alosines via the installation of a removable box trap. Passage efficiencies were 7 percent and 37 percent, respectively. However, to date, no directed studies of downstream alosine passage route selection has been conducted at the Lowell Project. These information gaps need to be filled so the natural resource agencies can assess the relative and cumulative impacts of project operations on outmigrating juvenile alosines and develop adequate passage and protection measures to meet management goals and objectives.

Studies conducted farther upstream on the Merrimack River, at Garvins Falls (FERC No. 1893), have shown it is possible to radio-tag juvenile alewife to evaluate alosine outmigration (Normandeau 2016). Alewife can be used as a proxy, in this instance, for the natural resource agencies to assess blueback herring and shad downstream migration patterns.

Nexus to Project Operations and Effects

Adult alosines, passed at Lowell via the fishways and/or stocking efforts, utilize upstream habitat to spawn on an annual basis. Similarly, juvenile alosines require safe and timely downstream passage measures at the project in order to successfully emigrate back to the ocean to contribute to the population. Presently, downstream migrants can easily enter the Lowell canal system, via the Pawtucket canal, as there are no exclusionary measures in place. There are 19 turbines located in the canal, housed at four powerhouses (Assets, Bridge Street, Hamilton, and John Street), none of which have passage or protection measures. There are a variety of unit-types housed in each of the powerhouses, ranging in speed from 100 to 150 rpm. A study is needed to assess the impacts project operations have on outmigrating juvenile alosines.

MassWildlife is not aware of any studies conducted specifically designed to determine:

1. What is the rate of alewife survival under a range of spill and gate configurations?
2. Are there delays in migration/movement at the dam, gatehouse, or in the canal?
3. For juveniles that enter the Pawtucket canal, what proportion subsequently enter the Western, Merrimack, Pawtucket, or Hamilton canals?
4. What is the rate of movement through the canal, what is the delay to juvenile alosine outmigration, and the potential accumulation of juveniles in the canal?
5. What proportion of juvenile alosines use the downstream bypass sluice versus the E.L. Field powerhouse turbines under varied operational conditions?

MassWildlife is concerned project operations are: (1) impacting juvenile alosine outmigration survival; and (2) contributing to the failure of the Merrimack River alosine population to meet management targets.

Methodology Consistent with Accepted Practice

The impact of project operations to juvenile alewife outmigration, passage route selection, and migratory delay would be best studied via radio telemetry. This methodology has successfully been tested and employed by Normandeau Associates, Inc., at the Garvins Falls hydroelectric project (FERC No. 1893; Normandeau 2013; Normandeau 2016). Project discharge over a full range of existing and, to the extent possible, potential future operational conditions at the dam (likely increased bypass reach flows in new license), should be examined relative to migration rate and passage route selection of juvenile alosines to, and through, various areas of the project.

In addition, study fish should be collected and balloon-tagged to empirically determine rates of survival for fish passed over or through the dam's bypass sluice, main powerhouse, and 19 canal units under varied operations. For spill mortality sites (dam spillway and downstream bypass), tagged alosines should be injected or released into spill flow at points where water velocity exceeds 10 ft/sec to minimize the possibility of the fish swimming upstream into the headpond or canal. Passed balloon-tagged alosines will be recovered below areas of spill and held for 48 hours in isolated tanks for observation of injury and latent mortality; unrecovered balloon-tagged alosines will be censored from the data.

For turbine mortality sites, tagged alosines will be injected into intakes of units operating at or near full generation at points where intake water velocity exceeds 10 ft/sec to minimize the possibility of fish swimming back upstream through the intakes. Passed balloon-tagged alosines will be recovered in the tailrace and held for 48 hours in isolated tanks for observation of injury and latent mortality; unrecovered balloon-tagged alosines will be censored from the data.

Radio-tagged juvenile alewife will be released in areas upstream of the project at multiple release locations, to determine operation effects on migration rates, route, orientation, and entrainment, over a full range of permitted and operational conditions. The release of radio-tagged fish upstream of the project, and induction into the power canal, will provide data on concerns of delay and route selection to the canal, downstream bypass, crest gates, and turbines. Additionally, since fish can drift a considerable distance downstream after they have died (Havn et al. 2017); a minimum of 50 dead alewife should also be released as a control group in this study.

Level of Effort/Cost, and Why Alternative Studies Will Not Suffice

Boott does not propose any studies to meet this need. Estimated costs for the study are expected to be moderate to high, between $100,000 and $300,000, with the majority of costs associated with equipment (radio tags, radio receivers) and related field work labor.

REFERENCES

Havn, T. B., F. Økland, M.A. Teichert, L. Heermann, J. Borcherding, S.A. Sæther, O.H. Tambets and E.B. Thorstad. 2017. Movements of dead fish in rivers. Animal Biotelemetry, 5: 7.

Normandeau 2013. Juvenile Alosine Radio Tag Attachment Test. Submitted to Boot Hydro, LLC. Final report. Normandeau Associates, Inc., Westmoreland, New Hampshire. 2 pp.

Normandeau 2016. Garvins Falls Juvenile Alosine Downstream Passage Telemetry Assessment. Submitted to Boot Hydro, LLC. Final report. Normandeau Associates, Inc., Westmoreland, New Hampshire. 13 pp.

Boott Study Request # 5

Downstream American Eel Passage Assessment
(Lowell, P-2790)

Goals and Objectives

The goal of this study is to determine the impact of the Lowell hydroelectric project on the outmigration of silver eels in the Merrimack River. Entrainment in the canal and at the conventional turbines at the project powerhouses (E.L. Field, Assets Station, Bridge Street, Hamilton Station, and John Street) can result in mortality or injury. It is important to understand the passage routes at the project and the potential for delay, injury, and mortality to assess alternative management options to increase survival.

The objectives of this study are:

1. Quantify the movement rates (including delays) and relative proportion of eels passing via various routes at the project (i.e., through the turbines, through the downstream bypass, spilled at the dams, etc.).
2. Evaluate instantaneous and latent mortality and injury of eels passed via each potential route.

Resource Management Goals

The Atlantic States Marine Fisheries Commission has developed two documents related to the management of American eel:

1. Interstate Fishery Management Plan for American Eel. April 2000. Atlantic States Marine Fisheries Commission.
2. Addendum II to the Fishery Management Plan for American Eel. Atlantic States Marine Fisheries Commission. Approved October 23, 2008. 8 pp.

Objectives of the management plan include: (1) protect and enhance American eel abundance in all watersheds where eel now occur; and (2) where practical, restore American eel to those waters where they had historical abundance, but may now be absent, by providing access to inland waters for glass eel, elvers, and yellow eel, and adequate escapement to the ocean for pre-spawning adult eel.

Addendum II contains specific recommendations for improving upstream and downstream passage of American eel, including requesting that member states and jurisdictions seek special consideration for American eel in the Commission relicensing process.

MassWildlife seeks the accomplishment of a number of resource goals and objectives through the relicensing process for the project. General goals include the following:

1. Ensure that protection, mitigation and enhancement measures are commensurate with project effects and help meet regional fish and wildlife objectives for the basin.
2. Conserve, protect, and enhance the habitats for fish, wildlife, and plants that continue to be affected by the project.

Specific to downstream passage of American eel, MassWildlife's goals are:

1. Minimize current and potential negative project operation effects that could hinder management goals and objectives.

2. Minimize project-related sources of downstream passage delay, injury, stress, and mortality in order to maximize the number of silver eels migrating to the spawning grounds.

Our study requests are intended to facilitate the collection of information necessary to conduct effects analyses and to develop reasonable and prudent conservation measures, and protection, mitigation, and enhancement measures pursuant to the Fish and Wildlife Coordination Act, as amended (16 U.S.C. §661, et seq.), and the Federal Power Act (16 U.S.C. §791a, et seq.).

Public Interest

The requester is a natural resource agency.

Existing Information and the Need for Additional Information

Data on downstream migratory movements and rates of American eels past the project are sparse and relatively incomplete. A single study was performed by Normandeau Associates, Inc., in 2017 (Normandeau 2017). Seventeen silver-phase eels were tagged and released into the Merrimack River upstream of the Garvins Falls project. Of the 17 released individuals, 14 approached the Pawtucket dam. Eight were determined to have passed through the gatehouse and enter the forebay canal upstream of the E.L. Field powerhouse. Five eels passed the project via spill flow. One eel's passage route was classified as unknown. Zero individuals used the downstream bypass. This study had a small sample size, was of a relatively short duration (October 20-November 28, 2017), did not include monitoring stations or antenna arrangements in the canal, and was performed prior to the installation of the pneumatic crest gate system.

To date, no other directed studies of eel entrainment or mortality have been conducted at the Lowell Project. These information gaps need to be filled so the natural resource agencies can assess the relative and cumulative impacts of project operations on outmigrating eels and develop adequate passage and protection measures to meet management goals and objectives.

Nexus to Project Operations and Effects

The project configuration presents problems with respect to providing safe, timely, and effective passage for outmigrating eels. The intakes are likely deep and, while no specification for the trashracks were provided in the PAD, it is unlikely they would prevent entrainment of eels. The anadromous downstream passage facility at the project is also not expected to be effective for eels; the target anadromous species are surface-oriented, while eels tend to move much deeper in the water column. Additionally, there are no data pertaining to eel movements in the Lowell canal. Eels which move into the canal potentially have no alternative but to pass through hydropower turbines at the Assets, Bridge Street, Hamilton, and John Street powerhouses. Eels are known to occur upstream of the dam; therefore, it is necessary to understand how eels move through the project and the level of injury and/or mortality resulting from each potential passage route (i.e., the spillway, the downstream bypass facility, or the 21 turbines associated with the project).

Methodology Consistent with Accepted Practice

In order to understand the movements of outmigrating silver eels as they relate to operations at Lowell, radio telemetry technology should be utilized. Radio telemetry is an accepted technology which has been used for a number of studies associated with hydropower projects, including at the Bellows Falls (FERC No. 1855), Wilder (FERC No. 1892), and Vernon (P-1904) projects.

Studies should be designed to investigate route selection (i.e., entrainment vs. spill) independently from estimation of mortality/injury, because these metrics require different methodologies. Studies will also likely benefit from data collected over 2 study years (especially route selection studies, which may be more significantly affected by environmental conditions during a given season than mortality/injury studies). It is also envisioned that the results from route selection studies can guide design of turbine mortality studies. Therefore, it is proposed, at a minimum, route selection studies be conducted in multiple years, but mortality/injury studies may be conducted after the first year of route selection studies have been completed.

Objective 1: Route Selection

This study will involve systematic releases of radio-tagged silver phase eels at strategic points above areas of interest, to assess general routes of passage (i.e., via spill, bypass, or turbines). Active downstream migrants should be collected within-basin if possible (i.e., Cabot or Holyoke bypass samplers), but fish sourced from out-of-basin may be acceptable to meet sample size demands. Experimental fish must meet morphometric (e.g., eye diameter relative to body size) criteria to ensure they are migrant silver phase. Collections should be made within the migratory season (late August to mid-October), and eels should be tagged and released within 21 days after capture, but preferably within 7 days (particularly if the test eels are from out-of-basin).

All telemetered eels will be radio- and PIT-tagged. PIT antennas will be installed and monitored continuously to verify passage of eels via bypass channels.

A minimum number of 150 telemetered eels (e.g., five separate groups of approximately 30 eels each) will be required to maximize the data return. Tagged eels should be released at least 5 km upstream of the Lowell Project. Groups of eels should be released during spill (if any) and non-spill and during periods of low, moderate, and high generation conditions. Up to 50 additional eels should also be released in the upper canal and allowed to volitionally descend through the canal to assure that a sufficient number of eels are exposed to canal conditions. Groups of eels should be released when the canal units are running and when the canal units are off. Additionally, since fish can drift a considerable distance downstream after they have died (Havn et al. 2017), a minimum of 25 dead eels should also be released as a control group in this study.

Telemetry receivers and antennas should be located upstream and downstream of the spillway, at the canal entrance, within the canal, in the downstream fish bypass entrance, at turbine intakes, the station tailrace, and downstream of the confluence of the Merrimack and Concord rivers. These locations will permit assessment of passage via the following potential routes: the power canal; spillway; downstream fish bypass; station turbines; and upstream fishway attraction water intake. The final placement of receivers and antennas should be developed in consultation with the fisheries agencies.

Mobile tracking (i.e., via boat) in the River and canal between release sites and several km downstream will be performed at regular intervals during and after releases to confirm routes and fates of passed fish or lost fish.

Movement rates (time between release and detection at radio antenna locations, and between radio antenna locations) of eels passing the projects by various routes will also be quantified.

The route selection portion of this study should occur in both study years.

Objective 2: Spill, Bypass, and Turbine Mortality/Injury Studies

Spill, bypass, and turbine mortality will be assessed using a balloon-tag method.

For spill mortality sites (dam spillways and downstream bypasses), tagged eels will be injected or released into spill flow at points where water velocity exceeds 10 ft/sec to minimize the possibility of eels swimming upstream into the headpond or canal. Passed balloon-tagged eels will be recovered below areas of spill and held for 48 hours in isolated tanks for observation of injury and latent mortality; unrecovered balloon-tagged eels will be censored from the data.

For turbine mortality sites, tagged eels will be injected into intakes of all 21 units associated with the project, operating at a full range of settings where intake water velocity exceeds 10 ft/sec to minimize the possibility of eels swimming back upstream through the intakes. Passed balloon-tagged eels will be recovered in the tailrace(s) and held for 48 hours in isolated tanks for observation of injury and latent mortality; unrecovered balloon-tagged eels will be censored from the data.

If the balloon-tag mortality component of the study occurs in study year one, all possible route selection sites would need to be evaluated. If the balloon-tag mortality component of the study occurs in study year two, results from the route selection study could be used to inform which sites need to be evaluated for mortality. Eels recovered from balloon-tag studies should not be used for route selection studies.

Data analyses of route selection and mortality (instantaneous and latent) will follow standard methodology.

Project operation (flows, levels, gate openings, number of units operating and operation level) and environmental conditions (river flow, temperature, turbidity, air temperature, precipitation) will be monitored regularly (hourly measurements if possible) throughout the duration of the studies and assessed for potential relationships to passage route selection, migratory delay, and/or passage survival.

These methodologies are consistent with accepted practice.

Level of Effort/Cost, and Why Alternative Studies Will Not Suffice

The level of cost and effort for the downstream eel passage study will be moderate to high; silver eels would need to be collected, tagged, and released in several locations over the course of the migration season. Antennas and receivers would need to be installed throughout the canal, at the intakes of the E.L. Field powerhouse, at the dam spillways and station bypass and monitored regularly. Data would need to be retrieved periodically, then analyzed. A multi-site route selection study conducted by the USGS Conte Lab on the Shetucket River in Connecticut cost approximately $75,000 for the first year of study. Costs are estimated at $100,000 per year for the route selection study and $50,000 to $75,000 for the spill, bypass, canal, and turbine mortality/injury study.

Boott did not propose any studies to meet this need in the PAD.

REFERENCES

Havn, T. B., F. Økland, M.A. Teichert, L. Heermann, J. Borcherding, S.A. Sæther, O.H. Tambets and E.B. Thorstad. 2017. Movements of dead fish in rivers. Animal Biotelemetry, 5: 7.

Normandeau Associates, Inc. 2017. Downstream Passage Evaluation for Silve-Phase American Eels at the Lowell Hydroelectric Project. 2017. Submitted to the City of Holyoke Gas and Electric Department. Final report. Normandeau Associates, Inc., Westmoreland, New Hampshire. 17 pp.

Boott Study Request # 6

Operations Analysis of the Lowell Canal
(Lowell, P-2790)

Goals and Objectives

The goal of this study is to understand the operations of the Lowell canal system. The specific objective of this study is to describe the operations of the Lowell canal (how all of the canal units interact with the main units, how the canal units are sequenced, how often each of the units operate, the prioritization sequence of canal unit operations, the amount of time the units are operated during the downstream passage season, etc.).

Resource Management Goals

MassWildlife seeks the accomplishment of a number of resource goals and objectives through the relicensing process for the project. General goals include the following:

1. Ensure that protection, mitigation, and enhancement measures are commensurate with project effects and help meet regional fish and wildlife objectives for the basin.
2. Conserve, protect, and enhance the habitats for fish, wildlife, and plants that continue to be affected by the project.

Specific to aquatic resources, MassWildlife's goals are:

1. Protect, enhance, or restore diverse high quality aquatic and riparian habitats for plants, animals, food webs, and communities in the watershed and mitigate for loss or degradation of these habitats.
2. Minimize current and potential negative project operation effects on fish in the project area.

Public Interest

The requestor is a natural resource agency.

Existing Information and the Need for Additional Information

The Merrimack River supports a variety of migratory fish species. However, there is no information pertaining to fish mortality and population effects resulting from entrainment in the canal and/or the canal units. Since there are no exclusionary measures at the entrance of the project's canal system, fish can easily enter the two-tiered network of man-made canals, which are approximately 5.5 miles in length. These man made canals provide flow to 19 Boott-owned hydroelectric units. Since obtaining the original license for the project, there have been no directed studies of the Pawtucket, Western, Merrimack, or Hamilton canal units. Additionally, the PAD provides little operational information regarding the canal: flows of up to 2,000 cfs are routed into the canal, typically once the E.L. Field station's hydraulic capacity of 8,000 cfs has been reached. These information gaps need to be filled so the natural resource agencies can assess the relative and cumulative impacts of project operations on riverine fishes and migratory alosines which may be moving through, or inhabiting, the canal and develop adequate passage and protection measures to meet management goals and objectives.

Nexus to Project Operations and Effects

The Lowell Project consists of a two-tiered, 5.5-mile-long, network of man-made canals which include several small dams and 19 turbine units. Flows enter the canal system upstream of the Pawtucket dam via the Pawtucket canal.

There are no exclusionary measures for fish in place. Therefore, the Lowell canal presents problems with respect to providing safe, timely, and effective passage for fish trying to move past the project through the canal system.

Methodology Consistent with Accepted Practice

In order to determine the relative risk the canal units present to riverine and migratory fishes, it is necessary to understand how the canal operates. Therefore, we request Boott provide a detailed description of the operational protocol it uses to determine when and how much water flows into the canal at a time scale relevant to the migratory fish species expected to potentially utilize the canal as a passage route (e.g., May, June, and July for spent alosines; August through November for adult eels and juvenile alosines). Historical operations data should be examined relative to the hydrological data set to determine the percent of time the canal units would be expected to operate during each passage month. This analysis should be used in conjunction with the results of the passage route and turbine mortality studies to estimate total through project mortality for each target fish species/life stage.

Level of Effort/Cost, and Why Alternative Studies Will Not Suffice

The expected level of effort and anticipated cost will be low. Operations and hydrologic data are readily available and only need to be compiled and analyzed. We estimate the cost to be less than $10,000.

Boott Study Request # 7

Three-Dimensional Computational Fluid Dynamics (CFD) Modeling in the Vicinity of Fishway Entrances and Powerhouse Forebays
(Lowell, P-2790)

Goals and Objectives

The goal of this study is to determine the flow field conditions which exist in and around fishway entrances and the powerhouse forebay. The information from this request is meant to be coupled with data from the telemetry studies, such that a comprehensive understanding of fish behavior is developed.

The objective of this study is to create a series of color contour maps of velocity magnitude at select discharges agreed upon by the resource agencies and the licensee. With respect to upstream passage, the results will show approach velocities and flow fields that may create a response in fish. This information can be coupled with telemetry data (from the requested shad and river herring telemetry study) and passage counts to understand which conditions are optimal for guiding migrating fish to the fishway entrances and stimulating fishway entry.

With respect to downstream migration, the results will show velocities and flow fields in front of the E.L. Field powerhouse. Additionally, the results will indicate to what degree, if any, flow directs downstream migrating fish towards the downstream bypass facility.

Resource Management Goals

The management goals of this study request are to obtain information that will assist in enhancing the effectiveness of the current upstream fish passage facilities for upstream migrating trust species and reduce impingement, entrainment, and delay for downstream migrating fish. CFD models are a relatively cost effective way to analyze existing and future conditions. As such, changes in the amount of attraction water, changes in which turbines are operating, and which spillway gates are releasing water can all be examined. As stated, the results from this study are meant to be used along with the data generated from the requested telemetry study. The combined analysis from these two data sources can help assess which flow conditions are most advantageous for migrating trust species to enter the fishway under current and proposed conditions.

As for downstream migration of adult and juvenile shad, river herring, and adult eel, the results from the models will reveal flow magnitude and direction in front of the powerhouse. Given the limited information that currently exists on survival through the project, our management goal is to direct as many downstream migrating fish as possible towards the downstream bypass facility. With respect to upstream passage, we want to maximize the number of fish that find and enter the fishway entrances.

Our study requests are intended to facilitate the collection of information necessary to conduct effects analyses and to develop reasonable and prudent conservation measures, and protection, mitigation, and enhancement measures pursuant to the Fish and Wildlife Coordination Act, as amended (16 U.S.C. §661, et seq.), and the Federal Power Act (16 U.S.C. §791a, et seq.).

Public Interest

The requestor is a natural resource agency.

Existing Information and the Need for Additional Information

To date, no CFD modeled data exists in front of either the fish ladder or lift, nor do they exist in front of the E.L. Field powerhouse. A comprehensive understanding of fish behavior at the ladder and lift entrance, and the powerhouse forebay, is needed in order to create safe, timely, and effective upstream and downstream passage for American shad, river herring, and eels. Additionally, a better understanding of flow and how it affects fish passage is needed after Boott performs the ledge removal excavation project.

Nexus to Project Operations and Effects

The Lowell Project has direct impacts to upstream and downstream migrating shad, river herring, and eel. The development of these models will give resource agencies valuable information into the hydraulic cues which may elicit a response from upstream migrants. For downstream passage, MassWildlife has approach velocity guidelines; the output from these models would inform the resource agencies under what conditions appropriate approach velocities are being met and when they are being exceeded.

With respect to upstream migration, the auxiliary water system (AWS) plays a critical role in determining whether or not fish are attracted to the entrance. The results from this study would allow us to assess how well the AWS is performing and under what conditions it attracts the most fish.

With respect to downstream migration, the development of a CFD model under existing conditions also informs the design of future modifications and improves the survivability of downstream migrating shad, river herring, and eel.

The CFD models for the Pawtucket fishway and fish lift should be developed as part of year two studies, after the ledge excavation project is complete. It would be useful to have the gatehouse area CFD modeling completed in year one. This analysis may provide information on adjustments to canal operations or structures that can subsequently be analyzed.

Understanding the entrance conditions of the Pawtucket fishway under a range of spill conditions would be informative. If developed prior to the year one upstream shad telemetry studies, it would provide information on spill gate settings which would likely best achieve entrance and ultimately passage. Further work with the model can help in evaluating changes in ladder entrance or spill conditions that could improve passage and be tested with telemetry, video, and/or count data.

CFD modeling of the flows leading to the canal would aide in our interpretation of year one downstream passage telemetry results, but would not need to be completed prior to the year one telemetry (downstream juvenile alewife and downstream eel) studies. Those studies will provide the context for how and where shad, river herring, and eels are passing the project and how successful passage is. The CFD modeling could focus on the locations identified as important in the study results and Boott could assess changes to structures or operations and evaluate them in the model. Promising alternatives would then be tested in year three studies.

Methodology Consistent with Accepted Practice

A three-dimensional CFD model has become an increasingly common standard of analysis at hydroelectric projects around the nation. Within the northeast region, we have seen these types of models developed at the Holyoke (P-2004), Brunswick (P-2284), Shawmut (P-2322), Milford (P-2534) and Orono (P-2710) projects. We would expect to engage with the licensee in terms of determining the appropriate area and flows to be modeled. We expect the spatial extent of the model at each study site will vary. Given the large number of ways in which output from these models can be presented and the near infinite number of flows which could potentially be modeled, we would expect to consult with the licensee to reach agreed upon modeling efforts and scenarios to be examined.

Level of Effort/Cost, and Why Alternative Studies Will Not Suffice

The cost of developing, running and testing a CFD model can vary tremendously; one large variable in determining the cost is based on the amount of existing bathymetric data to which Boott currently has access. We roughly estimate that the cost of each CFD model could run as high as $50,000, assuming no bathymetric data currently exists. Proactive communication with resource agencies will reduce the cost and iterative effort. Given the level of effort that has occurred at other projects that have proposed to amend their license, we see the level of effort requested here as reasonable, given that Boott is seeking a renewal of its license.

Boott Study Request # 8

Bypass Reach Zone of Passage Study
(Lowell, P-2790)

Goals and Objectives

The goal of this study is to determine zone-of-passage flows in the bypass reach which facilitate safe, timely, and effective fish passage through the project.

Specifically, the objectives of this study are:

1. complete a detailed survey of the bypass reach;
2. develop a high-resolution, two-dimensional hydraulic model of the bypass reach;
3. release multiple flows from the dam to collect calibration data for the model;
4. simulate additional flows through the bypass reach with the calibrated model; and
5. determine minimum and optimal zone-of-passage flows for the project.

Resource Management Goals

MassWildlife seeks the accomplishment of a number of resource goals and objectives through the relicensing process for the project. General goals include the following:

1. Ensure that protection, mitigation and enhancement measures are commensurate with project effects and help meet regional fish and wildlife objectives for the basin.
2. Conserve, protect, and enhance the habitats for fish, wildlife, and plants that continue to be affected by the project.

Specific to aquatic resources within the Lowell bypassed reach, MassWildlife's goals are:

1. Protect, enhance, or restore diverse high quality aquatic and riparian habitats for plants, animals, food webs, and communities in the watershed and mitigate for loss or degradation of these habitats.
2. Provide a flow regime in the bypassed reach that meets the life history requirements of resident fish and wildlife (including invertebrates such as freshwater mussels) and diadromous fishes.
3. Minimize current and potential negative project operation effects on water quality and aquatic habitat.

Our study requests are intended to facilitate the collection of information necessary to conduct effects analyses and to develop reasonable and prudent conservation measures, and protection, mitigation, and enhancement measures pursuant to the Fish and Wildlife Coordination Act, as amended (16 U.S.C. §661, et seq.), and the Federal Power Act (16 U.S.C. §791a, et seq.).

Public Interest

The requester is a natural resource agency.

Existing Information and the Need for Additional Information

Article 36 of the original license required the licensee, in consultation with resource agencies, to develop an in-stream flow study plan to determine: (1) the relationship between project discharges and downstream aquatic habitat; and (2) a fishery study plan to determine project discharges necessary to provide for the migration of anadromous fish (i.e., zone of passage). After completion of the approved studies, the licensee was to file a report on the results of the studies, and, for Commissions approval, recommendations for the flow releases from the project. The study plan was filed on August 13, 1983, with proof of agency consultation (Accession No. 19830818-0191). However, there are no study reports included in the record. Therefore, we have no quantitative data supporting the agreement that 300 cfs at night and 500 cfs during the day are adequate flows for zone of passage in the bypass reach.

In the Comprehensive Fish Passage Plan filed on March 9, 2000 (Accession No. 20000313-0322), the licensee states "The adequacy of flows for upstream fish passage at the Project was addressed by BHI's construction of six (6) concrete flow control weirs (with adjustable stoplog sections) in the bypass reach, at the request of U.S. Fish and Wildlife Service and in response to Article 36, section (2) of the Project's FERC license." Similar to the study plan, this is an agreement with no supporting information to substantiate the conclusion flows in the bypass reach are adequate for the full suite of diadromous species.

As part of compliance for Article 34 of the original license, the licensee filed as-built drawings of the existing fish passage facilities (Accession No. 19860902-0215). Within this abbreviated drawing set, drawing number 344D-PC001, 3844D-FC001, and 3844D-FC004 show topographic surveys for portions of the bypass reach. However, the drawings do not document the accuracy and precision of the survey, do not show the majority of the bypass reach, and are otherwise illegible.

Since agreeing upon the current zone-of-passage flows during the original license, there have been developments in topographic survey capabilities, a better understanding of the hydraulic requirements of diadromous species, multi-dimensional hydraulic modeling capabilities, and an increased need to pass fish at the spillway ladder.

Nexus to Project Operations and Effects

Diadromous fish orient their migration based on the environmental conditions of the river: flow, depth, velocity, and temperature (Goodwin 2014). Project operations affect the environmental conditions in the River, specific to this study request, the bypass reach. Two key hydraulic model outputs from the requested study are depth and depth-averaged velocity, which can be used to determine the likelihood of predation, delay, and the cessation of migration. Evaluating the flow fields in the bypass reach under different spill conditions will assist in the consultation process for determining an appropriate zone-of-passage flow in the bypass reach to optimize fish passage at the project. These data will also contribute to the development of an administrative record in support of a potential settlement agreement, Section 18 fishway prescriptions, or 10(j) recommendations.

Methodology Consistent with Accepted Practice

We proposed the following methodology to accomplish the five objectives and ultimately the goal of the study, to determine zone-of-passage flows for the bypass reach.

Topographic survey

The bypass reach area is large, making traditional topographic survey methods laborious and costly. We recommend using Light Detection and Ranging (LiDAR) methods with limited traditional surveying. Outside of the fish passage season and during a river flow when the project is in control of the River, the bypass reach will be mostly dewatered. At this time, a licensed surveyor can fly the area to collect LiDAR data. Once this data is processed, traditional methods will fill in the gaps (e.g., pooled water areas, under bridges). The topographic survey shall be of sufficient resolution and quality to complete the remaining objectives.

Two-dimensional hydraulic model

There are many two-dimensional hydraulic models that are acceptable for accomplishing the goal of this requested study, many of which are open source. We are not requiring one model over the other, but Boott should understand and document the limitations of the modeling software used. At a minimum, the modeling output should produce depth-average velocity and depth for each cell in the mesh. The modeling domain shall be of sufficient size and mesh to delineate a zone of passage through the entire length and width of the bypass reach.

Calibration flows

The licensee should collect calibration data by spilling a minimum of two flows from the Pawtucket dam. The calibration flows should bracket the range of simulated flows in the study. We recommend 300 cfs for the low flow as it represents the current lowest operation flow for the fish ladder. For the high calibration flow, we recommend collecting data near the high fish passage design flow (i.e., the 5 percent exceedance value for the migratory period of record) which is approximately 26,000 cfs in the Merrimack River (bypass flow would be approximately 17,000 cfs with full project operation). Boott should collect calibration data (depth-averaged velocity and depth) with an Acoustic Doppler Current Profiler (ADCP) at a minimum of four cross sections, including the downstream boundary condition and use the ADCP in locations spread evenly throughout the bypass which are less turbulent.

Additional flow simulations

After calibrating the model, additional bypass flows should be simulated (and agreed upon with the natural resource agencies), including 500 cfs, 1,000 cfs, and up to the high calibration flow. The additional simulations should represent the full range of hydraulic conditions in the bypass reach from the low to high fish passage design flow.

Zone-of-passage determination

The model output should be used to delineate a zone-of-passage pathway for each of the modeled flows. To determine the zone of passage, we recommend Boott use the SprintSwim model developed by U.S. Geological Survey researchers (Haro et al. 2004).

Level of Effort/Cost, and Why Alternative Studies Will Not Suffice

The licensee should be able to finish the bypass zone-of-passage study in one year depending on seasonal flow conditions. The level of effort and cost is commensurate with a project the size of the Lowell facility and the likely license term. No alternatives are proposed.

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Boott Study Request # 9

Fish Assemblage Assessment
(Lowell, P-2790)

Goals and Objectives

The goal of this study request is to determine the assemblage of fish species present in the areas affected by the Lowell Hydroelectric Project, which potentially includes Species of Greatest Conservation Need (SGCN) for Massachusetts.

Specific objectives include:

1) Describe fish assemblage structure, distribution and abundance within the project affected area along spatial and temporal gradients.

2) Compare historical records of fish species occurrence in the project area to results of this study.

Resource Management Goals

The mission of the Massachusetts Division of Fisheries and Wildlife (MassWildlife) is to protect and conserve fish, wildlife and their habitats. Anadromous, Catadromous, and Riverine fish species are important components of the river's ecology and are the basis for the sport fishery.

Our study requests are intended to facilitate the collection of information necessary to conduct impact analyses and develop reasonable conservation, protection, mitigation and enhancement measures pursuant to the Fish and Wildlife Coordination Act, as amended (16 U.S.C. §661 et seq.), the Federal Power Act (16 U.S.C. §791a, et seq.), the Clean Water Act (33 U.S.C. §1251 et seq.), and the WPA.

Determining species occurrence, distribution, and abundance of fish species more generally will better clarify what species occur in the project area both spatially and temporally relative to habitats which may be affected by Project operations. This information will better inform results from other study requests that will be examining the effects of Project operation on various aquatic habitats, water quality and other related concerns. This information will be used to make recommendations and enable full consideration for all species, including those that might not otherwise be known to occur in the Project-affected area and impacts that may affect their population status through direct or indirect effects of Project operations.

Public Interest

The requestor is a fish and wildlife resource agency, with regulatory authority under the MESA and the WPA.

Existing Information

The PAD cites general information on the fish community found in the Lower Merrimack River Management Plan which is 10 years old (Lower Merrimack River Local Advisory Committee [LMRLAC] 2008) and is unclear on where the information come from.

Nexus to Project Operations and Effects

Project operations have the potential to directly impact fish species life history requirements, biological interactions, and habitat quantity and quality. For example, headpond and tailwater water level fluctuations could dewater important spawning areas, limiting productivity of fish species by direct impacts to their spawning success and indirectly limiting the spawning success of forage fish species. Accordingly, a thorough understanding of the current fish assemblage structure and associated metrics are needed in order to examine potential Project impacts. Determining species distribution and abundance will better clarify what species occur in the Project area, spatially and temporally, relative to habitats that may be affected by Project operations.

The information requested through this study will help assess how the Project has and will affect the structure, distribution and abundance of fish species, and help the Division develop recommendations that will protect and/or enhance populations of these species.

Methodology Consistent with Accepted Practice

An accepted and robust field sampling design (e.g., as described in Pollock et al. 2002 or MacKenzie et al. 2006) and accepted methods for collecting fish species likely to be present in the project-affected areas (Bonar et al. 2009) should be used to conduct field surveys. Fish sampling, measuring length and weight, and calculating associated metrics are commonly used methods to determine fish assemblages and assess fish populations (Bonar et al. 2009). Randomly sampling multiple habitat types using a multi-gear approach will be required to ensure that all fish species present are sampled. The spatial scope of the study will be from the upstream extent of the impoundment downstream to the head of the Lawrence Projects impoundment, including the bypassed reach. Sampling should occur at each selected site across multiple seasons (spring, summer, and fall). Digital photographs should be taken to avoid misidentification of certain species such as Cyprinids.

This will be a one-year study, provided river discharge conditions fall within the 25th to 75th percentile for weekly averages.

Specific Methodology

The study will employ a stratified-random sampling design. The study area will be divided into strata based on mesohabitat type. Each mesohabitat type will be further stratified into two broad microhabitat types. Proposed sampling methods include daytime boat/barge electrofishing, nighttime boat electrofishing, gill nets, seine nets, and minnow traps. Sampling should be performed during in the spring, summer and fall.

The stratified random sampling design will randomly assign sampling stations within particular mesohabitat types in proportion to their linear habitat distance. Multiple methods of fish capture will be used in each stratum, and both near-shore (shallow) and mid-channel (deep) habitats will be sampled to evaluate the potential differential effect of hydropeaking on the fish species and life stages that utilize these two habitat types (Bain 1985). Selected locations within each station will be sampled either by day and nighttime boat/barge electrofishing (shoreline and littoral habitat), gill nets (deeper, benthic areas), seine net (wadeable shoreline and littoral habitat), minnow traps, and eel pots. The exact number of sampling locations will be dependent on the weighted stratification of the study area by mesohabitat and sampling within each station will be further stratified by depth and proximity to shore.

In addition to biological data, supporting data also will be collected for each sample site including: location (GPS), sampling gear type, sampling effort, mesohabitat type, average depth, average velocity, river flow, water temperature, turbidity, predominant substrate, time of day, day of year, presence of cover, and proportion of vegetation cover. All data will be recorded on dedicated data sheets.

All data will be standardized by effort expended (seconds of electrofishing, net/trap-hours, and number of seine hauls. Catch per unit effort (CPUE) and standard errors will be calculated for each species, station, and sampling technique. Data will also be separated into groups by size and a CPUE per size group will be calculated. Values of CPUE for each segment and gear type will be calculated as the sum of catch from all samples within a station divided by the sum effort expended within that station. The Shannon-Weiner index of diversity, which is a function of species richness and evenness, will also be calculated.

Information collected during this study will be compiled and presented in a final report. The report will include tabular data summarizing length, weight, and size class of fish captured, a map of the study area to depict the location of sample stations, and overall results including occurrence, distribution and relative abundance. Comparisons will be made with historical records. Results will be described in relation to other studies. Raw data should be provided to stakeholders in digital format upon request.

This study design is similar to the one detailed in Study 3.3.11 of FirstLight Power Resources Revised Study Plan for the relicensing of its Turners Falls Project (FERC No. 1889),[1] which was approved by the Commission (with modifications) in its Study Plan Determination letter dated February 21, 2014; therefore, the methodology is consistent with accepted practice.

Task 1: Sampling Location Selection

During this assessment, a stratified-random sampling design will be utilized to provide unbiased and precise fish assemblage data. The proposed design incorporates general river morphology along with mesohabitat through the use of strata and sub-strata. To accomplish this, the underlying strata allow for delineation of the study area spatially, based on locations where changes in river morphology occur.

Due to inherent variability of flows, water levels, and likely fish movements within the study area, different sampling locations will be selected for each sampling event; this statistically valid practice will avoid bias. Prior to field sampling, stations to be sampled will be selected to ensure all mesohabitat types are adequately represented. Mesohabitat types include:

- **Riffle:** shallow, moderate velocity, turbulent, high gradient, moderate to large substrates (cobble/gravel)
- **Rapid:** shallow, moderate to high velocity, turbulent, chutes and eddies present, high gradient, large substrates or bedrock
- **Run:** moderately deep to deep, well defined non-turbulent laminar flow, low to moderate velocity, well defined thalweg, typically concave stream geometry, varying substrates, gentle slope
- **Glide:** moderately shallow, well defined non-turbulent laminar flow, low velocity, well defined thalweg, typically flat stream geometry, typically finer substrates, transitional from pool
- **Pool:** deep, low velocity, well defined hydraulic control at outlet
- **Backwater:** varying depth, minimal or no velocity, long backwatered reaches
- **Impounded:** varying depth, low velocity influenced by the presence of a dam
    - **Nearshore/Shallow**: less than 8ft in depth
    - **Mid-Channel**
    - **Deep water:** depths greater than 20ft

Alternative sampling locations will also be identified by mesohabitat in case a selected sampling station is inaccessible. Furthermore, within each mesohabitat type, each of two general microhabitats will be sampled (Bain 1985):

- Nearshore areas: shallow water and lower flow velocities
- Mid-channel areas: deeper water and higher flow velocities

Task 2: Fish Capture

A variety of techniques will be used to sample the various habitat types within the study area, including day and night boat/barge electrofishing, gill netting, seining, and minnow traps as described below. The type of gear utilized will be <u>largely</u> dictated by habitat type. In addition to biological data, supporting data will also be collected for each sample site including: location (GPS), sampling gear type, sampling effort, mesohabitat type, average depth, average velocity, river flow, water temperature, turbidity, predominant substrate, time of day, day of year, presence of cover, and proportion of vegetation cover. All data will be recorded on dedicated data sheets. Upon return from the field, data sheets will be reviewed for quality assurance and archived.

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[1] Study 3.3.11 of the Revised Study Plan for the Turners Falls Hydroelectric Project (No. 1889) and Northfield Mountain Pumped Storage Project (No. 2485). August 14, 2013. FirstLight Power Resources.

Boat/barge Electrofishing

Boat electrofishing will occur during the day and at night. Barge electrofishing will be day only. All electrofishing transects will be standardized by time (500 seconds fished) such that a catch per unit effort (CPUE) may be calculated. Boat/barge electrofishing can effectively sample fish from most near-shore littoral habitats present within the Deerfield River (typically 10 feet deep or less).

Electrofishing will be accomplished with the use of a boat electrofisher with the capacity to adjust the pulse rates between 30 - 120 pulses/second and vary voltage to accommodate ambient conductivity. A barge capable of negotiating riffles and shoals, similarly rigged with an electrofishing unit may be deployed for sampling in the shallower riverine habitats.

Electrofishing will be conducted in a downstream manner, following standardized methods developed specifically for large river quantitative electrofishing surveys (MBI, 2002, Yoder and Kulik, 2003). The start point, end point, and boat track for each sampling station will be geo-referenced using a handheld GPS and transposed to corresponding topographic mapping software program to produce maps of areas sampled.

All stunned fish will be collected with ¼-inch mesh dip nets and deposited into a live-well filled with aerated ambient river water. At the conclusion of each sample, all captured fish will be identified to species, classified as adult, juvenile or Young-of-Year (YOY), enumerated, weighed, measured for total length, and then released. If large numbers (n > 25) of small fish (YOY fish or cyprinids less than 100 mm) are captured, they will be grouped by size class, enumerated, and batch-weighed with length measurements only taken from one large and one small representative specimen within each group. Fish that are not able to be identified in the field, such as small cyprinids, will be brought back to the lab for identification.

Gill Netting

For sampling deeper habitat sub-strata (Depth 12-25 feet; Depth 25-40 feet; Depth > 40 feet), where electrofishing will not be effective, sampling will be conducted with experimental gill nets consistent with standardized methods for fish capture from rivers (Bonar, Hubert, & Willis, 2009). The nets will be 12-foot feet high by 100-foot in length and will be constructed of 4 to 5 panels of increasing mesh size (e.g., 1.5, 2, 2.5, 3, 3.5-inch stretched mesh) to accommodate collection of the various sized fish in the project waters.

The nets will be deployed to maximize capture area where water depths are greater than net height. Nets will be set in selected locations and allowed to fish for at least 4 hours prior to retrieval.

The exact locations of each net set will be recorded using a handheld GPS and the time of deployment and retrieval will also be recorded. Fish processing will occur as described above for electrofishing.

Seining

In shallow shoreline locations where boat access may not be feasible sampling will be performed via seining with a 100-ft long, 6-ft deep, 1/4-inch mesh bag seine net.

Seine samples will be collected by extending the net parallel to shore and then pulling the upstream end of the net into the water and in a downstream direction for a 180 degree sweep while the opposite end of the net is held in place (Bonar, Hubert, & Willis, 2009). The start point and end point for each sweep will be geo-referenced using a handheld GPS and transposed to corresponding topographic mapping software program to produce maps of areas sampled. Total fish catch will be processed following each haul in the same manner as described above for electrofishing and gill netting.

Minnow traps/eel pots

For sampling deeper habitat sub-strata (Depth 12-25 feet; Depth 25-40 feet; Depth > 40 feet), where electrofishing will not be effective, sampling will be conducted with minnow traps and eel pots to sample fish too small to be captured by gill nets (minnows) and to determine presence of American Eel. The exact locations of each trap will be recorded using a handheld GPS and the time of deployment and retrieval will also be recorded. Fish processing will occur as described above for electrofishing.

Task 3: Data Analysis and Reporting

All data will be standardized by effort expended (seconds of electrofishing, net/trap-hours, and number of seine hauls. Catch per unit effort (CPUE) and standard errors will be calculated for each species, station, and sampling technique. Data will also be separated into groups by size and a CPUE per size group will be calculated. Values of CPUE for each segment and gear type will be calculated as the sum of catch from all samples within a station divided by the sum effort expended within that station. The Shannon-Weiner index of diversity, which is a function of species richness and evenness, will also be calculated.

Information collected during this study will be compiled and presented in a final report. The report will include tabular data summarizing length, weight, and size class of fish captured, a map of the study area to depict the location of sample stations, and overall results including occurrence, distribution and relative abundance. Comparisons will be made with historical records. Raw data will be provided to stakeholders in digital format upon request.

Level of Effort/Cost, and Why Alternative Studies will not suffice

This study will require sampling of the Project-affected areas of during spring, summer, and fall. Sampling multiple mesohabitat types and from several microhabitat types (including shallow, near-shore microhabitats and deeper, mid-channel microhabitats), and using a multi-gear approach will be required to ensure that all fish species present are sampled. The cost of the study would be moderate to high. Based on first year study results, a second year of sampling or specific studies examining impacts of Project Operations on specific fish species may be requested. MassWildlife estimates the cost of this study to be $50,000 to $75,000, based on the estimated cost to conduct a similar study at the Turners Falls Project (FERC No. 1889).[2]

Boott did not propose any studies to meet this need in the PAD.

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[2] Ibid.

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Document Content(s)

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Glenn Normandeau
Executive Director

August 13, 20018

Kimberly D. Bose, Secretary
Federal Energy Regulatory Commission
888 First Street, N.E., Room 1A
Washington, DC 20426

RE: Study Requests for FERC Hydroelectric Projects P-2790 Lowell Hydropower Project located on the Merrimack River in Middlesex County, Massachusetts

Dear Secretary Bose:

As the agency responsible for protecting fish and wildlife resources in New Hampshire, the New Hampshire Fish and Game Department (NHFGD) monitors and attempts to reduce the impacts of hydroelectric facilities on fish and wildlife species and their habitats. The mission of the NHFGD is to conserve, manage and protect the state's fish, wildlife and marine resources and their habitats, and to provide the public with opportunities to use and appreciate these resources. The NHFGD's 1998-2010 Strategic Plan contains four goals relevant to the relicensing process under the Federal Energy Regulatory Commission (FERC). These goals are to ensure that New Hampshire:

1) has a wide range of naturally occurring habitats and healthy, naturally functioning ecosystems.

2) has abundant and varied fish, wildlife, and marine species at levels that ensure sustainable, healthy populations.

3) has fish, wildlife, and marine populations that support desirable levels of hunting, trapping, fishing, and wildlife viewing.

4) Human activities and land uses are compatible with desired population and recreational goals for fish, wildlife, and marine species and the ecosystems that sustain them.

Also, the New Hampshire Wildlife Action Plan identifies a number of fish and wildlife species of concern, which may be impacted by the project under review. The complete New Hampshire Wildlife Action Plan is available online at: http://www.wildlife.state.nh.us/Wildlife/wildlife_plan.htm.

Although the Lowell project is not located in the State of New Hampshire, we feel it is prudent to comment on this project and support all study requests because the Lowell hydropower project has the potential to impact fish migrating to and from New Hampshire waters within the Merrimack River watershed. For example, American eel, American shad, River herring, and sea lamprey all have to successfully migrate upstream past the Lowell hydropower facility; in order to reach New Hampshire waters. Additionally, fish that are reared (American shad and sea lamprey), spawn (American shad), and grow to maturity (American eel) in New Hampshire portions of the Merrimack River watershed all have to successfully migrate downstream past the Massachusetts hydropower projects; in order to complete their life cycle.

Boott has not proposed any studies for relicensing at this time, but has identified potential resource issues which include: bypass flows, fish passage, historical resources, boating access, and inundation of upstream floodplains. Relevant to fish and aquatic resources, the Department believes new studies need to be conducted, with sufficient fish sample sizes, to better understand upstream and downstream passage at the project; as well as instream flows in the bypass reach.

Fish and Aquatic Resources

Downstream Passage

The Department recommends Boott conduct new studies to fully understand how post-spawned adult shad and river herring, juvenile shad and river herring, and adult silver phase eels move past the Pawtucket dam, through the canal system, turbine intakes, and the downstream bypass facility. In addition, turbine injury and mortality studies are needed and should be used in conjunction with the results of the passage routing studies, where applicable, to calculate total through-project survival rates. The Department herein provides study requests in order to address these information needs.

Upstream Passage

Yearly site inspections, performed by the USFWS, have identified a number of problems with respect to American shad at the lift and ladder fishway entrances. The Department believes that a comprehensive radiotelemetry study is needed to understand the relationship between project operations, including spill flows, and shad and river herring movement through the Merrimack River (including attraction to and passage through these facilities). Additionally, a study to define the relationship of the complex hydraulic conditions at the spillway fish ladder entrance and the tailrace fish lift entrance is needed in order to evaluate data on fish behavior and passage at those locations. Therefore, the Department is providing herein study requests to address these information needs.

Instream Flows in the Lowell Bypass

The bypass reach is 0.7 mile long (from the Pawtucket dam to the E.L. Field powerhouse) and contains diverse habitat. There are approximately 11 miles of free-flowing river downstream of the Pawtucket dam which also contain a diversity of habitat, including important spawning and rearing habitat for migratory fish species, such as American shad. To date, there have not been any empirical studies, which assess the adequacy of the existing flow protocols. The Department herein submits study requests intended to address these information gaps.

RECOMMENDED STUDIES

The following formal study requests will expand on the information presented in the Pre-Application Document (PAD) and lead to informed management decisions intended to reduce impacts on fish and wildlife. It is understood that there is overlap between some of the requested studies, and where appropriate, the NHFGD supports the combination of studies to reduce cost and effort as long as the goals and objectives within each individual study proposal are still achieved.

Enclosed please find our formal study requests (Attachment A) in the format required pursuant to 18 CFR §4.38(b)(5). In addition to the study requests provided herein, please note that NHFGD also supports the study requests submitted by other natural resource agencies, including but not limited to, the Massachusetts Division of Environmental Protection, New Hampshire Department of Environmental Services (NHDES), the Massachusetts Department of Fish and Game (MADFG), National Marine Fisheries Service (NMFS) and the U.S. Fish and Wildlife Service (USFWS).

Thank you for this opportunity to comment.

Sincerely,

Glenn Normandeau
Executive Director

Attachment A

Study Request # 1

Instream Flow Habitat Assessment of the Lowell Bypassed Reach
(Lowell, P-2790)

Goals and Objectives

The goal of this study is to determine an appropriate flow regime which will protect and enhance the aquatic resources in the bypass reach between the Pawtucket dam and the E.L. Field powerhouse. Specifically, the objective of this study is to conduct an instream flow habitat study to assess the impacts of a range of project discharges on the wetted area and optimal habitat for key species, including the quantity and location of suitable habitat.

The specific objectives of this field study, at a minimum, include:

1. characterize and map wetted perimeter of the bypass reach over a range of bypass flows;
2. survey and evaluate the water depth and mean channel velocity at transects within the bypass reach over a range of flows; and
3. map and assess the value of aquatic habitat in the bypass reach over a range of flows, focusing on potential habitat for resident species, and spawning and migration habitat or rest/regrouping areas for migratory species.

Target fish species should include American shad, river herring (alewife and blueback herring), fallfish, white sucker, freshwater mussels and benthic macroinvertebrates. The final target species list should be developed in consultation with the fisheries agencies and based on the results of the mesohabitat mapping.

Resource Management Goals

The Department seeks the accomplishment of a number of resource goals and objectives through the relicensing process for the project. General goals include the following:

1. Ensure that protection, mitigation, and enhancement measures are commensurate with project effects and help meet regional fish and wildlife objectives for the basin.
2. Conserve, protect, and enhance the habitats for fish, wildlife, and plants that continue to be affected by the project.

Specific to aquatic resources within the Lowell bypassed reach, the Department's goals are:

1. Protect, enhance, or restore diverse high quality aquatic and riparian habitats for plants, animals, food webs, and communities in the watershed and mitigate for loss or degradation of these habitats.
2. Provide a flow regime in the bypassed reach that meets the life history requirements of resident fish and wildlife (including invertebrates such as freshwater mussels) and diadromous fishes.
3. Minimize current and potential negative project operation effects on water quality and aquatic habitat.

Our study requests are intended to facilitate the collection of information necessary to conduct effects analyses and to develop reasonable and prudent conservation measures, and protection, mitigation, and enhancement measures pursuant to the Fish and Wildlife Coordination Act, as amended (16 U.S.C. §661, *et seq*.), and the Federal Power Act (16 U.S.C. §791a, *et seq*.).

Public Interest

The requester is a natural resource agency.

Existing Information

The Lowell Project bypasses a 0.7-mile-long section of the Merrimack River, from the Pawtucket dam to the E.L. Field powerhouse. There is presently no required minimum bypass flow. However, during the upstream fish passage season, the bypass reach receives 500 cfs. through operation of the spillway fish ladder. In addition, the bypass reach receives flow whenever inflow exceeds the hydraulic capacity of all the project's stations. Pursuant to Article 37, Boott Hydropower, LLC, (Boott) maintains a minimum flow of 1,990 cfs. or inflow, whichever is less, as measured immediately downstream of the project.

Available information in the PAD does not indicate how project operations have altered downstream hydrology, habitat quantity and quality, and water quality, which may affect resident and migratory fish, macroinvertebrates, aquatic plants and other biota and natural processes in the Merrimack River. The PAD provides no detailed description of the physical or biological characteristics of the bypassed reach.

An empirical study is needed to provide information on the relationship between flow and habitat in the bypassed reach for the Department to use in determining a flow recommendation.

Nexus to Project Operations and Effects

Although the project license requires Boott to maintain a minimum flow of 1,990 cfs. or inflow (if less), downstream of the project, Boott states in practice the project operates in a true run-of-river mode. The Department is not recommending a below-project flow study based on the assumption that any new license issued for the project will require instantaneous run-of-river operation (essentially codifying current operations).

The project includes a 0.7-mile-long bypassed reach. The current license contains no minimum bypass flow requirement. During the upstream fish passage season, the bypass reach receives 500 cfs. via operation of the spillway fish ladder; otherwise, the reach only receives flow when inflow exceeds the hydraulic capacity of the project's generating capacity. To our knowledge, the lack of a required bypass flow was not based on any quantitative, rigorous scientific studies.

This section of the Merrimack River contains habitat which supports native riverine species, including important spawning and rearing habitat for migratory species like American shad and river herring. While the existing license does not require a minimum bypass flow, the Department believes one is needed to sufficiently protect the aquatic resources inhabiting the bypassed reach.

Results of the flow study should be used to determine an appropriate flow recommendation, which will protect and/or enhance the aquatic resources in the bypassed reach for the duration of any new license issued by the Federal Energy Regulatory Commission (Commission).

Methodology Consistent with Accepted Practice

Bypass flow habitat assessments are commonly employed in developing flow release protocols which will reduce impacts or enhance habitat conditions in reaches of river bypassed by hydroelectric projects.

Given the size of the bypassed reach (0.7 mile long) and the important resources known to inhabit the reach (i.e., diadromous fishes); we believe a study methodology which utilizes an instream flow incremental methodology (IFIM) approach is appropriate for this site. This same protocol was used during the relicensing of the Housatonic River Project (FERC No. 2576),[1] and has been accepted by the Commission in other licensing proceedings.[2]

The study should have two components. The first component entails mapping habitat within the bypass reach. The number, location, and size (area and linear distance) of each mesohabitat type in the reach should be documented, including qualitative characterizations (e.g., dominant substrate, average depth, overhead and instream cover, etc.). The second component consists of conducting an instream flow study.

At a minimum, the study design should involve collecting wetted perimeter, depth, velocity, and substrate data within a range of discharge levels along transects located in the reach of river between the dam and the E.L. Field powerhouse. The measurements should be taken over a range of test flows, to be agreed upon by the natural resource agencies. This information should then be synthesized to quantify habitat suitability (using mutually agreed upon Habitat Suitability Index curves) of each test flow for target species/life stages identified by the fisheries agencies. We recommend Boott perform habitat modeling using one dimensional modeling techniques to better characterize flows and velocities in this complex channel area.

Level of Effort/Cost, and Why Alternative Studies Will Not Suffice

Field work for flow studies can be reasonably extensive but will depend on consultation with Boott on study methodology and on-site decisions on locations for data collection and the number of collection locations. Post-field work data analysis would result in a moderate cost and effort. We anticipate that the level of effort and costs will be comparable to those experienced on similar Commission relicensing projects (e.g., the Glendale Project, FERC No. 2801).

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[1] Housatonic River Project License Application, Volume 4, Appendix F. Connecticut Light and Power Company, August 1999.

[2] Glendale Project (FERC No. 2801) Final Bypass Reach Aquatic Habitat and Instream Flow Study in Glendale Hydroelectric Project Application for Subsequent License (FERC No. 2801), Volume 2, Appendix B, pp. 7-8, October 2007.

Study Request # 2

Adult Alosine Downstream Passage Assessment and Protection Evaluation
(Lowell, P-2790)

Goals and Objectives

The goal of this study is to assess the adequacy of the turbines at the E.L. Field, Assets, Bridge Street, Hamilton, and John Street powerhouses, to minimize injury, entrainment, and mortality of fishes residing in the Merrimack River, and to recommend appropriate mitigative measures as necessary.

The specific objectives of the field study, at a minimum, are: (1) assess the risk of adult American shad and alewife becoming injured, impinged, or entrained in the E.L. Field, Assets, Bridge Street, Hamilton, and John Street powerhouse units; (2) estimate turbine survival; (3) assess the risk of injury or mortality at the spillway and downstream bypass; and (4) evaluate potential passage and protection measures.

Resource Management Goals

The Atlantic States Marine Fisheries Commission has developed several documents related to the management of American shad and river herring:

1. Atlantic States Marine Fisheries Commission. 1999. Amendment 1 to the Interstate Fishery Management Plan for shad and river herring. (Report No. 35). April 1999.
2. Atlantic States Marine Fisheries Commission. 2000. Technical Addendum 1 to Amendment 1 of the Interstate Fishery Management Plan for shad and river herring. February 9, 2000.
3. Atlantic States Marine Fisheries Commission. 2009. Amendment 2 to the Interstate Fishery Management Plan for shad and river herring, Arlington, Virginia. May 2009.
4. Atlantic States Marine Fisheries Commission. 2010. Amendment 3 to the Interstate Fishery Management Plan for shad and river herring, Arlington, Virginia. February 2010.

Amendment 3 to the Interstate Fishery Management Plan for Shad and River Herring includes an objective of maximizing the number of juvenile recruits emigrating from freshwater stock complexes and recommends enhancing survival at dams during emigration by evaluating survival of post-spawned adults and juvenile fish passed via each route (e.g., turbines, spillage, bypass facilities, or a combination of the three) at any given facility, and implementing measures to pass fish via the route with the best survival rate.

Specific to resident riverine and migratory fish entrainment, the Department's goals are:

1. Minimize current and potential negative project operation effects such as turbine entrainment that could hinder management goals and objectives.

2. Minimize project-related sources of mortality to resident and migratory fishes in order to restore natural food web interactions and ecosystem functions and values.

Our study requests are intended to facilitate the collection of information necessary to conduct effects analyses and to develop reasonable and prudent conservation measures, and protection, mitigation, and enhancement measures pursuant to the Fish and Wildlife Coordination Act, as amended (16 U.S.C. §661, *et seq*.), and the Federal Power Act (16 U.S.C. §791a, *et seq*.).

Public Interest

The requestor is a natural resource agency.

Existing Information and the Need for Additional Information

No project-specific information exists regarding risk of impingement and/or entrainment of adult alosines. In the PAD, Boott provided little information, which would inform the relative risk of impingement or entrainment in any of the 21 units associated with the project. Moreover, information regarding fish mortality at the spillway and the downstream bypass was not discussed. While Normandeau Associates, Inc., performed a study in 2003 pertaining to the survival of Atlantic salmon smolts through the turbines, (1) the sample size was small (20 fish); (2) the study was not performed at a full range of gate settings; and (3) salmon are a robust fish species and cannot be used as a proxy for alosines. The 2003 study did shed light on a predation issue, however, in the project's tailrace. Of the salmon that passed downstream, 69 percent were suspected to be preyed upon after using the downstream bypass facility. As Normandeau Associates, Inc., noted in their study results, predators residing in the tailrace can have a large impact on emigrating migratory fish species that use the current bypass facility at the project.

To date, no directed studies of alosine injury, entrainment, or mortality have been conducted at the project's modified spillway, the downstream fish bypass facility, or through the turbines. These information gaps need to be filled so the natural resource agencies can assess the relative and cumulative impacts of project operations on outmigrating adult alosines and develop adequate passage and protection measures to meet management goals and objectives.

Nexus to Project Operations and Effects

Hydropower projects generate electricity by moving water through a turbine-generator system. Typically, there are trashracks in front of the intakes leading to the turbines. If the rack spacing is narrow and the velocities at the racks too high (relative to the swim speeds of fish species inhabiting or moving through the headpond), fish may become impinged against the racks and die. If the rack spacing is wide and the velocities too high (relative to the swim speeds of fish species inhabiting or moving through the headpond), fish may become entrained (i.e., pass through the racks) and get injured or die while passing through the turbines.

Lowell's configuration likely presents problems with respect to providing safe, timely, and effective passage for outmigrating alosines. Pre-spawned adult American shad and river herring pass upstream through the Lowell fishways and/or are stocked into upstream habitats. These fish need to be able to migrate back downstream because they are iteroparous in this region. Therefore, it is necessary to understand how alosines move through the project area and the level of injury or mortality caused by entrainment through the project's turbines and/or passage via the dam spillway and downstream bypass facility.

Methodology Consistent with Accepted Practice

The Department proposes a phased approach to this study.

Phase 1:

Spill, bypass, and turbine mortality should be assessed using a balloon-tag method. For spill mortality sites (dam spillway and downstream bypass), tagged alosines will be injected or released into spill flow at points where water velocity exceeds 10 ft./sec to minimize the possibility of the fish swimming upstream into the headpond or canal. Passed balloon-tagged alosines will be recovered below areas of spill and held for 48 hours in isolated tanks for observation of injury and latent mortality; unrecovered balloon-tagged alosines will be censored from the data.

For turbine mortality sites, tagged alosines will be injected into the intakes of units operating at or near full generation at points where intake water velocity exceeds 10 ft. /sec to minimize the possibility of fish swimming back upstream through the intakes. Passed balloon-tagged alosines will be recovered in the tailrace and held for 48 hours in isolated tanks for observation of injury and latent mortality; unrecovered balloon-tagged alosines will be censored from the data.

Phase 2:

Boott should investigate existing or potential future operational and/or physical measures that would minimize injury or mortality to outmigrating adult alosines moving past the project. Based on the results of this investigation, we recommend Boott provide a range of potential alternatives (e.g., increasing attraction to the existing downstream bypass, installing exclusionary screening, etc.).

Project operations (flows, levels, gate openings, number of units operating, and operation level) and environmental conditions (river flow, temperature, turbidity, air temperature, precipitation) should be monitored regularly (hourly measurements if possible) throughout the duration of the study.

These methodologies are consistent with accepted practice.

Level of Effort/Cost, and Why Alternative Studies Will Not Suffice

The cost and effort of each individual phase of this study are expected to be moderate. Based on the scale and scope of the subject study, we estimate the cost to be $25,000 to $50,000. In the PAD, Boott proposes no studies to address this issue. The Department is not aware of any previously conducted or ongoing studies related to impingement, entrainment or survival of adult alosines at the project.

REFERENCES

Normandeau. 2003. Passage Route Selection and Survival of Atlantic Salmon Smolts Passed through the Lowell Hydroelectric Project. Submitted to Boot Hydro, LLC. Final report. Normandeau Associates, Inc. Westmoreland, New Hampshire. 130 pp.

Study Request # 3

Telemetry Study of Upstream and Downstream Migrating Adult American Shad and River Herring to Assess Passage Routes, Effectiveness, and Delay

(Lowell, P-2790)

Goals and Objectives

The goal of this study is to assess the behavior, approach routes, passage success, survival, and delay of adult American shad and river herring as they encounter the Lowell Project during their upstream and downstream migrations to determine if project operations negatively impact their survival and production.

The following objectives will address this request:

1. assess project operations effects on the timing, orientation, routes, and migration rates of shad and river herring;
2. determine route selection and behavior of upstream migrating shad and river herring at the project under varied operational conditions, including a range of spill conditions (e.g., movement to the dam, attraction to the E.L. Field station discharge, movement between locations, delay, timing, etc.);
3. determine delay/fallback associated with the northern canal;
4. assess near field attraction to, and entrance efficiency of, the fish lift under a range of spill conditions and with the river-side entrance and street-side entrances open;
5. assess near field attraction to, and entrance efficiency of, the spillway ladder under a range of spill conditions;
6. evaluate the internal efficiency of the Pawtucket dam ladder;
7. collect ladder and lift efficiency data, to include rates of approach to fishway entrances, entry into fishways, and passage under varied operational conditions, including a range of spill conditions;
8. determine the proportion of post-spawned adults that select the power canal as a downstream passage route under varied operation conditions, including a range of spill conditions up to full spill; determine post-spawned adult downstream migration route selection, passage efficiency, and delay associated with the power canal under various operational conditions, including a range of spill conditions; and
9. compare rates and measures of delay and movement among project areas and routes utilized (e.g., spill at dam vs. power canal) under the range of permitted and proposed spill and operational conditions.

If project operations are adversely affecting shad or river herring migration timing or are resulting in other deleterious population effects, we recommend Boott identify operational solutions or other passage measures that will reduce and minimize these impacts within the project area.

This study will require 3 years of field data due to the tailrace ledge excavation project which will be completed in 2019 and to capture inter-annual variability of river discharge, water temperatures, and variability in outmigration timing. We recommend Boott perform the downstream routing portion of the study in 2019 (pre-ledge excavation) and 2020 (post-ledge excavation). In 2020 and 2021, after the ledge has been excavated, we recommend Boott perform the upstream portion of this study.

Resource Management Goals

The Atlantic States Marine Fisheries Commission, Amendment 3 to the Interstate Fishery Management Plan for Shad and River Herring, approved in 2010, includes the following objectives:

Upstream Passage

1. Fish must be able to locate, enter, and pass the passage facility with little effort and without stress.
2. Where appropriate, upstream fish passage effectiveness should be improved through operational or structural modifications.
3. Fish which have ascended the passage facility should be guided to an appropriate area so they can continue their upstream migration and avoid being swept back downstream.

Downstream Passage

1. Enhance survival at dams during emigration.
2. Evaluate survival of post-spawned adults and juvenile fish passed via each project route (e.g., turbines, spillage, bypass facilities, or a combination of the three).
3. Implement measures to pass fish via the route with the least delay and best survival rate.

The Department seeks the accomplishment of a number of resource goals and objectives through the relicensing process for the projects. General goals include the following:

1. Ensure that protection, mitigation and enhancement measures are commensurate with project effects and help meet regional fish and wildlife objectives for the basin.
2. Conserve, protect, and enhance the habitats for fish, wildlife, and plants that continue to be affected by the project.

Specific to American shad and river herring movement and migration, the Department's goal is to minimize current and potential negative project operation effects on the safe, timely and effective upstream and downstream passage of adult American shad and river herring.

Our study requests are intended to facilitate the collection of information necessary to conduct effects analyses and to develop reasonable and prudent conservation measures, and protection, mitigation, and enhancement measures pursuant to the Fish and Wildlife Coordination Act, as amended (16 U.S.C. §661, *et seq*.), the Federal Power Act (16 U.S.C. §791a, *et seq*.), the Atlantic States Marine Fisheries Compact (P.L. 539, 77th Congress, as amended by P.L. 721, 81st Congress), and the Atlantic Coastal Fisheries Cooperative Management Act (16 U.S.C. 5107).

Public Interest

The requestor is a natural resource agency.

Existing Information and the Need for Additional Information

Several studies pertaining to the fish lift and downstream passage facilities at Lowell have been conducted for American shad. Studies of alewife passage are limited to a single downstream test performed in 1991. Previous studies pertaining to upstream shad migration (listed in Table 5.4-3 of the PAD) demonstrate passage through the existing lift at Lowell is relatively poor. Also, when analyzing annual passage counts for river herring and shad, the number of fish which utilize the Lowell lift versus those that pass at Lawrence is low (from 1996 to 2017 passage efficiency at Lowell has not exceeded 30 percent).

Until 2016, the fish lift has been the primary route of upstream passage at the project. The ladder, located at the Pawtucket dam, has typically only been operated during periods of high flow. Therefore, to date, studies performed at Lowell have not tested the near field attraction, entrance efficiency, or internal efficiency of the ladder. Moreover, past studies have had statistically low sample sizes (less than 60 fish) and were all performed prior to the ledge excavation project which will occur in August 2019. Future studies should have a robust sample size (at a minimum, 150 fish per species) and array system. Additionally, to obtain a comprehensive understanding of fish behavior at Lowell, for both upstream and downstream migration, studies are needed to: (1) determine if project operations affect pre-spawned and post-spawned river herring and shad migration timing; (2) assess fish movement to, and through, the ladder at the Pawtucket dam; and (3) assess passage success at the tailrace fish lift post-ledge removal.

Nexus to Project Operations and Effects

Lowell tailrace turbulence (potentially exacerbated by the existing ledge outcropping) creates attraction issues at the entrance of the fish lift. Moreover, a lack of effective protection at the 21 turbines associated with the project increases the risk of entrainment and mortality alosines may experience as they migrate downstream to the ocean. During the upstream fish passage season, the Lowell bypass reach receives 500 cuffs. during the day and 300 cfs. at night via operation of the spillway fish ladder; otherwise, the reach only receives flow when inflow exceeds the hydraulic capacity of the project's generating capacity. The spillway ladder is, therefore, only partially effective due to lack of flow.

Existing project operations and limited bypass flows can have a direct impact on diadromous fish migration. Migration delays, increased predation, mortality during passage over the dam or through turbines, and changes in route selection under different flow conditions are potential influences of the project on shad and river herring populations in the Merrimack River. Effective upstream and downstream passage and successful spawning and juvenile production are necessary to help achieve shad and river herring management restoration goals for the Merrimack River, particularly in the upstream reaches.

Methodology Consistent with Accepted Practice

The movement of migratory shad and river herring would be best studied by using radio telemetry, including passive integrated transponder (PIT) tags. Radio telemetry is an accepted technology that has been used for a number of studies associated with hydropower projects, including at the Bellows Falls (FERC No. 1855), Wilder (FERC No. 1892), and Vernon (P-1904) projects.

The study design must specify sample sizes, as well as tag and receiver configurations, to ensure rates of entry and exit to the tailrace, fish lift and fish ladder, downstream bypass, the bypassed reach, and canal, can be calculated with sufficient precision. We recommend Boott capture shad and river herring below Lawrence and tag at least 150 individuals per species. Double-tagged (radio and PIT) shad and river herring should be released upstream of the Lawrence dam and upstream of the Lowell dam. Fish should also be released directly into the Pawtucket canal to adequately assess project conditions likely to be encountered during downstream migration. Additional, tagged, individuals may need to be released farther upstream to ensure enough fish encounter the dam during a sufficient range of turbine and operational conditions to test for project effects (especially in 2020 and 2021). A large array of stationary monitoring stations (radio and PIT) will be needed to provide an appropriate level of resolution for data analyses and to answer the natural resource agencies' questions regarding project operation effects. Additionally, since fish can drift a considerable distance downstream after they have died (Havn et al. 2017); a minimum of 25 dead river herring and 25 dead shad should also be released as a control group in this study. A plan and schedule for spill releases should be developed which provides sufficient periods of spill and various generating levels (treatments will require multiple days of consistent discharge).

Each component of this study will require 2 years of field data collection to attempt to account for inter-annual variability in river discharge, water temperatures, and the ledge excavation project which will be completed in 2019. We recommend Boott perform the downstream routing portion of the study in 2019 (pre-ledge excavation) and 2020 (post-ledge excavation). In 2020 and 2021, after the ledge has been excavated, the upstream portion of this study should be performed.

A related study request on computational fluid dynamics (CFD) modeling in the Lowell tailrace, in and around the fish lift and fish ladder entrances and powerhouse forebay, will complement this study and address related project operational effects.

These methodologies are consistent with accepted practice.

Level of Effort/Cost, and Why Alternative Studies Will Not Suffice

Estimated cost for this study is expected to range from $400,000 to $500,000, with the majority of costs associated with equipment (radio and PIT tags, radio receivers, and PIT readers) and related field work labor. Since tagged shad and river herring will move throughout the area, to varying degrees, there will be expected cost savings (e.g., radio tags) to Boott, provided cooperation in study planning and implementation occurs.

Boott did not propose any studies to meet this need in the PAD.

REFERENCES

Havn, T. B., F. Økland, M.A. Teichert, L. Heermann, J. Borcherding, S.A. Sæther, O.H. Tambets and E.B. Thorstad. 2017. Movements of dead fish in rivers. Animal Biotelemetry, 5: 7.

Study Request # 4

Impact of Project Operations on Downstream Migration of Juvenile Alosines
(Lowell, P-2790)

Goals and Objectives

The goals of this study are: (1) conduct a field study of juvenile alewife outmigration in the Lowell impoundment, the power canal, and at the Pawtucket dam, to determine if project operations negatively impact juvenile alosine survival and production; and (2) determine if project operations affect juvenile alosine outmigration survival, recruitment, and production.

The following objectives will address this request:

1. assess project operations effects of the Pawtucket dam on the timing, orientation, passage routes, migration rates, and survival of juvenile alewife;
2. determine the proportion of juvenile alewife that select the Lowell canal versus the Pawtucket powerhouse, downstream bypass facility, or dam spill as a downstream passage route, under varied operational conditions;
3. determine if there are any delays associated with downstream movement related to either dam spill or the Pawtucket powerhouse due to operations;
4. determine the juvenile downstream passage timing and route selection in the Lowell canal, assess delays associated with the canal, and with project operations (e.g., stockpiling in the canal).

If it is determined the project operations are adversely affecting juvenile alosine survival, migration timing, or other deleterious population effects, identify operational solutions or other passage measures which will reduce and minimize these impacts within the project area. This study will require 2 years of field data to capture inter-annual variability of river discharge and water temperatures.

Resource Management Goals

The Atlantic States Marine Fisheries Commission Amendment 3 to the Interstate Fishery Management Plan for Shad and River Herring (American Shad Management), approved in 2010, includes the following objective:

> Maximize the number of juvenile recruits emigrating from freshwater stock complexes.
> To enhance survival at dams during emigration, evaluate survival of post spawning and juvenile fish passed via each route (e.g., turbines, spillage, bypass facilities, or a combination of the three) at any given facility, and implement measures to pass fish via the route with the best survival rate.

The Department seeks the accomplishment of a number of resource goals and objectives through the relicensing process for the projects. General goals include the following:

1. Ensure that protection, mitigation, and enhancement measures are commensurate with project effects and help meet regional fish and wildlife objectives for the basin.

2. Conserve, protect, and enhance the habitats for fish, wildlife, and plants that continue to be affected by the project.

Specific to juvenile American shad and river herring movement and migration, the Department's goal is to minimize current and potential negative project operation effects on the safe, timely and effective downstream passage.

Our study requests are intended to facilitate the collection of information necessary to conduct effects analyses and to develop reasonable and prudent conservation measures, and protection, mitigation, and enhancement measures pursuant to the Fish and Wildlife Coordination Act, as amended (16 U.S.C. §661, *et seq*.), the Silvio O. Conte National Fish and Wildlife Refuge Act (P.L. 102-212; H.R. 794), the Federal Power Act (16 U.S.C. §791a, *et seq*.), the Atlantic States Marine Fisheries Compact (P.L. 539, 77th Congress, as amended by P.L. 721, 81st Congress), and the Atlantic Coastal Fisheries Cooperative Management Act (16 U.S.C. 5107).

Public Interest

The requestor is a natural resource agency.

Existing Information and the Need for Additional Information

The seaward migration of juvenile alosines is of great importance to the restoration of alewife, blueback herring, and American shad in the Merrimack River. However, data on the downstream migratory movements and rates of alosines past Lowell is sparse and relatively incomplete. In 1994 and 1995, Normandeau Associates, Inc., documented the use of the bypass facility by downstream migrating alosines via the installation of a removable box trap. Passage efficiencies were 7 percent and 37 percent, respectively. However, to date, no directed studies of downstream alosine passage route selection has been conducted at the Lowell Project. These information gaps need to be filled so the natural resource agencies can assess the relative and cumulative impacts of project operations on outmigrating juvenile alosines and develop adequate passage and protection measures to meet management goals and objectives.

Studies conducted farther upstream on the Merrimack River, at Garvins Falls (FERC No. 1893), have shown it is possible to radio-tag juvenile alewife to evaluate alosine outmigration (Normandeau 2016). Alewife can be used as a proxy, in this instance, for the natural resource agencies to assess blueback herring and shad downstream migration patterns.

Nexus to Project Operations and Effects

Adult alosines, passed at Lowell via the fishways and/or stocking efforts, utilize upstream habitat to spawn on an annual basis. Similarly, juvenile alosines require safe and timely downstream passage measures at the project in order to successfully emigrate back to the ocean to contribute to the population. Presently, downstream migrants can easily enter the Lowell canal system, via the Pawtucket canal, as there are no exclusionary measures in place. There are 19 turbines located in the canal, housed at four powerhouses (Assets, Bridge Street, Hamilton, and John Street), none of which have passage or protection measures. There are a variety of unit-types housed in each of the powerhouses, ranging in speed from 100 to 150 rpm. A study is needed to assess the impacts project operations have on outmigrating juvenile alosines.

The Department is not aware of any studies conducted specifically designed to determine:

1. What is the rate of alewife survival under a range of spill and gate configurations?
2. Are there delays in migration/movement at the dam, gatehouse, or in the canal?
3. For juveniles that enter the Pawtucket canal, what proportion subsequently enter the Western, Merrimack, Pawtucket, or Hamilton canals?
4. What is the rate of movement through the canal, what is the delay to juvenile alosine outmigration, and the potential accumulation of juveniles in the canal?
5. What proportion of juvenile alosines use the downstream bypass sluice versus the E.L. Field powerhouse turbines under varied operational conditions?

The Department is concerned project operations are: (1) impacting juvenile alosine outmigration survival; and (2) contributing to the failure of the Merrimack River alosine population to meet management targets.

Methodology Consistent with Accepted Practice

The impact of project operations to juvenile alewife outmigration, passage route selection, and migratory delay would be best studied via radio telemetry. This methodology has successfully been tested and employed by Normandeau Associates, Inc., at the Garvins Falls hydroelectric project (FERC No. 1893; Normandeau 2013; Normandeau 2016). Project discharge over a full range of existing and, to the extent possible, potential future operational conditions at the dam (likely increased bypass reach flows in new license), should be examined relative to migration rate and passage route selection of juvenile alosines to, and through, various areas of the project.

In addition, study fish should be collected and balloon-tagged to empirically determine rates of survival for fish passed over or through the dam's bypass sluice, main powerhouse, and 19 canal units under varied operations. For spill mortality sites (dam spillway and downstream bypass), tagged alosines should be injected or released into spill flow at points where water velocity exceeds 10 ft./sec to minimize the possibility of the fish swimming upstream into the headpond or canal. Passed balloon-tagged alosines will be recovered below areas of spill and held for 48 hours in isolated tanks for observation of injury and latent mortality; unrecovered balloon-tagged alosines will be censored from the data.

For turbine mortality sites, tagged alosines will be injected into intakes of units operating at or near full generation at points where intake water velocity exceeds 10 ft./sec to minimize the possibility of fish swimming back upstream through the intakes. Passed balloon-tagged alosines will be recovered in the tailrace and held for 48 hours in isolated tanks for observation of injury and latent mortality; unrecovered balloon-tagged alosines will be censored from the data.

Radio-tagged juvenile alewife will be released in areas upstream of the project at multiple release locations, to determine operation effects on migration rates, route, orientation, and entrainment, over a full range of permitted and operational conditions. The release of radio-tagged fish upstream of the project, and induction into the power canal, will provide data on concerns of delay and route selection to the canal, downstream bypass, crest gates, and turbines. Additionally, since fish can drift a considerable distance downstream after they have died (Havn et al. 2017); a minimum of 50 dead alewife should also be released as a control group in this study.

Level of Effort/Cost, and Why Alternative Studies Will Not Suffice

Boott does not propose any studies to meet this need. Estimated costs for the study are expected to be moderate to high, between $100,000 and $300,000, with the majority of costs associated with equipment (radio tags, radio receivers) and related field work labor.

REFERENCES

Havn, T. B., F. Økland, M.A. Teichert, L. Heermann, J. Borcherding, S.A. Sæther, O.H. Tambets and E.B. Thorstad. 2017. Movements of dead fish in rivers. Animal Biotelemetry, 5: 7.

Normandeau 2013. Juvenile Alosine Radio Tag Attachment Test. Submitted to Boot Hydro, LLC. Final report. Normandeau Associates, Inc., Westmoreland, New Hampshire. 2 pp.

Normandeau 2016. Garvins Falls Juvenile Alosine Downstream Passage Telemetry Assessment. Submitted to Boot Hydro, LLC. Final report. Normandeau Associates, Inc., Westmoreland, New Hampshire. 13 pp.

Study Request # 5

Downstream American Eel Passage Assessment
(Lowell, P-2790)

Goals and Objectives

The goal of this study is to determine the impact of the Lowell hydroelectric project on the outmigration of silver eels in the Merrimack River. Entrainment in the canal and at the conventional turbines at the project powerhouses (E.L. Field, Assets Station, Bridge Street, Hamilton Station, and John Street) can result in mortality or injury. It is important to understand the passage routes at the project and the potential for delay, injury, and mortality to assess alternative management options to increase survival.

The objectives of this study are:

1. Quantify the movement rates (including delays) and relative proportion of eels passing via various routes at the project (i.e., through the turbines, through the downstream bypass, spilled at the dams, etc.).
2. Evaluate instantaneous and latent mortality and injury of eels passed via each potential route.

Resource Management Goals

The Atlantic States Marine Fisheries Commission has developed two documents related to the management of American eel:

1. <u>Interstate Fishery Management Plan for American Eel</u>. April 2000. Atlantic States Marine Fisheries Commission.
2. <u>Addendum II to the Fishery Management Plan for American Eel</u>. Atlantic States Marine Fisheries Commission. Approved October 23, 2008. 8 pp.

Objectives of the management plan include: (1) protect and enhance American eel abundance in all watersheds where eel now occur; and (2) where practical, restore American eel to those waters where they had historical abundance, but may now be absent, by providing access to inland waters for glass eel, elvers, and yellow eel, and adequate escapement to the ocean for pre-spawning adult eel.

Addendum II contains specific recommendations for improving upstream and downstream passage of American eel, including requesting that member states and jurisdictions seek special consideration for American eel in the Commission relicensing process.

The Department seeks the accomplishment of a number of resource goals and objectives through the relicensing process for the project. General goals include the following:

1. Ensure that protection, mitigation and enhancement measures are commensurate with project effects and help meet regional fish and wildlife objectives for the basin.
2. Conserve, protect, and enhance the habitats for fish, wildlife, and plants that continue to be affected by the project.

Specific to downstream passage of American eel, the Department's goals are:

1. Minimize current and potential negative project operation effects that could hinder management goals and objectives.
2. Minimize project-related sources of downstream passage delay, injury, stress, and mortality in order to maximize the number of silver eels migrating to the spawning grounds.

Our study requests are intended to facilitate the collection of information necessary to conduct effects analyses and to develop reasonable and prudent conservation measures, and protection, mitigation, and enhancement measures pursuant to the Fish and Wildlife Coordination Act, as amended (16 U.S.C. §661, *et seq*.), and the Federal Power Act (16 U.S.C. §791a, *et seq*.).

Public Interest

The requester is a natural resource agency.

Existing Information and the Need for Additional Information

Data on downstream migratory movements and rates of American eels past the project are sparse and relatively incomplete. A single study was performed by Normandeau Associates, Inc., in 2017 (Normandeau 2017). Seventeen silver-phase eels were tagged and released into the Merrimack River upstream of the Garvins Falls project. Of the 17 released individuals, 14 approached the Pawtucket dam. Eight were determined to have passed through the gatehouse and enter the forebay canal upstream of the E.L. Field powerhouse. Five eels passed the project via spill flow. One eel's passage route was classified as unknown. Zero individuals used the downstream bypass. This study had a small sample size, was of a relatively short duration (October 20-November 28, 2017), did not include monitoring stations or antenna arrangements in the canal, and was performed prior to the installation of the pneumatic crest gate system.

To date, no other directed studies of eel entrainment or mortality have been conducted at the Lowell Project. These information gaps need to be filled so the natural resource agencies can assess the relative and cumulative impacts of project operations on outmigrating eels and develop adequate passage and protection measures to meet management goals and objectives.

Nexus to Project Operations and Effects

The project configuration presents problems with respect to providing safe, timely, and effective passage for outmigrating eels. The intakes are likely deep and, while no specification for the trashracks were provided in the PAD, it is unlikely they would prevent entrainment of eels. The anadromous downstream passage facility at the project is also not expected to be effective for eels; the target anadromous species are surface-oriented, while eels tend to move much deeper in the water column. Additionally, there are no data pertaining to eel movements in the Lowell canal. Eels which move into the canal potentially have no alternative but to pass through hydropower turbines at the Assets, Bridge Street, Hamilton, and John Street powerhouses. Eels are known to occur upstream of the dam; therefore, it is necessary to understand how eels move through the project and the level of injury and/or mortality resulting from each potential passage route (i.e., the spillway, the downstream bypass facility, or the 21 turbines associated with the project).

Methodology Consistent with Accepted Practice

In order to understand the movements of outmigrating silver eels as they relate to operations at Lowell, radio telemetry technology should be utilized. Radio telemetry is an accepted technology which has been used for a number of studies associated with hydropower projects, including at the Bellows Falls (FERC No. 1855), Wilder (FERC No. 1892), and Vernon (P-1904) projects.

Studies should be designed to investigate route selection (i.e., entrainment vs. spill) independently from estimation of mortality/injury, because these metrics require different methodologies. Studies will also likely benefit from data collected over 2 study years (especially route selection studies, which may be more significantly affected by environmental conditions during a given season than mortality/injury studies). It is also envisioned that the results from route selection studies can guide design of turbine mortality studies. Therefore, it is proposed, at a minimum, route selection studies be conducted in multiple years, but mortality/injury studies may be conducted after the first year of route selection studies have been completed.

Objective 1: Route Selection

This study will involve systematic releases of radio-tagged silver phase eels at strategic points above areas of interest, to assess general routes of passage (i.e., via spill, bypass, or turbines). Active downstream migrants should be collected within-basin if possible (i.e., Cabot or Holyoke bypass samplers), but fish sourced from out-of-basin may be acceptable to meet sample size demands. Experimental fish must meet morphometric (e.g., eye diameter relative to body size) criteria to ensure they are migrant silver phase. Collections should be made within the migratory season (late August to mid-October), and eels should be tagged and released within 21 days after capture, but preferably within 7 days (particularly if the test eels are from out-of-basin).

All telemetered eels will be radio- and PIT-tagged. PIT antennas will be installed and monitored continuously to verify passage of eels via bypass channels.

A minimum number of 150 telemetered eels (e.g., five separate groups of approximately 30 eels each) will be required to maximize the data return. Tagged eels should be released at least 5 km upstream of the Lowell Project. Groups of eels should be released during spill (if any) and non-spill and during periods of low, moderate, and high generation conditions. Up to 50 additional eels should also be released in the upper canal and allowed to volitionally descend through the canal to assure that a sufficient number of eels are exposed to canal conditions. Groups of eels should be released when the canal units are running and when the canal units are off. Additionally, since fish can drift a considerable distance downstream after they have died (Havn et al. 2017), a minimum of 25 dead eels should also be released as a control group in this study.

Telemetry receivers and antennas should be located upstream and downstream of the spillway, at the canal entrance, within the canal, in the downstream fish bypass entrance, at turbine intakes, the station tailrace, and downstream of the confluence of the Merrimack and Concord rivers. These locations will permit assessment of passage via the following potential routes: the power canal; spillway; downstream fish bypass; station turbines; and upstream fishway attraction water intake. The final placement of receivers and antennas should be developed in consultation with the fisheries agencies.

Mobile tracking (i.e., via boat) in the River and canal between release sites and several km downstream will be performed at regular intervals during and after releases to confirm routes and fates of passed fish or lost fish.

Movement rates (time between release and detection at radio antenna locations, and between radio antenna locations) of eels passing the projects by various routes will also be quantified.

The route selection portion of this study should occur in both study years.

Objective 2: Spill, Bypass, and Turbine Mortality/Injury Studies

Spill, bypass, and turbine mortality will be assessed using a balloon-tag method.

For spill mortality sites (dam spillways and downstream bypasses), tagged eels will be injected or released into spill flow at points where water velocity exceeds 10 ft./sec to minimize the possibility of eels swimming upstream into the headpond or canal. Passed balloon-tagged eels will be recovered below areas of spill and held for 48 hours in isolated tanks for observation of injury and latent mortality; unrecovered balloon-tagged eels will be censored from the data.

For turbine mortality sites, tagged eels will be injected into intakes of all 21 units associated with the project, operating at a full range of settings where intake water velocity exceeds 10 ft/sec to minimize the possibility of eels swimming back upstream through the intakes. Passed balloon-tagged eels will be recovered in the tailrace(s) and held for 48 hours in isolated tanks for observation of injury and latent mortality; unrecovered balloon-tagged eels will be censored from the data.

If the balloon-tag mortality component of the study occurs in study year one, all possible route selection sites would need to be evaluated. If the balloon-tag mortality component of the study occurs in study year two, results from the route selection study could be used to inform which sites need to be evaluated for mortality. Eels recovered from balloon-tag studies should not be used for route selection studies.

Data analyses of route selection and mortality (instantaneous and latent) will follow standard methodology.

Project operation (flows, levels, gate openings, number of units operating and operation level) and environmental conditions (river flow, temperature, turbidity, air temperature, precipitation) will be monitored regularly (hourly measurements if possible) throughout the duration of the studies and assessed for potential relationships to passage route selection, migratory delay, and/or passage survival.

These methodologies are consistent with accepted practice.

Level of Effort/Cost, and Why Alternative Studies Will Not Suffice

The level of cost and effort for the downstream eel passage study will be moderate to high; silver eels would need to be collected, tagged, and released in several locations over the course of the migration season. Antennas and receivers would need to be installed throughout the canal, at the intakes of the E.L. Field powerhouse, at the dam spillways and station bypass and monitored regularly. Data would need to be retrieved periodically, then analyzed. A multi-site route selection study conducted by the USGS Conte Lab on the Shetucket River in Connecticut cost approximately $75,000 for the first year of study. Costs are estimated at $100,000 per year for the route selection study and $50,000 to $75,000 for the spill, bypass, canal, and turbine mortality/injury study.

Boott did not propose any studies to meet this need in the PAD.

REFERENCES

Havn, T. B., F. Økland, M.A. Teichert, L. Heermann, J. Borcherding, S.A. Sæther, O.H. Tambets and E.B. Thorstad. 2017. Movements of dead fish in rivers. Animal Biotelemetry, 5: 7.

Normandeau Associates, Inc. 2017. Downstream Passage Evaluation for Silve-Phase American Eels at the Lowell Hydroelectric Project. 2017. Submitted to the City of Holyoke Gas and Electric Department. Final report. Normandeau Associates, Inc., Westmoreland, New Hampshire. 17 pp.

Study Request # 6

Operations Analysis of the Lowell Canal
(Lowell, P-2790)

Goals and Objectives

The goal of this study is to understand the operations of the Lowell canal system. The specific objective of this study is to describe the operations of the Lowell canal (how all of the canal units interact with the main units, how the canal units are sequenced, how often each of the units operate, the prioritization sequence of canal unit operations, the amount of time the units are operated during the downstream passage season, etc.).

Resource Management Goals

The Department seeks the accomplishment of a number of resource goals and objectives through the relicensing process for the project. General goals include the following:

1. Ensure that protection, mitigation, and enhancement measures are commensurate with project effects and help meet regional fish and wildlife objectives for the basin.
2. Conserve, protect, and enhance the habitats for fish, wildlife, and plants that continue to be affected by the project.

Specific to aquatic resources, the Department's goals are:

1. Protect, enhance, or restore diverse high quality aquatic and riparian habitats for plants, animals, food webs, and communities in the watershed and mitigate for loss or degradation of these habitats.
2. Minimize current and potential negative project operation effects on fish in the project area.

Public Interest

The requestor is a natural resource agency.

Existing Information and the Need for Additional Information

The Merrimack River supports a variety of migratory fish species. However, there is no information pertaining to fish mortality and population effects resulting from entrainment in the canal and/or the canal units. Since there are no exclusionary measures at the entrance of the project's canal system, fish can easily enter the two-tiered network of man-made canals, which are approximately 5.5 miles in length. These man made canals provide flow to 19 Boott-owned hydroelectric units. Since obtaining the original license for the project, there have been no directed studies of the Pawtucket, Western, Merrimack, or Hamilton canal units. Additionally, the PAD provides little operational information regarding the canal: flows of up to 2,000 cfs. are routed into the canal, typically once the E.L. Field station's hydraulic capacity of 8,000 cfs. has been reached. These information gaps need to be filled so the natural resource agencies can assess the relative and cumulative impacts of project operations on riverine fishes and migratory alosines which may be moving through, or inhabiting, the canal and develop adequate passage and protection measures to meet management goals and objectives.

Nexus to Project Operations and Effects

The Lowell Project consists of a two-tiered, 5.5-mile-long, network of man-made canals which include several small dams and 19 turbine units. Flows enter the canal system upstream of the Pawtucket dam via the Pawtucket canal. There are no exclusionary measures for fish in place. Therefore, the Lowell canal presents problems with respect to providing safe, timely, and effective passage for fish trying to move past the project through the canal system.

Methodology Consistent with Accepted Practice

In order to determine the relative risk the canal unit's present to riverine and migratory fishes, it is necessary to understand how the canal operates. Therefore, we request Boott provide a detailed description of the operational protocol it uses to determine when and how much water flows into the canal at a time scale relevant to the migratory fish species expected to potentially utilize the canal as a passage route (e.g., May, June, and July for spent alosines; August through November for adult eels and juvenile alosines). Historical operations data should be examined relative to the hydrological data set to determine the percent of time the canal units would be expected to operate during each passage month. This analysis should be used in conjunction with the results of the passage route and turbine mortality studies to estimate total through project mortality for each target fish species/life stage.

Level of Effort/Cost, and Why Alternative Studies Will Not Suffice

The expected level of effort and anticipated cost will be low. Operations and hydrologic data are readily available and only need to be compiled and analyzed. We estimate the cost to be less than $10,000.

Study Request # 7

Three-Dimensional Computational Fluid Dynamics (CFD) Modeling in the Vicinity of Fishway Entrances and Powerhouse Forebays

(Lowell, P-2790)

Goals and Objectives

The goal of this study is to determine the flow field conditions which exist in and around fishway entrances and the powerhouse forebay. The information from this request is meant to be coupled with data from the telemetry studies, such that a comprehensive understanding of fish behavior is developed.

The objective of this study is to create a series of color contour maps of velocity magnitude at select discharges agreed upon by the resource agencies and the licensee. With respect to upstream passage, the results will show approach velocities and flow fields that may create a response in fish. This information can be coupled with telemetry data (from the requested shad and river herring telemetry study) and passage counts to understand which conditions are optimal for guiding migrating fish to the fishway entrances and stimulating fishway entry.

With respect to downstream migration, the results will show velocities and flow fields in front of the E.L. Field powerhouse. Additionally, the results will indicate to what degree, if any, flow directs downstream migrating fish towards the downstream bypass facility.

Resource Management Goals

The management goals of this study request are to obtain information that will assist in enhancing the effectiveness of the current upstream fish passage facilities for upstream migrating trust species and reduce impingement, entrainment, and delay for downstream migrating fish. CFD models are a relatively cost effective way to analyze existing and future conditions. As such, changes in the amount of attraction water, changes in which turbines are operating, and which spillway gates are releasing water can all be examined. As stated, the results from this study are meant to be used along with the data generated from the requested telemetry study. The combined analysis from these two data sources can help assess which flow conditions are most advantageous for migrating trust species to enter the fishway under current and proposed conditions.

As for downstream migration of adult and juvenile shad, river herring, and adult eel, the results from the models will reveal flow magnitude and direction in front of the powerhouse. Given the limited information that currently exists on survival through the project, our management goal is to direct as many downstream migrating fish as possible towards the downstream bypass facility. With respect to upstream passage, we want to maximize the number of fish that find and enter the fishway entrances.

Our study requests are intended to facilitate the collection of information necessary to conduct effects analyses and to develop reasonable and prudent conservation measures, and protection, mitigation, and enhancement measures pursuant to the Fish and Wildlife Coordination Act, as amended (16 U.S.C. §661, *et seq*.), and the Federal Power Act (16 U.S.C. §791a, *et seq*.).

Public Interest

The requestor is a natural resource agency.

Existing Information and the Need for Additional Information

To date, no CFD modeled data exists in front of either the fish ladder or lift, nor do they exist in front of the E.L. Field powerhouse. A comprehensive understanding of fish behavior at the ladder and lift entrance, and the powerhouse forebay, is needed in order to create safe, timely, and effective upstream and downstream passage for American shad, river herring, and eels. Additionally, a better understanding of flow and how it affects fish passage is needed after Boott performs the ledge removal excavation project.

Nexus to Project Operations and Effects

The Lowell Project has direct impacts to upstream and downstream migrating shad, river herring, and eel. The development of these models will give resource agencies valuable information into the hydraulic cues which may elicit a response from upstream migrants. For downstream passage, the Department has approach velocity guidelines; the output from these models would inform the resource agencies under what conditions appropriate approach velocities are being met and when they are being exceeded.

With respect to upstream migration, the auxiliary water system (AWS) plays a critical role in determining whether or not fish are attracted to the entrance. The results from this study would allow us to assess how well the AWS is performing and under what conditions it attracts the most fish.

With respect to downstream migration, the development of a CFD model under existing conditions also informs the design of future modifications and improves the survivability of downstream migrating shad, river herring, and eel.

The CFD models for the Pawtucket fishway and fish lift should be developed as part of year two studies, after the ledge excavation project is complete. It would be useful to have the gatehouse area CFD modeling completed in year one. This analysis may provide information on adjustments to canal operations or structures that can subsequently be analyzed.

Understanding the entrance conditions of the Pawtucket fishway under a range of spill conditions would be informative. If developed prior to the year one upstream shad telemetry studies, it would provide information on spill gate settings which would likely best achieve entrance and ultimately passage. Further work with the model can help in evaluating changes in ladder entrance or spill conditions that could improve passage and be tested with telemetry, video, and/or count data.

CFD modeling of the flows leading to the canal would aide in our interpretation of year one downstream passage telemetry results, but would not need to be completed prior to the year one telemetry (downstream juvenile alewife and downstream eel) studies. Those studies will provide the context for how and where shad, river herring, and eels are passing the project and how successful passage is. The CFD modeling could focus on the locations identified as important in the study results and Boott could assess changes to structures or operations and evaluate them in the model. Promising alternatives would then be tested in year three studies.

Methodology Consistent with Accepted Practice

A three-dimensional CFD model has become an increasingly common standard of analysis at hydroelectric projects around the nation. Within the northeast region, we have seen these types of models developed at the Holyoke (P-2004), Brunswick (P-2284), Shawmut (P-2322), Milford (P-2534) and Orono (P-2710) projects. We would expect to engage with the licensee in terms of determining the appropriate area and flows to be modeled. We expect the spatial extent of the model at each study site will vary. Given the large number of ways in which output from these models can be presented and the near infinite number of flows which could potentially be modeled, we would expect to consult with the licensee to reach agreed upon modeling efforts and scenarios to be examined.

Level of Effort/Cost, and Why Alternative Studies Will Not Suffice

The cost of developing, running and testing a CFD model can vary tremendously; one large variable in determining the cost is based on the amount of existing bathymetric data to which Boott currently has access. We roughly estimate that the cost of each CFD model could run as high as $50,000, assuming no bathymetric data currently exists. Proactive communication with resource agencies will reduce the cost and iterative effort. Given the level of effort that has occurred at other projects that have proposed to amend their license, we see the level of effort requested here as reasonable, given that Boott is seeking a renewal of its license.

Study Request # 8

Bypass Zone of Passage

(Lowell, P-2790)

Goals and Objectives

The goal of this study is to determine zone-of-passage flows in the bypass reach which facilitate safe, timely, and effective fish passage through the project.

Specifically, the objectives of this study are:

1. complete a detailed survey of the bypass reach;
2. develop a high-resolution, two-dimensional hydraulic model of the bypass reach;
3. release multiple flows from the dam to collect calibration data for the model;
4. simulate additional flows through the bypass reach with the calibrated model; and
5. determine minimum and optimal zone-of-passage flows for the project.

Resource Management Goals

The Department seeks the accomplishment of a number of resource goals and objectives through the relicensing process for the project. General goals include the following:

1. Ensure that protection, mitigation and enhancement measures are commensurate with project effects and help meet regional fish and wildlife objectives for the basin.
2. Conserve, protect, and enhance the habitats for fish, wildlife, and plants that continue to be affected by the project.

Specific to aquatic resources within the Lowell bypassed reach, the Department's goals are:

1. Protect, enhance, or restore diverse high quality aquatic and riparian habitats for plants, animals, food webs, and communities in the watershed and mitigate for loss or degradation of these habitats.
2. Provide a flow regime in the bypassed reach that meets the life history requirements of resident fish and wildlife (including invertebrates such as freshwater mussels) and diadromous fishes.
3. Minimize current and potential negative project operation effects on water quality and aquatic habitat.

Our study requests are intended to facilitate the collection of information necessary to conduct effects analyses and to develop reasonable and prudent conservation measures, and protection, mitigation, and enhancement measures pursuant to the Fish and Wildlife Coordination Act, as amended (16 U.S.C. §661, *et seq*.), and the Federal Power Act (16 U.S.C. §791a, *et seq*.).

Public Interest

The requester is a natural resource agency.

Existing Information and the Need for Additional Information

Article 36 of the original license required the licensee, in consultation with resource agencies, to develop an in-stream flow study plan to determine: (1) the relationship between project discharges and downstream aquatic habitat; and (2) a fishery study plan to determine project discharges necessary to provide for the migration of anadromous fish (i.e., zone of passage). After completion of the approved studies, the licensee was to file a report on the results of the studies, and, for Commissions approval, recommendations for the flow releases from the project. The study plan was filed on August 13, 1983, with proof of agency consultation (Accession No. 19830818-0191). However, there are no study reports included in the record. Therefore, we have no quantitative data supporting the agreement that 300 cfs. at night and 500 cfs. during the day are adequate flows for zone of passage in the bypass reach.

In the Comprehensive Fish Passage Plan filed on March 9, 2000 (Accession No. 20000313-0322), the licensee states "The adequacy of flows for upstream fish passage at the Project was addressed by BHI's construction of six (6) concrete flow control weirs (with adjustable stoplog sections) in the bypass reach, at the request of U.S. Fish and Wildlife Service and in response to Article 36, section (2) of the Project's FERC license." Similar to the study plan, this is an agreement with no supporting information to substantiate the conclusion flows in the bypass reach are adequate for the full suite of diadromous species.

As part of compliance for Article 34 of the original license, the licensee filed as-built drawings of the existing fish passage facilities (Accession No. 19860902-0215). Within this abbreviated drawing set, drawing number 344D-PC001, 3844D-FC001, and 3844D-FC004 show topographic surveys for portions of the bypass reach. However, the drawings do not document the accuracy and precision of the survey, do not show the majority of the bypass reach, and are otherwise illegible.

Since agreeing upon the current zone-of-passage flows during the original license, there have been developments in topographic survey capabilities, a better understanding of the hydraulic requirements of diadromous species, multi-dimensional hydraulic modeling capabilities, and an increased need to pass fish at the spillway ladder.

Nexus to Project Operations and Effects

Diadromous fish orient their migration based on the environmental conditions of the river: flow, depth, velocity, and temperature (Goodwin 2014). Project operations affect the environmental conditions in the River, specific to this study request, the bypass reach. Two key hydraulic model outputs from the requested study are depth and depth-averaged velocity, which can be used to determine the likelihood of predation, delay, and the cessation of migration. Evaluating the flow fields in the bypass reach under different spill conditions will assist in the consultation process for determining an appropriate zone-of-passage flow in the bypass reach to optimize fish passage at the project. These data will also contribute to the development of an administrative record in support of a potential settlement agreement, Section 18 fishway prescriptions, or 10(j) recommendations.

Methodology Consistent with Accepted Practice

We proposed the following methodology to accomplish the five objectives and ultimately the goal of the study, to determine zone-of-passage flows for the bypass reach.

Topographic survey

The bypass reach area is large, making traditional topographic survey methods laborious and costly. We recommend using Light Detection and Ranging (LiDAR) methods with limited traditional surveying. Outside of the fish passage season and during a river flow when the project is in control of the River, the bypass reach will be mostly dewatered. At this time, a licensed surveyor can fly the area to collect LiDAR data. Once this data is processed, traditional methods will fill in the gaps (e.g., pooled water areas, under bridges). The topographic survey shall be of sufficient resolution and quality to complete the remaining objectives.

Two-dimensional hydraulic model

There are many two-dimensional hydraulic models that are acceptable for accomplishing the goal of this requested study, many of which are open source. We are not requiring one model over the other, but Boott should understand and document the limitations of the modeling software used. At a minimum, the modeling output should produce depth-average velocity and depth for each cell in the mesh. The modeling domain shall be of sufficient size and mesh to delineate a zone of passage through the entire length and width of the bypass reach.

Calibration flows

The licensee should collect calibration data by spilling a minimum of two flows from the Pawtucket dam. The calibration flows should bracket the range of simulated flows in the study. We recommend 300 cfs. for the low flow as it represents the current lowest operation flow for the fish ladder. For the high calibration flow, we recommend collecting data near the high fish passage design flow (i.e., the 5 percent exceedance value for the migratory period of record) which is approximately 26,000 cfs. in the Merrimack River (bypass flow would be approximately 17,000 cfs. with full project operation). Boott should collect calibration data (depth-averaged velocity and depth) with an Acoustic Doppler Current Profiler (ADCP) at a minimum of four cross sections, including the downstream boundary condition and use the ADCP in locations spread evenly throughout the bypass which are less turbulent.

Additional flow simulations

After calibrating the model, additional bypass flows should be simulated (and agreed upon with the natural resource agencies), including 500 cfs., 1,000 cfs., and up to the high calibration flow. The additional simulations should represent the full range of hydraulic conditions in the bypass reach from the low to high fish passage design flow.

Zone-of-passage determination

The model output should be used to delineate a zone-of-passage pathway for each of the modeled flows. To determine the zone of passage, we recommend Boott use the SprintSwim model developed by U.S. Geological Survey researchers (Haro et al. 2004).

Level of Effort/Cost, and Why Alternative Studies Will Not Suffice

The licensee should be able to finish the bypass zone-of-passage study in one year depending on seasonal flow conditions. The level of effort and cost is commensurate with a project the size of the Lowell facility and the likely license term. No alternatives are proposed.

REFERENCES

Goodwin, R. A., M. Politano, J.W. Garvin, J.M. Nestler, D. Hay, J.J. Anderson and M. Timko. 2014. Fish navigation of large dams emerges from their modulation of flow field experience. Proceedings of the National Academy of Sciences. p. 201311874.

Haro, A., T. Castro-Santos, J. Noreika and M. Odeh. 2004. Swimming performance of 716 upstream migrant fishes in open-channel flow: a new approach to predicting passage through velocity barriers. Canadian Journal of Fish and Aquatic Science. 61: 1590-1601.

Document Content(s)

United States Department of the Interior

OFFICE OF THE SECRETARY
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August 14, 2018

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ER 18/0281

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

RE: COMMENTS ON PRE-APPLICATION DOCUMENT
COMMENTS ON SCOPING DOCUMENT 1
STUDY REQUESTS
Boott Hydropower, LLC
Lowell Hydroelectric Project, FERC No. 2790-072
Merrimack River, Middlesex County, MA, and Hillsborough County, NH

Dear Secretary Bose:

This responds to the Pre-Application Document (PAD) for the Lowell Hydroelectric Project, (Project) located on the Merrimack River in Middlesex County, Massachusetts and in Hillsborough County, New Hampshire. The PAD is being provided in preparation of an application for a new Federal license for the project. The U.S. Department of the Interior (Department) offers the following comments based on the PAD (submitted to us by Boott Hydropower, LLC, [Boott] on April 30, 2018) and additional information obtained at the Federal Energy Regulatory Commission (Commission, FERC) scoping meeting held on July 17, 2018, and the site visit held on July 18, 2018. The comments represent contributions from the Department's U.S. Fish and Wildlife Service (Service) and the Lowell National Historical Park, National Park Service (NPS).

U.S. FISH and WILDLIFE SERVICE

PRE-APPLICATION DOCUMENT

PROPOSAL

The Lowell Project consists of a 1,093-foot-long, 15-foot-high masonry gravity dam (Pawtucket dam) topped by a 5-foot-high, pneumatic crest gate system,[1] which creates a 720-acre

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[1] On April 18, 2013, the Commission amended the project license authorizing Boott to replace the wooden flashboards on the Pawtucket dam with a pneumatic crest gate system (143 FERC ¶ 61,048). Installation of the crest gate system is currently in progress.

impoundment extending approximately 23 miles upstream. The dam has a gross storage capacity of approximately 3,600 feet between the maximum normal water surface elevation of 92.2 feet National Geodetic Vertical Datum of 1929 (NGVD) and the minimum water surface elevation of 87.2 feet NGVD when all five pneumatic gates are fully lowered. The spillway is 980.5 feet long. The project includes a two-tiered network of man-made canals, totaling approximately 5.5 miles in length, which provide flow to 21 Boott-owned hydroelectric units.[2] Nineteen of the units are located in four powerhouses (Assets, Bridge Street, Hamilton, and John Street) situated in the canal and have various runner speeds and diameters. The remaining two units are located in the main powerhouse (E.L. Field) on the Merrimack River, which uses water from the northern canal to generate power. Units in the E.L. Field powerhouse are identical, 8.6-MW horizontal Kaplan turbine-generator units, each with a maximum hydraulic capacity of 4,000 cfs.

Boott currently operates the project in a run-of-river mode. The current license requires an instantaneous minimum flow of 1,990 cfs or inflow, whichever is less, as measured immediately downstream of the project.

Boott operates both upstream and downstream fish passage facilities at the project. These include a lift at the E.L. Field powerhouse that conveys fish to the northern canal, an upstream anadromous vertical-slot fishway at the Pawtucket dam, and a downstream bypass facility at the E.L. Field powerhouse. The fish ladder has a total operating flow of 500 cfs and acts as the primary source of flow in the 0.7-mile-long bypass reach (other than spillage over the Pawtucket dam spillway when inflow exceeds the maximum hydraulic capacity of the project's stations). The current license contains no minimum bypass flow requirement.

In the PAD, Boott has proposed no additional protection, mitigation, or enhancement (PME) measures.

COMMENTS

4.0 Project Location, Facilities, and Operations

Boott provided a detailed description of the project facilities. However, several important pieces of information are missing:

- the minimum hydraulic capacities, runner diameters and runner speeds of turbines at the project (housed in the E.L. Field, Assets Station, Bridge Street, Hamilton Station, and John Street powerhouses);
- clear trashrack spacing at intakes to all of the turbines; and,
- the calculated approach velocity at the trashracks/intakes (based on the wetted trashrack area).

[2] Boott submitted an Application for Amendment of License to the Commission on March 16, 2017. The amendment of license proposes the removal of four of the project's currently authorized generating units from the license. These units include Bridge Street 1, 2, 3, and 12.

4.1 Civil Works

Tailrace Channel

Telemetry studies in 2002, 2011, and 2013, showed emigrating American shad that approach the Project via the tailrace have difficulty using the fishway entrance (Sprankle 2005; Alden 2011; Blue Leaf Environmental 2013). In 2016, Gomez and Sullivan engineers performed an analysis of upstream passage at the lift and recommended that Boott excavate the ledge outcropping in the tailrace channel to approximately 10 feet below normal tailwater level extending 50 to 100 feet downstream from the entrance (Gomez and Sullivan 2016). On July 18, 2017, Boott submitted design plans to the Merrimack River Technical Committee (MRTC; comprised of Federal and State agencies) for review prior to the start of construction. On July 26, 2017, the MRTC submitted their recommendations. On August, 18, 2017, at the request of Boott, the National Oceanic and Atmospheric Administration (NOAA) and the United States Fish and Wildlife Service (Service) provided additional information pertaining to the MRTC's recommendations (Attachment A). The PAD does not contain any information regarding the tailrace excavation project. We recommend Boott update the PAD to include the details we have provided here.

In the PAD, and the Commission's pre-filing milestone timetable included in the scoping document, the first study season is scheduled to begin during spring of 2019. However, Boott plans to complete the tailrace excavation project during late summer of 2019 (Attachment B). The tailrace excavation project will change flow dynamics in the tailrace channel and therefore the hydraulic conditions fish will likely encounter as they migrate upstream. As such, we ask that the studies requested herein related to upstream fish migration and flow in the tailrace area occur after the excavation is complete (second study season, or 2020) so natural resource agencies can properly assess the impacts project operations might have on migratory fish and develop adequate passage and protection measures if necessary.

4.5 Description of Project Operations

Fish Passage Operations

Boott states it has provided, and assessed the effectiveness of, American eel (*Anguilla rostrata*) passage at Lowell. The effort to pass eels at the project began in 2014 when temporary eel ramps were deployed near the ladder. However, the effectiveness of these structures has never been quantified. In 2018, Boott agreed to: (1) continue to operate the existing anadromous fish ladder for eels (releasing 30 cfs) until September 30; and, (2) perform six, dewatered, visual inspections of the ladder. To date, there have been no siting surveys performed at Lowell. Therefore, it is unknown if eels congregate at other areas within the project boundary (e.g., the outfall of the canal power stations) or if passing eels at the ladder is the most appropriate technique. The Department likely will include, in any fishway prescription issued for the project, a requirement that Boott conduct an upstream eel passage siting survey after a new bypass flow regime has been implemented to determine areas of eel concertation so permanent upstream passage facilities can be properly sited.

National Park Service Requirements

In this section of the PAD, Boott states that it maintains canal water levels "within appropriate limits during the May 15 to October 15 tour boat operating season," however no additional information is provided. We recommend Boott update the PAD to include further information regarding water levels maintained in the canal and any additional, relevant, information regarding the operations agreement they have with the National Park Service.

5.4 Fish and Aquatic Resources

Overview

The fish ladder at the Pawtucket dam has a total operating flow of 500 cfs and is the primary source of flow in the 0.7-mile-long bypass reach which extends from the Pawtucket dam downstream to the E.L. Field powerhouse. However, there is no information provided in the PAD to support this flow release is adequate to meet the life history requirements of fish and wildlife (including invertebrates such as freshwater mussels). Therefore, the Department recommends that Boott undertake a study that evaluates habitat in the bypass reach at a range of flows, including the existing 500 cfs release. The study design should include habitat mapping of the entire bypass reach in addition to collecting hydraulic and habitat measurements (i.e., depth, velocity, wetted perimeter, substrate) along a number of transects to assess the existing flow release and alternative flows.

Boott states, "fish are capable of bypassing the Project's entire canal system via the Merrimack River and can use the existing upstream and downstream fish passage facilities at the Pawtucket Dam and the E.L. Field Powerhouse." While downstream-migrating fish can potentially avoid entering the canal, despite there being no exclusionary measures in place, a study by Normandeau Associates, Inc., found only 7 percent of juvenile alewives utilized the bypass (Normandeau 1991). A follow up study (Normandeau 1995) performed after the bypass was enlarged found that of 1,779 marked fish, only 37 percent utilized the downstream fish passage facilities. While efficiency increased by approximately 30 percent from 1991 to 1995, the bypass remains less than 40 percent effective at passing fish downstream.

Although bypass effectiveness studies were performed at Lowell in the early 1990s, it is still unclear as to which route American shad (*Alosa sapidissima*), alewife (*Alosa pseudoharengus*), blueback herring (*Alosa aestivalis*), and eel select as they move downstream (spillway, fish ladder, canal, turbines, existing bypass), the survival estimates associated with each route, the effect the Pawtucket gatehouse has on downstream movement, the effect the pneumatic crest gates have on emigration, etc. To fill these data gaps and better understand downstream passage at Lowell, especially in relation to the canal, the Department recommends that Boott conduct studies which assess: (1) the behavior, approach routes, passage success, survival and delay of adult American shad and river herring as they emigrate to the ocean; (2) the impact project operations have on the downstream migration of juvenile alewife which can serve as a proxy for blueback herring and American shad in this instance; and (3) downstream route of passage and survival of adult silver-phase American eel.

Abundance

The Merrimack River supports a variety of migratory fish species, including American shad, river herring (alewife and blueback herring), American eel, and sea lamprey (*Petromyzon marinus*). Table 5.4-2 lists the number of river herring, shad, and eel that have passed the Lawrence Project (FERC No. 2800, the first hydroelectric dam on the Merrimack River), and Lowell since 1983. In 2017, Boott claims that 177,738 eels swam upstream past Lawrence. However, our records indicate an estimated 8,645 elvers were lifted in the hopper and 17,691 passed the eelway at the dam (26,336 eels total). The Department recommends that Boott update Table 5.4-2 to: (1) ensure listed, annual, fish passage counts are accurate; and (2) include sea lamprey passage counts.

Other Site-Specific Fisheries Information

In this section of the PAD, Boott states that American shad studies were conducted in 1999 and 2000, which led to significant modifications and upgrades to the E.L. Field powerhouse fish lift, thereby improving passage efficiency. However, it is unclear as to which modifications Boott is referring.

According to our records, a lack of modifications and upgrades to the project coupled with poor fish passage led to a radio-telemetry study of shad migration in 2002 (Sprankle 2005). This study found 55 percent of the shad that passed upstream of Lawrence made their way into the Project tailrace near the fishway entrance. However, only 6.2 percent of the tagged shad were actually passed upstream of the project via the fish lift. This was consistent with fish passage counts taken at Lowell in 2002; only 9.7 percent of the shad which passed Lawrence subsequently passed Lowell. These data led to a dye test, also conducted by Ken Sprankle, in June 2003. During this qualitative evaluation, concentrated dye was released into the fishway entrance channel and observed. Results demonstrated the flow field extends downstream from the fishway and stalls approximately 35 feet from the entrance, effectively cutting off the progression of shad moving up the tailrace and into the fishway. Based on fish counts at Lawrence and Lowell, passage efficiencies for American shad have not improved at the project over the past 20 years. From 1996 to 2017, passage efficiency at the project has not exceeded 30 percent. Additionally, the internal fish lift efficiency has remained low. In 1996, fish lift efficiency ranged from 0.5 to 2.4 percent. In 2000, studies conducted by Boott suggested efficiency increased to 42 percent (Boott 2000). While this latest assessment does suggest an improvement in operations compared to previous years, an internal fish lift efficiency of 42 percent is still low as overall passage efficiency is based on the combined near/far field attraction efficiency and internal lift and ladder efficiency. Based on the information above, and considering the ledge removal improvements which will take place in 2019, the Department recommends that Boott perform a study assessing American shad upstream route selection passage effectiveness and migratory delay after the ledge is removed.

Boott goes on to state, “A 1988 acoustic telemetry study performed by RMC Environmental Services (RMC) of adult American shad movement through the Northern canal demonstrated successful passage through the Pawtucket Gatehouse, as well as incidental information regarding downstream passage routes for post-spawning individuals. In a follow-up study in 1991 by Normandeau Associates, Inc., found similar findings as the 1988 adult American shad telemetry study.” While it is true that 80 percent of the fish successfully exited the canal, it should be noted: (1) the sample size was small, only 25 fish were used in the analysis; and (2) the delay caused by existing infrastructure was substantial, ranging from 1 to 5 days. Also, as a point of clarification, there were two studies conducted in 1991 by Normandeau Associates, Inc., which focused on downstream passage of river herring and shad. The scope and findings of these studies did not include upstream passage through the gatehouse, which was the focus of the RMC 1988 study. To date, the RMC study has been the only evaluation of upstream passage of shad in the northern canal and gatehouse. As a component of the studies provided herein, we recommend that Boott track and monitor clupeid behavior in the canal.

<u>Major Findings of Fish Passage Studies Since 1988</u>

In the PAD, Boott provides an overview of the fish passage facilities at both projects, when they began operating, and studies which have been conducted to determine their effectiveness at passing target species. We would like to offer some points of clarification, specifically on information listed in Table 5.4-3.

- 1988: Passage of Radio-Tagged American Shad through the Northern Canal Headgate Structure. Boott states that “24 of 25 radio-tagged shad (96%) released at fish lift exit passed the Northern Canal headgate structure with little delay.” However, 19 of the 24 shad (80 percent) which successfully passed did not pass through the headgate structure but rather the adjacent boat lock facility. When the boat lock was closed, delay ranged from 1 to 5 days. Since a majority of the shad were observed reaching the headgate structure within an hour, the delay in migration associated with closing the boat lock was approximately 23-119 hours. The study notes that most fish approached the road bridge adjacent to the gatehouse but fell back downstream. The delay experienced by these shad is significant and, from the information provided by Boott, it is unclear how often the boat lock has been open during the upstream migratory season since the 1988 study was performed. We are concerned that the operation and management of the northern canal headgate may contribute to migratory delay and is an issue that will need to be resolved in order to successfully pass fish upstream and achieve a sustainable population of shad in the Merrimack River.

- 1991: An Assessment of the Effectiveness of a Fish Bypass for Passing Juvenile Alewives at the Lowell Hydroelectric Project. The findings listed in the table fail to include two critical results: (1) the bypass effectiveness for juvenile alewife was only 7 percent, even when bypass flows reached 2 percent of the turbine flow; and (2) when the bypass flow was increased by 50 percent, due to the units shutting down, the number of fish using the bypass increased by a significant amount (4,250 alewives in 10 minutes versus 0 in the previous 4.5 hours)

- 1996: Lowell Hydroelectric Project Internal Fish Lift Efficiency Monitoring Program. The internal fish lift efficiencies should be included in the findings, as they were extremely low, ranging from 0.5 percent to 2.4 percent.

- 1999: An Assessment of Internal Fish Lift Efficiency at the Lowell Hydroelectric Project. The study findings section states, “The ratio of total shad lifted at the Lowell Project to the total lifted at the downstream Lawrence facility was nearly doubled, reaching approximately 29% in 1999 compared to a historic ratio of 15% since 1986, and in the preceding two years." While this statistic may technically be correct, it actually represents a decrease from 1992 and 1995, when the ratios of total shad lifted at Lowell were 31 percent and 38 percent, respectively.

- Boott performed two fish lift internal efficiency studies and in the major findings column claims the crowder position has a beneficial impact on fish passage efficiency. However, this contradicts the study findings listed for the 1996 Normandeau Associates, Inc. study. As noted above, the Department suggests that Boott include information regarding modifications made to the fish lift which supports its contention of improved internal efficiency.

- A report by Gomez and Sullivan (2016) titled "Analysis of Upstream Fish Passage Facilities and Operations" was not included in the PAD. We recommend Boott update Table 5-4.3 to include this study, which identifies specific areas of improvement needed to increase the Lowell fishways reliability and upstream passage efficiency. Recommendations provided in the report include: (1) installing a pivot gate to update the existing vertical gate; (2) excavating the ledge outcrop downstream of the fishway entrance; (3) reopening the street side entrance; and (4) installing an entrance extension. The analysis also highlights the aging infrastructure at the project and the need to replace specific components, along with cost estimates.

6.0 Preliminary Issues, Project Effects, and Potential Studies

<u>Fish and Aquatic Resources</u>

Boott has not proposed any studies for relicensing at this time, but has identified potential resource issues which include: bypass flows, fish passage, historical resources, boating access, and inundation of upstream floodplains. Relevant to fish and aquatic resources, the Department believes new studies need to be conducted, with sufficient fish sample sizes, to better understand upstream and downstream passage at the project as well as instream flows in the bypass reach.

Downstream Passage

The Department recommends that Boott conduct new studies to fully understand how post-spawned adult shad and river herring, juvenile shad and river herring, and adult silver phase eels move past the Pawtucket dam, through the canal system, turbine intakes, and the downstream bypass facility. In addition, turbine injury and mortality studies are needed and should be used in conjunction with results of the passage routing studies, where applicable, to calculate total through-project survival rates. The Department herein provides study requests in order to address these information needs.

Upstream Passage

Yearly site inspections, performed by the Service, have identified a number of problems with respect to American shad at the lift and ladder fishway entrances. The Department believes that a comprehensive radiotelemetry study is needed to understand the relationship between project operations, including spill flows, and shad and river herring movement through the Merrimack River, including attraction to and passage through these facilities. Additionally, a study to define the relationship of the complex hydraulic conditions at the spillway fish ladder entrance and the tailrace fish lift entrance is needed in order to evaluate data on fish behavior and passage at those locations. Therefore, the Department is providing herein study requests to address these information needs.

Instream Flows in the Lowell Bypass

The bypass reach is 0.7 mile long (from the Pawtucket dam to the E.L. Field powerhouse) and contains diverse habitat. There are approximately 11 miles of free-flowing river downstream of the Pawtucket dam which also contain a diversity of habitat, including important spawning and rearing habitat for migratory fish species such as American shad. To date, there have not been any empirical studies which assess the adequacy of the existing flow protocols. The Department herein submits study requests intended to address these information gaps.

ADDITIONAL INFORMATION

The following information is needed:

- the minimum hydraulic capacities, runner diameters and speeds of the turbines in each powerhouse associated with the project;
- a more thorough description of how project operations are monitored and recorded;
- hourly data (water surface elevations, dam discharge, generation) for the project in spreadsheet format for the past 5 years;
- a detailed description of modifications made to the existing fish passage facilities, including dates changes were made;
- a detailed description of canal operations; and
- a detailed description of modifications made to the bypass extending from the Pawtucket dam to the E.L. Field powerhouse (weir installation, excavation, etc.).

RECOMMENDED STUDIES

Boott is not proposing to undertake any studies as part of this relicense proceeding. Enclosed please find formal study requests (Attachment C) by the Service in the format required pursuant to 18 CFR §4.38(b)(5). Please note the Service also supports the study requests provided by the other agencies including, but not limited to, National Marine Fisheries Service, Massachusetts Division of Fish and Wildlife, and Massachusetts Department of Environmental Protection.

SCOPING DOCUMENT 1

3.6.3 Project Decommissioning

The Commission proposes to eliminate this alternative from detailed study in the environmental analysis, because no party has suggested project decommissioning would be appropriate in this case. The Commission asserts that there would be significant costs involved with decommissioning the project, including lost energy production.

We recommend that the Commission include project decommissioning in the environmental analysis. Although no party has suggested this alternative, up to this point in the Integrated

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Licensing Process, there has been no formal opportunity to provide such a recommendation. Further, the Commission has supplied no supporting information to justify the contention of significant decommissioning costs (which could run the gamut from "locking the door" to full dam removal at the Lowell Project). Given the substantial increase in the numbers of proposed renewable energy projects, it is possible that there may be no net loss of energy production when viewed on a regional basis. Also, we are requesting a number of studies to understand the impacts of the project. Study results could identify impacts which either cannot be mitigated or would be prohibitively expensive to mitigate. In light of that possibility, decommissioning of the Lowell Project should be retained as a potential alternative that the Commission may need to address.

4.1.2 Geographic Scope

The Service recommends the geographic scope of the Commission's environmental analysis (pertaining to impacts to cumulatively affected fishery, water quantity, and water quality resources) extend from the Eastman Falls dam (FERC No. 2457) and Lake Winnipesaukee to the confluence of the Pemigewasset and Winnipesaukee Rivers, downstream to the Atlantic Ocean, as this represents the extent in which river herring and American eel are managed in the basin.

4.2.1 Aquatic Resources

Effects of project facilities and operations on fish migration should be analyzed cumulatively as well as for individual projects. Additionally, effects of entrainment should not be limited to fish populations, but should include impacts to food web interactions and overall ecosystem productivity.

<u>LOWELL NATIONAL HISTORICAL PARK, NATIONAL PARK SERVICE</u>

COMMENTS

PAD Section 1.0 Introduction and Background

The 5.6 miles of historic canals are wholly within the boundary of Lowell National Historical Park and are a principle resource that Congress directed the Park to protect. Additionally, the canal system and support buildings are designated as a National Historic Landmark, offering the highest provision of historic preservation protection under the National Historical Policy Act of 1966. The canal system is also located within the boundaries of:

- Lowell Locks and Canals National Historic Landmark District;
- Lowell Water Power System National Historic Civil Engineering Landmark; and
- Lowell Power Canal System and Pawtucket Gatehouse National Historic Mechanical Engineering Landmark.

The first mention of historic resources in the PAD is located on Page 28, section 4.9 following the description of all resources. These significant designations should be inserted into the Intro/Background Section.

PAD Section 4.0 Project Location, Facilities, and Operations

Nearly all of the Civil Works described in Section 4.1 are historically significant structures, listed as contributing features within the National Historic Landmark District. Please include date of construction for each of the Civil Works referenced on pages 10-15 or Sections 4.1.1 through 4.1.11. Please also include, where applicable, a reference to significant historical resources in this section. For example, “Constructed in 1847, the Pawtucket Gatehouse is located at the southern abutment of the Pawtucket Dam…The Pawtucket Gatehouse is the site of origin for the historically significant Francis Turbine which is still intact within the building.”
The following table cross-references PAD names with the language produced by Proprietors of Locks and Canals on Merrimack River (PLC) as recorded in the “Lowell Canal Survey” by the 1976 Historic American Engineering Record (HAER). The current PAD names of certain Civil Works do not match the naming convention used in the National Register Nomination or by the National Historical Park and should be revised accordingly.

PAD ID	**PAD name**	**Historic Name (construction dates) [alternate names]**
4.1-1	Pawtucket Dam	Pawtucket Dam (1826, 1830, 1847,1875)
4.1.2	Northern Canal	Northern Canal (1848)
4.1.2a		Great River Wall (1848)
4.1.2b		Northern Canal Waste Gates (1848,1872)
4.1.3	Pawtucket Gatehouse	Pawtucket Gatehouse (1848) [a.k.a. Northern Canal Gatehouse]
4.1.4	Pawtucket and Downtown Canals	
4.4.4a		Pawtucket Canal (1796, 1823)
4.4.4b		Merrimack Canal (1823)
4.4.4c		Lowell Canal (1828)
4.4.4d		Hamilton Canal (1828)
4.4.4e		Western Canal (1831)
4.4.4f		Lawrence Canal (c. 1831)
4.4.4g		Eastern Canal (1836)
4.4.4h		Moody Street Feeder (1848) [see 4.1.5.2 below]
4.1.5	Miscellaneous Canal Structures	
4.1.5.1	Guard Lock and Gates Facility	
4.1.5.1a		Guard Locks (1824, 1850) [Gatehouse over upper lock gates constructed 1881]
4.1.5.1b		Francis Gate (1850)
4.1.5.1c		Pawtucket Canal Gatehouse (1870)
4.1.5.2	Moody Street Feeder Gatehouse	Moody Street Feeder Gatehouse (1848)
4.1.5.3	Lawrence Dam	Lawrence Dam (1831) [at junction of Western and Lawrence Canals]
4.1.5.4	Hall Street Dam	[on Western Canal]
4.1.5.5	Tremont Wasteway [Treemont on map – PAD fig 4.0.2]	[at confluence of Western and Northern canals]
4.1.5.6	Lower Locks and Dam	Lower Locks (1824, 1843) [includes two chamber navigation lock, dam, gatehouse, spillway, and associated structures]

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4.1.5.7	Swamp Locks and Dam	Swamp Locks (1824, 1841) [Where the upper Pawtucket Canal splits into the Western, Merrimack, Lower Pawtucket, and Hamilton canals. Swamp Locks complex includes two chamber navigation lock, dam, spillway, control house, and associated structures]
4.1.5.8	Merrimack Dam and Merrimack Gate	[at foot of Merrimack Canal]
4.1.5.9	Rolling Dam	[controls flow from Merrimack Canal into Boott Mill arm of the Eastern Canal]
4.1.5.10	Boott Dam	
4.1.5x	[Historic canal water control structures not identified in PAD of concern to National Park Service]	
		Western Canal Guard Gates [between Merrimack and Moody streets]
		Hamilton Canal Guard Gates [at head of Hamilton Canal near Swamp Locks]
		Hamilton Wasteway and Gatehouse [at foot of Hamilton Canal near Central St]
		Massachusetts Wasteway Gatehouse [at Bridge St, where Eastern Canal bents to feed Boott Mills/John Street Powerhouse]
4.1.6	Mill Buildings	The PAD notes that only the turbines and associated equipment are included in the project boundary, not the buildings that surround them. Nonetheless, it would be useful to cross reference generating facilities and the mill complexes where they are housed
	John Street Power Station	Boott Mills
	Bridge Street Power Station	Massachusetts Mills (unit numbers?) and Prescott Mills (unit numbers?)
	Hamilton Power Station	Hamilton Mills (unit numbers?) and Appleton Mills (unit numbers)
	Assets Power Station	Market Mills Powerhouse
4.1.7	Tailrace Channel	
4.1.8	Bypass Reach	
4.1.9	Control Structures	[across Northern Canal at EL Field powerhouse. Colloquially called “Hydro Lock” by National Park Service staff. Need more precise name to avoid confusion with 4.1.3 Pawtucket Gatehouse, a.k.a. Northern Canal Gatehouse.]
4.1.10	Fish Passage Structures	
4.1.11	Eldred L. Field Powerhouse	

PAD Section 5.8 Recreation and Land Use

In Section 5.8.1 – Please include canal-adjacent walkways and NPS boat tours as recreational resources.

On Page 108, please revise "Portions of the Lowell National Historical Park are within the project boundary" to "The entire 5.6 mile power canal system and supporting historic structures and equipment along with paved recreational trails constructed immediately adjacent to the canals are recreational resources within the Project Area and boundary of the National Historical Park. Additionally, the 5.6 mile power canal system is located within the boundary of the Lowell Locks and Canals National Historic Landmark District, Lowell Water Power System National Historic Civil Engineering Landmark; and Lowell Power Canal System and Pawtucket Gatehouse National Historic Mechanical Engineering Landmark."

Please add in the system of interconnected walkways/multi-use trails located along the canal and river edge as existing recreational facilities. Lowell National Historical Park has worked for decades, together with our partners, to build a system of interconnected river and canal adjacent trails. Boott has helped facilitate the construction of some trails by providing necessary easements. As key links in the trail network are constructed, we've witnessed increases in both recreational and transportation use by park visitors and the local community. Trails are an essential component of the Park's alternative transportation system – which also includes trolleys and tour boats – designed to link the Park's scattered sites located throughout the densely developed city. The vision for the trail system is outlined in the Park's 1980 General Management Plan and sister documents, the Preservation Plan (1980) and the Preservation Plan Amendment (1990). Because Lowell was developed as a textile factory town, with industrial efficiency as the most important factor in determining historical land uses, very few parks exists. These linear trails connect residents to waterfronts and offer a reprieve from the industrial city. In addition, trail systems have been an economic engine for the City with $54 million in public investments toward trail development resulting in over $527M in private investment in the development of adjacent properties. With strong support from our partners and local community, developing the missing links and connecting to other regional trails, increasing public access, and maintaining trails in good condition continues to be a priority of the national park.

The National Park Service offers seasonal ranger-guided canal and river boat tours which provide unprecedented access to the historic canals. Each summer, thousands of visitors experience the canals and learn about their history in NPS-led boat tours, https://www.nps.gov/lowe/planyourvisit/guidedtours.htm.

PAD Section 5.9 Aesthetic Resources

Please include mention of trash accumulation and vegetation in the Aesthetic Resources as an existing condition. One of the top public complaints/concerns regarding aesthetics relates to the presence of trash and the overgrowth of vegetation which collects additional trash. (See photo, August 2018 near Hamilton Gatehouse).

PAD Section 5.10 Cultural Resources

The section on Historic Resources is only 3 pages long, does not reference the Congressional mandate for the National Park Service to protect and preserve the historic 5.6 mile canal system for this and future generations, and does not include any photos. Many of the resources listed as "Key Components" of the Locks and Canals Historic District on pages 135-136 are also described in Section 4.1 "Civil Works." The historical significance of these structures and date of construction should be described in further detail in this section of the report given their national significance, location within the boundary of multiple protected areas, and because the resources contribute to the significance of the Lowell National Historical Park; Lowell Locks and Canals National Historic Landmark District; Lowell Water Power System National Historic Civil Engineering Landmark; and Lowell Power Canal System and Pawtucket Gatehouse National Historic Mechanical Engineering Landmark.

Please find and replace reference to National Historic Park to the correct naming convention Lowell National Historical Park throughout the document.

"The Lowell National Historical Park" Section contains numerous inaccuracies. Please reference PL 95-290, Lowell Canal System Cultural Resources Inventory, and subsequent plans and studies referenced in this letter to correct, or to incorporate text below:

> Lowell National Historical Park was established by Congress June 5, 1978 (PL 95-290). Although the area within the park boundary is 142 acres and the larger Lowell Historic Preservation District encompasses 583 acres, only 19 acres are in federal ownership. The Park is by design a partnership park in which federal, state, and local governments as well as the private sector and local community carry out the legislative intent of the park unit. Physical resources protected by the park include the original 5.6-mile power canal system, a nationally recognized engineering marvel with its sophisticated dams, locks, and gatehouses; 7 of the original 10 textile mill complexes (5.3 million square feet); significant examples of early housing types, institutions, and transportation facilities; and diverse museum collections. In addition to the industrial artifacts, Lowell retains much of its rich cultural heritage, as reflected in the ethnic diversity and preserved traditions of its citizens.
>
> Lowell National Historical Park's museum collection includes the Proprietors of Locks and Canals (PLC) Records from 1747 through 2008 which document the original construction and on-going maintenance of the canal system and includes 9,304 architectural / engineering drawings, 6,770 original photographic prints, 79 film

negatives, 9 glass-plate negatives, and 39 glass lantern-slides produced by PLC between the years 1883 and 1956.

PLC Volume I https://www.nps.gov/lowe/learn/historyculture/upload/LOWE-ARCHIV-FindingAid-0908-PL-CI.pdf
PLC Volume II https://www.nps.gov/lowe/learn/historyculture/upload/LOWE-ARCHIV-FindingAid-0908-PL-CII.pdf

Lowell National Historical Park together with the University of Massachusetts Lowell College of Education facilitate education programs at the Tsongas Industrial History Center at the Boott Mills that reach approximately 40,000 students and teachers annually. These programs use the resources of the National Park including the historic canals, industrial mills powered by the canals, and the Merrimack River.

Lowell National Historical Park would not be a unit of the national park system if the historic canal system were not present. Continued preservation of and public access to the 5.6 mile historic canal system and supporting historic structures are essential to meet Lowell National Historical Park's Congressional intent.

There is no reference to the Lowell Heritage State Park in the Historic Resources section of the PAD. A summary description of the state park should be included in the Historic Resources Section. The Massachusetts Department of Conservation and Recreation (DCR) issued a comprehensive Resource Management Plan in 2014, that describes its complex rights on the canal system, including gatehouse structures and other elements.

Page 137 – The current condition of buildings in the historic district is not up to date and requires additional research and revision. As of August 2018, the collaboration between Lowell National Historical Park and its partners has resulted in the rehabilitation of over 98% of the 5.3 million square feet of historic mill space adjacent to the canals and hundreds of additional buildings in the downtown historic district.

PAD Section 6.2.1 – Preliminary List of Resource Issues Table

Please add "**Historic Resources**" as a "Resource Area" and "**Ownership and maintenance responsibilities / obligations of the 5.6 mile historic canal system and supporting historic buildings and mechanical equipment, Impacts of High/Low Water Levels, Vegetation"** as "Issues pertaining to Specific Resource Areas."
Please add "**Aesthetic Resources**" as a resource area and "**Vegetation and Trash**" as "Issues…"

Under **Recreation**, please also include "**Flow rates, water levels, and functional lock chambers**" under "Issues."

In April 2008, FERC initiated a request to Lowell National Historical Park for information regarding compliance and status of the license agreement. NPS enumerated several on-going license issues in a response letter. The NPS letter was forwarded to Enel/Boott Hydropower, Inc. and an additional response was provided by Enel/Boott Hydropower, Inc. These letters illuminate many on-going issues and areas of concern between the national park and licensee and are attached as Attachment D for reference.

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Additionally, preliminary discussions with staff and partners following the July 17 Scoping Meeting revealed the following specific issues which are directly related to Boott Hydropower Inc.'s (Boott's) current license / project operations.

IMPACT OF PROJECT OPERATIONS ON CULTURAL RESOURCES

Cultural Resource Issues Requiring Repair

1. **Great River Wall Maintenance:** The structural integrity of the Great River Wall and public safety are issues of highest concern to the NPS, given a past collapse of a portion of the wall. Vegetation management, water levels, and other factors related to Boott's operation may affect the structural integrity of this National Historic Landmark District feature as well as the life and safety of trail and canal users.
2. **Repair Hydro Locks:** This set of locks was installed by Boott as part of the mitigation for their 1983 FERC license and remains under the applicant's ownership. The Park has been unable to use the lock chamber because the gates need repair and are mired in mud. This needed repair is also a high priority for the NPS.
3. **Repair Northern Canal Waste Gatehouse:** The water level in the Northern Canal runs high and damages some of the wood structure under this gatehouse at the Great River Wall. The National Park hired EYP Architects to assess the repair needs which are now substantial (See Attachment E, 2017 Northern Canal Waste Gatehouse Project Scoping Report). Plans and specifications can be provided. The damage is directly attributable to Boott operations and should be repaired.
4. **Replace/Repair of Moody St Feeder Gatehouse Gate:** Boott cut a hole in a portion of one of the gates some years ago to install a high voltage power line and never replaced the gate materials. If the hole in the gate was filled, the Park could continue using its historic water turbine for student and visitor programs at Suffolk Mill when the system is drained. This will also be an essential issue if partner organizations would like to move forward with plans to activate ice skating or other recreational activities in the Merrimack Canal.
5. **Lower Locks Fill Valve:** The Lower Locks Fill Valve is owned by Boott while DCR owns the adjacent lock chambers and gatehouse superstructure. Boott does not use the valve in its canal system control operations and no longer maintains it. The valve, which is no longer operable, is needed for the operation of the locks, which are most often used for recreational purposes by the Lowell Parks and Conservation Trust for its whitewater rafting program. In addition, the above-water part of the valve mechanism, the granite platform, and its railing are a focal point of the Lower Locks site, forming a part of the historic scene. The valve is in failure mode because of the deterioration of the section of canal wall on which the mechanism and its operating platform are set. The National Park had 50% construction documents prepared by a consultant in 2012 for the rehabilitation of the valve, which would consist of reconstruction of the section of failing wall beneath and the resetting of the valve operating mechanism and its granite platform slab atop the wall. Those documents can be shared with Boott, but would have to be finalized to be used as contract documents. The NPS consultant's contract has since expired. The full repairs were not completed because that contract was modified due to funding limitations

to instead provide documents for a temporary stabilization of the valve mechanization, which was exhibiting signs of potential catastrophic failure. In 2012, the National Park contracted the stabilization of the valve platform as a temporary stopgap measure. However, that stabilization was presumed to be a temporary fix to last 2 or 3 years because it could not address the root problem of the deterioration of the wall supporting the valve. Permanent repairs are needed.

6. **Hall Street Dam & Lawrence Dam:** This is a scenic area beside the arena and Lawrence Mills. There is a lot of vegetation that has grown on and around the dam so that the point may be lost on a visitor that it is a dam. The vegetation is further damaging the existing stone work. Rebuilding the dam would allow the water to cascade over the stepped dam as it did in the past and refill the pond that existed behind the dam. The nearby Lawrence Dam needs rehabilitation work so that the gates will allow the basin between Hall Street Dam and the Lawrence Dam to be maintained at a higher water level more regularly. The reconstruction of the missing gatehouse structure on the dam is a long term goal.
7. **Western Canal Sectional Gates:** Repairs are needed to many gates which isolate water levels within the system. If the Western Canal Sectionalized Gates are repaired, areas of the canals could be de-watered without interrupting power production while keeping the optimal water levels in other areas throughout construction duration.

IMPACT OF PROJECT OPERATIONS ON RECREATIONAL, LAND USE, AND AESTHETIC RESOURCES

Recreational, Land Use, and Aesthetic Resource Issues Requiring Repair

1. **Repair Hydro Locks:** This set of locks was installed by Boott as part of the mitigation for its FERC license. They have not been transferred to NPS and remain owned by Boott. The Park has been unable to use the lock chamber because the gates need repair and are mired in mud. NPS cannot operate boat tours along the Northern Canal without repair to the locks.
2. **Replace/Repair of Moody St Feeder Gatehouse Gate:** Boott cut a hole in a portion of one of the gates some years ago to install a high voltage power lines and never replaced the gate materials. Water leaks through the whole cut in the gate for the cable and as a result water levels cannot be controlled. This could prohibit future on-water recreation proposed by partners due to lack of water control.
3. **Trash removal:** One of the top public complaints Lowell NHP hears is regarding trash floating in the canal. Trash accumulation can result in negative impacts to recreational users as well as aesthetic resources. A plan for optimal trash removal should be documented in a formal agreement among parties.

PAD Section 7.1 Qualifying Comprehensive Plans Deemed Applicable

The NPS intends to file a number of the plans listed below with FERC for certification as Comprehensive Plans pursuant to Section 10(a)(2)(A) of the Federal Power Act.

Legislative History of the Lowell National Historical Park (LOWE) and Associated Planning and Management Documents.

In 1976, the Lowell Locks and Canals National Historic District (the District) was listed on the National Register of Historic Places (NR). It was included as part of Lowell National Historical Park's designation as a National Historic Landmark (NHL) in 1977. The NHL District encompasses approximately 125 acres of land including canals, gates, locks, dams and associated structures. The first canal dates to 1796 and was initially used for transportation of goods around Pawtucket Falls. The canal system was adapted in 1822 to provide waterpower for the developing textile industry. The District also included several mill yards and worker housing associated with the textile industry that were constructed in the early 19th century.
On June 5, 1978, Congress established Lowell National Historical Park. The enabling legislation states that the purpose of the park is to "preserve and interpret the nationally significant historical and cultural sites, structures, and districts in Lowell, Massachusetts, for the benefit and inspiration of present and future generation by implementing to the extent practicable the recommendations in the Report of the Lowell Historic Canal District Commission." The "five-and-sixth-tenths-mile power canal system" is named specifically as a historical resource to be protected and preserved by the NPS and is located wholly within the 142 acre boundary of the National Historical Park and the 583 acre Preservation District established under the 1978 Act.

The Lowell Canal Survey by the Historic American Engineering Record (1976) documented the history of the development of the canal system in Lowell and includes detailed narrative, photographs, drawings, and maps of the historic canal system.

The Brown Book (1977) entitled *Report of the Lowell Historic Canal District Commission to the Ninety Fifth Congress of the United States of America*
https://www.nps.gov/lowe/learn/management/upload/1977_-Brown-Book-_reduced.pdf provided the justification for the **establishment of the Lowell National Historical Park (LOWE) in 1978. PL 95-290 June 5, 1978** https://www.gpo.gov/fdsys/pkg/STATUTE-92/pdf/STATUTE-92-Pg290.pdf established LOWE and tasked the Commission with develop what became the ***Preservation Plan* in 1980**
https://www.nps.gov/lowe/learn/management/upload/LOWE_475_D5_A_0001-18-0613.pdf.
That plan set out the primary themes and responsibilities for LOWE which are listed at page 5 as 1. "Preserving the 19th Century Setting," 2. Encouraging the Varieties of Cultural Expression," and 3. Projects Mandated by the enabling legislation. ***Details of the Preservation Plan*** was issued shortly afterward.
https://www.nps.gov/lowe/learn/management/upload/LOWE_475_D5_18-0612.pdf.

The 1981 General Management Plan for Lowell National Historical Park (LOWE)
https://www.nps.gov/lowe/learn/management/upload/1981-LOWE-GMP.pdf was the initial long term planning document for LOWE. Included in the GMP at page 37 is a discussion on Canal System Management which identifies the initial parties to the cooperative agreement that formed the basis for future MOU's, the most recent of which was signed 1991 in association with the original licensing of the hydro project in 1983. Those parties included the NPS, the City of Lowell and the Commonwealth of Massachusetts. The NPS, along with the City of Lowell and the Commonwealth of Massachusetts (DCR) intend to work with the applicant to develop a new MOU to address canal operations and management.

LOWE and its associated canal system was designated a National Historic Landmark in 1977. The Commonwealth of Massachusetts effected a Taking (see Middlesex North Registry of Deeds Book 3830 Page 70) in 1986 whereby the Commonwealth took ownership of various canal resources in order to consolidate ownership. This gave the Commonwealth the right to provide public access to the canal system and adjacent walkways, and provided authority to spend money to improve and maintain various historic structures.

In 1987, Congress (PL 100-143) reauthorized the Lowell Historic Preservation Commission http://uscode.house.gov/statutes/pl/100/134.pdf and directed them to prepare a **Preservation Plan Amendment which was submitted to the Secretary of the Interior on May 19, 1990.** https://www.nps.gov/lowe/learn/management/upload/LOWE_475_D5_A_0001-18-0613.pdf. The Amendment focuses on development, management and use of the canal system and adjacent properties, many of which were developed into public walkways which remain an integral part of the park and the visitor experience.

In 1995, the Commonwealth granted an easement, assigning the Commonwealth's non-fee interests to the NPS for the purpose of developing canal resources, preservation of historic resources associated with the canal and providing continued and additional public access. The 1978 enabling legislation provided for the NPS to manage resources associated with the District without fee ownership, in what is now referred to as a Partnership Park.

In 2003, the NPS completed the **Addendum to the 1981 General Management Plan for LOWE** https://www.nps.gov/lowe/learn/management/upload/2003-LOWE-2003-GMP-Addendum.pdf, focused primarily on re-establishing roles and responsibilities following the sunset of the Commission. Most of the Commission's responsibilities were transferred to NPS staff at LOWE.

The most recent NPS prepared document is the **September 2017 *Foundation Document*** https://www.nps.gov/lowe/learn/management/upload/2017_LOWE-Foundation-Doc_Email-Size.pdf for LOWE, outlines why LOWE was established, which resources are nationally significant, and updates our management priorities. The Foundation Document (FD) reaffirms our Legislative Purpose, National Significance and Fundamental Resources and Values.
As part of the FD, NPS prepares Significance Statements (P.6) that express why a park's resources and values are important enough to merit designation as a unit of the National Park System. Among those are The Lowell Canal System[3] and Integrity of Historical Urban Landscape.[4] The plan identified LOWE's Fundamental Resources and Values, those resources or values essential to meeting the legislated purpose of the park and warrant primary consideration for future planning and management decisions including maintenance and operations.

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[3] The Lowell canal system is nationally recognized as one of the most impressive civil and mechanical engineering achievements of the 19th century because of its grand scale and technological complexity, and is the site of origin for the famed "Francis" turbine. The canal system, used as both a transportation corridor and power source, facilitated the growth of the industrial city. Lowell NHP Foundation Document (Lowell, MA: NPS, 2017) p6.

[4] A very large proportion of original buildings, structures, and urban landscapes have survived in Lowell's park and preservation district and now are recognized as important historical artifacts. These include the entire 5.6-mile power canal system with its sophisticated dams, locks, and gatehouses, 7 of the original 10 mill complexes, and significant examples of early housing types, institutions, and transportation facilities. Lowell NHP Foundation Document (Lowell, MA: NPS, 2017) p7.

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Fundamental Resources and Values (P.7) include the **Water Power System/Canal System**[5] and the **Immersive Experience**[6] provided to visitors, including water-based tours of the canal system and hands on interpretive and educational opportunities that provide insights into Lowell's industrial past and that of the nation as a whole. Significance Statements outlined current conditions and trends, and identified key threats to NPS resources as well as opportunities to protect and enhance those resources. NPS developed a fundamental resources and values table in the 2017 Foundation Document that provides details on data and planning needs associated with the **Water Power System/Canal System** (P.12-14) and for the **Immersive Experience** (P.18-20). Key Issues and Associated Data Needs were identified at pages 33-35 and the associated tables at pages 36-41. Among them are the Renewal of the Enel Green Power License, Jurisdictional Challenges (land rights and ownership), and Private Ownership in the Park and Preservation District. See Attachment F for further detail.

RECOMMENDED STUDIES

Please see Attachment G for study requests recommended by NPS.

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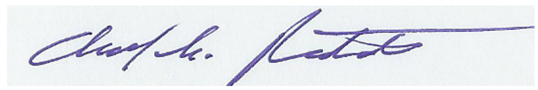
[5] **Water Power System / Canal System.** The Lowell National Historical Park boundary includes 9.6 miles of major riverbanks and all 5.6 miles of historic canals in Lowell, all of which comprise the waterpower system that harnessed waters of the Merrimack River to power the city's mills. In fact, the Merrimack River and its natural attributes dictated the location of the city itself. The water power and canal system includes the Pawtucket, Merrimack, Hamilton, Western, Eastern, Lowell, and Northern Canals and canal banks, as well as several associated locks, gatehouses and dams, and Pawtucket Falls. This system, which still operates as a source of hydroelectric power, provides an opportunity to interpret both the historic significance of water in industry, as well as the engineering of a waterpower system. Public access has been expanded over the years to support these interpretive opportunities, including creation of a pedestrian canalway and riverwalk and the development of related exhibits and programs such as the Suffolk Mill Turbine Exhibit.

[6] **Immersive Experience.** Lowell National Historical Park provides a variety of hands-on interpretive and educational opportunities that allow visitors to immerse themselves in Lowell's industrial past. Key park experiences include exhibits that feature a working turbine and weave room, as well as boat tours of the canal system and rides through the park on historic replica trolleys, which are among the most popular and unique experiences in the park. The Tsongas Industrial History Center, a partnership between Lowell National Historical Park and the University of Massachusetts Lowell College of Education, is a hands-on center where students can learn about the American Industrial Revolution through interactive activities such as weaving, working on an assembly line, creating canal systems and testing water wheels, and measuring water quality.

Thank you for the opportunity to review and comment on this project. If you have questions regarding these comments, please contact Julianne Rosset, U.S. Fish and Wildlife Service at julianne_rosset@fws.gov, (603) 227-6436 or Kevin Mendik, National Park Service at kevin_mendik@nps.gov, (617) 223-5299. Please contact me at (617) 223-8565 if I can be of further assistance.

Sincerely,



Andrew L. Raddant
Regional Environmental Officer

ATTACHMENTS

CC: Enel (kevin.webb@enel.com

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ATTACHMENT A

United States Department of the Interior

FISH AND WILDLIFE SERVICE

New England Field Office
70 Commercial Street, Suite 300
Concord, NH 03301-5087
http://www.fws.gov/newengland

September 26, 2017

Mr. Randald Bartlett, P.E.
ENEL Green Power North America, Inc.
100 Brickstone Square, Suite 300
Andover, Massachusetts 01810

Dear Mr. Bartlett:

Ref: Lowell Hydro Project – FERC No. 2790
Ledge Excavation Design Comments and Recommendations

This responds to the Lowell Ledge Excavation Designs that you submitted to us via email on July 18, 2017. We have been working with ENEL Green Power North America, Inc. (ENEL) for many years to enhance upstream fish passage, and the proposed ledge removal is part of a larger effort to address upstream fish passage performance at the Lowell Hydroelectric Project (FERC No. 2790). Thus far, progress has been made to improve internal fish lift operations protocols, fish lift entrance evaluations, and fish ladder repairs and maintenance. However, the U.S. Fish and Wildlife Service (Service), along with other agencies, have indicated in prior meetings and correspondence that additional measures are necessary at both the tailrace fish lift and spillway fish ladder in order to achieve adequate American shad and river herring passage effectiveness.

At a meeting on August 15, 2017, ENEL's proposed ledge removal designs were discussed and the Service and other agency representatives outlined our recommendations on the proposed designs. As agreed to at the meeting, the Service's Bryan Sojkowski and Bjorn Lake (of the National Marine Fisheries Service) prepared the attached memo which provides more explanation and details regarding our recommendations.

Thank you for meeting with us and providing us the opportunity to comment on the designs. If you have any questions, please contact John Warner at 603-227-6420 or Julianne Rosset at 603-227-6436.

Sincerely yours,

Thomas R. Chapman
Supervisor
New England Field Office

Enclosure

cc: CNEFRO - Joe McKeon, Mike Bailey (via email)
RO/Fisheries - Bryan Sojkowski (via email)
NHFGD - Matt Carpenter (via email)
MDFW- Caleb Slater (via email)
MDMF- Gloucester - Ben Gahagan (via email)
NMFS - Sue Tuxbury (via email)
NMFS - Bjorn Lake (via email)
FERC - Division of Hydropower Administration and Compliance
Reading File
ES: JRosset: 9-26-17:603-227-6436

Technical Memorandum

To: Randald Bartlett, P.E., Senior Operations Manager – Northeast, ENEL Green Power North America, Inc.

From: Bjorn Lake, P.E., PhD, NOAA Fisheries; Bryan Sojkowski, P.E., USFWS

Re: P-2790 Lowell Ledge Removal Project

Date: August 18, 2017

Objective

The purpose of this project is to remove a ledge outcropping that is a potential deterrent to immigrating diadromous fish readily detecting and entering the fish lift entrance at the Lowell Hydroelectric Project (P-2790). Telemetry studies in 2002, 2011, and 2013 have shown that immigrating American shad that approach the project via the tailrace have difficulty utilizing the entrances of the fishway (Sprankle 2005; Alden 2011; 2013). In 2016, Gomez and Sullivan Engineers completed an analysis of the upstream passage system and recommended excavation of the ledge outcropping to approximately 10 feet below normal tailwater level extending 50 to 100 feet downstream from the entrance. During the March 30, 2017, Merrimack River Technical Committee meeting, we all agreed that the ledge removal project should move forward.

On July 18, 2017, the Merrimack River Technical Committee received the design plans for review before the commencement of construction. We sent a technical memorandum to ENEL Green Power North America, Inc., on July 26, 2017, providing our recommendations. Upon the request of ENEL, Julianne Rosset, Bryan Sojkowski, and Bjorn Lake met with ENEL representatives on August 15, 2017, at their Andover, Massachusetts office to discuss our recommendation. At that meeting, it was determined that the agencies should provide updated information on the low design flow for the upstream fishway and the corresponding tailwater elevation. This technical memorandum provides those updates.

Recommendation

The provided design drawings show a vertical excavation limit at an elevation of 48 feet (NAVD 88), extending approximately 80 feet downstream from the centerline of the fishway entrance. This excavation limit elevation roughly corresponds with the existing floor elevation of the fishway entrance chamber of 48.2 feet (NAVD 88), not including the 1-foot-high concrete lip at the entrance gate. Our criteria (both NOAA Fisheries and USFWS) for fishways is to be operational between the 5-95 percent flow exceedance values. Therefore, we recommend that the fishway be operational at tailwater elevations down to approximately 50 feet (NAVD 88), which corresponds to the tailwater elevation at the 95 percent exceedance flow.

Additionally, we recommend that the minimum water depth above the entrance channel floor sit at 4 feet. Typically, gate structures are utilized to constrict the flow at the entrance in order to achieve an attraction jet with a 4-6-foot-per-second velocity. Lowell currently operates a vertical gate that varies from 0.3-3 feet above the lip of concrete at the downstream end of the entrance floor. An ancillary criterion to the minimum of 4 feet of depth is that the water surface elevation of the tailwater is recommended to be, at a minimum, two times the body depth of the largest target species. An American shad with a body depth of 10" would require a minimum of 1.5 feet of depth. The current entrance at Lowell does not meet this criterion for the full range of fish passage flows and tailwater fluctuations. Therefore, only excavating the ledge to an elevation of 48 feet (NAVD88) will necessitate additional future ledge excavation, when modifications to the gate and entrance channel are made to meet our design criteria. We understand that those entrance modifications are outside the scope of work for the ledge removal project, however, we recommend altering the ledge removal design such that additional excavation is not necessary in the future.

In support of our flow and tailwater elevation recommendation, we conducted a hydrologic analysis of the project flows. We downloaded daily average flow data from the U.S. Geological Survey gauges on the Merrimack River below the confluence with the Concord River (USGS #01100000) and the Concord River immediately upstream from the Lowell canal system (USGS #01099500). The difference between these average daily flow values is the flow in the Merrimack River that passes through the Lowell Project. We downloaded the last 30 years of record (1987 to 2016) and calculated a flow duration curve for the upstream migration season (April 15-July 15). In addition, to predict corresponding tailwater elevations at the upstream fishway operational flow range, we used the updated tailwater rating curve provided in the recent upstream fish passage assessment (Gomez and Sullivan 2016). We fit a logarithmic function to the provided tailwater data ($R^2 = 0.9991$) such that we could use the resulting equation ($y = 2.786\ln[x] + 29.824$) to predict the corresponding tailwater elevation for the flow exceedance values. Table 1 shows the results of this analysis providing the justification for a design tailwater elevation of approximately 50 feet (NAVD 88).

Table 1. Flow duration exceedance values and predicted tailwater elevations for the Lowell Project.

Flow Exceedance Value	Project Flow (cfs)	Tailwater Elevation (ft)
5%	26,210	58.17
10%	19,870	57.40
25%	12,470	56.10
35%	9,752	55.41
50%	6,912	54.46
65%	4,938	53.52
75%	3,830	52.81
85%	2,851	51.99
95%	1,735	50.60

The three-dimensional telemetry studies conducted by Alden Labs in 2011 generated fish density plots that showed where immigrating American shad congregated in the tailrace (Figure 1 and Figure 2). The 80-foot length of the proposed ledge excavation appropriately reaches the zone of highest density at the turn in the tailrace (Figure 1). However, the proposed elevation of ledge excavation does not match the highest density of fish depth-wise (Figure 2). Over 80 percent of the fish detections occurred between the tailwater elevations of 40-50 feet with the highest density in the 45- to 50-foot bin (Figure 2). During the 2011 study period, the flow in the River was at or above the median for the period of record with the exception of one week in June when flow was lower than normal, suggesting that the density plots represent conditions during normal flow conditions, not low flow conditions (Figure 3). This provides further evidence that the entrance elevation needs to be lower than the existing 49.2 feet (NAVD 88), and only excavating the ledge to an elevation of 48 feet (NAVD 88) would not provide appropriate conditions for optimal entrance efficiency for the Lowell fish lift.

There are likely many ways to modify the entrance conditions at Lowell to improve fish passage performance. As the Technical Committee continues working with ENEL to improve passage at the Lowell Project, we can discuss various options that satisfy our fisheries management goals. At this time, we believe it is appropriate to excavate ledge down to an elevation of 44 feet (NAVD 88), as this provides more flexibility for future fishway entrance modifications.

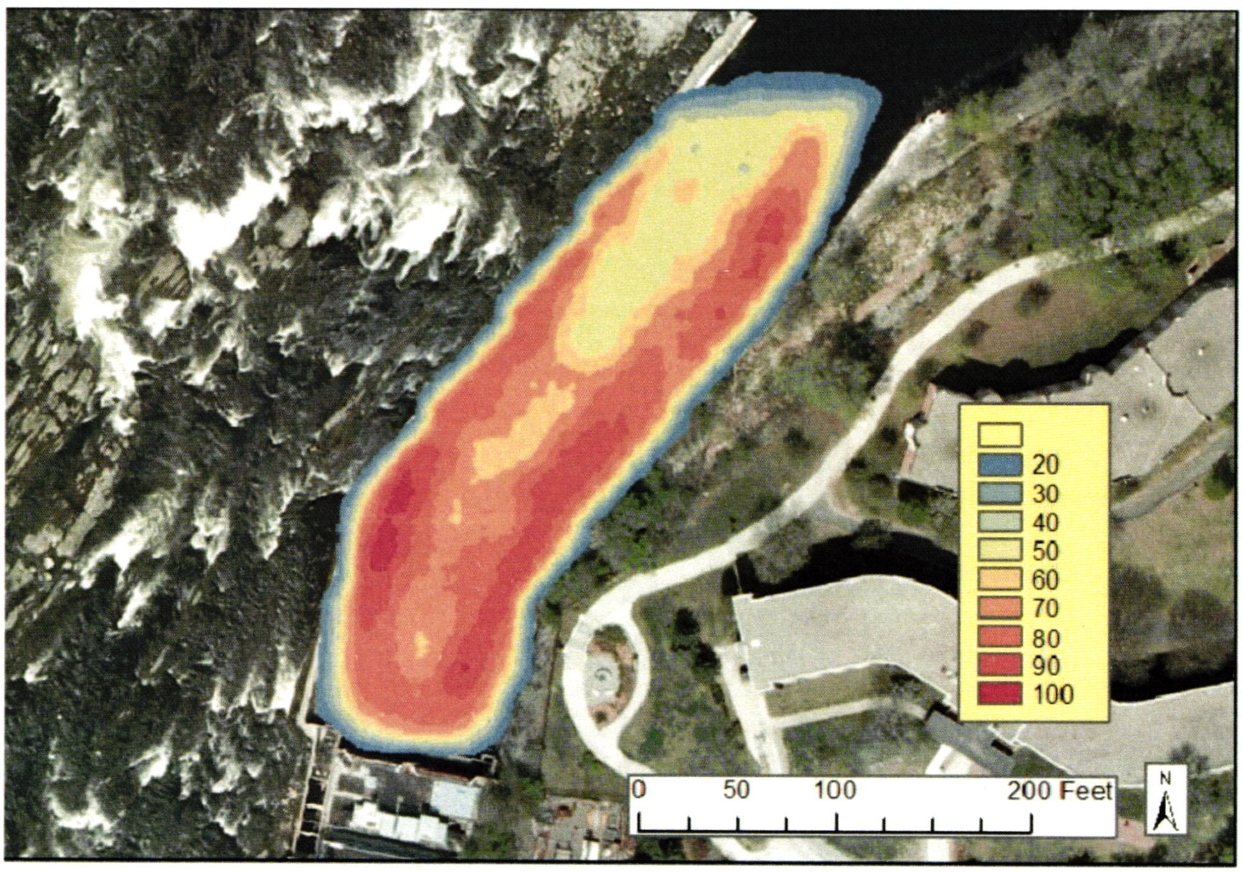

Figure 1. Bin density of tagged American shad during the study period (May 27-June 21) in the Lowell tailrace (Alden 2011).

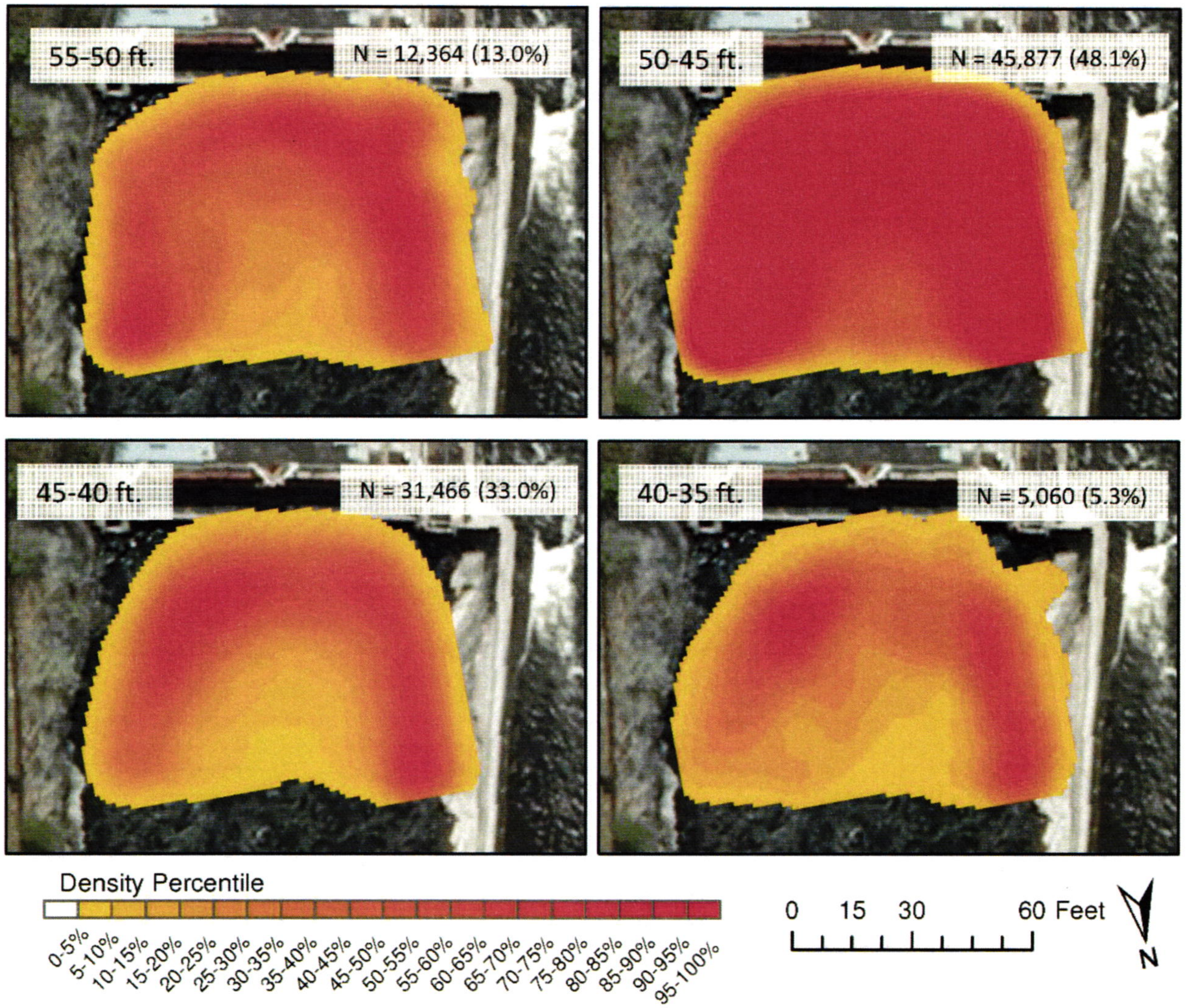

Figure 2. Bin density of tagged American shad within 65 feet of the Lowell powerhouse during the study period (May 27-June 21). Data are presented in 5-foot elevation bins (Alden 2013).

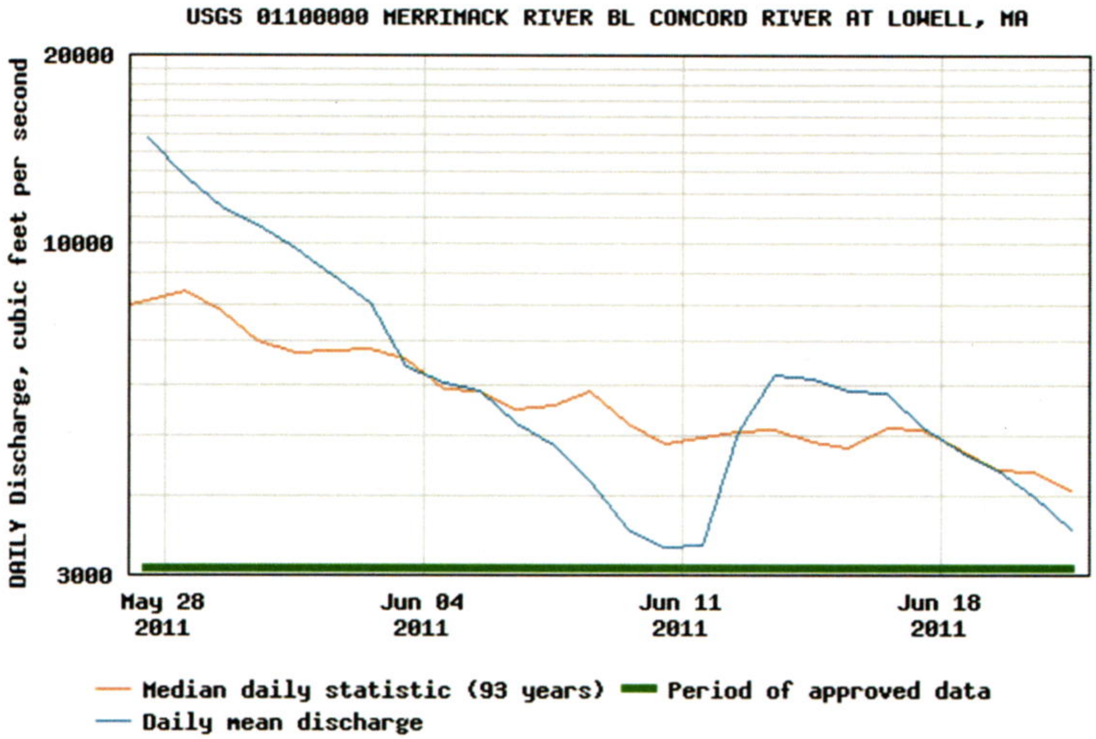

Figure 3. Hydrograph during the 2011 study period.

Document Content(s)

ATTACHMENT B

Rosset, Julianne <julianne_rosset@fws.gov>

[EXTERNAL] Lawrence and Lowell 2018 Action Items List

1 message

St Pierre, Conrad (EGP North America) <Conrad.StPierre@enel.com> Tue, Jun 19, 2018 at 2:37 PM
To: "Rosset, Julianne" <julianne_rosset@fws.gov>
Cc: "Smithwood, Doug" <doug_smithwood@fws.gov>, Bryan Sojkowski <Bryan_Sojkowski@fws.gov>, Michael_bailey <Michael_bailey@fws.gov>, Matthew A Carpenter <Matthew.Carpenter@wildlife.nh.gov>, "Donahue, Pat (EGP North America)" <Pat.Donahue@enel.com>, "Medford, Skip (EGP North America)" <Skip.Medford@enel.com>, "Fournier, Scott (EGP North America)" <Scott.Fournier@enel.com>, "ben.gahagan" <ben.gahagan@state.ma.us>, Bjorn Lake - NOAA Federal <bjorn.lake@noaa.gov>, "claudia_hernandez@fws.gov" <claudia_hernandez@fws.gov>, Caleb Slater <caleb.slater@state.ma.us>, "Tuxbury, Sue" <Susan.Tuxbury@noaa.gov>

To All—Per our meeting in March, we now have an update on the Lowell tailrace excavation project. Early in 2018, Enel permitting staff submitted applications for the project to local, state and federal agencies for approval. Unfortunately, some of these approval processes now appear to approach or exceed 9 months in duration. Also, after receiving only a single initial bid for the 2018 work, we received several competitive proposals in a second RFP, when the schedule was extended to summer, 2019. Because of these factors, Boott plans to complete the tailrace excavation project during late summer of 2019.

We appreciate your understanding and patience on this important but long-awaited improvement. Please feel free to contact me or anyone on the team with questions.

Thank you,

Conrad St. Pierre, PE.
Sr. Director of Hydro North America
Operations and Maintenance

Enel Green Power North America, Inc.

100 Brickstone Square, Ste 300

Andover, MA 01810

(978) 513 3441 office

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Conrad.StPierre@Enel.com

ATTACHMENT C

U.S. Fish and Wildlife
Study Requests

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Boott Study Request # 1

Instream Flow Habitat Assessment of the Lowell Bypassed Reach
(Lowell, P-2790)

Goals and Objectives

The goal of this study is to determine an appropriate flow regime that will protect and enhance the aquatic resources in the bypass reach (Northern Canal) between the Pawtucket dam and the E.L. Field powerhouse. Specifically, the objective of this study is to conduct an instream flow habitat study to assess the impacts of a range of project discharges on the wetted area and optimal habitat for key species, including the quantity and location of suitable habitat.

The specific objectives of this field study, at a minimum, include:

1. Characterize and map wetted perimeter of the bypass reach over a range of bypass flows;
2. Survey and evaluate the water depth and mean channel velocity at transects within the bypass reach over a range of flows; and
3. Map and assess the value of aquatic habitat in the bypass reach over a range of flows, focusing on potential habitat for resident species, and spawning and migration habitat or rest/regrouping areas for migratory species.

Target fish species should include American shad, river herring (alewife and blueback herring), fallfish, white sucker, freshwater mussels and benthic macroinvertebrates. The final target species list should be developed in consultation with the fisheries agencies and based on the results of the mesohabitat mapping.

Resource Management Goals

The U.S. Fish and Wildlife Service (Service) seeks the accomplishment of a number of resource goals and objectives through the relicensing process for the project. General goals include the following:

1. Ensure that protection, mitigation, and enhancement measures are commensurate with project effects and help meet regional fish and wildlife objectives for the basin.
2. Conserve, protect, and enhance the habitats for fish, wildlife, and plants that continue to be affected by the project.

Specific to aquatic resources within the Lowell bypassed reach, the Service's goals are:

1. Protect, enhance, or restore diverse high quality aquatic and riparian habitats for plants, animals, food webs, and communities in the watershed and mitigate for loss or degradation of these habitats.
2. Provide a flow regime in the bypassed reach that meets the life history requirements of resident fish and wildlife (including invertebrates such as freshwater mussels) and diadromous fishes.

3. Minimize current and potential negative project operation effects on water quality and aquatic habitat.

These study requests are intended to facilitate the collection of information necessary to conduct effects analyses and to develop reasonable and prudent conservation measures, and protection, mitigation, and enhancement measures pursuant to the Fish and Wildlife Coordination Act, as amended (16 U.S.C. §661, *et seq*.), and the Federal Power Act (16 U.S.C. §791a, *et seq*.).

Public Interest

The requester is a natural resource agency.

Existing Information

The Lowell Project bypasses a 0.7-mile-long section of the Merrimack River, from the Pawtucket dam to the E.L. Field powerhouse. There is presently no required minimum bypass flow. However, during the upstream fish passage season, the bypass reach receives 500 cfs through operation of the spillway fish ladder. In addition, the bypass reach receives flow whenever inflow exceeds the hydraulic capacity of all the project's stations. Pursuant to Article 37, Boott Hydropower, LLC, (Boott) maintains a minimum flow of 1,990 cfs or inflow, whichever is less, as measured immediately downstream of the project.

Available information in the PAD does not indicate how project operations have altered downstream hydrology, habitat quantity and quality, and water quality, which may affect resident and migratory fish, macroinvertebrates, aquatic plants and other biota and natural processes in the Merrimack River. The PAD provides no detailed description of the physical or biological characteristics of the bypassed reach.

An empirical study is needed to provide information on the relationship between flow and habitat in the bypassed reach for the Service to use in determining a flow recommendation.

Nexus to Project Operations and Effects

Although the project license requires Boott to maintain a minimum flow of 1,990 cfs or inflow (if less), downstream of the project, Boott states that in practice the project operates in a true run-of-river mode. The Department of the Interior is not recommending a below-project flow study, based on the assumption that any new license issued for the project will require instantaneous run-of-river operation (essentially codifying current operations).

The project includes a 0.7-mile-long bypassed reach. The current license contains no minimum bypass flow requirement. During the upstream fish passage season, the bypass reach receives 500 cfs via operation of the spillway fish ladder; otherwise, the reach only receives flow when inflow exceeds the hydraulic capacity of the project's generating capacity. To our knowledge, the lack of a required bypass flow was not based on any quantitative, rigorous scientific studies.

This section of the Merrimack River contains habitat which supports native riverine species, including important spawning and rearing habitat for migratory species like American shad and river herring (MRTC 2010). While the existing license does not require a minimum bypass flow, the Service believes one is needed to sufficiently protect the aquatic resources inhabiting the bypassed reach.

Results of the flow study will be used by the Service to determine an appropriate flow recommendation which will protect and/or enhance the aquatic resources in the bypassed reach for the duration of any new license issued by the Federal Energy Regulatory Commission (Commission).

Methodology Consistent with Accepted Practice

Bypass flow habitat assessments are commonly employed in developing flow release protocols that will reduce impacts or enhance habitat conditions in reaches of river bypassed by hydroelectric projects.

Given the size of the bypassed reach (0.7 mile long) and the important resources known to inhabit the reach (i.e., diadromous fishes); we believe a study methodology which utilizes an instream flow incremental methodology (IFIM) approach is appropriate for this site. This same protocol was used during the relicensing of the Housatonic River Project (FERC No. 2576),[1] and has been accepted by the Commission in other licensing proceedings.[2]

The study should have two components. The first component entails mapping habitat within the bypass reach. The number, location, and size (area and linear distance) of each mesohabitat type in the reach should be documented, including qualitative characterizations (e.g., dominant substrate, average depth, overhead and instream cover, etc.). The second component consists of conducting an instream flow study.

At a minimum, the study design should involve collecting wetted perimeter, depth, velocity, and substrate data within a range of discharge levels along transects located in the reach of river between the dam and the E.L. Field powerhouse. The measurements should be taken over a range of test flows, to be agreed upon by the natural resource agencies. This information should then be synthesized to quantify habitat suitability (using mutually agreed upon Habitat Suitability Index curves) of each test flow for target species/life stages identified by the fisheries agencies. We recommend Boott perform habitat modeling using one dimensional modeling techniques to better characterize flows and velocities in this complex channel area.

Level of Effort/Cost, and Why Alternative Studies Will Not Suffice

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[1] Housatonic River Project License Application, Volume 4, Appendix F. Connecticut Light and Power Company, August 1999.

[2] Glendale Project (FERC No. 2801) Final Bypass Reach Aquatic Habitat and Instream Flow Study in Glendale Hydroelectric Project Application for Subsequent License (FERC No. 2801), Volume 2, Appendix B, pp. 7-8, October 2007.

Field work for flow studies can be reasonably extensive but will depend on consultation with Boott on study methodology and on-site decisions on locations for data collection and the number of collection locations. Post-field work data analysis would result in a moderate cost and effort. We anticipate that the level of effort and costs will be comparable to those experienced on similar Commission relicensing projects (e.g., the Glendale Project, FERC No. 2801).

REFERENCES

MRTC, 2010. A Plan for the restoration of American shad, Merrimack River Watershed. Prepared by the Technical Committee for Anadromous Fish Management of the Merrimack River Basin. 12 pp.

Boott Study Request # 2

Adult Alosine Downstream Passage Assessment and Protection Evaluation
(Lowell, P-2790)

Goals and Objectives

The goal of this study is to assess the adequacy of the turbines at the E.L. Field, Assets, Bridge Street, Hamilton, and John Street powerhouses, to minimize injury, entrainment, and mortality of fishes residing in the Merrimack River, and to recommend appropriate mitigative measures as necessary.

The specific objectives of the field study, at a minimum, are: (1) assess the risk of adult American shad and alewife becoming injured, impinged, or entrained in the E.L. Field, Assets, Bridge Street, Hamilton, and John Street powerhouse units; (2) estimate turbine survival; (3) assess the risk of injury or mortality at the spillway and downstream bypass; and (4) evaluate potential passage and protection measures.

Resource Management Goals

The Atlantic States Marine Fisheries Commission has developed several documents related to the management of American shad and river herring:

1. Atlantic States Marine Fisheries Commission. 1999. Amendment 1 to the Interstate Fishery Management Plan for shad and river herring. (Report No. 35). April 1999.
2. Atlantic States Marine Fisheries Commission. 2000. Technical Addendum 1 to Amendment 1 of the Interstate Fishery Management Plan for shad and river herring. February 9, 2000.
3. Atlantic States Marine Fisheries Commission. 2009. Amendment 2 to the Interstate Fishery Management Plan for shad and river herring, Arlington, Virginia. May 2009.
4. Atlantic States Marine Fisheries Commission. 2010. Amendment 3 to the Interstate Fishery Management Plan for shad and river herring, Arlington, Virginia. February 2010.

Amendment 3 to the Interstate Fishery Management Plan for Shad and River Herring includes an objective of maximizing the number of juvenile recruits emigrating from freshwater stock complexes and recommends enhancing survival at dams during emigration by evaluating survival of post-spawned adults and juvenile fish passed via each route (e.g., turbines, spillage, bypass facilities, or a combination of the three) at any given facility, and implementing measures to pass fish via the route with the best survival rate.

Specific to resident riverine and migratory fish entrainment, the Service’s goals are:

1. Minimize current and potential negative project operation effects such as turbine entrainment that could hinder management goals and objectives.

2. Minimize project-related sources of mortality to resident and migratory fishes in order to restore natural food web interactions and ecosystem functions and values.

These study requests are intended to facilitate the collection of information necessary to conduct effects analyses and to develop reasonable and prudent conservation measures, and protection, mitigation, and enhancement measures pursuant to the Fish and Wildlife Coordination Act, as amended (16 U.S.C. §661, *et seq*.), and the Federal Power Act (16 U.S.C. §791a, *et seq*.).

Public Interest

The requestor is a natural resource agency.

Existing Information and the Need for Additional Information

No project-specific information exists regarding risk of impingement and/or entrainment of adult alosines. In the PAD, Boott provided little information that would inform the relative risk of impingement or entrainment in any of the 21 units associated with the project. Moreover, information regarding fish mortality at the spillway and the downstream bypass was not discussed. While Normandeau Associates, Inc., performed a study in 2003 pertaining to the survival of Atlantic salmon smolts through the turbines, (1) the sample size was small (20 fish); (2) the study was not performed at a full range of gate settings; and (3) salmon are a robust fish species and cannot be used as a proxy for alosines. The 2003 study did shed light on a predation issue, however, in the project's tailrace. Of the salmon that passed downstream, 69 percent were suspected to be preyed upon after using the downstream bypass facility. As Normandeau Associates, Inc., noted in their study results, predators residing in the tailrace can have a large impact on emigrating migratory fish species that use the current bypass facility at the project.

To date, no directed studies of alosine injury, entrainment, or mortality have been conducted at the project's modified spillway, the downstream fish bypass facility, or through the turbines. These information gaps need to be filled so the natural resource agencies can assess the relative and cumulative impacts of project operations on outmigrating adult alosines and develop adequate passage and protection measures to meet management goals and objectives.

Nexus to Project Operations and Effects

Hydropower projects generate electricity by moving water through a turbine-generator system. Typically, there are trashracks in front of the intakes leading to the turbines. If the rack spacing is narrow and velocities at the racks too high (relative to the swim speeds of fish species inhabiting or moving through the headpond), fish may become impinged against the racks and die. If rack spacing is wide and the velocities too high (relative to the swim speeds of fish species inhabiting or moving through the headpond), fish may become entrained (i.e., pass through the racks) and get injured or die while passing through the turbines.

Lowell's configuration likely presents problems with respect to providing safe, timely, and effective passage for outmigrating alosines. Pre-spawned adult American shad and river herring pass upstream through the Lowell fishways and/or are stocked into upstream habitats. These fish need to be able to migrate back downstream because they are iteroparous in this region (McBride et al. 2016). Therefore, it is necessary to understand how alosines move through the project area and the level of injury or mortality caused by entrainment through the project's turbines and/or passage via the dam spillway and downstream bypass facility.

Methodology Consistent with Accepted Practice

The Service proposes a phased approach to this study.

Phase 1:

Spill, bypass, and turbine mortality should be assessed using a balloon-tag method.

For spill mortality sites (dam spillway and downstream bypass), tagged alosines will be injected or released into spill flow at points where water velocity exceeds 10 ft/sec to minimize the possibility of the fish swimming upstream into the headpond or canal. Passed balloon-tagged alosines will be recovered below areas of spill and held for 48 hours in isolated tanks for observation of injury and latent mortality; unrecovered balloon-tagged alosines will be censored from the data.

For turbine mortality sites, tagged alosines will be injected into the intakes of units operating at or near full generation at points where intake water velocity exceeds 10 ft/sec to minimize the possibility of fish swimming back upstream through the intakes. Passed balloon-tagged alosines will be recovered in the tailrace and held for 48 hours in isolated tanks for observation of injury and latent mortality; unrecovered balloon-tagged alosines will be censored from the data.

Phase 2:

Boott should investigate existing or potential future operational and/or physical measures that would minimize injury or mortality to outmigrating adult alosines moving past the project. Based on the results of this investigation, we recommend Boott provide a range of potential alternatives (e.g., increasing attraction to the existing downstream bypass, installing exclusionary screening, etc.).

Project operations (flows, levels, gate openings, number of units operating, and operation level) and environmental conditions (river flow, temperature, turbidity, air temperature, precipitation) should be monitored and recorded regularly (hourly measurements if possible) throughout the duration of the study to establish a more comprehensive understanding of how migration patterns are influenced by these parameters.

These methodologies are consistent with accepted practice.

Level of Effort/Cost, and Why Alternative Studies Will Not Suffice

The cost and effort of each individual phase of this study are expected to be moderate. Based on the scale and scope of the subject study, we estimate the cost to be $25,000 to $50,000. In the

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PAD, Boott proposes no studies to address this issue. The Service is not aware of any previously conducted or ongoing studies related to impingement, entrainment or survival of adult alosines at the project.

REFERENCES

McBride, R. S., Ferreri, R., Towle, E. K., Boucher, J. M., & Basilone, G. 2016. Yolked oocyte dynamics support agreement between determinate-and indeterminate-method estimates of annual fecundity for a northeastern United States Population of American Shad. PloS one, 11:e0164203.

Normandeau. 2003. Passage Route Selection and Survival of Atlantic Salmon Smolts Passed through the Lowell Hydroelectric Project. Submitted to Boot Hydro, LLC. Final report. Normandeau Associates, Inc. Westmoreland, New Hampshire. 130 pp.

Boott Study Request # 3

Telemetry Study of Upstream and Downstream Migrating Adult American Shad and River Herring to Assess Passage Routes, Effectiveness, and Delay
(Lowell, P-2790)

Goals and Objectives

The goal of this study is to assess the behavior, approach routes, passage success, survival, and delay of adult American shad and river herring as they encounter the Lowell Project during their upstream and downstream migrations to determine if project operations negatively impact their survival and production.

The following objectives will address this request:

1. Assess project operations effects on the timing, orientation, routes, and migration rates of shad and river herring;
2. Determine route selection and behavior of upstream migrating shad and river herring at the project under varied operational conditions, including a range of spill conditions (e.g., movement to the dam, attraction to the E.L. Field station discharge, movement between locations, delay, timing, etc.);
3. Determine delay/fallback associated with the northern canal;
4. Assess near field attraction to, and entrance efficiency of, the fish lift under a range of spill conditions and with the river-side entrance and street-side entrances open;
5. Assess near field attraction to, and entrance efficiency of, the spillway ladder under a range of spill conditions;
6. Evaluate the internal efficiency of the Pawtucket dam ladder;
7. Collect ladder and lift efficiency data, to include rates of approach to fishway entrances, entry into fishways, and passage under varied operational conditions, including a range of spill conditions;
8. Determine the proportion of post-spawned adults that select the power canal as a downstream passage route under varied operation conditions, including a range of spill conditions up to full spill; determine post-spawned adult downstream migration route selection, passage efficiency, and delay associated with the power canal under various operational conditions, including a range of spill conditions; and
9. Compare rates and measures of delay and movement among project areas and routes utilized (e.g., spill at dam vs. power canal) under the range of permitted and proposed spill and operational conditions.

If project operations are adversely affecting shad or river herring migration timing or are resulting in other deleterious population effects, we recommend Boott identify operational solutions or other passage measures that will reduce and minimize these impacts within the project area.

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This study will require 3 years of field data due to the tailrace ledge excavation project which will be completed in 2019 and to capture inter-annual variability of river discharge, water temperatures, and variability in outmigration timing. We recommend that Boott perform the downstream routing portion of the study in 2019 (pre-ledge excavation) and 2020 (post-ledge excavation). In 2020 and 2021, after the ledge has been excavated, we recommend Boott perform the upstream portion of this study.

Resource Management Goals

The Atlantic States Marine Fisheries Commission, Amendment 3 to the Interstate Fishery Management Plan for Shad and River Herring, approved in 2010, includes the following objectives:

Upstream Passage

1. Fish must be able to locate, enter, and pass the passage facility with little effort and without stress.
2. Where appropriate, upstream fish passage effectiveness should be improved through operational or structural modifications.
3. Fish which have ascended the passage facility should be guided to an appropriate area so they can continue their upstream migration and avoid being swept back downstream.

Downstream Passage

1. Enhance survival at dams during emigration.
2. Evaluate survival of post-spawned adults and juvenile fish passed via each project route (e.g., turbines, spillage, bypass facilities, or a combination of the three).
3. Implement measures to pass fish via the route with the least delay and best survival rate.

The Service seeks the accomplishment of a number of resource goals and objectives through the relicensing process for the projects. General goals include the following:

1. Ensure that protection, mitigation and enhancement measures are commensurate with project effects and help meet regional fish and wildlife objectives for the basin.
2. Conserve, protect, and enhance the habitats for fish, wildlife, and plants that continue to be affected by the project.

Specific to American shad and river herring movement and migration, the Service's goal is to minimize current and potential negative project operation effects on the safe, timely and effective upstream and downstream passage of adult American shad and river herring.

These study requests are intended to facilitate the collection of information necessary to conduct effects analyses and to develop reasonable and prudent conservation measures, and protection, mitigation, and enhancement measures pursuant to the Fish and Wildlife Coordination Act, as amended (16 U.S.C. §661, *et seq*.), the Federal Power Act (16 U.S.C. §791a, *et seq*.), the Atlantic States Marine Fisheries Compact (P.L. 539, 77th Congress, as amended by P.L. 721, 81st Congress), and the Atlantic Coastal Fisheries Cooperative Management Act (16 U.S.C. 5107).

Public Interest

The requestor is a natural resource agency.

Existing Information and the Need for Additional Information

Several studies pertaining to the fish lift and downstream passage facilities at Lowell have been conducted for American shad. Studies of alewife passage are limited to a single downstream test performed in 1991. Previous studies pertaining to upstream shad migration (listed in Table 5.4-3 of the PAD) demonstrate passage through the existing lift at Lowell is relatively poor. Also, when analyzing annual passage counts for river herring and shad, the number of fish that utilize the Lowell lift versus those that pass at Lawrence is low (from 1996 to 2017 passage efficiency at Lowell has not exceeded 30 percent).

In 2016, for the first time since the issuance of the original license for the project, Boott agreed to operate the fish ladder at the Pawtucket dam for the duration of the anadromous fish upstream passage season, consistent with the operating timeframes defined for the powerhouse fish lift in the project’s Commission-approved Comprehensive Fish Passage Plan. Therefore, to date, studies performed at Lowell have not tested the nearfield attraction, entrance efficiency, or internal efficiency of the ladder. Moreover, past studies have had statistically low sample sizes (less than 60 fish) and were all performed prior to the ledge excavation project which will occur in August 2019. Future studies should have a robust sample size (at a minimum, 150 fish per species) and array system. Additionally, to obtain a comprehensive understanding of fish behavior at Lowell, for both upstream and downstream migration, studies are needed to: (1) determine if project operations affect pre-spawned and post-spawned river herring and shad migration timing; (2) assess fish movement to, and through, the ladder at the Pawtucket dam; and (3) assess passage success at the tailrace fish lift post-ledge removal.

Nexus to Project Operations and Effects

Lowell tailrace turbulence, potentially exacerbated by the existing ledge outcropping, creates attraction issues at the entrance of the fish lift. Moreover, a lack of effective protection at the 21 turbines associated with the project increases the risk of entrainment and mortality alosines may experience as they migrate downstream to the ocean. During the upstream fish passage season, the Lowell bypass reach receives 500 cfs during the day and 300 cfs at night via operation of the spillway fish ladder; otherwise, the reach only receives flow when inflow exceeds the hydraulic capacity of the project’s generating capacity. The spillway ladder is, therefore, only partially effective due to lack of flow.

Existing project operations and limited bypass flows can have a direct impact on diadromous fish migration. Migration delays, increased predation, mortality during passage over the dam or through turbines, and changes in route selection under different flow conditions are potential influences of the project on shad and river herring populations in the Merrimack River. Effective upstream and downstream passage and successful spawning and juvenile production are necessary to help achieve shad and river herring management restoration goals for the Merrimack River, particularly in the upstream reaches.

Methodology Consistent with Accepted Practice

The movement of migratory shad and river herring would be best studied by using radio telemetry, including passive integrated transponder (PIT) tags. Radio telemetry is an accepted technology that has been used for a number of studies associated with hydropower projects, including at the Bellows Falls (FERC No. 1855), Wilder (FERC No. 1892), and Vernon (P-1904) projects.

The study design must specify sample sizes, as well as tag and receiver configurations, to ensure rates of entry and exit to the tailrace, fish lift and fish ladder, downstream bypass, the bypassed reach, and canal, can be calculated with sufficient precision. We recommend that Boott capture shad and river herring below Lawrence and tag at least 150 individuals per species. Double-tagged (radio and PIT) shad and river herring should be released upstream of the Lawrence dam and upstream of the Lowell dam. Fish should also be released directly into the Pawtucket canal to adequately assess project conditions likely to be encountered during downstream migration. Additional, tagged, individuals may need to be released farther upstream to ensure enough fish encounter the dam during a sufficient range of turbine and operational conditions to test for project effects (especially in 2020 and 2021). A large array of stationary monitoring stations (radio and PIT) will be needed to provide an appropriate level of resolution for data analyses and to answer the natural resource agencies' questions regarding project operation effects. Additionally, since fish can drift a considerable distance downstream after they have died (Havn et al. 2017); a minimum of 25 dead river herring and 25 dead shad should also be released as a control group in this study. A plan and schedule for spill releases should be developed which provides sufficient periods of spill and various generating levels (treatments will require multiple days of consistent discharge).

Each component of this study will require 2 years of field data collection to attempt to account for inter-annual variability in river discharge, water temperatures, and the ledge excavation project which will be completed in 2019. We recommend Boott perform the downstream routing portion of the study in 2019 (pre-ledge excavation) and 2020 (post-ledge excavation). In 2020 and 2021, after the ledge has been excavated, the upstream portion of this study should be performed.

A related study request on computational fluid dynamics (CFD) modeling in the Lowell tailrace, in and around the fish lift and fish ladder entrances and powerhouse forebay, will complement this study and address related project operational effects.

These methodologies are consistent with accepted practice.

Level of Effort/Cost, and Why Alternative Studies Will Not Suffice

Estimated cost for this study is expected to range from $400,000 to $500,000, with the majority of costs associated with equipment (radio and PIT tags, radio receivers, and PIT readers) and related field work labor. Since tagged shad and river herring will move throughout the area, to varying degrees, there will be expected cost savings (e.g., radio tags) to Boott, provided cooperation in study planning and implementation occurs.

Boott did not propose any studies to meet this need in the PAD.

REFERENCES

Havn, T. B., F. Økland, M.A. Teichert, L. Heermann, J. Borcherding, S.A. Sæther, O.H. Tambets and E.B. Thorstad. 2017. Movements of dead fish in rivers. Animal Biotelemetry, 5: 7.

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Boott Study Request # 4

Impact of Project Operations on Downstream Migration of Juvenile Alosines

(Lowell, P-2790)

Goals and Objectives

The goals of this study are: (1) conduct a field study of juvenile alewife outmigration in the Lowell impoundment, the power canal, and at the Pawtucket dam, to determine if project operations negatively impact juvenile alosine survival and production; and (2) determine if project operations affect juvenile alosine outmigration survival, recruitment, and production.

The following objectives will address this request:

1. Assess project operations effects of the Pawtucket dam on the timing, orientation, passage routes, migration rates, and survival of juvenile alewife;
2. Determine the proportion of juvenile alewife that select the Lowell canal versus the Pawtucket powerhouse, downstream bypass facility, or dam spill as a downstream passage route, under varied operational conditions;
3. Determine if there are any delays associated with downstream movement related to either dam spill or the Pawtucket powerhouse due to operations;
4. Determine the juvenile downstream passage timing and route selection in the Lowell canal, assess delays associated with the canal, and with project operations (e.g., stockpiling in the canal).

If it is determined the project operations are adversely affecting juvenile alosine survival, migration timing, or causing other deleterious population effects, identify operational solutions or other passage measures which will reduce and minimize these impacts within the project area. This study will require 2 years of field data to capture inter-annual variability of river discharge and water temperatures.

Resource Management Goals

The Atlantic States Marine Fisheries Commission Amendment 3 to the Interstate Fishery Management Plan for Shad and River Herring (American Shad Management), approved in 2010, includes the following objective:

> Maximize the number of juvenile recruits emigrating from freshwater stock complexes. To enhance survival at dams during emigration, evaluate survival of post spawning and juvenile fish passed via each route (e.g., turbines, spillage, bypass facilities, or a combination of the three) at any given facility, and implement measures to pass fish via the route with the best survival rate.

The Service seeks the accomplishment of a number of resource goals and objectives through the relicensing process for the projects. General goals include the following:

1. Ensure that protection, mitigation, and enhancement measures are commensurate with project effects and help meet regional fish and wildlife objectives for the basin.
2. Conserve, protect, and enhance the habitats for fish, wildlife, and plants that continue to be affected by the project.

Specific to juvenile American shad and river herring movement and migration, the Service's goal is to minimize current and potential negative project operation effects on the safe, timely and effective downstream passage.

These study requests are intended to facilitate the collection of information necessary to conduct effects analyses and to develop reasonable and prudent conservation measures, and protection, mitigation, and enhancement measures pursuant to the Fish and Wildlife Coordination Act, as amended (16 U.S.C. §661, *et seq*.), the Silvio O. Conte National Fish and Wildlife Refuge Act (P.L. 102-212; H.R. 794), the Federal Power Act (16 U.S.C. §791a, *et seq*.), the Atlantic States Marine Fisheries Compact (P.L. 539, 77th Congress, as amended by P.L. 721, 81st Congress), and the Atlantic Coastal Fisheries Cooperative Management Act (16 U.S.C. 5107).

Public Interest

The requestor is a natural resource agency.

Existing Information and the Need for Additional Information

The seaward migration of juvenile alosines is of great importance to the restoration of alewife, blueback herring, and American shad in the Merrimack River. However, data on the downstream migratory movements and rates of alosines past Lowell is sparse and relatively incomplete. In 1994 and 1995, Normandeau Associates, Inc., documented use of the bypass facility by downstream migrating alosines via the installation of a removable box trap. Passage efficiencies were 7 percent and 37 percent, respectively. However, to date, no directed studies of downstream alosine passage route selection has been conducted at the Lowell Project. These information gaps need to be filled so the natural resource agencies can assess the relative and cumulative impacts of project operations on outmigrating juvenile alosines and develop adequate passage and protection measures to meet management goals and objectives.

Studies conducted farther upstream on the Merrimack River, at Garvins Falls (FERC No. 1893), have shown it is possible to radio-tag juvenile alewife to evaluate alosine outmigration (Normandeau 2016). Alewife can be used as a proxy, in this instance, for the natural resource agencies to assess blueback herring and shad downstream migration patterns.

Nexus to Project Operations and Effects

Adult alosines, passed at Lowell via the fishways and/or stocking efforts, utilize upstream habitat to spawn on an annual basis. Similarly, juvenile alosines require safe and timely downstream passage measures at the project in order to successfully emigrate back to the ocean to contribute to the population. Presently, downstream migrants can easily enter the Lowell canal system, via the Pawtucket canal, as there are no exclusionary measures in place. There are 19 turbines located in the canal, housed at four powerhouses (Assets, Bridge Street, Hamilton, and John Street), none of which have passage or protection measures. There are a variety of unit-types housed in each of the powerhouses, ranging in speed from 100 to 150 rpm. A study is needed to assess the impacts project operations have on outmigrating juvenile alosines.

The Service is not aware of any studies conducted specifically designed to answer the following questions:

1. What is the rate of alewife survival under a range of spill and gate configurations?
2. Are there delays in migration/movement at the dam, gatehouse, or in the canal?
3. For juveniles that enter the Pawtucket canal, what proportion subsequently enter the Western, Merrimack, Pawtucket, or Hamilton canals?
4. What is the rate of movement through the canal, what is the delay to juvenile alosine outmigration, and the potential accumulation of juveniles in the canal?
5. What proportion of juvenile alosines use the downstream bypass sluice versus the E.L. Field powerhouse turbines under varied operational conditions?

The Service is concerned project operations are: (1) impacting juvenile alosine outmigration survival; and (2) contributing to the failure of the Merrimack River alosine population to meet management targets.

Methodology Consistent with Accepted Practice

The impact of project operations to juvenile alewife outmigration, passage route selection, and migratory delay would be best studied via radio telemetry. This methodology has successfully been tested and employed by Normandeau Associates, Inc., at the Garvins Falls hydroelectric project (FERC No. 1893; Normandeau 2013; Normandeau 2016). Project discharge over a full range of existing and, to the extent possible, potential future operational conditions at the dam (likely increased bypass reach flows in new license), should be examined relative to migration rate and passage route selection of juvenile alosines to, and through, various areas of the project.

In addition, study fish should be collected and balloon-tagged to empirically determine rates of survival for fish passed over or through the dam's bypass sluice, main powerhouse, and 19 canal units under varied operations. For spill mortality sites (dam spillway and downstream bypass), tagged alosines should be injected or released into spill flow at points where water velocity exceeds 10 ft/sec to minimize the possibility of the fish swimming upstream into the headpond or canal. Passed balloon-tagged alosines will be recovered below areas of spill and held for 48 hours in isolated tanks for observation of injury and latent mortality; unrecovered balloon-tagged alosines will be censored from the data.

For turbine mortality sites, tagged alosines will be injected into intakes of units operating at or near full generation at points where intake water velocity exceeds 10 ft/sec to minimize the possibility of fish swimming back upstream through the intakes. Passed balloon-tagged alosines will be recovered in the tailrace and held for 48 hours in isolated tanks for observation of injury and latent mortality; unrecovered balloon-tagged alosines will be censored from the data.

Radio-tagged juvenile alewife will be released in areas upstream of the project at multiple release locations, to determine operation effects on migration rates, route, orientation, and entrainment, over a full range of permitted and operational conditions. The release of radio-tagged fish upstream of the project, and induction into the power canal, will provide data on concerns of delay and route selection to the canal, downstream bypass, crest gates, and turbines. Additionally, since fish can drift a considerable distance downstream after they have died (Havn et al. 2017); a minimum of 50 dead alewife should also be released as a control group in this study.

Level of Effort/Cost, and Why Alternative Studies Will Not Suffice

Boott does not propose any studies to meet this need. Estimated costs for the study are expected to be moderate to high, between $100,000 and $300,000, with the majority of costs associated with equipment (radio tags, radio receivers) and related field work labor.

REFERENCES

Havn, T. B., F. Økland, M.A. Teichert, L. Heermann, J. Borcherding, S.A. Sæther, O.H. Tambets and E.B. Thorstad. 2017. Movements of dead fish in rivers. Animal Biotelemetry, 5: 7.

Normandeau 2013. Juvenile Alosine Radio Tag Attachment Test. Submitted to Boot Hydro, LLC. Final report. Normandeau Associates, Inc., Westmoreland, New Hampshire. 2 pp.

Normandeau 2016. Garvins Falls Juvenile Alosine Downstream Passage Telemetry Assessment. Submitted to Boot Hydro, LLC. Final report. Normandeau Associates, Inc., Westmoreland, New Hampshire. 13 pp.

Boott Study Request # 5

Downstream American Eel Passage Assessment
(Lowell, P-2790)

Goals and Objectives

The goal of this study is to determine the impact of the Lowell hydroelectric project on the outmigration of silver eels in the Merrimack River. Entrainment in the canal and at the conventional turbines at the project powerhouses (E.L. Field, Assets Station, Bridge Street, Hamilton Station, and John Street) can result in mortality or injury. It is important to understand the passage routes at the project and the potential for delay, injury, and mortality to assess alternative management options to increase survival.

The objectives of this study are:

1. Quantify the movement rates (including delays) and relative proportion of eels passing via various routes at the project (i.e., through the turbines, through the downstream bypass, spilled at the dams, etc.).
2. Evaluate instantaneous and latent mortality and injury of eels passed via each potential route.

Resource Management Goals

The Atlantic States Marine Fisheries Commission has developed two documents related to the management of American eel:

1. Interstate Fishery Management Plan for American Eel. April 2000. Atlantic States Marine Fisheries Commission.
2. Addendum II to the Fishery Management Plan for American Eel. Atlantic States Marine Fisheries Commission. Approved October 23, 2008. 8 pp.

Objectives of the management plan include: (1) protect and enhance American eel abundance in all watersheds where eel now occur; and (2) where practical, restore American eel to those waters where they had historical abundance, but may now be absent, by providing access to inland waters for glass eel, elvers, and yellow eel, and adequate escapement to the ocean for pre-spawning adult eel.

Addendum II contains specific recommendations for improving upstream and downstream passage of American eel, including requesting that member states and jurisdictions seek special consideration for American eel in the Commission relicensing process.

The Service seeks the accomplishment of a number of resource goals and objectives through the relicensing process for the project. General goals include the following:

1. Ensure that protection, mitigation and enhancement measures are commensurate with project effects and help meet regional fish and wildlife objectives for the basin.
2. Conserve, protect, and enhance the habitats for fish, wildlife, and plants that continue to be affected by the project.

Specific to downstream passage of American eel, the Service's goals are:

1. Minimize current and potential negative project operation effects that could hinder management goals and objectives.
2. Minimize project-related sources of downstream passage delay, injury, stress, and mortality in order to maximize the number of silver eels migrating to the spawning grounds.

These study requests are intended to facilitate the collection of information necessary to conduct effects analyses and to develop reasonable and prudent conservation measures, and protection, mitigation, and enhancement measures pursuant to the Fish and Wildlife Coordination Act, as amended (16 U.S.C. §661, *et seq*.), and the Federal Power Act (16 U.S.C. §791a, *et seq*.).

Public Interest

The requester is a natural resource agency.

Existing Information and the Need for Additional Information

Data on downstream migratory movements and rates of American eels past the project are sparse and relatively incomplete. A single study was performed by Normandeau Associates, Inc., in 2017 (Normandeau 2017). Seventeen silver-phase eels were tagged and released into the Merrimack River upstream of the Garvins Falls project. Of the 17 released individuals, 14 approached the Pawtucket dam. Eight were determined to have passed through the gatehouse and enter the forebay canal upstream of the E.L. Field powerhouse. Five eels passed the project via spill flow. One eel's passage route was classified as unknown. Zero individuals used the downstream bypass. This study had a small sample size, was of a relatively short duration (October 20-November 28, 2017), did not include monitoring stations or antenna arrangements in the canal, and was performed prior to the installation of the pneumatic crest gate system.

To date, no other directed studies of eel entrainment or mortality have been conducted at the Lowell Project. These information gaps need to be filled so the natural resource agencies can assess the relative and cumulative impacts of project operations on outmigrating eels and develop adequate passage and protection measures to meet management goals and objectives.

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Nexus to Project Operations and Effects

The project configuration presents problems with respect to providing safe, timely, and effective passage for outmigrating eels. The intakes are likely deep and, while no specification for the trashracks were provided in the PAD, it is unlikely they would prevent entrainment of eels. The anadromous downstream passage facility at the project is also not expected to be effective for eels; the target anadromous species are surface-oriented, while eels tend to move much deeper in the water column. Additionally, there are no data pertaining to eel movements in the Lowell canal. Eels that move into the canal potentially have no alternative but to pass through hydropower turbines at the Assets, Bridge Street, Hamilton, and John Street powerhouses. Eels are known to occur upstream of the dam; therefore, it is necessary to understand how eels move through the project and the level of injury and/or mortality resulting from each potential passage route (i.e., the spillway, the downstream bypass facility, or the 21 turbines associated with the project).

Methodology Consistent with Accepted Practice

In order to understand the movements of outmigrating silver eels as they relate to operations at Lowell, radio telemetry technology should be utilized. Radio telemetry is an accepted technology which has been used for a number of studies associated with hydropower projects, including at the Bellows Falls (FERC No. 1855), Wilder (FERC No. 1892), and Vernon (P-1904) projects.

Studies should be designed to investigate route selection (i.e., entrainment vs. spill) independently from estimation of mortality/injury, because these metrics require different methodologies. Studies will also likely benefit from data collected over 2 study years (especially route selection studies, which may be more significantly affected by environmental conditions during a given season than mortality/injury studies). It is also envisioned that results from route selection studies can guide design of turbine mortality studies. Therefore, it is proposed, at a minimum, route selection studies be conducted in multiple years, but mortality/injury studies may be conducted after the first year of route selection studies have been completed.

Objective 1: Route Selection

This study will involve systematic releases of radio-tagged silver phase eels at strategic points above areas of interest, to assess general routes of passage (i.e., via spill, bypass, or turbines). Active downstream migrants should be collected within-basin if possible (i.e., Cabot or Holyoke bypass samplers), but fish sourced from out-of-basin may be acceptable to meet sample size demands. Experimental fish must meet morphometric (e.g., eye diameter relative to body size) criteria to ensure they are migrant silver phase. Collections should be made within the migratory season (late August to mid-October), and eels should be tagged and released within 21 days after capture, but preferably within 7 days (particularly if the test eels are from out-of-basin).

All telemetered eels will be radio- and PIT-tagged. PIT antennas will be installed and monitored continuously to verify passage of eels via bypass channels.

A minimum number of 150 telemetered eels (e.g., five separate groups of approximately 30 eels each) will be required to maximize the data return. Tagged eels should be released at least 5 km upstream of the Lowell Project. Groups of eels should be released during spill (if any) and non-spill and during periods of low, moderate, and high generation conditions. Up to 50 additional eels should also be released in the upper canal and allowed to volitionally descend through the canal to assure that a sufficient number of eels are exposed to canal conditions. Groups of eels should be released when the canal units are running and when the canal units are off. Additionally, since fish can drift a considerable distance downstream after they have died (Havn et al. 2017), a minimum of 25 dead eels should also be released as a control group in this study.

Telemetry receivers and antennas should be located upstream and downstream of the spillway, at the canal entrance, within the canal, in the downstream fish bypass entrance, at turbine intakes, the station tailrace, and downstream of the confluence of the Merrimack and Concord rivers. These locations will permit assessment of passage via the following potential routes: the power canal, spillway, downstream fish bypass, station turbines,and upstream fishway attraction water intake. The final placement of receivers and antennas should be developed in consultation with the fisheries agencies.

Mobile tracking (i.e., via boat) in the River and canal between release sites and several km downstream will be performed at regular intervals during and after releases to confirm routes and fates of passed fish or lost fish.

Movement rates (time between release and detection at radio antenna locations, and between radio antenna locations) of eels passing the projects by various routes will also be quantified.

The route selection portion of this study should occur in both study years.

Objective 2: Spill, Bypass, and Turbine Mortality/Injury Studies

Spill, bypass, and turbine mortality will be assessed using a balloon-tag method.

For spill mortality sites (dam spillways and downstream bypasses), tagged eels will be injected or released into spill flow at points where water velocity exceeds 10 ft/sec to minimize the possibility of eels swimming upstream into the headpond or canal. Passed balloon-tagged eels will be recovered below areas of spill and held for 48 hours in isolated tanks for observation of injury and latent mortality; unrecovered balloon-tagged eels will be censored from the data.

For turbine mortality sites, tagged eels will be injected into intakes of all 21 units associated with the project, operating at a full range of settings where intake water velocity exceeds 10 ft/sec to minimize the possibility of eels swimming back upstream through the intakes. Passed balloon-tagged eels will be recovered in the tailrace(s) and held for 48 hours in isolated tanks for observation of injury and latent mortality; unrecovered balloon-tagged eels will be censored from the data.

> If the balloon-tag mortality component of the study occurs in study year one, all possible route selection sites would need to be evaluated. If the balloon-tag mortality component of the study occurs in study year two, results from the route selection study could be used to inform which sites need to be evaluated for mortality. Eels recovered from balloon-tag studies should not be used for route selection studies.

Data analyses of route selection and mortality (instantaneous and latent) will follow standard methodology.

Project operation (flows, levels, gate openings, number of units operating and operation level) and environmental conditions (river flow, temperature, turbidity, air temperature, precipitation) will be monitored regularly (hourly measurements if possible) throughout the duration of the studies and assessed for potential relationships to passage route selection, migratory delay, and/or passage survival.

These methodologies are consistent with accepted practice.

Level of Effort/Cost, and Why Alternative Studies Will Not Suffice

The level of cost and effort for the downstream eel passage study will be moderate to high; silver eels would need to be collected, tagged, and released in several locations over the course of the migration season. Antennas and receivers would need to be installed throughout the canal, at the intakes of the E.L. Field powerhouse, at the dam spillways and station bypass and monitored regularly. Data would need to be retrieved periodically, then analyzed. A multi-site route selection study conducted by the USGS Conte Lab on the Shetucket River in Connecticut cost approximately $75,000 for the first year of study. Costs are estimated at $100,000 per year for the route selection study and $50,000 to $75,000 for the spill, bypass, canal, and turbine mortality/injury study.

Boott did not propose any studies to meet this need in the PAD.

REFERENCES

Havn, T. B., F. Økland, M.A. Teichert, L. Heermann, J. Borcherding, S.A. Sæther, O.H. Tambets and E.B. Thorstad. 2017. Movements of dead fish in rivers. Animal Biotelemetry, 5: 7.

Normandeau Associates, Inc. 2017. Downstream Passage Evaluation for Silve-Phase American Eels at the Lowell Hydroelectric Project. 2017. Submitted to the City of Holyoke Gas and Electric Department. Final report. Normandeau Associates, Inc., Westmoreland, New Hampshire. 17 pp.

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Boott Study Request # 6

Operations Analysis of the Lowell Canal
(Lowell, P-2790)

Goals and Objectives

The goal of this study is to understand the operations of the Lowell canal system. The specific objective of this study is to describe the operations of the Lowell canal which include, but are not limited to: how all of the canal units interact with the main units, how the canal units are sequenced, how often each of the units operate, the prioritization sequence of canal unit operations, the amount of time the units are operated during the downstream passage season, etc.

Resource Management Goals

The Service seeks the accomplishment of a number of resource goals and objectives through the relicensing process for the project. General goals include the following:

1. Ensure that protection, mitigation, and enhancement measures are commensurate with project effects and help meet regional fish and wildlife objectives for the basin.
2. Conserve, protect, and enhance the habitats for fish, wildlife, and plants that continue to be affected by the project.

Specific to aquatic resources, the Service's goals are:

1. Protect, enhance, or restore diverse high quality aquatic and riparian habitats for plants, animals, food webs, and communities in the watershed and mitigate for loss or degradation of these habitats.
2. Minimize current and potential negative project operation effects on fish in the project area.

Public Interest

The requestor is a natural resource agency.

Existing Information and the Need for Additional Information

The Merrimack River supports a variety of migratory fish species. However, there is no information pertaining to fish mortality and population effects resulting from entrainment in the canal and/or the canal units. Since there are no exclusionary measures at the entrance of the project's canal system, fish can easily enter the two-tiered network of man-made canals, which are approximately 5.5 miles in length. These man made canals provide flow to 19 Boott-owned hydroelectric units. Since the issuance of the original license for the project, there have been no directed studies of the Pawtucket, Western, Merrimack, or Hamilton canal units. Additionally, the PAD provides little operational information regarding the canal: flows of up to 2,000 cfs are routed into the canal, typically once the E.L. Field station's hydraulic capacity of 8,000 cfs has been reached. These information gaps need to be filled so the natural resource agencies can assess the relative and cumulative impacts of project operations on riverine fishes and migratory alosines which may be moving through, or inhabiting, the canal and develop adequate passage and protection measures to meet management goals and objectives.

Nexus to Project Operations and Effects

The Lowell Project consists of a two-tiered, 5.5-mile-long, network of man-made canals which include several small dams and 19 turbine units. Flows enter the canal system upstream of the Pawtucket dam via the Pawtucket canal. There are no exclusionary measures for fish in place. Therefore, the Lowell canal presents problems with respect to providing safe, timely, and effective passage for fish trying to move past the project through the canal system.

Methodology Consistent with Accepted Practice

In order to determine the relative risk the canal units present to riverine and migratory fishes, it is necessary to understand how the canal operates. Therefore, we request Boott provide a detailed description of the operational protocol it uses to determine when and how much water flows into the canal at a time scale relevant to the migratory fish species expected to potentially utilize the canal as a passage route (e.g., May, June, and July for spent alosines; August through November for adult eels and juvenile alosines). Historical operations data should be examined relative to the hydrological data set to determine the percent of time the canal units would be expected to operate during each passage month. This analysis should be used in conjunction with the results of the passage route and turbine mortality studies to estimate total through project mortality for each target fish species/life stage.

Level of Effort/Cost, and Why Alternative Studies Will Not Suffice

The expected level of effort and anticipated cost will be low. Operations and hydrologic data are readily available and only need to be compiled and analyzed. We estimate the cost to be less than $10,000.

Boott Study Request # 7

Three-Dimensional Computational Fluid Dynamics (CFD) Modeling in the Vicinity of Fishway Entrances and Powerhouse Forebays

(Lowell, P-2790)

Goals and Objectives

The goal of this study is to determine the flow field conditions that exist in and around fishway entrances and the powerhouse forebay. The information from this request is meant to be coupled with data from the telemetry studies, such that a comprehensive understanding of fish behavior is developed.

The objective of this study is to create a series of color contour maps of velocity magnitude at select discharges agreed upon by the resource agencies and the licensee. With respect to upstream passage, the results will show approach velocities and flow fields that may create a response in fish. This information can be coupled with telemetry data (from the requested shad and river herring telemetry study) and passage counts to understand which conditions are optimal for guiding migrating fish to the fishway entrances and stimulating fishway entry.

With respect to downstream migration, the results will show velocities and flow fields in front of the E.L. Field powerhouse. Additionally, the results will indicate to what degree, if any, flow directs downstream migrating fish towards the downstream bypass facility.

Resource Management Goals

The management goals of this study request are to obtain information that will assist in enhancing the effectiveness of the current upstream fish passage facilities for upstream migrating trust species and reduce impingement, entrainment, and delay for downstream migrating fish. CFD models are a relatively cost effective way to analyze existing and future conditions. As such, changes in the amount of attraction water, changes in which turbines are operating, and which spillway gates are releasing water can all be examined. As stated, the results from this study are meant to be used along with the data generated from the requested telemetry study. The combined analysis from these two data sources can help assess which flow conditions are most advantageous for migrating trust species to enter the fishway under current and proposed conditions.

As for downstream migration of adult and juvenile shad, river herring, and adult eel, the results from the models will reveal flow magnitude and direction in front of the powerhouse. Given the limited information that currently exists on survival through the project, our management goal is to direct as many downstream migrating fish as possible towards the downstream bypass facility. With respect to upstream passage, we want to maximize the number of fish that find and enter the fishway entrances.These study requests are intended to facilitate the collection of information necessary to conduct effects analyses and to develop reasonable and prudent conservation measures, and protection, mitigation, and enhancement measures pursuant to the Fish and

Wildlife Coordination Act, as amended (16 U.S.C. §661, *et seq*.), and the Federal Power Act (16 U.S.C. §791a, *et seq*.).

Public Interest

The requestor is a natural resource agency.

Existing Information and the Need for Additional Information

To date, no CFD modeled data exists in front of either the fish ladder or lift, nor do they exist in front of the E.L. Field powerhouse. A comprehensive understanding of fish behavior at the ladder and lift entrance, and the powerhouse forebay, is needed in order to create safe, timely, and effective upstream and downstream passage for American shad, river herring, and eels. Additionally, a better understanding of flow and how it affects fish passage is needed after Boott performs the ledge removal excavation project.

Nexus to Project Operations and Effects

The Lowell Project has direct impacts to upstream and downstream migrating shad, river herring, and eel. The development of these models will give resource agencies valuable information into the hydraulic cues which may elicit a response from upstream migrants. For downstream passage, the Service has approach velocity guidelines; the output from these models would inform the resource agencies under what conditions appropriate approach velocities are being met and when they are being exceeded.

With respect to upstream migration, the auxiliary water system (AWS) plays a critical role in determining whether or not fish are attracted to the entrance. The results from this study would allow an assessment of how well the AWS is performing and under what conditions it attracts the most fish.

With respect to downstream migration, the development of a CFD model under existing conditions also informs the design of future modifications and improves the survivability of downstream migrating shad, river herring, and eel.

The CFD models for the Pawtucket fishway and fish lift should be developed as part of year two studies, after the ledge excavation project is complete. It would be useful to have the gatehouse area CFD modeling completed in year one. This analysis may provide information on adjustments to canal operations or structures that can subsequently be analyzed.

Understanding the entrance conditions of the Pawtucket fishway under a range of spill conditions would be informative. If developed prior to the year one upstream shad telemetry studies, it would provide information on spill gate settings which would likely best achieve entrance and ultimately passage. Further work with the model can help in evaluating changes in ladder entrance or spill conditions that could improve passage and be tested with telemetry, video, and/or count data.

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CFD modeling of the flows leading to the canal would aide in our interpretation of year one downstream passage telemetry results, but would not need to be completed prior to the year one telemetry (downstream juvenile alewife and downstream eel) studies. Those studies will provide the context for how and where shad, river herring, and eels are passing the project and how successful passage is. The CFD modeling could focus on the locations identified as important in the study results and Boott could assess changes to structures or operations and evaluate them in the model. Promising alternatives would then be tested in year three studies.

Methodology Consistent with Accepted Practice

A three-dimensional CFD model has become an increasingly common standard of analysis at hydroelectric projects around the nation. Within the northeast region, we have seen these types of models developed at the Holyoke (P-2004), Brunswick (P-2284), Shawmut (P-2322), Milford (P-2534) and Orono (P-2710) projects. We would expect to engage with the licensee in terms of determining the appropriate area and flows to be modeled. We expect the spatial extent of the model at each study site will vary. Given the large number of ways in which output from these models can be presented and the near infinite number of flows which could potentially be modeled, we would expect to consult with the licensee to reach agreed upon modeling efforts and scenarios to be examined.

Level of Effort/Cost, and Why Alternative Studies Will Not Suffice

The cost of developing, running and testing a CFD model can vary tremendously; one large variable in determining the cost is based on the amount of existing bathymetric data to which Boott currently has access. We roughly estimate that the cost of each CFD model could run as high as $50,000, assuming no bathymetric data currently exists. Proactive communication with resource agencies will reduce the cost and iterative effort. Given the level of effort that has occurred at other projects that have proposed to amend their license, we see the level of effort requested here as reasonable and in line with frequent modern industry practice.

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Boott Study Request # 8

Bypass Zone of Passage
(Lowell, P-2790)

Goals and Objectives

The goal of this study is to determine zone-of-passage flows in the bypass reach that facilitate safe, timely, and effective fish passage through the project.

Specifically, the objectives of this study are:

1. Complete a detailed survey of the bypass reach;
2. Develop a high-resolution, two-dimensional hydraulic model of the bypass reach;
3. Release multiple flows from the dam to collect calibration data for the model;
4. Simulate additional flows through the bypass reach with the calibrated model; and
5. Determine minimum and optimal zone-of-passage flows for the project.

Resource Management Goals

The Service seeks the accomplishment of a number of resource goals and objectives through the relicensing process for the project. General goals include the following:

1. Ensure that protection, mitigation and enhancement measures are commensurate with project effects and help meet regional fish and wildlife objectives for the basin.
2. Conserve, protect, and enhance the habitats for fish, wildlife, and plants that continue to be affected by the project.

Specific to aquatic resources within the Lowell bypassed reach, the Service's goals are:

1. Protect, enhance, or restore diverse high quality aquatic and riparian habitats for plants, animals, food webs, and communities in the watershed and mitigate for loss or degradation of these habitats.
2. Provide a flow regime in the bypassed reach that meets the life history requirements of resident fish and wildlife (including invertebrates such as freshwater mussels) and diadromous fishes.
3. Minimize current and potential negative project operation effects on water quality and aquatic habitat.

These study requests are intended to facilitate the collection of information necessary to conduct effects analyses and to develop reasonable and prudent conservation measures, and protection, mitigation, and enhancement measures pursuant to the Fish and Wildlife Coordination Act, as amended (16 U.S.C. §661, *et seq*.), and the Federal Power Act (16 U.S.C. §791a, *et seq*.).

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Public Interest

The requester is a natural resource agency.

Existing Information and the Need for Additional Information

Article 36 of the original license required the licensee, in consultation with resource agencies, to develop an in-stream flow study plan to determine: (1) the relationship between project discharges and downstream aquatic habitat; and (2) a fishery study plan to determine project discharges necessary to provide for the migration of anadromous fish (i.e., zone of passage). After completion of the approved studies, the licensee was to file a report on the results of the studies, and, for Commissions approval, recommendations for the flow releases from the project. The study plan was filed on August 13, 1983, with proof of agency consultation (Accession No. 19830818-0191). However, there are no study reports included in the record. Therefore, we have no quantitative data supporting the agreement that 300 cfs at night and 500 cfs during the day are adequate flows for zone of passage in the bypass reach.

In the Comprehensive Fish Passage Plan filed on March 9, 2000 (Accession No. 20000313-0322), the licensee states “The adequacy of flows for upstream fish passage at the Project was addressed by BHI’s construction of six (6) concrete flow control weirs (with adjustable stoplog sections) in the bypass reach, at the request of U.S. Fish and Wildlife Service and in response to Article 36, section (2) of the Project’s FERC license.” Similar to the study plan, this is an agreement with no supporting information to substantiate the conclusion flows in the bypass reach are adequate for the full suite of diadromous species.

As part of compliance for Article 34 of the original license, the licensee filed as-built drawings of the existing fish passage facilities (Accession No. 19860902-0215). Within this abbreviated drawing set, drawing number 344D-PC001, 3844D-FC001, and 3844D-FC004 show topographic surveys for portions of the bypass reach. However, the drawings do not document the accuracy and precision of the survey, do not show the majority of the bypass reach, and are otherwise illegible.

Since agreeing upon the current zone-of-passage flows during the original license, there have been developments in topographic survey capabilities, a better understanding of the hydraulic requirements of diadromous species, multi-dimensional hydraulic modeling capabilities, and an increased need to pass fish at the spillway ladder.

Nexus to Project Operations and Effects

Diadromous fish orient their migration based on the environmental conditions of the river: flow, depth, velocity, and temperature (Goodwin 2014). Project operations affect the environmental conditions in the River, specific to this study request, the bypass reach. Two key hydraulic model outputs from the requested study are depth and depth-averaged velocity, which can be used to determine the likelihood of predation, delay, and the cessation of migration. Evaluating the flow fields in the bypass reach under different spill conditions will assist in the consultation process for determining an appropriate zone-of-passage flow in the bypass reach to optimize fish passage

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at the project. These data will also contribute to the development of an administrative record in support of a potential settlement agreement, Section 18 fishway prescriptions, or 10(j) recommendations.

Methodology Consistent with Accepted Practice

We proposed the following methodology to accomplish the five objectives and ultimately the goal of the study, to determine zone-of-passage flows for the bypass reach.

Topographic survey

The bypass reach area is large, making traditional topographic survey methods laborious and costly. We recommend using Light Detection and Ranging (LiDAR) methods with limited traditional surveying. Outside of the fish passage season and during a river flow when the project is in control of the River, the bypass reach will be mostly dewatered. At this time, a licensed surveyor can fly the area to collect LiDAR data. Once this data is processed, traditional methods will fill in the gaps (e.g., pooled water areas, under bridges). The topographic survey shall be of sufficient resolution and quality to complete the remaining objectives.

Two-dimensional hydraulic model

There are many two-dimensional hydraulic models that are acceptable for accomplishing the goal of this requested study, many of which are open source. We are not requiring one model over the other, but Boott should understand and document the limitations of the modeling software used. At a minimum, the modeling output should produce depth-average velocity and depth for each cell in the mesh. The modeling domain shall be of sufficient size and mesh to delineate a zone of passage through the entire length and width of the bypass reach.

Calibration flows

The licensee should collect calibration data by spilling a minimum of two flows from the Pawtucket dam. The calibration flows should bracket the range of simulated flows in the study. We recommend 300 cfs for the low flow as it represents the current lowest operation flow for the fish ladder. For the high calibration flow, we recommend collecting data near the high fish passage design flow (i.e., the 5 percent exceedance value for the migratory period of record) which is approximately 26,000 cfs in the Merrimack River (bypass flow would be approximately 17,000 cfs with full project operation). Boott should collect calibration data (depth-averaged velocity and depth) with an Acoustic Doppler Current Profiler (ADCP) at a minimum of four cross sections, including the downstream boundary condition and use the ADCP in locations spread evenly throughout the bypass which are less turbulent.

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Additional flow simulations

After calibrating the model, additional bypass flows should be simulated (and agreed upon with the natural resource agencies), including 500 cfs, 1,000 cfs, and up to the high calibration flow. The additional simulations should represent the full range of hydraulic conditions in the bypass reach from the low to high fish passage design flow.

Zone-of-passage determination

The model output should be used to delineate a zone-of-passage pathway for each of the modeled flows. To determine the zone of passage, we recommend Boott use the SprintSwim model developed by U.S. Geological Survey researchers (Haro et al. 2004).

Level of Effort/Cost, and Why Alternative Studies Will Not Suffice

The licensee should be able to finish the bypass zone-of-passage study in one year depending on seasonal flow conditions. The level of effort and cost is commensurate with a project the size of the Lowell facility and the likely license term. No alternatives are proposed.

REFERENCES

Goodwin, R. A., M. Politano, J.W. Garvin, J.M. Nestler, D. Hay, J.J. Anderson and M. Timko. 2014. Fish navigation of large dams emerges from their modulation of flow field experience. Proceedings of the National Academy of Sciences. p. 201311874.

Haro, A., T. Castro-Santos, J. Noreika and M. Odeh. 2004. Swimming performance of 716 upstream migrant fishes in open-channel flow: a new approach to predicting passage through velocity barriers. Canadian Journal of Fish and Aquatic Science. 61: 1590-1601.

ATTACHMENT D

FEDERAL ENERGY REGULATORY COMMISSION
Office of Energy Projects
Division of Dam Safety and Inspections – New York Regional Office
19 West 34th Street, Suite 400
New York, NY 10001
Telephone No. (212) 273-5900 **Fax No. (212) 631-8124**

April 30, 2008

Re: Hydropower Projects Inspection and Compliance

To the Party Addressed:

Staff from this office conduct periodic inspections to ensure that hydropower projects licensed or exempted by the Federal Energy Regulatory Commission (FERC) are properly operated and maintained in compliance with license and exemption terms and conditions.

During FERC staff dam safety inspections, the project's structural features are inspected and all matters of dam safety, operations, maintenance and compliance are reviewed and discussed with the licensee or exemptee. During FERC Environmental and Public Use Inspections (EPUI), recreation, fish, and wildlife requirements are specifically addressed. Any concerns or questions resulting from the inspections are discussed at the projects, with follow-up letters as necessary.

Since an important part of these inspections includes an assessment as to whether the projects are being operated and maintained in compliance with their license or exemption terms and conditions, it is requested that you provide this office with information relative to any project-specific concerns within 45 days from the date of this letter. Following receipt of this information, we will contact your staff as appropriate.

To help ensure that projects are operating in compliance with the licenses and exemptions, and to improve liaison among the licensees, exemptees, FERC staff, and resource agencies, we will continue to notify you of each EPUI and dam safety inspection, as appropriate, by forwarding a copy of our inspection confirmation letter to your agency. Because of our workload and the necessity to maintain tight scheduling during the inspection season, the scheduled time and dates for the inspections cannot be changed. If your representatives plan to accompany our staff on the inspection, they should contact our inspector sufficiently in advance of the scheduled inspection so that arrangements can be made to accommodate all participants, and they should arrive at the site at the scheduled time. We also wish to emphasize that, should your representative have any questions about matters of compliance or project operations during the inspections, these questions or concerns should be directed to the FERC representative who has the responsibility to ensure compliance with the license or exemption. We will then take whatever action is appropriate to resolve any problems or answer your questions.We appreciate your continued cooperation in our inspection program and look forward to working with you. If you have any questions, please call me at (212) 273-5930.

Sincerely,

Peter R. Valeri

Peter R. Valeri
Acting Regional Engineer

File FERC
Boott Hydro

United States Department of the Interior

NATIONAL PARK SERVICE
Lowell National Historical Park
67 Kirk Street
Lowell, Massachusetts 01852-1029

IN REPLY REFER TO:

June 12, 2008

Peter R. Valeri
Acting Regional Engineer
Office of Energy Projects
Division of Dam Safety and Inspections
Federal Energy Regulatory Commission
19 West 34th Street, Suite 400
New York, NY 10001

Re: FERC Project no. 2790-000, Lowell, MA

Dear Mr. Valeri:

Thank you for the opportunity to comment on the above referenced hydropower project located on the Lowell Canal System in Lowell, MA by Enel/Boott Hydropower, Inc.

We do work with this licensee on a regular basis to accommodate the canal tours offered by the Lowell National Historical Park and on protection of the historic resources that make up the Lowell Canal System, which is a National Engineering Landmark and on the National Register of Historic Places, as well as being located fully within the Lowell National Historical Park, a unit of the National Park Service, as designated by P. L. 95-290, Title I § 103.

First and foremost, we wish to reinforce the requirements enacted in the law establishing the National Park in Lowell, which are applicable to FERC actions:

§ 410cc-12. **Consultations, cooperation, and conduct of activities by Federal entities; issuance of licenses or permits by Federal entities**

(a) "Any federal entity conducting of supporting activities directly affecting the park or preservation district shall-

(1) Consult with, cooperate with, and to the maximum extent practicable, coordinate its activities with the Secretary and the Commission; and

(2) Conduct or support such activities in a manner which (A) to the maximum extent practicable is consistent with the standards and criteria established pursuant to section 410cc-32(e) of this title, and (B) will not have an adverse effect on the resources of the park or preservation district.

(b) No Federal entity may issue any license or permit to any person to conduct an activity within the park or preservation district unless such entity determines that the proposed activity will be conducted in a manner consistent with the standards and criteria established pursuant to section 410cc-32(e) of this title and will not have an adverse effect on the resources of the park or preservation district.

The Commission referenced in the law is the Lowell Historic Preservation Commission which is defunct, but whose legal obligations have been assumed by the Lowell National Historical Park. The Secretary reference is the Secretary of the Interior, under which the Lowell National Historical Park operates.

The National Park's primary concerns fall within two categories:

1. Operation of National Park canal-related programs in a safe manner and allow for consistent public programming based on the Park's annual operating program.
2. Preservation of the Canal and related structures that make up the Lowell Canal system.

1. Operation of National Park canal related programs in a safe and responsive manner.

Article 33, Section 7 of the License calls for "the Advisory Council on Historic Preservation to review and comment upon any future actions related to the project that would change the mean seasonal water levels in the canal system or that would impair navigability in the system."

a. Maintaining appropriate water levels for tour operations: The National Park Service has made considerable public investment in the development of the Canalway that includes public walkways and boat tour operations. The main attraction for visitors to come to Lowell National Historical Park is to experience Lowell by boat via the canals. The park collects a fee for the general public boat tours as well as a school group fee that is charged for school's participating in our daylong programs. The school programs in particular, are programmed well in advance. The inability to use the canals because of unexpected water levels drops causes great concern due to the loss of revenue and credibility to a nationally recognized education experience.

At the current level of the river (June 2008) National Park tour boats cannot enter the river pond for two reasons: 1) because of the removal of the flashboards, the water level is too low to operate above the guard lock chambers of both the Northern and Pawtucket Canals a and in the Merrimack River above the Pawtucket Dam, and 2) the trash boom is still across the mouth of the Pawtucket Canal. Because the water is so low, National Park Maintenance crews cannot get a work boat into the river to open up the boom. If the water levels are not raised soon this will have a major impact in the park tour operation for the beginning of our full summer season.

b. Timely Communication of Changing Water Levels for Safe Tour Operations: The park is respectful of the operational requirements for Boott Hydro but there needs to be a more formalized agreement/plan in place to ensure that changes in operation that effect water levels are communicated to the park to ensure that there will not be damage to property, injury to park visitors that use the canals, and a loss of revenue and integrity to the visitor's experience. As boat tours expand in the canal system, as they have by the restoration of the Swamp Locks this year, certain bridge clearances have become tighter which requires slower more deliberate changes in the canal surface elevations to help assure the safety of the boat passengers. Unsafe operational procedures which quickly change canal levels without proper notice need to be reduced to a minimum with continual effort made to eliminate them.

c. **Impairing Navigability:** Many of the Boott Hydro owned bridges that the Park visitors pass under are in poor condition. This year the Pawtucket Street Bridge over the Northern Canal by the Hydro Plant is in particularly rough shape with the reinforced concrete walkways on each side sending concrete chunks falling to the lock chamber below. This condition makes it unsafe for the Park to exercise its right to run boat tours and open the walkway under the bridge without some protective scaffolding type structure or heavy duty netting to protect Park visitors from the falling concrete. Similarly, the Pawtucket Street Bridge over the Upper Pawtucket Canal has some exposed reinforcing and deteriorating concrete although not to the extent of the bridge over the Northern Canal. Lastly, the Broadway Street Bridge over the Pawtucket Canal requires constant vigilance in order to prevent an unsafe condition for Park visitors.

d. **Accommodating Public Use; Operation of Surge Gate:** The Commonwealth of Massachusetts acquired Recreation and Transportation Rights to sections of the Lowell Canal System, which have been made available to the National Park by easements provided by acts of the State Legislature. The National Park and other city and state agencies concurred with installation of a surge gate in the Northern Canal by the Licensee based on a stated, if not written, understanding that adding this structure would increase recreation access. However, Licensee's policy of locking down the surge gate "for safety reasons" whenever there are tours scheduled or walkway access is occurring along that canal negates what we were given to believe was the purpose of the surge gate. In other words, "Why did the surge gate get built if it's not operational when the public has access?" We understood that boating and pedestrian safety would be enhanced by having the surge gate operational at the times of public use and that the time of pedestrian access could potentially be extended as well.

2. **Preservation of the Canal and related structures that make up the Lowell Canal system.**

In the Cultural Resources section of the FERC License, mitigation is defined in order to address potential adverse effects of the original plant development to the Locks and Canal Historic District. However, this mitigation does not allow inconsistent actions <u>after</u> the date of the license that could result in adverse effects to the historic resources of the Lowell Canal System. Several past and proposed actions should be subjected to appropriate reviews:

a. **Overtopping The Great River Wall:** As a result of running the water at high levels within the Northern Canal, overtopping, extended surcharge loading, and lack of maintenance of the Great River Wall resulted in a failure of a section of that wall March 15, 1994.While repairs were accomplished with historical sensitivity, the National Park Service continues to be concerned that practice could result in further wall failures that would constitute an adverse effect to the historic district. There is a need to adjust the operating levels in this canal to assure that overtopping does not occur and historic resources are protected.

b. **Pawtucket Dam:** Preservation of the historic Pawtucket Dam is a major preservation objective of the Lowell National Historical Park. We have communicated on several occasions with the Licensee in response to proposals to install a Bladder Dam system. The Pawtucket Dam is the reason the city of Lowell, MA exists and a fundamental element of the historic resources that justified the creation of a National Park here. The National Park will continue to oppose a Bladder Dam solution on this historic site.

c. **Flashboards & Pins:** As FERC is aware, there are great concerns in the community that the flashboard system is not working in the same manner as in the past and there is a belief that the pins and/or the flashboard system have been strengthened to prevent the purposeful bending over of the flashboards to reduce upstream flooding. We note that Boott Hydro was issued a permit by the Lowell Historic Board in 2000 to drill a new row of flashboard pin holes in the capstones, which Boott Hydro represented in that permit application as "moving the hole location" so as "to decrease or eliminate capstone breaking problems." As actually carried out, it now appears that many more pin holes were made in the new row than in the earlier two rows closer to the face of the dam. In addition to other problems this situation has been causing, we are especially concerned that this practice of more closely spaced pins could result in damage to the capstones of the Pawtucket Dam. The National Park has not been included in any correspondence on this issue locally and request that FERC not take any action to finalize an agreement with regard to the pins and flashboards without consultation with us and a determination as to whether further Section 106 action is needed. We are also concerned that the unilateral change from using smaller boards to plywood sheets as flashboards some years ago occurred without such consultation and may have resulted in higher water levels and the risk of additional damage to historic resources.

On behalf of the Lowell National Historical Park, I would like to thank you for consideration of these issues and would respectfully request a meeting to review them with you or your staff so that proper procedures will be in place going forward to assure that the power generation can occur without the impacts described above. I look forward to hearing from you at your earliest convenience. I may be reached at 978-275-1700 or Michael_creasey@nps.gov

Sincerely,

Michael Creasey
Superintendent

cc: Bernard Lynch, City Manager
U. S. Rep. Niki Tsongas
ENEL/Boott Hydropower, Inc.

BOOTT HYDROPOWER, INC.
A SUBSIDIARY OF ENEL NORTH AMERICA, INC.

Energy in tune with you.

Enel North America, Inc.

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Via eFiling

August 4, 2008

Peter R. Valeri, P.E.
Regional Engineer
Federal Energy Regulatory Commission
19 West 34th Street, Suite 400
New York, NY 10001

Re: Lowell Hydroelectric Project (FERC No. 2790-MA);
Response to National Park Service letter.

Dear Mr. Valeri:

We are in receipt of your letter of June 20, 2008 in which you requested our response to a letter from the National Park Service (NPS) dated June 12, 2008, which raised a number of issues regarding the perceived impact of the Lowell Hydroelectric Project on the NPS' operations at the Lowell National Historical Park. For the record, we note that the NPS' letter is dated the day before the June 13 Operations Inspection of the project by your staff, which inspection was attended by an NPS representative. None the concerns listed in the NPS' letter were voiced by the NPS representative during the inspection.

Our response to each of the concerns raised by the NPS follow:

1. Operation of National Park canal related programs in a safe and responsive manner.

Article 33, Section 7 of the License calls for "the Advisory Council on Historic Preservation to review and comment upon any future actions related to the project that would change the mean seasonal water levels in the canal system or that would impair navigability in the system."

Response: There presently are no future actions proposed by BHI which would change the mean seasonal water levels in the canal system, that would impair navigability, or which would otherwise invoke review and comment by the Advisory Council on Historic Preservation under Article 33.

a. ***Maintaining appropriate water levels for tour operations:***
The National Park Service has made considerable public investment in the development of the Canalway that includes public walkways and boat tour operations. The main attraction for visitors to come to Lowell National Historical Park is to experience Lowell by boat via the canals. The park collects a fee for the general public boat tours as well as a school group fee that is charged for school's participating in our daylong programs. The school programs in particular, are programmed well in advance. The inability to use the canals because of unexpected water levels drops causes great concern due to the loss of revenue and credibility to a nationally recognized education experience.

At the current level of the river (June 2008) National Park tour boats cannot enter the river pond for two reasons: 1) because of the removal of the flashboards, the water level is too low to operate above the guard lock chambers of both the Northern and Pawtucket Canals a and in the Merrimack River above the Pawtucket Dam, and 2) the trash boom is still across the mouth of the Pawtucket Canal. Because the water is so low, National Park Maintenance crews cannot get a work boat into the river to open up the boom. If the water levels are not raised soon this will have a major impact in the park tour operation for the beginning of our full summer season.

Response: The Lowell canal system has multiple uses and operating conditions based on river flows and corresponding river elevations which are neither predictable nor constant. BHI manages and maintains canal system water levels to the best of its ability within the limits as agreed to with the NPS. In many cases the target operating band is relatively narrow, constrained by the minimum level necessary to pass tour boats through the locks and the maximum level necessary to allow for safe passage of tour boats under bridges. Any adjustments necessary to maintain the proper water levels and system water balance typically take time to achieve and must be done gradually.

BHI has the right to maintain its project works, including the flashboards, and to the extent feasible attempts to accommodate the needs of other water and canal users, including the NPS, in its operations and maintenance planning. BHI provides ample prior notice of all water level changes to the NPS and other affected parties.

With respect to the low water levels experienced during 2008, BHI removed the flashboards from the crest of the Pawtucket Dam on May 30, 2008 in direct response to a Commission order. BHI expeditiously undertook the necessary corrective measures, and after gaining Commission approval and purchasing new flashboard pins, completed reinstallation of the flashboards on June 20, 2008. BHI immediately began to refill the headpond while maintaining the project's downstream minimum flow requirement, and restored the headpond to normal levels on June 25, 2008. Shortly after refilling the impoundment, damage to the flashboards occurred as a result of elevated river flows and debris impact. Had BHI not repaired the flashboards quickly, the impoundment could not have been maintained near normal levels, due to low river inflows, likely resulting in impacts to recreational use upstream of the Pawtucket Dam. Notifications were made that the impoundment was to be lowered again for the repairs which were accomplished on July 10, 2008.

b. ***Timely Communication of Changing Water Levels for Safe Tour Operations:***
The park is respectful of the operational requirements for Boott Hydro but there needs to be a more formalized agreement/plan in place to ensure that changes in operation that effect water levels are communicated to the park to ensure that there will not be damage to property, injury to park visitors that use the canals, and a loss of revenue and integrity to the visitor's experience. As boat tours expand in the canal system, as they have by the restoration of the Swamp Locks this year, certain bridge clearances have become tighter which requires slower more deliberate changes in the canal surface elevations to help assure the safety of the boat passengers. Unsafe operational procedures which quickly change canal levels without proper notice need to be reduced to a minimum with continual effort made to eliminate them.

Response: BHI keeps the NPS and other affected parties informed of any planned changes in operations that would impact river or canal water levels. Other than for emergencies or in unusual circumstances, BHI provides at least a 24 to 48 hour advance notification of any major water level changes (e.g., drawdowns) by email or telephone. For planning purposes, BHI has requested and obtained the NPS' anticipated event schedule which, to the extent possible, BHI attempts to accommodate by postponing scheduled maintenance canal draw downs to avoid conflicts.

Canal water surface elevations and bridge clearances are addressed in BHI's Revised Report on Recreational Resources, filed pursuant to license Article 38, which included a canal system water elevation maintenance plan. BHI's Article 38 filing was approved by the Commission on September 12, 1984. As noted above, in many cases the target operating band for the lower canal system is relatively narrow, constrained by the minimum level necessary to pass tour boats through the locks and the maximum level necessary to allow for safe passage of tour boats under bridges. The lower canal system below the Swamp Locks has siphon outlets to assist in maintaining the water surface elevations within this narrow elevation band.

c. ***Impairing Navigability:***

Many of the Boott Hydro owned bridges that the Park visitors pass under are in poor condition. This year the Pawtucket Street Bridge over the Northern Canal by the Hydro Plant is in particularly rough shape with the reinforced concrete walkways on each side sending concrete chunks falling to the lock chamber below. This condition makes it unsafe for the Park to exercise its right to run boat tours and open the walkway under the bridge without some protective scaffolding type structure or heavy duty netting to protect Park visitors from the falling concrete. Similarly, the Pawtucket Street Bridge over the Upper Pawtucket Canal has some exposed reinforcing and deteriorating concrete although not to the extent of the bridge over the Northern Canal. Lastly, the Broadway Street Bridge over the Pawtucket Canal requires constant vigilance in order to prevent an unsafe condition for Park visitors.

Response: BHI owns and maintains several bridges which provide public access across the canal system throughout downtown Lowell. All of these bridges are specifically excluded from the project boundary as shown on the approved Exhibit G-2, and furthermore are not described as project features within the Lowell Project's license. These bridges are therefore not subject to the Commission's jurisdiction.

Nevertheless, BHI has a program of continually monitoring, performing engineering evaluations of and repairing its bridges. As was discussed during a meeting with the NPS in early June, BHI anticipates that repair work will be performed on each of the bridges referenced above during 2008. As it has recently done during previous work on its bridges, BHI will provide the NPS with ample advance notice of its anticipated work schedule, and will ensure that its bridge repair contractors make special provisions to not impede tour boat operations and canal navigability during construction activities.

d. ***Accommodating Public Use; Operation of Surge Gate:***

The Commonwealth of Massachusetts acquired Recreation and Transportation Rights to sections of the Lowell Canal System, which have been made available to the National Park by easements provided by acts of the State Legislature. The National Park and other city and state agencies concurred with installation of a surge gate in the Northern Canal by the Licensee based on a stated, if not written, understanding that adding this structure would increase recreation access. However, Licensee's policy of locking down the surge gate "for safety reasons" whenever there are tours scheduled or walkway access is occurring along that canal negates what we were given to believe was the purpose of the surge gate. In other words, "Why did the surge gate get built if it's not operational when the public has access?" We understood that boating and pedestrian safety would be enhanced by having the surge gate operational at the times of public use and that the time of pedestrian access could potentially be extended as well.

Response: Following the partial failure of the bayboard section of the canal wall in 1994, BHI undertook feasibility studies to determine the best option for surge suppression in the Northern Canal. A hydraulically-activated surge control gate was installed in January, 1997 and was fully automated in 1999. The surge gate is designed to automatically open when the E.L. Field station is tripped off-line to mitigate overtopping of the Great River Wall to provide safe pedestrian access to the wall and island areas, to prevent flooding of the historic Northern Gatehouse, and to prevent undermining and/or weakening of the gatehouse and portions of the Northern Canal. The gate was never intended to enhance boating in the Northern Canal, and in fact raises the safety concern that should the station trip off-line while the NPS is operating tour boats on the Northern Canal, the boat and passengers could be drawn through the open surge gate. Because it has been demonstrated that the transient wave produced on unit trip is not large enough to overtop the Great River Wall when the Northern Canal flow is less than 3,500 cfs, the gate may be temporarily deactivated under such conditions. Thus, NPS and BHI have agreed that boating tour operations can occur on the Northern Canal only if the canal flow is less than 3,500 cfs and if the surge gate is locked out and tagged out to prevent automatic opening. This lock-out/tag-out procedure is jointly undertaken by BHI and NPS personnel.

There are also circumstances under which BHI can not deactivate the surge gate in order to protect worker safety and/or to ensure compliance with the project's minimum flow requirement. For example, during any work on the crest of the Pawtucket Dam, such as during flashboard maintenance, the surge gate must remain active to prevent spillage from occurring in the event of a unit trip. Likewise, while the impoundment is being refilled following flashboard repairs the gate must remain active to ensure minimum flow compliance should the E.L. Field Station trip off-line. In such situations BHI notifies the NPS and advises against any boat access to the Northern Canal until normal operations resume. BHI has never denied pedestrian access to the Canal Walkway due to inactivation of the surge gate, and has only recommended that the NPS restrict such access due to general safety concerns not related to the surge gate (e.g., lack of appropriate safety fencing).

2. Preservation of the Canal and related structures that make up the Lowell Canal system.

In the Cultural Resources section of the FERC License, mitigation is defined in order to address potential adverse effects of the original plant development to the Locks and Canal Historic District. However, this mitigation does not allow inconsistent actions after the date of the license that could result in adverse effects to the historic resources of the Lowell Canal System. Several past and proposed actions should be subjected to appropriate reviews:

a. Overtopping The Great River Wall:

As a result of running the water at high levels within the Northern Canal, overtopping, extended surcharge loading, and lack of maintenance of the Great River Wall resulted in a failure of a section of that wall March 15, 1994. While repairs were accomplished with historical sensitivity, the National Park Service continues to be concerned that practice could result in further wall failures that would constitute an adverse effect to the historic district. There is a need to adjust the operating levels in this canal to assure that overtopping does not occur and historic resources are protected.

Response: There is no need to adjust the water level in the Northern Canal to prevent overtopping, because overtopping is prevented by the surge gate. Following the 1994 Northern Canal wall failure, BHI installed the surge gate, as described above, to prevent to overtopping of the Great River Wall when the two generating units at the E.L. Field Station are suddenly tripped offline. During normal operations BHI maintains the water level within the Northern Canal at or near El. 91.5 with the surge gate engaged in automatic mode. The only time the Great River Wall can become overtopped is when the Northern Canal flow is greater than 3,500 cfs (i.e., more than the capacity of one unit at the E.L. Field Station) while the surge gate is disengaged from automatic mode. Overtopping of the Great River Wall may also occur when NPS personnel inadvertently leave the lock chamber open at the Northern Gatehouse, which allows the Northern Canal to rise to the same level as the project impoundment.

b. Pawtucket Dam:

Preservation of the historic Pawtucket Dam is a major preservation objective of the Lowell National Historical Park. We have communicated on several occasions with the Licensee in response to proposals to install a Bladder Dam system. The Pawtucket Dam is the reason the city of Lowell, MA exists and a fundamental element of the historic resources that justified the creation of a National Park here. The National Park will continue to oppose a Bladder Dam solution on this historic site.

Response: Historical preservation is but one of many resource areas which would need to be considered in any assessment of installing a "Bladder Dam" or inflatable crest gate system on the crest of the Pawtucket Dam. Such a system would have positive benefits for a wide range of resource areas including water management, fish passage, upstream recreation, reduction of upstream backwatering impacts, worker safety, and most importantly with respect to the NPS' concerns, protection of the historical structure from debris and ice.

BHI does not agree that an inflatable crest gate system would be inconsistent with the historical nature of the Pawtucket Dam. The history of Lowell is founded on continual innovation in hydropower technology, most notably the numerous developments by James B. Francis. The construction of the E.L. Field powerhouse along the historic canal system juxtaposes these historic technologies with more modern technologies. If determined to be feasible, installation of a crest gate system on the Pawtucket Dam would be in keeping with this line of innovation. The compatibility of an inflatable crest gate system mounted on a historic dam is clearly demonstrated immediately downstream at the historic Great Stone Dam at the Lawrence Project (P-2800).

Should BHI actively pursue the installation of an inflatable crest gate system on the Pawtucket Dam in the future, an application for amendment of license would be filed with the Commission. In preparing any such application BHI would conduct the necessary consultation with all appropriate agencies, including the Advisory Council on Historic Preservation, the Lowell Historic Board and the NPS. BHI has already consulted with the NPS on this subject on two separate occasions.

c. ***Flashboards & Pins:***

As FERC is aware, there are great concerns in the community that the flashboard system is not working in the same manner as in the past and there is a belief that the pins and/or the flashboard system have been strengthened to prevent the purposeful bending over of the flashboards to reduce upstream flooding. We note that Boott Hydro was issued a permit by the Lowell Historic Board in 2000 to drill a new row of flashboard pin holes in the capstones, which Boott Hydro represented in that permit application as "moving the hole location" so as "to decrease or eliminate capstone breaking problems." As actually carried out, it now appears that many more pin holes were made in the new row than in the earlier two rows closer to the face of the dam. In addition to other problems this situation has been causing, we are especially concerned that this practice of more closely spaced pins could result in damage to the capstones of the Pawtucket Dam. The National Park has not been included in any correspondence on this issue locally and request that FERC not take any action to finalize an agreement with regard to the pins and flashboards without consultation with us and a determination as to whether further Section 106 action is needed. We are also concerned that the unilateral change from using smaller boards to plywood sheets as flashboards some years ago occurred without such consultation and may have resulted in higher water levels and the risk of additional damage to historic resources.

Response: BHI has previously submitted evidence to the Commission demonstrating that the flashboard and pin materials in use today are the same as those used prior to commercial operation of the Lowell Project in 1985. Furthermore, the NPS' charge that the use of plywood flashboards instead of "smaller boards" may have resulted in higher water levels and damage to the Pawtucket Dam is without basis. The strength of the flashboard system and the height of failure are controlled by the spacing and strength of the supporting pins and have little, if anything to do with the material used for flashboard panels. We note that in their review of BHI's updated flashboard design specifications, Commission staff did not raise any concerns over the use of plywood flashboards on the Pawtucket Dam, and in fact approved same in the Commission's order authorizing re-installation of the flashboards dated June 4, 2008.

Contrary to the NPS's claim there are **fewer**, not more, holes in the row of flashboard pin holes now used by BHI than exist in the original alignment. The flashboard pin socket holes have been re-drilled several times over the dam's 150+ year history as the original holes have become worn or broken. These holes are generally aligned in three rows running along the dam's axis: 1) the original alignment of 776 holes drilled approximately 6 inches upstream from the downstream face of the capstones; 2) a row of 333 more widely spaced holes drilled approximately 12 inches back from the downstream face of the capstones, which were historically used as a safety measure to tie off workboats when working on the dam crest; and 3) a total of 723 holes in the row currently used by BHI which are drilled approximately 16 inches upstream from the downstream face of the capstones. As noted by the NPS, this latter alignment of pin socket holes includes the 660 holes drilled by BHI in 2000, to prevent damage to the capstones and to preserve the dam. As now installed, BHI has selectively eliminated flashboard pins such that only 588 of the holes in the back row are being used, in order to achieve the 20-inch average pin spacing approved by the Commission.

Thank you for this opportunity to clarify and address the issues raised by the National Park Service. Please do not hesitate to contact me at (978) 681-1900, extension 809 if you have any questions concerning any of the topics addressed above.

Sincerely,
Boott Hydropower, Inc.

/S/

Kevin M. Webb
Environmental Affairs Coordinator

cc: M. Creasey, NPS
V. Engel, BHI

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ATTACHMENT E

Project Scoping Report

Task Order #P17PD03094; Contract #P15PC00036; PMIS #225866

Northern Canal Waste Gatehouse

13 November 2017

EYP/

EYP Architecture & Engineering, PC
Independence Wharf
470 Atlantic Avenue, 7th Floor
Boston, MA 02210

T 617 305 9800
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NATIONAL PARK SERVICE

Introduction

On 17 August 2017, architects and engineers from EYP (Eric Ward, RA; Rebecca Young, RA; and Mark Kanonik, PE) visited the site to observe the general condition of the Northern Canal Waste Gatehouse. On 19 and 20 October 2017, Mark Kanonik and Chuck Volans of EYP again visited the site to observe the general condition of the building. The Gatehouse is a single-story, heavy-timber-framed building that measures approximately 70' by 15' in plan. The building was built circa 1872 atop a dam that was built circa 1847 and houses the canal gates, including the machinery that operates the gates. Refer to Photograph 1 for additional information.

We understand that the canals and gatehouse structure are owned by the Commonwealth of Massachusetts but maintained by Lowell National Historical Park and that the operational machinery within the gatehouse is controlled and maintained by Enel Green Power North America, Inc. It is our understanding that the wood siding, the roofing membrane, and a portion of the sill at the northeast corner of the building were replaced in the 1980s by NPS staff. At an unknown time in the past, supplemental steel shoring was installed to support both the south and north walls of the building.

Please note that no calculations were performed to determine the load-carrying capacity of any of the elements of the gatehouse building; furthermore, no destructive tests were performed, and no material samples were collected. Lastly, no evaluations of any of the utilities inside or outside of the building were made.

Observations

The Northern Canal Waste Gatehouse is a single-story, heavy-timber-framed, building that measures approximately 70' by 15' in plan. The gatehouse building is built atop a horizontally-curved masonry dam that separates the Northern Canal above from the Merrimack River below. The sills of the sidewalls do not bear directly on the dam; the sill of the north (downstream) wall bears on iron posts which are themselves bolted into the masonry dam, and the sill on the south (upstream) side bears on a wooden ledger that was bolted into the masonry dam. The sills of the endwalls bear directly on the dam.

The roofing is not original and is estimated to be about 30 years old; while it appears to be generally watertight, the edges of the roof membrane are delaminating around the perimeter of the roof. Refer Photograph 2 for additional information. The roofing has reached the end of its useful life and should be replaced. The siding appears to be original, but some siding boards at the eastern end of the north wall were replaced about 30 years ago. The siding is in remarkably good condition except for a few missing siding boards at the eastern end of the north wall. Refer to Photograph 3 for additional information. The paint is reaching the end of its useful life, and the siding should be repainted.

Except for the sills under the north and south walls, the wood framing is in very good condition. The sills themselves are in very poor condition. The eastern end of the north sill was replaced about 30 years ago, but it is now completely missing in some areas. Refer to Photographs 3 and 4 for additional information.

It appears that the normal operating elevation of the Northern Canal was raised when the hydroelectric power plant was installed to the east of the gatehouse building. Photograph 5 (Historic American Engineering Record [HAER] Photograph MA-8C-2, taken in either 1974 or 1975) shows the south face of the dam and gatehouse when the Northern Canal was dewatered and the walkway decking was removed. Photograph 6 is a close-up of the southeast corner of the building, showing the heavy timber ledger which supports the south (upstream) sidewall. Staining of the large masonry units under the gatehouse, as well as vegetation growing in a few masonry joints, indicate that the elevation of the Northern Canal was typically about 4 feet below the top of the dam. However, it appears that the "normal" canal elevation is now only a few inches below the top of the dam, and the heavy timber ledger is now nearly constantly partially submerged. Refer to Photograph 5 for additional information. Not surprisingly, the heavy timber ledger and the wall sill plate atop the ledger are badly deteriorated and are completely missing in some areas. Refer to Photographs 7 and 8 for additional information. At an unknown time in the recent past, 12 shoring posts (with shoring beams and cable ties) were installed throughout the gatehouse building, presumably to redistribute the load away from the deteriorated walls. Given the level of deterioration of the wood framing, it is possible that the building would have partially collapsed if these shoring posts were not installed. Please note that it is impossible to repair the deteriorated heavy timber ledger and south wall sill to match the original design without permanently lowering the elevation of the canal; we assume that this is not feasible, so an alternate method to repair / restore the south (upstream) sidewall will be detailed in the construction documents that are currently progressing.

HAER Photograph MA-8C-2 (Photograph 5) appears to indicate several open joints in the larger masonry units at the top of the dam, directly underneath the eastern half of the gatehouse building. Inside the gatehouse building, the capping stones atop the dam are separated and have settled a couple of inches, and water can be both seen and heard flowing through the open joints. At some time in the recent past, steel staples were installed in the capping stones, presumably to stop the stones from separating further. Refer to Photograph 9 for additional information. Vegetation is growing on the north face of the dam, and a significant quantity of water can be seen flowing through the side of the dam. Refer to Photograph 10 for additional information. It seems very likely that the water flowing through the dam is eroding the mortar joints, thus causing both the lateral movement and the settlement seen in the capping stones at the top of the dam. It seems very unlikely that the issues in the capping stones are caused by uneven settlement of the dam as a whole since bedrock is visible throughout the bed of the Merrimack River. We understand that NPS does not "own" the dam and is not, therefore, responsible for maintaining and/or repairing the dam; however, we recommend that NPS share our concerns expressed in this Report with the Enel Green Power North America, Inc., at which point they may choose to commission a detailed engineering study. Our concerns expressed in this Report are based solely on very limited information; it should be noted that we did not perform an analysis of the dam to determine its load-carrying capacity, nor did we perform any destructive tests or any investigations of the dam.

Recommendations

The deterioration noted in the bases of the walls is adversely affecting the structural stability of the gatehouse building, although it is not yet affecting the operation of the gates. If no action is taken to address these areas of deterioration, the deterioration will continue to worsen until the building settles or shifts to such an extent that the operation of the canal gates is compromised. Consequently, we recommend the following:

1. Shore the building until all loads are removed from the wall framing and/or the temporary shoring posts.
2. Remove all deteriorated sections of the wall framing (such as wall studs, sill plates, etc.) at the north and south walls, estimated to be about 6 to 12" above the top of the dam.
3. Install new steel framing to support the north wall.
4. Install additional steel framing to support the south wall.
5. Provide wood decking atop the steel framing along both the south and north walls.
6. Remove all temporary shoring posts, beams, and cables.
7. Remove and replace the roofing with an adhered EPDM roof membrane.
8. Repair all windows on the north wall so that the windows may be opened if desired.

No work will be performed to the gates or the gate-operating machinery, including active utilities serving the gate-operating machinery.

Refer to Appendix A for a Class C cost estimate corresponding to the recommended work listed above.

Photographs

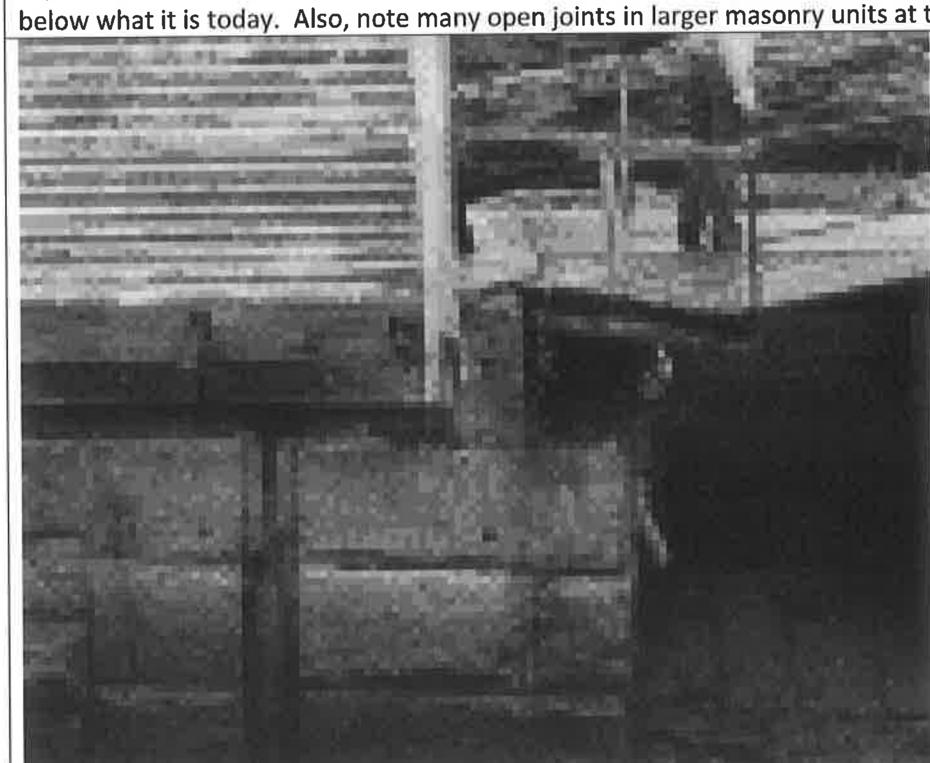
Photograph 1 – Northern Canal Waste Gatehouse, viewed from the southeast.

Photograph 2 – Delaminated edge of roof membrane at northeast corner of roof.

Photograph 3 – Deteriorated / missing sill and missing siding boards at eastern end of north wall; entire building has settled in this area, as evidenced by the downward curvature of the siding boards under the left-most window.

Photograph 4 – Deteriorated / missing sill under eastern edge of north wall; note large gap between dam and wall.

Photograph 5 – HAER Photograph MA-8C-2, taken in 1974 or 1975; note staining in wall and vegetation in joints below gatehouse, indicating that the normal elevation of the Northern Canal was several feet below what it is today. Also, note many open joints in larger masonry units at the top of the dam.

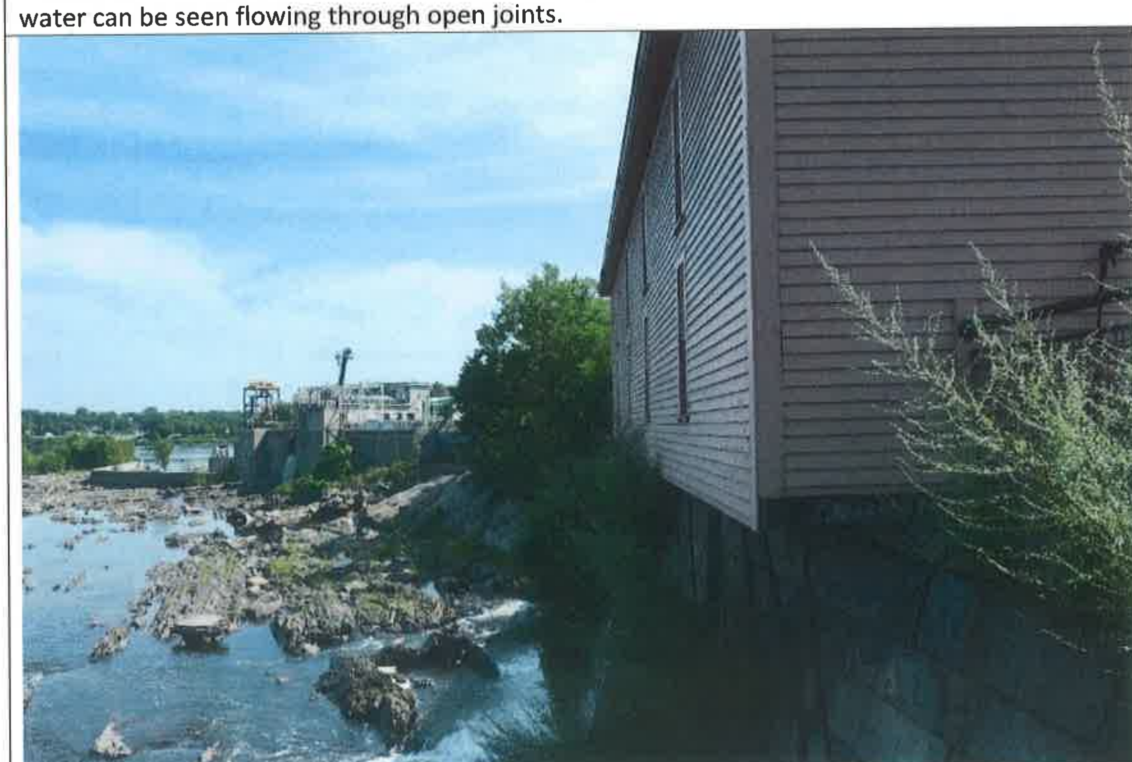


Photograph 6 – Close-up of HAER Photograph MA-8C-2, taken from Photograph 5, showing heavy timber ledger and wall sill.

Photograph 7 – Underside of walkway along south side of gatehouse; the deteriorated sill that is now partially submerged in water is visible in Photographs 5 and 6.

Photograph 8 – Deteriorated heavy timber ledger and wall sill plate at eastern end of south wall.

Photograph 9 – Capping stones atop dam, inside gatehouse building; several units have separated, and water can be seen flowing through open joints.



Photograph 10 – North face of dam and gatehouse building; note vegetation growing on face of dam and significant water flowing through dam.

ATTACHMENT F

PARK PURPOSE

The purpose statement identifies the specific reason(s) for establishment of a particular park. The purpose statement for Lowell National Historical Park was drafted through a careful analysis of its enabling legislation and the legislative history that influenced its development. The park was established when the enabling legislation adopted by Congress was signed into law on June 5, 1978 (see appendix A for enabling legislation and legislative acts). The purpose statement lays the foundation for understanding what is most important about the park.

Lowell National Historical Park preserves and interprets the historic structures and stories of the Industrial Revolution and its legacies in Lowell, serving as a catalyst for revitalization of the city's physical and economic environment and promoting cultural heritage and community programming.

PARK SIGNIFICANCE

Significance statements express why a park's resources and values are important enough to merit designation as a unit of the national park system. These statements are linked to the purpose of Lowell National Historical Park, and are supported by data, research, and consensus. Statements of significance describe the distinctive nature of the park and why an area is important within a global, national, regional, and systemwide context. They focus on the most important resources and values that will assist in park planning and management.

The following significance statements have been identified for Lowell National Historical Park. (Please note that the sequence of the statements does not reflect the level of significance.)

1. Lowell's (economic) success was based in innovation, from manufacturing technology and processes, to new business models, to city planning designed to benefit both industry and the worker. Unique industrial concepts were implemented and demonstrated at a massive scale at the Lowell mills, which served as a model for textile production and industrial cities.

2. A very large proportion of original buildings, structures, and urban landscapes have survived in Lowell's park and preservation district and now are recognized as important historical artifacts. These include the entire 5.6-mile power canal system with its sophisticated dams, locks, and gatehouses, 7 of the original 10 mill complexes, and significant examples of early housing types, institutions, and transportation facilities.

3. The Lowell canal system is nationally recognized as one of the most impressive civil and mechanical engineering achievements of the 19th century because of its grand scale and technological complexity, and is the site of origin for the famed "Francis" turbine. The canal system, used as both a transportation corridor and power source, facilitated the growth of the industrial city.

4. Lowell National Historical Park preserves and interprets the stories and heritage of the people of Lowell, including the early female workforce (aka “mill girls”) and those who came from across the globe seeking opportunities. Today, Lowell’s residents continue to shape the culture of the city and contribute to its revitalization.

5. The collaboration between Lowell National Historical Park and its partners has resulted in the rehabilitation of almost all of the 5.3 million square feet of historic mill space and hundreds of additional buildings in the downtown historic district. This effort continues to serve as a successful example of leveraging public-private partnerships for economic development through historic preservation.

6. Lowell National Historical Park embraces partnerships as an integral approach to accomplishing park and community goals. Lowell National Historical Park serves as a model for leveraging collaborative public-private partnerships and community engagement.

FUNDAMENTAL RESOURCES AND VALUES

Fundamental resources and values (FRVs) are those features, systems, processes, experiences, stories, scenes, sounds, smells, or other attributes determined to warrant primary consideration during planning and management processes because they are essential to achieving the purpose of the park and maintaining its significance. Fundamental resources and values are closely related to a park’s legislative purpose and are more specific than significance statements.

Fundamental resources and values help focus planning and management efforts on what is truly significant about the park. One of the most important responsibilities of NPS managers is to ensure the conservation and public enjoyment of those qualities that are essential (fundamental) to achieving the purpose of the park and maintaining its significance. If fundamental resources and values are allowed to deteriorate, the park purpose and/or significance could be jeopardized.

The following fundamental resources and values have been identified for Lowell National Historical Park:

Water Power System / Canal System. The Lowell National Historical Park boundary includes 9.6 miles of major riverbanks and all 5.6 miles of historic canals in Lowell, all of which comprise the waterpower system that harnessed waters of the Merrimack River to power the city’s mills. In fact, the Merrimack River and its natural attributes dictated the location of the city itself. The water power and canal system includes the Pawtucket, Merrimack, Hamilton, Western, Eastern, Lowell, and Northern Canals and canal banks, as well as several associated locks, gatehouses and dams, and Pawtucket Falls. This system, which still operates as a source of hydroelectric power, provides an opportunity to interpret both the historic significance of water in industry, as well as the engineering of a waterpower system. Public access has been expanded over the years to support these interpretive opportunities, including creation of a pedestrian canalway and riverwalk and the development of related exhibits and programs such as the Suffolk Mill Turbine Exhibit.

Boott Cotton Mills Complex. This complex is architecturally and historically the most significant mill site in the city, and the only one with buildings owned and managed by the National Park Service. The millyard was constructed and then adapted over a 100-year period by the Boott Cotton Mills company, one of the 10 major textile corporations in Lowell. Of the city’s original millyards, the Boott Cotton Mills complex is the most intact example of Lowell’s historic mill complexes. Changes in technology and production capability influenced the development and appearance of the millyard over time. Its clock tower, completed about 1865, survives today as one of the most distinctive architectural monuments in Lowell and has become a symbol of the park. Today, the restored mill complex houses the park's Boott Cotton Mills Museum, the Tsongas Industrial History Center, and several NPS Northeast Region offices.

Immersive Experience. Lowell National Historical Park provides a variety of hands-on interpretive and educational opportunities that allow visitors to immerse themselves in Lowell's industrial past. Key park experiences include exhibits that feature a working turbine and weave room, as well as boat tours of the canal system and rides through the park on historic replica trolleys, which are among the most popular and unique experiences in the park. The Tsongas Industrial History Center, a partnership between Lowell National Historical Park and the University of Massachusetts Lowell Graduate School of Education, is a hands-on center where students can learn about the American Industrial Revolution through interactive activities such as weaving, working on an assembly line, creating canal systems and testing water wheels, and measuring water quality.

Cultural Heritage and Arts Programming. Immigration and cultural expression were a part of Lowell's story from the beginning—from the Yankee "mill girls" who flocked to the city in search of economic independence to the Irish, French-Canadians, Greeks, Poles, Portuguese, and other ethnic groups that came in search of the American Dream. This cultural heritage, its evolution over time, and its impacts on the cultural character of Lowell today are expressed through programming and exhibitions at the park, including the Mill Girls &Immigrant Exhibit at the Patrick J. Mogan Cultural Center, the Lowell Folk Festival, and the Lowell Summer Music Series. Cultural heritage and arts events are among the most well known and best attended at the park, and feature a range of activities that appeal to local and nonlocal visitors alike.

Historic Urban Industrial Landscape. Lowell is often recognized as one of America's most significant industrial cities, and, as such, the assemblage of buildings, structures, and public spaces that comprise its historic urban industrial landscape are critical to telling the story of the mills and the Industrial Revolution in America. Lowell was an innovative mill town where the focus was on both industry and the worker, and it includes not only extensive mill space and supporting structures but also boardinghouses, churches, and parks. Although the landscape is central to the story of Lowell, many of the buildings, structures, and greenscapes are owned and managed by other entities. Lowell National Historical Park works with the community and partner organizations as well as private owners and developers to ensure continued preservation of the historic urban industrial landscape, including mill buildings and smokestacks. This collaborative preservation effort is fundamental and will continue to be a central focus for Lowell National Historical Park into the future.

Partnerships. Since its establishment Lowell National Historical Park has embraced partnerships as an integral tool for accomplishing park and community goals. Partnerships with entities such as the City of Lowell, the state, and community organizations have allowed the leverage of funds for historic preservation and supported the economic growth of the city. These partners have been critical to meeting the mission of the park, assisting with interpretation, education, and resource stewardship. Through strong, mutually beneficial relationships with its partners, the park has not only succeeded but thrives as a model for community cooperation in the National Park Service.

Museum Collections. The museum collections at Lowell National Historical Park contain more than one-half million artifacts and historical documents, spanning from the early 19th century to the present. These objects and documents provide a tangible link to the Industrial Revolution in Lowell and its enduring legacies.

INTERPRETIVE THEMES

Interpretive themes are often described as the key stories or concepts that visitors should understand after visiting a park—they define the most important ideas or concepts communicated to visitors about a park unit. Themes are derived from, and should reflect, park purpose, significance, resources, and values. The set of interpretive themes is complete when it provides the structure necessary for park staff to develop opportunities for visitors to explore and relate to all park significance statements and fundamental resources and values.

Interpretive themes are an organizational tool that reveal and clarify meaning, concepts, contexts, and values represented by park resources. Sound themes are accurate and reflect current scholarship and science. They encourage exploration of the context in which events or natural processes occurred and the effects of those events and processes. Interpretive themes go beyond a mere description of the event or process to foster multiple opportunities to experience and consider the park and its resources. These themes help explain why a park story is relevant to people who may otherwise be unaware of connections they have to an event, time, or place associated with the park.

The following interpretive themes have been identified for Lowell National Historical Park:

The creation of the Waltham-Lowell system helped to change the nature and meaning of work by revolutionizing labor relations in the United States and transforming gender, racial, and ethnic identities ultimately leading to socioeconomic opportunity and inequity.

The accumulation of capital led to new investment opportunities in the United States centered on industrialization. Innovations in large-scale production systems in Lowell affected society in social, political, and economic ways and became a model for the future.

Through innovations in textile production, transportation, waterpower, and canal engineering, Lowell became a premier industrial city and helped propel the United States into a new industrial age. Cycles of innovation and technological development shaped, and continue to shape, the city and Lowell's influence on the world.

The commodification and use of abundant natural resources in Lowell, as part of a global Industrial Revolution, changed human relationships with the environment and modernized societies throughout the world but resulted in environmental damage that presents challenges today.

Lowell is a microcosm of the historical and contemporary shifting of cultural identities and tensions brought about by broader social changes such as industrialization, urbanization, and globalization.

From its earliest days as a planned industrial city, through boom and bust economic cycles to today's historic preservation renaissance, Lowell's urban landscape has evolved and now serves as a model of development and revitalization.

Analysis of Fundamental Resources and Values

The fundamental resource or value analysis table includes current conditions, potential threats and opportunities, planning and data needs, and selected laws and NPS policies related to management of the identified resource or value.

Fundamental Resource or Value	Water Power System / Canal System
Related Significance Statements	Lowell's (economic) success was based in innovation, from manufacturing technology and processes, to new business models, to city planning designed to benefit both industry and the worker. Unique industrial concepts were implemented and demonstrated at a massive scale at the Lowell mills, which served as a model for textile production and industrial cities. A very large proportion of original buildings, structures, and urban landscapes have survived in Lowell's park and preservation district and now are recognized as important historical artifacts. These include the entire 5.6-mile power canal system with its sophisticated dams, locks, and gatehouses, 7 of the original 10 mill complexes, and significant examples of early housing types, institutions, and transportation facilities. The Lowell canal system is nationally recognized as one of the most impressive civil and mechanical engineering achievements of the 19th century because of its grand scale and technological complexity, and is the site of origin for the famed "Francis" turbine. The canal system, used as both a transportation corridor and power source, facilitated the growth of the industrial city.
Current Conditions and Trends	**Conditions** ▪ The canal system is in fairly good condition overall. ▪ The canal system actively generates power and houses high-voltage submarine cables. ▪ All canals are within the park boundary. The canal system comprises roughly half of the overall park acreage. ▪ Elements of the canal system are owned and operated by a variety of entities that are responsible for the overall condition of the system. The canal walls and floor and waterpower equipment are owned by Enel Green Power, whereas the buildings and gatehouses, with the exception of the Moody Street Feeder Gatehouse, are owned by the Massachusetts Department of Conservation and Recreation. ▪ The park has easements associated with properties owned by the state and hydropower company, such as the gatehouses, canal walls, and much of the canal margins. These easements enable the park to create walkways, install railings, support trolley tracks, and perform related maintenance. ▪ The public walkways along the canal are in fairly good condition. ▪ Water flow through the canal affects the overall condition of the canal infrastructure, including walls that support NPS-owned assets (e.g., walkways, trolley, Boott Mill). ▪ There are 52 interpretive waysides. As areas are added to the park, additional waysides will be needed. **Trends** ▪ Use of the canalway system is increasing as additional disparate segments are connected. ▪ Visitation to the canalway system is increasing as community efforts to bring new events to the canalway increase. ▪ Use of the canalway system will increase as downtown development continues.

Fundamental Resource or Value	Water Power System / Canal System
	▪ Activation of a new canal lighting system by the City of Lowell has increased attention to the canalway. If proposals by the public to expand the lighting system are implemented, visitation could increase.
Threats and Opportunities	**Threats** ▪ There is a negative public response to trash in and around the canal system. The cleanup of debris remains a challenge due to the active power generation function and subsequent limitations on access authorized by Enel Green Power. ▪ Some perceive the canalways to be unsafe, particularly at night, and poor lighting is often identified as a concern. ▪ Gatehouses are sometimes broken into and vandalized. ▪ Clear lines of jurisdictional law enforcement authority have not been defined for much of the canal's resources (see key issue on "Jurisdictional Challenges"). ▪ Lack of maintenance of the canal walls, which are not owned by the National Park Service, can threaten the stability of canal walkways and the trolley system, much of which runs adjacent to the canalway. ▪ Vegetation growing along the canal walls can cause structural deterioration over time and poses an ongoing maintenance challenge, especially as NPS staff levels decrease. ▪ The park is monitoring environmental containment efforts to manage the lasting effects of prior industrial uses along the canal. These effects are most prominent along the Upper Pawtucket Canal adjacent to the former location of a coal/gas plant. ▪ Water flow and levels are controlled by Enel Green Power. Fluctuating water levels directly affect public access, historic structures, the natural environment, and the overall visitor experience (e.g., presence of visible debris). ▪ Modernization of the historic dam, approved by the Federal Energy Regulatory Commission, has changed a system used for more than 200 years. The effects of the new crestgate system on water levels in the canal system, and on the scenic wonder of the falls over the dam, remain to be seen. **Opportunities** ▪ Continue dialogue with Enel Green Power on how it could work with the park and its partners to allow for increased public use and/or interpretation. ▪ Work with independent volunteer groups to clean up the canal system. ▪ Expand recreational access through walkways along all of the canal system. ▪ Explore new recreational opportunities through increased use of surface water, such as kayaking and paddle boating and ice skating in the winter. ▪ Expand signage along walkways, which could increase visitation. ▪ Consider offering science-based programming along the canals. This programming could include expanded discussions about the tradeoffs between industrial uses and the environment and the effects of climate change. ▪ Collaborate with community partners on an anti-litter campaign to discourage littering along and in the canalway. ▪ Engage the community in discussions related to safety along the canals. Explore opportunities to install LED lighting along canalways as that technology improves. ▪ Install additional lighting and retrofit existing lighting to LED to reduce energy footprint. Additional lighting would probably attract visitors and improve public perception of threats to safety. ▪ Advocate for an overlook at Pawtucket Falls within the preservation district. ▪ Advocate for completion of the final section of the canalway along the Upper Pawtucket Canal.
Data and/or GIS Needs	▪ Visitor surveys. ▪ Visitor counts. ▪ Population survey. ▪ GIS data for jurisdictional inventory and cooperative management. ▪ Customized high-water study.

Fundamental Resource or Value	Water Power System / Canal System
	▪ Mapping of List of Classified Structures data related to the canal system. ▪ Wayfinding study. ▪ List of roles and responsibilities related to maintenance, leasing agreements, special events, and jurisdiction. ▪ Administrative history. ▪ Historic resource study.
Planning Needs	▪ Updated Downtown Lowell Historic District Design Review Standards (in collaboration with Lowell Historic Board). ▪ Lighting plan for canalways. ▪ Comprehensive interpretive and education plan. ▪ Planning for adaptation to climate change. ▪ Accessibility self-evaluation and transition plan. ▪ Preservation advocacy and funding strategy.
Laws, Executive Orders, and Regulations That Apply to the FRV, and NPS Policy-level Guidance	**Laws, Executive Orders, and Regulations That Apply to the FRV** ▪ Clean Air Act (42 USC 7401 et seq.) ▪ Clean Water Act (33 USC 1251-1387,33 USC 1151) ▪ Historic Sites Act of 1935 (54 USC 320101 et seq.) ▪ National Environmental Policy Act of 1969 (42 USC 4321) ▪ National Historic Preservation Act of 1966, as amended (54 USC 300101 et seq.) ▪ Secretarial Order 3289, "Addressing the Impacts of Climate Change on America's Water, Land, and Other Natural and Cultural Resources" **NPS Policy-level Guidance (NPS *Management Policies 2006* and Director's Orders)** ▪ NPS *Management Policies 2006* (§4.1) "General Management Concepts" ▪ NPS *Management Policies 2006* (§4.1.4) "Partnerships" ▪ NPS *Management Policies 2006* (§4.7.2) "Weather and Climate" ▪ NPS *Management Policies 2006* (chapter 7) "Interpretation and Education" ▪ NPS *Management Policies 2006* (chapter 8) "Use of the Parks" ▪ NPS *Management Policies 2006* (chapter 9) "Park Facilities" ▪ Director's Policy Memorandum 12-02, "Applying National Park Service Management Policies in the Context of Climate Change" ▪ Director's Policy Memorandum 15-01, "Addressing Climate Change and Natural Hazards for Facilities"

Fundamental Resource or Value	Immersive Experience
Related Significance Statements	A very large proportion of original buildings, structures, and urban landscapes have survived in Lowell's park and preservation district and now are recognized as important historical artifacts. These include the entire 5.6-mile power canal system with its sophisticated dams, locks, and gatehouses, 7 of the original 10 mill complexes, and significant examples of early housing types, institutions, and transportation facilities. The Lowell canal system is nationally recognized as one of the most impressive civil and mechanical engineering achievements of the 19th century because of its grand scale and technological complexity, and is the site of origin for the famed "Francis" turbine. The canal system, used as both a transportation corridor and power source, facilitated the growth of the industrial city.

Fundamental Resource or Value	Immersive Experience
	Lowell National Historical Park preserves and interprets the stories and heritage of the people of Lowell, including the early female workforce (aka "mill girls") and those who came from across the globe seeking opportunities. Today, Lowell's residents continue to shape the culture of the city and contribute to its revitalization. The collaboration between Lowell National Historical Park and its partners has resulted in the rehabilitation of almost all of the 5.3 million square feet of historic mill space and hundreds of additional buildings in the downtown historic district. This effort continues to serve as a successful example of leveraging public-private partnerships for economic development through historic preservation.
Current Conditions and Trends	**Conditions** ▪ A wide variety of well-received, full-sensory experiences are offered at the park, including canal boat tours, Lowell Folk Festival, Tsongas Industrial History Center programs, weave room, and Lowell Summer Music Series. ▪ The Tsongas Industrial History Center provides popular programs targeted at providing students with curriculum-based, place-based immersive experiences. ▪ Overall, visitors report consistently high levels of satisfaction with immersive experiences at the park. ▪ Existing signage does not provide consistent or adequate direction to visitors navigating to and through the park. ▪ Educational offerings at the Tsongas Industrial History Center continue to be responsive to changing curriculum standards. **Trends** ▪ Visitation by different grade levels varies at the Tsongas Industrial History Center because of changing curriculums and educational standards. For example, visitation by fourth grade classes has increased because of the current framework for social studies education, whereas visitation by eighth grade classes has decreased because the topic of industrialization is now addressed in the high school curriculum. ▪ Visitation for external partner-led/coordinated programs is increasing. ▪ The need for science, technology, engineering, and mathematics educational programs is increasing. ▪ The park's immersive experiences meet the needs of 21st-century learners who desire more engaging, free-choice, and self-directed learning environments.
Threats and Opportunities	**Threats** ▪ Immersive experiences are generally staff intensive, requiring more personnel with specialized skills than other interpretive experiences. Thus, these experiences can be difficult to sustain as employees retire and staff levels decrease. ▪ Immersive experiences have high operating costs and require ongoing infrastructure improvements and maintenance. ▪ Hiring uniquely skilled employees (e.g., trolley operators and maintenance staff, weavers and loom fixers, museum curators, bilingual interpreters) can be challenging. ▪ Immersive experiences require attention to safety and related training, staffing, and equipment, including the operation of heavy equipment and machinery (e.g., boats, trolleys, looms) and the movement and management of large numbers of people during bigger events (e.g., Tsongas Industrial History Center programs, Lowell Summer Music Series, Lowell Folk Festival). ▪ There are challenges associated with offering immersive experiences in an urban environment such as traffic, noise, etc. ▪ Immersive experiences are considered the primary driver for attracting audiences, but their use is not up to date with trends in delivering immersive and other interpretive experiences to new and diverse audiences.

Fundamental Resource or Value	Immersive Experience
	▪ Fluctuations in canal levels, which are managed by the power company, limit the park's ability to use the canals for immersive experiences. **Opportunities** ▪ Continue to update and evolve programming to ensure relevancy. Examples include updating exhibits using 21st-century practices, co-leading programs with community members to explore contemporary topics, and conducting evening programming that uses park resources in creative ways (e.g., open-mic nights based on park themes and tied to community-relevant topics). ▪ Continue to explore and evolve business models and partnerships that support operational costs, needs, and staffing required by immersive programming. ▪ Continue to develop community engagement and partner-led initiatives that use immersive experiences to attract new audiences and build the next generation of park stewards. ▪ Research and institute new techniques to improve current immersive experiences and develop new experiences at Lowell National Historical Park and the Tsongas Industrial History Center. These could include greater emphasis on audience-centered learning, family learning, audio tours and experiences, and bilingual offerings. ▪ Leverage assistance of nonprofit groups, partners, and volunteers to help meet staffing needs. ▪ Adapt programs and facilities at the Tsongas Industrial History Center to engage nonstudent visitors. ▪ Develop succession plan and training opportunities to maintain skilled staffing levels necessary to offer immersive experiences. ▪ Pursue phased design and funding strategy to introduce 21st century immersive experiences to park exhibits. ▪ Engage with partners to expand awareness of park's immersive experiences and attract new audiences. ▪ Continue to develop creative programming in response to shifts in visitation and/or other trends. ▪ Consider ways in which the National Park Service might certify canal boat operators for watercraft use as an alternative to the U.S. Coast Guard certification process.
Data and/or GIS Needs	▪ Visitor surveys. ▪ Visitor counts. ▪ Wayfinding study. ▪ Customized high-water study. ▪ Population survey. ▪ Administrative history. ▪ Trolley system condition assessment.
Planning Needs	▪ Marketing plan and visitation/tourism plan. ▪ Comprehensive interpretive and education plan. ▪ Wayfinding/sign plan. ▪ Succession plan. ▪ Collection management plan (update). ▪ Accessibility self-evaluation and transition plan.
Laws, Executive Orders, and Regulations That Apply to the FRV, and NPS Policy-level Guidance	**Laws, Executive Orders, and Regulations That Apply to the FRV** ▪ Americans with Disabilities Act (42 USC 12101 et seq.) ▪ Architectural Barriers Act (42 USC 4151 et seq.) ▪ Rehabilitation Act of 1973 (29 USC 701 et seq.) ▪ "Architectural Barriers Act Accessibility Guidelines" (36 CFR1191.1) **NPS Policy-level Guidance (NPS *Management Policies 2006* and Director's Orders)**

Fundamental Resource or Value	Immersive Experience
	▪ NPS *Management Policies 2006* (chapter 7) "Interpretation and Education" ▪ NPS *Management Policies 2006* (chapter 8) "Use of the Parks" ▪ NPS *Management Policies 2006* (chapter 9) "Park Facilities" ▪ Director's Order 6: *Interpretation and Education* ▪ Director's Order 42: *Accessibility for Visitors with Disabilities in National Park Service Programs and Services*

Identification of Key Issues and Associated Planning and Data Needs

This section considers key issues to be addressed in planning and management and therefore takes a broader view over the primary focus of part 1. A key issue focuses on a question that is important for a park. Key issues often raise questions regarding park purpose and significance and fundamental resources and values. For example, a key issue may pertain to the potential for a fundamental resource or value in a park to be detrimentally affected by discretionary management decisions. A key issue may also address crucial questions that are not directly related to purpose and significance, but that still affect them indirectly. Usually, a key issue is one that a future planning effort or data collection needs to address and requires a decision by NPS managers.

The following are key issues for Lowell National Historical Park and the associated planning and data needs to address them:

Jurisdictional Challenges. Lowell National Historical Park has complicated boundaries and multiple jurisdictions. As a result, there can be confusion regarding ownership, boundaries, and law enforcement jurisdiction. It can be difficult to determine ownership of key parcels and identify areas lacking lands processing. Continued collaboration with partners to update agreements specifically regarding law enforcement and maintenance jurisdictions is needed. The park should continue to work with the NPS Northeast Region to advocate that the state legislature update designated national park lands in Massachusetts to concurrent law enforcement jurisdiction.

Associated data needs:
Updating and digitization of park segment maps
GIS data for jurisdictional inventory and cooperative management
Jurisdictional inventory (update)

Outreach and Relevancy. Lowell National Historical Park has evolved with the city of Lowell, and it is a challenge to effectively communicate that changing story in an inclusive and relevant way. Conveying the historic context of Lowell and the national historical park to community members is particularly challenging because some exhibits are outdated. It is essential to connect with people and their stories more effectively, including updating interpretative media to provide information to nonnative English speakers. Tourism should be promoted more broadly to increase visitation and overcome the negative perception of Lowell that began during the city's post-industrial decline.

Associated planning needs:
Marketing plan and visitation/tourism plan
Wayfinding/sign plan

Comprehensive interpretive and education plan
Exhibit plan for Mill Girls & Immigrant Exhibit and Boott Cotton Mills Museum

Associated data needs:
Visitor surveys
Visitor counts
Population survey
Wayfinding study
Historic resources study: *Lowell, A City of Spindles* (update)

Maintenance/Preservation of Park-Owned Resources and Facilities. The park owns and operates a variety of resources and assets that require significant staffing and funding, including historic mill buildings, boardinghouses, boats, trolleys, and associated infrastructure. Collaboration with park partners to identify ways to leverage funding for maintenance is essential. Reclassification of maintenance positions would allow greater flexibility within the park's diminishing workforce (e.g., maintenance mechanics vs. specialists). Continued creative thinking about appropriate paths for hiring, as well as effective ways to attract and retain maintenance staff, is necessary, including using University of Massachusetts Lowell work-study students and partnering with the local vocational technical high school, social services agencies, and the Student Conservation Association.

Associated planning need:
Comprehensive management and maintenance plan

Associated data needs:
List of roles and responsibilities related to maintenance, leasing agreements, special events, and jurisdiction
Trolley system condition assessment

Loss of Specialized Skills and Knowledge. The nature of the resources of the park requires a large number of staff having specialized skills, such as loom fixers, masons, and woodworkers. Many staff members have worked with the park since its establishment or were part of the Lowell Historic Preservation Commission. They have knowledge of the park and city that is irreplaceable, including the history of preservation and changes in park management over time. As those individuals retire or otherwise move on from the park, specialized skills and knowledge will be lost and must be replaced if possible or somehow captured.

Associated planning needs:
Succession plan
Record management plan
Collection management plan (update)

Associated data needs:
Administrative history
Oral history project on development/preservation

Private Ownership in the Park and Preservation District. Many lands and buildings within the park and preservation district are privately owned but are major components of the historic urban industrial landscape. Their preservation, maintenance, and integrity of design are critically important to the park. Although there are certain mechanisms in place to ensure historic and new buildings in the district meet design and preservation standards, such as city design review processes, maintaining historic integrity is a continual challenge. As the economy has improved and development pressures have increased, challenges increase. The City of Lowell and the commonwealth are exempt from the Lowell Historic Board standards and controls. Additionally, development of structures on nonpark land could encroach on historic resources (e.g., gatehouses and canalways) and diminish the visitor experience. Review of the Lowell Historic Board standards and new, creative approaches to preservation and design control might provide new solutions to these challenges.

Associated planning needs:
Updated Downtown Lowell Historic District Design Review Standards (in collaboration with Lowell Historic Board)
Preservation advocacy and funding strategy

Renewal of Enel Green Power License. The water power license, issued by the Federal Energy Regulatory Commission to Enel Green Power, is near its renewal date. Use of the canal system, a major component of the park experience and interpretation, is subject to terms in that agreement, and the National Park Service should be involved in renewal conversations. Terms should be sought that allow for expanded recreational use of the canalways. Through proactive NPS involvement, the needs of both Enel Green Power and the National Park Service could be met.

Associated data need:
Customized high-water study

Climate Change. Some parts of the park, including the Boott Mill No. 6 building and Counting House, are within a designated floodplain that primarily is related to the canal system surrounding the central part of the city of Lowell. As a result, a majority of park buildings, structures, and other resources are at risk to the effects of climate change, with the threat of increased storm incidents and more regular flooding. Resources most at risk include those associated with the water power system / canal system, which is identified as a fundamental resource. Planning is needed to determine potential impacts and provide mitigation strategies.

Associated planning need:
Planning for adaptation to climate change

Associated data need:
Customized high-water study

ATTACHMENT G

National Park Service
Study Requests

NPS Boott Study Request #1

Resources, Ownership, Boundaries and Land Rights Study
(Lowell, P-2790)

Goals and Objectives

Ownership and use of the canal system in Lowell is very complex. In any given area, there could be several entities with land rights or other entitlements granting authority to access, maintain, or utilize the canal system. The objectives of a boundary study would be to determine current ownership of resources within the canal system in a comprehensive manner, record maintenance responsibilities and obligations to those resources, clarify FERC jurisdiction, and document recreational, educational, or other land access rights to resources within the canal system. The study should also project future conditions for the terms of the license. Decommissioning downtown power stations could result in impairment to historic resources. The large historic water power infrastructure will continue to require costly maintenance, but risks disinvestment if it is no longer needed for on-going project operations and remains under the licensee's ownership. Decommissioning of canal infrastructure and other reasonably foreseeable changes in project operations that could result in changes in ownership or maintenance liabilities should also be considered within the study.

The ultimate goal of this study would be to denote which entity is ultimately responsible for specific resources, in light of overlapping jurisdictions and to serve as a factual baseline document to update the MOU for Canal Maintenance Responsibilities in the Project Area with Boott Hydropower Inc., Lowell National Historical Park, the Department of Conservation and Recreation, and the City of Lowell as signatories.

Resources Management Goals

See Attachment E from September 2017 Foundation Document.

Public Interest

Requester is a Federal Resource Agency.

Existing Information

NPS has a complete record of its land rights and can provide this for the study. Land rights obtained by Boott Hydropower Inc., Massachusetts Department of Conservation and Recreation, City of Lowell, and private entities would also need to be accessed for this study.

Nexus to Project Operations and Effects

Property ownership and less than fee easement rights are directly related to the ongoing maintenance and preservation of the historic canal system. Identifying which parties have authority to maintain and use and/or an obligation/right to maintain/use the canal system will inform the development of license requirements as well as roles and responsibilities of any future MOUs for the historic canals. Boott also needs the rights necessary to comply with license requirements; a firm understanding of what rights Boott has or may need to acquire will be essential to the licensing determination.

Methodology Consistent with Accepted Practice

The information from this study can be pulled from title and land records, existing legislation, and other legal documents.

Level of Effort/Cost, and Why Alternative Studies Will Not Suffice

This type of study can be completed at a reasonable cost within the FERC study period.

NPS Boott Study Request #2

Water Level and Flow Effects on Historic Resources (Lowell, P-2790)

Goals and Objectives

Changes to the elevation of water or flow rates throughout the system directly affect the condition of historic resources. Abnormally high water levels in the Northern Canal, for example, have caused damage to wooden structural elements of the Northern Canal Waste Gatehouse and structural undermining of the Great River Wall. Conversely, extended drain downs and low water levels have caused damage to historic turbines and waterwheels made of wood and leather elsewhere in the system. The effects of the Crest Gate operation are unstudied and may include acute or prolonged impacts to historic resources throughout the system. Decommissioning downtown power stations may also result in changes to water levels and flows in some areas of the canal system and the effects are unstudied and unknown.

The objectives of this study should include evaluating how project operations, including manipulation of the newly installed Crest Gate, canal headgates, spillways, locks, fish passage structures, and generating units will change water levels in any location within the canal, and determine the extent to which water flows or elevations can be modified and or controlled to diminish loss of historic resources. The study would:

- Document impacts of current project operations on nationally significant historic resources, including a structural engineering assessment of the Great River Wall.
- Project future water levels and flows as a result of reasonably foreseeable changes to the project operation such as operating the Crest Gate system, decommissioning certain facilities, or modifying operations for fish passage.
- Evaluate impact of on-going and future project operations on nationally significant historic resources.
- Develop 100 and 500-year flood plans to protect nationally significant historic resources.

Resources Management Goals

See Attachment E from September 2017 Foundation Document.

Public Interest

Requester is a Federal Resource Agency.

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Existing Information

NPS can provide an architectural and engineering evaluations of historic structures at multiple locations as well as maintenance records for previous repairs. Boott Hydro Power may have existing data on the impacts high and low water flows and elevations have on historic resources, but new data demonstrating how the new Crest Gate System effects water levels and flows would also need to be analyzed.

Nexus to Project Operations and Effects

Understanding the impacts water levels and flows will have on nationally significant historic resources will directly inform the development of license requirements and will inform future MOUs. The study data can also be used to better understand public and dam safety threats.

Methodology Consistent with Accepted Practice

The study would compare existing conditions of structures associated with canal operations and identify potential changes in conditions that may result from changes in project operations and resulting water and flow levels. This study would require an engineering assessment of the Great River Wall and may require additional structural assessment of other historic properties damaged by current project operations.

Level of Effort/Cost, and Why Alternative Studies Will Not Suffice

This type of study can be conducted within the study period.

NPS Boott Study Request #3

Water Level and Flow Effects on Recreation Study:
(Lowell, P-2790)

Goals and Objectives

Water levels and flows directly affect public recreational access to and within the canals. The elevation and flow rates currently limit the number of days canal walkways are safely accessible to the public, particularly the Northern Canal Walkway which opens seasonally when flow rates are lower than 3,500 cubic feet per second (cfs). For years, NPS has received numerous complaints regarding the walkway's closure and the public has repeatedly requested increased access to the Northern Canal Island and Great River Wall. This study would assess if changes to project operations can be made to increase recreational access and whether 3,500 cfs is an appropriate threshold for the walkway's closure.

NPS boat passage is another recreational issue affected by water level and flows. NPS boats barely pass under the Pawtucket Street Bridge over Pawtucket Canal and the Central Street Bridge over the Lower Pawtucket Canal. With even 1 foot elevation rise to the crest pool, NPS boats would be unable to pass under the Pawtucket Street Bridge. A study is needed to determine the effects the Crest Gate system on on-going project operations will have on NPS tour boats and other potential future on-water recreational uses.

Additionally, NPS partners and the public have expressed interest in new, different, and expanded recreational access to and within the canals. The canal system should be evaluated to determine which segments are most suitable for various recreational opportunities (paddle boarding, ice skating, kayaking, etc.) so that recreational and economic development partners develop plans only where deemed compatible with on-going project operations and preservation of nationally significant historic resources.

The objectives of this study should include evaluating how project operations, including manipulation of the newly installed Crest Gate, canal headgates, spillways, locks, fish passage structures, and generating units will change water levels in any location within the canal, determine the extent to which water flows or elevations can be modified and or controlled to diminish public access restrictions to recreational amenities. Information to be obtained would come from photos, videos and direct observations of flows under different levels, magnitude and duration. The study would address the following issues:

- Effect of water levels and flow rates on existing recreational facilities and activities, including the Northern Canal Walkway and NPS Boat Operations
- Potential for future recreation within or adjacent to the canal system.

Resources Management Goals

See Attachment F from September 2017 Foundation Document.

Public Interest

Requester is a Federal Resource Agency.

Existing Information

Boott Hydro Power may have existing data on the impacts high and low water flows and elevations have on historic resources and recreation, but new data demonstrating how the new Crest Gate System effects water levels and flows would also need to be analyzed.

Nexus to Project Operations and Effects

Understanding the impacts water levels and flows will have on recreational opportunities and nationally significant historic resources will directly inform the development of license requirements and will inform future MOUs.

Methodology Consistent with Accepted Practice

The study would compare existing conditions on structures associated with canal operations and identify potential changes in conditions that may result from changes in project operations and resulting water and flow levels.

Level of Effort/Cost, and Why Alternative Studies Will Not Suffice

This type of study can be conducted within the study period.

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NPS Boott Study Request #4

**Vegetation and Aquatic Trash Management Study
(Lowell, P-2790)**

Goals and Objectives

Study the impact of vegetation growth on historic canal walls and propose appropriate techniques and schedules for vegetation removal to prevent deterioration and obviate long term capital needs. Review the current waterborne trash removal operation, determine the extent to which the operation can be changed to prevent damage to historic resources, improve access to recreation, aesthetics, and public safety.

Resources Management Goals

See Attachment E from September 2017 Foundation Document.

Public Interest

Requester is a Federal Resource Agency.

Existing Information

The study could pull maintenance records from stakeholders to determine the baseline cyclical vegetation and trash management activities and use condition assessment data to determine asset condition. The study could also involve a public feedback component to better understand areas of particular concern.

Nexus to Project Operations and Effects

The results of the study will have a direct impact on the terms of the license agreement and corresponding updates to the canal maintenance MOU among stakeholders.

Methodology Consistent with Accepted Practice

The study would use baseline vegetation and trash removal activities as a no action alternative and develop at least two alternatives to demonstrate how changes in frequency or level of effort would result in changes to the condition of historic resources, the total dollar amount of deferred maintenance, access to recreation, canal aesthetics, and public safety. Results of the study will enable stakeholders to determine an optimal and appropriate maintenance reoccurring maintenance schedule for clearing vegetation and trash which would hopefully result in fewer major capital investments towards stabilizing canal walls and increased protection of the historic resources, and increased public safety.

Level of Effort/Cost, and Why Alternative Studies Will Not Suffice

This type of study can be conducted within the study period.

NPS Boott Study Request #5

Historically Significant Water Power Equipment Study (Lowell, P-2790)

Goals and Objectives

The objectives of this study are to identify historically significant water power equipment and develop plans to preserve the equipment and provide public access for their future enjoyment or make use of scrap parts from the equipment. The ultimate goal of this study is to diminish loss of historic property. Protection of historically significant water power equipment is complicated by boundary issues. Vertical ownership is current set at 101 ft. MSL. Historic hoisting equipment, gates, and control equipment that are not used for modern operations fall into a state of disrepair and can be abandoned or thrown away without communication. For example, two hydraulic cylinders at Guard Locks were discarded and NPS would have liked to interpret them to visitors. As power buildings are decommissioned, NPS may want to evaluate equipment for exhibit potential or for scrap equipment to maintain and operate other historic machinery.

Resources Management Goals

See Attachment E from September 2017 Foundation Document.

Public Interest

Requester is a Federal Resource Agency.

Existing Information

The study could reference Lowell National Historical Park’s Scope of [Museum] Collections.

Nexus to Project Operations and Effects

The results of the study will have a direct impact on the terms of the license agreement and corresponding updates to the canal maintenance MOU among stakeholders. It will also be essential information in the Commission’s consultation under the NHPA.

Methodology Consistent with Accepted Practice

The study would photograph existing mechanical equipment, provide documentation of the history of that equipment, and document current equipment ownership. This information would be used in subsequent meetings between the applicant and the National Park Service so that historical equipment worthy of preservation and interpretation may be saved for the enjoyment of current and future generations.

Level of Effort/Cost, and Why Alternative Studies Will Not Suffice

This type of study can be conducted within the study period.

Document Content(s)

dcr
Massachusetts

August 14, 2018

Kimberly D. Bose, Secretary
Federal Energy Regulatory Commission
888 First Street, N.E. Room 1A
Washington, D.C. 20246

RE: Lowell Hydroelectric Project (P-2790-072)

Dear Secretary Bose:

The Department of Conservation and Recreation ("DCR" or the "Department") is pleased to submit the following comments in response to the Scoping Document 1 for the Lowell Hydroelectric Project (the "Project"). The Scoping Document is the first formal submission to FERC by Boott Hydropower LLC ("Boott" or the "Proponent") to relicense the Project. The current license for the project expires on April 30, 2023. The Project consists of the Pawtucket Dam, located on the Merrimack River, and other assets within nearby canals that include several small dams, gatehouses, power stations, and other associated infrastructure.

Overseeing one of the largest state parks agencies in the country, DCR manages 450,000 acres that includes a wealth of natural, cultural, and recreational resources including forests, parks, greenways, historic sites and landscapes, seashores, lakes, ponds, reservoirs and watersheds.

In 1986, a predecessor agency to DCR (the Department of Environmental Management or "DEM") took land along the Merrimack River and certain canal systems in Lowell that created the majority of Lowell Heritage State Park (the "State Park") and its holdings in the vicinity of the Project. Under the terms of the acquisition, DEM acquired fee interest in land and structures near the Pawtucket Dam, including the Pawtucket Gatehouse, the Gatekeeper's House and Barn, the Blacksmith Shop and a parcel between Varnum Avenue and the Merrimac River where the Pawtucket Dam meets the northern Merrimack River shoreline. DCR understands that it has care and control of assets used by the Proponent for its hydropower activities including the Northern Great Wall, Guard Locks and Gates Facility, Swamp Locks Dam, and Lower Locks Dam, from the terms of the 1986 taking.

In 1996, a Memorandum of Agreement lapsed between DEM, the National Park Service, and Boott that, when active, arranged roles and responsibilities for maintenance of the various overlapping infrastructure among the entities. DCR collaborates closely with the National Park Service in maintaining the infrastructure related to the canal system and interpreting the historic resources of the canal system.

In addition to historic resources, DCR also oversees recreational infrastructure upstream from the Project including the Michael Rynne Bathhouse, located at 160 Pawtucket Boulevard approximately one-half mile westerly from the Pawtucket Dam; and the Rourke Brothers Boat Ramp (approximately two miles westerly from the Pawtucket Dam).

Memorandum of Agreement

As part of the relicensing process, DCR requests that the Proponent be required to undergo a process to develop a joint agreement with DCR and the National Park Service that outlines agreed rights and responsibilities of properties in Lowell related to the Project. Items should include all dams, waterway training walls, trash racks, gates, valves, pipes, conduits, locks, canal walls, canal bottoms or floors, canal wall capstones, appurtanances that abut canal walls, and gate houses (including the interior and exterior space, abutting grounds, and water control devices in the gatehouses). DCR believes such an agreement is necessary to ensure proper ongoing maintenance and repair of the resources that comprise the Project, as the lack of a current agreement among the parties leaves corresponding roles and responsibilities undefined, and, consequently, subject to neglect.

Recreational Resources

The Proponent is in the final stages of improving the Pawtucket Dam with a pneumatic crest gate system that will allow rapid raising and lowering of the water level above the dam. DCR notes that ongoing operation of the dam could potentially affect water levels at the Rynne Bathhouse and the Rourke Brothers Boat Ramp (located upstream from the dam) during the prime recreational season (between late May and early October). As part of the scoping, DCR requests that the Proponent evaluate whether and how upstream recreational facilities will be affected with water level changes during the prime recreational season, resulting from ongoing use of the Pawtucket Dam.

As part of this study, DCR requests that the Proponent predict the range of anticipated water levels at the Rynne Bathhouse and Rourke Brothers Boat Ramp under normal conditions and extreme weather events. DCR requests that the Proponent commit to communicating any anticipated water level changes with the Department prior to execution of those changes. DCR further requests that the Proponent describe any existing agreements regarding water levels that will affect the Proponent's operation of its hydroelectric infrastructure.

As part of the Environmental Assessment, DCR requests that the Proponent develop and implement a plan to install a dam safety barrier upstream to prevent boaters from going over the Pawtucket Falls Dam. The current safety barrier is maintained and installed seasonally by others. DCR believes dam safety should be the responsibility of the Proponent and the upstream barrier should be installed and removed seasonally by the Proponent.

Access to DCR Property

Under the Environmental Assessment process, DCR requests that the Proponent map protected recreational lands in the vicinity of the Project, and identify the locations where DCR property needs to be accessed for routine or emergency maintenance. This section should include a narrative that discusses the recreational lands, how they are used by the public, how traditionally under the No-Action Alternative these lands are accessed including size and weight of equipment and the duration of access. DCR notes that Construction and Access permits are required for any construction access on DCR property. As part of the Environmental Assessment, the Proponent should make the commitment to repair any damage to recreational assets resulting from their use.

During extreme flooding, the Proponent's plan to access the Francis Gate lock (to install a steel barrier by crane) is through the rear of DCR property at 719 Broadway. DCR notes that the 719 Broadway property may be sold and developed by a private party, as legislation has been filed to authorize the conveyance of this property to the City of Lowell. If this conveyance occurs, the rear access could be limited or removed. To help plan for future contingencies, DCR requests that the Proponent evaluate alternative methods of access for the Francis Gate lock. As part of its evaluation, DCR notes that the Proponent could consider installing a wide curb cut and multi-use paved path at 719 Broadway that would facilitate visitor access to the Francis Gate lock.

DCR also requests that the Proponent identify the anticipated maintenance activities for the Pawtucket Dam and associated infrastructure over the course of a new license agreement, and evaluate alternatives for accessing sites required for ongoing maintenance. DCR notes that its nearby Gatekeeper's House, Barn and Blacksmith Shop and landscape features such as retaining wall and fences have been adversely impacted by ongoing activities over the course of the existing license, with heavy construction equipment impacting landscaping. DCR leases the Gatekeeper's House to a curator, under a long term (15 years) agreement, who resides at the property while providing labor to rehabilitate, manage and maintain the property. The ongoing access has been problematic at times for the lessee/curator to adequately care for the property. Accordingly, the use of barges should be included in the analysis for any routine maintenance activities that requires heavy machinery, such as cranes.

For the alternative exploring maintaining existing access from the road, DCR requests that the license require certain protocols to protect the structures and grounds. For instance, all grounds and property should be repaired each time the crane accesses the site, including the repair of any displaced soil, and loaming and seeding the area. Prior to access, the Proponent should meet with a DCR arborist on site to plan for the pruning and dead-limbing of all trees on the property impacted by the crane's activity. The Proponent should avoid any damage to the buildings and landscape features on the site, including the house, barn and fences. If damage does occur, the Proponent should be required to coordinate repairs with the Lessee and with DCR and perform any repairs, once approved, in a timely manner. DCR encourages alternative treatments to the southeast corner of the house that would allow crane access without requiring the installation and removal of the gravel and steel plates. DCR also encourages a less destructive solution for the removal of the fence section. Possibilities include hinging a section of the gate to swing clear of the entry path. Lastly, the Proponent and/or its contractors should directly contact the lessee prior to accessing the Gatekeeper's House property. DCR is available for consultation on this request.

Recreational Use Data
As part of the Environmental Assessment, DCR requests that the Proponent study how visitors currently use the project areas, including the Visitor Center at the E.L Field Powerhouse, including number of visitors, type of recreation, time of year, etc. A number of the project facilities are an important part of the recreational network in Lowell and the applicant should develop a plan to maintain and improve those opportunities.

American Disabilities Act (ADA)
As part of the recreational uses study of the project area, DCR requests that the Proponent assess required improvements to recreational or educational facilities within the Project area to meet current ADA (Americans with Disabilities Act) requirements for access.

Thank you for the opportunity to comment on the first Scoping Document. Should you have any questions, please do not hesitate to contact Kevin Hollenbeck, Metrowest District Manager at 617-828-1634 or kevin.hollenbeck@state.ma.us. Questions regarding access near the Gatekeeper's House can be directed to Kevin Allen at 617-626-1361 or kevin.allen@state.ma.us.

Sincerely,

Leo Roy
Commissioner

Document Content(s)

UNITED STATES DEPARTMENT OF COMMERCE
National Oceanic and Atmospheric Administration
NATIONAL MARINE FISHERIES SERVICE
GREATER ATLANTIC REGIONAL FISHERIES OFFICE
55 Great Republic Drive
Gloucester, MA 01930-2276

August 14, 2018

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

RE: Comments on Enel's Notice of Intent to File License Application and Filing of Pre-Application Document for the Lowell Hydro Electric Project (No. 2790)

Dear Secretary Bose,

On June 15, 2018, you issued a *Notice of Intent to file a license application, filing of Pre-Application Document (PAD), commencement of pre-filing process, and scoping; request for comments on the PAD and Scoping Document*, and identification of issues and associated study requests by Enel (P-2790). The PAD contains information about the project itself and the environmental resources affected by the project. As part of the Integrated Licensing Process, we (National Marine Fisheries Service (NMFS)) have an opportunity to comment on the PAD and to submit study requests.

Attached for filing, please find our comments regarding the PAD. In addition, we are including six requested studies. If you have any questions or need additional information, please contact Sean McDermott (sean.mcdermott@noaa.gov) or 978-281-9113.

Sincerely,

Louis A. Chiarella

Louis A. Chiarella
Assistant Regional Administrator
for Habitat Conservation

cc: Service List

National Marine Fisheries Service's Comments and Study Requests on Enel Pre-Application Document for the Lowell Hydro Electric Project (FERC No.2790)

August 14, 2018

1 PROJECT BACKGROUND

Boott Hydropower, LLC (Licensee) owns and operates the Lowell Hydroelectric Project (FERC No. 2790) on the Merrimack River in the City of Lowell, Massachusetts. The project is located at river mile 41 and has a 23-mile long impoundment extending into New Hampshire. The project has an authorized capacity of 24.8 megawatts (MW) operating in run-of-river mode with no useable storage capacity. The major project components include:

- the 1,090-foot long, stone masonry Pawtucket Dam with 5-foot tall pneumatic crest gates,
- an upstream fish ladder at the apex of the Pawtucket Dam,
- a two-tiered, 5.5-mile long canal system through downtown Lowell with various hydraulic control structures including 19 Francis units housed in four powerhouses,
- a main powerhouse containing two 8.6 MW Kaplan units, and
- an upstream fish lift and downstream bypass system at the main powerhouse.

The Federal Energy Regulatory Commission (FERC) issued the existing license on April 13, 1983 and it expires on April 30, 2023. The Licensee must file an application for a new license with FERC no later than April 30, 2018. The Licensee filed their Notice of Intent and Pre-Application Document electing to pursue a new license using the Integrated Licensing Process with FERC. On June 15, 2018, FERC issued the Scoping Document 1 commencing the licensing proceeding.

2 NOAA TRUST RESOURCES

As NOAA's National Marine Fisheries Service (NMFS), under the U.S. Department of Commerce (DOC), we are responsible for the stewardship of the nation's living marine resources, fisheries and their habitat. Estuaries and coastal riverine habitat systems, including rivers such as the Merrimack River, provide an integral component of significant ecological functions for the larger marine environment. Many living marine resources are supported by estuaries and coastal rivers throughout their life cycles. Species such as the endangered shortnose sturgeon (*Acipenser brevirostrum*), Atlantic sturgeon (*Acipenser oxyrinchus oxyrinchus*) the endangered Atlantic salmon (*Salmo salar*), alewife (*Alosa pseudoharengus*), blueback herring (*Alosa aestivalis*), American shad (*Alosa sapidissima*), American eel (*Anguilla rostrata*), and sea lamprey (*Petromyzon marinus*) rely on these coastal systems for refuge, spawning, rearing and nursery habitat. NOAA's 2009-2014 National Strategic Plan (Strategic Plan) recognizes the significance of these resources in its mission goals, which include "Protect, restore, and manage the use of coastal and ocean resources through an ecosystem approach to management." Historically, these species were present within the Lowell project boundary. Currently, there is no critical habitat for shortnose sturgeon, Atlantic sturgeon or Atlantic salmon designated in this reach of the Merrimack River. Our primary goal in carrying out our trust responsibilities in the Merrimack River watershed is to rebuild and ultimately maintain self-sustaining diadromous fish runs in the Merrimack River basin and to fully use the available habitat and production potential.

Atlantic salmon are present in the project area. However, the project area is not designated critical habitat nor is the species actively managed in the Merrimack River.

3 FEDERAL STATUTORY REQUIREMENTS

We are responsible for conservation, management, and protection of America's living marine and aquatic resources throughout jurisdictional river basins in coordination with other state and federal agencies, local governments, Indian tribes, fisheries commissions, commercial and recreational fishers, and conservation organizations. Our authority to manage diadromous fish in these river basins comes from Congress. Specifically, Congress has directed us (NMFS) to manage diadromous species in river basins, including a grant of discretionary authority to order fish passage at dams licensed by the Federal Energy Regulatory Commission. NMFS' congressionally mandated statutory authorities include the Federal Power Act, the Endangered Species Act, the Magnuson-Stevens Fishery Conservation and Management Act, the Atlantic Coastal Fisheries Cooperative Management Act, the Fish and Wildlife Coordination Act, and the National Environmental Policy Act.

3.1 THE FEDERAL POWER ACT (FPA) (AS AMENDED)(16 USC §§791A, *ET SEQ*.)

Section 18 of the FPA - Section 18 of the FPA expressly grants to the DOC and the Department of the Interior (DOI) unilateral authority to prescribe fishways. Section 18 of the FPA states that FERC must require construction, maintenance, and operation by a licensee at the licensee's own expense of such fishways, as may be prescribed by the Secretary of Commerce or the Secretary of the Interior. Within the DOC, the authority to prescribe fishways is delegated to the NMFS Regional Administrators.

Section 10(j) of the FPA - Under Section 10(j) of the FPA, licenses for hydroelectric projects must include conditions to protect, mitigate damages to, and enhance fish and wildlife resources, including related spawning grounds and habitat. These conditions are to be based on recommendations received from Federal and State fish and wildlife agencies. FERC is required to include such recommendations unless it finds that they are inconsistent with Part I of the FPA or other applicable law, and that alternative conditions must adequately address fish and wildlife issues. Before rejecting an agency recommendation, FERC must attempt to resolve the inconsistency, giving due weight to the agency's recommendations, expertise, and statutory authority. If FERC does not adopt a Section 10(j) recommendation, in whole or in part, it must publish findings that adoption of the recommendation is inconsistent with the purposes and requirements of Part 1 of the FPA or other applicable provisions of law, and that conditions selected by FERC adequately and equitably protect, mitigate damages to, and enhance fish and wildlife and their habitats.

Section 10(a)(1) of the FPA - Resource agencies may also recommend conditions under Section 10(a)(1) of the FPA for the protection, mitigation and enhancement of fish and wildlife (including related spawning grounds and habitat).

3.2 ENDANGERED SPECIES ACT (ESA) (AS AMENDED) (16 USC §1531 *ET SEQ.*)

Section 7(a)(2) of the ESA, states that each Federal agency shall, in consultation with the Secretary, insure that any action an agency authorizes, funds, or carries out is not likely to jeopardize the continued existence of a listed species or result in the destruction or adverse modification of designated critical habitat. Any discretionary federal action that may affect a listed species must undergo Section 7 consultation. Section 7(a)(1) requires Federal agencies to use their authorities to further the conservation of listed species.

3.3 MAGNUSON-STEVENS FISHERY CONSERVATION AND MANAGEMENT ACT (MSA) (AS AMENDED) (MSA) (16 USC §§1801, *ET SEQ*)

The 1996 amendments to the MSA set forth a number of mandates for us, the Fishery Management Councils (Councils), and other Federal agencies to identify and protect important marine and diadromous fish habitats. The councils are required to identify and describe essential fish habitat (EFH) for all managed species in order to protect habitat from fishing impacts and to allow for consultation with federal agencies whose actions may adversely impact essential fish habitat. EFH is defined as “those waters and substrates necessary to fish for spawning, breeding, feeding or growth to maturity” 16 U.S.C. § 1853(a)(7) and § 1802(10). The MSA requires federal agencies to consult with the Secretary of Commerce, through us, with respect to “any action authorized, funded, or undertaken, or proposed to be authorized, funded, or undertaken, by such agency that may adversely affect any essential fish habitat identified under this Act” 16 U.S.C. § 1855(b)(2). In the EFH consultation process, the federal action agency initiates consultation by preparing and submitting a completed EFH assessment describing the potential impacts of the action on EFH.

3.4 ATLANTIC COASTAL FISHERIES COOPERATIVE MANAGEMENT ACT (ACFCMA) (AS AMENDED) (16 USC §§5101, *ET SEQ.*)

The purpose of the ACFCMA is to provide for more effective fishery resource conservation of coastal fish species that are distributed across the jurisdictional boundaries of the Atlantic States and the Federal Government. These coastal fish species, which include American eel, shad and river herring, are managed by various species boards of the Atlantic States Marine Fisheries Commission (ASMFC), which develop fishery management plans and recommend management action to the states and NMFS.

3.5 FISH AND WILDLIFE COORDINATION ACT (FWCA) (AS AMENDED) (16 USC §§661, *ET SEQ.*)

The FWCA provides that fish and wildlife conservation shall receive equal consideration and be coordinated with other features of water resource development programs. A Federal action agency, such as the Federal Energy Regulatory Commission (FERC), shall consult with us with a view to the conservation of fish and wildlife resources by preventing loss of and damage to such resources as well as providing for the development and improvement thereof in connection with such water resource development. We may provide recommendations to the Federal action agency to which the action agency shall give full consideration.

3.6 National Environmental Policy Act (NEPA) (as amended) (42 USC §§4321, *et seq.*)

The NEPA of 1969 (42 USC §§4321 *et seq.*) and its implementing regulations require Federal action agencies to analyze the direct and indirect environmental effects and cumulative impacts of project alternatives and connected actions. The NEPA requires the Federal action agency to conduct a comparative evaluation of the environmental benefits, costs, and risks of the proposed action, and alternatives to the proposed action.

3.7 Policy and coordination

Based on the above listed laws, we have developed policies designed to implement these laws.

3.7.1 NOAA Strategic Plan

To achieve this mission, NOAA's Next Generation Strategic Plan identifies the Habitat program for the protection and restoration of coastal marine habitats that support NOAA trust resources. An important objective of the Habitat program is to "improve ecosystem health through conservation and restoration of habitat." Our strategic plan further identifies the Protected Resources program to protect and work to recover species at risk of extinction, and the Fisheries Management program to ensure maintenance of fisheries at productive levels for supporting sustainability and the ecosystems to which they contribute. Strategies utilized to achieve this objective include implementing cooperative approaches at the local level in habitat conservation and restoration, including greater involvement in the review of FERC activities; and, by working to increase the survival of anadromous fish passing through hydroelectric facilities.

3.7.2 Atlantic States Marine Fisheries Commission (ASMFC)

The role of the ASMFC is to facilitate cooperative management of inter-jurisdictional fish stocks. ASMFC does this by creating Interstate Fisheries Management Plans for jurisdictional species. These plans set forth the management strategy for the fishery and are based upon the best available information from the scientists, managers, and industry. The plans are created and adopted at the ASMFC Policy Board level and the plans provide recommendations to the states and Federal government that allow all jurisdictions to independently respond to fishery conditions in a unified, coordinated way. The Atlantic Coastal Fisheries Cooperative Management Act requires the Federal government to support the ASMFC's management efforts. The Federal government enacts regulations to complement ASMFC recommendations when appropriate. To the extent the Federal government seeks to regulate an ASMFC managed species, those Federal regulations must be compatible with the ASMFC's plan and consistent with the 10 National Standards set forth in the Magnuson-Stevens Act.

The ASMFC has developed two plans that relate to our trust species. We highlight the plans' goals and recommendations below.

3.7.3 ASMFC'S AMENDMENT 3 TO THE INTERSTATE FISHERY MANAGEMENT PLAN FOR SHAD AND RIVER HERRING (2010)

The Atlantic States Marine Fisheries Commission, Amendment 3 to the Interstate Fishery Management Plan for Shad and River Herring (American Shad Management), approved in 2010 includes the following objective:

1. Maximize the number of juvenile recruits emigrating from freshwater stock complexes

When considering options for restoring alosine habitat, NOAA should include study of impacts and possible alteration of dam-related operations to enhance river habitat.

This document includes the following recommendations:

General Fish Passage

1) States should work in concert with the U.S. Fish and Wildlife Service (USFWS) and the National Oceanic and Atmospheric Administration's (NOAA)National Marine Fisheries Service (NMFS) to identify hydropower dams that pose significant impediment to diadromous fish migration, and target them for appropriate recommendations during FERC relicensing.
2) States should identify and prioritize barriers in need of fish passage based on clear ecological criteria (e.g., amount and quality of habitat upstream of barrier, size, and status of affected populations). These prioritizations could apply to a single species, but are likely to be more useful when all diadromous species are evaluated together.
3) A focused, coordinated, well supported effort among federal, state, and associated interests should be undertaken to address the issue of fish passage development and efficiency. The effort should attempt to develop new technologies and approaches to improve passage efficiency with the premise that existing technology is insufficient to achieve restoration and management goals for several Atlantic coast river systems.
4) Where obstruction removal is not feasible, install appropriate passage facilities, including fish lifts, fish locks, fishways, navigation locks, or notches (low-head dams and culverts).
5) At sites with passage facilities, evaluate the effectiveness of upstream and downstream passage; when passage is inadequate, facilities should be improved.
6) Facilities for monitoring the effectiveness of the fish passage devices should be incorporated into the design where possible.
7) When designing and constructing fish passage systems, the behavioral response of each species of interest to appropriate site-specific physical factors should be considered.
8) If possible, protection from predation should be provided at the entrance, exit, and throughout the passage.
9) The passage facility should be designed to work under all conditions of head and tail water levels that prevail during periods of migration.
10) Passages are vulnerable to damage by high flows and waterborne debris. Techniques for preventing damage include robust construction, siting facilities where they are least exposed to adverse conditions, and removing the facilities in the winter.

11) Passage facilities should be designed specifically for passing alosines at optimum efficiency.

Upstream Fish Passage

1) American shad must be able to locate and enter the passage facility with little effort and without stress.
2) Where appropriate, improve upstream fish passage effectiveness through operational or structural modifications at impediments to migration.
3) Fish that have ascended the passage facility should be guided/routed to an appropriate area so that they can continue upstream migration, and avoid being swept back downstream below the obstruction.

Downstream Fish Passage

1) To enhance survival at dams during emigration, evaluate survival of post spawning and juvenile fish passed via each route (e.g., turbines, spillage, bypass facilities, or a combination of the three) at any given facility, and implement measures to pass fish via the route with the best survival rate.

Other Dam Issues

1) Where practicable, remove obstructions to upstream and downstream migration in lieu of fishway construction.
2) Locate water intakes where impingement/entrainment rates are likely to be lowest, employ intake screens or deterrent devices to prevent egg and larval mortality, and alter water intake velocities to reduce mortalities.
3) To mitigate hydrological changes from dams, consider operational changes such as turbine venting, aerating reservoirs upstream of hydroelectric plants, aerating flows downstream, and adjusting in-stream flows.
4) Natural river discharge should be taken into account when instream flow alterations are being made to a river (flow regulation) because river flow plays an important role in the migration of diadromous fish.
5) Ensure that decisions on river flow allocation (e.g., irrigation, evaporative loss, out of basin water transport, hydroelectric operations) take into account instream flow needs for American shad migration, spawning, and nursery use, and minimize deviation from natural flow regimes.
6) When considering options for restoring alosine habitat, include study of impacts and possible alteration of dam-related operations to enhance river habitat.

The relicensing process for the Lowell project provides an excellent opportunity to incorporate many of the ASMFC recommendations.

3.7.4 ASMFC's Interstate Fisheries Management Plan for American Eel (2000)

The goals in this plan include the following:

1. Protect and enhance the abundance of American eel in inland and territorial waters of the Atlantic States and jurisdictions and contribute to the viability of the American eel spawning population

2. Protect and enhance American eel abundance in all watersheds where eel now occur
3. Where practical, restore American eel abundance in all watersheds where they had historical abundance but may now be absent by providing access to inland waters for glass eel, elvers and yellow eel and adequate escapement to the ocean for pre-spawning adult eel.

Recommendations for Federal Energy Regulatory Commission Relicensing

The ASMFC recognizes that many factors influence the American eel population, including harvest, barriers to migration, habitat loss, and natural climatic variation. The ASMFC's authority, through its member states is limited to controlling commercial and recreational fishing activity; however, to further promotes the rebuilding of the American eel population, the ASMFC strongly encourages member states and jurisdictions, as well as the USFWS, to consider and mitigate, if possible, other factors that limit eel survival. Specifically, the ASMFC requests that member states and jurisdictions request special consideration for American eel, in the FERC relicensing process. This consideration should include, but not be limited to, improving upstream passage and downstream passage, and collecting data on both means of passage.

4 NMFS Comments on the Pre-Application Document (PAD)

Based on our review of the PAD submitted by Licensee, we offer the following comments.

4.1 PAD Section 4.0 Project Location, Facilities, and Operations

Figure 4.0-1 shows two approximate upstream Project Boundary locations. One in Tyngsborough, MA and the other in Merrimack/Litchfield, NH. The Licensee should explain the significance of these two points in the project boundary. We recommend the geographic scope under the environmental analysis of fisheries resource be extended to fully evaluate cumulative effects. The geographic scope should extend from the Eastman Falls dam (FERC no. 2457 and Lake Winnipesaukee to the confluence of the Pemigewasset and Winnipesaukee Rivers, downstream to the Atlantic Ocean.

4.2 PAD Section 4.5 Description of Project Operations

According to information described in the PAD, the Lowell Project operates in a run-of-river (ROR) mode and has no usable storage capacity. The Licensee should describe how they are defining ROR: instantaneous, daily average, or some other time step. In addition, with the pneumatic crest gates now operational, typical headpond fluctuation should also be clarified and described in detail.

4.2.1 PAD Subsection 4.5.1.1 General Operation

The Licensee should describe the tolerance of the automatic pond level control. In the previous description of the E.L. Field Powerhouse turbines, the rated hydraulic capacity of each turbine is 3,300 cfs. We understand that under different headpond and tailwater conditions, the maximum hydraulic capacity can vary, but the description should remain consistent throughout the draft license application to prevent confusion by the reader. Therefore, the maximum hydraulic capacity of the E.L. Field Powerhouse is 6,600 cfs, and river flow that exceeds that value goes through the Pawtucket Canal up to 2,000 cfs with the remainder spilling over the Pawtucket Dam. Minimum flow is 1,990 cfs or inflow, whichever is less, as measured downstream from the project. The license application should describe the purpose of this flow and why it proposes to continue to operate in this manner. In addition, at flows below 6,600 cfs, the license application should describe the preferential operation of the two turbines and state the minimum hydraulic capacity. Such details are necessary to fully understand project operation and evaluate potential impacts of project operation on fisheries resources.

4.2.2 PAD Subsection 4.5.1.2 Canal System Operations

The Licensee should provide more detail on canal operations. For example, it is not clear from the PAD when the Pawtucket Canal generation begins once river flow exceeds the E.L. Field Powerhouse hydraulic capacity. During the recent site visit on July 18, 2018, we learned that the Licensee decommissioned the Assets Power Station as part of the City's redevelopment plans. The license application should describe in detail, which generation assets will be operating during the upcoming license and the routing protocol through the Pawtucket Canal system, which turbines are first on and last off, etc. based on hydraulic conditions. In addition, the license application should provide estimates of leakage flow and other latent flow conveyed through the canal when National Park Service tour boats are operating, if measurable.

4.2.3 PAD Subsection 4.5.1.3 Pneumatic Crest Gate Operations

The pneumatic crest gate consists of multiple zones from the Pawtucket Gatehouse to the fish ladder. The Licensee should describe the actuation of these zones during times of spill (e.g., first on, etc.). This information is important to understand project impacts on fisheries resources, as zones that are distal from the fish ladder may result in false attraction away from the fish ladder entrance, which can lead to significant migratory delay.

4.2.4 PAD Subsection 4.5.1.4 Fish Passage Operations

The license application should append the existing Comprehensive Fish Passage Plan (CFPP). In addition, much of the existing CFPP is outdated and the Licensee should provide updates to the plan based on current and proposed fish passage measures and operations.

4.3 PAD Section 5.4 Fish and Aquatic Resources

4.3.1 PAD Subsection 5.4.5.6 Alosine Clupeids

The license application should state that river herring are currently under status review by NMFS for listing under the Endangered Species Act.

4.3.2 PAD Subsection 5.4.6 Other Site-Specific Fisheries Information

This section of the PAD describes past studies at the site, including a 1988 study evaluating fish passage at the Pawtucket Gatehouse (RMC Environmental Services 1988). The Licensee states, "In addition, a 1988 acoustic telemetry study performed by RMC Environmental Services of adult American shad movement through the Northern Canal demonstrated successful passage through the Pawtucket Gatehouse, as well as incidental information regarding downstream passage routes for post-spawning individuals". We do not consider the conclusions drawn from this study to be accurate. In that study, gatehouse passage was extremely limited and the majority of fish that did pass upstream went through the boat lock. All the fish in the study had significant delay. We do not deem this as successful passage through the Pawtucket Gatehouse.

The license application should include information from the recent study entitled, *Analysis of Upstream Fish Passage Facilities and Operation* (Gomez and Sullivan Engineers 2016). As part of that study, one of the recommendation was to remove part of the ledge downstream from the E.L. Field Powerhouse fish lift entrance to improve entrance efficiency. The licensee has previously agreed to remove ledge downstream of the fish lift entrance. Our agency engineer, as well as the U.S. Fish and Wildlife Service (USFWS) worked with the Licensee on the excavation design plans, providing feedback through an August 2017 technical memo, which was filed with FERC on September 28, 2017. The Licensee confirmed plans, in an email dated June 19, 2018, to complete this work during the 2019 construction season. A detailed description of the ledge excavation is important information to include in the license application. We expect some studies evaluating upstream passage at the project may need to be delayed until the ledge excavation is complete.

Table 5.4-3 includes major findings of fish passage studies performed during the last license term. In that table, the Licensee labels the first column 'Year'; we determined some inconsistencies with the year representing either the year published or the migratory year the study occurred. We have the following comments regarding the conclusions and omissions in the table.

- The 1988 Study (RMC Environmental Services, Inc.) – We disagree that there was 'little delay' for the tagged fish that passed to upstream spawning grounds. Tagged fish released at E.L. Field power station reached the Pawtucket Gatehouse in a few hours, but then exhibited delay behaviors going up and down the Northern Canal numerous times. Fish that used the boat lock (after opening) passed usually within a day, but the fish that used the gatehouse wells took up to 3 days to pass. We do not consider this timely fish passage. We do not agree with the statement, 'The Pawtucket Canal should not entrap emigrating adult shad'. One tagged shad passed the Francis Guard Locks gatehouse. Six other shad initially approached the Francis Guard Locks gatehouse exhibiting delay behavior. Overall project mortality estimated from stationary tags was 61.5%.
- The 1991 Juvenile Study (Normandeau Associates, Inc.) – The corrected bypass efficiency was 7%. Delay was less than 72 hours with 95% passing within 24 hours.
- The 1991 Adult Study (Normandeau Associates, Inc.) – In this study, release of the tagged fish was in the Northern Canal testing the effectiveness the Pawtucket Gatehouse passage. Only 72% of the fish passed the gatehouse to upstream spawning habitat and the boat lock was open throughout the study. Twelve post-spawn adults approached the project with 42% passing through the turbines, 17% passing through the downstream bypass, 17% through the Pawtucket Canal, and 25% passing over the Pawtucket Dam. Of the 23 tagged fish that passed downstream of the project (both post-spawn fish and fish that did not pass the Pawtucket Gatehouse), an estimated 61% died. E.L. Field Powerhouse turbine mortality was 64%.
- The 1994 Study (Normandeau Associates, Inc.) – Though much better than the corrected bypass efficiency of 7% from the 1991 study, we do not consider a downstream bypass efficiency of 32% as 'very efficient'.

- The 1995 Study (Normandeau Associates, Inc.) – no comments.
- The 1996 Fish Lift Efficiency Study (Normandeau Associates, Inc.) – Publication date was 1997.
- The 1996 Downstream Passage Smolt Study (Normandeau Associates, Inc.) – This study included a mixture of hatchery and wild sources of fish. Of the 49 released fish, 61% passed the project via the powerhouse (77%), the fish bypass (13%), the Pawtucket Canal (7%), and an unknown route (3%). Of the fish that passed the project, hatchery fish took approximately 100 hours to pass and wild fish took about 28 hours.
- From 1999 through 2001, the Licensee performed yearly internal fish lift efficiency studies. Table 5.4-3 in the Pre-Application Document does not clearly describe the chronology, the purpose, and results of these studies. The Licensee should be consistent by only using the publication date to avoid confusion. Each study tested a specific component or modification these tests need more clarification.
- The 2002 USFWS Study – no comments.
- The 2003 Downstream Passage and Smolt Survival Study (Normandeau Associates, Inc.) – The Licensee studied three fish bypass flows (2%, 3.5%, and 4.5% station discharge) with 20 tagged smolts each. Bypass efficiency improved with increased flow, though none of the tests resulted in adequate passage efficiency. Cumulatively, 59% went through the turbines, 32% went through the bypass, and 9% were undetermined. Turbine survival was very high, but predation in the tailrace was also extremely high. We consider tailrace predation a project effect. Turbine passage and other designated downstream passage routes that concentrate the migration into a small area provide predators unfettered access to easy prey. Without the project, dispersal of prey would result in decreased predatory efficiency.
- The 2011 Upstream Three-Dimensional Study (Alden Research Laboratory, Inc. – no comments.
- The 2013 Upstream Three-Dimensional Study Further Analysis (Blue Leaf Environmental) – The study showed that greater than 80% of the detections of tagged shad were between the elevations of 40 and 50 feet suggesting that fishway entrance efficiency would dramatically improve by lowering the invert of the entrance and maintaining the entrance jet velocity.
- The Licensee should include a description of the 1990 Normandeau Associates study entitled, "An assessment of the effectiveness of a fish bypass for passing downstream migrating Atlantic salmon smolts and estimated survival of salmon smolts passed through the 8.6-MW Kaplan Turbines at the E.L. Field Hydroelectric Project, Lowell, Massachusetts".
- The Licensee should include a description of the 2016 study entitled, "Analysis of Upstream Fish Passage Facilities and Operation".

5 REQUESTED STUDIES

Our study requests intend to facilitate the collection of information necessary to conduct effects analyses; develop reasonable and prudent conservation measures; and protection, mitigation, and enhancement measures pursuant to the Fish and Wildlife Coordination Act, as amended (16 U.S.C. §661 *et seq.),* and the Federal Power Act (16 U.S.C. §791a, *et seq.).*

5.1 REQUESTED STUDY #1: AMERICAN EEL PASSAGE DOWNSTREAM STUDY

The Merrimack River is a migratory corridor for American eel. This species must be able to pass the project without undue harm or delay to complete their life cycle. Poor passage at the project limits access to spawning habitats in the Sargasso Sea harming genetic diversity and resilience within the population. The Lowell project includes potential emigration routes over the Pawtucket Dam, through the E.L. Field Powerhouse turbines, over the E.L. Field Powerhouse fish bypass, and through the Pawtucket Canal including multiple dams and powerhouses. The Licensee is installing a pneumatic crest gate at the dam that decreases leakage through the flashboards and provides more control of spill over the dam. We request a study to determine the downstream passage routes at multiple river flows and operating conditions to inform safe, timely, and effective passage measures at the project.

GOALS AND OBJECTIVES

The goal of this study is to determine the impact of the Lowell hydroelectric project on the emigration of silver eels in the Merrimack River. Project operations can result in delay, mortality or injury during emigration. We need to understand the extent of delay, the passage routes, and the potential for mortality to determine measures and recommendations to increase survival and improve fish passage at the project.

The objectives of this study are:

- Quantify the movement rates and delay caused by multiple river flows and project operations
- Quantify the relative proportion of eels passing each emigration route at the project during multiple river flows and various project operations.
- Quantify instantaneous and latent mortality of eels passed via each emigration route.

RESOURCE MANAGEMENT GOALS

The ASMFC has developed five documents related to the management of American eel including:

- Interstate Fishery Management Plan for American Eel. April 2000. Atlantic States Marine Fisheries Commission.
- Addendum II to the Fishery Management Plan for American Eel. Atlantic States Marine Fisheries Commission. Approved October 23, 2008. 8 pp.

Objectives of the fishery management plan include:

(1) protect and enhance American eel abundance in all watersheds where eel now occur; and

(2) where practical, restore American eel to those waters where they had historical abundance, but may now be absent, by providing access to inland waters for glass eel, elvers, and yellow eel, and adequate escapement to the ocean for pre- spawning adult eel.

Addendum II contains specific recommendations for improving upstream and downstream passage of American eel, including requesting that member states and jurisdictions seek special consideration for American eel in the Federal Energy Regulatory Commission relicensing process.

The American eel population is severely depressed in the Merrimack River watershed. Our goal is to restore American eel to historical habitats and ensure safe migratory pathways to build abundance and resilience in the population.

PUBLIC INTEREST

The requestor, NMFS, is a federal resource agency.

EXISTING INFORMATION AND NEED FOR ADDITIONAL INFORMATION

Upstream of the Lowell Hydroelectric Project is the Merrimack Project (FERC No. 1893) which has been conducting ongoing silver eel downstream passage studies. In 2017, the Licensee installed receivers at the Lowell project to continue the monitoring of the tagged eels that passed the Merrimack Project (Normandeau Associates 2018). The study detected fourteen eels near the Lowell Project with eight going through the turbines, five passing over the spillway, and one undetermined route. One of the eels that passed through the E.L. Field Powerhouse died. The study did not monitor the Pawtucket Canal or the downtown project facilities. Throughout the study, the canal system was not operating though there was sufficient river flow to operate. Therefore, the study lacks information regarding project effects in the canal system on silver eel emigration. In addition, the study has an insufficient sample size and does not have a control group or mobile tracking to account for drifting of dead eels.

PROJECT NEXUS

The Lowell Hydroelectric Project does not have entrainment prevention at any of the turbine intakes. Adult eels have an average mortality of 10.9% (±13.0 S.D.) passing through Francis turbines and an average mortality of 25.7% (±10.6 S.D.) passing through Kaplan turbines (Pracheil et al. 2016). E.L. Field Powerhouse has two Kaplan turbines and the canal system has 19 Francis turbines (12 still operate). Silver eels emigrate during the mid-summer through late fall (Haro 2003), a time of year when Merrimack River flows equal or exceed the operating capacity of the stations only part of the time. Therefore, we expect the project to spill infrequently during the silver eel emigration forcing eels to pass through the canal system, the E.L. Field Powerhouse, or the fish bypass. We assume entrained eel at the project powerhouses will incur unacceptable levels of mortality. We base this assumption on published mortality statistics, the age and specifications of the turbines, the complexity of canal routing, and the likelihood that emigrating silver eels will have to pass two turbines to reach downstream of the project (upper canal and lower canal). Therefore, as a first step in understanding overall project mortality, we need to understand the routes of emigration and the potential for delay under different river flow conditions and project operations. This study will contribute to the development of an administrative record in support of potential Section 18 fishway prescriptions or 10(j) recommendations.

Proposed Methodology

This study should be conducted using radio telemetry, with a study design that specifies sample size and tag and receiver configurations. A statistically significant number of telemetered eels are necessary to establish a clear understanding of how project operations affect eel emigration. The Licensee should release groups of eels during spill and non-spill periods. The Licensee should operate the Pawtucket Canal system turbines during the study. The Licensee should record river flow and project operations throughout the study. Release of tagged eels should be a few kilometers (km) upstream of the Pawtucket Dam. The project design should include a smaller sample of dead eel to act as a control group, as fish can drift significant distances downstream after they have died (Havn et al. 2017). Telemetry receivers and antennas should be located above and below the project to assess passage. Receivers should monitor the following potential routes: entrance into Pawtucket Canal via the Guard Lock and Gates Facility, passage over the Pawtucket Dam, entrance into Northern Canal at Pawtucket Gatehouse, entrance into E.L. Field Powerhouse turbines, and entrance into the E.L. Field Powerhouse bypass.

Mobile tracking (i.e., via boat) in river reaches between release sites and several km downstream of E.L. Field Powerhouse should be performed at regular intervals during and after releases to confirm routes and fates of fish.

Movement rates (time between release and passage) of eels passing the projects by various routes should also be quantified using time-to-event analyses (Castro-Santos and Perry 2012).

This study will require two years of field data collection to account for inter-annual variability in river discharge and water temperatures.

Level of Effort and Cost

The level of cost and effort for the downstream eel passage study is moderate to high. We anticipate the study will require two migratory seasons to acquire enough data. The Licensee will need to purchase silver eels from a distributor with ample supply, as the Merrimack River does not have an adequate population to harvest. To use the acquired eels, the Licensee will need to permit the use of out-of-basin eels in the study. Each group of eels will require tagging and release over the course of each migration season representing seasonal flows and project operations. The Licensee will download the data periodically, analyze it, and report the results. We estimate the cost will be approximately $150,000 per year for the study. No alternatives are proposed.

5.2 Requested Study #2: Juvenile Alosine Downstream Study

The Merrimack River is a migratory corridor for juvenile alosines. These species must be able to pass the project without undue harm or delay to complete their life cycle. Poor passage at the project limits access to marine habitats harming stock recruitment and resilience within the population and ecosystem benefits to other trophic levels. The Lowell project includes potential emigration routes over the Pawtucket Dam, through the E.L. Field Powerhouse turbines, over the E.L. Field Powerhouse fish bypass, and through the Pawtucket Canal including multiple dams and powerhouses. The Licensee is installing a pneumatic crest gate at the dam that decreases leakage through the flashboards and provides more control of spill over the dam. We request a study to determine the downstream passage routes at multiple river flows and operating conditions to inform safe, timely, and effective passage measures at the project.

Goals and Objectives

The goal of this study is to determine the impact of the Lowell Hydroelectric Project on the emigration of juvenile alosines in the Merrimack River. Project operations can result in delay, mortality or injury during emigration. We need to understand the extent of delay, the passage routes, and the potential for mortality to determine measures and recommendations to increase survival and improve fish passage at the project.

The objectives of this study are:

- Quantify the movement rates and delay caused by project operations
- Quantify the relative proportion of juvenile alosines passing each emigration route at the project during various project operations.
- Quantify instantaneous and latent mortality of juvenile alosines passed via each emigration route.

Resource Management Goals

The NMFS is a federal resource agency with a mandate to protect and conserve fishery resources and associated habitat. Regulatory statutes codify our resource management goals and plans. We rely on the best available data to support conservation recommendations and management decisions. Data sought in this study are not available. This study is an appropriate request for the pre-application period.

The ASMFC has developed six documents related to the management of alosines including:

- Interstate Fishery Management Plan for American Shad and River Herring. October 1985. Atlantic States Marine Fisheries Commission.
- Supplement to American Shad and River Herring Fishery Management Plan. October 1988. Atlantic States Marine Fisheries Commission.
- Amendment II to the Interstate Fishery Management Plan for Shad and River Herring (River Herring Management). May 2009. Atlantic States Marine Fisheries Commission.
- Amendment III to the Interstate Fishery Management Plan for shad and river herring (American Shad Management). February 2010. Atlantic States Marine Fisheries Commission.

Relevant objectives in the fishery management plans include:

(1) Improve habitat accessibility and quality in a manner consistent with appropriate management actions for non-anadromous fisheries.

   a. Improve or install fish passage facilities at dams and other obstacles preventing fish from reaching potential spawning areas

   b. Ensure that decisions on river flow allocation (e.g., hydroelectric operations) take into account flow needs for alosine migration, spawning, and nursery usage

   c. Ensure that water withdrawal effects (e.g., impingement and entrainment) do not affect alosine stocks to the extent that they result in stock declines

Addendum II and III contains specific management recommendations for improving upstream and downstream passage of alosines, including requesting that member states and jurisdictions seek special consideration for alosines in the Federal Energy Regulatory Commission relicensing process.

The alosine population is severely depressed in the Merrimack River watershed (Technical Committee for Anadromous Fishery Management of the Merrimack River Basin 2010). We have achieved dramatic increases in alewife returns in recent years through a stocking effort lead by fisheries agencies and compliance with fish passage conditions in existing hydroelectric licenses, but American shad and blueback herring populations still have not shown improvement. Our goal is to restore alosines to historical habitats and ensure safe migratory pathways to build abundance and resilience in the population.

PUBLIC INTEREST

The requestor, NMFS, is a federal resource agency.

EXISTING INFORMATION AND NEED FOR ADDITIONAL INFORMATION

The Licensee conducted three separate mark-recapture studies of emigrating juvenile alosines from 1990 to 1995 (Normandeau Associates, Inc., 1991, 1994, 1995). These studies examined only entrainment into E.L. Field Powerhouse turbines and the fish bypass at the powerhouse as potential routes of passage. The early 1990's studies used antiquated technology that did not adequately address the goals and objectives of this study. We have no information regarding usage of the Pawtucket Canal or the spillway as emigration routes for juvenile alosines at the Lowell Hydroelectric Project.

PROJECT NEXUS

The Lowell Hydroelectric Project does not have entrainment prevention at the turbine intakes or designated spillway passage routes. The designated fish bypass system at the E.L. Field Powerhouse has a documented poor entrance efficiency and is unable to operate throughout the diurnal cycle. Juvenile alosines emigrate during the fall at the project, a time of year when Merrimack River flows equal or exceed the operating capacity of the power stations only part of the time. Therefore, we expect juvenile alosines have the opportunity to use multiple routes of passage during emigration. We assume entrained juvenile alosines at the Pawtucket Canal powerhouses will incur unacceptable levels of delay, injury and mortality. We base this assumption on published mortality statistics, the age and specifications of the turbines, the complexity of canal routing, and the likelihood that emigrating juvenile alosines will have to pass two turbines to reach downstream of the project (upper canal and lower canal). Conversely, we assume that turbine passage at the E.L. Field Powerhouse and passage over the spillway may be viable routes of downstream passage, but we do not have delay or mortality information supporting those assumptions. Therefore, to determine overall project survival, we need to understand the routes of emigration and the potential for delay under different river flow conditions and project operations. This study will contribute to the development of an administrative record in support of potential Section 18 fishway prescriptions or 10(j) recommendations.

PROPOSED METHODOLOGY

This study should be conducted using radio telemetry, with a study design that specifies sample size and tag and receiver configurations. Through the agency-led stocking program in the Merrimack River watershed, large numbers of juvenile alewife emigrate from the upper watershed on a yearly basis. The Licensee should catch these juveniles for the study, as these fish have been used successfully in acoustic telemetry studies for other facilities on the Merrimack River (Accession No. 20170223-5040). A statistically significant number of telemetered juvenile alewife are necessary to establish a clear understanding of how project operations affect juvenile alosine emigration (juvenile alewife will serve as a proxy for juvenile American shad and blueback herring). The Licensee should release groups of juvenile alewife during spill and non-spill periods. The Licensee should operate the Pawtucket Canal system turbines during the study. The Licensee should record river flows and project operations throughout the study. Release of tagged juvenile alewife should be a few kilometers (km) upstream of the Pawtucket Dam. Telemetry receivers and antennas will be located above and below the project to assess passage. Receivers should monitor the following potential routes: entrance into Pawtucket Canal via the Guard Lock and Gates Facility, passage over the Pawtucket Dam, entrance into Northern Canal at Pawtucket Gatehouse, entrance into E.L. Field Powerhouse turbines, and entrance into the E.L. Field Powerhouse bypass.

Mobile tracking (i.e., via boat) in river reaches between release sites and several km downstream of E.L. Field Powerhouse will be performed at regular intervals during and after releases to confirm routes and fates of fish.

Movement rates (time between release and passage) of juvenile alewife passing the projects by various routes will also be quantified using time-to-event analyses (Castro-Santos and Perry 2012).

This study will require two years of field data collection to account for inter-annual variability in river discharge and water temperatures.

Level of Effort and Cost

The level of cost and effort for the downstream juvenile alosine passage study is moderate to high. We anticipate the study will require two migratory seasons to acquire enough data. The Licensee will download the data periodically, analyze it, and report the results. We estimate the cost will be approximately $125,000 per year for the study. No alternatives are proposed.

5.3 Requested Study #3: Upstream and Downstream Adult Alosine Passage Study

The Merrimack River is a migratory corridor for alosines. These species must be able to pass the project without undue harm or delay to complete their life cycle. Poor passage at the project limits access to freshwater spawning habitats and marine habitats harming resilience within the population and ecosystem benefits to other trophic levels. The Lowell project includes potential immigration routes through the E.L. Field Powerhouse fish lift and the Pawtucket Dam fish ladder. Potential emigration routes include over the Pawtucket Dam, through the E.L. Field Powerhouse turbines, over the E.L. Field Powerhouse fish bypass, and through the Pawtucket Canal including multiple dams and powerhouses. The Licensee is installing a pneumatic crest gate at the dam that decreases leakage through the flashboards and provides more control of spill over the dam. We request a study to determine the effectiveness of the upstream fishways and downstream passage routes at multiple river flows and operating conditions to inform safe, timely, and effective passage measures at the project.

Goals and Objectives

The goal of this study is to determine the impact of the Lowell Hydroelectric Project on the migration of adult alosines in the Merrimack River. Project operations can result in delay, mortality or injury during migration. We need to understand the extent of delay, the passage routes, and the potential for mortality to determine measures and recommendations to increase survival and improve fish passage at the project.

The objectives of this study are:

- Quantify the movement rates and delay caused by project operations at multiple river flows.
- Quantify the relative proportion of alosines passing each migration route at the project during various project operations at multiple river flows.
- Quantify instantaneous and latent mortality of alosines passed via each migration route at multiple river flows.

Resource Management Goals

The NMFS is a federal resource agency with a mandate to protect and conserve fishery resources and associated habitat. Regulatory statutes codify our resource management goals and plans. We rely on the best available information and data to support conservation recommendations and management decisions. Data sought in this study are not available. This study is an appropriate request for the pre-application period.

Public Interest

The requestor, NMFS, is a federal resource agency.

Existing Information and Need for Additional Information

Since the commissioning of the fish passage facilities at the Lowell Hydroelectric Project, passage of alosines has been unable to meet management goals. For example, greater than 50% of the tagged adult American shad that pass the downstream Lawrence Hydroelectric Project reach the Lowell tailrace, yet only a small percentage of those fish use the designated upstream fishways (Sprankle 2005), (Alden Research Laboratory 2011). Therefore, through the course of the original license, the Licensee conducted numerous studies to investigate fish passage at the project (Table 1).

Table 1. Adult Alosine Upstream and Downstream Fish Passage Studies.

Year	Study Title	Author	Study Results
1988	Passage of Radio-tagged American shad through the Northern Canal Headgate Structure: Lowell	RMC Environmental Services, Inc.	Upstream Results: Of the 25-tagged fish, 24 passed the Northern Canal Gatehouse and one died through turbine passage. Of the 24 passed fish, 19 used the boat lock and 5 used the gate wells. Fish took a few hours to reach the gatehouse from the fish lift. Those that

	Hydroelectric Project		passed the boat lock took less than a day and those that passed through the gate wells took 1 to 3 days to get to the headpond. Downstream Results: Of the 24-tagged fish, 13 approached Lowell after spawning. One of these entered the Pawtucket Canal and died. Eight went through either the Northern Canal and the remainder were undetermined routes. Only 5 fish reached Lawrence suggesting a project mortality of 61.5%. There was delay behavior approaching the gatehouse and Pawtucket Canal.
1991	Downstream Passage Routes of Radio-tagged Adult American shad at the Lowell Hydroelectric Project on the Merrimack River: Lowell, Massachusetts	Normandeau Associates, Inc.	Upstream Results: 28 of the 45-tagged fish passed the gatehouse. Downstream Results: 12 of the 28 fish approached the project after spawning. 5 went through the turbines, 2 went through the Pawtucket Canal, 2 went through the fish bypass, and 3 went over the dam. Of the 17 fish that did not pass upstream of the gatehouse, 6 died in the Northern Canal, 8 went through the powerhouse, and 3 went through the fish bypass. Project mortality through various downstream passage routes was 61%.
1997	Lowell Hydroelectric Project Internal Fish Lift Efficiency Monitoring Program, Spring 1996	Normandeau Associates, Inc.	At 50 cfs attraction flow, the fishway efficiency was 0.5%. At 90 cfs, the fishway efficiency was 2.4%. Both entrances were operating. Entrance #2 was a net loss of 4,175 shad and entrance #1 was a net gain of 113 shad.
1999	An Assessment of Internal Fish Lift Efficiency at the Lowell Hydroelectric Project, Spring 1998	Normandeau Associates, Inc.	The fishway internal efficiency increased by 10% from previous years after modifications.
2000	An Assessment of Internal Fish Lift Efficiency at the Lowell	Normandeau Associates, Inc.	At 120 cfs attraction flow, the fishway efficiency was 42% ranging from 9% to 98%.

	Hydroelectric Project, Spring 1999		
2001	An Assessment of Internal Fish Lift Efficiency at the Lowell Hydroelectric Project, Spring 2000	Normandeau Associates, Inc.	At 120 cfs attraction flow, the fishway average efficiency was 46.4% ranging from 13% to 92%. Efficiency was best at the 2-foot crowder opening (72%) and worst at the 4-foot opening (29%)
2002	Interdam Movements and Passage Attraction of American shad in the Lower Merrimack River Main Stem	U.S. Fish and Wildlife Service	Upstream results: Of the tagged fish at Lawrence, 55% entered the Lowell tailrace and 66% reached the project. Passage efficiency was 6% using tagged fish and was 10% using count room data. Downstream results: Of the four-tagged fish that passed Lowell, one died upstream, one died using the fish bypass, and the other two reached Lawrence suggesting a 33% project mortality.
2011	Shad Upstream Passage Assessment at Lowell Hydroelectric Project (FERC 2790)	Alden Research Laboratory, Inc.	Of the tagged fish at Lawrence, 57% reach the Lowell project. Shad explored the tailrace in a "U" shaped pattern along the edges. Only three fish entered the fishway.
2013	Additional Analysis of American Shad Three-Dimensional Behavior in the Tailrace of the Lowell Project	Blue Leaf Environmental	Shad exhibited a random roaming behavior within the previously determined "U" shaped pattern. Greater than 80% of the detections were between the elevations of 40 and 50 feet.

Though the Licensee has completed numerous studies over the course of their original license, additional information is necessary to determine appropriate fish passage and protection measures for adult alosines in the upcoming license. Concerning upstream passage, none of the studies simultaneously focused on both the Pawtucket Dam fish ladder and the E.L. Field Powerhouse fish lift. As both facilities are necessary to meet management goals, we need to understand route selection and delay approaching the project with both fish passage facilities operating and monitored. In 2019, the Licensee will excavate part of the Lowell tailrace to improve attraction to the riverside fish lift entrance. Therefore, we need to understand whether this measure will improve entrance efficiency. In addition, none of the previous studies incorporated both Passive Integrated Transponder (PIT) tags and radio tags on the same fish. Dual tagging of the upstream migrating fish will allow us to quantify route selection, delay, and internal fishway efficiency. Concerning downstream passage, none of the previous studies had a statistically significant number of fish to account for tagging effects, natural post-spawn mortality, or the myriad of route selections during emigration. In addition, the new pneumatic crest gate constitutes a new hydraulic condition that may affect route selection during emigration. Finally, none of the previous studies focused on adult river herring, which exhibit different migratory behaviors than American shad.

PROJECT NEXUS

The Lowell Hydroelectric Project has two fishways that have not met alosine management goals for the Merrimack River watershed. The project also does not have entrainment prevention at any of the operating turbine intakes. In addition, project operations produce a myriad of migratory routes, both upstream and downstream, that can lead to delay, increased predation, and mortality. Information gained from this study will greatly increase our understanding of project effects. This study will contribute to the development of an administrative record in support of potential Section 18 fishway prescriptions or 10(j) recommendations.

PROPOSED METHODOLOGY

We recommend incorporating state-of-the-art telemetry methods for this study including both PIT and radio tag technology. The study design should specify sample size and tag and receiver configurations and include two years of field data collection to attempt to account for inter-annual variability in river discharge and water temperatures. Because ledge excavation in the tailrace will be occurring in 2019, a third year of study may be necessary to account for delay of the upstream passage evaluation.

The first year of study, prior to the completion of the ledge excavation, should focus on downstream passage and upstream passage through the Northern Canal only. The Licensee should tag a statistical significant number of both adult river herring and American shad during the migration run of each species captured at the Lawrence project. Each species should have two release locations, one group at the E.L. Field Powerhouse fish lift exit and the other in the Lowell project impoundment. The E.L. Field Powerhouse group should be dual tagged and the Northern Canal Gatehouse wells should be equipped with PIT tag receivers (if the boat lock is open, then receivers should be installed there as well). Release of radio-tag only groups of American shad and river herring should be a few kilometers (km) upstream of the Pawtucket Dam. A small sample of dead river herring and shad should be included in this release to act as a control group, as fish can drift significant distances downstream after they have died (Havn et al. 2017) Radio telemetry receivers and antennas will be located above and below the project to assess passage. Receivers should monitor the following potential routes: entrance into Pawtucket Canal via the Guard Lock and Gates Facility, passage over the Pawtucket Dam, entrance into Northern Canal at Pawtucket Gatehouse, entrance into E.L. Field Powerhouse turbines, and entrance into the E.L. Field Powerhouse bypass.

During the study seasons following the ledge excavation, the Licensee should tag a statistical significant number of both adult river herring and adult American shad captured at the Lawrence project during their migration run. Half of the test specimens for each species should be dual-tagged. The release location for all test specimens should be the Lawrence impoundment. In addition to the receivers installed during the first year of study, the Licensee should equip the entrance and exit of both fishways with PIT tag receivers (the ladder should have an additional PIT receiver in the turning pool) to evaluate fishway efficiencies. The Licensee should also equip the tailrace entrance, the fish lift entrance, and three equally spaced locations within the bypass reach (e.g., downstream cross-section, mid-point cross-section, and proximal to the ladder entrance) with radio tag receivers.

The Licensee should release groups of test specimens during spill and non-spill periods. The Licensee should operate the Pawtucket Canal system turbines during the study. The Licensee should record river flows and project operations throughout the study.

Mobile tracking (i.e., via boat) in river reaches between release sites and several km downstream of E.L. Field Powerhouse will be performed at regular intervals during and after releases to confirm routes and fates of fish.

Movement rates (time between release and passage) of juvenile alewife passing the projects by various routes will also be quantified using time-to-event analyses (Castro-Santos and Perry 2012).

Level of Effort and Cost

The level of cost and effort for the upstream and downstream alosine passage study is high. The study will require at least two migratory seasons to acquire enough data. Because of the ledge excavation, a third year of study is likely for the comprehensive upstream and downstream telemetry study depending on the environmental and operating conditions of the second year. The Licensee will download the data periodically, analyze it, and report the results. We estimate the cost will be approximately $150,000 for the first year study and $300,000 per year for the comprehensive study. No alternatives are proposed.

5.4 Requested Study #4: Project Survival Study

The Merrimack River is migratory corridor for a multitude of diadromous fish species including American eel, American shad, river herring, and Atlantic salmon. These species must be able to pass the Lowell Hydroelectric Project without significant mortality. The Lowell project includes 2 identical full Kaplan units at the E.L. Field Powerhouse and 19 Francis units of various specifications through a two-tiered canal system in downtown Lowell (12 units are still operating). Each of these turbine passage routes represent a significant risk of mortality to emigrating fish. In addition, the Licensee installed new pneumatic crest gates on the Pawtucket Dam with improved spill control that may provide a safe emigration route. We request a study to determine project survival by quantifying turbine mortality and injury under multiple operating conditions to inform safe, timely, and effective downstream passage measures at the project.

Goals and Objectives

The goal of this study is to quantify project survival for emigrating diadromous species that pass through project turbines. The objectives of the study are to:

- Conduct a field study of turbine survival at the E.L. Field Powerhouse with adult American eels and adult American shad.
- Conduct a desktop survival study for the full suite of diadromous species and life stages through all of the project units.

Resource Management Goals

The NMFS is a federal resource agency with a mandate to protect and conserve fishery resources and associated habitat. Regulatory statutes codify our resource management goals and plans. We rely on the best available data to support conservation recommendations and management decisions. Data sought in this study are not available. This study is an appropriate request for the pre-application period.

PUBLIC INTEREST

The requestor, NMFS, is a federal resource agency.

EXISTING INFORMATION AND NEED FOR ADDITIONAL INFORMATION

Turbine mortality is a well-documented effect of hydroelectric facility operation on the fisheries resource. In the last half-century, dozens of previous licensing studies quantified the effects of many types of turbines. Industry professionals have compiled much of this information in a database (EPRI 1997). In general, American eels have higher survival passing Francis turbines and alosines have higher survival passing Kaplan turbines (Pracheil et al. 2016). However, the extent of turbine mortality relates to the species, life stage, and the specifications of the turbine, which result in dramatic differences in turbine survival. Fish length, runner rotational speed, and the number of runner blades are key variables determining turbine mortality (Headrick 2001).

In 2003, the Licensee completed a comprehensive study of the Atlantic salmon smolt survival through the E.L. Field Powerhouse (Normandeau Associates Inc. 2003). The results from that study were favorable with the desktop analysis predicting 94% survival and the field test results showing 100% survival. However, the average length of the Atlantic salmon smolts in that study was 202.8 millimeters (mm). Adult American eel and American shad are much longer, approximately 1,000 mm and 450 mm, respectively. Because fish length is a key determinant of turbine survival, we need quantitative field data for larger fish with different swimming forms and abilities to conclude that the E.L. Field Powerhouse turbines are a safe route of emigration for the full suite of diadromous species. In addition, the previous smolt study only looked at one operational scenario for the full Kaplan units. Unlike smolts, both American eel and American shad will emigrate past the facility during times when river flow is well below operational capacity. Finally, American eels are more susceptible to blade strike with Kaplan turbines and the previous telemetry studies of American shad suggested poor turbine survival at the E.L. Field Powerhouse (RMC Environmental Services 1988) (Normandeau Associates Inc. 1991).

None of the previous studies conducted at the Lowell Hydroelectric Facility examined the potential for eel or alosine turbine mortality in the Pawtucket Canal units using estimates from either turbine mortality equations or field studies. Based on our hydrologic analysis, during the downstream fish passage season as defined in the existing Comprehensive Fish Passage Plan, the downtown canal units will be operating approximately 40% of the time (Figure 1). Therefore, the Pawtucket Canal may be an emigration route. We need to understand the risks of mortality for fish that migrate through the Pawtucket Canal.

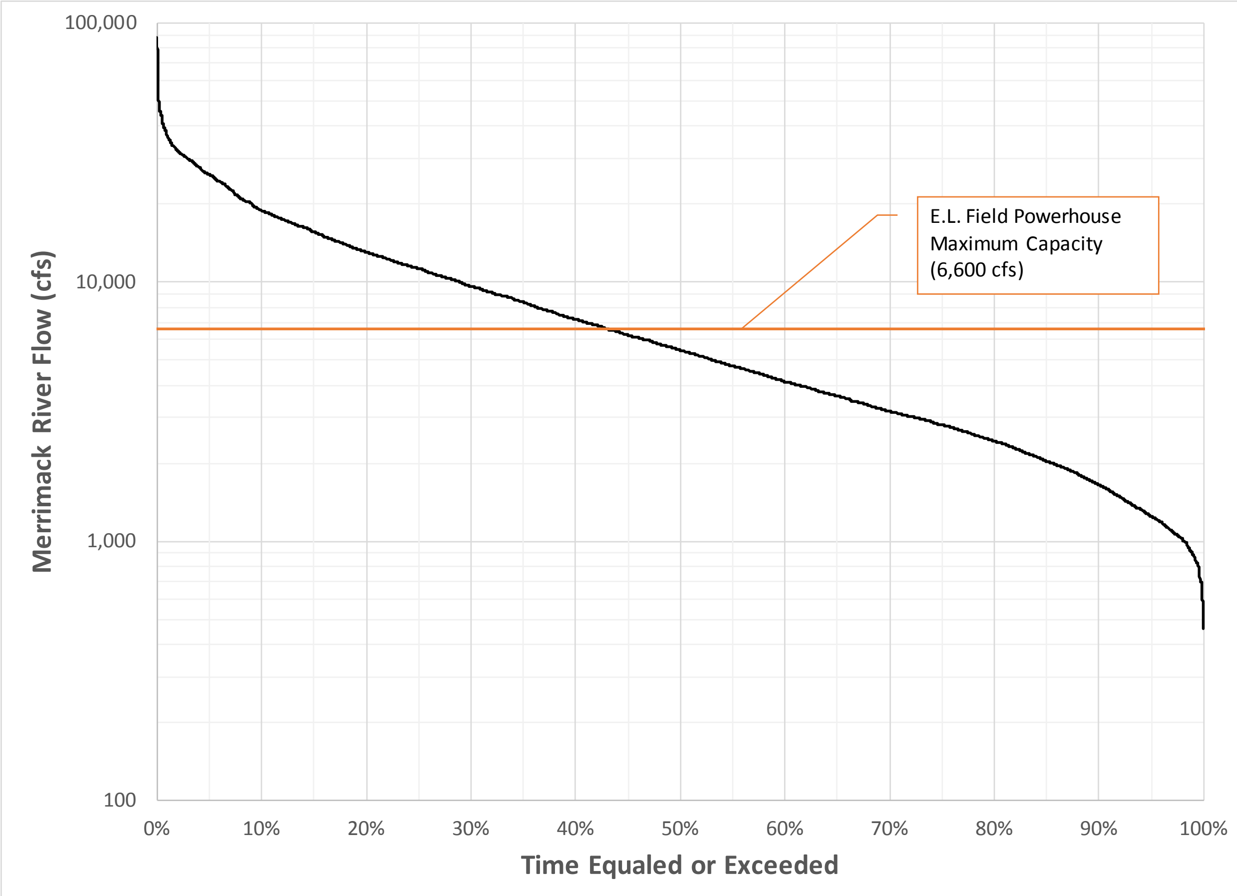

Figure 1. Flow duration curve for the Merrimack River during the downstream fish passage season showing the amount of time river flow equals or exceeds the E.L. Field Powerhouse maximum discharge capacity.

PROJECT NEXUS

Operation of the Lowell Hydroelectric Project has a direct effect on the survival of emigrating diadromous fish through turbine passage. None of the 14 operating turbines has entrainment prevention leading to the potential for high turbine mortality at the project. Information gained from this study will greatly increase our understanding of project effects. This study will contribute to the development of an administrative record in support of potential Section 18 fishway prescriptions or 10(j) recommendations.

PROPOSED METHODOLOGY

The E.L. Field Powerhouse turbine field study should use the balloon tag-recapture technology. A methodology similar to the one outlined in the previous Atlantic salmon study is acceptable (Normandeau Associates Inc. 2003). A statistically significant number of both adult American eels and American shad are necessary for testing at two turbine settings, a low operational flow (less than 1,200 cfs) and a high operational flow (between 1,800 and 3,300 cfs). The Licensee should evaluate and document the fitness of the test specimens used in the study.

The desktop turbine survival study should use standard methodology appropriate for the type of turbine and empirical information available (Franke et al. 1997). The Licensee should evaluate each of the unique turbines still in operation including:

- the E.L. Field, Fuji Horizontal Full Kaplan,
- the Bridge Street, Hercules Type D Single Runner,
- the Hamilton, Leffel Type Z Single Runner at
  - 120 rpm
  - 133 rpm
  - 150 rpm,
- the John Street, Leffel Single Runner, and
- the John Street, Allis Chalmers Singe Runner.

The turbine survival assessment should evaluate American shad, American eel, and river herring. The Licensee should evaluate both adult and juvenile life stages for the alosines. The study should use published average length values for each species and life stage in the calculations. Alewife may be used as a proxy for both river herring species. After determining estimates for each unique turbine, the Licensee will derive overall project survival estimates using typical operating curves and expected flows (i.e., the flow duration curve) during the downstream migration season for each species. The Licensee should use the rule of thumb that fish will emigrate proportionally with flow to estimate overall project survival. Where applicable, the Licensee should use turbine survival based on field collected data instead of calculated estimates.

Level of Effort and Cost

The level of cost and effort for the project survival study is moderate. The study will likely take one year. The Licensee will collect the field data during the migratory season, calculate the turbine survival estimates, estimate overall project survival, and report the results. We estimate the cost will be approximately $120,000 for the study. No alternatives are proposed.

5.5 Requested Study #5: Three-dimensional Hydraulic Modeling

Complex flow fields occur upstream of the entrance to powerhouse intakes and dedicated fish bypasses, downstream of fishway entrances, and internally within a fishway. With respect to downstream passage, we need to understand the direction and magnitude of flow fields that are upstream of the turbine intakes and fish bypass in order to inform license conditions that may improve downstream passage. Concerning upstream passage, we need to understand the hydraulic conditions proximal to the entrances of both fishways to inform license conditions that may improve fishway attraction. In addition, internal hydraulics (particularly upwelling from floor diffusers) can cause fallback from committed immigrants in a fishway. We request a three-dimensional computational fluid dynamics (CFD) modeling study to understand the hydraulics of integral components of the fish passage facilities at the Lowell Hydroelectric Project.

Goals and Objectives

The goal of this study is to determine the flow field conditions that exist in and around the Lowell fish passage facilities. The objectives of the study are to:

- Develop and calibrate a three-dimensional model of the E.L. Field Powerhouse forebay and downstream bypass facility then run simulations of various operational conditions.
- Develop and calibrate a three-dimensional model of the E.L. Field Powerhouse fish lift then run simulations of various operational conditions.
- Develop and calibrate a three-dimensional model of the Pawtucket Dam fish ladder then run simulations of various operational conditions.

RESOURCE MANAGEMENT GOALS

The NMFS is a federal resource agency with a mandate to protect and conserve fishery resources and associated habitat. Regulatory statutes codify our resource management goals and plans. We rely on the best available data to support conservation recommendations and management decisions. Data sought in this study are not available. This study is an appropriate request for the pre-application period.

PUBLIC INTEREST

The requestor, NMFS, is a federal resource agency.

EXISTING INFORMATION AND NEED FOR ADDITIONAL INFORMATION

No three-dimensional models exist for the fish passage facilities at the Lowell Hydroelectric Project. Documented issues with the fish passage facilities include poor entrance efficiency at the E.L. Field Powerhouse downstream bypass, poor entrance efficiency at the E.L. Field Powerhouse upstream fish lift, and fallback in both fishways. Detailed hydraulic modeling of the fish passage facilities will elucidate potential license conditions and measures that may improve fish passage at the project.

PROJECT NEXUS

With the existing fish passage facilities, the Lowell Hydroelectric Project has not met management goals for anadromous fish in the Merrimack River Watershed. Either new infrastructure, operational changes, or both are necessary to avoid and minimize project effects on fish populations in the Merrimack River and the Atlantic Ocean. The results of this study will inform future measures at the project to improve fish passage.

PROPOSED METHODOLOGY

A three-dimensional CFD model has become an increasingly common standard of analysis at hydroelectric projects around the nation. Within the Northeast region, we have used these models to address fish passage issues at the Holyoke (P-2004), Turners Falls (P-1889) Brunswick (P-2284), Shawmut (P-2322), Milford (P-2534) and Orono (P-2710) projects. Many three-dimensional hydraulic software packages are acceptable for this requested study, one of which is open source. We are not recommending one model over another, but the Licensee shall understand and document the limitations of the modeling software used. At a minimum, the modeling output should produce velocity, turbulence, and water depth for each cell in the mesh. The modeling domain shall be of sufficient size and mesh to characterize the hydraulic environment for each fishway evaluated. The domain for the forebay model should include the Northern Canal where the flow is relatively uniform and continue to the trash racks and to the point of free discharge in the fish bypass. The domain for the E.L. Field Powerhouse fish lift model should include upstream of the hopper through the tailrace where the highest density of detections occurred in the three-dimensional telemetry study (Alden Research Laboratory 2011), (Blue Leaf Environmental 2013). This model should reflect conditions after ledge removal in the tailrace. The domain of the Pawtucket Dam fish ladder model should include the exit flume through the ladder and past the influence of the entrance jet and any auxiliary attraction water supply (e.g., adjacent crest gate and sluice gates). Calibration of each model should include a low and a high design flow to bracket the simulated hydraulic conditions, if possible. In order to understand project effects, multiple simulations of each calibrated model are necessary to evaluate hydraulic issues for the full range of design flows (i.e., up to 5% exceedance values during the migratory period) and typical existing operating conditions. At a minimum, we expect the following simulations:

- Forebay model with downstream bypass set at 5% E.L. Field Powerhouse turbine discharge.
    - Minimum flow, Unit 1
    - Minimum flow, Unit 2
    - 5% exceedance, both units
    - 75% exceedance, typical unit setting
- Fish lift model with auxiliary water supply (AWS) set at recommended settings.
    - Minimum flow, Unit 1
    - Minimum flow, Unit 2
    - 5% exceedance, both units
    - 50% exceedance, both units
- Fish ladder model with AWS set at recommended settings.
    - Minimum flow, AWS from adjacent crest gate
    - Minimum flow, AWS from sluice gate
    - 5% exceedance, typical spill settings

Model output should show potential hydraulic conditions that effect fish passage. For example, eddy formation, zones of rapid acceleration/deceleration, upwelling, high/low velocity, and high turbulence areas.

LEVEL OF EFFORT AND COST

The level of cost and effort for the three-dimensional CFD modeling study is moderate. The study will likely take one year. The Licensee will develop the models using existing drawings supplemented with limited survey, collect calibration data, run simulations, and report the results. We estimate the cost will be approximately $175,000 for the study. No alternatives are proposed.

5.6 REQUESTED STUDY #6: BYPASS ZONE-OF-PASSAGE STUDY

The Merrimack River is migratory corridor for a multitude of diadromous fish species including American eel, American shad, river herring, sea lamprey, and Atlantic salmon. These species must be able to pass the project without undue harm or delay to complete their life cycles. Poor passage at the project limits access to upstream spawning habitats harming genetic diversity and resilience within the population. The Lowell project includes an approximately 0.7-mile-long bypass reach from Pawtucket Dam to the E.L. Field Powerhouse tailrace. The powerhouse houses a fish lift and the dam includes a fish ladder that provide fish passage. The Licensee installed the dam fish ladder as a condition under the original license to provide passage at the dam during periods when river flow was high enough that the Project spilled. Due to increased numbers of diadromous species and fish observed at Lowell over the last decade and the ineffectiveness of the fish lift, the Merrimack River Anadromous Fish Restoration Technical Committee decided to operate the fish ladder throughout the season, regardless of spill conditions. In addition, the Licensee has subsequently installed a pneumatic crest gate at the dam that decreases leakage through the flashboards and provides more control of spill over the dam. We request a study to determine a zone-of-passage through the bypass reach at multiple flows to ensure safe, timely, and effective passage at the project. A zone-of-passage is defined as 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 hydroelectric project (USFWS 2017).

Goals and Objectives

The goal of this study is to determine the zone-of-passage at multiple flows in the bypass reach that facilitate safe, timely, and effective fish passage through the project. The objectives of the study are to:

- complete a detailed survey of the bypass reach,
- develop a high-resolution, two-dimensional hydraulic model of the bypass reach,
- release multiple flows from the dam to collect calibration data for the model,
- simulate additional flows through the bypass reach with the calibrated model, and
- determine minimum and optimal zone-of-passage in the project bypass reach.

Resource Management Goals

The NMFS is a federal resource agency with a mandate to protect and conserve fishery resources and associated habitat. Regulatory statutes codify our resource management goals and plans. We rely on the best available data to support conservation recommendations and management decisions. Data sought in this study are not available. This study is an appropriate request for the pre-application period.

Public Interest

The requestor, NMFS, is a federal resource agency.

Existing Information and Need for Additional Information

Article 36 of the original license required the Licensee, after consultation with resource agencies, to develop an in-stream flow study plan to determine the relationship between project discharges and downstream aquatic habitat and a fishery study plan to determine project discharges necessary to provide for the migration of anadromous fish (i.e., zone of passage). After completion of the approved studies, the Licensee shall file a report on the results of the studies, and, for Commission approval, recommendations for the flow releases from the project. The Licensee filed the study plan on August 13, 1983 with proof of agency consultation (Accession No. 19830818-0191). However, we have been unable to obtain the reports required under Article 36. We have no reports on file nor have we found that the Licensee filed the reports in the eLibrary. Therefore, we have no quantitative data supporting the agreement that 300 cubic feet per second (cfs) at night and 500 cfs during the day are adequate for a zone-of-passage in the bypass reach as mentioned in the letter dated August 8, 1983 accompanying the study plan.

In the Comprehensive Fish Passage Plan filed on March 9, 2000 (Accession No. 20000313-0322), the Licensee states:

The adequacy of flows for upstream fish passage at the Project was addressed by BHI's construction of six (6) concrete flow control weirs (with adjustable stoplog sections) in the bypass reach, at the request of U.S. Fish and Wildlife Service and in response to Article 36, section (2) of the Project's FERC license.

Similar to the study plan, we have an agreement with no supporting information that substantiates the conclusion that these are adequate flows for a zone-of-passage in the bypass reach for the full suite of diadromous species.

As part of compliance for Article 34 of the original license, the Licensee filed as-built drawings of the fish passage facilities (Accession No. 19860902-0215). Within this abbreviated drawing set, drawing number 344D-PC001, 3844D-FC001, and 3844D-FC004 show topographic survey for small portions of the bypass reach. However, the drawings do not document the accuracy and precision of the survey, the drawing quality is illegible, and the drawings do not show the majority of the bypass reach.

This existing, supporting data is sparse, antiquated, and inadequate to determine the zone-of-passage at multiple flows in the bypass reach. Since agreeing upon the current zone-of-passage flows during the original license, we have new technologies in topographic survey methods, a better understanding of the hydraulic requirements of diadromous species, multi-dimensional hydraulic modeling capabilities, and an increased need to pass fish at the spillway ladder.

PROJECT NEXUS

Diadromous fish orient their migration based on the environmental conditions of the river: flow, depth, velocity, and temperature (Goodwin et al. 2014). Project operations affect the environmental conditions in the river, including the bypass reach. Two key hydraulic model outputs from the requested study are depth and depth-averaged velocity, which we can use to determine the likelihood of predation, delay, and the cessation of migration. Evaluating the flow fields in the bypass reach under different spill conditions will assist in the consultation process for determining a zone-of-passage in the bypass reach to optimize fish passage at the project. These data will contribute to the development of an administrative record in support of a potential settlement agreement, Section 18 fishway prescriptions, or 10(j) recommendations.

PROPOSED METHODOLOGY

We proposed the following methodology to accomplish the five objectives and ultimately the goal of the study, to determine zone-of-passage flows for the bypass reach.

1) Topographic survey

   The bypass reach area is large making traditional topographic survey methods laborious and costly. We recommend using Light Detection and Ranging (LiDAR) methods with limited traditional surveying. Outside of the fish passage season and during a river flow when the project is in control of the river, the bypass reach will be mostly dewatered. At this time, a licensed surveyor can fly the area to collect LiDAR data. Once this data is processed, traditional methods will fill in the gaps (e.g., pooled water areas, under bridges). The topographic survey shall be of sufficient resolution and quality to complete the remaining objectives.

2) Two-dimensional hydraulic model

There are many two-dimensional hydraulic models that are acceptable for accomplishing the goal of this requested study, many of which are open source. We are not requiring one model over the other, but the Licensee shall understand and document the limitations of the modeling software used. At a minimum, the modeling output should produce depth-average velocity and water depth for each cell in the mesh. The modeling domain shall be of sufficient size and mesh to delineate a zone-of-passage through the entire length and width of the bypass reach.

3) Calibration flows

The Licensee shall collect calibration data by spilling a minimum of two flows from the Pawtucket Dam. The calibration flows shall bracket the range of simulated flows in the study. We recommend 300 cfs for the low flow as it represents the current lowest operation flow for the fish ladder. For the high calibration flow, we recommend collecting data near the high fish passage design flow (i.e., the 5% exceedance value for the migratory period of record) which is approximately 26,000 cfs in the Merrimack River (bypass flow would be approximately 17,000 cfs with full project generation). The Licensee shall collect calibration data (depth-averaged velocity and depth) with an Acoustic Doppler Current Profiler (ADCP) at a minimum of four cross sections, including the downstream boundary condition. The Licensee shall use the ADCP in locations spread evenly throughout the bypass that have hydraulic conditions that are conducive to accurate readings (i.e., less turbulence).

4) Additional flow simulations

After calibrating the model, the Licensee shall simulate additional bypass flows including 500 cfs, 1,000 cfs, and couple other flows up to the high calibration flow. The additional simulations should represent the full range of hydraulic conditions in the bypass reach from the low to high fish passage design flow.

5) Zone-of-passage determination

The Licensee will use the model output to delineate a zone-of-passage pathway for each of the modeled flows. To determine the zone-of-passage, the Licensee will use the SprintSwim model developed by U.S. Geological Survey researchers (Haro et al. 2004).

LEVEL OF EFFORT AND COST

The level of cost and effort for the project survival study is low to moderate. The Licensee should be able to finish the bypass zone-of-passage study in one year depending on seasonal flow conditions. We estimate the cost to be approximately $80,000. No alternatives are proposed.

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Appendix C. Pre-Run Survey Form

Lowell Hydroelectric Project (FERC No. 2790)
FERC Relicensing
Whitewater Boating Flow Pre-Run Survey

Lowell Hydroelectric Project Bypass Reach

Name: ____________________ **Affiliation:** ____________________

Home Zip Code: ____________________

E-Mail Address: ____________________

1) What whitewater crafts do you think are appropriate for this reach? (*Please choose all that apply*)
   a. Hard shell kayak / C1
   b. Inflatable kayak
   c. Open canoe with flotation
   d. Cataraft (include length)
   e. Self-bailing raft (include length)
   f. Stand-up paddleboard
   g. Other (please list)

2) What is your skill level?
   a. Novice (comfortable running Class II whitewater)
   b. Intermediate (comfortable running Class III whitewater)
   c. Advanced (comfortable running Class IV whitewater)
   d. Expert (comfortable running Class V whitewater

3) How many years have you been whitewater boating?

4) Over the past 3 years, approximately how many days per month did you whitewater boat?

5) Have you ever participated in a whitewater boating study associated with the relicensing of a hydroelectric project?

   a. _____Yes _____No
   b. If yes, when, and for which project(s)?

6) How many times have you boated this reach before today?

   a. If you have boated this reach before, what were the flows?

      i. Approximately: _____________cfs to: _____________cfs
      ii. What type of craft did you use? (*Please choose all that apply*)
         1. Hard shell kayak / C1
         2. Inflatable kayak
         3. Open canoe with flotation
         4. Cataraft (include length)
         5. Self-bailing raft (include length)
         6. Stand-up paddleboard
         7. Other (please list)

Thank You for Your Participation

Appendix D. Post-Run Survey Form

Lowell Hydroelectric Project (FERC No. 2790)
FERC Relicensing
Whitewater Boating Flow Post-Run Survey

Lowell Hydroelectric Project Bypass Reach

Name: ________________________________ **Date of Run:** ______________________

Flow: __________________**cfs**

1) What type of craft did you use for this run?
   a. Hard shell kayak / C1
   b. Inflatable kayak
   c. Open canoe with flotation
   d. Cataraft (include length)
   e. Self-bailing raft (include length)
   f. Stand-up paddleboard
   g. Other (please list)

2) Please identify the put-in and take-out locations you used for this run.

Put-in location: ______________________________ Time: ________________

Take-out location: ______________________________ Time: ________________

3) Please estimate the number of unintended hits, stops, boat drags, and portages you had on this run:
   a. I accidently hit rocks or other obstacles (but did not stop) about_____times.
   b. I was stopped after hitting rocks or other obstacles about_____times (but did not have to get out of my boat to continue downstream).
   c. I had to get out to drag or pull my boat off rocks or other obstacles about ______ times.
   d. I had to portage around rapids or sections about_____times.

4) How many rapids and play spots did you experience at this flow?

   a. ______Rapids _____Play Spots

5) Please evaluate the availability of the following factors at this flow.

	Totally Unacceptable	Unacceptable	Neutral	Acceptable	Totally Acceptable
Navigability	1	2	3	4	5
Challenging Technical Boating	1	2	3	4	5
Powerful Hydraulics	1	2	3	4	5
Whitewater “Play Areas”	1	2	3	4	5
Size/Difficulty of Rapids	1	2	3	4	5
Overall Whitewater	1	2	3	4	5
Challenge	1	2	3	4	5
Safety	1	2	3	4	5

6) At this flow, what minimum skill level would a paddler need to be to safely paddle this reach?
   a. Beginner
   b. Novice
   c. Intermediate
   d. Advanced
   e. Expert

7) Are you likely to return for future boating if this flow were to be provided or available?
   a. Definitely no
   b. Possibly
   c. Probably
   e. Definitely yes

8) Was this flow optimal, or would you prefer a flow that was higher or lower than this flow?
   a. Much lower
   b. Lower
   c. About the same (this flow was optimal)
   d. Higher
   e. Much higher

9) If you feel qualified to offer an opinion of the desirability of this run at this flow using different types of crafts, please respond to the following statements.

This run at this flow would work well for:	**Strongly Disagree**	**Disagree**	**No Opinion**	**Agree**	**Strongly Agree**
Hard shell kayaks / C1	1	2	3	4	5
Inflatable kayaks	1	2	3	4	5
Open canoes with floatation	1	2	3	4	5
Catarafts	1	2	3	4	5
Self-bailing rafts	1	2	3	4	5
Stand-up paddleboards	1	2	3	4	5
Other (Please specify):	1	2	3	4	5

10) Did you observe or experience any significant safety issues on your run (e.g., swims, pins, wrapped boats, constructed or natural river features, etc.)? Please explain.

11) Please use the space below to provide any other comments about your boating experience at this flow.

Thank You for Your Participation

Appendix E. Flow Comparison Survey Form

Lowell Hydroelectric Project (FERC No. 2790)
FERC Relicensing
Whitewater Boating Flow Comparison Survey

Lowell Hydroelectric Project Bypass Reach

Name: ______________________ **Date:** ______________

1) Craft used?
   a. Hard shell kayak / C1
   b. Inflatable kayak
   c. Open canoe with flotation
   d. Cataraft (include length)
   e. Self-bailing raft (include length)
   f. Stand-up paddleboard
   g. Other (please list)

2) What is your skill level?
   a. Novice (comfortable running Class II whitewater)
   b. Intermediate (comfortable running Class III whitewater)
   c. Advanced (comfortable running Class IV whitewater)
   d. Expert (comfortable running Class V whitewater

3) Which study dates/flows did you participate in? Please select from the list below.

Study Flows	Study Date	Participated	Did Not Participate
cfs			
cfs			
cfs			

4) Approximately how many times have you boated this reach before this study?

5) A number of factors can affect your satisfaction with a whitewater trip. How important are each of these factors to you?

	Not Important		Somewhat Important		Very Important
Navigability	1	2	3	4	5
Challenging Technical Boating	1	2	3	4	5
Powerful Hydraulics	1	2	3	4	5
Whitewater "Play Areas"	1	2	3	4	5
Size/Difficulty of Rapids	1	2	3	4	5
Overall Whitewater Challenge	1	2	3	4	5
Safety	1	2	3	4	5
Crowding	1	2	3	4	5
Long Run(s)	1	2	3	4	5
Short Run(s)	1	2	3	4	5
Low Number of Portages	1	2	3	4	5
High Number of Rapids	1	2	3	4	5
Low Number of Rapids	1	2	3	4	5
Easy Access	1	2	3	4	5
Easy Shuttles	1	2	3	4	5

6) Please evaluate the study flows for your craft and skill level. In making your evaluations, please consider all the flow-dependent characteristics that contribute to a high-quality trip (*note, please evaluate only the study flows that you participated in*).

	cfs	cfs	cfs
Totally Acceptable	5	5	5
Acceptable	4	4	4
Marginal	3	3	3
Unacceptable	2	2	2
Totally Unacceptable	1	1	1

7) Which of the following best describes your desired paddling experience (s) for this reach (*Note, you may select more than one)*:

Type of Experience	Description	Desired Experience	
Technical	I am interested in "technical" whitewater trips at relatively low flows	Yes	No
Standard	I am interested in "standard" whitewater trips at relatively moderate flows	Yes	No
High Challenge	I am interested in "high challenge" whitewater trips at relatively high flows	Yes	No

8) Based on the boating trips that you participated in for this study, please specify the flow(s) that, in your opinion, provide the following for your desired experience(s) *(note you can specify flows that you have not seen, but which you think would provide the following for your desired experience[s]).* Please list craft, desired experience (from Question 7), and related acceptable flow. If providing input on more than one craft or type of experience, please use the back of this form.

a. What is the minimum flow needed to boat this reach in your craft?

iii. Craft: _________________Experience:_________________Flow:________cfs

b. Based on your skill level, factors that affect your satisfaction with a whitewater trip, and the flow-dependent characteristics of this reach, what is the minimum acceptable flow for this reach (the lowest flow at which you would return to paddle it)?

iv. Craft: _________________Experience:_________________Flow:________cfs

c. What is the optimal range of flows that provides the best whitewater characteristics for this run?

v. Craft: _______________Experience:_____________Flow: _____cfs to:___cfs

d. What is the highest safe flow for your craft and skill level?

vi. Craft: _________________Experience:_________________Flow:________cfs

9) Please evaluate the acceptability of current river access for your craft and skill level, assuming that no shuttle(s) are available:

	Put In	Take Out
Totally Acceptable	5	5
Acceptable	4	4
Marginal	3	3
Unacceptable	2	2
Totally Unacceptable	1	1

10) Where would you prefer to put in to and take out of this reach if suitable parking and river access were available at that location, and what type of access facilities would facilitate a high-quality paddling experience?

a. Put In Location: ________________________Facilities:________________________

b. Take Out Location:______________________Facilities:________________________

11) In your experience, what whitewater reaches in the region do you find similar to this one at your optimum flow for this reach? Also, please select how often you boat these reaches.

b. Whitewater reach name or description:_____________________________________
   i. Trips per Year: 0-3 4-8 9-15 15+

c. Whitewater reach name or description:_____________________________________
   i. Trips per Year: 0-3 4-8 9-15 15+

d. Whitewater reach name or description:_____________________________________
   i. Trips per Year: 0-3 4-8 9-15 15+

Thank You for Your Participation

Document Content(s)