



Amended Final License Application

Volume II of III

Exhibit E

Lowell Hydroelectric Project
(FERC No. 2790)

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Prepared by:



Prepared for:

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Table of Contents

Exhibit E Environmental Report (18 C.F.R. § 5.18)	E-1
E.1 Introduction	E-1
E.1.1 Summary of Relicensing Activities	E-3
E.2 General Description of the River Basin (18 C.F.R. § 5.18 (b)(1))	E-5
E.2.1 Drainage Area and Length of River	E-5
E.2.2 Tributary Rivers and Streams	E-6
E.2.3 Topography	E-8
E.2.4 Dams and Diversion Structures within the Basin	E-8
E.2.5 Wetland and Vegetative Cover	E-9
E.2.6 Climate	E-10
E.2.7 Major Land and Water Uses	E-11
E.2.8 Economic Activities	E-12
E.3 Cumulative Effects (18 C.F.R. § 5.18(b)(2))	E-13
E.3.1 Resources That Could Be Cumulatively Affected	E-13
E.3.2 Geographic Scope	E-13
E.3.3 Temporal Scope	E-13
E.4 Compliance with Applicable Laws (18 C.F.R. § 5.18 (b)(3))	E-14
E.4.1 Section 401 of the Clean Water Act	E-14
E.4.2 Endangered Species Act	E-14
E.4.3 Magnuson-Stevens Fishery Conservation Management Act	E-14
E.4.4 Coastal Zone Management Act	E-15
E.4.5 National Historic Preservation Act	E-15
E.4.6 Wild and Scenic Rivers and Wilderness Act	E-16
E.5 Project Facilities and Operation (18 C.F.R. § 5.18(b)(4))	E-17
E.5.1 Maps of Project Facilities within Project Boundaries (18 C.F.R. § 5.18(b)(4)(i))	E-17
E.5.2 Project Location and Facilities Overview (18 C.F.R. § 5.18(b)(4)(ii))	E-17
E.5.3 Structures Constructed During Project Redevelopment	E-26
E.5.4 Estimated Average Annual Energy Production (18 C.F.R. §5.18(b)(4)(v))	E-31
E.5.5 Estimated Dependable Capacity (18 C.F.R. §5.18(b)(4)(v))	E-33
E.5.6 Current and Proposed Project Operations (18 C.F.R. §5.18(b)(4)(vi))	E-33
E.6 Proposed Action and Action Alternatives	E-37
E.6.1 Summary of Existing Measures	E-37
E.6.2 Summary of Proposed Action and Enhancement Measures	E-38
E.7 Environmental Analysis by Resource Area	E-43
E.7.1 Geology and Soil Resources	E-44
E.7.2 Water Quantity and Quality	E-53
E.7.3 Fish and Aquatic Resources	E-84
E.7.4 Terrestrial Resources	E-125
E.7.5 Rare, Threatened and Endangered Species	E-155
E.7.6 Recreation and Land Use	E-163
E.7.7 Aesthetics and Socioeconomic Resources	E-210
E.7.8 Cultural Resources	E-223
E.8 Economic Analysis	E-244
E.9 Consistency with Comprehensive Plans	E-245
E.9.1 Federal Plans	E-245

E.9.2	Massachusetts Comprehensive Plans	E-246
E.9.3	New Hampshire Comprehensive Plans	E-247
E.10	Consultation Documentation	E-248
E.11	Literature Cited	E-249

Appendices

Appendix A United States Department of Agriculture Soil Descriptions

Appendix B Technical Study Reports

Appendix C Copies of Correspondence

Table of Figures

Figure E.1-1.	Lowell Project Location and Existing Boundary Map	E-2
Figure E.2-1.	Merrimack River Watershed and Major Subbasins	E-7
Figure E.5-1.	Lowell Hydroelectric Project Canal System Map – Existing Facilities	E-19
Figure E.7-1.	Merrimack River Watershed Bedrock Geology	E-46
Figure E.7-2.	Lowell Project Soils Map Showing Proposed Project Boundary	E-50
Figure E.7-3.	Sampling Locations for Continuous Water Quality Loggers 2022	E-63
Figure E.7-4.	Continuous Water Quality Logger Locations Within the Lowell Canal System (July-September 2023)	E-64
Figure E.7-5.	USGS and STORET Water Quality Sample Locations and Proposed Project Boundary	E-68
Figure E.7-6.	Water Temperature Data Collected at USGS Gage 01100000 <i>Merrimack River BL Concord River at Lowell, MA</i> on the Merrimack River, 1998 – 2004	E-69
Figure E.7-7.	Dissolved Oxygen Data Collected at USGS Gage 01100000 <i>Merrimack River BL Concord River at Lowell, MA</i> on the Merrimack River, 1998 – 2004	E-69
Figure E.7-8.	Dissolved Oxygen Percent Saturation Data Collected at USGS Gage 01100000 <i>Merrimack River BL Concord River at Lowell, MA</i> on the Merrimack River, 1998 – 2004	E-70
Figure E.7-9.	pH Data Collected at USGS Gage 01100000 <i>Merrimack River BL Concord River at Lowell, MA</i> on the Merrimack River, 1998 – 2004	E-70
Figure E.7-10.	Specific Conductance Data Collected at USGS Gage 01100000 <i>Merrimack River BL Concord River at Lowell, MA</i> on the Merrimack River, 1998 – 2004	E-71
Figure E.7-11.	Water Temperature STORET Data Collected at three sites by the NHDES in the Merrimack River, 1998 – 2015	E-75
Figure E.7-12.	Dissolved Oxygen STORET Data Collected at three sites by the NHDES in the Merrimack River, 1998 – 2015	E-75
Figure E.7-13.	Dissolved Oxygen Percent Saturation STORET Data Collected at three sites by the NHDES in the Merrimack River, 1998 – 2015	E-76
Figure E.7-14.	pH STORET Data Collected at three sites by the NHDES in the Merrimack River, 1998 – 2015	E-76

Figure E.7-15. Specific Conductance STORET Data Collected at two sites by the NHDES in the Merrimack River, 1998 – 2015.....	E-77
Figure E.7-16. Relationship between WUA (m ²) and flow (cfs) in Bypass Reach according to species and life stage	E-89
Figure E.7-17. Population Density in the Merrimack River Basin.....	E-128
Figure E.7-18. Land Use in the Merrimack River Basin.....	E-129
Figure E.7-19. Wetlands in the Vicinity of the Lowell Hydroelectric Project and Proposed Project Boundary.....	E-141
Figure E.7-20. Recreation Opportunities in the Vicinity of the Lowell Hydroelectric Project	E-166
Figure E.7-21. Recreation Facilities Inventoried During Recreation and Aesthetics Study.....	E-176
Figure E.7-22. Project Headpond Water Surface Elevation During 2020 Monitoring Period.	E-182
Figure E.7-23. Merrimack River – Pawtucket Dam Headpond Elevations for Period of Record (1995-2010) ¹	E-183
Figure E.7-24. Northern Canal River Left Location – Water Surface Elevation During 2020 Monitoring Period.....	E-183
Figure E.7-25. Damage to the Northern Canal Lock Timber Gate	E-184
Figure E.7-26. Land Use in the Vicinity of the Lowell Hydroelectric Project and Proposed Project Boundary.....	E-198
Figure E.7-27. Identified Recreation Areas Potentially Compatible with Project Operations	E-204
Figure E.7-28. Pedestrian Walk with View of the Northern Canal (left) and Bypass Reach (right).	E-212
Figure E.7-29. Guard Lock and Gates Facility.....	E-213
Figure E.7-30. Upstream View of Bypass Reach Near University Avenue	E-214
Figure E.7-31. Westerly View of Pawtucket Canal Near the Confluence with the Merrimack River	E-214
Figure E.7-32. Westerly View of Pawtucket Dam from the Pawtucket Gatehouse	E-215
Figure E.7-33. E.L. Field Powerhouse with University of Massachusetts Lowell in the Background ...	E-216
Figure E.7-34. Waterborne trash on the Pawtucket Canal at Guard Lock and Gates Facility.	E-217
Figure E.7-35. Waterborne trash on the Merrimack River upstream of the Northern Canal Gatehouse.....	E-217
Figure E.7-36. Project Headpond Water Surface Elevation During 2020 Monitoring Period	E-233
Figure E.7-37. Merrimack River – Pawtucket Dam Headpond Elevations for Period of Record (1995-2010).....	E-234
Figure E.7-38. Northern Canal River Right Location - Water Surface Elevation During 2020 Monitoring Period.....	E-235
Figure E.7-39. Damage to the Northern Canal Lock Timber Gate	E-236

Table of Tables

Table E.1-1. Lowell Hydroelectric Project Study Reports	E-4
Table E.2-1. FERC-regulated Developments on the Merrimack River	E-9
Table E.5-1. Lowell Hydroelectric Project Turbine, Generator, and Unit Capacity Data	E-30
Table E.5-2. Lowell Hydroelectric Project Monthly and Annual Generation (MWh)	E-32
Table E.5-3. Pneumatic Crest Gate System Current Operational Scheme	E-35
Table E.7-1. Lowell Project Hydrologic Data (1987-2024).....	E-53
Table E.7-2. Water Quality Classification Applicable to the Lowell Project in Massachusetts	E-56
Table E.7-3. Water Quality Standards for Class B Waters with the Warm Water Qualifier in Massachusetts	E-56
Table E.7-4. Water Quality Standards for Class B Waters in New Hampshire	E-57
Table E.7-5. Summary of Water Quality Data Obtained in the Project’s Impoundment and Bypassed Reach by NAI in 2019.	E-60
Table E.7-6. Water quality data collected by a volunteer monitoring program established by the MRWC at 9 sites along the Merrimack River from Essex Dam to the Pawtucket Dam in Lowell, 2009.....	E-72
Table E.7-7. Water quality data collected by a volunteer monitoring program established by the MRWC at 8 sites along the Merrimack River from Pawtucket Dam to the Massachusetts/New Hampshire border, 2009.....	E-73
Table E.7-8. Water quality data collected by a volunteer monitoring program established by the MRWC at 7 sites along the Merrimack River from Massachusetts/New Hampshire border to Greeley Park in Nashua, 2009.....	E-74
Table E.7-9. Description of Integrated Report Categories in Massachusetts (MADEP 2016)	E-78
Table E.7-10. Impaired Water Segments within the Lowell Project vicinity (MADEP 2016)	E-78
Table E.7-11. Description of Integrated Report Categories in New Hampshire	E-79
Table E.7-12. Impaired Water Segments within Project vicinity in New Hampshire (NHDES 2019b)	E-80
Table E.7-13. Weighted Usable Area (WUA) in m ² in the Bypass Reach according to flow, species, and life stage	E-87
Table E.7-14. Fish Assemblage Observed During the 2019 Sampling of the Impoundment and Bypass Reach	E-94
Table E.7-15. Additional Fish Species Observed Historically at the Project	E-95
Table E.7-16. Lowell and Lawrence Diadromous Fish Passage Counts Since 1983	E-98
Table E.7-17. Downstream passage route selection for radio-tagged eels released upstream of the Lowell project boundary and upstream of Garvins Falls Dam during the fall 2019 downstream passage assessment.	E-102
Table E.7-18. TBSA predicted survival estimates for adult American eels at the E.L. Field powerhouse.....	E-103
Table E.7-19. Downstream passage route selection and percent utilization of route options after detection at Station 21 for radio-tagged juvenile alosines released upstream of Pawtucket Dam during the fall 2019 downstream passage assessment.	E-105
Table E.7-20. TBSA predicted survival estimates for juvenile American shad and river herring at the E.L. Field powerhouse.	E-105

Table E.7-21. TBSA predicted survival estimates for juvenile American shad and river herring at the E.L. Field powerhouse.	E-110
Table E.7-22. Aquatic Invasive Species Likely to Occur in the Project Vicinity.....	E-112
Table E.7-23. Top five most abundant fish species each season in the impoundment from the 2019 Fish Assemblage Study.	E-114
Table E.7-24. Most abundant fish species each season in the bypass reach from the 2019 Fish Assemblage Study.	E-115
Table E.7-25. Percent total acreage and mapped vegetation acreage of the six major canals associated with the Lowell Project Canal system.....	E-135
Table E.7-26. Invasive Plant Species in Massachusetts and Prohibited Invasive Plant Species in New Hampshire.....	E-136
Table E.7-27. National Wetlands Inventory Classification System.....	E-144
Table E.7-28. Mammalian Species Potentially Occurring in the Vicinity of the Lowell Project.....	E-146
Table E.7-29. Avian Species Potentially Occurring in the Vicinity of the Lowell Project.	E-148
Table E.7-30. List of Herptile Species Observed or Anticipated to Occur in the Project Vicinity	E-152
Table E.7-31. State-listed threatened, endangered, species of special concern, candidate species, and communities potentially occurring within the Project vicinity.....	E-156
Table E.7-32. Agency Responsibilities Identified in 1977 Report of the LHCDC	E-189
Table E.7-33. Agency Responsibilities Identified in 1977 Report of the LHCDC	E-238
Table E.8-1. Annual Costs of Proposed PM&E Measures	E-244

List of Acronyms

μS/cm	microsiemens per centimeter
ACHP	Advisory Council on Historic Preservation
ADA	Americans with Disabilities Act
APE	area of potential effects
ASRSC	Atlantic Sea Run Salmon Commission
AW	American Whitewater
BMI	Benthic macroinvertebrates
Boott	Boott Hydropower, LLC (or Licensee, or Applicant)
CEII	Critical Energy Infrastructure Information
CFPP	Comprehensive Fish Passage Plan
C.F.R.	Code of Federal Regulations
cfs	cubic feet per second
Chapter 91	M.G.L. Chapter 91 of the Waterways Act
CMR	Codes of Massachusetts Regulations
COMP	Canal Operations and Maintenance Plan
CSO	Combined Sewer Overflow
CSPA	Comprehensive Shoreland Protection Act
CWA	Clean Water Act
DDT	Dichlorodiphenyltrichloroethadreneane
DLA	Draft License Application
DMMSPs	Dam Safety Surveillance and Monitoring Plan
DO	dissolved oxygen
EA	Environmental Assessment
EAP	Emergency Action Plan
E.L. Field	Eldred L. Field
EPT	Ephemeroptera (mayflies), Plecoptera (stoneflies), and Trichoptera (caddisflies)
ESA	Endangered Species Act
FERC	Federal Energy Regulatory Commission (or Commission)
FGMP	Final General Management Plan
FHA	Federal Highway Administration

Exhibit E Environmental Report (18 C.F.R. § 5.18)
Lowell Hydroelectric Project

FLA	Final License Application
FPA	Federal Power Act
GECC	General Electric Credit Corporation
GIS	Geographic Information System
GPS	Global Positioning System
HAER	Historic American Engineering Record
ILP	Integrated Licensing Process
Integrated List	Integrated List of Waters
IPaC System	Information, Planning and Consultation System
IPANE	Invasive Plant Atlas of New England
ISR	Initial Study Report
kV	kilovolt
LHCDC	Lowell Historic Canal District Commission
LIHI	Low Impact Hydropower Institute
LMRLAC	Lower Merrimack River Local Advisory Committee
LNHP	Lowell National Historical Park
LRWU	Lowell Regional Water Utility
M	magnitude
MADCR	Massachusetts Department of Conservation and Recreation
MADEM	Massachusetts Department of Emergency Management
MADEP	Massachusetts Department of Environmental Protection
MADFW	Massachusetts Division of Fish and Wildlife
MADMF	Massachusetts Division of Marine Fisheries
Massachusetts NHESP	Massachusetts Natural Heritage Endangered Species Program
MassGIS	Massachusetts Bureau of Geographic Information
MDMR	Maine Department of Marine Resources
MDPW	Massachusetts Department of Public Works
MEOEEA	Massachusetts Executive Office of Energy and Environmental Affairs
MESA	Massachusetts Endangered Species Act
M.G.L.	Massachusetts General Law
mg/L	milligrams per liter
MHC	Massachusetts Historical Commission

MIPAG	Massachusetts Invasive Plant Advisory Group
MOU	Memorandum of Understanding
MRI	Merrimack River Initiative
MRTC	Merrimack River Technical Committee
MRWC	Merrimack River Watershed Council
MW	megawatt
MWh	megawatt hours
NAI	Normandeau Associates, Inc.
NEFMC	New England Fishery Management Council
New Hampshire NHB	New Hampshire Natural Heritage Bureau
NGOs	non-governmental organizations
NGVD 29	National Geodetic Vertical Datum 1929
NHDES	New Hampshire Department of Environmental Services
NHDFG	New Hampshire Department of Fish and Game
NHDHR	New Hampshire Division of Historical Resources
NHDNCR	New Hampshire Department of Natural and Cultural Resources
NHFGD	New Hampshire Fish and Game Department
NHL	National Historic Landmark
NHPA	National Historic Preservation Act of 1966
NMFS	National Marine Fisheries Service
NOAA	National Oceanic and Atmospheric Administration
NOI	Notice of Intent
NPDES	National Pollutant Discharge Elimination System
NPS	National Park Service
NRHP	National Register of Historic Places
NRPC	Nashua Regional Planning Commission
NTU	Nephelometric Turbidity Unit
NWI	Nation Wetland Inventory
O&M	operations and maintenance
OSHA	Occupational Safety and Health Administration
PAD	Pre-Application Document
PM&E	protection, mitigation, and enhancement measures

Exhibit E Environmental Report (18 C.F.R. § 5.18)
Lowell Hydroelectric Project

Project	Lowell Hydroelectric Project
Proprietors	Proprietors of the Locks and Canals on the Merrimack River
PSP	Proposed Study Plan
Revised PPS	Revised Process Plan and Schedule and Determination on Requests for Study Modifications for the Lowell Hydroelectric Project
RM	river mile
RMC	RMC Environmental Services
ROR	run-of-river
RSA	Revised Statutes Annotated
RSP	Revised Study Plan
RTE	rare, threatened, and endangered
SAV	submerged aquatic vegetation
SCORP	Statewide Comprehensive Outdoor Recreation Plan
SDR	Supporting Design Report
SD1	Scoping Document 1
SD2	Scoping Document 2
Section 106	Section 106 of the NHPA
SPD	Study Plan Determination
SHPO	State Historic Preservation Officer
stakeholders	resource agencies, federally recognized Indian tribes, non-governmental organizations (NGOs), and other interested parties
SWQS	surface water quality standards
Merrimack River Technical Committee	Representatives from NHDFG, MADFW, USFWS, USFS, NMFS
THPO	Tribal Historic Preservation Officers
TMDL	total maximum daily loads
TBSA	turbine blade strike analysis
USACE	U.S. Army Corps of Engineers
USC	United States Code
USDA	U.S. Department of Agriculture
USEPA	U.S. Environmental Protection Agency
USFS	U.S. Forest Service
USFWS	U.S. Fish and Wildlife Service

USGS	U.S. Geological Survey
VP	vegetation points
WPA	Wetlands Protection Act
WQC	Water Quality Certification
WUA	Weighted Useable Area
YOY	Young-of-year

Exhibit E Environmental Report (18 C.F.R. § 5.18)

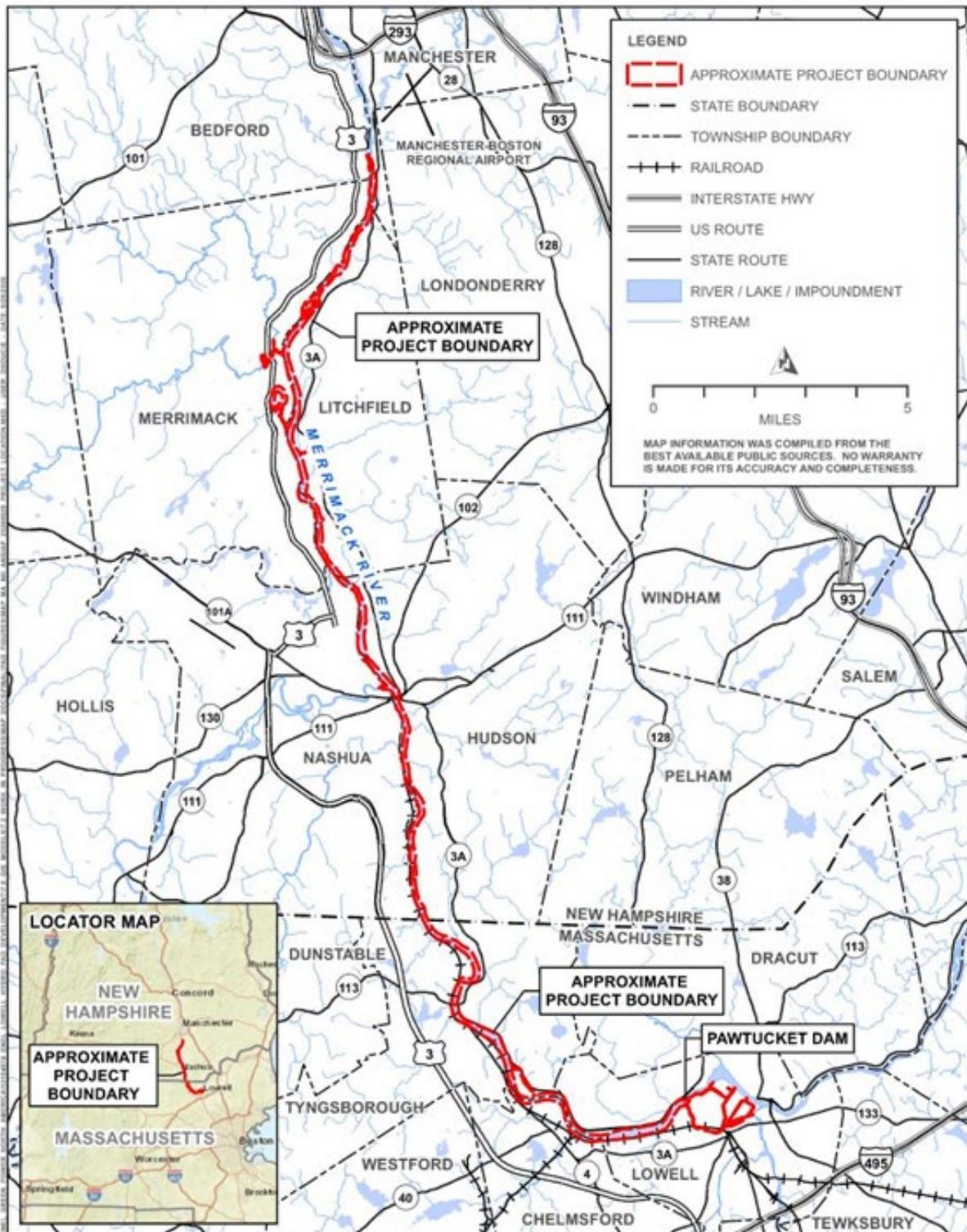
E.1 Introduction

Boott Hydropower, LLC (Boott or Licensee) is the Licensee, owner, and operator of the Lowell Hydroelectric Project (Project or Lowell Project) (FERC No. 2790). The Lowell Project is located at river mile (RM) 41 on the Merrimack River in the City of Lowell in Middlesex County, Massachusetts. The approximate existing Project boundary is provided in Figure E.1-1. Exhibit G shows the Project boundary as proposed.

Boott operates and maintains the Lowell Project under a license from the Federal Energy Regulatory Commission (FERC or Commission). The Commission, under the authority of the Federal Power Act (FPA), 16 United States Code (USC) §791(a), et seq., may issue a license for up to 50 years for the construction, operation, and maintenance of non-federal hydroelectric developments. Boott is pursuing a new license for the Project using the Commission's Integrated Licensing Process (ILP) as defined in 18 Code of Federal Regulations (C.F.R.) Part 5. The existing license was issued by FERC on April 13, 1983, and expired on April 30, 2023. On May 19, 2023, the Commission issued a Notice of Authorization for Continued Project Operation that authorized Boott to continue operation of the Lowell Project under the terms and conditions of the existing license.

In accordance with applicable regulations, 18 C.F.R. §5.17(a), Boott filed the Final License Application (FLA) with the Commission on April 30, 2021. Since the 2021 filing, FERC has issued several Additional Information Requests (AIRs) regarding Boott's previously proposed action in the FLA to decommission fifteen turbine-generator units and subsequently remove the majority of the downtown canal system from the FERC license. In the time since the filing of the FLA, Boott has reconsidered its proposal to remove the canal system and associated power stations from the license. Based on this decision, Boott has consulted with key stakeholders regarding reintroducing the downtown canal system and power stations into the new license. Exhibit E of this amended license application includes the proposed measures developed in consultation with stakeholders regarding the operation and management of the Project relative to the canal system over the term of the new FERC license.

Figure E.1-1. Lowell Project Location and Existing Boundary Map



E.1.1 Summary of Relicensing Activities

On February 25, 2021, Boott filed the Initial Study Reports for the studies noted below in Table E.1-1. Boott held a Revised ISR Meeting to discuss the results of these studies on March 11, 2021. Pursuant to the ILP, Boott filed a Revised ISR Meeting Summary with the Commission on March 26, 2021. Stakeholders were provided a 30-day period (ending on April 25, 2021) to provide comments on the Revised ISR Meeting Summary, recommend study modifications, or propose new studies. By letters to the Commission, National Marine Fisheries Service (NMFS), Massachusetts Division of Fisheries and Wildlife (MADFW), and the U.S. Fish and Wildlife Service (USFWS) provided comments on the February 2021 Revised ISR and Revised ISR Summary.

On December 2, 2020, and in accordance with 18 C.F.R. §5.16(c), Boott filed the Draft License Application (DLA) with the Commission. FERC and stakeholders had 90 days to provide comments on the DLA (i.e., until March 2, 2021). Boott reviewed and considered all comments received, as evidenced through further development of the Licensee's measures proposed in this amended Final License Application.

In accordance with applicable regulations, 18 C.F.R. §5.17(a), Boott filed its FLA which included a previous proposal to remove the downtown canal system from the license on April 30, 2021. FERC issued a series of AIRs on May 27 and October 14, 2021; March 1 and April 19, 2022, and February 14, 2023, in regard to the FLA and Boott's previous proposal to remove the downtown canal units from the license. Boott filed responses to the AIRs on August 25 and November 15, 2021; January 18, March 31, October 4, and October 17, 2022; and May 15, 2023.

In accordance with 18 C.F.R. §5.15(f), Boott filed the Updated Study Report (USR) on November 1, 2021, and held a Study Report Meeting on November 16, 2021. Pursuant to 18 C.F.R. §5.15(c)(3), Boott filed a Study Report Meeting Summary with the Commission on December 1, 2021. Stakeholders were allowed 30 days (i.e., until December 31, 2021) to file any disagreements with the summary and/or any proposals to modify ongoing studies with the Commission. On December 23, 2021, the NPS filed comments on the USR. On January 28, 2022, Boott filed a response to stakeholder comments on the USR meeting and subsequent USR meeting summary.

FERC issued Scoping Document 3 (SD3) on February 1, 2022. The SD3 was intended to advise stakeholders as to key differences in proposed actions between the PAD and the license application. FERC received seven comment letters on SD3, including comments from the University of Massachusetts, the City of Lowell, Northeast Legal Aid, NPS, Greater Lowell Community Foundation, the Lowell Historic Board, and individuals. Additionally, on March 3, 2022, Boott filed comments on SD3.

On August 22, 2022, Boott filed the Lowell Hydroelectric Project Settlement Agreement for Fish Passage (2022 Fish Passage Settlement) between Boott, USFWS, NMFS, the New Hampshire Fish and Game Department (NHFGD), the Massachusetts Division of Marine Fisheries (MDMF), and the Massachusetts Division of Fisheries and Wildlife (MDFW), which set forth a proposal for the issuance of New License for the Project and license requirements related to fish passage and bypass flows. On May 11, June 14, and October 10, 2023, Boott filed an Extension of Time (EOT) request to revise the Exhibit F

drawings and respond to additional information requests under the previous license proposal. On November 9, 2023, the Commission issued an EOT until January 10, 2024.

In review of the comments and information received since Boott filed the FLA in April 2021, Boott reconsidered its proposal to remove the canals from the Project. On January 10, 2024, Boott filed a request that Commission staff delay issuance of the notice that the Project is ready for environmental analysis (REA notice) to allow Boott time to reevaluate its relicensing proposal to remove the downtown canal system from the Project boundary and its proposed fish passage measures outlined in the fish passage settlement agreement included with the license application. On January 31, 2024, the Commission issued an AIR requesting Boott provide a schedule for consultation and timeline outlining the proposed date that the amended application would be filed, to which Boott responded on February 9, 2024. On February 21, 2024, FERC granted the request to delay the notice until after September 30, 2024.

Boott filed quarterly progress reports in April, July, and September 2024 that outlined consultation efforts related to potential amendments to the application. In its September 13, 2024 progress report, Boott requested an extension of time to continue consulting with the resource agencies and other stakeholders to develop the amended FLA. On October 7, 2024, the Commission approved Boott’s request to delay the REA notice until after December 31, 2024.

On October 23, 2024, Boott provided the National Marine Fisheries Service (NMFS) and United States Fish and Wildlife Service (USFWS) with a preliminary draft version of select Exhibits of the amended FLA. On December 5, 2024, Boott received comments from the NMFS and USFWS on the preliminary draft exhibits. On December 23, 2024, the National Park Service (NPS) filed information with the Commission related to various water retaining structures within the canal system that are owned by the Federal Government under fee ownership or easement. Boott requested a third request for EOT on December 31, 2024, to further consult on comments received on the preliminary draft and issues raised by the resource agencies. On January 22, 2025, the Commission denied Boott’s EOT request. In preparation of this license application, Boott has continued consultation and anticipates further consultation with the agencies and consulting entities regarding the potential need for additional canal related measures.

This supplemental analysis of potential effects is based on the information resulting from ongoing consultation with stakeholders, studies completed, and data collected subsequent to previous USR filings and AIR responses.

Table E.1-1. Lowell Hydroelectric Project Study Reports

Study Report	Filing Type	Filing Date
Downstream American Eel Passage Assessment	Public	November 1, 2021
Juvenile Alosine Downstream Passage Assessment	Public	November 1, 2021
Upstream and Downstream Adult Alosine Passage Assessment	Public	November 1, 2021

Study Report	Filing Type	Filing Date
Fish Passage Survival Study	Public	November 1, 2021
Three-Dimensional Computational Fluid Dynamics (CFD) Modeling	Public	November 1, 2021
Instream Flow Habitat Assessment and Zone of Passage Study in the Bypassed Reach	Public	November 1, 2021
Fish Assemblage Study	Public	November 1, 2021
Recreation and Aesthetics Study	Public	May 31, 2022
Initial Whitewater Boating and Access Study	Public	May 31, 2022
Updated Study Report (USR)	Public	November 1, 2021
Resources, Ownership, Boundaries, and Land Rights Study	Public	November 1, 2021
Water Level and Flow Effects on Historic Resources Study	Public/Privileged	November 1, 2021
Operation Analysis of the Lowell Canal Study	Public	November 1, 2021
Historically Significant Waterpower Equipment Study	Public	November 1, 2021
Updated Whitewater Boating and Access Study	Public	January 23, 2023
Final Whitewater Boating and Access Study	Public	December 23, 2024

The following sections describe: (1) the existing and proposed Project facilities, including Project lands and waters; (2) the existing and proposed Project operation and maintenance, to include measures for protection, mitigation, and enhancement (PM&E) with respect to each resource affected by the Project proposal; and (3) the continuing impacts of existing Project operations and maintenance on resources, including direct, indirect, and cumulative impacts based on information generated during the relicensing studies.

E.2 General Description of the River Basin (18 C.F.R. § 5.18 (b)(1))

E.2.1 Drainage Area and Length of River

The 116-mile-long Merrimack River originates near Franklin, New Hampshire at the confluence of the Pemigewasset and Winnepesaukee Rivers (USACE 2003). The river flows southward for approximately 78 miles in New Hampshire, turns abruptly at the New Hampshire-Massachusetts boarder, and flows in a northeasterly direction for

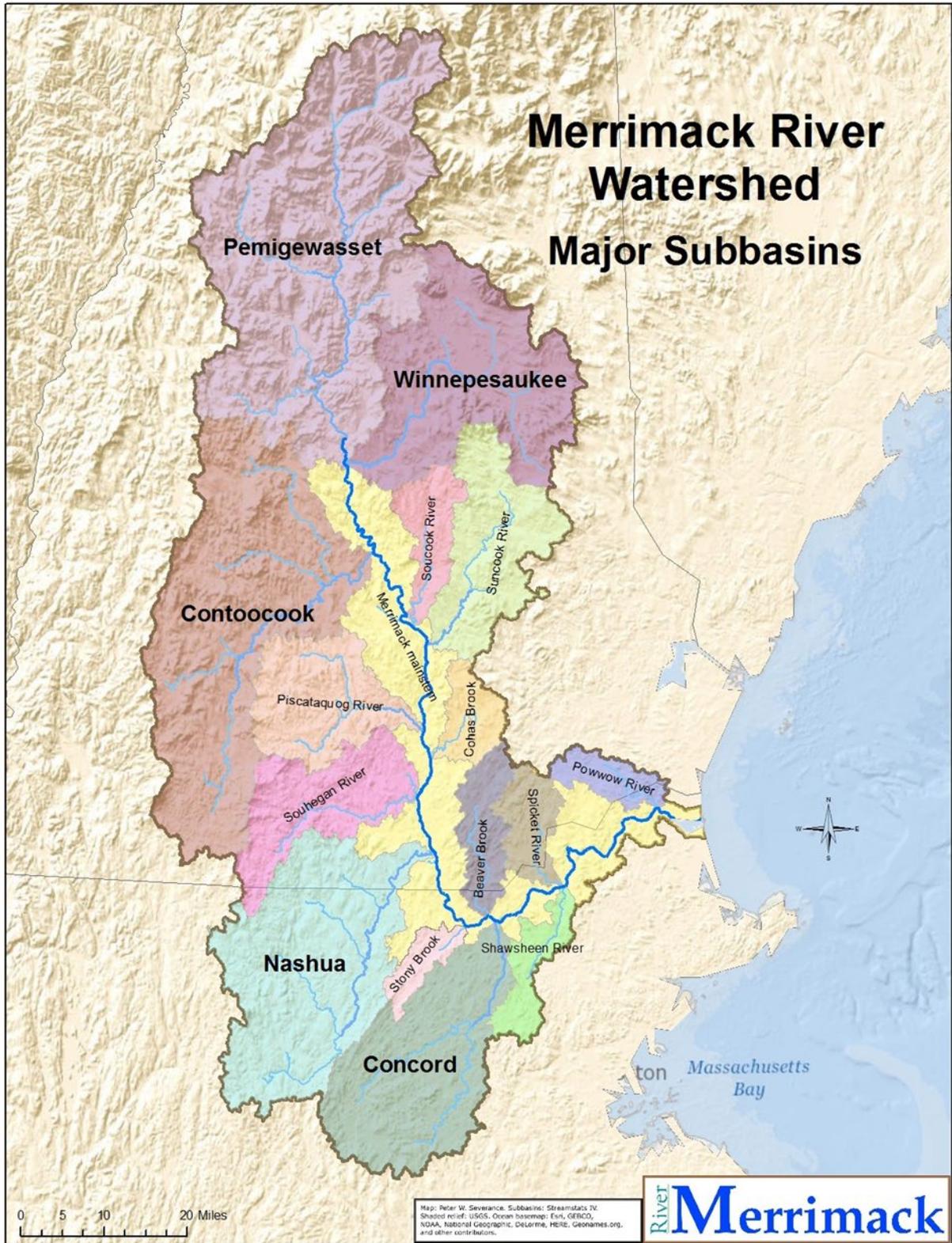
approximately 40 miles before draining into the Atlantic Ocean near Newburyport, Massachusetts. The final 22 miles of the river, downstream of Haverhill, Massachusetts, are tidally influenced (USACE 2003; NHDES 2019a).

The Merrimack River watershed has a total drainage area of approximately 5,010 square miles within the states of New Hampshire and Massachusetts, where about 3,800 square miles lie in New Hampshire and 1,200 square miles lie in Massachusetts (MEOEEA 2002). Lakes and ponds comprise 200 square miles, or four percent of the total area (Boott 1980). The Lowell Hydroelectric Project is located on the Merrimack River in Lowell, Massachusetts. The drainage area of the Lowell Project is approximately 3,979 square miles.

E.2.2 Tributary Rivers and Streams

The Merrimack River Basin (Basin) is the fourth largest river basin in New England (MEOEEA 2001). The Basin extends from the White Mountain region of northern New Hampshire to southeastern Massachusetts and spans the major cities of Laconia, Concord, Manchester, Nashua in New Hampshire and Lowell, Lawrence, Haverhill in Massachusetts. The Pemigewasset River flows for 64 miles, and the Winnepesaukee River stretches for ten miles. In addition to the Pemigewasset and Winnepesaukee River Basins, four principal tributaries contribute to the Merrimack River flow: the Contocook, Piscataquog, Nashua, and Concord Rivers (USACE 2003; MEOEEA 2001). The Merrimack River Watershed and Major Subbasins are shown below in Figure E.2-1. The Lowell Project is located at RM 41 on the Merrimack River in the City of Lowell, Massachusetts. Several other smaller streams are contributory to the Merrimack or Concord Rivers within the City of Lowell and complete the major drainage pattern.

Figure E.2-1. Merrimack River Watershed and Major Subbasins



E.2.3 Topography

The Basin encompasses a variety of terrain as it ranges from steep, rugged conditions of the Northern New Hampshire White Mountain region to the estuarine coastal basin of northeastern Massachusetts (USACE 2003). The Basin is a part of the Eastern New England Upland physiographic unit containing three major sections - the White Mountains, the New England Uplands, and the Seaboard Lowlands. The majority of the Basin is located in the New England Uplands, characterized by narrow floodplains and rolling hills ranging in elevation from below 1,000 feet to above 2,000 feet (USACE 2003). The Merrimack River itself drops 269 vertical feet over its long track to the Atlantic Ocean, with a more than 30-foot drop at the Project. The topography of the City of Lowell (13.4 square miles) is a combination of floodplain and, predominantly, gently undulating upland. The Merrimack corridor surface waters, in conjunction with the river's large watershed, form an extensive system of rivers, streams, lakes, ponds, wetlands and groundwater as well as densely forested lands consisting of evergreen or mixed evergreen-deciduous forests (NRPC 2008).

E.2.4 Dams and Diversion Structures within the Basin

There are five hydroelectric developments on the Merrimack River, comprising three separate Projects licensed by the Commission. Table E.2-1 presents information on the five FERC-regulated hydroelectric developments on the Merrimack River. All of the hydroelectric facilities on the Merrimack River operate in run-of-river (ROR) mode.

In New Hampshire, there are four U.S. Army Corps of Engineers (USACE) flood storage dams within the Merrimack River basin. Boott and other licensees in the Merrimack River basin help to support the operational costs of these flood storage projects through Headwater Benefits payments assessed by FERC.

The USACE flood storage system in the Merrimack River basin consists of the following:

- Franklin Falls Dam is located in Franklin, New Hampshire, on the Pemigewasset River. The dam is three miles upstream of the confluence of the Pemigewasset and Winnepesaukee rivers where the Merrimack River originates. The dam is the key unit in the flood risk management for the Merrimack River basin. It provides flood protection for principal industrial and residential centers along the entire length of the Merrimack River. The construction of Franklin Falls Dam was completed in 1943, and it can store up to 50.2 billion gallons of water for flood control purposes (USACE 2016a).
- The Hopkinton-Everett Lakes Flood Risk Management Project consists of two dams, the dam at Hopkinton Lake, located on the Contoocook River in Hopkinton, New Hampshire, and the dam at Everett Lake, located on the Piscataquog River in Weare, New Hampshire. The two dams are connected by a two-mile-long canal and in moderate to severe flooding are operated as a single flood risk management project. Construction of the project was completed in 1963. Together, the flood storage areas behind both dams can hold 52.6 billion gallons of water, which would cover approximately 8,000 acres (12.5 square

miles). This is equivalent to 6.8 inches of water covering its drainage area of 446 square miles (USACE 2016b).

- The Blackwater Dam is located on the Blackwater River in Webster, New Hampshire. There is no lake at Blackwater Dam. The flood storage area of the project covers approximately 3,280 acres and extends upstream about seven miles through Salisbury, having a maximum width of one mile. Blackwater Dam can store up to 15 billion gallons of water for flood control purposes (USACE 2016c).

Table E.2-1. FERC-regulated Developments on the Merrimack River

Facility	FERC Project #	Licensee	River Mile	Generation Capacity (MW)	License Expiration
Garvins Falls (Merrimack River Project)	1893	CRP NH Amoskeag, LLC	87	12.3	April 30, 2047
Hooksett (Merrimack River Project)	1893	CRP NH Amoskeag, LLC	81	1.6	April 30, 2047
Amoskeag (Merrimack River Project)	1893	CRP NH Amoskeag, LLC	73	16	April 30, 2047
Lowell	2790	Boott Hydropower, LLC	40	20.16	April 30, 2023
Lawrence	2800	Essex Company, LLC	29	16.8	November 30, 2028

E.2.5 Wetland and Vegetative Cover

Wetlands and vegetative cover with the Project area are consistent with these areas of New Hampshire and Massachusetts. Wetlands along the Merrimack River primarily consist of low-lying areas near and adjacent to the river, with other isolated wetlands farther away from the river proper. The wetlands directly surrounding the Lowell Project are largely considered riverine wetlands with an unconsolidated bottom. Riverine wetlands include all wetlands and deepwater habitats contained within a channel, with two exceptions: (1) wetlands dominated by trees, shrubs, persistent emergents, emergent mosses, or lichens, and (2) habitats with water containing ocean-derived salts of 0.5 parts per thousand (or greater (Cowardin et al. 1979)). The majority of the wetlands near or adjacent to the Project area are palustrine wetlands. Palustrine wetlands, often

called fens, swamps, marshes, or bogs, are nontidal wetlands. These wetlands are dominated by trees, shrubs, and/or persistent plants/mosses. These wetlands may also be composed of shallow, open-water ponds (Cowardin et al. 1979). According to the USACE (2002), freshwater wetland habitats play an integral role in the ecology of the Merrimack River corridor. The combination of high nutrient levels and primary productivity found in these habitats is ideal for the development of organisms that form the base of the food web.

Natural forest cover encompasses 75 percent of the Basin and consists of a mix of deciduous and evergreen forest. Natural vegetation in the region consists of mesic to dry Appalachian oak-pine forests with various combinations of red oak (*Quercus rubra*), white oak (*Q. alba*), and black oaks (*Q. velutina*), some scarlet (*Q. coccinea*) or chestnut oaks (*Q. prinus*) to the south, white pine (*Pinus strobus*), sugar maple (*Acer saccharum*), red maple (*A. rubrum*), hickories (*Carya spp.*), and other central or northern hardwoods. Floodplain forests are typically dominated with silver maple (*A. saccharinum*), American elm (*Ulmus americana*), and green ash (*Fraxinus pennsylvanica*) (Griffith et al. 2009).

E.2.6 Climate

The Project is within a climate region typical of north central New England and inland New Hampshire, as it is characterized by moderately warm summers, cold winters, and adequate precipitation. The climatic conditions of the Basin vary significantly from its headwaters in the White Mountains to its discharge along the Atlantic Ocean (USACE 2003). The Basin is located partially with the Northern and Coastal Climatic divisions, but the majority of the watershed falls within the Central Climatic division. The Central division is generally more moderate than the Northern section due to its lower elevation and latitude; this division experiences some climate modification due to maritime influences (USACE 2003; National Oceanic and Atmospheric Administration [NOAA] 2020a). Precipitation in the watershed is evenly distributed throughout the year and weather systems throughout the Basin operate primarily from prevailing westerly winds and the confluence of many continental weather patterns in North America. The Basin's climate is humid continental climate (Dfa/Dfb) according to the Köppen-Geiger climate classification.

NOAA data from 1897 to 2020 for the Boston, Massachusetts weather station indicates an average temperature of 52.1 Fahrenheit (°F), with an average maximum temperature of 96°F and average minimum temperature of 2.0°F. The warmest temperatures occur in July and coolest temperatures occur in January. NOAA 1897 to 2020 data for Boston, Massachusetts shows an average annual precipitation of 41.45 inches with relatively even monthly averages (NOAA 2020b).

Three predominant storm patterns occur in the Merrimack River Basin: continental, coastal, and local summer thunderstorms. Continental storms are associated with the usual easterly or northeasterly air flows that bring western or central storm disturbances to the Northeast. These continental storms are experienced in all months of the year. Coastal storms originate in the Gulf or southeast coastal states and bring moist, generally warmer air into the region (Boott 1980).

E.2.7 Major Land and Water Uses

E.2.7.1 Major Land Uses

Historically, the Merrimack River Basin played a large role in the development of the region's economy and land use patterns. The Industrial Revolution in the mid-1800s encouraged many families towards more promising work in urban settings. Many of the larger towns adjacent to the Merrimack River mainstem began as factory or mill towns due to the need for hydromechanical and later hydroelectric power to power the emerging industries. This economic shift from farming to urban settings resulted in the reclamation of previously predominantly agricultural lands by forest and woodland (USACE 2003; Boott 1980).

Although the Merrimack River watershed is heavily forested (75 percent of the land area is covered with forest), it also supports all or parts of approximately 200 communities with a total population of 2.6 million people (U.S Environmental Protection Agency [USEPA] 2020; USACE 2006). The population density in the Basin tends to increase from north to south as the lower region is characterized by five major urban cities along the Merrimack River: Manchester and Nashua in New Hampshire, and Lowell, Lawrence, and Haverhill in Massachusetts (USACE 2003). Basin population density ranges from fewer than 100 people per square mile in the northeastern and northwestern portions of New Hampshire, to greater than 800 people per square mile in Manchester and Nashua, New Hampshire, and northeastern Massachusetts. A majority (74 percent) of the Basin's urban area is residential while the remaining areas consist of commercial, transportation, industrial, and other urban uses. In addition to the 75 percent forested land, the Basin generally consists of 13.3 percent urban land, four to five percent surface water, and 5.5 percent agriculture. Recreation and timber harvesting for lumber are the primary economic activities occurring in forested lands, while agricultural lands are dominated by hay and livestock farming (Flanagan 1999). Land use is discussed in further detail in Section E.7.6 of this application.

E.2.7.2 Major Water Uses

Consumptive users of the Merrimack River water are primarily municipal and industrial, with specific uses including domestic, thermoelectric, commercial, mining, livestock, and irrigation uses. Many of the municipalities bordering the Merrimack River, or within its watershed, use the river as a potable water source as well as a wastewater discharge point. The Merrimack River is the only major New England river used as a drinking water supply and is used as such by the communities of Lowell, Lawrence, Tewksbury, Methuen, and Andover in Massachusetts and Nashua, New Hampshire. Two more cities in New Hampshire, Manchester and Concord, plan to use the river for drinking water supply in the near future (MRWC 2018b).

E.2.8 Economic Activities

The Lowell Project is located in Middlesex County, Massachusetts, and Hillsborough County, New Hampshire. According to the U.S. Census Bureau, the median household income from 2019-2023 (in 2023 inflation-adjusted dollars) was estimated at \$126,779 in Middlesex County, \$100,436 in Hillsborough County, and \$76,205 for the City of Lowell (U.S. Census Bureau 2023). The main employment sectors in the region include professional, scientific, and tech services, educational services, healthcare and social assistance, manufacturing, and retail trade (Data USA undated).

E.3 Cumulative Effects (18 C.F.R. § 5.18(b)(2))

A cumulative effect is the impact on the environment which results from the incremental impact of a Proposed Action when added to other past, present, and reasonably foreseeable future actions, regardless of agency (federal or non-federal) or person undertaking such other actions. Cumulative effects can result from individually minor but collectively significant actions taking place over a period of time, including hydropower project operations and other land and water development activities.

E.3.1 Resources That Could Be Cumulatively Affected

The Commission's September 27, 2018, Scoping Document 2 (SD2) identified migratory fisheries in the Merrimack River as a resource with potential to be cumulatively affected by the proposed continued operation and maintenance of the Project, in combination with other hydroelectric projects and activities in the Merrimack River Basin.

E.3.2 Geographic Scope

The geographic scope of the cumulative effects analysis defines the physical limits or boundaries of the proposed action's effect on the resources. Because a proposed action can affect resources differently, the geographic scope for each resource may vary. Any potential reasonably foreseeable impacts are discussed in individual resource sections.

The geographic scope of analysis for cumulatively affected resources is defined by the physical limits or boundaries of: (1) the proposed action's effect on the resources, and (2) contributing effects from other actions, both federal and non-federal, within the Merrimack River Basin.

In the SD2, FERC identified the geographic scope for migratory fisheries to include Pemigewasset River from the Eastman Falls Dam and the Winnepesaukee River from the Lakeport Dam to the confluence of the Winnepesaukee and Pemigewasset Rivers (which form the Merrimack River), and the Merrimack River downstream to the Atlantic Ocean. The Eastman Falls Dam (at river mile 1 of the Pemigewasset River) and the Lakeport Dam (at river mile 17 of the Winnepesaukee River and 4 miles downstream from the outlet of Lake Winnepesaukee) are migration barriers that represent the upstream limits to which river herring and American eel are managed within the river basin.

E.3.3 Temporal Scope

The temporal scope of the cumulative effects analysis in this exhibit addresses past, present, and reasonably foreseeable future actions and their effects on each resource that may be cumulatively affected. Based on the potential terms of the new license, the Commission's SD2 defined the temporal scope of this analysis to address reasonably foreseeable actions 30-50 years into the future. Historical discussion would by necessity, be limited by the amount of available information for each resource. As noted in SD2, the quality and quantity of information are diminished as resources that are further away in time from the present are analyzed.

E.4 Compliance with Applicable Laws (18 C.F.R. § 5.18 (b)(3))

E.4.1 Section 401 of the Clean Water Act

Under Section 401 of the Clean Water Act (CWA), any federal license or permit to conduct any activity that may result in a discharge into navigable waters requires a certification from the state in which the discharge originates, that such discharge will comply with the applicable provisions of the CWA, unless such certification is waived. Therefore, a state Water Quality Certification (WQC) or waiver is a prerequisite for obtaining a license from FERC. The MADEP is the state agency designated to carry out the certification requirements as prescribed in Section 401 of the CWA for waters of the Commonwealth of Massachusetts. Pursuant to 18 C.F.R. § 5.23(b), Boott will file an application for a WQC with the MADEP within 60 days of FERC's Notice of Acceptance and Ready for Environmental Analysis (REA). The MADEP must act on the request for a WQC within the one-year time frame allowed under the CWA.

E.4.2 Endangered Species Act

Section 7 of the Endangered Species Act (ESA) (19 U.S.C. § 1536(c)), as amended, requires federal agencies to ensure that their actions are not likely to jeopardize the continued existence of endangered or threatened species, or result in the destruction or adverse modification of the critical habitat of such species. Under the ESA, the USFWS is responsible for freshwater and terrestrial species; and the NMFS (NOAA Fisheries) is responsible for marine and anadromous species.

In the Notice of the Licensee's Intent to File a License Application, Filing of the PAD, Commencement of the Pre-filing Process, and Scoping Document 1 issued on June 15, 2018, the Commission designated Boott as the Commission's non-federal representative for carrying out informal consultation, pursuant to section 7 of the ESA. Information from the USFWS and the MADFW has been used by the Licensee to identify rare, threatened, and/or endangered (RTE) species in the Project area. A discussion of the RTE species relevant to this Project is contained in Section E.7.5 of this Exhibit.

E.4.3 Magnuson-Stevens Fishery Conservation Management Act

The 1996 amendments to the Magnuson-Stevens Act authorized the NMFS, in coordination with regional fisheries management councils, to delineate essential fish habitat (EFH) for the protection of habitat of marine, estuarine, and anadromous finfish, mollusks, and crustaceans. EFH includes "those waters and substrate necessary to fish for spawning, breeding, feeding, or growth to maturity."

Based on a review of the NMFS online database, the Lowell Project reach of the Merrimack River is designated EFH under the Magnuson-Stevens Fishery Conservation

and Management Act for Atlantic salmon (NOAA undated). This EFH was defined as “all waters currently or historically accessible to Atlantic salmon within the streams, rivers, lakes, ponds, wetlands, and other water bodies of Maine, New Hampshire, Vermont, Massachusetts, Rhode Island, and Connecticut” (New England Fishery Management Council [NEFMC] 1998).

E.4.4 Coastal Zone Management Act

Section 307(c)(3) of the Coastal Zone Management Act (CZMA) requires that activities conducted or supported by a federal agency that affect the coastal zone be consistent with the enforceable policies of the federally approved state coastal management plan to the maximum extent practicable. Section 307(c)(3) of the CZMA requires that all federally licensed activities that affect a state’s coastal zone be consistent with the enforceable policies of the state’s federally approved coastal management plan.

The Massachusetts Office of Coastal Zone Management (MOCZM) is the lead policy and planning agency on coastal and ocean issues within the Massachusetts Executive Office of Energy and Environmental Affairs (MEOEEA). The New Hampshire Coastal Program (NHCP) is the lead policy and planning agency on coastal and ocean issues within the New Hampshire Department of Environmental Services (NHDES).

Boott initiated consultation with MOCZM and NHCP in 2018 requesting a determination from the states’ coastal zone agencies as to whether the Project was located in each states’ coastal zones or required a coastal zone consistency determination. In response to the Commission’s February 14, 2023, AIR, Boott sent emails to the agencies on May 1, 2023, to which the New Hampshire Department of Environmental Services concurred with Boott’s determination that the Project does not require a consistency certification. Boott did not receive a response to its May 1, 2023 request from the MOCZM. In response to the Commission’s January 22, 2025, request for documentation of consultation, Boott reached out to the MOCZM via phone and email. On January 23, 2025, the MOCZM responded by email confirming that the Project is not within the Massachusetts coastal zone and therefore is not subject to a federal consistency review. The Lowell Hydroelectric Project is not located in either state’s coastal zone and does not have any reasonably foreseeable effects on coastal resources. As the Project is not subject to coastal zone management program review, no consistency certification is needed for FERC’s relicensing of the Project.

E.4.5 National Historic Preservation Act

Section 106 of the National Historic Preservation Act (NHPA) (Section 106) requires federal agencies to consider the effects of their undertakings on historic properties and to afford the Advisory Council on Historic Preservation (ACHP) a reasonable opportunity to comment on such actions. Historic properties include significant sites, buildings, structures, districts, and individual objects that are listed in, or eligible for listing in the NRHP. FERC’s issuance of a new license for the Project is considered an undertaking subject to the regulations and requirements of Section 106 and its implementing regulations at 36 C.F.R. Part 800. In accordance with 36 C.F.R. § 800.14(b), FERC

typically fulfills its responsibilities pursuant to Section 106 by entering into a Programmatic Agreement with the appropriate State and/or Tribal Historic Preservation Officer(s) (SHPO/THPO), and in some cases the ACHP.

FERC initiated consultation under Section 106 with federally recognized Indian tribes by letter dated April 26, 2017. By notice dated June 15, 2018, FERC designated Boott its nonfederal representative for purposes of conducting informal consultation pursuant to Section 106.

A discussion of historical properties within the Project's Area of Potential Effects (APE) and the consultation under Section 106 conducted to date for the relicensing of the Project is contained in E.7.8 of this Exhibit.

Early in the relicensing process, Boott contacted prospective stakeholders to determine their interest in this relicensing proceeding. As part of this outreach, Boott corresponded with representatives of the Massachusetts SHPO and federally recognized Indian tribes with a potential interest in the effects of this relicensing on historic properties. The Project does not occupy tribal reservation lands and the U.S. Bureau of Indian Affairs (BIA), via consultation, documented the following tribes as having historical interest in the Project area:

- Mashpee Wampanoag Tribe
- Wampanoag Tribe of Gay Head
- Penobscot Nation

By letter dated April 26, 2017, FERC invited the Mashpee Wampanoag Tribe, Narragansett Indian Tribe, Stockbridge Munsee Tribe of Mohican Indians, and Wampanoag Tribe of Gay Head (Aquinnah) to participate in the relicensing process for the Project. The Mashpee Wampanoag Tribe was the only tribe to respond and stated they do not have concerns with relicensing unless new construction is proposed that has the potential to disturb cultural resources.

E.4.6 Wild and Scenic Rivers and Wilderness Act

There are no rivers designated under the Wild and Scenic Rivers Act within or adjacent to the Project boundary; therefore, this act is not applicable to the relicensing of the Project. No Project facilities are located within any designated wilderness areas.

E.5 Project Facilities and Operation (18 C.F.R. § 5.18(b)(4))

E.5.1 Maps of Project Facilities within Project Boundaries (18 C.F.R. § 5.18(b)(4)(i))

The Lowell Hydroelectric Project boundary is shown in detail in Exhibit G of this license application. The physical composition, dimensions, and generation configuration of the facilities that comprise the Project are described in the following subsections.

E.5.2 Project Location and Facilities Overview (18 C.F.R. § 5.18(b)(4)(ii))

This section provides a summary of the existing facilities at the Project; additional, detailed descriptions of Project facilities are presented in Exhibit A of this license application.

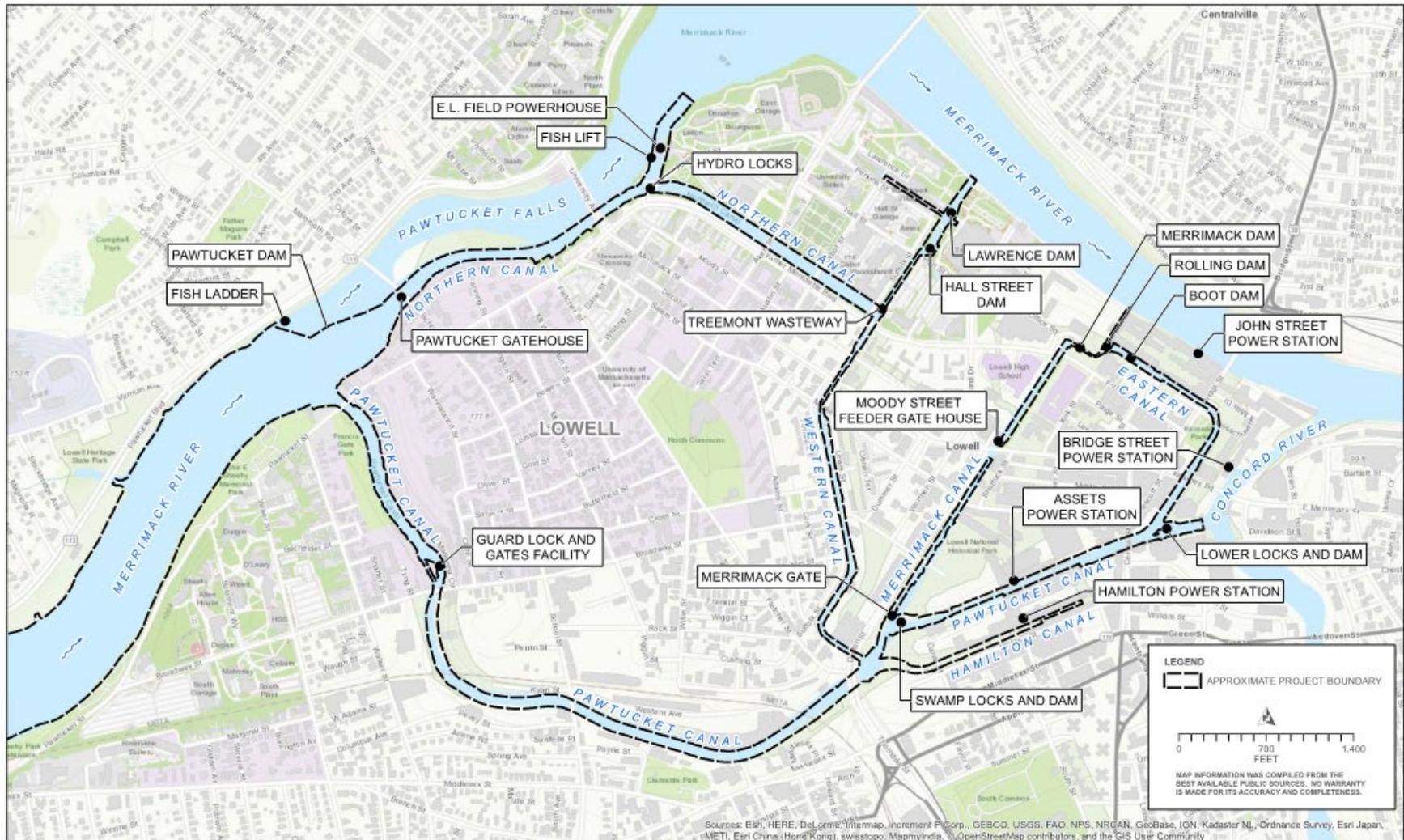
The Project is located at the Pawtucket Dam on the Merrimack River in the City of Lowell in Middlesex County, Massachusetts. The Project is located approximately 11 miles upstream of the Lawrence Project (FERC No. 2800) and approximately 30 miles downstream of the Amoskeag Dam (a development of the Merrimack River Project, FERC No. 1893) in New Hampshire. The 116-mile-long Merrimack River begins at the confluence of the Winnepesaukee and Pemigewasset Rivers in Franklin, New Hampshire; flows southward into Massachusetts; and then travels northeast until it discharges into the Atlantic Ocean. As currently licensed, the Project includes the 15.0 MW E.L. Field powerhouse constructed in 1985-1986 during Project redevelopment, and four smaller generating stations located within mill buildings along the downtown canal system. The current total installed capacity of the project is 20,164 kW. A Project location map is presented above as Figure E.1-1.

The E.L. Field powerhouse utilizes the existing Pawtucket Dam and the first 2,200 feet of the Northern Canal. The powerhouse is located close to the canal, downstream of the University Avenue Bridge (also called the Moody Street Bridge), with an intake structure drawing water from the canal. A 440-foot tailrace channel, surge gate and fish passage facilities comprise other major E.L. Field powerhouse features. The current FERC license includes the Assets, Bridge Street, John Street, and Hamilton Power Stations which are housed within large nineteenth-century mill buildings sited along the 5.5-mile canal system (Figure E.5-1). The Project boundary includes only the turbines and associated equipment at these downtown mill sites, and not the buildings themselves.

The Hamilton Power Station draws water from the Hamilton Canal and discharges into the Lower Pawtucket Canal. The Bridge Street Power Station (also known as “Section 8”) draws water from the Eastern Canal and discharges into the Concord River. The John Street Power Station also draws water from the Eastern Canal and discharges into the Merrimack River. The Assets Power Station draws water through an intake structure

at the Merrimack Canal and discharges into the Lower Pawtucket Canal. As noted in Section E.6 below, Boott is proposing to decommission the Assets power station and remove it from the FERC License.

Figure E.5-1. Lowell Hydroelectric Project Canal System Map – Existing Facilities



E.5.2.1 The Pawtucket Dam

Pawtucket Dam is of dressed masonry gravity construction with a length of 1,092.5 feet, a spillway crest length of 982.5 feet, a spillway crest elevation of 87.2 feet NGVD 29, and an average height of 15 feet. The dam was built in two sections in 1847 and 1875, the latter being grouted during construction. The dam foundation rests on bedrock, except for a short section on hardpan. The Pawtucket Dam fishway is located at the left dam abutment (looking downstream), and the Pawtucket Gatehouse, which provides flows the Northern Canal, is at the right abutment.

A pneumatically-operated crest gate system is mounted on the dam's spillway crest to maintain the Project's upstream impoundment at its normal elevation of 92.2 feet NGVD 29. The pneumatic crest gate system consists of five-foot-high, 20-foot-long, hinged, steel panels that are raised and lower by tubular rubber air bladders installed immediately downstream of the panels. The crest gate system is installed in five independently controllable zones. Air compressors, which supply system inflation and deflation pressure, and the crest gate control system are housed in a building located near the fish ladder and the left abutment of the dam.

E.5.2.2 The Northern Canal

The Northern Canal is approximately 4,300 feet in length, consisting of mixed materials lining the bottom, including masonry, wood, or existing bedrock. The width of the Northern Canal varies along its length. At the head of the canal, the canal is approximately 95 feet wide. The canal's most narrow point is approximately 78 feet wide where the canal flows under the University Bridge overpass. Approximately 2,200 feet downstream of the Pawtucket Gatehouse, the canal widens to approximately 80 feet as it bifurcates and discharges into the E.L. Field Powerhouse forebay. The canal then turns southeasterly at Pawtucket Street and Hydro Locks, widening to 105 feet between Pawtucket Street and the Tremont Gatehouse. The Great River Wall is the left retaining wall of the Northern Canal. The Great River Wall runs from the Pawtucket Gatehouse to a natural rock outcrop upstream of the E.L. Field Powerhouse. The wall is a mixed masonry structure that is 2,485 feet long and 32 feet in height. The first 1,000 feet combines masonry walls and an earth dike (with masonry core) as the river wall. The second length is a dressed mixed masonry gravity structure to the site of the E.L. Field powerhouse. The crest of the Great River Wall is approximately 103.0 feet NGVD 29 adjacent to the Pawtucket Gatehouse and varies in elevation along its length. The lowest point of the wall is approximately 93.3 feet NGVD at the University Bridge overpass. The width of the wall varies from 8 feet upstream at the Pawtucket Gatehouse to 10 feet at the downstream end.

E.5.2.3 Pawtucket Gatehouse

The Pawtucket Gatehouse (also known as the "Northern Canal Gatehouse") is located at the right abutment of the Pawtucket Dam (looking downstream) and controls flow to the Northern Canal. The Pawtucket Gatehouse is 125 feet long by 22 feet wide, and approximately 55 feet high from the base of the foundation to the roof peak. The

gatehouse contains the guard sluice gates, brick gatehouse, and a navigation lock. These structures were a part of the Northern Canal construction project of 1846-47. The gatehouse is principally constructed of dressed mixed masonry with concrete over lintels and contains ten 8-foot-wide by 15-foot-high, motor-operated, timber sliding gates that feed the Northern Canal. An additional intake feeds a historic Francis-designed turbine, which formerly powered the gate mechanisms through a line shaft. The structure's water passages are nearly 80 feet in length. Most of the original equipment, including the Francis turbine, is intact, although alteration and modernization of the gates and associated equipment has been performed in the past to support hydropower operations. Other alterations include a watertight enclosing wooden cover in the turbine pit in 1872 to prevent flooding of the turbine chamber in high water.

The navigation lock, which is constructed of dressed mixed masonry with two sets of wooden miter gates (upstream and downstream), is located at the southern end of the Pawtucket Gatehouse. The navigation lock is approximately 12-foot wide and 97.8-foot long.

E.5.2.4 The Pawtucket Canal

The Pawtucket Canal branches off the Merrimack River approximately 950 feet upstream of the Pawtucket Gatehouse and feeds water into the downtown canal system. From its starting point, the 9,000-foot-long canal curves south and then east, then northeast to meet the Concord River near its junction with the Merrimack River. The width of the Pawtucket Canal varies from 80 to 100 feet and the average depth is approximately 8 feet. The walls consist of materials ranging from granite, ledge, or concrete materials. The canal beds are of ledge, concrete, or wood-planked virgin soil. Over the Project lifetime, the canal's characteristics have changed as it was repaired with various materials, which is observed throughout the system; changing the overall visual aesthetics.

E.5.2.5 Additional Canals

The Project's three downtown power stations (Bridge Street, Hamilton, and John Street Power Stations) are fed by various sections of the 5.5-mile-long canal system. The primary canals in the system are the Pawtucket Canal and the Northern Canal, as described above. Multiple secondary canals receive flows from the system's two primary canals. The canal wall construction throughout the system is a combination of granite, ledge, and/or concrete materials. There are several examples of modernization improvements throughout all of the canals. The canal beds consist of ledge, concrete, or wood-planked virgin soil. Again, significant sections of the canals have been repaired or improved over time using a variety of materials.

The Hamilton Canal branches off the Pawtucket Canal and begins upstream of Swamp Locks and Dam and continues northeast. The Hamilton Canal is 1,936 feet in length, has an average depth of 10 feet deep, and is 35 to 100 feet wide. The Hamilton canal is generally rectangular in shape.

The Merrimack Canal is 2,580 feet in length and branches off the Pawtucket Canal, where it flows to the northeast. Portions of the Merrimack Canal are rectangular in shape; however, the majority of the canal was gouged out of the native rock and is irregular in shape. In general, the Merrimack Canal is 10 feet deep and 40 to 50 feet wide.

The Eastern Canal begins just upstream of Lower Locks of the Pawtucket Canal and continues northeast then west. The Eastern Canal runs for 2,037 feet and is rectangular in shape. The Eastern Canal averages 8 feet in depth and 65 feet in width.

The Western Canal connects the Northern Canal to the Pawtucket Canal and flows into the Tremont Wasteway. The Western Canal historically served as a two-level waterpower system; however, the lock structures were removed and filled in 1840. The total length of the Western Canal is 4,964 feet. Its width varies from 35 to 55 feet, and its average depth is 9 feet. The Western Canal is not used for power generation at the Project and no power stations draw water from the canal for generation; nor are any of the power generating facilities located along the Western Canal.

E.5.2.6 Miscellaneous Canal Structures

Over time, the additional canal structures have been owned, operated, and maintained by various parties. The structures throughout the canal system have been repaired and improved throughout their existence using a variety of materials and repair techniques. In many cases, the original materials of the canal structures is unknown.

E.5.2.6.1 Guard Lock and Gates Facility

The Guard Lock and Gates facility consists of a five-bay gatehouse located on the Pawtucket Canal and a series of three gate structures located within a boat lock. The gatehouse on the Pawtucket Canal includes a variety of materials, including dressed masonry, brick masonry, and wood frame. Adjacent to this structure is a boat lock consisting of the upper locking gate, Great Guard Gate (or Francis Gate), and lower locking gate. The gates span the lock chamber which is 24 feet wide with masonry walls. The upper locking gate and Great Guard Gate are housed in frame buildings. The only features at this location that are owned/operated by the Licensee are the five gates. The other gates and gate house structures are operated/owned by others.

The Great Guard Gate is a large portcullis gate located within the lock chamber between the upstream and downstream lock gates. This 25-foot-wide by 25-foot-high wooden gate is designed to be lowered into the lock chamber during extreme flood conditions on the Merrimack River to prevent flooding of downtown Lowell via the Pawtucket Canal. A wood frame structure, the Francis Gatehouse, houses the Great Gate. When needed, the Great Gate can be dropped under its own weight to the bottom of the lock chamber, thereby closing off any flow through the boat lock channel at the Guard Locks, preventing flooding in downtown Lowell via the Pawtucket Canal. The original Great Gate has been used twice during its history, the year following its construction in 1852 and again in 1936. The Great Guard Gate is no longer functional or tested. This structure has mixed ownership, owned in part by MADCR and Proprietors of the Locks and Canals on the Merrimack River (Proprietors).

Due to the historic nature, public safety concerns, and questionable functionality of the historic Great Guard Gate, in 2005 Boott designed and implemented a replacement gate in consultation with the FERC and NPS. The replacement gate is a segmented structural steel stoplog gate and frame which is stored on-site. The steel stoplog gate was designed and implemented to functionally replace the historic Great Guard Gate, which remains in place within the Francis Gatehouse. The steel stoplog gate fits immediately upstream of the Francis Gate House within existing stoplog slots in the granite masonry. When required, installation of the steel stoplog gate can be accomplished within a day by a local crane operator.

E.5.2.6.2 Moody Street Feeder and Gate House

The Moody Street Feeder is a 1,400-foot-long, underground conduit which allows flow to be passed from the Northern Canal to the Merrimack Canal. It terminates at the Moody Street Feeder Gate House which is located on the Merrimack Canal at the intersection of Dutton Street and Merrimack Street. Three 10-foot-wide gates allow closure of the three separate, arched water passages. The gates are housed in a brick building measuring 62.5 feet long by 22.5 feet wide. The Moody Street feeder is primarily constructed of stone, with sections of brick and concrete integrated throughout. Certain areas reflect improvements made to the facility over the years as technology, construction material, and mechanical techniques evolved.

Moody Street Feeder Gatehouse controls flows from the Moody Street Feeder Canal to the Merrimack Canal. Two consecutive dam structures occur downstream of the Moody Street Feeder Gatehouse on the Merrimack Canal, including the 8-foot-high Merrimack Dam and the 19-foot-high Rolling Dam. The Rolling Dam was originally constructed using locally sourced stone and has undergone repairs over time with additional stone and standard grouting imported from other regions. The gate consists of a wooden stoplog system. The Merrimack Dam consists of concrete block abutments paired with wooden stoplogs. The canal is primarily built of stone, with newer concrete sections indicating a later modification to raise the canal walls. The Merrimack Canal flows into the Merrimack Wasteway, which flows into the Merrimack River.

E.5.2.6.3 Lawrence Dam

The Lawrence Street dam is located approximately 300 feet downstream of the Hall Street dam and 300 feet upstream of the confluence with the Merrimack River. The Lawrence wasteway is located just downstream of Lawrence Street dam.

The Lawrence Dam's original construction consisted of a rock-filled, timber-crib substructure with a three-tiered apron. The upper apron was timbers overlaying rubble masonry. The second and third aprons consist of massive masonry. Over time, the dam has undergone significant modifications, including the replacement of certain sections with concrete gravity structures and smaller spillways that appear to be constructed of stone. These changes reflect substantial improvements made to the structure over the years. The superstructure is made of steel beams, fitted with wood bay boards. The crest of the spillway is approximately 75.0 feet in elevation. The structure is 100 feet long by 12 feet high and is located at the head of the 49-foot-wide Lawrence Wasteway, which leads to the Merrimack River. The Lawrence wasteway is constructed from stone and

concrete materials; several sections have been modernized with complete sections of wall from floor to cap with concrete material.

E.5.2.6.4 Hall Street Dam

The Hall Street Dam is located on the Tremont Wasteway. The Hall Street Dam consists of a rubble masonry structure with a noted stepped construction, masonry/rubble apron. The length of the structure is 115 feet with a maximum height of 15 feet, and a width of 29 feet. The crest of the spillway is approximately at elevation 81.0 feet with the toe approximately at elevation 66.0 feet. From the Hall Street Dam water flows downstream to the Lawrence dam via several open sections of the dam.

E.5.2.6.5 Tremont Wasteway

The Tremont Gate House is located at the confluence of the Northern and Western Canals and at the head of the Tremont Wasteway. The gatehouse consists of brick superstructure with masonry substructure. The gatehouse is a 32.5-foot long by 11-foot-wide building consisting of brick superstructure with granite block / masonry substructure. Housed in the gatehouse are two 9-foot-wide gates control the flow of water into the Tremont Wasteway.

The Tremont Wasteway is adjacent to Suffolk Street and forms the water passageway between the Northern Canal and the Hall Street Dam. The wasteway is a canal structure constructed of masonry and granite walls and is 30 feet wide by 600 feet long. The wasteway forms the water passageway between the Northern Canal and the Hall Street Dam.

E.5.2.6.6 Lower Locks and Dam

The Lower Locks and Dam is located on the Lower Pawtucket Canal and empties to the Concord River. The dam is located at the west end of the upper lock and has a maximum height of 12 feet and an approximate length of 120 feet. The dam consists of a rubble masonry structure with a sloping timber apron. Energy dissipation is accomplished by large rubble masonry located downstream of the dam. The superstructure is constructed of cast iron frames, fitted with wood bay boards. A gated sluiceway is also provided on the north side of the dam. The lock structure contains two 30.5 feet wide by 85 feet long chambers. The width at the gate passageway is 12.5 feet. The lock walls are of hand-laid masonry. Subsequent repairs since the original construction likely involved alternative materials and construction techniques as part of ongoing constructive modifications.

E.5.2.6.7 Swamp Locks and Dam

The Swamp Locks and Dam are at the head of the Lower Pawtucket Canal. The complex at the Swamp Locks and Dam consists of a left concrete dam section, right concrete dam section and gatehouse, and a two-chamber lock structure. The maximum height of the dam is 15 feet and the length is approximately 105 feet. The dam consists of a concrete

apron overlaying a rubble masonry structure. The superstructure is made of cast iron frames, fitted with wood bay boards.

The left concrete dam section is an originally masonry structure with a concrete cover. The concrete crest supports 6 foot long by 4.6 feet high stanchion bays and a wood-frame structure which houses a plank walkway. The right concrete dam section supports the southern segment of the wood-frame structure over the spillway, and its interior planked walkway. The canals near this area have been substantially modernized with concrete on river left.

A sluiceway is provided on the south side of the dam. The lock structure extends from the right side of the sluiceway to a point downstream where it re-enters the Pawtucket Canal. The two-chamber lock with narrowest width of 12.5 feet is constructed of rubble masonry and allows passage by the Swamp Locks and Dam. The canal walls at Swamp Locks and Dam consist of mixed materials from stone to conventional smooth concrete.

E.5.2.6.8 Rolling Dam

Rolling Dam is located downstream of the Merrimack Dam and consists of a masonry and concrete structure with a curved apron protected by wood planks. The maximum height of the dam is 19 feet, and the width is approximately 16 feet. The masonry construction is carried downstream of the dam to provide scour protection but appears to have repointing work completed along with concrete / shotcrete work just above the waterline. The gate structure just upstream allows for flows to be diverted into the Eastern Canal. The gate structure consists of concrete and the wooden stop logs.

E.5.2.6.9 Merrimack Dam, Merrimack Gate and Boott Dam

Merrimack Dam is located on the Merrimack Canal downstream of Moody Street Feeder Gate House and just upstream of Rolling Dam. Merrimack Dam consists of a sloping apron, rubble masonry structure. The apron is protected with timber planks. The maximum height of the dam is 8 feet, and the approximate length is 47 feet. The dam acts as a submerged weir, no longer used to control water elevations.

The Merrimack Gate is located at the beginning of the Merrimack Canal and consists of a concrete dam structure with a sloping upstream face and vertical downstream face with concrete abutments; this gate controls flow from Merrimack Canal to the Pawtucket Canal. The center portion of the structure is fitted with a 10-foot-wide by 6-foot-high timber gate. The maximum height of the dam is 9 feet.

The Boott Dam is located 80 feet southeast of the Merrimack Wasteway, adjacent to Boott Mills. It consists of a masonry structure 40 feet long with a maximum height of 7 feet and includes a gated sluiceway.

E.5.2.7 Power Stations and Mill Buildings

The Bridge Street ("Section 8"), Hamilton, and John Street power stations are housed within three former mill buildings associated with and located adjacent to the Project's canal system. However, the various buildings throughout the City of Lowell and located adjacent to the canal system are not needed for Project purposes and, as such, are not

included as licensed Project works, nor are they included within the FERC Project boundary. Rather, they are used principally for small industrial manufacturers, storage space, and/or apartment/condominium units. The FERC license is limited to structures and equipment required for power generation.

The Bridge Street power station is located on the Concord River near its confluence with the Merrimack River. It draws water from the Eastern Canal and discharges to the Concord River. Bridge Street includes three 360 kW generating units, with a total authorized generation of 1,080 kW. The units are designed for 22 feet of head and a hydraulic capacity of 333 cfs each (total: 999 cfs). The intake entrance trifurcates into three separate intakes for each unit, each approximately 10-feet wide by 8.3-feet high. The powerhouse inlets are situated behind 13-feet high by 119-feet wide trashracks that have clear bar spacing of 1.25 inch, and bar thickness of 0.75 inch.

The John Street power station is located on river right (looking downstream) of the Merrimack River, just upstream of its confluence with the Concord River. It draws water from the Eastern Canal and discharges to the Merrimack River. John Street includes four units—three 300 kW generating units with a design head of 21 feet and a hydraulic capacity of 250 cfs, and one 1,200 kW generating unit with a design head of 21 feet and a hydraulic capacity of 1,025 cfs. The John Street Unit No. 1 intake consists of three 9-foot-wide archways and one 7-foot-wide square opening that are 6-feet high. The intake of John Street Unit No. 6 conveyance consists of five bays that are 6-foot by 6-foot. John Street Unit Nos. 3, 4 and 5 share a single conveyance is identical to that of Unit No. 6. Trashracks over the intakes are 8-feet high by 100-feet long.

The Hamilton power station is located on the Hamilton Canal and draws water from the Hamilton Canal and discharges into the Lower Pawtucket Canal. Hamilton includes five varying units, with a total authorized capacity of 1,180 kW and a total hydraulic capacity of 1,638 cfs (See Table E.5-1 below for details). Trashracks over the intakes are in sections 12 feet high by 73 feet long and 12 feet high by 62 feet long.

E.5.3 Structures Constructed During Project Redevelopment

The principal civil works constructed during project redevelopment in 1985-1986 include the E.L. Field powerhouse, associated intake and tailrace channels, a canal control structure with navigation lock, fish passage facilities and a substation.

E.5.3.1 Eldred L. Field Powerhouse

E.L. Field powerhouse is a reinforced concrete structure, located on river right (looking downstream). The powerhouse is approximately 109-feet-long by 96-feet-wide and houses two 7.5 MW generating units with a total authorized capacity of 15.0 MW. The powerhouse incorporates a separate conventional intake structure for each of the station's two identical units. Each intake is approximately 50 feet wide and 50 feet high and is equipped with trashracks; intake and draft tube gate slots with permanent or bulkhead style gates for emergency shutdown and dewatering purposes are also provided. The powerhouse is equipped with a traversing trash rake to remove debris at the intake. Both mobile and on-site cranes are used for heavy equipment movement at the facility. The E.L. Field powerhouse

forebay is an excavated rock channel approximately 200 feet long, 50 feet deep, and 80 feet wide. The left (northern) side of the forebay is a reinforced-concrete wall and includes an exit channel for the downstream movement of fish that enter the canal system.

E.5.3.2 Tailrace Channel

A 440-foot-long tailrace channel was excavated out of bedrock in the river. The channel excavation is approximately 60 feet wide by an average of 20 feet deep. The tailrace is protected from high river flows by a 10 to 16-foot-high concrete training wall, which directs bypassed river flows away from the tailrace.

E.5.3.3 Crest Gate System

A pneumatically operated crest gate system is mounted on the spillway crest to maintain the headpond at its normal maximum water surface elevation of 92.2 feet NGVD 29. The pneumatic crest gate system consists of five-foot-high, 20-foot-long hinged steel panels supported on their downstream side by tubular rubber air bladders. The crest gate system is installed in five independently controllable zones. Air compressors, which supply system inflation and deflation pressure, and the crest gate control system are housed in a building located near the fish ladder and the left (northerly) abutment of the dam.

E.5.3.4 Control Structures

A concrete control structure known as “Hydro Locks” was constructed during project redevelopment in the 1980s, at the bend in the Northern Canal upstream of the E.L. Field intake and immediately underneath the Pawtucket Street Bridge. The control structure includes a navigation lock and was constructed to maintain the effective net head at the E.L. Field Powerhouse by isolating the powerhouse forebay from the remainder of the Lowell canal system. The control structure runs 100 feet long, underneath the Pawtucket Street Bridge, and is 26 feet high by 22.25 feet wide. The lock structure is approximately 88 feet long, located on the canal side along Father Morissette Boulevard, with sets of butterfly wicket lock gates approximately 15 feet high and 56 feet apart on either end of the lock. The lock structure is also equipped with stoplog slots and rubber fenders.

Located just downstream of the Great River Wall is the canal surge gate, constructed in the bedrock in the left forebay wall just upstream of the E.L. Field Powerhouse. The steel gate is pneumatically operated and is 15-feet-high by 78-feet-wide set on a masonry weir with a crest elevation of 77.0 feet. This system is designed to attenuate the surge wave in the canal that occurs when there is a sudden plant shutdown. When flow is less than 3,500 cfs, the surge suppressor gate is manually disabled. Should the flow increase to over 3,500 cfs, the gate is returned to the automatic operating condition. A safety boom has been installed in the canal above the gate.

E.5.3.5 Fish Passage Facilities

All fish passage facilities were designed in consultation with the USFWS. Boott proposes to implement fish passage at the Project in accordance with the measures approved by the resource agencies in accordance with the 2022 Settlement Agreement for Fish Passage. Existing upstream and downstream fish passage facilities at the Project include a fish lift and downstream fish bypass at the E.L. Field powerhouse, and a vertical-slot fish ladder at the Pawtucket Dam. All existing fish passage facilities were designed in consultation with the applicable resource agencies. The fish ladder at the Pawtucket Dam is designed to allow for controlled fish passage at river flows up to 25,000 cfs. The fishway operates at 200 cfs, including attraction flow, with an additional 300 cfs of supplemental attraction flow released from a slide gate adjacent to the passage facility. The fish ladder is a vertical slot design with 13-foot-wide by 10-foot-long pools. A counting station is incorporated into the ladder.

The existing upstream fishway at the powerhouse is a fish lift (i.e., elevator). The design discharge capacity is 200 cfs. A fish collection gallery with two entrances spans the downstream wall of the powerhouse to collect fish migrating upstream via the Project's tailrace channel, however only the westerly "river side" entrance has been used since the 1990's, by agreement with the fishery agencies. The fish are artificially attracted into the 30-foot crowding pool, trapped, and crowded with supplemental attraction flows. From the crowding pool, fish enter the elevator and are lifted in a hopper to the exit channel which provides access to the Northern Canal, which leads to the Merrimack River.

The existing downstream fishway at the E.L. Field powerhouse consists of an adjustable-flow sluiceway and bypass adjacent to the Project's intake headwall. On a seasonal basis, fish moving downstream of the Project via the Northern Canal may enter the sluiceway and be discharged to the Merrimack River adjacent to the powerhouse.

Boott is proposing modifications to the existing upstream and downstream fish passage structures consistent with *August 12, 2022 Settlement Agreement for Fish Passage*. Since 2022, fish passage technology has continued to advance, and Boott remains open to exploring innovative and emerging solutions that are currently available or anticipated to enter the market. Boott will collaborate with all relevant stakeholders and FERC once the information review is complete and the fishway retrofit design, particularly at the tailrace, for the Project are prepared.

E.5.3.6 Impoundment Characteristics (18 C.F.R. §5.18 (b)(4)(iii))

The Project operates in a ROR mode and has no usable storage capacity. The existing Project boundary extends approximately 23 miles upstream to Moore's Falls in Litchfield and Merrimack, New Hampshire. In this amended license application, Boott is proposing to modify the impoundment to follow more accurately the 92.2 feet NGVD 29 contour. This proposed impoundment extends approximately 16 miles upstream of the dam to the limit of the 92.2 feet NGVD 29 contour located at Cromwell's Falls in Litchfield and Merrimack, New Hampshire. The surface area of the proposed Project impoundment is approximately 1,236 acres; approximately 800 acres would be removed from the current Project boundary.

The gross storage capacity between the normal surface elevation of 92.2 feet NGVD 29 and the minimum pond level of 87.2 feet NGVD 29 is approximately 6,180 acre-feet.

E.5.3.7 Generating Equipment (18 C.F.R. §5.18(b)(4)(iv))

Turbine and generator data for each of the four power stations (including the E.L. Powerhouse) are provided below in Table E.5-1.

Table E.5-1. Lowell Hydroelectric Project Turbine, Generator, and Unit Capacity Data

Powerhouse	Unit #	Type	TURBINES						GENERATORS						
			Size Inches	Speed RPM	Head Feet	Flow cfs	Power HP	Power kW	Type	Power kVA	Power Factor	Power kW	Voltage Volts	Speed RPM	Unit Capacity
E. L. Field	1	Fuji Horizontal Full Kaplan	152.4	120	39	3,300	11,540	8,655	Fuji Electric	8,340	0.9	7,506	4,160	120	7,506
E. L. Field	2	Fuji Horizontal Full Kaplan	152.4	120	39	3,300	11,540	8,655	Fuji Electric	8,340	0.9	7,506	4,160	120	7,506
Bridge Street	4	Hercules Type D Single Runner	42	138.5	22	333	655	491	General Electric Co. Type ATB	450	0.8	360	600	138.5	360
Bridge Street	5	Hercules Type D Single Runner	42	138.5	22	333	655	491	General Electric Co. Type ATB	450	0.8	360	600	138.5	360
Bridge Street	6	Hercules Type D Single Runner	42	138.5	22	333	655	491	General Electric Co. Type ATB	450	0.8	360	600	138.5	360
Hamilton	1	Leffel Type Z Single Runner	45	120	13	374	459	344	Westinghouse Electric Co.	350	0.8	280	600	120	280
Hamilton	2	Leffel Type Z Single Runner	39	133	13	279	341	256	Electric Machinery Co.	225	0.8	180	600	133	180
Hamilton	3	Leffel Type Z Single Runner	36	150	13	237	287	215	Electric Machinery Co.	200	0.8	160	600	150	160
Hamilton	4	Leffel Type Z Single Runner	45	120	13	374	459	344	Electric Machinery Co.	350	0.8	280	600	120	280
Hamilton	5	Leffel Type Z Single Runner	45	120	13	374	459	344	Electric Machinery Co.	350	0.8	280	600	120	280
John Street	3	Leffel Single Runner	33	200	21	250	482	362	General Electric Co. Type ATI	375	0.8	300	600	200	300
John Street	4	Leffel Single Runner	33	200	21	250	482	362	General Electric Co. Type ATI	375	0.8	300	600	200	300
John Street	5	Leffel Single Runner	33	200	21	250	482	362	General Electric Co. Type ATI	375	0.8	300	600	200	300
John Street	6	Allis Chalmers Single Runner	72	100	21	1,000	1,925	1,444	Allis-Chalmers Type AV	1,500	0.8	1,200	600	100	1,200
TOTAL PROJECT CAPACITY:															19,372

E.5.4 Estimated Average Annual Energy Production (18 C.F.R. §5.18(b)(4)(v))

The average annual energy generation of the Lowell Hydroelectric Project for the period of 2008 through 2017 was 84,501 megawatt-hours (MWh). The Project operates in a ROR mode and, therefore, experiences seasonal and annual variations in generation based on natural hydrologic conditions in the Merrimack River Watershed. Table E.5-2 provides a summary of monthly Project generation for a 10-year period from 2008 through 2017 in MWh. Given that the E.L. Field Powerhouse has recently been offline due to a flood and subsequent facility refurbishment, Boott believes that this 10-year period provides a good representation of the Project's annual energy production.

Table E.5-2. Lowell Hydroelectric Project Monthly and Annual Generation (MWh)

Month	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
January	10,610	2,574	6,403	7,163	10,272	8,064	10,422	6,624	9,258	9,325
February	10,955	3,851	6,672	5,228	8,928	8,304	5,232	3,216	9,312	6,335
March	11,727	5,088	8,555	10,176	12,432	12,784	10,536	5,820	10,042	9,395
April	10,876	7,341	8,061	11,088	7,872	13,392	10,959	10,128	8,427	8,387
May	7,690	10,147	8,094	11,472	11,712	9,600	9,264	5,219	7,244	8,181
June	4,512	10,464	4,752	8,304	9,792	11,551	3,075	6,563	2,577	9,716
July	5,615	11,252	2,963	3,552	3,216	11,520	4,608	6,432	1,010	6,635
August	4,810	8,026	2,072	4,416	4,560	6,144	5,472	2,412	1,044	2,959
September	4,962	4,012	1,677	10,128	3,696	6,214	4,428	1,898	498	3,462
October	5,287	5,703	8,457	11,136	7,344	3,894	4,314	5,297	1,059	3,332
November	4,726	4,404	10,216	10,272	6,384	5,376	6,880	6,367	3,649	7,380
December	4,656	4,747	9,687	10,272	8,880	7,772	10,700	8,395	9,025	7,946
Annual	86,425	77,609	77,608	103,207	95,088	104,614	85,890	68,371	63,146	83,053

E.5.5 Estimated Dependable Capacity (18 C.F.R. §5.18(b)(4)(v))

Dependable capacity is generally defined as the amount of load a hydroelectric plant can carry under adverse hydrologic conditions during a period of peak demand, for example, during the hot, dry conditions typical of August in the Project area. The estimated dependable capacity is also determined by the minimum flow requirements included in the existing license. Under the current license, the Project's estimated dependable capacity is approximately 4.9 MW, based on the August median flow of 1,940 cfs at the Project site.

E.5.6 Current and Proposed Project Operations (18 C.F.R. §5.18(b)(4)(vi))

The Project is operated using the automatic pond level control capability of the E.L. Field Powerhouse. Boott is proposing to continue to operate the Project in the same manner as it is currently operated (automatic).

E.5.6.1 General Operations

Under the Project's existing FERC license, Boott operates the Project in run-of-river (ROR) mode using the Project's automatic pond level control capability. Through these operations, the project is operated to provide the required fishway flows, maintain established water elevations in the Project's canal system, and provide flows to the E.L. Field Powerhouse and canal power stations when available. Given that the E.L. Field turbine-generator units are more efficient and operate at a higher head than the Project's canal units, when the canal units are available, the E.L. Field turbine-generator units (primary units) are the Project's primary units during normal operations.

When river flows exceed the hydraulic capacity of the E.L. Field units (6,600 cfs for both units) and the bypass flow (year round 100 cfs; 500 cfs during the upstream fish passage season), excess flows up to approximately 2,000 cfs may be routed through the downtown canal system and to the canal units. Therefore, when the canal units are available for generation, flows in excess of approximately 8,600 cfs, and flows required for fish passage, are passed over the Pawtucket Dam spillway. This is how the Project currently uses the available flows. Boott proposes to continue this existing operation during the term of the Project's new license. In addition, even when the canal units are not available for generation, Boott proposes to provide between 50 and 100 cfs to the canal system in support of maintaining canal water elevations and water quality. In addition, Boott proposes to provide a minimum of 100 cfs to the Project's bypassed reach on a year-round basis and 500 cfs during the upstream fish migration season.

In addition to this operating approach, Boott operates the Project in accordance with additional management and operating plans (e.g., Crest Gate System Operation Plan, Canal Operation and Maintenance Plan, and Emergency Action Plan) as described below and in Exhibit E.

E.5.6.2 Canal Operations

The Project includes a two-tiered network of man-made canals, totaling 5.5 miles in length. Much of the flow to support the canal system enters upstream of the Pawtucket Dam via the Pawtucket Canal and is controlled by the Guard Lock and Gates Facility. The flow capacity of the downtown canal system via the Pawtucket Canal and the Guard Lock and Gates Facility is approximately 2,000 cfs. Additionally, flows enter the Northern Canal just before the ELF Powerhouse. Additionally, no power generation occurs along the Western Canal.

Project works include four power stations located within mill buildings along the downtown canal system. The Hamilton Power Station contains five units and draws water from the Hamilton Canal in the upper canal system and discharges into the Lower Pawtucket Canal in the lower canal system at a head of approximately 13 feet. In the lower canal system, the Bridge Street and John Street Power Stations each draw from the Eastern Canal and discharge to the Merrimack River or the Concord River, at a head of approximately 21 feet. The John Street Power Station contains four units and discharges into the Merrimack River. The Bridge Street Power Station has three units known as “Section 8” and discharges into the Concord River.

In general, when all the canal units are available, the canal unit dispatch sequence is intended to maximize the efficiency of the downtown canal units. Due to the imbalance of unit flow capacities between the units along the Hamilton Canal and the lower Pawtucket and Eastern canals, the Hamilton units would generally be the first units to be dispatched. Flows through the Hamilton units (up to 1,638 cfs total) are discharged into the Lower Pawtucket Canal, which then flow through the Eastern Canal to feed to units at John Street (1,700 cfs) and/or Bridge Street (999 cfs), or discharge at Lower Locks into the Concord River. The Bridge Street units and the John Street units along the Eastern Canal are typically sequenced to match the operating Hamilton canal units. By diverting canal flows through Hamilton units first, Boott can “reuse” canal flows at John Street and Bridge Street, while staying under the total canal flow of 2,000 cfs.

Boott will entirely suspend generation and operations of the downtown canal units during the downstream fish passage season for alosines and American eel (typically May through November – and to be defined annually in consultation with the Merrimack River Technical Committee). At the start of the downstream fish passage season, all downtown canal units will be shut off and flows will not be diverted into the downtown canal system (except as needed to maintain the canal water level and flows as per the Canal Operation and Maintenance Plan). At the end of the fish passage season, when river flows exceed the hydraulic capacity of the E.L. Field units (6,600 cfs for both units) and the bypass flow, excess flows up to approximately 2,000 cfs may be routed through the downtown canal system and to the canal units.

From May 15 to October 15, Boott maintains an operating agreement with the NPS to allow tour boat operations to navigate the canal system. Boott maintains canal water levels within appropriate limits during the May 15 to October 15 tour boat operating season, and typically will not be operating the downtown canal units, due to flow conditions and fish passage considerations.

E.5.6.3 Pneumatic Crest Gate Operations

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. The plan describes the operation of the pneumatic crest gate system under normal and high-water operations.

The pneumatic crest gate system works in conjunction with the automatic pond level control system at the E.L. Field Powerhouse to maintain consistent headpond level conditions.

Below (Table E.5-3) is a tabular description of the operating curve currently used for operations.

Table E.5-3. Pneumatic Crest Gate System Current Operational Scheme

Approximate Spillway Flow (cfs) †	Crest Gate Status	Target Pond Level (ft NGVD 1929)	Unit Operation
0	Full elevation	92.2 ft (Normal pond)	Pond level control maintained at E.L. Field Powerhouse; additional flow passed through downtown canal system as necessary.
0 – 3,250	Full elevation	Rising to ± 93.2 ft	Full available output
3,250 - ± 23,000 (est.)	Automatic pond level control	± 93.2 ft	Full available output
± 23,000 (est.) – 35,000††	Automatic pond level control if High Water Operations Protocol is not triggered.	± 93.2 ft	Full available output
	Fully lowered if High Water Operations Protocol is triggered	Pond level follows spillway rating curve based on spillway flow.	Full available output
>35,000	Fully lowered	Rises above 93.2 ft as spillway discharge increases.	Fully available output

Source: FERC 2015.

† Flow over the spillway is the inflow to the headpond minus any flow through the turbines at the E.L. Field Powerhouse, through the downtown canal system or through the fish ladder. The maximum combined hydraulic capacity of E.L. Field Powerhouse and the canal system is approximately 9,000 cfs, but may be restricted by unit availability, debris accumulation at the Northern Canal Gatehouse, high tailwater conditions, and other factors.

†† The potential range of spillway flows over which the crest gate may be fully lowered per the High-Water Operations Protocol. 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.

E.5.6.4 Normal Operation

Under normal operations, the crest gate is maintained at full elevation, and the E.L. Field Powerhouse control system adjusts the main units' output to match inflow and maintain the impoundment water level at the normal, authorized pond elevation of 92.2 feet NGVD 29.

E.5.6.5 Operations During Low Water and Adverse Conditions

During low inflow conditions, Boott operates the Project to maintain the impoundment level of 92.2 feet NGVD 29 and provides the required minimum downstream releases and flows necessary for operation of the fish passage structures in accordance with Articles 36 and 37 of the Project's license. Boott is proposing to continue this operational strategy through a new FERC license for the Project.

E.5.6.6 Operations During High Water and Adverse Conditions

When river flows exceed the flows required for the Project's fishway and the hydraulic capacity of the E.L. Field Powerhouse units, excess flows up to approximately 2,000 cfs can be routed through the downtown canal system and to the canal units (as described below). Flows in excess of these flows are passed over the Pawtucket Dam spillway into the bypassed reach.

During high-water conditions, when flows in the Merrimack River exceed the Project's hydraulic capacity, the crest gate control system at the E.L. Field Powerhouse automatically adjusts the gates to maintain the impoundment elevation no higher than 93.2 feet NGVD 29, or one foot above the normal pond elevation. When under automatic control, the crest gates are fully lowered at spillway flows of approximately 35,000 cfs and above. In addition, the approved Crest Gate Operations Plan requires Boott to fully lower the crest gate panels in anticipation of potential flood events. This minimizes the upstream backwater effect of the Pawtucket Dam to the extent possible. (FERC 2015).

In the canal system, the Great Guard Gate, a large portcullis gate was constructed in 1851 at the Guard Lock and Gates facility, to prevent flooding in downtown Lowell via the Pawtucket Canal. The Great Guard Gate and gatehouse is operated and maintained by NPS. However, in 2005, Boott designed and implemented a replacement for the Great Guard Gate under a FERC recommendation. The replacement is a frame and steel stoplogs that are stored on-site. The stoplog gate structure replaces the Great Guard Gate, which remains in place within the Francis Gate House. When deployed, the steel stoplogs are installed immediately upstream of the Francis Gate House within existing stoplog slots in the granite masonry. Installation of the steel stoplog gate can be accomplished within a day via a crane. The Project's Emergency Action Plan provides that the stoplogs should be installed when the water level at the Pawtucket Dam rises above 98.0 ft NGVD 29. Boott proposes to continue implementation of the existing Emergency Action Plan associated with the facility.

E.6 Proposed Action and Action Alternatives

E.6.1 Summary of Existing Measures

Boott proposes to continue operating the Project in ROR mode and to decommission the Assets power station and remove it from the FERC License. Boott currently implements the following PM&E measures for the protection of aquatic, water quality, geologic/soil, recreation, and cultural resources pursuant to the existing license for the Project.

Article 33 (amended April 18, 2013 and approved May 18, 2016): Requires the Licensee, prior to the commencement of any construction activities, to cooperate with the Massachusetts State Historic Preservation Officer (SHPO) and the NPS to carry out a mitigation program for avoiding or minimizing adverse effects on the Locks and Canals Historic District and the Lowell National Historical Park (The license was amended to replace wooden flashboards on Pawtucket Dam with pneumatic crest gate system and mitigation measures were required).

Article 34 (approved September 24, 1984): Requires the Licensee to design and construct upstream and downstream fish passage facilities at the Project, in consultation with the fishery agencies. Accordingly, in the late 1980s the Licensee constructed a fish lift and downstream fish passage facility at the E.L. Field powerhouse and a fish ladder at the Pawtucket Dam. These facilities are operated and managed under the CFPP, as discussed below.

Article 35 (approved November 28, 2000): Requires the Licensee to conduct an operational study to determine the effectiveness of the fish passage facilities required under Article 34, in consultation with the fishery agencies. During the term of the license The Licensee has conducted numerous fish passage studies and has implemented operational and facility improvements based on the results of those studies. These studies and improvements have been carried out pursuant to the CFPP, as discussed below.

Article 36 (approved November 27, 1984; November 28, 2000; July 11, 2001): Required the Licensee develop (1) an instream flow study plan to determine 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.

Pursuant to Article 35 and 36, Boott adheres to the Comprehensive Fish Passage Plan, approved by FERC on November 28, 2000. The CFPP requires operations of a fish ladder at the Pawtucket Dam. The fish ladder has a total operating flow of 500 cfs including attraction flow. The 500 cfs is the primary source of flow in the bypass reach, other than spillage over the Pawtucket Dam spillway. The fish lift system at E.L Field Powerhouse has a total flow capacity of 180 cfs; however, it presently operates at 100-120 cfs. Boott is required to operate both the fish ladder and the fish lift daily during spring of each year when a cumulative total of 50 American Shad or 200 River Herring are passed at the downstream Lawrence Hydroelectric Project. Additionally, Boott is

required to operate the downstream bypass facility from April 1 through July 15 and from September 1 through November 15 (Cleantech Analytics 2017).

Article 37 (Amended July 13, 2023): FERC issued an Order Amending License to amend the Project's license to formally designate the Project's current operations as ROR operations through revising Article 37 of the license.

Article 38 (ordered September 12, 1984): Requires the Licensee to file a revised Report on Recreational Resources to include: (1) functional plans for certain repairs and improvements to the Northern Canal and a visitor facility at the E.L. Field Powerhouse; (2) a canal system water level agreement with the NPS.

Boott is also required to adhere to the following operations-related plan:

Crest Gate Operation Plan (approved March 30, 2015): Requires the Licensee to adhere to the detailed plan for operation of the pneumatic crest gate system filed on July 16, 2013, and revised on July 30, 2014. The plan describes the operation of the pneumatic crest gate system under normal and high-water operations. Table E.5-3 above provides a tabular description of the operating curve used for operations.

The pneumatic crest gate system works in conjunction with the automatic pond level control system at the E.L. Field Powerhouse to maintain consistent headpond level conditions. Under normal operations, the crest gate will be maintained at full elevation, and the E.L. Field control system will adjust the main units' output to match inflow and maintain the impoundment water level at the normal, authorized pond elevation (92.2 feet). When inflows begin to exceed the capacity of the available units, the crest gate control system will automatically adjust the gates to maintain the impoundment elevation no higher than 93.2 feet, or one foot above the normal pond elevation. When under automatic control, the crest gates would all be fully lowered at spillway flows of approximately 35,000 cfs and above (FERC 2015a). Under high-water operations, Boott will fully lower the crest gate system in anticipation of potential flood events in order to minimize the upstream backwater effect of the Pawtucket Dam to the extent possible.

E.6.2 Summary of Proposed Action and Enhancement Measures

Based on the studies conducted in support of this relicensing, consultation with stakeholders to date, and operation plans and agreements approved by relicensing parties, Boott proposes the following measures to be included in the new Project license:

Project Facilities and Operations

- Boott proposes to operate the Project in a ROR mode using automatic pond level control of the E.L. Field powerhouse units, for the purpose of protection of fish and wildlife resources downstream from the Project. ROR operation may be temporarily modified for short periods to allow flow management for other project and non-project needs, e.g., downtown canal water level management, raising the crest gates following a high-water event, or for recreational purposes.

- On a seasonal basis during the upstream passage season (i.e., typically from early May through late June/early July – and to be defined annually in consultation with the Merrimack River Technical Committee (MRTC))¹, Boott will provide a zone of passage flow of 500 cfs or inflow, whichever is less, into the Project's bypassed reach to provide appropriate fish passage conditions.
- Boott proposes to release a minimum flow of 100 cfs or inflow, whichever is less, to the bypassed reach downstream of the Pawtucket Dam during the period outside of the upstream fish passage season for the protection of aquatic and recreational resources. The minimum flow would be provided as spillage over one or more of the crest gate zones.
- Boott proposes to entirely suspend generation and operations of the downtown canal units during the downstream fish passage season for alosines and American eel. Downstream passage season is typically May through July for alosines, and August through November for American eel. The specific suspension of generation will be defined annually in consultation with the MRTC. At the start of the downstream fish passage season, all downtown canal units will be shut off and flows will not be diverted into the downtown canal system (*except as noted below under Canal Water Elevations and Canal Water Flows*). At the end of the fish passage season, when river flows exceed the hydraulic capacity of the E.L. Field units (6,600 cfs for both units) and the bypass flow, excess flows up to approximately 2,000 cfs may be routed through the downtown canal system and to the canal units.
- Between August 15 and November 15 of each year until the proposed downstream passage protection measures are fully implemented (as discussed more under Section A.2.12 and Section B.1.3.5), Boott is proposing nighttime shutdowns at the E.L. Field as an interim measure to protect out-migrating adult American eel. The downtown units will also be shutdown during this period as per the measure above.
- Boott is proposing to decommission the Assets power station and remove it from the new license. Within one year of license issuance, Boott will file a decommissioning plan with the Commission including measures to avoid, minimize, or mitigate Project-related effects during decommissioning.
- From May 15 to October 15, Boott maintains an operating agreement with the NPS to allow tour boat operations to navigate the canal system. Boott maintains canal water levels within appropriate limits during the May 15 to October 15 tour boat operating season, and typically will not be operating the downtown canal units, due to flow conditions and fish passage considerations.
- In support of the NPS's canal boat operations and additional recreational activities (provided by others), as well as for aesthetics, canal wall integrity, and

¹ The Merrimack River Technical Committee is comprised of the following state and federal agencies: New Hampshire Department of Fish and Game (NHDFG), Massachusetts Division of Fisheries and Wildlife (MADFW), Massachusetts Division of Marine Fisheries (MADMF), United States Fish and Wildlife Service (USFWS), United States Forest Service (USFS), and National Marine Fisheries Service (NMFS).

vegetation control, Boott will make a good-faith effort to maintain the water elevations within the canal system consistent with the elevations established in a Canal Operations and Maintenance Plan (COMP) that will be prepared by Boott in consultation with NPS and other stakeholders and filed with FERC for inclusion in the new license. See below for Boott's proposed operations as they pertain to *Canal Water Elevations* and *Canal Water Flows*.

- Boott proposes continued adherence to the requirements of the Project's existing Crest Gate Operation Plan (approved by FERC on March 30, 2015).

Canal Water Elevations

Boott is actively collaborating with key stakeholders to finalize the COMP. Once the COMP is finalized, a copy of the Plan will be submitted to FERC. One of the primary components being addressed in the COMP is the management of canal water elevations.

Canal Water Flows

Boott is actively collaborating with key stakeholders to finalize the COMP, which will include provisions for canal water flows. Once the COMP is finalized, it will be submitted to FERC for approval and inclusion in the new license. One of the primary components being addressed is the management of canal water flows.

Trash Management

Boott is actively collaborating with key stakeholders to finalize the COMP. Once it is finalized, a copy of the COMP will be submitted to FERC for approval and inclusion in the new license. One of the primary components being addressed is trash management in the canals.

Vegetation Management

Boott is actively collaborating with key stakeholders to finalize the COMP. Once it is finalized, a copy of the COMP will be submitted to FERC for approval and inclusion in the new license. One of the primary components being addressed is vegetation management in the canals.

Fish Passage

Boott is proposing modifications to the existing upstream and downstream fish passage structures consistent with August 12, 2022 Settlement Agreement for Fish Passage. Since 2022, fish passage technology has continued to advance, and Boott remains open to meeting passage requirements under the Settlement Agreement through innovative and emerging solutions that may be available or anticipated to enter the market. Boott will continue to collaborate with all relevant stakeholders and FERC in exploring potential options, if any. Proposed fish protection measures include:

- Boott proposes to replace the existing fish lift with a short fish ladder to pass migratory fish from the E.L. Field powerhouse tailrace to the bypass reach, such that fish would be passed upstream of the Project via the existing fish ladder at

the Pawtucket Dam. As approved by the MRTC, the proposed fish ladder will be operated on a seasonal basis. In accordance with the Settlement Agreement, Boott will consult with USFWS and NMFS to determine the design and installation schedule for the proposed ladder. Boott may consult with the MRTC to discuss the possibility of requesting a reevaluation of new technology in the future.

- Following installation and operation of the proposed upstream fish passage structure, Boott proposes to cease operation of the fish elevator and associated operations described above. Cessation of the fish elevator operations will be determined based on consultation with relevant agencies and Boott should not have to continue to incur maintenance costs once the upstream passage structure is constructed and tested.
- Boott proposes to install a new fish exclusion structure or approved equivalent at the E.L. Field Powerhouse to prevent entrainment of fish through the turbines. Downstream passage of fish will continue to be provided via the existing sluice gate in the left forebay wall of the E.L. Field Powerhouse. Boott will consult with the MRTC member agencies to determine the design and installation schedule for the proposed downstream fish exclusion system. Boott plans to seasonally deploy the new exclusion facility only during the downstream fish passage season.
- Between August 15 and November 15 of each year until the proposed downstream fish passage protection measures are fully implemented, Boott is proposing nighttime shutdowns as an interim measure to protect out-migrating adult American eel. Interim nighttime shutdowns will be implemented in accordance with the provisions of the Interim Nighttime Shutdown Plan for Downstream Eel Passage developed in consultation with the MRTC pursuant to Section 4.2 of the Settlement Agreement.
- Additionally, Boott proposes to release a minimum flow of 100 cfs or inflow, whichever is less, to the bypass reach downstream of the Pawtucket Dam during the period outside of the upstream fish passage season. The minimum flow would be provided as spillage over one or more of the crest gate zones. On a seasonal basis during the upstream passage season (i.e., typically from early May through late June/early July – and to be defined annually in consultation with the MRTC), the Licensee will provide a zone of passage flow of 500 cfs or inflow, whichever is less, into the Project's bypassed reach to provide appropriate fish passage conditions.
- Consistent with the 2022 Settlement Agreement, within three months of the issuance of the new license, Boott will develop a Fishway Operations and Management Plan (FOMP) in consultation with the resource agencies and approved by the USFWS and NMFS.

Historic Properties

- Within one year of license issuance, Boott will develop a Historic Properties Management Plan (HPMP) for the Project that will describe appropriate

management measures to avoid, minimize, or mitigate Project-related adverse effects on historic and archaeological resources over the term of the new license issued for the Project. The measures provided in the HPMP will direct the Licensee's management of NRHP-listed or eligible historic properties within the proposed Project boundary. Boott will develop the HPMP in consultation with the NPS, MHC, New Hampshire Division of Historic Resources (NHDHR), and Indian tribes.

Recreation

- Within one year of license issuance, Boott will develop a Recreation Access and Facilities Management Plan in consultation with the stakeholders to continue to manage the Project's recreation facility, the E.L. Field Powerhouse Visitor Center.

License Term

- In view of the substantial capital investment in new or improved fish passage facilities that Boott is committing to within this license application, Boott requests that the Commission issue the new license for a term of 50 years. This request is consistent with the Commission's 2017 Policy Statement on Establishing License Terms for Hydroelectric Projects,² which recognizes "significant measures expected to be required under the new license" when considering extension of a license term beyond the 40-year default period.

² PL17-3-000, October 19, 2017

E.7 Environmental Analysis by Resource Area

Pursuant to 18 C.F.R. § 5.18(b), this section discusses the existing Project related resources in more detail and analyzes the effects of the proposed action on these Project area resources. This section incorporates by reference all relevant prior relicensing materials including the resource study reports. The most important and relevant information from the reports and prior documentation are summarized herein as part of the analysis of the effects.

This section is divided into the following major resource areas:

- Geological and Soil Resources
- Water Quantity and Quality
- Fish and Aquatic Resources
- Terrestrial Resources
- Rare, Threatened, and Endangered (RTE) Species
- Recreation and Land Use
- Aesthetic and Socioeconomic Resources, and
- Cultural Resources

Each of the above resource areas is further divided into the following major subsections:

- **Affected Environment** - This subsection presents information on the affected environment using the information filed in the Licensee's PAD, information developed through the Licensee's FERC-approved study plans, and other information otherwise developed or obtained by the Licensee.
- **Environmental Analysis** - This subsection describes the beneficial and potential adverse effects of continued operation of the Project as proposed. Where appropriate, this subsection addresses both site-specific and cumulative Project effects, as required by Scoping Document 2 (SD2). The environmental analysis for each resource area is based on information presented in the PAD, the results of studies conducted in support of the license application, professional expertise, and other information obtained by the Licensee. This subsection also describes the Licensee's proposed environmental measures designed to address potential Project effects, and how the Licensee's proposed measures would protect or enhance the existing environment. The measures are listed above and described in greater detail in these subsections, as appropriate.
- **Proposed environmental measures** - This subsection describes any proposed new environmental measures, including, but not limited to, changes in the project design or operations, to address the environmental effects identified above and its basis for proposing the measures.
- **Unavoidable Adverse Effects** - This subsection describes any adverse impacts that would occur despite the Licensee's proposed environmental measures.

E.7.1 Geology and Soil Resources

The subsections below describe geology and soil resources in the vicinity of the Project and consider the effects of continued operation of the Project as proposed by the Licensee on geological and soil resources.

E.7.1.1 Affected Environment

E.7.1.1.1 Geology

Physiography and Topography

The Lowell Project is located in the New England Physiographic Province. This broad physiographic section is characterized as a mountainous area of significant relief. The area is made up of highly deformed Precambrian and Paleozoic metamorphic rocks, including gneiss, schist, slate, quartzite, and marble. The province was glaciated during the Pleistocene and shows both depositional and erosional effects of glacial ice. The Taconic, Green, and White Mountain ranges are distinct features of the New England Physiographic Province. The Taconic Mountains are a north-south trending mountain range along the western edge of the province and are thought to be formed by erosion of an upper block of a large thrust fault. Also, trending north south, the Green Mountains exist primarily in Vermont and are made of Precambrian gneisses. The White Mountains are an exhumed mass of Paleozoic granite and include Mount Washington in New Hampshire, the tallest mountain in the region at 6,288 feet. The province is valued for its mineral resources, both industrial and as building materials. Marble, granite, and slate are all widely distributed and quarried within the province (NPS undated a).

The Merrimack River watershed traverses each of the three major sections of the New England Physiographic Province: the White Mountains, New England Uplands, and Seaboard Lowlands (Flanagan et al. 1999 as cited in USACE 2003). The majority of the basin falls within the New England Uplands region, which is characterized by rolling hills and has a local relief ranging from a few hundred feet to 1,000 feet in more mountainous regions. The watershed elevation ranges from a high of 5,249 feet on Mount Lafayette in the White Mountain region to mean sea level along the northeastern Massachusetts coast (USACE 2003).

The Lowell Project is located in the Seaboard Lowlands Section of the New England Physiographic Province. The Seaboard Lowlands Section is lower in elevation and less hilly than the New England Upland Section. The boundary between these two sections is between 400 and 500 feet in elevation in most places. According to Flanagan et al. (1999), topographic relief in the Seaboard Lowlands Section is limited to less than approximately 200 feet in most places. In the vicinity of the Project, the Merrimack River flows through a region of rapid population growth and development that is heavily influenced by the Lowell metropolitan area. The local relief in the Merrimack River Valley in the Project vicinity is generally characterized as low, open hills.

Bedrock Geology

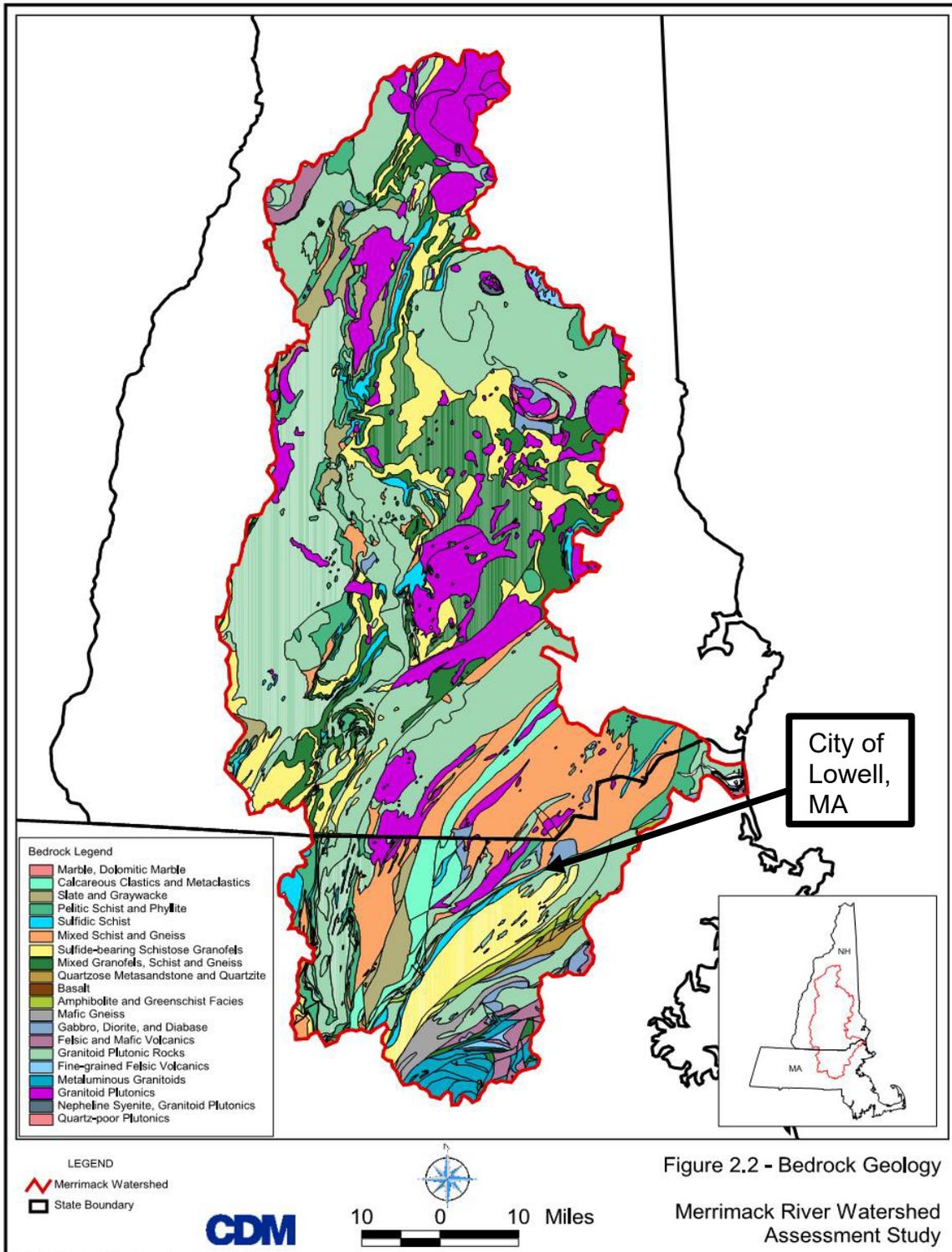
Bedrock in the Merrimack River watershed is generally of similar age and genesis. Intrusive igneous rocks, primarily Granitoid Plutonic rocks, dominate the northeastern portion of the river basin. Large deposits of metamorphic mixed and sulfide-bearing granofels cover the north-central and northwestern portion of the basin. A strip of metamorphic grade rocks, including mixed schist and gneiss deposits, cuts across the Massachusetts-New Hampshire border in a northeasterly direction (USACE 2003). The bedrock is generally layered and complexly deformed. Structures and contacts generally trend northeast to southwest, perpendicular to the direction of collision during the Acadian Orogeny. The mineralogy of the bedrock units is highly varied, from pure quartz in quartzite formations to thin layers of calc-silicate rocks, large bodies of schist with various mineral assemblages (often with high iron and manganese concentrations), and metavolcanics with high base-cation concentrations (Flanagan et al. 1999).

The Merrimack Quartzite is the principal bedrock unit underlying the Project. Although the rock is cut by abundant fractures, it is hard and relatively unweathered. The low-grade metasedimentary rock is of Silurian or Devonian age, approximately 400 million years old. Lithologically, the rock is a fine-grained, impure, bedded quartzite with minor schist. In places, quartzite consists of alternating coarse-grained sandy beds with silty beds (Boott 2015).

The Project is also nearby the mapped contact between the Merrimack Quartzite and the Ayer Granite. The Ayer Granite is a late Paleozoic intrusion. It is a complex igneous rock with an average composition of granodiorite. It is a light- to medium-gray, medium- to coarse-grained rock, commonly porphyritic, gneissic or migmatitic (Boott 2015).

A bedrock geology map of the Merrimack River watershed is presented in Figure E.7-1.

Figure E.7-1. Merrimack River Watershed Bedrock Geology



Source: USACE 2002

Surficial Geology

Glaciation has shaped the landscape of eastern North America during several major glacial periods. As glaciers flowed across the landscape, they scraped and sculpted the land surface. As glaciers retreated from the landscape during deglaciation, they created lakes and altered the course of rivers. Debris scraped off the land surface was carried by the ice and deposited as sand, gravel, and other unconsolidated sediments across the landscape. Some of the sediments were deposited by the ice directly, and the rest were carried by meltwater streams and deposited in the sea or elsewhere on land. Most of the surficial sediments found across New England are a result of glaciation (Flanagan et al. 1999).

The Merrimack River basin is generally covered by a sheet of glacial till, with areas of large fine- and large-grained, glacial-lake deposits along the river mainstem and major tributaries (Flanagan et al. 1999 as cited in USACE 2003). Till, known locally as “hardpan,” is composed of boulders, gravel, sand, silt, and clay mixed in various proportions, and is usually compact, stony, and difficult to dig. Lodgement (or basal) till, deposited directly beneath active ice, is generally more compact than ablation till (Flanagan et al. 1999).

According to the USACE (1977), the till cover within the Merrimack River basin is composed of variable, unstratified, silty, gravelly, sand and clays. The cover is generally thin on the hilltops and in the deep valleys, with exposed bedrock typically visible in the hilly upland regions. Large glacial melt-water lakes formed throughout the basin during glacial retreat (USACE 2003).

Mineral Resources

As mentioned above, the New England Physiographic Province is valued for its mineral resources, both industrial and as building materials. Marble, granite, and slate are all widely distributed and quarried within the province (NPS undated a). There are no mapped oil, gas, or mineral resources in the Lowell Project boundary. According to the USGS (USGS Undated a), there are three active mines in the Project vicinity, including the Westford Quarry located approximately 4.5 miles southwest of Pawtucket Dam, the Chelmsford Quarry located approximately 4.4 miles southwest of Pawtucket Dam, and a Sand and Gravel Operation located approximately 5.4 miles northeast of Pawtucket Dam in Essex County, MA.

E.7.1.1.2 Soils

Soil types in the vicinity of the Lowell Project are variable and reflect the diversity of parent materials, the local topography, and the physiographic position of landforms. The Project vicinity is composed of soil series formed primarily in glacial and glaciofluvial deposits, sandy outwash or eolian deposits, and recent alluvium. According to USACE (2003), soil types occurring in the vicinity of the Project include silt loam, unweathered bedrock, loamy sand, and areas mapped as mucky peat. Additionally, a large portion of the soils mapped in the Project vicinity are classified as Udorthents. There are many types of Udorthent soils, but in general they include areas of human altered soil and non-soil areas that are mapped based on their surface texture, type of alteration, depth to

water table, and geologic setting. Some human-altered map units include sand, gravel, till, quarry pits, areas of excavated (cut and fill) geologic material, and areas used for the disposal of refuse.

Mapped soils in the vicinity of the Project are presented in Figure E.7-2. A 100-foot buffer has been applied to the Project boundary to develop this figure. Map unit delineation on a soil map represents an area that is dominated by one or more major kinds of soil or miscellaneous area. Each map unit is identified, and names are in accordance with the taxonomic classification of the dominant soils. The U.S. Department of Agriculture's (USDA) Official Soil Series Descriptions for mapped soil series (Figure E.7-2) are presented in Appendix A of this FLA (USDA undated).

E.7.1.1.3 Impoundment Shoreline and Stream Banks

The shoreline surrounding the Merrimack River within the Project area typically consists of low-to-moderate slopes dominated by urban, commercial, industrial, and residential development. Some areas along the shoreline within the Project vicinity consist of agricultural areas and some areas consist of forest canopy vegetation underlain by established shrub and herbaceous layers. Large boulders, cobbles, or exposed bedrock are uncommon along the shoreline of the Merrimack River within the Project area. A portion of the shoreline is bordered by walking trails which are used by the public, and the majority of the southern shoreline is bordered by a railroad.

A summary description of the streambanks for the Merrimack River within the Project area in the vicinity of the Project is provided below based on the results of the Recreation and Aesthetics Study performed by Boott in 2020 (HDR 2021a).

A wide variety of vegetation types, occurrences, and distribution, ranging from herbaceous, non-woody plants to forested areas of trees and underbrush, and shoreline/canal types, ranging from earthen embankments to placed, uniformly sized blocks were observed during the study. Mapped vegetation was greatest in the Pawtucket Canal, followed by the Eastern Canal, Western Canal, and Northern Canal. Common vegetation species observed along the canals and within the Project area along the Merrimack River include tree of heaven (*Ailanthus altissima*), American elm (*Ulmus americana*), silver maple (*Acer saccharinum*), red maple (*A. rubrum*), Siberian elm (*Ulmus pumila*), various goldenrod (*Solidago*) species, and some weedy and invasive species including purple loosestrife (*Lythrum salicaria*), poison ivy (*Toxicodendron radicans*), Boston ivy (*Parthenocissus tricuspidata*), mullein (*Verbascum thapsus*), and common ragweed (*Ambrosia artemisiifolia*).

There is no evidence of erosion, slumping, or slope instability around the shoreline of the Project.

E.7.1.1.4 Seismicity

The northeast United States lies within the relatively tectonically stable and geologically old North American plate, where a great deal of the tectonic action took place over 200 million years ago when the Atlantic basin began to form due to the separation of Africa from North America. However, based on instrumental seismic records, earth scientists believe that the tectonic activity in the northeast is still ongoing (Ebel 1987).

The Project is located in Seismic Zone 2 and is subject to earthquakes of moderate intensity. The Clinton-Newbury fault zone forms an important regional crustal plate boundary and is located roughly 1.5 miles southeast of the Project area. No recent largescale earth movements are known along the Clinton-Newbury fault and it is considered inactive (Boott 2015).

Regarding historic seismicity, the USGS National Earthquake Information Center Database was searched regarding earthquakes within the Project region from 1970 to present day. The most significant (largest and closest) events were indicated by the USGS to be a magnitude (M) of 3.7 on October 2, 1994, 54 miles from the Project, and a M of 3.1 on January 10, 1999, 22.3 miles from the Project (USGS undated *b*).

E.7.1.2 Environmental Analysis

No potential issues related to geology or soil resources were identified by Boott or stakeholders throughout the relicensing process. There are currently no known adverse Project effects on geology or soils. Boott is not proposing major operational changes to the Project. Continued operation of the Project is not expected to have a material adverse effect on geologic resources, soils, or the geomorphology of the Project impoundment.

E.7.1.3 Proposed Environmental Measures

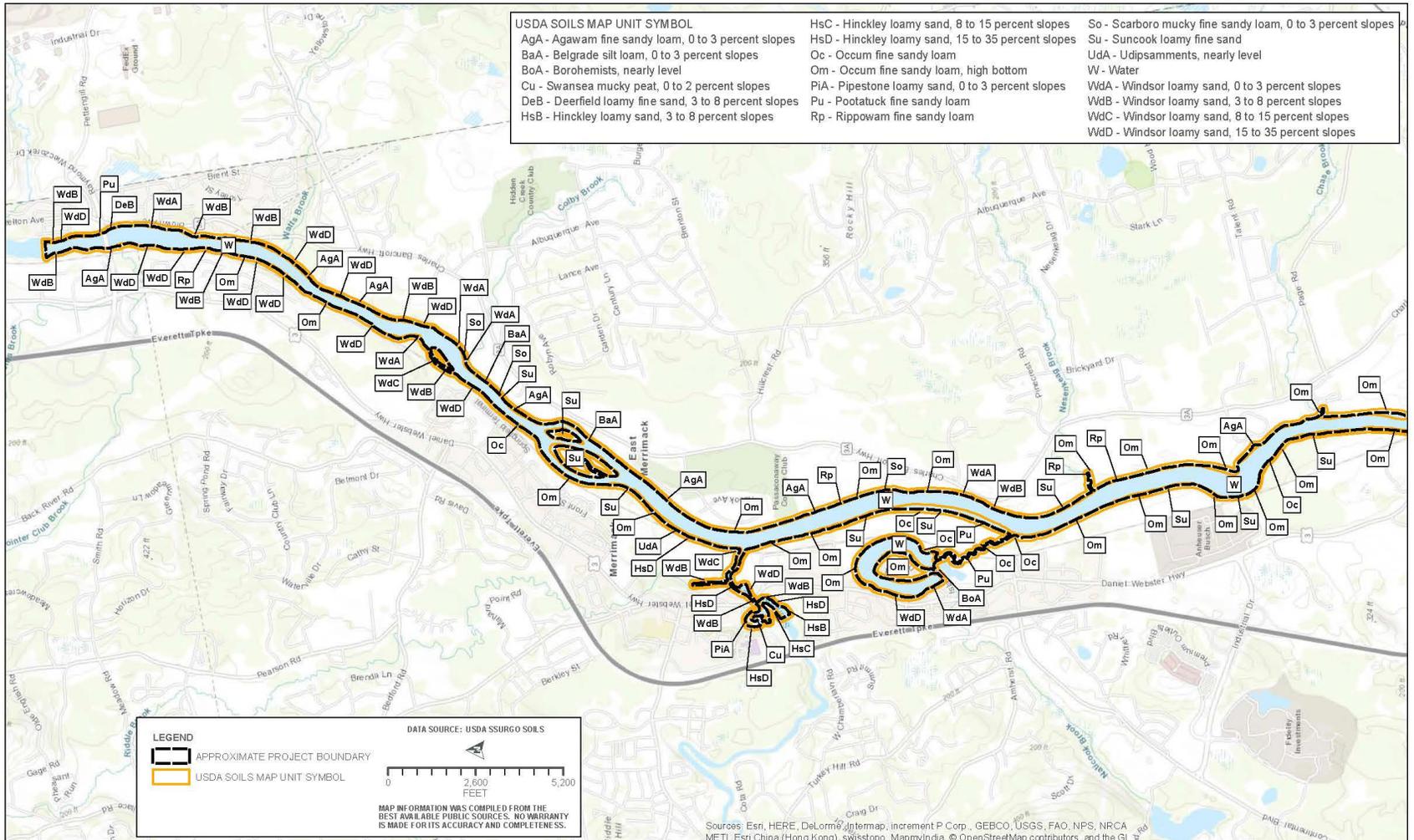
Boott is not proposing any PM&E measures related to geology and soils. No additional PM&E measures related to geology, geomorphology, or soils have been proposed by resource agencies or other consulting entities. Boott anticipates that the continued operation and maintenance of the Project, as proposed, will have minimal impact on geology and soils.

Boott will implement appropriate erosion and sediment control measures and obtain necessary approvals from resource agencies and permitting authorities for any Project maintenance or construction activities potentially required during the new license term.

E.7.1.4 Unavoidable Adverse Impacts

Unavoidable adverse impacts are those effects that may still occur after implementation of PM&E measures. Continued Project operations as proposed by the Licensee are not expected to have any unavoidable adverse impacts on geological or soils resources.

Figure E.7-2 continued



E.7.2 Water Quantity and Quality

The subsections below describe water resources in the vicinity of the Project and consider the effects of continued operation of the Project as proposed by the Licensee on water quantity and quality. Descriptions of the affected environment, the environmental analysis, the proposed environmental measures, and the identification of unavoidable adverse effects were developed based on available data presented in the Licensee’s PAD and water resources data collected from:

- Downstream American Eel Passage Assessment (Normandeau Associates, Inc [NAI] 2021a)
- Fish Assemblage Study (NAI 2021d)
- 2022 Water Quality Monitoring Study (NAI 2022)
- 2023 Water Quality Monitoring Study (NAI 2023)

E.7.2.1 Affected Environment

E.7.2.1.1 Water Quantity

The Merrimack River watershed has a total drainage area of approximately 5,010 square miles within the states of New Hampshire and Massachusetts (MEOEEA 2002). The Lowell Project is located at RM 41 on the Merrimack River in Massachusetts with an existing impoundment extending upstream approximately 16 miles to Cromwell’s Falls in Merrimack and Litchfield, New Hampshire.³ The drainage area of the Project is approximately 3,979 square miles.

E.7.2.1.2 Project Hydrology

The Project operates in a ROR mode, and therefore, experiences seasonal and annual variations in flows based on natural hydrologic conditions in the Merrimack River Watershed. Table E.7-1 provides Project hydrologic data from 1987-2024.

Table E.7-1. Lowell Project Hydrologic Data (1987-2024)

Month	Average Flow (cfs)	Minimum Flow (cfs)	Maximum Flow (cfs)	10% Exceedance (cfs)	90% Exceedance (cfs)
January	7,614	916	39,710	14,394	3,808
February	6,840	1,478	39,180	12,160	3,475
March	12,038	1,914	50,220	20,639	4,737

³ The preparation of Exhibit G boundary maps provided Boott the opportunity to make corrections and modifications consistent with the Project’s operations. Boott is proposing to remove about 7.4 miles from the upper limit of the current Project boundary, making the proposed Project impoundment about 16 miles in length. This removal more accurately follows the 92.2 NGVD 29 contour of the Project impoundment. See Exhibit G.

Month	Average Flow (cfs)	Minimum Flow (cfs)	Maximum Flow (cfs)	10% Exceedance (cfs)	90% Exceedance (cfs)
April	18,796	4,340	78,890	30,564	6,898
May	11,383	2,218	88,410	18,782	4,112
June	6,774	1,004	44,660	12,541	2,100
July	4,058	670	29,820	10,724	1,350
August	3,659	569	30,030	7,233	1,077
September	3,349	460	32,264	6,725	986
October	6,305	787	50,150	11,730	1,386
November	8,459	1,345	30,990	15,307	2,594
December	9,171	1,839	34,810	18,016	3,500
Annual	8,202	460	88,410	17,040	1,682

Source: USGS, 2024

Note: Project hydrology determined by subtracting flows from USGS Gage No. 01099500 (*Concord River Below Meadow Brook, at Lowell, MA*) from USGS Gage No. 01100000 (*Merrimack River Below Concord River at Lowell, MA*).

Existing Instream Flow Uses

Existing instream flow uses of the Merrimack River include hydropower generation and industrial uses with recreation (e.g., fishing and boating). There are five FERC-regulated hydroelectric projects on the Merrimack River, and another two located on the main stem Pemigewasset River. The Project is located approximately 11 miles upstream of the Lawrence Hydroelectric Project (FERC No. 2800) and approximately 30 miles downstream of the Amoskeag Dam (one of the three developments of the Merrimack River Project, FERC No. 1893) in New Hampshire. There are also four USACE flood storage dams within the Merrimack River basin.

Existing and Proposed Uses of Project Waters

In Massachusetts, the MADEP regulates the quantity of water withdrawn from both surface and groundwater supplies to ensure adequate water supplies for current and future water needs pursuant to the Massachusetts Water Management Act (MADEP 2018a). Available registrations and permits were reviewed. Two regulated water withdrawals were identified in Lowell. These withdrawal users were identified as Lowell Water Treatment Facility (Permit #9P231316003) and Western Avenue Dyers (Permit #9P131316001). Based on the 2016-2019 Annual Water Quality Reports by the Lowell Regional Water Utility (LRWU), the utility withdrew 3.9 to 4.2 billion gallons of water from the Merrimack River annually to provide drinking water for Lowell and the surrounding communities (LRWU 2016, 2017, 2018, 2019).

In New Hampshire, Pennichuck Water Works supplies water for the City of Nashua and ten surrounding New Hampshire municipalities located in southern New Hampshire, using both surface water and groundwater sources. The Nashua Core water system derives its water supply from the Pennichuck Brook and the Merrimack River watersheds (Pennichuck Water Works 2018). Since the completion of the new Merrimack River water treatment facility in August 2023, the city of Manchester has utilized the Merrimack River as an additional drinking water source (Manchester Water Works 2023).

In New Hampshire, the NHDES regulates large groundwater withdrawals under the state's Groundwater Protection Act to ensure that no adverse impacts to water users or natural resources occur as a result of withdrawals (NHDES 2018). The only two groundwater withdrawal permits within the Project vicinity were issued to the Merrimack Village District Water Works in New Hampshire (Permittee Number LGWP-2017-0001) for 432,000 gallons per day and to Manchester Water Works (Permittee Number LGWP-2020-0001) for 7.2 million gallons per day. However, neither permit holder has started withdrawing from the permitted source (NHDES 2020).

The USEPA is the permitting authority in Massachusetts and New Hampshire for issuing National Pollutant Discharge Elimination System (NPDES) permits, which are required whenever a municipality, industry, or other entity wishes to discharge pollutants to a surface water of the United States. In Massachusetts, NPDES permits are typically co-issued by the USEPA and MADEP (MADEP 2018b). Available NPDES permits were reviewed for the Project vicinity in Massachusetts (Commonwealth of Massachusetts 2020a, USEPA 2018). The only permit located within the Project area was issued to the City of Lowell for Combined Sewer Overflow (CSO) outfalls at nine locations, seven of which are discharged into the main stem of the Merrimack River, and one of these outfalls is located just upstream of the Pawtucket Dam. The other two outfalls discharge in Beaver Brook and the Concord River, which are both tributaries to the Merrimack River just downstream from the Pawtucket Dam (USEPA 2019a).

Three NPDES permits were identified within the Project vicinity in New Hampshire, which were issued for wastewater treatment facilities and combined sewer overflows to the city of Manchester (Permit Number NH0100447), the town of Merrimack (Permit Number NH0100161) and the city of Nashua (Permit Number NH0100170) (USEPA 2020a). Another permit was issued to Nylon Corporation of America in Manchester for two separate outfalls (USEPA 2019b).

The Lowell Project has four NPDES permits issued under the Massachusetts General Permit no. MAG360000. These are: Permit No. MAG360024 for the Eldred L. Field Powerhouse; No. MAG360026 for the Hamilton powerhouse; No. MAG360025 for the John St. powerhouse; and No. MAG360027 for the Section 8 powerhouse.

E.7.2.1.3 Water Quality

Massachusetts Water Quality Standards

Water quality standards for the Commonwealth are contained in the Code of Massachusetts Regulations (CMR) at 314 CMR 4.00: Massachusetts Surface Water Quality Standards (SWQS). Inland surface waters of the Commonwealth are classified

by appropriate use Class (A, B, or C) as defined in 314 CMR 4.05. Qualifiers applied to these classifications indicate special considerations and uses applicable to a waterbody segment that may affect the application of criteria or antidegradation provisions. The classification of surface water in Massachusetts is provided in 314 CMR 4.06.

The MADEP’s Division of Water Pollution Control has classified waters within the Project vicinity as Class B with specific qualifiers (Table E.7-2). As defined in 314 CMR 4.05(3)(b), Class B waters are designated as:

[A] habitat for fish, other aquatic life, and wildlife, including for their reproduction, migration, growth, and other critical functions, and for primary and secondary contact recreation. Where designated in 314 CMR 4.06, Class B waters shall be suitable as a source of public water supply with appropriate treatment (“Treated Water Supply”). Class B waters shall be suitable for irrigation and other agricultural uses and for compatible industrial cooling and process uses. These waters shall have consistently good aesthetic value.

A summary of the standards applicable to Class B waters with the Warm Water qualifier is provided in Table E.7-3.

Table E.7-2. Water Quality Classification Applicable to the Lowell Project in Massachusetts

Boundary	Mile Points	Class	Qualifiers
State line to Pawtucket Dam	49.8 – 40.6	B	Warm Water ¹ Treated Water Supply ² CSO ³
Pawtucket Dam to Essex Dam, Lawrence	40.6 – 29.0	B	Warm Water ¹ Treated Water Supply ² CSO ³

Source: 314 CMR 4.06.

¹ In these waters, dissolved oxygen and temperature criteria for warm water fisheries apply.

² Denotes those Class B waters that are used as a source of public water supply after appropriate treatment. These waters may be subject to more stringent site-specific criteria established by the Department as appropriate to protect and maintain the use. See, also, 310 CMR 22.00.

³ These waters are identified as impacted by the discharge of combined sewer overflows (CSO); however, a long-term control plan has not been approved or fully implemented for CSO discharges.

Table E.7-3. Water Quality Standards for Class B Waters with the Warm Water Qualifier in Massachusetts

Parameter	Class B Warm Water Standards
Dissolved Oxygen (DO)	Shall not be less than 5.0 milligrams per liter (mg/L) in warm water fisheries. Where natural background conditions are lower, DO shall not be less than natural background conditions. Natural seasonal and daily variations that are necessary to protect existing and designated uses shall be maintained.

Parameter	Class B Warm Water Standards
Temperature	<p>Shall not exceed 83 degrees Fahrenheit (°F) (28.3 degrees Celsius [°C]) in warm water fisheries. The rise in temperature due to a discharge shall not exceed 5°F (2.8°C) in rivers and streams designated as warm water fisheries (based on the minimum expected flow for the month).</p> <p>Natural seasonal and daily variations that are necessary to protect existing and designated uses shall be maintained. There shall be no changes from natural background conditions that would impair any use assigned to this Class, including those conditions necessary to protect normal species diversity, successful migration, reproductive functions, or growth of aquatic organisms.</p>
pH	Shall be in the range of 6.5 through 8.3 standard units and not more than 0.5 units outside of the natural background range. There shall be no change from natural background conditions that would impair any use assigned to this Class.
Color and Turbidity	These waters shall be free from color and turbidity in concentrations or combinations that are aesthetically objectionable or would impair any use assigned to this Class.

Source: 314 CMR 4.05.

New Hampshire Water Quality Standards

Water quality standards in New Hampshire are contained in New Hampshire’s Revised Statutes Annotated (RSA) 485A:8, Standards for Classification of Surface Waters of the State, and in Env-Wq 1700, the Surface Water Quality Standards. RSA 485A:8 establishes that all New Hampshire surface waters must be classified as either Class A or Class B waters and establishes certain minimum surface water quality criteria for each classification (NHDES 2019b). The Merrimack River is designated as a Class B in New Hampshire, which pursuant to RSA 485A:8 shall be considered acceptable for fishing, swimming, and other recreational purposes and, after adequate treatment, for use as water supplies. A summary of the applicable standards to Class B is provided in Table E.7-4.

Table E.7-4. Water Quality Standards for Class B Waters in New Hampshire

Parameter	Class B Warm Water Standards
DO	Except as naturally occurs, waters shall have a DO concentration of at least 75% of saturation based on a daily average and an instantaneous minimum DO concentration of at least 5 mg/L.
Temperature	Any stream temperature increase associated with the discharge of treated sewage, waste or cooling water, water diversions, or releases shall not be such as to appreciably interfere with the uses assigned to this class.
pH	Shall be 6.5 to 8.0 unless due to natural causes.
Turbidity	Shall not exceed naturally occurring conditions by more than 10 Nephelometric Turbidity Units (NTUs).

Parameter	Class B Warm Water Standards
Color	Shall contain no color in such concentrations that would impair any existing or designated uses, unless naturally occurring.

E.7.2.1.4 Existing Water Quality Data

Water quality data have been collected throughout the Project area including: (1) in the Project’s impoundment and bypassed reach in support of recent relicensing activities, (2) at a USGS gage just downstream from the Pawtucket Dam, (3) at three NHDES monitoring sites in the Project impoundment, and (4) at numerous sites from RM 29.6 to 55.9 by a volunteer monitoring program established by the Merrimack River Watershed Council.

Relicensing Study Data

In support of relicensing the Project, water quality data were collected in the Project’s impoundment and bypassed reach during the Fish Assemblage Study (NAI 2021d) in the spring, summer, and fall of 2019. Water temperature, dissolved oxygen, conductivity, and pH data were collected at 12 locations throughout the impoundment and at three locations⁴ throughout the bypassed reach. Turbidity data was also collected at the impoundment site locations, which trended towards shallower at the upper end of the reach upstream of the Pawtucket Dam in areas classified as pool and run, and deeper at the lower end in areas classified as impoundment. Sampling in the impoundment was conducted at a depth of approximately one meter. Sampling in the Project’s bypass reach was conducted during low flows. All data collected in the impoundment and bypassed reach met state water quality standards.

In the impoundment, the average water temperature was 21.5°C (20.6-22.1°C) during the spring sampling, 25.6°C (25.2-26.0°C) during the summer sampling, and 10.8°C (10.3-11.5°C) during the fall sampling (Table E.7-5). The average dissolved oxygen concentration was 8.7 mg/L (8.4-9.0 mg/L) during the spring sampling, 8.4 mg/L (8.1-8.8 mg/L) during the summer sampling, and 10.6 mg/L (9.8-11.1 mg/L) during the fall sampling. Conductivity averaged 114 microsiemens per centimeter (µs/cm) (97-139 µs/cm) during the spring sampling, 181 µs/cm (166-199 µs/cm) during the summer sampling, and 117 µs/cm (91-152 µs/cm) during the fall sampling. The pH ranged from 6.5-7.5 units and turbidity ranged from 0.8-3.7 NTUs.

In the bypassed reach, data were only obtained at one location in the spring where the water temperature averaged 22.9°C, dissolved oxygen concentration was 9.5 mg/L, conductivity was 148 µS/cm, and the pH was 6.5 units (Table E.7-5). The average water temperature was 23.8°C (23.4-24.1°C) in the summer and 13.1°C (13.0-13.2°C) in the fall. The average dissolved oxygen concentration was 9.4 mg/L (9.1-9.6 mg/L) in the summer and 9.8 mg/L (8.9-10.6 mg/L) in the fall. Conductivity averaged 194 µS/cm (191-197 µS/cm) in the summer and 100 µS/cm (95-104 µS/cm) in the fall. The pH ranged

⁴ Water quality data were only obtained from one location in the spring.

from 6.3-8.1 units, with the average river pH in the bypassed reach being higher during the summer (7.8 units) than was observed during the spring (6.5) or fall (6.6).

Continuous water temperature data was also collected at the Project's intake canal from October 9, 2019, until November 31, 2019, during the Downstream American Eel Passage Assessment (NAI 2021a). Water temperatures ranged from 2°C to 16°C and were below the state of Massachusetts's maximum temperature criterion.

Table E.7-5. Summary of Water Quality Data Obtained in the Project’s Impoundment and Bypassed Reach by NAI in 2019.

Location	Season	Water Temperature (°C)			Dissolved Oxygen (mg/L)			Conductivity (µS/cm)			pH (units)			Turbidity (NTU)		
		Avg	Min	Max	Avg	Min	Max	Avg	Min	Max	Avg	Min	Max	Avg	Min	Max
Impoundment	Spring	21.5	20.6	22.1	8.7	8.4	9.0	114.0	97.0	139.0	-	6.5	7.4	2.6	1.6	3.7
	Summer	25.6	25.2	26.0	8.4	8.1	8.8	181.0	166.0	199.0	-	6.7	7.5	1.8	1.5	1.9
	Fall	10.8	10.3	11.5	10.6	9.8	11.1	117.0	91.0	152.0	-	6.5	7.4	1.6	0.8	2.2
Bypassed Reach	Spring	-	22.9	22.9	-	9.5	9.5	-	148.0	148.0	-	6.5	6.5	-	-	-
	Summer	23.8	23.4	24.1	9.4	9.1	9.6	194.3	191.0	197.0	-	7.4	8.1	-	-	-
	Fall	13.1	13.0	13.2	9.8	8.9	10.6	100.3	95.0	104.0	-	6.3	6.8	-	-	-

2022 Water Quality Monitoring Study

In support of this relicensing, continuous water quality monitoring was conducted at three mainstem river locations and six canal system locations from August to September/October 2022 (Figure E.7-5). In addition to the nine in-water loggers, an Onset Hobo U20-001 level logger was dry mounted at the E.L. Field powerhouse to collect barometric pressure reading at a 15-minute interval, which were used to calculate oxygen saturation values. The logger installed within the bypassed reach downstream of the Pawtucket Dam could not be retrieved due to flow conditions.

Monitoring locations for the collection of continuous temperature and DO readings during 2022 are identified in Figure E.7-5 and included:

- Lowell Impoundment
- Pawtucket Dam Bypassed Reach
- E.L. Field Tailrace
- Hamilton Canal
- Merrimack Canal
- Swamp Locks
- Guard Locks
- Northern Canal and
- Western Canal.

Water temperature during the study ranged from 14.5 to 25.7°C and the observed ranges were comparable among stations. Water temperature exhibited a seasonal declining trend over the period from logger deployment during late August until retrieval during mid-September (mainstem) and early-October (canal). There were no recorded exceedances of water temperature greater than the 28.3°C attainment criteria for Class B warm water.

Dissolved oxygen mostly attained state standards at all stations throughout the study and varied from a low of 3.8 mg/L (43.4 percent saturation) in the Western Canal on September 2 to a high of 10.3 mg/L (122.4 percent saturation) in the Western Canal on September 13. DO readings attained the 5.0 mg/L for the duration of the monitoring period at the E.L. Field Powerhouse tailrace and at the Guard Locks (Pawtucket Canal). Readings failing to attain the 5.0 mg/L standard for DO were observed at six of the eight monitoring locations and represented between 0.1 percent (Hamilton Canal) to 6.1 percent (Western Canal) of all readings for the period of record at each location. DO values less than the 5.0 mg/L standard represented 0.2 percent, 1.0 percent, 1.7 percent, and 3.5 percent of all readings for the period of record for the Lowell impoundment, Merrimack Canal, Northern Canal, and Swamp Locks, respectively.

2023 Water Quality Monitoring Study

In support of this licensing, water quality was monitored at a total of seven locations throughout the downtown Lowell canal system from July 1, 2023, to September 30, 2023.

Monitoring locations for the collection of continuous temperature and DO readings during 2023 are identified in Figure E.7-6 and included:

- Hamilton Canal (CS-HC),
- Merrimack Canal (CS-MC),
- Swamp Locks (CS-SL),
- Guard Locks (CS-GL),
- Northern Canal (CS-NC),
- Western Canal (CS-WC), and
- Eastern Canal (CS-EC).

Figure E.7-3. Sampling Locations for Continuous Water Quality Loggers 2022

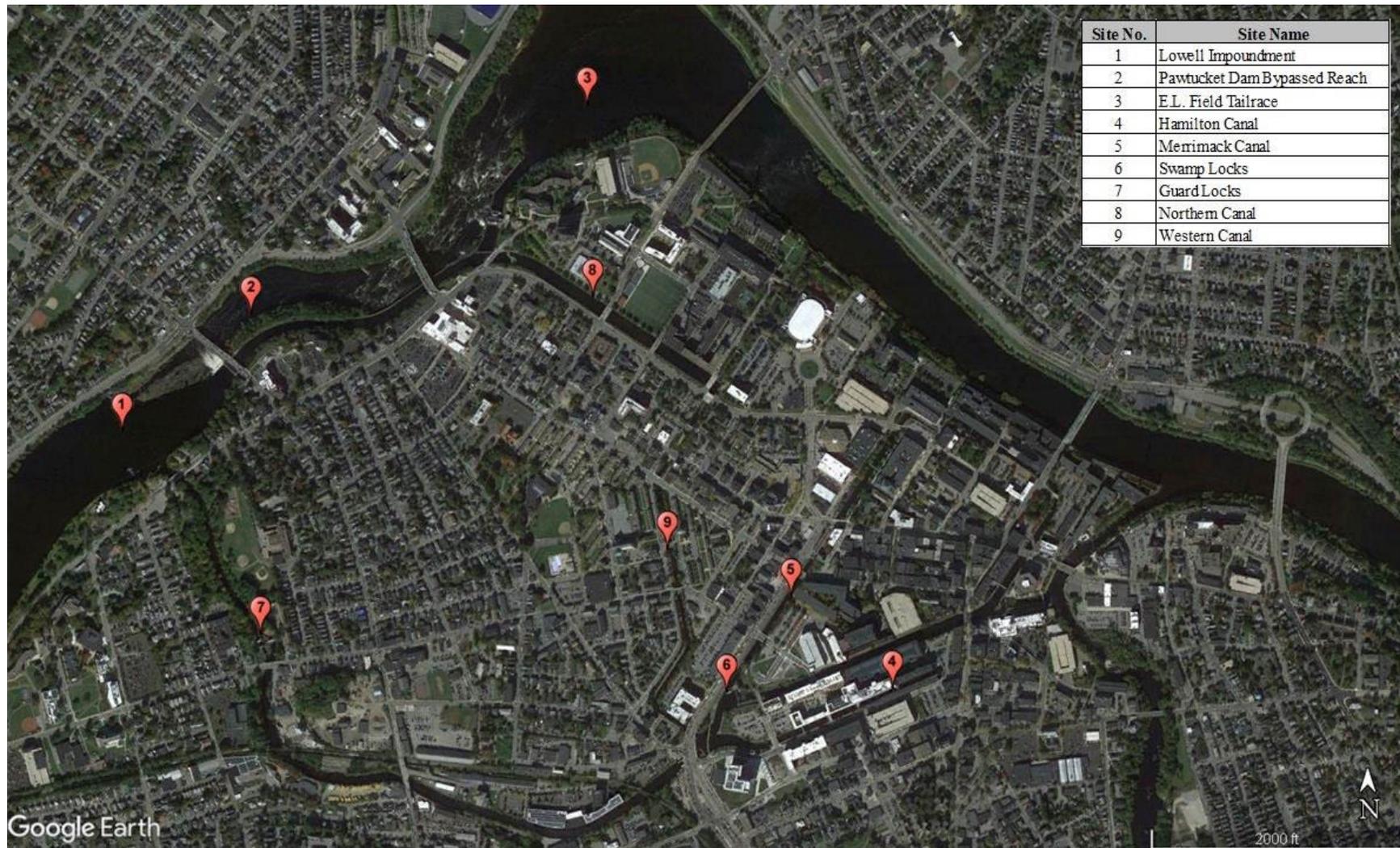


Figure E.7-4. Continuous Water Quality Logger Locations Within the Lowell Canal System (July-September 2023)



Construction activities did result in drawdown of the lower Northern Canal, half of the Merrimack Canal and half of the Western Canal to facilitate repairs to the Moody Street Feeder for most of the period from July 1, 2023, through August 9, 2023, and drawdown of the lower Pawtucket Canal and Eastern Canal to allow for repairs at the Section 8 Powerhouse from August 1, 2023, through the end of the monitoring study.

Water temperature readings collected at each continuous logger location were compared to the Massachusetts Surface Water Quality Standards (314 CMR 4.00) for Class B warm water which states water temperature shall not exceed 28.3°C (83°F). There were no observed instances of water temperature exceeding the Class B warm water standard during the 2023 monitoring period at any of the canal system logger locations.

Dissolved oxygen measurements collected from the Lowell canal system were assessed relative to specific criteria provided by the State of Massachusetts in their CALM guidance manual. The CALM manual provides criteria for evaluating DO relative to the “early” and “other” life stages of warm water fish species. Early life stages are compared relative to a 1-day minimum DO criteria of 5.0 mg/L and a 7-day mean (i.e., a 7-day average of daily average) of 6.5 mg/L. Other life stages (i.e., juvenile and adult warm water fish) are compared relative to a 1-day minimum DO criteria of 4.0 mg/L, a 7-day mean minimum (i.e., a 7-day average of daily minimum) of 5.0 mg/L, and a 30-day mean of 6.0 mg/L. If DO data statistics meet the relevant criteria then DO is considered sufficient to support the Aquatic Life Use. In cases where the criteria are not met, the CALM guidelines indicate that it must be determined whether the condition is “natural”. DO is identified as a cause of impairment if excursions from the criterion are not natural.

The downtown Lowell canal system is not a “natural” system and therefore it may not be appropriate to evaluate water quality in the canal system relative to the CALM Aquatic Life Use criteria. Merrimack River flows are drawn into the Pawtucket Canal and routed through the downtown canal network prior to being discharged back into the Merrimack or Concord Rivers. DO levels within the Lowell canal system met the guidance criteria for both the early life and “other” life stages of fish for most of the monitoring period. There were limited instances where the 1-day minimum DO criteria for early or “other” fish life stages, 7-day mean DO criteria for early life stages, or the 7-day mean minimum DO criteria for “other” life stages were not met. These occurrences were primarily limited to the Western Canal with most events occurring on dates when the lower Northern Canal was dewatered and flow through that reach was limited to only leakage at the Western Canal lock gates. The dewatering of the lower Pawtucket Canal and Eastern Canal during the months of August and September reduced the inflow into the canal system from the normal 150 cfs to approximately half (75 cfs). Despite this, DO levels met the relevant criteria to be considered sufficient to support the Aquatic Life Use for the majority of the sample period.

USGS Gage Data

The USGS periodically collected water quality data approximately 1.6 RM downstream from the Project powerhouse at gage 01100000 (Merrimack River BL Concord River at Lowell, MA) between 1953 and 2004 (USGS 2018), Figure E.7-5. The most recent data are presented in figures below, which consists of water temperature, DO, pH, and

specific conductance data collected between 1998-2004 (Figure E.7-6 through Figure E.7-10). Data were collected at numerous times during the summer, often when temperatures are the highest and DO concentrations are the lowest, except in 1998. Water temperatures were seasonal and were below the state of Massachusetts's maximum temperature criterion. DO concentrations were well above the state minimum criterion of 5.0 mg/L and were near saturation, except on one occasion in August 1999. The pH met state standards, except on a single sampling event in December 2003 when it was 6.3 units. Specific conductance ranged from 83 to 328 $\mu\text{S}/\text{cm}$ (USGS 2018).

Merrimack River Watershed Council Data

A volunteer monitoring program established by the Merrimack River Watershed Council (MRWC) collected water quality data at 41 monitoring stations located along the mainstem of the Merrimack River in 2009 (MRWC 2010). Results were grouped into one of the five river segments identified during the study. Results from three sections, including from the Essex Dam to the Pawtucket Dam in Lowell (Section 3), from the Pawtucket Dam to the Massachusetts/New Hampshire state border (Section 4), and from the state border to Greeley Park in Nashua (Section 5), are presented in Table E.7-6 through Table E.7-8. Nine sites were sampled in Section 3, eight sites were sampled in Section 4, and seven sites were sampled in Section 5. Monitoring occurred periodically between May and October in 2009, which included sampling during the summer months. Water temperatures ranged from 8.1 to 25.7°C and were below the maximum temperature criterion in Massachusetts of 28.3°C. DO concentrations ranged from 7.2 mg/L to 12.1 mg/L and were well above the Massachusetts and New Hampshire minimum state criterion of 5.0 mg/L. The pH was frequently below the acceptable minimum Massachusetts and New Hampshire criterion of 6.5 units and ranged from 3.3 to 6.8 units. However, according to the MRWC (2010) these data could be erroneous and could not be confirmed by the USEPA. Specific conductance ranged from 99 to 211 $\mu\text{S}/\text{cm}$.

The study also conducted continuous water quality monitoring over two weeks in 2009 off of the Lowell Motor Boat Club dock located on the right descending bank immediately upstream of the Pawtucket and Northern Canals in the Project's impoundment. Water temperature, dissolved oxygen, conductivity, and pH were recorded in 10-minute intervals from September 22 to October 5 at a depth of one meter. According to the Project's Low Impact Hydropower Institute (LIHI) certification, results indicate that data met state quantitative water quality standards for parameters with numeric limits except episodic low pH readings (LIHI 2018).

NHDES Data

A search was conducted using the USEPA's STORET database for water quality data within the Project vicinity in Massachusetts and New Hampshire. Water temperature, DO, pH, and specific conductance data were available for the following three sites in New Hampshire, which were sampled by the NHDES (Figure E.7-5):

1. Bridge Connecting RTE 3 & 3A (Station ID 11113300-02-MER)
2. RTE 111 BRIDGE, EAST HOLLIS ST (Station ID 11113300-03-MER)

3. RR BRIDGE D.S. OF MANCHESTER WWTF (Station ID 11113300-08-MER)

Data collected over the past 20 years (1998-2015) are presented in Figure E.7-6 through Figure E.7-10. Water temperatures ranged up to 28°C. DO concentrations ranged from 6.6 to 10.8 mg/L, which were well above the minimum criterion in New Hampshire of 5.0 mg/L, and waters were 82.1 to 121.0 percent saturated. The pH ranged from 5.7 to 7.5 units and levels were frequently below the minimum criterion of 6.5 units. Specific conductance ranged from 64 to 180 µS/cm.

Merrimack River Watershed Assessment Study

DO concentrations were also monitored during the Merrimack River Watershed Assessment Study, which was a joint effort between federal, state, and local communities to develop a comprehensive watershed management plan for the Merrimack River (USACE 2018). During the study, water quality sampling was conducted along the mainstem of the Merrimack River from Concord, New Hampshire, to its estuary in Newburyport, Massachusetts. From 2003 to 2005, three dry-weather surveys and four wet-weather surveys were conducted. Additionally, a continuous survey of DO and temperature was conducted at two locations for a one-month period during low-flow conditions in August and September 2003. These data were not available, but the study summary indicated DO along the mainstem of the Merrimack River from Manchester, New Hampshire, to the Atlantic Ocean were well above the minimum criterion of 5 mg/L.

Figure E.7-6. Water Temperature Data Collected at USGS Gage 01100000 Merrimack River BL Concord River at Lowell, MA on the Merrimack River, 1998 – 2004

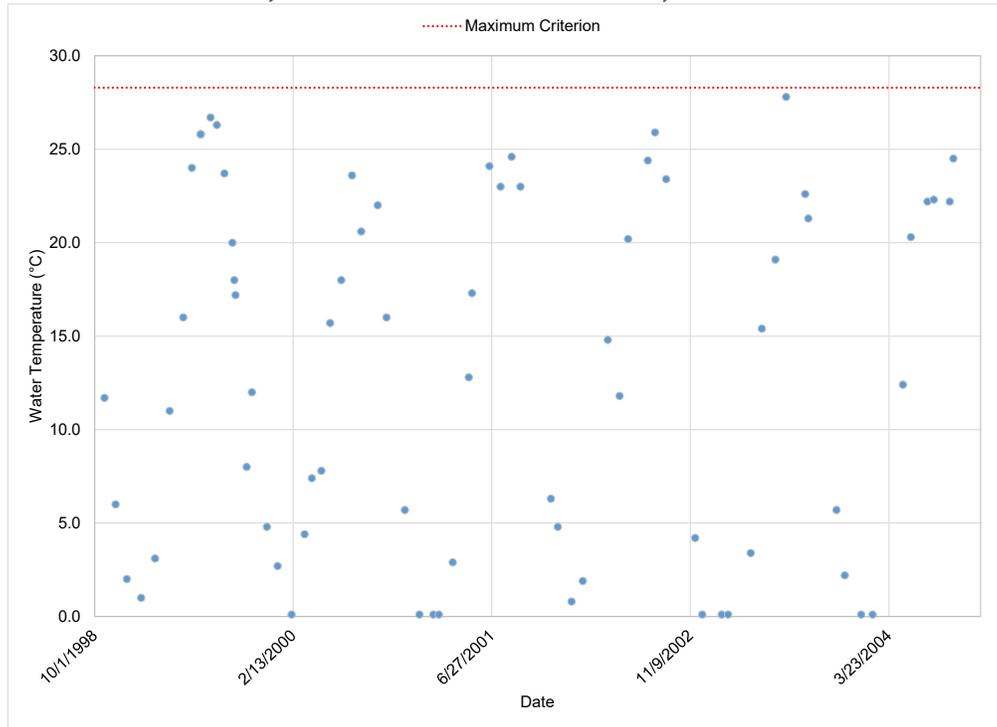


Figure E.7-7. Dissolved Oxygen Data Collected at USGS Gage 01100000 Merrimack River BL Concord River at Lowell, MA on the Merrimack River, 1998 – 2004

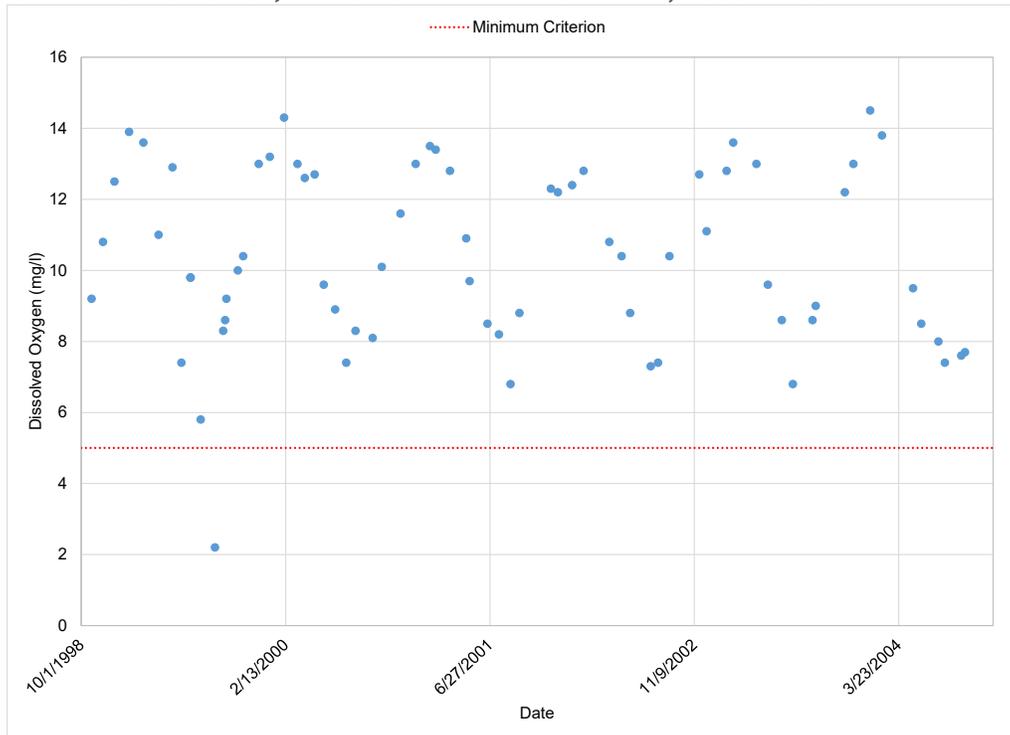


Figure E.7-8. Dissolved Oxygen Percent Saturation Data Collected at USGS Gage 01100000 Merrimack River BL Concord River at Lowell, MA on the Merrimack River, 1998 – 2004

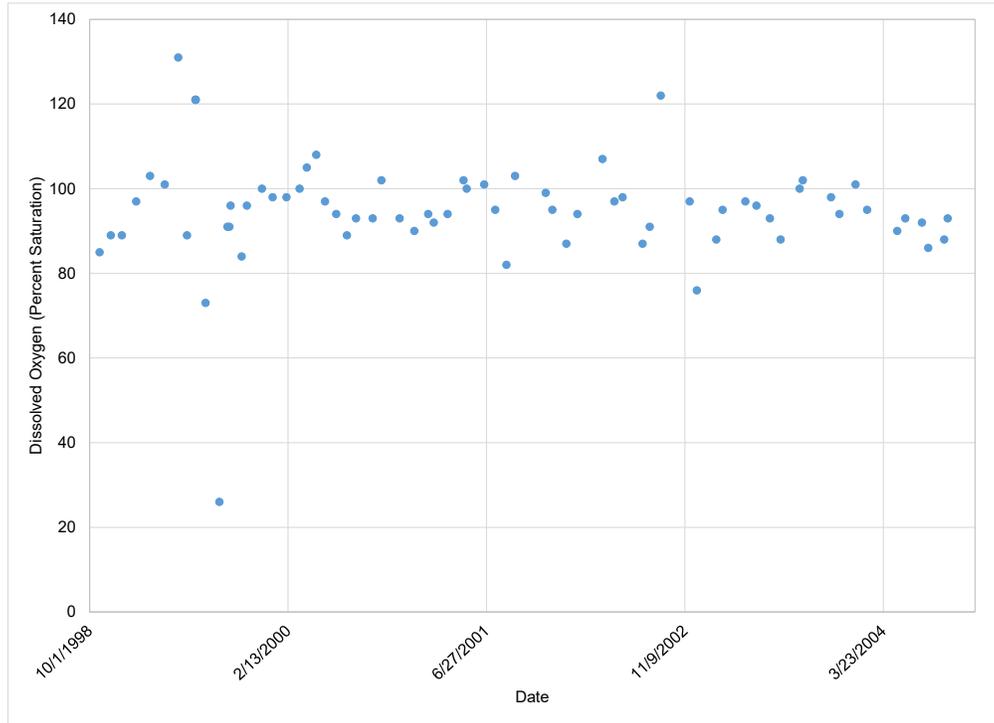


Figure E.7-9. pH Data Collected at USGS Gage 01100000 Merrimack River BL Concord River at Lowell, MA on the Merrimack River, 1998 – 2004

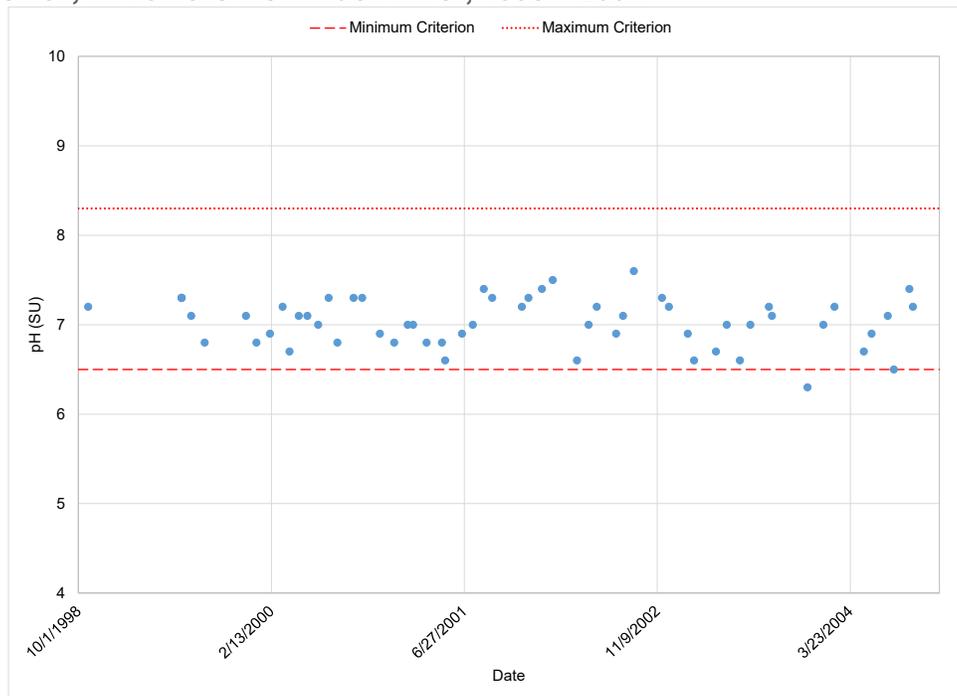


Figure E.7-10. Specific Conductance Data Collected at USGS Gage 01100000 Merrimack River BL Concord River at Lowell, MA on the Merrimack River, 1998 – 2004

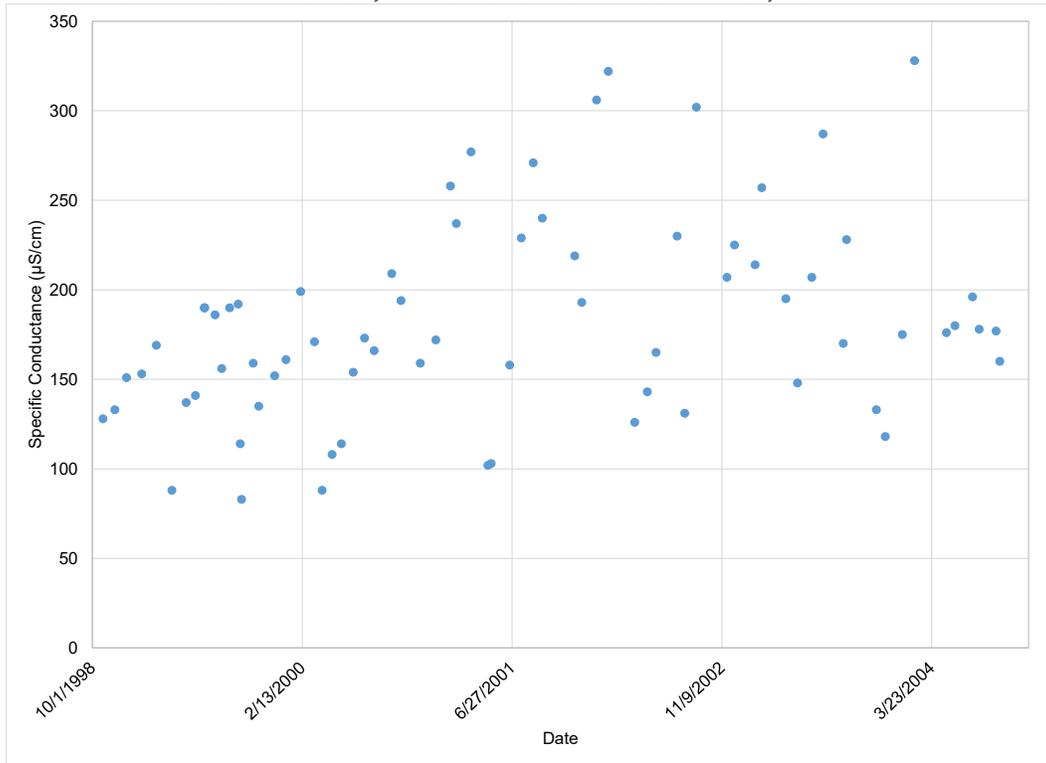


Table E.7-6. Water quality data collected by a volunteer monitoring program established by the MRWC at 9 sites along the Merrimack River from Essex Dam to the Pawtucket Dam in Lowell, 2009

River Mile	Description	Water Temperature (°C)						DO (mg/L)						pH (SU)						Specific Conductance (µS/cm)					
		14-May	30-May	11-Jun	23-Jul	1-Aug	13-Aug	14-May	30-May	11-Jun	23-Jul	1-Aug	13-Aug	14-May	30-May	11-Jun	23-Jul	1-Aug	13-Aug	14-May	30-May	11-Jun	23-Jul	1-Aug	13-Aug
29.6	Above Essex Dam	15.6	16.6	19.2	22.5	23.3	23.4	11.1	10.5	8.5	7.9	9.9	8.0	6.5	4.8	6.6	6.3	4.2	-	117	169	189	178	109	160
31.4	Methuen Water Intake	15.4	16.6	19.4	22.3	23.3	23.2	11.2	8.5	8.5	7.6	10.0	7.8	6.4	6.0	6.7	6.4	5.6	-	119	159	190	169	106	147
32.2	Bartlett Brook	15.4	16.5	19.3	22.4	23.3	23.1	11.6	8.2	8.5	7.6	10.0	7.8	6.4	6.1	6.6	6.4	4.6	-	118	157	194	169	103	144
33.4	Fish Brook	15.6	16.5	19.2	22.4	23.2	23.2	12.1	7.8	8.3	7.5	10.0	7.7	6.5	4.1	6.6	6.4	5.5	-	124	161	195	187	119	170
35.1	Gravel Pit	15.6	16.7	19.1	22.4	23.1	23	11.7	7.7	8.1	7.5	10.1	8.0	6.5	4.6	6.5	6.4	6.0	-	122	152	176	155	104	142
36.3	Trull Brook	15.4	16.9	19.2	22.5	23.0	23.2	11.6	7.8	8.7	7.9	10.2	7.9	6.4	4.3	6.7	6.4	6.0	-	111	170	211	177	99	166
37.9	Duck Island	15.4	16.8	19.2	22.4	-	23.1	11.7	7.6	8.6	7.7	-	7.9	6.2	5.8	6.6	6.3	-	6.5	106	135	176	151	-	133
38.9	Concord River	-	-	-	-	-	23.3	-	-	-	-	-	7.2	-	-	-	-	-	6.6	-	-	-	-	-	196
40.0	Oulette Bridge	-	-	-	-	-	23.2	-	-	-	-	-	7.7	-	-	-	-	-	6.5	-	-	-	-	-	122
	Minimum	15.4	16.5	19.1	22.3	23	23	11.1	7.6	8.1	7.5	9.9	7.2	6.2	4.1	6.5	6.3	4.2	6.5	106	135	176	151	99	122
	Maximum	15.6	16.9	19.4	22.5	23.3	23.4	12.1	10.5	8.7	7.9	10.2	8.0	6.5	6.1	6.7	6.4	6.0	6.6	124	170	211	187	119	196

Note: dash (-) indicates no data collected.

Table E.7-7. Water quality data collected by a volunteer monitoring program established by the MRWC at 8 sites along the Merrimack River from Pawtucket Dam to the Massachusetts/New Hampshire border, 2009

River Mile	Description	Water Temperature (°C)								DO (mg/L)								pH (SU)								Specific Conductance (µS/cm)							
		12-May	10-Jun	24-Jun	14-Jul	11-Aug	19-Aug	8-Sep	20-Oct	12-May	10-Jun	24-Jun	14-Jul	11-Aug	19-Aug	8-Sep	20-Oct	12-May	10-Jun	24-Jun	14-Jul	11-Aug	19-Aug	8-Sep	20-Oct	12-May	10-Jun	24-Jun	14-Jul	11-Aug	19-Aug	8-Sep	20-Oct
41.1	Pawtucket Dam	15.7	19.9	18.3	21.3	22.3	25.7	20.8	8.4	9.6	9.4	8.8	8.8	8.4	7.9	8.0	-	6.1	6.4	6.0	6.0	6.6	3.3	6.3	6.0	108	143	102	119	121	130	132	128
42.4	Rourke Bridge	15.6	19.8	-	21.4	22.3	-	20.5	8.1	9.4	8.4	-	8.8	8.4	-	8.0	-	6.2	6.4	-	6.1	6.7	-	6.3	5.9	104	145	-	118	120	-	132	121
43.4	Stony Brook	15.6	19.7	-	21.4	22.4	-	20.4	8.1	9.4	8.2	-	8.8	8.5	-	8.0	-	6.2	6.4	-	6.1	6.7	-	6.3	5.8	103	143	-	114	118	-	129	118
44.6	Vesper Country Club	15.5	19.7	-	21.4	22.4	-	20.2	8.2	9.3	8.0	-	8.8	8.3	-	8.0	-	6.2	6.5	-	6.2	6.6	-	6.3	5.9	103	141	-	114	119	-	127	120
46.4	Lawrence Brook	15.4	19.7	-	21.2	22.4	-	20.4	8.3	9.3	7.8	-	8.8	8.4	-	8.2	-	6.2	6.4	-	6.2	6.7	-	6.4	6.0	102	145	-	113	116	-	135	138
47.3	Tyngsborough (Rte. 113) bridge	15.3	19.6	-	21.2	22.4	-	20.5	8.3	9.3	7.8	-	8.8	8.3	-	8.2	11.9	6.2	6.4	-	6.2	6.7	-	6.4	5.9	100	144	-	113	116	-	133	131
48.9	Limit Brook	15.3	19.3	-	21.1	22.5	-	20.5	8.3	9.3	7.7	-	8.7	8.5	-	8.3	11.6	6.2	6.4	-	6.1	6.7	-	6.3	5.9	102	144	-	112	111	-	128	123
49.6	MA/NH border	15.3	19.2	18.2	21.1	22.4	-	20.4	8.3	9.4	7.7	9.8	8.8	8.3	-	8.0	11.6	6.3	6.4	6.0	6.0	6.8	-	6.3	5.9	99	142	99	114	114	-	129	129
	Minimum	15.3	19.2	18.2	21.1	22.3	25.7	20.2	8.1	9.3	7.7	8.8	8.7	8.3	7.9	8.0	11.6	6.1	6.4	6.0	6.0	6.6	3.3	6.3	5.8	99	141	99	112	111	130	127	118
	Maximum	15.7	19.9	18.3	21.4	22.5	25.7	20.8	8.4	9.6	9.4	9.8	8.8	8.5	7.9	8.3	11.9	6.3	6.5	6.0	6.2	6.8	3.3	6.4	6.0	108	145	102	119	121	130	135	138

Note: dash (-) indicates no data collected.

Table E.7-8. Water quality data collected by a volunteer monitoring program established by the MRWC at 7 sites along the Merrimack River from Massachusetts/New Hampshire border to Greeley Park in Nashua, 2009

River Mile	Description	Water temperature (°C)					DO (mg/L)					pH (SU)					Specific conductance (µS/cm)				
		12-May	13-Jul	11-Aug	8-Sep	20-Oct	12-May	13-Jul	11-Aug	8-Sep	20-Oct	12-May	13-Jul	11-Aug	8-Sep	20-Oct	12-May	13-Jul	11-Aug	8-Sep	20-Oct
49.9	Pheasant Lane Mall	-	21.0	22.4	20.3	8.3	-	8.3	8.4	8.0	11.3	-	6.3	6.7	6.4	5.9	-	117	121	132	127
50.9	Spit Brook	15.5	21.1	22.4	20.3	8.3	9.3	8.4	8.3	8.2	11.3	6.3	6.3	6.8	6.4	5.9	103	128	116	133	126
51.8	Unnamed stream	-	20.9	-	-	-	-	8.7	-	-	-	-	6.0	-	-	-	-	97	-	-	-
52.5	Nashua Country Club	-	20.9	-	-	-	-	8.6	-	-	-	-	6.3	-	-	-	-	139	-	-	-
53.1	Nashua WWTP	-	20.9	-	-	-	-	8.6	-	-	-	-	6.5	-	-	-	-	199	-	-	-
54.4	Nashua River	-	20.8	-	-	-	-	8.6	-	-	-	-	6.2	-	-	-	-	164	-	-	-
55.9	Greeley Park	-	21.2	-	-	-	-	8.9	-	-	-	-	6.2	-	-	-	-	96	-	-	-
	Minimum	15.5	20.8	22.4	20.3	8.3	9.3	8.3	8.3	8.0	11.3	6.3	6.0	6.7	6.4	5.9	103	96	116	132	126
	Maximum	15.5	21.2	22.4	20.3	8.3	9.3	8.9	8.4	8.2	11.3	6.3	6.5	6.8	6.4	5.9	103	199	121	133	127

Note: dash (-) indicates no data collected.

Figure E.7-11. Water Temperature STORET Data Collected at three sites by the NHDES in the Merrimack River, 1998 – 2015

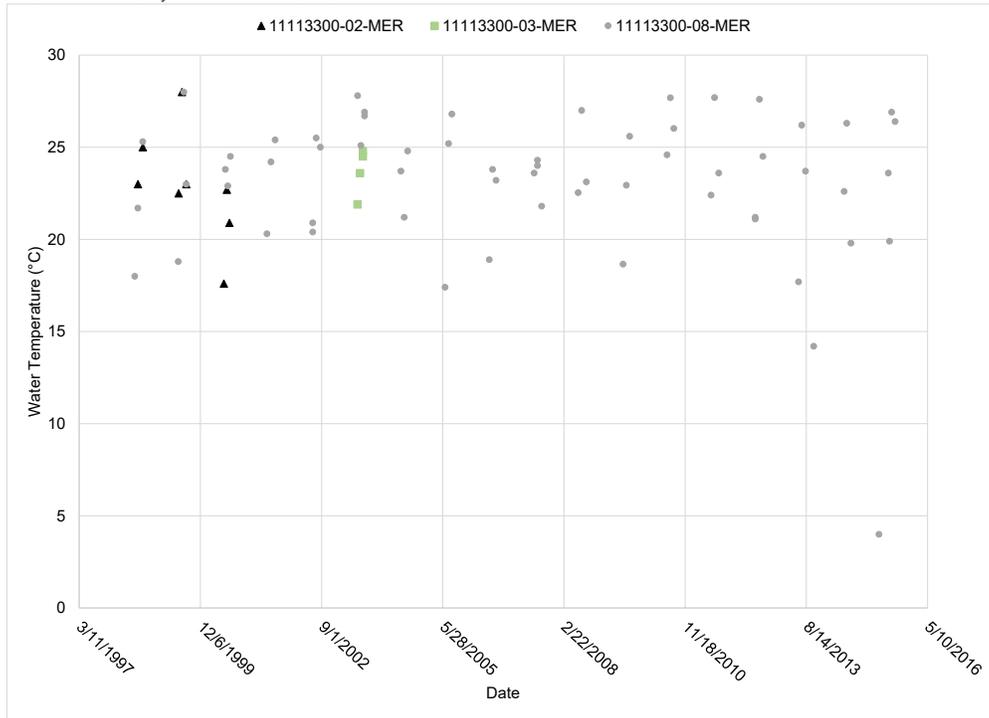


Figure E.7-12. Dissolved Oxygen STORET Data Collected at three sites by the NHDES in the Merrimack River, 1998 – 2015

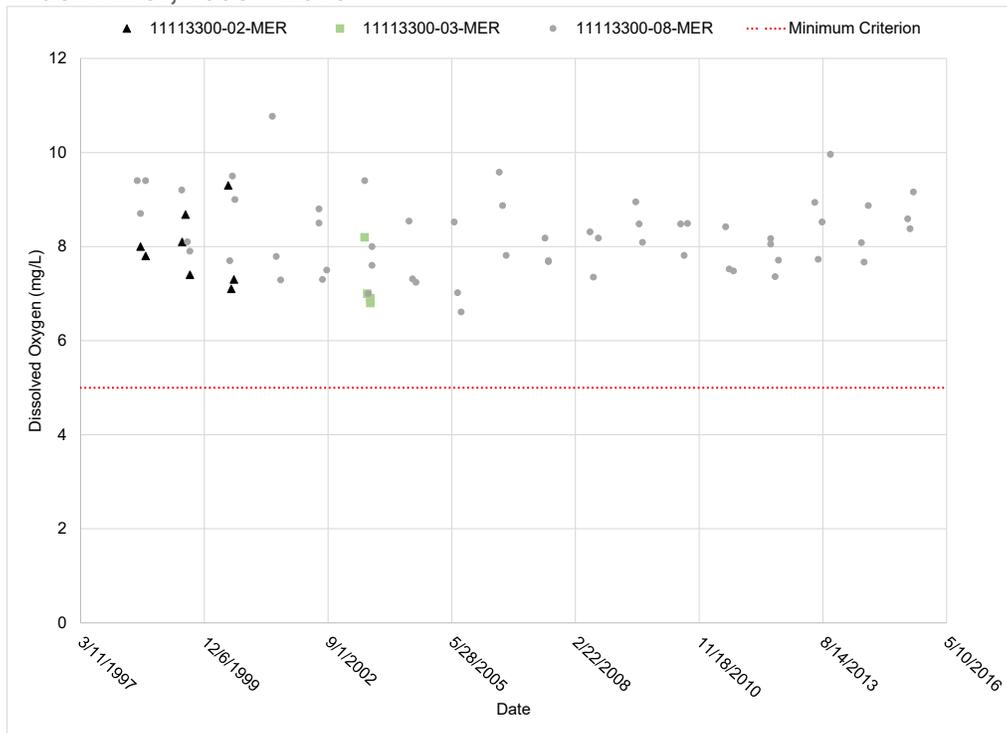


Figure E.7-13. Dissolved Oxygen Percent Saturation STORET Data Collected at three sites by the NHDES in the Merrimack River, 1998 – 2015

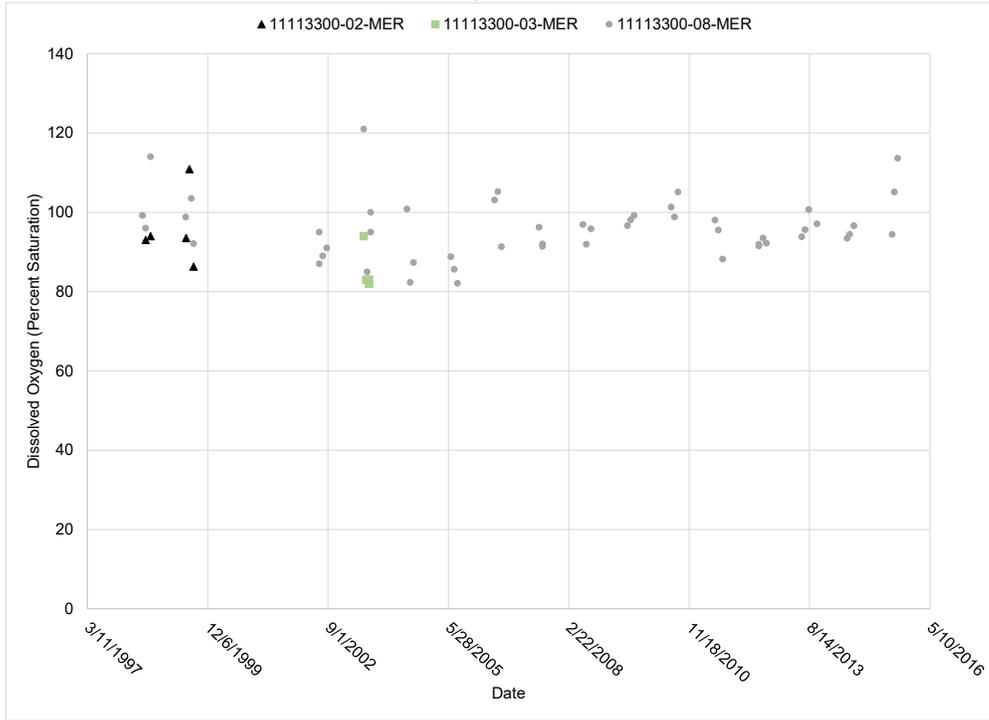


Figure E.7-14. pH STORET Data Collected at three sites by the NHDES in the Merrimack River, 1998 – 2015

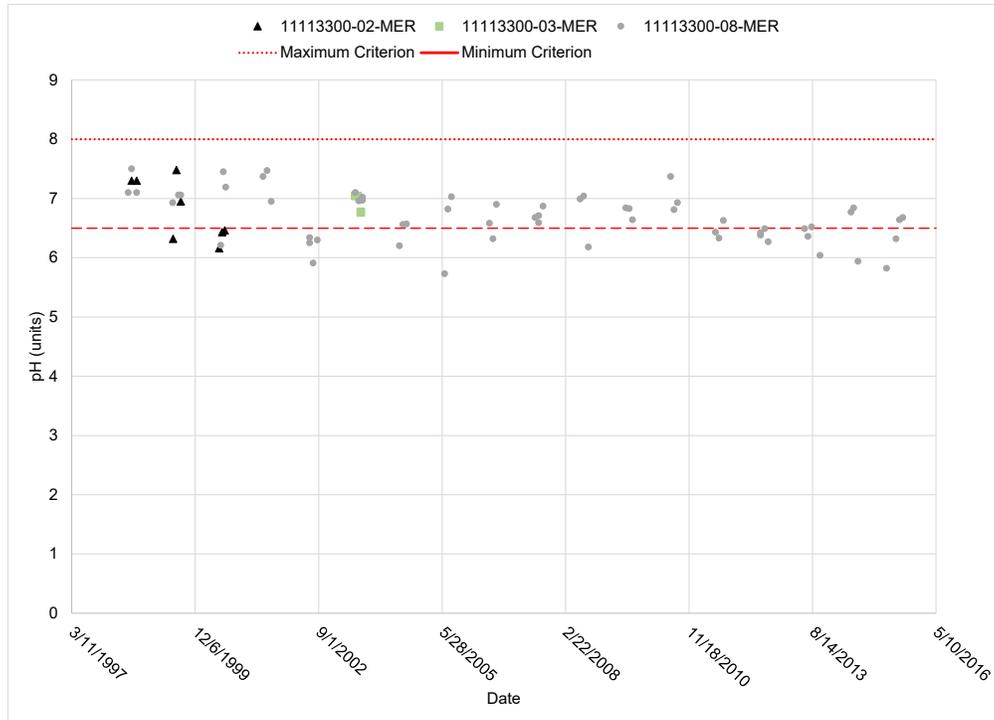
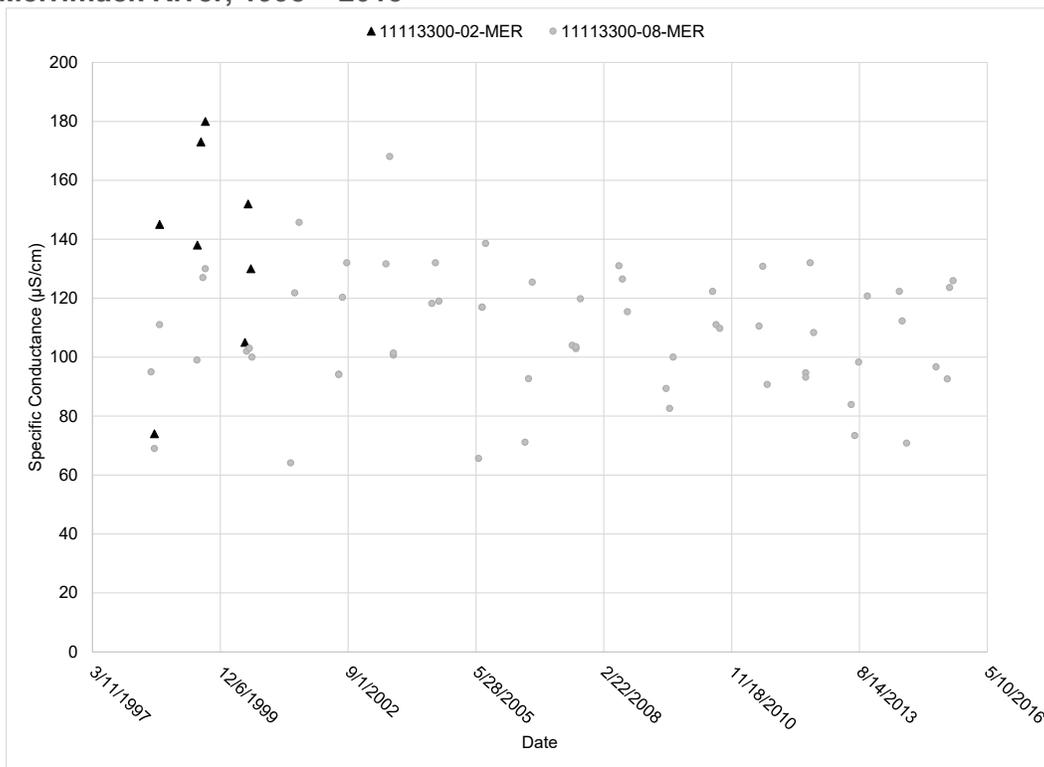


Figure E.7-15. Specific Conductance STORET Data Collected at two sites by the NHDES in the Merrimack River, 1998 – 2015



E.7.2.1.5 Use Impairment

An Integrated List of Waters (Integrated List) for Massachusetts and New Hampshire is submitted to the USEPA in fulfillment of reporting requirements under the CWA. Section 303(d) of the CWA requires states to identify those water bodies that are not expected to meet surface water quality standards after the implementation of technology-based controls and to prioritize and schedule them for the derivation of total maximum daily loads (TMDLs).

E.7.2.1.6 Massachusetts Standards

The Integrated List in Massachusetts assigns waterbody segments to one of five categories, depending upon their status with respect to designated use support (Table E.7-9). The Merrimack River is listed as Category 5 impaired waters in Massachusetts, which includes portions within the Project vicinity (Table E.7-10) (MADEP 2016). Probable sources contributing to impairment included atmospheric deposition, CSOs from municipal discharges, impacts from hydrological flow regulation/modification, wet weather discharges from municipal discharges/sewage, municipal point source discharges of municipal discharges/sewage, and urban-related runoff/stormwater. The canal system at the Project is also listed as Category 5 waters (MADEP 2016).

A draft Pathogen TMDL has been drafted for the Merrimack River Watershed (MADEP et al. undated). No other TMDLs were located for the Merrimack River Watershed (Commonwealth of Massachusetts 2020b).

Table E.7-9. Description of Integrated Report Categories in Massachusetts (MADEP 2016)

Category	Description
1	Unimpaired and not threatened for all designated uses
2	Unimpaired for some uses and not assessed for others
3	Insufficient information to make assessments for any uses
4	Impaired or threatened for one or more uses, but not requiring the calculation of a TMDL
5	Impaired or threatened for one or more uses requiring a TMDL

Table E.7-10. Impaired Water Segments within the Lowell Project vicinity (MADEP 2016)

Name	Segment ID	Description	Length (miles)	Impairment
Project Impoundment	MA84A-01	State line at Hudson, NH/Tyngsborough, MA to Pawtucket Dam, Lowell	9	<i>Escherichia Coli</i> (<i>E. Coli</i>) Fecal coliform Mercury in fish tissue
Project Canal System	MA84A-29	Canal System near Pawtucket Falls, Lowell	4.90	DDT in fish tissue Lead Mercury in fish tissue PCBs in fish tissue
Bypassed/ Downstream Reach	MA84A-02	Pawtucket Dam, Lowell to Lowell Regional Wastewater Utilities outfall at Duck Island, Lowell	3.2	Dewatering* <i>E. Coli</i> Mercury in fish tissue Total phosphorus
Downstream Reach	MA84A-03	Lowell Regional Wastewater Utilities outfall at Duck Island, Lowell to Essex Dam, Lawrence	8.80	<i>E. Coli</i> Mercury in fish tissue PCBs in fish tissue
Reach Downstream of Essex Dam	MA84A-04	Essex Dam, Lawrence to confluence with Little River, Haverhill	10.00	<i>E. Coli</i> PCBs in fish tissue Total phosphorus

*TMDL not required (non-pollutant).

E.7.2.1.7 New Hampshire Standards

The Section 305(b) and 303(d) consolidated list in New Hampshire assigns waterbody segments to various categories (Table E.7-11). Portions of the Merrimack River in New Hampshire are identified as Category 5 waters and are included in the 2018 303(d) list (Table E.7-12) (NHDES 2019b). Sources of impairment in these sections are unknown.

Table E.7-11. Description of Integrated Report Categories in New Hampshire

Category	Description
1	Attaining all designated uses and no use is threatened.
2	Attaining some of the designated uses; no use is threatened; and insufficient or no data and information is available to determine if the remaining uses are attained or threatened (i.e., more data is needed to assess some of the uses).
3	Insufficient or no data and information are available to determine if any designated use is attained, impaired, or threatened (i.e., more monitoring is
4	Impaired or threatened for one or more designated uses but does not require development of a TMDL because:
4A	A TMDL has been completed, or
4B	Other pollution control requirements are reasonably expected to result in attainment of the water quality standard in the near future, or
4C	The impairment is not caused by a pollutant.
5	Impaired or threatened for one or more designated uses by a pollutant(s), and requires a TMDL, which is the 303(d) list.

Table E.7-12. Impaired Water Segments within Project vicinity in New Hampshire (NHDES 2019b)

Assessment Unit ID	Water Name	Primary Town	Water Size (miles)	Use Description	Impairment Name	DES Category	TMDL Priority
NHRIV700061206-24	Merrimack River	Nashua	5.2	Aquatic Life	Aluminum	5-M	Low
					pH	5-M	Low
				Primary Contact Recreation	Chlorophyll-a	5-M	Low
NHRIV700061002-14	Merrimack River	Nashua	3.7	Aquatic Life	pH	5-M	Low
				Primary Contact Recreation	Creosote	5-M	Low

E.7.2.2 Environmental Analysis

FERC’s SD2 identified effects of continued Project operations on streamflow and water quality in the impoundment, canal system, bypassed reach, and Merrimack River, as well as the following issues related to water quantity and quality:

- Effects of continued project operation on flooding along the shoreline of the project impoundment and surrounding areas.
- Effects of continued project operation on streamflow in the impoundment, canal system, bypassed reach, and Merrimack River.
- Effects of continued project operation on water quality in the impoundment, canal system, bypassed reach, and Merrimack River.

The Project operates in a ROR mode and has no useable storage capacity. Therefore, seasonal and annual variations in flows within the Project area are based on natural hydrologic conditions in the Merrimack River Watershed. In 2011, the MADEP specified that it had waived Water Quality Certification related to a Project license amendment (i.e., replacement of the flashboard system with the crest gate system) (LIHI 2018), which suggests there were not water quality concerns at that time and there have been no substantial changes to Project operations since.

In 2019, the Licensee completed the construction of a pneumatically operated crest gate on the spillway crest to maintain the headpond at its normal level of 92.2 feet NGVD 1929. The system was installed to prevent flooding in the impoundment zone, after backwater analysis and technical evaluation found the system would enhance project operational control and generation and would provide significant advantages for other

resources that are dependent on water levels, including flood control, recreation, and fish passage. The Commission's Environmental Assessment completed prior to the crest gate installation noted up to 46 miles of shoreline aquatic habitat could benefit from installing the crest gate, and the system would normally provide slightly lower water level elevations during flood events of less than 75,000 cfs. The Pawtucket Dam spillway becomes submerged at flows greater than 75,000 cfs, which causes the water level upstream to be influenced by the river channel structure within the bypassed reach downstream of the dam. The proposal was strongly endorsed by the MADFW and NMFS, who both noted the Project's beneficial effect on fish habitat and movement within the project area (FERC 2011).

Some hydroelectric facilities can influence instream flows, and those that have large deep impoundments can impact water quality. The Project is operated as a ROR hydroelectric project. Therefore, the Project's ability to influence flow and thus its effect on water quality is minimal due to its limited storage and hydraulic capacity. At the normal pond elevation of 92.2 feet NGVD 29 (crest of the pneumatic flashboards), the surface area of the impoundment encompasses an area of approximately 1,236 acres. The gross storage capacity between the normal surface elevation of 92.2 feet and the minimum pond level of 87.2 feet (at spillway crest) is approximately 6,180 acre-feet.

Under proposed operations, when river flows exceed the hydraulic capacity of the E.L. Field Powerhouse units (3,300 cfs per unit or 6,600 cfs for both units) and the bypass flow (either 100 cfs or 500 cfs depending on the upstream fish passage season), excess flows up to approximately 2,000 cfs are routed through the downtown canal system and to the canal units. As currently operated, any flows in excess of approximately 8,600 cfs (6,600 cfs at E.L. Field plus 2,000 cfs via canals) are passed over the Pawtucket Dam spillway. As a result of the Project's ROR operations, there is a constant flow downstream of the Project during summer low flow conditions, which prevents impacts to downstream water quality.

On a seasonal basis during the upstream passage season (i.e., typically from early May through late June/early July – and to be defined annually in consultation with the MRTC), Boott proposes provide a zone of passage flow of 500 cfs or inflow, whichever is less, into the Project's bypassed reach to provide appropriate fish passage conditions. Boott proposes to release a minimum flow of 100 cfs or inflow, whichever is less, to the bypass reach downstream of the Pawtucket Dam during the period outside of the upstream fish passage season. The minimum flow would be provided as spillage over one or more of the crest gate zones. This year-round flow into the bypassed reach is expected to minimize Project impacts below the dam, and to benefit water quality and quantity.

In support of relicensing the Project, water quality data were collected in the Project's impoundment and bypass reach during the Fish Assemblage Study in the spring, summer, and fall of 2019. Water temperature, dissolved oxygen, conductivity, and pH data were collected at 12 locations throughout the impoundment and at three locations throughout the bypass reach. Turbidity data was also collected at the impoundment site locations. All data collected in the impoundment and bypassed reach met state water quality standards. Additionally, as stated above, waters in the Project impoundment, bypassed reach, and downstream reaches have historically met state water quality

standards. This suggests that the Project operation has little to no effect on the overall water quality in the Merrimack River, which is consistent with a ROR hydroelectric project. Water quality data indicates that water quality in the Project area is consistent with the water quality of the lower Merrimack River and is likely driven by natural environmental and biological factors as well as anthropogenic disturbance within the larger context of this regional portion of the river basin. Since the Project operates in a ROR mode, seasonal and annual variations in flows within the Project area are based on natural hydrologic conditions in the Merrimack River Watershed. Continued operation of the Project is not expected to have negative effects on water quality, and therefore the fish and aquatic resources in the Merrimack River.

Water quality data have been collected throughout the general Project area including throughout the 16-mile impoundment, the bypassed reach, and downstream from the Project in the Merrimack River. Much of these data were collected during the summer months and data were collected in the bypassed reach during periods of minimum flows. Often these are when water temperatures are highest and dissolved oxygen levels are lowest. Regardless, water quality in the Project area met or exceeded all state water quality standards.

The man-made canal system utilizes flows upstream of the Pawtucket dam and discharges at multiple locations just upstream of the USGS gage 1.6 RM downstream of the Project. The data obtained from this gage met or exceeded all state water quality standards and there is no indication that the canal system is impacting water quality in the Merrimack River. The waters of the canal system are listed as impaired by the state of Massachusetts; however, the impairments (i.e., Dichlorodiphenyltrichloroethane [DDT] in fish tissue, lead, and mercury/PCBs in fish tissue) are not related to the Project or Project operations and are likely a result of atmospheric deposition and historical contamination from the mills and industrial facilities that line the canal system (LIHI 2018).

In support of relicensing the Project, water quality data were collected at a total of seven locations throughout the downtown Lowell canal system from July 1 to September 30, 2023. There were no observed instances of water temperature exceeding the Class B warm water standard during the 2023 monitoring period at any of the canal system logger locations. DO levels within the Lowell canal system met the guidance criteria for both the early life and “other” life stages of fish for most of the monitoring period. There were limited instances where the 1-day minimum DO criteria for early or “other” fish life stages, 7-day mean DO criteria for early life stages, or the 7-day mean minimum DO criteria for “other” life stages were not met. These occurrences were primarily limited to the Western Canal with most events occurring on dates when the lower Northern Canal was dewatered and flow through that reach was limited to only leakage at the Western Canal lock gates. The dewatering of the lower Pawtucket Canal and Eastern Canal during the months of August and September reduced the inflow into the canal system from the normal 150 cfs to approximately half (75 cfs). Despite this, DO levels met the relevant criteria to be considered sufficient to support the Aquatic Life Use for the majority of the sample period.

Boott will continue to manage its canal structures and facilities, water levels, and flows in line with existing rights, responsibilities, and agreements among the concerned

stakeholders. With respect to water levels in the downtown canal system, Boott is proposing to maintain the water levels, canal water flows, and trash management as described in Sections E.5.7 and E.6.2 above. These proposals, including diverting up to 2,000 cfs through the downtown canal system to run the downtown units, as well as flushing flows, are expected to improve water quality by diverting more flows through the downtown canal system. The coordination with stakeholders in drawdown planning should further minimize potential impacts to water quality during drawdown events.

Boott proposes to develop a Water Quality Management Plan in consultation with the MADEP. The Water Quality Management Plan will define the water quality standards to be maintained within the canal (e.g., over the term of the Project's license), and if deemed necessary by the MADEP, subsequent monitoring activities to be performed to inform the potential need for supplemental minimum flows, potential future flushing flows, and/or additional means (e.g., aeration system) to address water quality within the canal.

E.7.2.3 Proposed Environmental Measures

Boott proposes continued operation of the Project with certain PM&E measures consistent with the measures required by the Project's existing license. Boott believes that the continued operation of the Project, as proposed with the PM&E measures described below, will limit effects on water quality and quantity.

- Boott proposes to operate the Project in a ROR mode using automatic pond level control of the E.L. Field powerhouse units. ROR operation may be temporarily modified for short periods to allow flow management for other project and non-project needs, e.g., downtown canal water level management, raising the crest gates following a high-water event, or for recreational purposes.
- On a seasonal basis during the upstream passage season (i.e., typically from early May through late June/early July – and to be defined annually in consultation with MRTC) the Licensee will provide a zone of passage flow of 500 cfs or inflow, whichever is less, into the Project's bypassed reach to provide appropriate fish passage conditions.
- Boott proposes to release a minimum flow of 100 cfs or inflow, whichever is less, to the bypass reach downstream of the Pawtucket Dam during the period outside of the upstream anadromous fish passage season. The minimum flow will be provided through the fishway and as spillage over one or more of the crest gate zones.
- Between August 15 and November 15 of each year until the proposed downstream passage protection measures are fully implemented, Boott is proposing nighttime shutdowns as an interim measure to protect out-migrating adult American eel. The downtown units will also be shut down during this period.
- In support of the NPS's canal boat operations and additional recreational activities (provided by others), as well as for aesthetics, canal wall integrity, and vegetation control, Boott will make a good-faith effort to maintain the water elevations within the canal system consistent with the elevations established in a

Canal Operations and Maintenance Plan (COMP) that will be prepared by Boott in consultation with NPS and other stakeholders and filed with FERC for inclusion in the new license. See below for Boott's proposed operations as they pertain to *Canal Water Elevations* and *Canal Water Flows*.

- Boott proposes continued adherence to the requirements of the Project's existing Crest Gate Operation Plan (approved by FERC on March 30, 2015).

Canal Water Elevations

Boott is actively collaborating with key stakeholders to finalize the COMP. Once the COMP is finalized, a copy of the COMP will be submitted to FERC for approval and inclusion in the new license. One of the primary components being addressed is the management of canal water elevations.

Canal Water Flows

Boott is actively collaborating with key stakeholders to finalize the COMP. Once the COMP is finalized, a copy of the Plan will be submitted to FERC for approval and inclusion in the new license. One of the primary components being addressed is the management of canal water flows.

Trash Management

Boott is actively collaborating with key stakeholders to finalize the COMP. Once it is finalized, a copy of the Plan will be submitted to FERC for approval and inclusion in the new license. One of the primary components being addressed is trash management in the canals.

E.7.2.4 Unavoidable Adverse Impacts

Continued Project operations as proposed by the Licensee are not expected to have any unavoidable adverse impacts on water quality or quantity. Boott continues to consult with stakeholders regarding the results and recommendations of the studies and has proposed potential PM&E measures. As appropriate, Boott may propose additional PM&E measures in an amendment to the license application.

E.7.3 Fish and Aquatic Resources

The subsections below describe fish and aquatic resources in the vicinity of the Project and consider the effects of continued operation of the Project as proposed by the Licensee on these resources. Descriptions of the affected environment, the environmental analysis, the proposed environmental measures, and the identification of unavoidable adverse effects were developed based on available data presented in the Licensee's PAD, and the:

- Downstream American Eel Passage Assessment Study Report (NAI 2021a)
- Juvenile Alosine Downstream Passage Assessment Study Report (NAI 2021b)

- Upstream and Downstream Adult Alosine Passage Assessment Study Report (NAI 2021c)
- Fish Assemblage Study Report (NAI 2021d)
- Instream Flow Habitat Assessment and Zone of Passage Study (NAI 2021e)
- Fish Passage Survival Study (NAI 2021f)

E.7.3.1 Affected Environment

E.7.3.1.1 Overview

Historically, the Merrimack River served as a major resource for fisheries. However, the increase in industrial and urban pollution and construction of numerous dams along its length during the past two centuries resulted in lowering the value of the river as an important aquatic habitat. The most affected fish populations have been the sensitive migrating species: anadromous fish that live in salt water and spawn in fresh water, and catadromous species that inhabit the river and spawn in the ocean. The changes in water quality of the Merrimack River combined with impoundments created by dams has increased the warm water fisheries habitat and resulted in the demise or severe reductions of migratory fish species (Massachusetts Department of Transportation Federal Highway Administration [FHA] and The Commonwealth of Massachusetts Department of Public Works [MDPW] 1985).

In more recent years, the quality of the Merrimack River has improved, and today there is a concerted effort on the part of state and federal fish and wildlife agencies to restore anadromous fish populations in the Merrimack River. These restoration efforts have included stocking the headwaters of the river with adult American shad (*Alosa sapidissima*) and juvenile Atlantic salmon (*Salmo salar*) and building fish ladders at dams to allow fish access to the upper reaches of the Merrimack River. Other anadromous fish that are returning to the Merrimack River include the alewife (*Alosa pseudoharengus*), blueback herring (*Alosa aestivalis*), and sea lamprey (*Petromyzon marinus*). According to the FHA and MDPW (1985), the only catadromous species in the Lowell portion of the Merrimack River is the American eel (*Anguilla rostrata*).

In 1969 the State of New Hampshire, the Commonwealth of Massachusetts, USFWS, United States Forest Service (USFS), and the NMFS combined their efforts and formed Policy and Technical Committees for the Anadromous Fishery Management of the Merrimack River. Largely through the efforts of these committees, much progress has recently been made (Boott Mills 1980).

The MRTC was formed to address the restoration of anadromous fish in the Merrimack River watershed and includes representatives from the following government organizations: New Hampshire Department of Fish and Game (NHDFG), MADFW, MADMF, USFWS, USFS, and NMFS (Technical Committee 2010). The MRTC coordinates restoration activities such as installation, evaluation, operation, and maintenance of fish passage and capture facilities at hydroelectric facilities along the Merrimack River. Boott collaborates with the MRTC under an adaptive management

framework regarding all activities related to managing the fishery resources impacted by the Lowell Project.

The MRTC oversees the management of the Lowell Project fisheries as directed by the Project's CFPP which was filed pursuant to Article 35 and 36 of the Project's existing license and approved by FERC in November 2000. The CFPP and fish passage at the Project is described in more detail in Section E.7.3.1.4.

E.7.3.1.2 Aquatic Habitat

Aquatic habitat in the Project vicinity consists of habitat types typical of most northeastern large rivers, which support a variety of cool and warm water species. Shallow water, littoral, and riparian habitat types exist along the shoreline of the Project's impoundment, as well as along the several islands scattered in the Project's impoundment. At low river flows, the habitat in the Project's bypass reach is generally broad, relatively shallow, and rocky with numerous areas of exposed bedrock, with a large pool occupying the middle portion of the bypass reach.

During the 2019 Fish Assemblage Study (NAI 2021d), habitat was visually evaluated and characterized in the impoundment and bypass reach. The dominant substrate, proportion of transect with submerged aquatic vegetation, and the proportion of transect with overhanging vegetative cover was recorded. Water depth and velocity was measured within each sampling transect. Water quality data (i.e., water temperature, dissolved oxygen, conductivity, pH, and turbidity data) was also collected during spring, summer, and fall at each transect at a depth of one meter.

Impoundment

Within the impoundment, habitat was identified primarily as impoundment (78 percent), with less amounts of run (7 percent) and pool (15 percent) habitat. Dominant substrate, presence of submerged aquatic vegetation (SAV), and presence of general cover were consistent among all sample units regardless of mesohabitat classification (i.e., pool, run or impoundment). Sampled areas upstream of Pawtucket Dam were characterized by sand-silt-clay sediments, presence of SAV over 0-25 percent of the sample area and the presence of general cover over 0-25 percent of the sample area. Mean water depth (as sampled at quarter points of the river channel at the upper, middle, and lower points of each transect) trended towards shallower at the upper end of the reach upstream of Pawtucket Dam in areas classified as pool and run, and deeper at the lower end in areas classified as impoundment (NAI 2021d).

Water temperature in the impoundment was relatively consistent among sample units with a $\pm 1\text{-}2^{\circ}\text{C}$ range in values within each season. The average Merrimack River water temperature was 21.5°C during the spring sampling, 25.6°C during the summer sampling, and 10.8°C during the fall sampling. Dissolved oxygen was measured at 8.1 mg/L or greater at all stations upstream of Pawtucket Dam regardless of season. Conductivity averaged $114\ \mu\text{s}/\text{cm}$ during the spring sampling, $181\ \mu\text{s}/\text{cm}$ during the summer sampling, and $117\ \mu\text{s}/\text{cm}$ during the fall sampling. In general, conductivity increased with proximity to the Pawtucket Dam. River pH was consistent across seasons ranging from 6.5-7.5. The average turbidity reading was higher during the spring

sampling (2.6 Nephelometric Turbidity Units [NTUs]) than was observed during the summer or fall periods (1.8 and 1.6 NTUs, respectively) (NAI 2021d).

Bypassed Reach

Within the bypass reach, habitat was identified primarily as pooled sections (75 percent) with ledge channels (25 percent). A range of substrate types was sampled during each of the three seasons, ranging from areas of boulders to sand-silt-clay habitat. Sampled areas within the bypass reach were characterized by the presence of SAV over 0-25 percent of the sample area and the presence of general cover over 0-25 percent of the sample area. Mean water depth was consistent among sample areas and season, ranging from 1.5-2.4 feet (NAI 2021d).

Water temperature was relatively consistent among sample units within each season and averaged 22.9°C during the spring sampling, 23.8°C during the summer sampling, and 13.1°C during the fall sampling. Dissolved oxygen was measured at 8.9 mg/L or greater at all bypass reach stations downstream of Pawtucket Dam regardless of season. Conductivity averaged 148 µs/cm during the spring sampling, 194 µs/cm during the summer sampling, and 100 µs/cm during the fall sampling. The average river pH in the bypass reach was higher during the summer sampling event (7.8) than was observed during the spring (6.5) or fall (6.6) (NAI 2021d).

During the Instream Flow Habitat Assessment and Zone of Passage Study (NAI 2021e), an aquatic habitat model was developed for 9 species and associated life stages in the Bypass Reach through the bedrock rapids to the tailrace confluence at flows from 250 cfs to 14,000 cfs. An index of suitable habitat at each modeled flow, expressed as weighted usable area (WUA) in m², is presented below in Table E.7-13. Figure E.7-16 illustrates the flow/habitat relationships for each species and life stage.

Table E.7-13. Weighted Usable Area (WUA) in m² in the Bypass Reach according to flow, species, and life stage

Flow	American Shad		River Herring	Sea Lamprey	Fallfish	
	Juvenile	Spawning	Spawning	Spawning	Juvenile	Adult
250	11,923	6,738	3,110	576	2,764	15,133
482	14,468	9,368	2,951	1,012	3,134	17,586
1,000	15,864	12,859	2,421	1,599	2,873	18,363
2,000	14,946	15,664	1,711	1,908	1,726	14,308
4,345	9,948	15,755	1,011	1,282	893	8,219
6,000	7,558	13,396	820	858	895	6,782
7,011	6,517	11,852	723	724	894	6,201
8,000	5,710	10,313	675	611	819	5,724
10,000	4,644	7,864	568	489	688	4,979

Exhibit E Environmental Report (18 C.F.R. § 5.18)
 Lowell Hydroelectric Project

Flow	American Shad		River Herring	Sea Lamprey	Fallfish	
cfs	Juvenile	Spawning	Spawning	Spawning	Juvenile	Adult
12,000	4,025	6,418	523	415	511	4,573
14,000	3,641	5,718	490	355	371	4,277
Flow	Smallmouth Bass				Longnose Dace	
cfs	Fry	Juvenile	Adult	Spawning	Juvenile	Adult
250	10,617	10,141	5,834	879	838	1,970
482	10,491	12,772	7,155	727	1,086	2,414
1,000	7,768	13,820	8,021	508	735	1,657
2,000	5,507	11,407	6,350	324	385	848
4,345	3,340	6,793	4,014	215	283	537
6,000	2,817	5,412	3,366	201	296	580
7,011	2,454	4,882	3,087	173	265	599
8,000	2,270	4,394	2,818	161	212	508
10,000	1,899	3,665	2,402	143	116	303
12,000	1,660	3,249	2,153	104	69	160
14,000	1,526	2,983	2,016	98	44	109
Flow	White Sucker			Freshwater Mussels	Benthic Macro-invertebrates	
cfs	Fry	Juvenile	Adult	Rearing	Rearing	
250	25,085	10,724	159	8,217	7,213	
482	22,449	12,398	95	9,686	12,031	
1,000	16,881	10,462	61	10,937	18,958	
2,000	11,986	6,989	21	11,066	24,062	
4,345	7,219	4,352	69	8,528	21,698	
6,000	6,041	3,758	123	6,679	17,847	
7,011	5,233	3,361	95	5,802	15,777	
8,000	4,787	3,165	66	5,039	13,819	
10,000	4,065	2,706	34	3,913	10,948	
12,000	3,657	2,481	12	3,244	8,867	
14,000	3,488	2,354	9	2,866	7,250	

Figure E.7-16. Relationship between WUA (m²) and flow (cfs) in Bypass Reach according to species and life stage

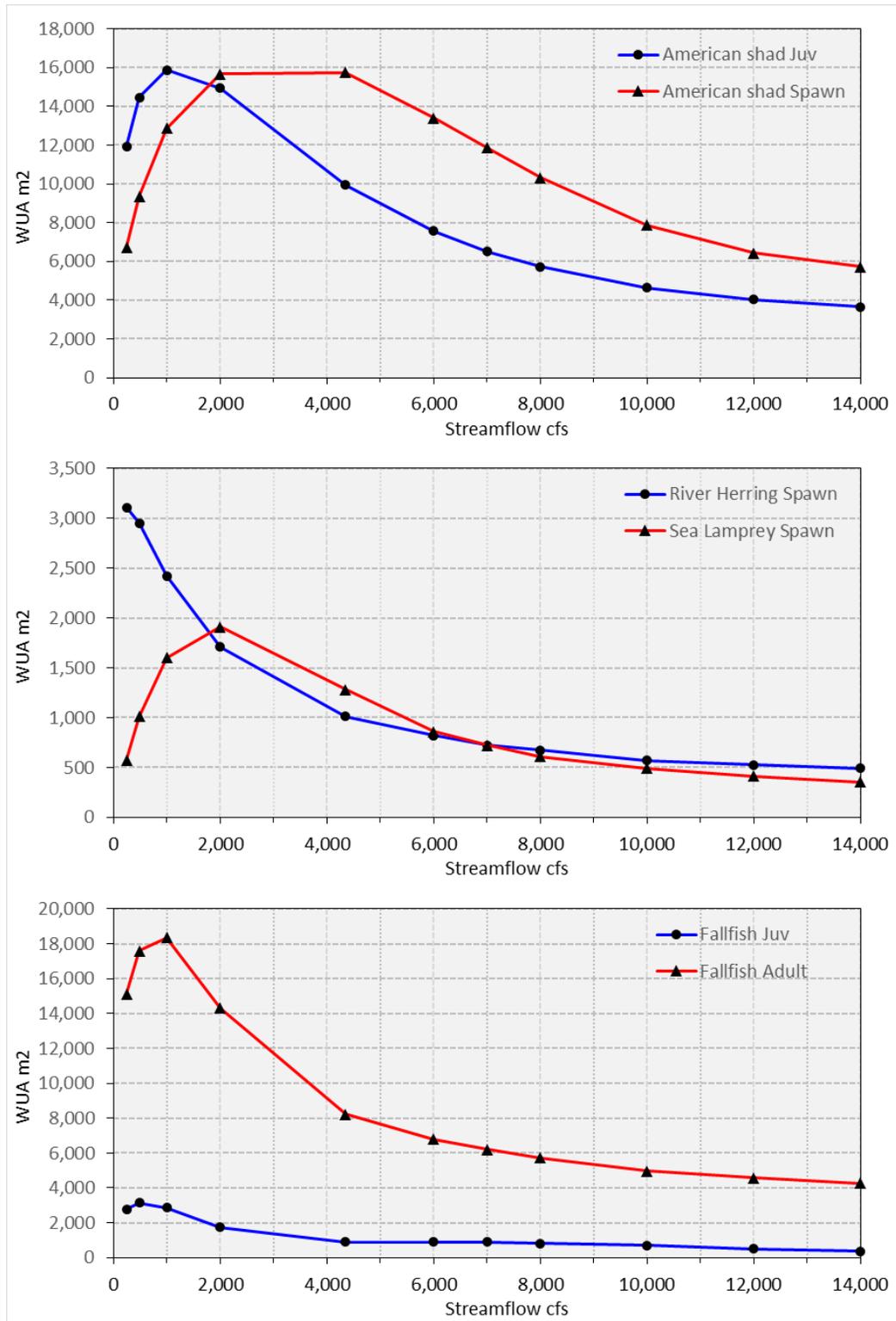


Figure E.7-16 continued

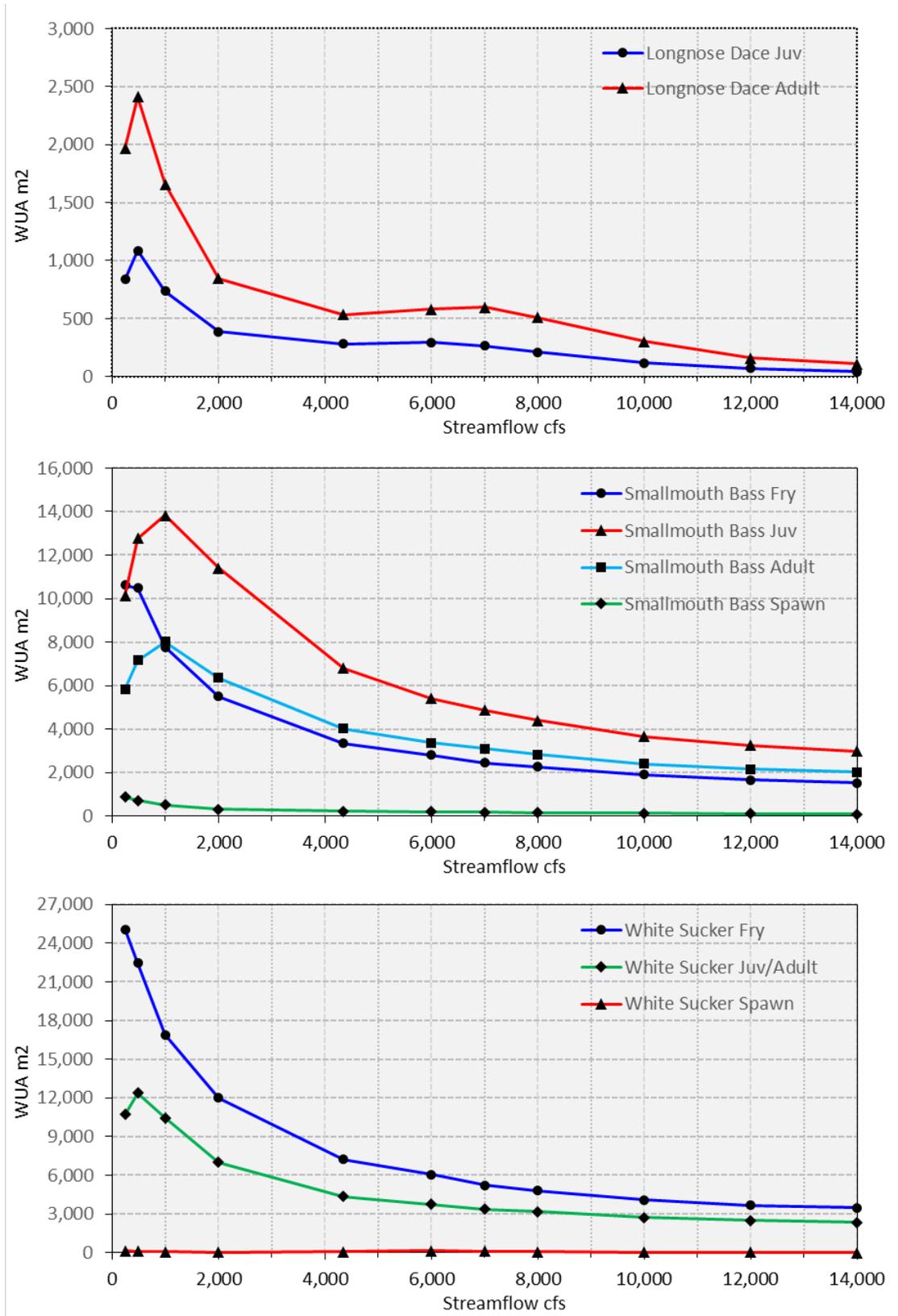
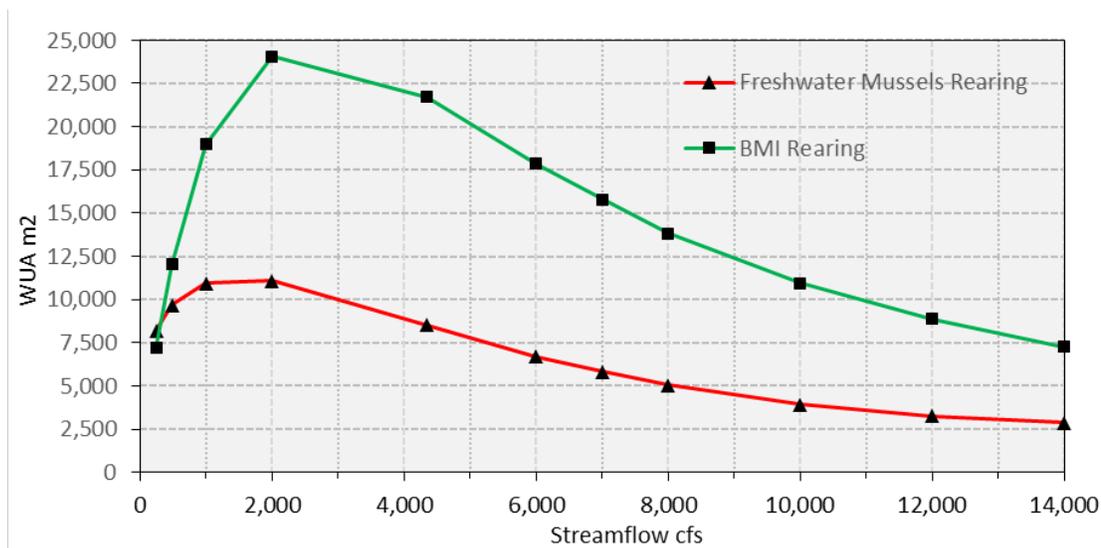


Figure E.7-16 continued



The index of suitable habitat for American shad juveniles remained relatively high (>10,000 m²) at flows between 250 cfs and 2,000 cfs, with declining suitability to a minimum (3,641 m²) at the maximum modeled flow of 14,000 cfs. The suitability index for shad spawning stayed high (>10,000 m²) over a wider range of flows (1,000-8,000 cfs), with minimum (~6,700 to ~5,700 m²) at the lowest and the highest modeled flows, respectively. Most suitable habitat for both life stages occurred in the upper half of the modeled reach.

The habitat index for spawning by river herring was highest at 3,110 m² at the lowest modeled flow (250 cfs), then progressively declined to 490 m² as flows increased to 14,000 cfs. Virtually all of the estimated habitat was of low suitability, due to the low suitability (0.1) for all rocky substrates.

As shown above, benthic macroinvertebrates showed the highest estimates of WUA of all species groups, with a maximum of 24,062 m² at 2,000 cfs, and maintained high habitat values (>10,000 m²) from 500 cfs to 10,000 cfs.

In most cases the habitat indexes for each species and life stage showed maximum suitable habitat at relatively low flows through the Bypass Reach. Thirteen of the 17 assessments produced maximum WUA at flows of 1,000 cfs or less, with 3 other species/life stages (lamprey spawning, freshwater mussels, and BMI rearing) reaching maximum WUA at 2,000 cfs, and one species/life stage (shad spawning) showing maximum habitat at a higher flow (4,345 cfs). This result is primarily due to the steep, bedrock dominated habitat that characterizes the Bypass Reach.

Canal System

The principal canals in the system are the Pawtucket Canal and the Northern Canal. Smaller canals lead off these two major canals (as further discussed below). The canals vary in width from 40 to 120 feet. The walls are of granite, ledge, concrete, or various

other materials such as wood. The canal beds consist of ledge, concrete, or wood-planked virgin soil (Boott 2017).

Flow enters the canal system upstream of the Pawtucket Dam via the Pawtucket Canal and is controlled by the Guard Lock and Gates Facility. The nominal flow capacity of the downtown canal system via the Pawtucket Canal and the Guard Lock and Gates Facility is approximately 2,000 cfs.

The Northern Canal is approximately 2,200 feet long, with masonry or bedrock lining its complete length. The first 1,000 feet combines masonry walls and an earth dike (with masonry core) as the river wall. The second length is a dressed masonry gravity structure to the site of the E.L. Field Powerhouse. This structure is approximately 30 feet in height (Boott 2017).

The downtown canal system has three downtown power stations (Hamilton, Bridge Street, and John Street Power Stations) and are fed by sections of the 5.5-mile canal system in Lowell.

This Merrimack Canal branches off the Pawtucket Canal. In some areas the section is rectangular, and the Merrimack Canal has simply been gouged out of the native rock and soil. The Merrimack Canal is 10 feet deep, 2,580 feet in length, and 40 to 50 feet wide. The Hamilton Canal begins at the Swamp Locks and is rectangular in section. The Hamilton Canal is 1,936 feet in length, 10 feet deep, 35 to 100 feet wide.

The Eastern Canal begins just above the Lower Locks of the Pawtucket Canal. The Eastern Canal runs for 2,037 feet and is rectangular in section. The Eastern Canal averages 8 feet in depth and 65 feet in width. The Western Canal was a two-level waterpower system, however the locks structures were removed and filled in 1840. The total length of the Western Canal is 4,964 feet. Its width varies from 35 to 55 feet, and its average depth is 9 feet.

E.7.3.1.3 Fish Assemblage

The Merrimack River is home to a diverse assemblage of fish species, including both cold water and warm water species. During the last 150 years, over 15 non-indigenous species such as largemouth bass (*Micropterus salmoides*), smallmouth bass (*M. dolomieu*), walleye (*Sander vitreus*), common carp (*Cyprinus carpio*), rainbow trout (*Oncorhynchus mykiss*), brown trout (*Salmo trutta*), various catfish species (*Ictalurus* spp.) and goldfish (*Carassius auratus*) have established themselves through human introduction within the Merrimack River. The Merrimack River basin is home to approximately 50 species of fish; nine of which are anadromous (Stolte 1982 as cited in Technical Committee for Anadromous Fishery Management of the Merrimack River Basin [Technical Committee] 1997). The slower-moving, ponded reaches within the basin contain the majority of the warm water species, while those areas having steeper gradients contain most of the cold-water species (Technical Committee 1997).

Common freshwater game species currently found in the Lower Merrimack River include yellow perch (*Perca flavescens*), chain pickerel (*Esox niger*), northern pike (*E. lucius*), brown bullhead (*Ameiurus nebulosus*), smallmouth and largemouth bass, walleye,

common carp and Centrarchid sunfishes (Lower Merrimack River Local Advisory Committee [LMRLAC] 2008).

2019 Fish Assemblage Study

In 2019, a Fish Assemblage Study was conducted at the Project to characterize the fish assemblage in the Project's impoundment and bypass reach (NAI 2021d). Sampling locations in the impoundment and bypass reach were randomly selected and weighted proportional to mesohabitat type frequency.

Fish community data in the impoundment were collected from twelve 500-meter sample units during spring (June 24-26), summer (August 19-21), and fall (October 28-30) nights of 2019 (total of 36). At each sample unit, boat electrofishing⁵ was conducted over a 500-meter reach of shoreline at depths less than 10 feet, an experimental gill net⁶ was set in areas with adequate water depths (>8ft) and flow conditions for 4 hours, and two minnow traps⁷ were set to sample deeper habitats (>10ft deep) for 4 hours simultaneously with the gill nets (NAI 2021d).

Fish community data in the bypass reach was collected from three 50-meter sample units during the spring (June 28), summer (August 27), and fall (October 21) of 2019 (total of 12). Due to safety and gear limitations, sampling was not conducted in: (1) the reach from the Pawtucket Dam downstream to the School Street Bridge (also known as Mammoth Road); and (2) the lowermost section of the bypass channel downstream of the Northern Canal surge gate. At each sample unit daytime backpack electrofishing⁸ was conducted during minimum flows.

Fish collected from the impoundment and bypass reach were identified to the lowest possible taxonomic classification, enumerated, measured to total length (to the nearest millimeter), and weighed (to the nearest gram). If large numbers of small fish (i.e., young-of-year [YOY] or small cyprinid species) were captured, length and weight information was collected from the first 25 individuals within the sample and the remaining individuals were grouped, enumerated, and batch weighed (NAI 2021d).

In the impoundment, a total of 1,847 individuals and 22 fish species were collected during the sampling efforts in the impoundment. Spottail shiner (*Notropis hudsonius*) (23.0 percent), redbreast sunfish (*Lepomis auratus*) (20.5 percent) and smallmouth bass (12.3 percent) were the three most numerically abundant species within the impoundment. Spottail shiners were the most abundant species in the spring (27.6 percent of seasonal catch) and fall (33.9 percent of seasonal catch) sampling, whereas

⁵ Boat electrofishing used 4.0 amps of pulsed DC current.

⁶ Gillnets were eight feet deep and constructed of four 25-ft panels of increasing mesh size (1.0, 2.0, 3.0, and 4.0-inch stretch mesh).

⁷ Traps were 2.5 feet long galvanized wire mesh (0.25 square inch) cylinders with two entry fykes.

⁸ Halltech Aquatic Research Model HT2000B/MK5, battery-powered backpack electrofishers with ring probes and rattail cathodes were used for sampling. The backpack units were set at 550 volts at 100 Hertz (Hz). A fine mesh seine was anchored at the downstream end of the 50-m sample unit. A pair of backpack electrofishing units and four technicians moved in a downstream direction towards the seine while actively netting stunned fish and kicking the substrate to drive additional stunned fish towards the collection net.

redbreast sunfish were the most abundant species in the summer sampling (27.1 percent of seasonal catch).

Through the impoundment sampling, centrarchid species were the most abundant within impoundment habitat with redbreast sunfish (24.2 percent), pumpkinseed (*Lepomis gibbosus*) (14.2 percent), and smallmouth bass (12.5 percent) representing the three most abundantly collected species. Spottail shiner were the most abundantly sampled fish species in the pool (28.4 percent) and run (46.3 percent) habitat areas.

Most of the catch in the impoundment were obtained via boat electrofishing, where a total of 1,792 fish and 20 species were collected. Spottail shiner, redbreast sunfish, and smallmouth bass were the most frequently collected species during boat electrofishing efforts. Total boat electrofish catch was fairly consistent across seasons. A total of 55 fish and 15 species were collected using gill nets. Yellow bullhead (*Ameiurus natalis*) were the most collected species, and most of the catch was recorded during the summer season. No fish were collected with minnow traps.

In the bypass reach, a total of 526 fish and fourteen fish species were collected. Fallfish (*Semotilus corporalis*) (39.9 percent), smallmouth bass (20.3 percent) and spottail shiner (16.7 percent) were the three most numerically abundant species. Spottail shiner were most abundant during the spring (48.8 percent) and fallfish during the summer (55.0 percent) and fall (39.9 percent).

In the bypass reach, fallfish were the most abundant fish collected within the pooled habitat, which represented 47 percent of the total catch. Smallmouth bass were the most abundant fish species collected in the ledge habitat in the bypass reach, which represented 60.6 percent of the total catch from that habitat. Close to 14 percent of the total catch in ledge habitat were American eels (*Anguilla rostrata*).

Table E.7-14 provides a comparison of the percent composition of all species collected during the 2019 Fish Assemblage Study. In comparison to the historical fish community in the vicinity of the Project, one new species was collected during the 2019 sampling effort, the channel catfish (*Ictalurus punctatus*). An additional 19 fish species have been observed historically in the Project vicinity, which are presented in Table E.7-15.

Table E.7-14. Fish Assemblage Observed During the 2019 Sampling of the Impoundment and Bypass Reach

Common Name	Scientific Name	Percent Composition	
		Impoundment	Bypass Reach
Alewife	<i>Alosa pseudoharengus</i>	6.1	-
American Eel	<i>Anguilla rostrata</i>	0.9	6.3
Black Crappie	<i>Pomoxis nigromaculatus</i>	0.3	-
Bluegill	<i>Lepomis macrochirus</i>	6.6	0.6
Brown Trout	<i>Salmo trutta</i>	-	0.2
Channel Catfish	<i>Ictalurus punctatus</i>	0.1	-

Common Name	Scientific Name	Percent Composition	
		Impoundment	Bypass Reach
Common Carp	<i>Cyprinus carpio</i>	0.3	-
Fallfish	<i>Semotilus corporalis</i>	7.7	39.9
Golden Shiner	<i>Notemigonus crysoleucas</i>	0.7	-
Largemouth Bass	<i>Micropterus salmoides</i>	2.2	0.4
Sunfish, species unidentified	<i>Lepomis</i> spp.	0.2	0.2
Longnose Dace	<i>Rhinichthys cataractae</i>	-	0.4
Margined Madtom	<i>Noturus insignis</i>	0.5	3.2
Pumpkinseed	<i>Lepomis gibbosus</i>	8.4	-
Redbreast Sunfish	<i>Lepomis auritus</i>	20.5	2.5
Rock Bass	<i>Ambloplites rupestris</i>	0.4	-
Sea Lamprey	<i>Petromyzon marinus</i>	1.1	0.2
Smallmouth Bass	<i>Micropterus dolomieu</i>	12.3	20.3
Spottail Shiner	<i>Notropis hudsonius</i>	23	16.7
Tessellated Darter	<i>Etheostoma olmstedii</i>	1.7	1.9
Walleye	<i>Sander vitreus</i>	0.1	-
White Perch	<i>Morone americana</i>	0.1	-
White Sucker	<i>Catostomus commersoni</i>	3	6.3
Yellow Bullhead	<i>Ameiurus natalis</i>	2.9	1
Yellow Perch	<i>Perca flavescens</i>	1.1	-

Source: NAI 2021d

Table E.7-15. Additional Fish Species Observed Historically at the Project

Common Name	Scientific Name
American shad	<i>Alosa sapidissima</i>
Atlantic salmon	<i>Salmo salar</i>
Banded killifish	<i>Fundulus diaphanus</i>
Banded sunfish	<i>Enneacanthus obesus</i>
Blacknose dace	<i>Rhinichthys atratulus</i>
Blueback herring	<i>Alosa aestivalis</i>

Common Name	Scientific Name
Bridle shiner	<i>Notropis bifrenatus</i>
Brook trout	<i>Salvelinus fontinalis</i>
Brown bullhead	<i>Ameiurus nebulosus</i>
Chain pickerel	<i>Esox niger</i>
Common shiner	<i>Luxilus cornutus</i>
Creek chubsucker	<i>Erimyson oblongus</i>
Gizzard shad	<i>Dorosoma cepedianum</i>
Goldfish	<i>Carassius auratus</i>
Northern pike	<i>Esox lucius</i>
Redfin pickerel	<i>Esox americanus</i>
Slimy sculpin	<i>Cottus cognatus</i>
Striped bass	<i>Morone saxatilis</i>
Swamp darter	<i>Etheostoma fusiforme</i>
White catfish	<i>Ameiurus catus</i>

Sources: Hartel et al. 2002; Merrimack River Technical Committee 1997.

E.7.3.1.4 Migratory Species and Fish Passage

Overview

Fish passage at the Lowell Hydroelectric Project is managed in accordance with the CFPP. The CFPP includes details of operational measures undertaken by Boott to protect upstream and downstream migrating anadromous fish. Upstream and downstream fish passage facilities at the Project include a fish lift and downstream fish bypass at the E.L. Field Powerhouse and a vertical-slot fish ladder at the Pawtucket Dam. The fish passage facilities at the Project were designed in consultation with the USFWS and current fish passage operations are supervised by both state and federal fishery agencies per the CFPP.

In accordance with the CFPP, Boott is required to begin operating the fish passage facilities at the Lowell Project when a cumulative total of 50 American shad (*Alosa sapidissima*) or 200 river herring (*A. pseudoharengus*) are passed at the downstream Lawrence Hydroelectric Project (FERC No. 2800). Termination of upstream fish passage operations at the end of the upstream passage season is determined each year in consultation with the MRTC, and typically occurs in early to mid-July. Additionally, in accordance with the CFPP, Boott is required to operate the downstream bypass facility from April 1 through July 15 and from September 1 through November 15 (Cleantech

Analytics 2017). Under the CFPP, Boott provides annual post-season updates to the MRTC. Fish can bypass the Project's entire canal system via the Merrimack River and use the existing upstream and downstream fish passage facilities at the Pawtucket Dam and E.L. Field Powerhouse. There are no exclusionary measures at the entrance of the Project's canal system. However, in the CFPP, Boott included an operational protocol to pass additional flows through the canal system in the rare instance where the Northern Canal needs to be dewatered to conduct repairs or maintenance on the main powerhouse during downstream fish passage season (Cleantech Analytics 2017). This provision has been implemented only once during the term of the license, to facilitate repairs to the Northern Canal wall in 1996.

As currently provided in the CFPP, the fish lift has historically been the primary route of upstream passage at the Project, whereas the ladder has typically been operated only during periods of higher flow when spillage at the dam may attract upstream migrants toward the bypass reach. In recent years, Boott and the MRTC have tested the success of passage through the ladder under normal, non-spill conditions with favorable results. In 2018, Boott agreed to operate both the lift and the ladder throughout the fish passage season, in exchange for agency support of LIHI certification of the Project.

As a component of the CFPP, Boott collects information regarding the abundance of diadromous fishes using the upstream fishways annually. This activity is a joint monitoring effort to inform the MRTC that manages these fishery resources. MADFW and Boott staff work cooperatively to record diadromous fish counts at the E. L. Field Powerhouse fish lift throughout the upstream migration season. Beginning in 2017, fish count records also were kept at the Pawtucket Dam fish ladder. Boott provides a summary of these counts as part of its annual fishway operations report to the MRTC (Table E.7-16).

The CFPP is based on several fisheries studies conducted at the Project and experience gained at the Project since the installation of the Project's fish lift and fish bypass facilities. The CFPP was developed in consultation with the resource agencies, and many of the agencies' recommendations have been incorporated into the CFPP. Since 2013 Boott has actively worked with USFWS to assess and improve upstream eel passage at the Pawtucket Dam.

In 2016, Boott purchased new radio telemetry equipment to assist the USFWS monitoring at three sites to assess the downstream movement of radio tagged adult eels released at the Merrimack River Project upstream (Cleantech Analytics 2017). In 2017 Boott deployed telemetry equipment at six locations at the Lowell Project and two locations at the Lawrence Project to again track the movement of radio-tagged eels released at the Merrimack River Project through the Lowell Project facilities. As discussed in more detail below, each of the fourteen radio-tagged eels determined to have successfully passed downstream of the Lowell Project, with the majority of individuals passing via the turbines and the remainder passing by spill.

The priority species for management at the Lowell Project are the catadromous American eel and three anadromous Alosidae species, American shad (*Alosa sapidissima*), blueback herring (*Alosa aestivalis*), and alewife (*Alosa pseudoharengus*).

Juvenile and adult American eel upstream and downstream migration periods overlap. Juveniles ascend beginning in May and continue through October. The adult outmigration period begins in late summer and lasts through November. The peak outmigration period is October through mid-November (Boott 2018).

Adult American shad and river herring ascend the Merrimack River from May through early July. The peak period is highly dependent on water temperature and total river discharge. The juvenile outmigration period is in the fall (September through November) and is also highly dependent on ambient water temperature and river discharge conditions (Boott 2018).

Outmigrating fish and eels encountering the Pawtucket Dam can: (1) pass through the Pawtucket Gatehouse and enter the power canal; (2) pass downstream over Pawtucket Dam via spill; or (3) enter the Pawtucket Canal and navigate downstream via the downtown canal system. Individuals which enter the Northern Canal can pass downstream via one of the two turbine units at the E.L. Field Powerhouse, utilize the downstream bypass, or pass via the surge gate (operated only in the event of a station trip).

Table E.7-16. Lowell and Lawrence Diadromous Fish Passage Counts Since 1983

Year	River Herring (Lawrence)	River Herring (Lowell)	American Shad (Lawrence)	American Shad (Lowell)	Atlantic Salmon (Lawrence)	American Eel (Lowell)	American Eel (Lawrence)
1983	4,794		5,629		114		
1984	1,769		5,497		115		
1985	23,112		12,793		213		
1986	16,265		18,173	1,630	103		
1987	77,209		16,909	3,926	139		
1988	361,012	56,739	12,359	1,289	65		
1989	387,973	137,296	7,875	940	84		
1990	254,242	9,888	6,013	443	248		
1991	379,588	6,920	16,098	428	332		
1992	102,166	32,501	20,796	6,491	199		
1993	14,027	4,315	8,599	1,679	61		
1994	88,913	33,735	4,349	383	21		
1995	33,425	11,848	13,861	5,255	34		
1996	51	51	11,322	400	76		
1997	403	403	22,661	4,446	71		
1998	1,362	13	27,891	4,159	123		
1999	7,898	2,930	56,461	16,347	185		
2000	19,405	673	72,800	12,716	82		
2001	1,550	58	76,717	7,740	83		

Exhibit E Environmental Report (18 C.F.R. § 5.18)
Lowell Hydroelectric Project

Year	River Herring (Lawrence)	River Herring (Lowell)	American Shad (Lawrence)	American Shad (Lowell)	Atlantic Salmon (Lawrence)	American Eel (Lowell)	American Eel (Lawrence)
2002	526		54,586	5,283	56		
2003	10,866	194	55,620	6,580	147		
2004	15,051	7,448	36,593	11,028	129		
2005	99	201	6,382	716	34		
2006	1,257	27	1,205		91		
2007	1,169		15,876	1,653	74		
2008	108		25,116	4,050	119		
2009	1,456	139	23,199	2,267	81		
2010	518	43	10,442	490	85		
2011	740	228	13,835	831	402		
2012	8,992	1,809	21,396	1,728	137		6,969
2013	17,359	13,490	37,149	9,756	22		915
2014	57,213	23,610	38,107	3,357	75	166	1,788
2015	128,692	31,323	89,467	20,937	13	2,647	8,124
2016	417,240	287,343	67,528	11,439	6	328	1,981
2017	91,616	5,656	62,846	5,086	5	1,981	17,738
2018	276,449	311,867	25,081	14,046	10	*	267,353
2019	43,108	43,871	19,450	2,201	15	*	81,179
2020	87,150	181,979	52,239	8,449	1	974	93,058
TOTAL	2,934,773	1,357,876	1,072,920	178,169	3,850	6,096	479,105

*continuously ran fish ladder in 2018 and 2019 was primary upstream passage for eels, accurate quantity was unavailable without trapping.

Source: Boott 2018; K. Webb, Boott Hydropower, personal communication, March 19, 2018

Historical Studies

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. Use and efficiency studies of the E.L. Field Powerhouse fish lift by American shad were conducted in 1999 and 2000 by Boott and by Alden Research Laboratory in 2011. The earlier studies led to significant modifications and upgrades of those facilities that improved the passage efficiencies of American shad. In addition, a 1988 acoustic telemetry study performed by RMC Environmental Services (RMC) of adult American shad movement through the Northern Canal demonstrated delayed movement through the Pawtucket Gatehouse, as well as incidental information regarding downstream passage routes for post-spawning individuals (RMC 1988). In a follow-up study in 1991 by NAI found similar findings as the 1988 adult American shad telemetry study (NAI 1991a).

Downstream bypass effectiveness studies in 1991 and subsequent studies in 1994 and 1995 by NAI yielded information regarding the use of the Project's bypass reach. This information led to phased modifications of the bypass which increased its use and efficiency at passing juvenile Alosids downstream. Similar studies were performed for Atlantic salmon smolts in 1996 and 2003 by NAI. A 2005 USFWS radio telemetry study provided information regarding American shad movement behavior between the downstream hydroelectric station, Lawrence, and the Lowell facilities. The upstream passage of American shad was also assessed at the Lowell Project in 2011 by Alden Research Laboratory, Inc, with additional analyses performed in 2013. Most recently, a study performed in 2017 by NAI yielded information regarding the downstream migratory behaviors of American eel in the Lowell Project.

During 2019 and 2020, three additional fish passage studies were conducted at the Lowell Hydroelectric Project, which are described below.

American Eel Passage

The downstream passage for silver-phase American eels was evaluated by NAI in 2017. As part of that evaluation, fourteen radio-tagged eels passing downstream of the Amoskeag Project (the next hydroelectric facility upstream of Lowell in Manchester, New Hampshire) were detected at Pawtucket Dam and thirteen of the fourteen study eels arriving at Lowell were subsequently detected downstream at Lawrence. The transit times between Amoskeag and Pawtucket Dam ranged from 10 – 244 hours. Eel passage events occurred primarily between sunset and sunrise via the turbines (eight) and over Pawtucket Dam (five); one individual was not detected at the passage detection fields at Lowell but was detected at the Lawrence Project. In addition, the E.L. Field Powerhouse bypass was not used as a downstream passage route.

More recently, a radio-telemetry assessment of the downstream passage success for adult silver-phase American eels was performed during the fall of 2019, pursuant to the SPD (NAI 2021a). Monitoring of outmigrating adult American eels focused on the evaluation of movement through the Project impoundment, residence time immediately upstream of the Pawtucket Dam and prior to passage, passage route utilization and estimation of downstream passage survival at the Project.

Following the release of 102 radio-tagged individuals⁹ into the Merrimack River 11 miles upstream of the Lowell impoundment, their movements were monitored using a series of stationary radio-telemetry receivers in place at the Project¹⁰ to inform on general movements, distribution among available passage routes and Project passage success (NAI 2021a). Radio-tagged eels moved through the existing 23-mile-long Project impoundment in a median duration of 2.1 days.

Route options for outmigrating American eels encountering the Pawtucket Dam are (1) pass through the Pawtucket Gatehouse and enter the power canal, (2) pass

⁹ Normandeau Associates simultaneously conducted an additional downstream adult eel passage study at the Merrimack River Project (FERC No. 1893) during fall 2019. A total of 60 eels were radio-tagged during that assessment and were also monitored for passage at Lowell. Results from that group of eels at Lowell and points downriver have been incorporated into this report.

¹⁰ 12 monitoring stations total.

downstream over Pawtucket Dam via spill, or (3) enter the Pawtucket Canal and navigate downstream via the downtown canal system.

Upon initial detection at the Pawtucket Dam, the median duration of time spent immediately upstream of the dam structure was 0.4 hours with 94 percent passing downstream within the first 24 hours of their initial detection. Closer examination of the total residence time for radio-tagged eels indicated that the 95 percent of individuals passing through the Pawtucket Gatehouse did so in 30 minutes or less and upon entry into the Northern Canal the median residence duration prior to downstream passage was 0.2 hours (NAI 2021a).

Similar to observations at the Pawtucket Gatehouse, radio-tagged eels which entered the Northern Canal and passed downstream of E.L. Field powerhouse did so relatively quickly. Of those individuals, 94 percent were resident in the power canal upstream of E.L. Field for 3 hours or less. The median residence duration in the Northern Canal was 0.2 hours (range = 0.1 hours to 22.1 days). Seven radio-tagged individuals were present in the Northern Canal for 36 hours or greater prior to downstream passage.

During the 2019 evaluation there was no detected use of the downtown canal system by outmigrating radio-tagged eels. The majority of radio-tagged individuals passed through the Pawtucket Gatehouse and approached the E.L. Field powerhouse with 92.5 percent eventually passing downstream via the turbine units (Table E.7-17). Use of the existing downstream bypass system was limited to only two individuals. Downstream passage at the Project peaked during late October with all passage events completed by October 31. The majority of downstream passage events occurred during the evening and overnight hours (NAI 2021a).

The high number of radio-tagged individuals that passed downstream via the turbine units likely resulted from drier than normal conditions in the region. Only two major spill events, associated with increases in river flows, occurred during the monitoring period. The first major spill event occurred from approximately October 29 to November 5 and the second occurred towards the end of the passage season (~November 25) (NAI 2021a). The timing of the spill events occurred primarily after the peak of downstream passage at the Project. Under normal conditions, the frequency of spill events would be greater due to more frequent increases in river flows, thereby increasing the downstream passage of individuals over the dam and decreasing individuals passing downstream via the turbine units.

Downstream passage survival was estimated for all radio-tagged eels from the point of initial detection upstream of the Pawtucket Dam downstream to Lawrence. This resulted in an estimated downstream passage survival for silver-phase American eel at Lowell of 75.5 percent (75 percent Confidence Interval [CI] = 71.4 percent-79.6 percent). This estimate of downstream passage survival for adult eels at the Project includes any background (i.e., natural) or tagging-related mortality for the species in the reach from approach to the Pawtucket Dam to Lawrence. As a result, this estimate should be viewed as a minimum estimate of total project survival (i.e., due solely to project effects) for adult eels at the Project. Due to the limited distribution of downstream passage route selection, route-specific estimates of passage were developed for only individuals using turbine

units at the E.L. Field powerhouse (n = 136; 75.0 percent survival; 75 percent CI = 70.6 percent-79.4 percent). The limited number of radio-tagged eels passing the Project via spill or the downstream bypass system were all determined to have successfully approached the Lawrence Project following downstream passage at Lowell (NAI 2021a).

Table E.7-17. Downstream passage route selection for radio-tagged eels released upstream of the Lowell project boundary and upstream of Garvins Falls Dam during the fall 2019 downstream passage assessment.

Release Location	Release Date	Lowell Downstream Passage Route					
		Did not Detect	Did Not Pass	Unknown	Turbine	Spill	Bypass
Garvins Falls	9-Oct	7	0	1	11	1	0
Garvins Falls	11-Oct	2	1	0	15	1	1
Garvins Falls	15-Oct	6	0	0	13	1	0
Garvins Falls	All	15	1	1	39	3	1
Lowell	9-Oct	0	0	1	19	0	0
Lowell	11-Oct	0	0	0	19	0	1
Lowell	16-Oct	0	0	1	18	1	0
Lowell	18-Oct	0	0	0	20	0	0
Lowell	23-Oct	0	0	1	21	0	0
Lowell	All	0	0	3	97	1	1
All		15	1	4	136	4	2
Percent Utilization			0.7%	2.7%	92.5%	2.7%	1.4%

Source: NAI 2021a.

The Fish Passage Survival Study (NAI 2021f) addressed the qualitative classification of impingement, entrainment, and the probability of turbine passage survival at the Project using a review of relevant biological criteria and physical Project characteristics for American eel. The study used a turbine blade strike analysis (TBSA) model, which relied on recent USFWS guidance on the use of a varied correlation coefficient for American eel, to calculate survival estimates through the E.L. Field Kaplan units. The estimated range of survival for eels passing downstream through the E.L. Field turbines ranged from 71-39 percent, with the predicted rate of survival for adult eels decreasing as body size/length increased (Table E.7-18). In the case of adult eels, the TBSA model tended to underestimate turbine survival when compared to empirical results from the Downstream American Eel Passage Assessment.

Table E.7-18. TBSA predicted survival estimates for adult American eels at the E.L. Field powerhouse.

Species/Life Stage	Size potentially encountered the region (in)	Body Length (inches)						
		21	24	28	32	36	40	45
American eel (Adult)	25-41	71.20%	67.30%	61.80%	56.50%	51.70%	46.00%	39.10%

Juvenile Alosine Downstream Passage

The downstream passage of juvenile alosines has been studied at the Lowell Project a number of times since 1990. After conducting a mark and recapture study in the fall of 1990 to determine the relative efficiency of its fish bypass system at passing juvenile clupeids, it was determined that because water depth in the vicinity of the E.L. Field Powerhouse's bypass is greater than 30 feet, the 91-centimeter-deep bypass opening at the facility may be too shallow for the majority of fish to locate it (NAI 1991b). During this study, a total of 7,882 juvenile clupeids were captured in the bypass net between September 25 and October 23. Alewives comprised 95 percent of the catch, shad 4.5 percent, and blueback herring less than 0.5 percent. Modifications to the fish bypass at the E.L. Field Powerhouse were subsequently completed, and downstream juvenile alosine passage was again examined during the fall of 1993 and 1994 to assess efficiency of the modified bypass opening. Both studies concluded that the modified bypass opening greatly improved passage efficiency, by approximately 30 percent (NAI 1994 and NAI 1995).

An evaluation of the potential impacts on the outmigration of juvenile alosines was conducted in the fall 2019 migration season using radio-telemetry as outlined in the RSP (NAI 2021b). Monitoring of outmigrating juvenile alosines focused on the evaluation of the residence time immediately upstream of the Pawtucket Dam and prior to passage as well as passage route utilization at the Project.

A total of 145 juvenile alosines¹¹ were tagged and released at mid-river locations approximately one mile upstream of the Pawtucket Gatehouse. Their subsequent downstream arrival and passage at the Project was monitored via a series of fixed-location telemetry receivers within the Lowell Project area.

Route options for outmigrating juvenile alosines encountering the Pawtucket Dam are (1) pass through the Pawtucket Gatehouse and enter the power canal (Northern Canal), (2) pass downstream over Pawtucket Dam via spill, or (3) enter the Pawtucket Canal and navigate downstream via the downtown canal system.

¹¹ The FERC-approved RSP indicated that a total of 150 radio-tagged juvenile alosines shall be used for the study. Five of the transmitters purchased for this study could not be activated. As a result, a total of 145 radio-tagged juvenile alosines were released and assessed for downstream passage at the Project. There were no additional variances from the FERC-approved study plan.

Upon initial detection at the Pawtucket Dam, the median duration of time spent immediately upstream of the dam structure was 1.3 days with 42 percent passing downstream within the first 24 hours of their initial detection and 68 percent in less than 48 hours after initial detection. Closer examination of the total residence time for radio-tagged juvenile alosines indicated that all individuals determined to have entered the Northern Canal passed through the Pawtucket Gatehouse in less than 30 minutes. The median duration of time for radio-tagged juvenile alosines to pass downstream of the Pawtucket Gatehouse following their approach at that structure was 0.1 hours (range <0.1 hours to 0.4 hours), indicating rapid passage at that structure.

Upon entry into the Northern Canal, the median residence duration prior to downstream passage was longer (22.0 hours; range = 0.2 hours to 4.7 days). Of those individuals, 56 percent were resident in the power canal upstream of E.L. Field for 24 hours or less. Nearly 70 percent of all downstream passage events for radio-tagged juvenile alosines occurred within 48 hours of initial detection in the E.L. Field forebay. A statistically significant interaction was suggested between mid and high generation conditions in relation to passage failure from the E.L. Field forebay. The presence of higher generation flows increased the probability that a radio-tagged individual would approach downstream passage options in the power canal (i.e., turbines or downstream bypass) and decreased the passage attempt relative to lower generation flows.

A small percentage (2.1 percent) of the radio-tagged juvenile alosines approaching the dam were detected at the Guard Locks (Station 24), indicating they had entered the downtown canal system. The majority of individuals passed downstream of the Project, with 9.2 percent over the Pawtucket Dam via spill, 12.0 percent navigating through the power canal and using the downstream bypass near the E.L. Field Powerhouse, and 57.7 percent passing through the turbine units. During the downstream fish passage season, which typically occurs from May through November 15 – to be determined annually in conversation with the MRTC, Boott will suspend generation and cease operation of the downtown canal system turbines and flows will not be diverted into the downtown canal system (*except as noted above under Canal Water Elevations and Canal Water Flows*). This measure will reduce and/or eliminate attraction flows to the generating areas of these sections of the Project. Subsequently, as observed during the study period, juvenile alosine presence in this section during turbine shutoff is expected to be extremely minimal or nonexistent. Most, if not all, will bypass the Project via Dam spill, power canal, or through the E.L. Field Powerhouse turbines.

During the 2019 evaluation, the majority of radio-tagged individuals passed through the Pawtucket Gatehouse and approached the E.L. Field Powerhouse (Table E.7-19). Of the individuals which approached the E.L. Field Powerhouse and had a known downstream passage route, 83 percent eventually passed downstream via the turbine units. Use of the existing downstream bypass system was estimated at 17 percent.

Table E.7-19. Downstream passage route selection and percent utilization of route options after detection at Station 21 for radio-tagged juvenile alosines released upstream of Pawtucket Dam during the fall 2019 downstream passage assessment.

Release Date	Lowell Downstream Passage Route						
	Did not Detect	Did Not Pass	Downtown Canal System	Spill	Bypass	Turbine	Unknown
9-Oct	0	2	1	1	5	6	0
11-Oct	0	2	1	0	4	8	0
13-Oct	1	3	0	1	4	4	1
14-Oct	1	1	1	0	1	10	1
15-Oct	0	2	0	2	2	8	1
16-Oct	0	0	0	6	0	7	2
17-Oct	0	2	0	2	0	9	3
18-Oct	0	2	0	0	0	13	0
23-Oct	1	3	0	0	1	11	1
24-Oct	0	4	0	1	0	6	0
All	3	18	3	13	17	82	9
Percent Utilization		12.7%	2.1%	9.2%	12.0%	57.7%	6.3%

Source: NAI 2021b.

During the Revised ISR Meeting on October 15, 2020, FERC and NAI discussed the models at the gatehouses and the correlations between flow and temperature. NAI stated they could likely make changes to the model to further explore those variables.

The Fish Passage Survival Study (NAI 2021f) used the TBSA desktop tool to estimate total project survival for juvenile alosines at the Project. Estimates of turbine passage were inversely related to body length for each species/life stage considered with highest survival estimated for small juvenile shad or herring at 2 inches of length (~99 percent) (Table E.7-20).

Table E.7-20. TBSA predicted survival estimates for juvenile American shad and river herring at the E.L. Field powerhouse.

Species/ Life Stage	Size potentially encountered the region (in)	Body Length (inches)		
		2	4	6
American shad (Juv)	2-6	98.6%	97.2%	95.9%
River herring (Juv)	1.5-6	98.6%	97.2%	95.9%

An empirical estimate of juvenile alosine survival was not derived during the 2019 Juvenile Alosine Downstream Passage Assessment at Lowell. The model required input of available downstream passage routes and an estimate of their proportional usage. Those rates were obtained from the 2019 study which estimated route usage for individuals passing the project via known mainstem routes as 11.6 percent via spill, 15.1 percent via the downstream bypass, and 73.2 percent via the E.L. Field turbine units. These observed route selection probabilities were imported into a multi-route TBSA model to evaluate the predicted whole-station survival for a normally distributed population of 1,000 3.5 inch (S.D. ± 1.0 inches) fish. For non-turbine routes (e.g., downstream bypass or spill), an estimate of passage mortality was required and was based on the empirical estimates obtained for adult alosines at the Project (12 percent at the downstream bypass and 11 percent via spill). Using this methodology, total project survival at Lowell for juvenile alosine-sized fish is estimated at 94.8 percent. Passage failures were attributed to fish passing downstream via the turbines (2.1 percent of total losses) and the downstream bypass facility/spill (3.1 percent of total losses).

Upstream and Downstream Adult Alosine Passage

Upstream and downstream passage of alosines at the Lowell Project has been evaluated several times since 1990. Downstream passage routes of radio-tagged American shad were evaluated in 1990. Approximately half of the shad tagged during their upstream migration returned to the Project site and 53 percent proceeded to pass through the E.L. Field Powerhouse, 22 percent passed using the fish bypass, 9 percent entered the Pawtucket Canal, and 13 percent spilled over the Pawtucket Dam. The study also indicated that the losses of adult shad upriver from the Lowell Project was consistent with shad runs in other rivers (NAI 1991a).

The internal efficiency of the Lowell Project fish lift at passing adult American shad upstream to spawn was evaluated in 1996 using underwater cameras. Study results indicated that internal fish lift efficiency for shad at the Project was low for both flows evaluated (50 cfs and 90 cfs), probably due to the low flow velocities inside the fish lift entrance channel, especially upstream of the crowder gates. With higher flows and velocities inside the fish lift entrance channel, fewer shad dropped out of the system and internal lift efficiency improved. However, even with the increased flow, most of the shad observed approaching the crowder gates did not pass through them. A similar study was performed in the spring of 1999, in which the upstream passage season was exceptionally successful at passing the highest number of shad since the fish lift was commissioned. Four hundred percent more individual shad were lifted in the spring 1999 season compared to both 1997 and 1998. The average internal lift efficiency (42 percent) achieved at the Lowell Project during the 1999 fish lifting season represented a substantial improvement over the previous results, increasing over seventeen-fold compared to results achieved in 1996. Additional upstream fish lift internal efficiency studies were performed in 2000 and 2001. Both studies concluded that the crowder gate opening has a significant effect on internal fish lift efficiency. Brail camera results, which are most comparable to previous studies at Lowell and Lawrence, clearly show that internal efficiency at Lowell had substantially improved due to the fish lift modifications and was comparable to efficiencies experienced at Lawrence.

The upstream passage of American shad was also assessed at the Lowell Project in 2011 by Alden Research Laboratory, Inc. Adult shad passage success or impediments and overall fish migration patterns from the Lawrence Hydroelectric Project into the Lowell tailrace and into the Lowell project's fish lift hopper was evaluated during this study. The acoustic telemetry results indicated that 57 percent of shad that pass the Lawrence Hydroelectric Project reach the Lowell tailrace. Only three individual fish were detected as entering the riverside fish lift entrance. Additional analysis in 2013 by Blue Leaf Environmental concluded that shad did not spend long periods of time holding in a specific position within the tailrace or reside in areas outside of the established pattern of movement. Shad were also determined to move in a clockwise and counter-clockwise direction along both walls in the tailrace, contrary to the 2011 study which suggested shad move in a "U" shaped swimming pattern following the edges of the tailrace and the wall of the powerhouse.

An evaluation of the upstream and downstream passage effectiveness for adult alewives and American shad was conducted during the spring 2020 passage season (May through June) (NAI 2021c). Merrimack River conditions were considered normal or low for the majority of May, and low for most of the month of June. The E.L. Field fish passage facilities (i.e., upstream fish lift and downstream fish bypass) were operated throughout the study period and those turbine units were in operation for the duration of the study period. Two major spill events, associated with increases in river flows, occurred during the early portion of the monitoring period (May 7 and May 18). Flows to the downstream canal system were limited during both months as Boott suspended operation of the generating units in that system prior to the onset of the study due to overriding safety concerns.

Following the release of radio-tagged individuals¹² into the Merrimack River both upstream and downstream of the Lowell facility, their movements were monitored using a series of stationary radio-telemetry receivers in place at the Project as well as at several additional stationary monitoring receivers installed at bank-side locations upstream and downstream of the Project to inform on general movements, distribution among available passage routes and Project passage success.

Of the dual-tagged¹³ adult alewives released downstream of the Project (150 individuals were dual-tagged and 204 were PIT-tagged), 85 percent were determined to have approached Lowell and were available to assess passage effectiveness of either the E.L. Field Powerhouse fish lift or the Pawtucket Dam fish ladder. The duration of time for fish to move upstream from the release location at Lawrence to Lowell was around one day for most dual-tagged adult alewives (median = 19.6 hours; 75th percentile = 28.6 hours). Following arrival downstream of the Project, 95 percent of dual-tagged adult alewives made at least one foray upstream towards either the fish lift or ladder. When examined by structure, 64 percent of dual-tagged alewives made at least one foray in the direction

¹² A total of 150 adult alewives and 150 adult American shad were radio-tagged and released upstream of the Pawtucket Dam for the purposes of evaluating downstream passage. A total of 354 adult alewives and 384 adult American shad were radio-tagged and released for the purposes of evaluating upstream passage.

¹³ Dual- and PIT-tagged individual fish were analyzed separately due to poor conditions at Monitoring Station 20, which precluded effected monitoring of PIT-tagged individuals.

of the fish lift, 67 percent in the direction of the fish ladder, and 39 percent in the direction of the fish lift and fish ladder. The overall effectiveness of the E.L. Field fish lift for adult alewife passage during 2020 was estimated at 43.9 percent (75 percent CI = 39.3-51.4 percent). The overall effectiveness of the Pawtucket Dam fish ladder for adult alewife passage during 2020 was estimated at 75.6 percent (75 percent CI = 69.2-82.2 percent).

Route options for outmigrating adult alosines encountering the Pawtucket Dam are (1) pass through the Pawtucket Gatehouse and enter the power canal, (2) pass downstream over Pawtucket Dam via spill, or (3) enter the Pawtucket Canal and navigate downstream via the downtown canal system. Of the 150 radio-tagged adult alewives released upstream of Lowell, 83 percent approached the Pawtucket Dam and were available to evaluate downstream passage at the Project. The median upstream residence time prior to downstream passage was 2.0 days with 77 percent of individuals passing downstream in less than 96 hours after their arrival.

The majority of individuals passed downstream through the Pawtucket Gatehouse and entered the Northern Canal of Lowell via the E.L. Field turbine units (52 percent of radio-tagged alewives) or utilized the downstream bypass (45 percent of radio-tagged alewives). A small percentage (2 percent) of radio-tagged adult alewives were detected at Monitoring Station 28 indicating those individuals entered the Pawtucket canal rather than remaining in the mainstem Merrimack River. Despite the low percentage of fish being attracted to the Pawtucket Canal, during the downstream fish passage season (which typically occurs from May through November – and to be determined annually based on consultation with the MRTC and consistent with other Project fish operations), Boott will suspend generation and cease operation of downtown canal system turbines and additional flows will not be diverted into the downtown canal system (*except as noted under Canal Water Elevations and Canal Water Flows in Section E.6.2*). This measure will significantly reduce and/or eliminate attraction flows to the Pawtucket Canal and generating areas of these sections of the Project. Subsequently, as observed during the study period, adult alewives presence in this section during turbine shutoff is expected to be insignificant or nonexistent. Most, if not all, will bypass the Project via dam spill, power canal, or through the E.L. Field Powerhouse turbines as demonstrated.

Downstream passage survival was calculated as the joint probability of the three reach-specific survival estimates which encompasses the full section of the Merrimack River from Lowell downstream to Lawrence and resulted in an estimated downstream passage survival for adult alewives at Lowell of 76.5 percent (75 percent CI = 71.5 percent-80.5 percent). This estimate of downstream passage survival for adult alewives at Lowell included background mortality (i.e., natural mortality) for the species in the downstream reach, along with any tagging-related mortalities or tag regurgitations. As a result, this estimate should be viewed as a minimum estimate of total project survival (i.e., due solely to project effects) for adult alewives at the Project.

Radio-tagged adult alewives released upstream of Lowell at Tyngsborough and which entered the Northern Canal and passed downstream of E.L. Field powerhouse did so relatively quickly. Of those individuals, 84 percent were resident in the power canal upstream of E.L. Field for 12 hours or less and the median residence duration in the Northern Canal was 0.5 hours (range = 0.2 hours to 1.8 days). Adult river herring tagged and released at locations in the Nashua River demonstrated longer residence periods

within the Northern Canal prior to downstream passage at Lowell. The quartile ranges (25th to 75th percentiles) for adult herring originally released at Pepperell ranged from 14.5-43.6 hours and for adult herring originally released at Mine Falls ranged from 4.7-69.6 hours. When all individuals are considered, 20 percent of adult river herring were present in the Northern Canal for greater than 24 hours prior to downstream passage. No power generation exists along the Northern Canal other than the power generation at E.L. Field. However, the NPS hydro exhibit does draw flows from the Northern Canal.

Of the 180 dual-tagged⁹ adult American shad released downstream of the Project, 40 percent were determined to have approached Lowell and were available to assess passage effectiveness of either E.L. Field Powerhouse fish lift or the Pawtucket Dam fish ladder. Upon entering the E.L. Field Power Canal dual-tagged adult shad proceeded quickly upstream to the downstream face of the Pawtucket Gatehouse (median duration = 0.8 hours). The median duration of time for dual-tagged adult shad to pass the Pawtucket Gatehouse was 5.4 days (range 3.3 days to 9.0 days). An additional 47 percent of the dual-tagged shad exhibited upstream movement following tagging and release at Lawrence but did not move the full length of the Merrimack River reach between the two Projects. The median duration of time for shad to move upstream from the release location at Lawrence to Lowell was 64.5 hours (2.7 days). The vast majority of those shad made one or more forays in the direction of the fish lift. Only a single dual-tagged shad was determined to have initiated an upstream ascent into the bypassed reach and in the direction of the fish ladder and two additional PIT-tagged shad entered the fish ladder. The overall effectiveness of the E.L. Field fish lift for adult American shad passage during 2020 was estimated at 30.4 percent (75 percent CI = 22.1-39.5 percent).

Of the 150 radio-tagged adult shad released upstream of Lowell, 79 percent approached the Pawtucket Dam and were available to evaluate downstream passage at the Project. The median upstream residence time prior to downstream passage was 3.9 days with 51 percent of individuals passing downstream in less than 96 hours after their arrival. The majority of individuals passed downstream of Lowell via the E.L. Field turbine units (26 percent), the downstream bypass (28 percent) or utilized the bypassed reach (38 percent). Of the 45 radio-tagged adult shad which were determined to have passed downstream via the bypassed reach, 89 percent were initially detected in the area immediately upstream of the Pawtucket Gatehouse prior to downstream passage. Of those same 45 individuals, 9 percent were determined to have entered and exited the Northern Canal via the Pawtucket Gatehouse prior to their eventual passage downstream via the bypassed reach.

Downstream passage survival was calculated as the joint probability of the three reach-specific survival estimates which encompasses the full section of the Merrimack River from Lowell downstream to Lawrence and resulted in an estimated downstream passage survival for adult shad at Lowell of 70.0 percent (75 percent CI = 64.5 percent-74.6 percent). This estimate of downstream passage survival for adult shad at Lowell included background mortality (i.e., natural mortality) for the species in the downstream reach, along with any tagging-related mortalities or tag regurgitations. As a result, this estimate should be viewed as a minimum estimate of total project survival (i.e., due solely to project effects) for adult American shad at the Project. The Fish Passage Survival Study

(NAI 2021f) used the TBSA tool to estimate survival for American shad and river herring. The TBSA produced a range of survival estimates for American shad and river herring turbine survival through the Project’s E.L. Field powerhouse Kaplan units. Within that range of estimates, the probability of mortality due to blade strike increased as body size increased. In the case of adult alosines, the TBSA model tended to overestimate turbine survival when compared to the 2019 empirical results from the Upstream and Downstream Adult Alosine Passage Assessment (NAI 2021c).

Table E.7-21. TBSA predicted survival estimates for juvenile American shad and river herring at the E.L. Field powerhouse.

Species/Life Stage	Size potentially encountered the region (in)	Body Length (inches)				
		8	12	16	20	25
American shad (adult)	15-23			89.0%	86.4%	83.1%
River herring (adult)	9-13	94.8%	91.8%	89.0%		

The Instream Flow Habitat Assessment and Zone of Passage Study (NAI 2021e) used River 2D (a two-dimensional hydraulic model) to assess the relationship between bypass flow and upstream passage through the bypassed reach. The zone of passage model was developed for three adult migratory species: American shad, blueback herring, and alewife. The 2.5 ft depth criteria for American shad showed that near full connectivity did not occur throughout the bypass reach until flows exceeded 4,000 cfs. This modeled lack of passage zones at low flows was largely due to the deep passage criteria for shad. Because the deep depth criteria may not be realistic for shad swimming through natural channels (as opposed to jumping weirs or ascending ladders), this analysis was re-run using 1.0 ft depth criteria, which is the depth criteria for river herring. Decreasing the depth criteria from 2.5 ft to 1.0 ft for shad resulted in almost continuous passage opportunities at just under 500 cfs, with multiple continuous pathways becoming available at flows of 1,000 cfs and above. Depth suitability for shad passage continued to increase at higher flows and velocities largely remain suitable for shad until flows exceed 6,000 cfs.

Passage conditions for river herring (blueback herring and alewife), using 1.0 ft minimum depth criteria show almost continuous passage opportunities at 482 cfs with multiple continuous pathways becoming available at flows over 1,000 cfs. Because the herring velocity criteria is somewhat slower than for American shad, the model predicted more impassable area within the bedrock channels due to rapid currents. However, it appears likely that herring could ascend the channels along the bottom or along the margins at 482 cfs. Velocities within the bedrock habitat increase with increasing flows, with excessive velocities through the bedrock at flows over 4,000 cfs.

Atlantic Salmon Passage

Efforts to restore Atlantic salmon (*Salmo salar*) to the Merrimack River were discontinued in 2013 after consistently low return numbers were observed (and shifting priorities within the USFWS, the primary funding agency), but the species may still occasionally be present in the Project area. Efforts since 2013 have shifted towards the restoration of the

remaining migratory fish species, notably river herring and shad (Cleantech Analytics 2017). Atlantic salmon counts are available for the Lawrence Project downstream (Table E.7-16).

In 1996, a radio telemetry study was performed to determine the extent to which the Lowell and Lawrence downstream fish bypass systems are used by radio-tagged Atlantic salmon smolts. The fish bypass systems at both the Lowell and Lawrence Hydroelectric Projects were not found to be effective at passing radio-tagged Atlantic salmon smolts, and at both sites, most of the downstream passage was through the turbines. At the Lowell Project, 13 percent of the radio-tagged salmon used the bypass, a significant increase compared to the 4 percent bypass usage by radio-tagged salmon in 1990. Only four (15 percent) of the radio-tagged salmon that passed the Lowell Project made it downstream to the Lawrence Project's headpond and of these, none were recorded passing the Lawrence site. Predation appears to have been a factor in the disappearance of some radio-tagged salmon released upstream of both hydroelectric sites (NAI 1996).

The effectiveness of the Lowell Project at safely passing downstream migrating Atlantic salmon smolts, as well as passage routing and turbine survival was evaluated in 2001. Using twenty radio-tagged salmon smolts to test three bypass flows, fish bypass efficiency at the Lowell Project averaged 32 percent and ranged from 15 percent passage with a bypass flow of approximately 2 percent of turbine flow to 42 percent passage with approximately 4 percent bypass flow. No turbine-passed fish appeared to be injured as a result of turbine passage. Similar to the 1996 study, predation in the tailrace and downstream of the Project seem to have a substantial impact on the survival rates of salmon smolts emigrating past the Lowell Project (Boott 2001).

E.7.3.1.5 Essential Fish Habitat

Based on a review of the NMFS online database, the Lowell Project reach of the Merrimack River is designated essential fish habitat (EFH) under the Magnuson-Stevens Fishery Conservation and Management Act for Atlantic salmon (National Oceanic and Atmospheric Administration [NOAA] undated). Essential fish habitat was defined as "all waters currently or historically accessible to Atlantic salmon within the streams, rivers, lakes, ponds, wetlands, and other waterbodies of Maine, New Hampshire, Vermont, Massachusetts, Rhode Island, and Connecticut" (New England Fishery Management Council [NEFMC] 1998).

E.7.3.1.6 Benthic Macroinvertebrates

Benthic macroinvertebrates (BMI) are small aquatic organisms and the aquatic larval stages of insects. They include dragonfly and stonefly larvae, snails, worms, and beetles. They lack a backbone, are visible without the aid of a microscope, and are found in and around waterbodies during some period of their lives. Benthic macroinvertebrates are often found attached to rocks, vegetation, logs and sticks or burrowed into the bottom sand and sediments (USEPA undated). These organisms provide a link between a system's primary productivity and its aquatic consumers through the conversion of plant biomass to consumable energy. Benthic macroinvertebrates can be useful indicators of

water quality because many species have a wide range of tolerances to pollution. Ephemeroptera (mayflies), Plecoptera (stoneflies), and Trichoptera (caddisflies) (EPT) species are highly sensitive to pollution. Furthermore, EPT species are high-quality forage for a variety of freshwater fish species.

In recent years, the MADEP, NHDES, the Merrimack River Initiative (MRI), and numerous smaller watershed committees have begun conducting macroinvertebrate biomonitoring studies in the Merrimack River basin (USACE 2003). According to the USACE (2003), benthic macroinvertebrate sampling was conducted at 44 locations throughout the Merrimack River Basin (10 mainstem and 34 tributary). Artificial substrates were deployed in August 1994 and collected seven weeks later after a colonization period. The results of the MRI study were published in November 1996 in a two-part study report titled Merrimack River Bi-State Water Quality Report, Part One and the Merrimack River Bi-State Biomonitoring Report, Part Two.

As shown above in Table E.7-13, the Instream Flow Habitat Assessment and Zone of Passage Study identified that benthic macroinvertebrates showed the highest estimates of WUA of all species groups, with a maximum of 24,062 m² at 2,000 cfs, and maintained high habitat values (>10,000 m²) from 500 cfs to 10,000 cfs. The 2D model predicted suitable habitat for BMI throughout the Bypass Reach, although the highest quality habitat occurred in the upper end of the reach and near the bottom of the reach.

Three macroinvertebrate species of management concern that are entirely or semi-aquatic potentially reside in the Lowell Project vicinity of the Merrimack River. These species include the eastern pondmussel (*Ligumia nasuta*), the cobra clubtail (*Gomphus vastus*) and the umber shadowdragon (*Neurocordulia obsoleta*). These species were identified as species of special concern in Massachusetts (Commonwealth of Massachusetts 2018 a).

E.7.3.1.7 Aquatic Invasive Species

Invasive species are defined as non-indigenous plant or animal species that aggressively compete with native species. These species often out-compete local native species, impacting biodiversity, recreation, and human health. The Merrimack River supports a relatively large number of invasive species. The Invasive Plant Atlas of New England (IPANE), NHDES, and the MRWC identifies the species listed in Table E.7-22 as potentially occurring in the general vicinity of the Project. Those species that were observed during field studies performed at the Project are indicated with an asterisk (*).

Table E.7-22. Aquatic Invasive Species Likely to Occur in the Project Vicinity

Common Name	Scientific Name
Common reed*	<i>Phragmites australis</i>
Curly-leaved pondweed	<i>Potamogeton crispus</i>
Eurasian water milfoil	<i>Myriophyllum spicatum</i>
Carolina fanwort	<i>Cabomba caroliniana</i>

Common Name	Scientific Name
Purple loosestrife*	<i>Lythrum salicaria</i>
Twoleaf milfoil	<i>Myriophyllum heterophyllum</i>
European water chestnut	<i>Trapa natans</i>
Yellow Iris	<i>Iris pseudacorus</i>
European water-clover	<i>Marsilea quadrifolia</i>
Watercress	<i>Nasturtium officinale</i>
Reed canarygrass	<i>Phalaris arundinacea</i>
Yellow iris	<i>Iris pseudacorus</i>
Flowering rush	<i>Butomus umbellatus</i>
Yellow floating heart	<i>Nymphoides peltata</i>
Asian clam	<i>Corbicula fluminea</i>

Sources: MRWC 2015; IPANE 2018

E.7.3.2 Environmental Analysis

FERC's SD2 identified effects of continued Project operations on fish and aquatic resources as potential resource issues. Specifically, SD2 identified the following needed to be analyzed for site-specific effects:

- 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.
- Effects of continued project operation on fish passage for migratory species, including American shad, river herring, and American eel.

The following potential resource issues related to fish and aquatic resources were identified to be analyzed for both cumulative and site-specific effects:

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

E.7.3.2.1 Site-Specific Effects

Effects of Continued Project Operation on Fish Passage for Resident and Migratory Species

The Merrimack River is home to a diverse assemblage of fish. Stolte (1982; as cited in the Merrimack River Technical Committee for Anadromous Fishery Management of the Merrimack River Basin, 1997) noted that during the last 150 years, over 15 non-indigenous species such as largemouth bass, smallmouth bass, walleye, common carp, rainbow trout, brown trout, various catfish species and goldfish have established through human introductions within the Merrimack River. At that time, the Merrimack River was identified as home to approximately 50 species of fish, nine of which were anadromous. The slower moving, ponded reaches of the Merrimack contain a higher predominance of warm-water species whereas those areas with higher gradient contain the majority of cold-water species. Hartel et al. (2002) identified a total of 57 reproducing fish species within the drainage; 21 primary species (i.e., those living full life cycle in freshwater), 8 secondary species (i.e., those with physiological capacity to move between fresh and salt water), 18 introduced species, and 10 diadromous species.

Fish assemblage sampling within the Lowell impoundment and bypass reach during the spring, summer and fall of 2019 resulted in the identification of 24 fish species. Of those species, 21 are considered freshwater and 3 are considered diadromous. The species collected during the 2019 sampling resulted in a similar and expected fish assemblage in the Project vicinity compared to existing information on the Merrimack River fish community (Hartel et al. 2002). Based on the results of the 2019 Fish Assemblage Study, approximately 75 percent of the composition of fish species in the impoundment and bypassed reach was comprised of five or less species in all sampling seasons (NAI 2021d). As expected, there is a slight seasonal shift in the fish community in both the impoundment and bypass reach. Table E.7-23 presents the most abundant fish species in the impoundment for each season and Table E.7-24 presents the most abundant fish species in the bypass reach for each season. Additionally, fish assemblage was found to differ based on habitat, as described in Section E.7.3.1.

Table E.7-23. Top five most abundant fish species each season in the impoundment from the 2019 Fish Assemblage Study.

Spring		Summer			Fall
Species	Percent Composition	Species	Percent Composition	Species	Percent Composition
Redbreast Sunfish	23.7	Redbreasted Sunfish	27.1	Spottail Shiner	33.9
Smallmouth Bass	21.9	Pumpkinseed	17.5	Alewife	16.8
Spottail Shiner	27.6	Spottail Shiner	10.9	Fallfish	13.7
Fallfish	5.9	Bluegill	10.7	Smallmouth Bass	9.2

Spring		Summer			Fall
Species	Percent Composition	Species	Percent Composition	Species	Percent Composition
Bluegill and White Sucker ¹	8.2	Smallmouth Bass	6.9	Redbreasted Sunfish	8.2
Total	87.3%	Total	73.1%	Total	81.8%

Note: 1 Bluegill and white sucker had the same percent composition (4.1 percent).

Table E.7-24. Most abundant fish species each season in the bypass reach from the 2019 Fish Assemblage Study.

Spring		Summer		Fall	
Species	Percent Composition	Species	Percent Composition	Species	Percent Composition
Spottail Shiner	48.8	Fallfish	55	Smallmouth Bass	64.2
Fallfish	27.5	Spottail Shiner	14.4	Margined Madtom	13.2
American Eel	12.5	Smallmouth Bass	10.9	Redbreast Sunfish	6.6
Bluegill	2.5	White Sucker	8.8	Tessellated Darter	3.8
Smallmouth Bass	2.5	American Eel	5.3	White Sucker	2.8
Total	93.8%	Total	94.4%	Total	90.6%

Overview of Migratory Species and Fish Passage

Existing information for the Project, along with the results of the studies completed by the Licensee in 2019 and 2020, demonstrate that existing operations under the terms of the current license and the Project’s CFPP are maintaining and supporting resident game and non-game fish species, as well as migrating anadromous fish, and habitat for aquatic species in the Merrimack River upstream and downstream of the dam.

The CFPP includes details of operational measures undertaken by Boott to protect upstream and downstream migrating anadromous fish. The CFPP is based on several fisheries studies conducted at the Project and experience gained at the Project since the installation of the Project’s fish lift and fish bypass facilities. The priority species for management at the Lowell Project are the catadromous American eel and three anadromous Alosidae species (American shad, blueback herring, and alewife). Atlantic salmon restoration is no longer a management focus for the Merrimack River. Because

of minimal fluctuation of the impoundment from Project ROR operation, the Project has little effect on overall river flow in the lower Merrimack River.

The licensee has consulted with the USFWS, New Hampshire Fish and Game Department (NHFGD), MADFW, and NMFS extensively regarding fish passage at the Project. Boott provides a post-season update on the fish passage at the Lawrence and Lowell Hydroelectric Projects annually and the agencies have the opportunity to recommend improvements to the fish passage facilities. The fish passage facilities at both Projects are continually monitored and modified to increase effectiveness at the agencies' requests and recommendations (Cleantech Analytics 2017).

The recent construction of the pneumatic crest gate was strongly endorsed by the Federal and state (both New Hampshire and Massachusetts) fishery agencies due to its anticipated benefits to migratory species. The USFWS, NMFS, MADFW, and NHFGD submitted letters of support to the Commission for the pneumatic crest gate system. The system allows rapid re-inflation following periods of high flow, which prevents delay in upstream fish passage which occurs with lost or damaged wooden flashboards. The pneumatic crest gate system is expected to maintain consistent water levels, reduce leakage from the dam, and minimize the need for impoundment drawdowns, which all provide improved fish passage and spawning habitat. The reduction in leakage is expected to improve upstream passage efficiency by decreasing false attraction flow at the dam (FERC 2011).

Boott is also proposing a seasonal suspension of generation and shutdown of the downtown canal system turbines during the downstream fish passage season (typically from May through November – and to be determined annually in consultation with the MRTC) and will not divert flows into the downtown canal system (*except as noted under Canal Water Elevations and Canal Water Flows in Section E.6.2*). This measure will reduce and/or eliminate attraction flows to these generating areas of the Project. As observed in 2019 and 2020 juvenile and adult alosine studies, respectively, the presence of both age groups in the downtown canal system was very low when the turbines were not operating. Most, if not all, fish are expected to bypass the Project via dam spill, the power canal, or the E.L. Field Powerhouse turbines.

On a seasonal basis during the upstream passage season (i.e., typically from early May through late June/early July – and to be defined annually in consultation with the MRTC), Boott is proposing to provide a zone of passage flow of 500 cfs or inflow, whichever is less, into the Project's bypassed reach to provide appropriate fish passage conditions. Boott proposes to release a minimum flow of 100 cfs or inflow, whichever is less, to the bypass reach downstream of the Pawtucket Dam during the period outside of the upstream fish passage season. The minimum flow would be provided as spillage over one or more of the crest gate zones.

American Eel Passage

The impoundment and river segment in the vicinity of the Project would be suitable for foraging, growth, and development of American eel prior to their downstream spawning migrations. American eels are adaptable and can utilize a wide range of riverine, lake, or reservoir habitat (McCleave 2001, Greene et al. 2009). The passage of American eel

upstream of hydropower dams can expose the eventual out-migrating silver eels to migratory delay at each dam and mortality when passing through turbines or over spillways.

A radio-telemetry assessment of the downstream passage success for adult silver-phase American eels was performed during the fall of 2019 (NAI 2021a). Monitoring of outmigrating adult American eels focused on the evaluation of movement through the Project impoundment, residence time immediately upstream of the Pawtucket Dam and prior to passage, passage route utilization and estimation of downstream passage survival at the Project. During the 2019 American Eel Passage Assessment, the majority of American eels (92.5 percent) passed downstream of Lowell via the E.L. Field turbine units, while two eels used the downstream bypass and four eels used the bypassed reach (NAI 2021a). No eels were documented in the Project's downtown canal system (NAI 2021a). The limited use of the downstream bypass system at E.L. Field is similar to the results of the 2018 downstream eel passage evaluation.

Downstream passage survival was estimated for all radio-tagged eels from the point of initial detection upstream of the Pawtucket Dam downstream to Lawrence. This resulted in an estimated downstream passage survival for silver-phase American eel at Lowell of 75.5 percent (75 percent CI = 71.4 percent-79.6 percent). This estimate of downstream passage survival for adult eels at the Project includes any background (i.e., natural) or tagging-related mortality for the species in the reach from approach to the Pawtucket Dam to Lawrence. As a result, this estimate should be viewed as a minimum estimate of total Project survival (i.e., due solely to Project effects) for adult eels at the Project. Due to the limited distribution of downstream passage route selection, route-specific estimates of passage were developed for only individuals using turbine units at the E.L. Field Powerhouse (n = 136; 75.0 percent survival; 75 percent CI = 70.6 percent-79.4 percent). The limited number of radio-tagged eels passing the Project via spill or the downstream bypass system were all determined to have successfully approached the Lawrence Project following downstream passage at Lowell (NAI 2021a).

A TBSA model was conducted as part of the Fish Passage Survival Study (NAI 2021f) for American eel. The estimated range of survival for eels passing downstream through the E.L. Field turbines ranged from 71-39 percent, with the predicted rate of survival for adult eels decreasing as body size/length increased. In the case of adult eels, the TBSA model tended to underestimate turbine survival when compared to the empirical results from the Downstream American Eel Passage Assessment.

We anticipate that the majority of outmigrating eels will continue to use the Pawtucket Gatehouse and approach the E.L. Field Powerhouse during nighttime and overnight hours for passage as they migrate downstream. As such, Boott is also proposing interim nighttime shutdowns from August 15 to November 15 each year until the full implementation of the proposed downstream passage protection measures (as outlined in Section A.2.12 and Section B.1.3.5). This interim measure aims to protect outmigrating adult American eels that could be in the Project area. During the 2019 American eel study, no tagged adult eels were documented in the Project's downtown canal system. With these additional interim measures, we expect further prevention of eels from utilizing these areas of the Project.

American shad and river herring passage

The presence of herring in the Merrimack River appears to be strong in recent years. In 2016, record numbers of herring (since the establishment of the restoration efforts,) were observed at the Amoskeag Dam, upstream of the Lowell project. The returns have been so successful that the large number of herring ascending the fish ladder at the Amoskeag Dam overwhelmed the trap and truck operation in 2016 (Cleantech Analytics 2017). In 2018, the Lawrence facility passed river herring upstream in the highest number (418,689) since the project was built over 30 years ago, and the Lowell project passed about 58 percent of those fish upstream, through its fish lift (62,421) and fish ladder (182,268) (Enel 2018). In 2016, 70 percent of the herring that passed at Lawrence also passed at Lowell (Enel 2016). Also, in 2018, while only 26,347 American shad were passed upstream at Lawrence, 56 percent of those were passed through the Lowell project, through its lift (4,630) and ladder (10,171). The high ratio of passage success for shad from Lawrence through Lowell is the highest ever observed in over 30 years of passage comparison (Enel 2018).

During the 2019 Juvenile Alosine Downstream Passage Assessment, 83 percent of juvenile alosines eventually passed downstream via the turbine units. Use of the existing downstream bypass system was estimated at 17 percent (NAI 2021b). A small percentage (2.1 percent) of the radio-tagged juvenile alosines approaching the dam were detected in the downtown canal system. The majority of individuals passed downstream of the Project, with 9.2 percent over the Pawtucket Dam via spill, 12.0 percent navigating through the power canal and using the downstream bypass near the E.L. Field Powerhouse, and 57.7 percent passing through the turbine units. During the migration season, Boott will shut off the downtown canal system turbines and will not divert flow into the downtown canal system (*except as noted under Canal Water Elevations and Canal Water Flows in Section E.6.2*), reducing and/or eliminating attraction flows to this area of the Project. Subsequently, as observed during study period, juvenile alosine presence in this section during turbine shutoff is expected to be minimal or nonexistent. Most, if not all, will bypass the Project via dam spill, power canal, or through the E.L. Field Powerhouse turbines.

During the 2019 Adult Alosine Downstream Passage Assessment, the majority of adult alewives passed downstream of Lowell via the E.L. Field turbine units (52 percent of radio-tagged alewives) or utilized the downstream bypass (45 percent of radio-tagged alewives). A small percentage (2 percent) of radio-tagged adult alewives passed downstream through the downtown canal system rather than remaining in the mainstem Merrimack River. As noted above, a similarly low presence of adult alewives is expected in the downtown canal system during the outmigration season, due to the lack of attraction flows from the non-operating turbines.

During 2020, the overall effectiveness of the E.L. Field fish lift for adult alewife passage was estimated at 43.9 percent, while the overall effectiveness of the Pawtucket Dam fish ladder for adult alewife passage was estimated at 75.6 percent. Also, during 2020, the overall effectiveness of the E.L. Field fish lift for adult American shad passage during 2020 was estimated at 30.4 percent, while only two tagged shad utilized the fish ladder (NAI 2021c). The Fish Passage Survival Study (NAI 2021f) used the TBSA desktop tool

to estimate total project survival for juvenile alosines at the Project. Estimates of turbine passage were inversely related to body length for each species/life stage considered with highest survival estimated for small juvenile shad or herring at two inches of length (~99 percent), and total project survival at Lowell for juvenile alosine-sized fish is estimated at 94.8 percent. Passage failures were attributed to fish passing downstream via the turbines (2.1 percent of total losses) and the downstream bypass facility/spill (3.1 percent of total losses).

The TBSA analysis conducted for adult alosines as part of the Fish Passage Survival Study produced a range of survival estimates for turbine survival through the Project's E.L. Field powerhouse Kaplan units. Within that range of estimates, the probability of mortality due to blade strike increased as body size increased. In the case of adult alosines, the TBSA model tended to overestimate turbine survival.

Effects of continued project operation on the aquatic macroinvertebrate community in the impoundment, canal system, bypassed reach, and Merrimack River

The pneumatic crest gate minimizes impoundment fluctuations and therefore helps to protect benthic macroinvertebrate communities and fish habitat within the littoral zone of the Project impoundment. Boott proposes to continue to operate the Project in ROR mode, for the purpose of protection of fish, aquatic habitat, and wildlife resources. Boott will also shut down the downtown canal system turbines during the anadromous migratory season to eliminate attraction flows and prevent fish from entering this part of the Project.

Hydroelectric projects have been shown to influence benthic macroinvertebrate communities by altering flow conditions and thereby habitat, water quality, and instream transport processes. The severity of impact on aquatic resources is largely influenced by the extent of flow regulation. The Project operates as a ROR facility, which uses the natural flow of the water to produce electricity. As such, flow regulation is minimal at ROR projects, which are often considered low impact facilities compared to peaking and storage hydroelectric projects. Although hydropower operations may affect the macroinvertebrate communities to some degree, the Licensee anticipates that the continued ROR operation of the Project will not affect macroinvertebrate communities.

Based on available information, the canals do not offer significant habitat for aquatic species. The canal beds consist of ledge, concrete, or wood-planked virgin soil, and there is little cover or structure to attract fish (Boott 2017).

Excess flows of up to approximately 2,000 cfs may be routed through the downtown canal system. NAI did not detect any use of the downtown canal system by outmigrating radio-tagged eels in 2019. Only two percent of all radio-tagged outmigrating juvenile alosines were determined to have entered the canal system, and there were no radio-tagged outmigrating adult shad determined to have utilized the downtown canal system. Furthermore, only a small percentage (2 percent) of radio-tagged adult alewives were detected migrating downstream through the downtown canal system, with the majority remaining in the mainstem Merrimack River. To prevent attraction flows and reduce fish

entry into the downtown canal system, Boott will cease operation of turbines and flows will not be diverted into the downtown canal system (*except as noted under Canal Water Elevations and Canal Water Flows in Section E.6.2*) during the downstream migration season (generally occurs between May through November – and to be determined annually based on consultation with the MRTC).

On a seasonal basis during the upstream passage season (i.e., typically from early May through late June/early July – and to be defined annually in consultation with the MRTC), Boott will provide a zone of passage flow of 500 cfs or inflow, whichever is less, into the Project's bypassed reach to provide appropriate fish passage conditions.

Boott proposes to release a minimum flow of 100 cfs or inflow, whichever is less, to the bypass reach downstream of the Pawtucket Dam during the period outside of the upstream fish passage season. The minimum flow would be provided as spillage over one or more of the crest gate zones.

Under the proposed measures, Boott will maintain the water elevations within the canal at the target elevations specified year round and will maintain flows. Boott will also develop a Water Quality Management Plan in consultation with the MADEP within one year of the effective date of the Project's license. In addition, Appendix A in Volume 1 provides a Canal Drawdown Plan and details the process and coordination to follow in support of canal drawdowns. The coordination with stakeholders in drawdown planning should further minimize potential impacts to fish and aquatic species during drawdown events.

Effects of Construction of Downstream Fish Passage Exclusion Facility and Upstream Passage Facilities

Boott proposes to design and install a downstream fish protection system (i.e., a new fish exclusion structure or approved equivalent). Downstream passage of fish will continue to be provided via the existing sluice gate in the left forebay wall of the E.L. Field Powerhouse. The design of the downstream fish protection system will be developed in consultation with the Agencies and approved by the USFWS and NMFS, and will be designed, constructed, and operated consistent with the latest version of the USFWS's Fish Passage Engineering Design Criteria and the FOMP.

Boott anticipates routing all flow into the bypassed reach during the installation of the proposed fish exclusion facility. This is not expected to have any adverse effects on migratory fish and other aquatic resources. The Upstream and Downstream Adult Alosine Passage Assessment by Normandeau Associates (filed with FERC on November 1, 2021) indicated high rates of survival for downstream-passing American shad via spill over the Pawtucket Dam. Use of the bypassed reach (i.e., spill or usage of the attraction water gate associated with the upstream fish ladder) was observed for 38 percent of the radio-tagged adult shad which approached the Project. Model results reported in the study show an adult American shad passage success rate via spill of 89.2 percent (the highest of all the downstream passage routes).

The individual alewife that passed via spill over the Pawtucket Dam was detected at the downstream Lawrence Hydroelectric Project (P-2800). The Downstream American Eel Passage Assessment (filed with FERC on November 1, 2021) determined that all of the

limited number of downstream-passing American eels that passed the Project via spill successfully approached the downstream Lawrence Hydroelectric Project. Diversion of flows into the bypassed reach is expected to have minimal impact to upstream fish passage given that construction is not likely to occur until the season is complete (mid-July). Boott anticipates diversion of flows into the bypassed reach will not adversely affect other aquatic resources, as conditions within the bypass will be similar to those that existed prior to the construction of the Project's E.L. Field powerhouse.

In addition to the new fish protection system, Boott will design and install a downstream fishway that will be integral to the fish protection system. During the first year of construction (2 years after license issuance) Boott will coordinate the construction of the proposed new system during an extended outage at the E.L. Field powerhouse, with the forebay dewatered and all inflow passed via the bypassed reach. Construction during this phase is expected to have minimal impact on fish and aquatic habitat because all inflows will be passed over the Pawtucket Dam into the bypassed reach, and conditions within the bypass will be similar to those that existed prior to the construction of the Project's E.L. Field powerhouse. Once the new structures are completed, the exit portion of the new fish ladder would be constructed 3 years after license issuance. During this phase the Project will resume normal operations with the E.L. Field powerhouse online and bypassed minimum flows maintained. Aquatic habitat conditions within the bypassed reach would be similar to those under normal operations. The construction area within the bypassed reach would likely be isolated within a small cofferdam.

Construction activities are tentatively planned to commence immediately following the end of the upstream passage season in early July. Thus, the majority of construction is tentatively planned to occur between July and November of each year. This is outside of the upstream fish passage season for American shad and river herring; thus construction is not anticipated to have effects on shad and herring upstream fish passage.

Construction will occur during the downstream passage seasons for juvenile American shad and river herring, as well as downstream and upstream American eel passage. However, downstream passage events for these species are typically more frequent at night, whereas a typical construction day will be 8:00 AM to 5:00 PM depending on environmental conditions. Also as noted, flows will be directed over the Pawtucket Dam and thus that is the primary route of passage for out-migrating species. Boott is also proposing interim nighttime shutdown measures to protect outmigrating adult American eel between August 15 and November 15 of each year until the proposed downstream passage protection measures are fully implemented (as discussed more under Section A.2.12 and Section B.1.3.5).

Proposed construction would produce noise effects; however, given that it is located in the City of Lowell, the noises would be a part of the surrounding densely populated urban environment. Sounds produced from equipment would be intermittent and at various noise levels given the different construction tasks. Construction sounds are most likely to be highest in the immediate vicinity of construction area and diminish with distance from the work areas. Construction noise would also be generated by trucks and other light vehicles traveling in and near construction areas at the E.L. Field Powerhouse. No changes in road conditions are anticipated as a result of the work.

E.7.3.2.2 Cumulative Effects

In SD2, the Commission identified that migratory fish resources could be cumulatively affected by the continued operation of the Project in combination with other hydroelectric Projects on the river. The geographic scope for the cumulative effects analysis on migratory fish is the Pemigewasset River from the Eastman Falls Dam and the Winnepesaukee River from the Lakeport Dam to the confluence of the Winnepesaukee and Pemigewasset Rivers (which form the Merrimack River), and the Merrimack River downstream to the Atlantic Ocean.

Boott believes that the continued operation of the Project, as proposed, will limit cumulative effects on the aquatic habitat, and resident and migratory fisheries resources in the impoundment, canal system, bypass reach, and Merrimack River based on the proposed minimum flow, proposed seasonal downtown canal system turbine shut off during migratory fish season, interim nighttime shutdowns between August 15 through November 15 until proposed downstream passage protection measures are fully implemented, operating the Project to maintain water quality standards, operating the pneumatic crest gate per the operation plan approved by FERC on March 30, 2015, operating fish passage facilities consistent with the CFPP approved by FERC on November 28, 2000.

The current operation of the Project has been designed to consider and support ongoing efforts to maintain resident and migratory fisheries to the Merrimack River Basin. The Project is operated in a ROR mode, consistent with minimum flow requirements, in order to comprehensively address river flows and related hydroelectric project operations to best support aquatic life downstream of the Project, including migratory fish species. Boott has undertaken substantial enhancements in the form of upstream and downstream passage measures at the Project, which should continue to minimize any cumulative effects to fisheries resources in the Merrimack River resulting from operation of the Project. As stated above, Boott also proposes a seasonal shutdown of the downtown canal system turbines and flows will be diverted into the downtown canal system (*except as noted under Canal Water Elevations and Canal Water Flows in E.6.2*) during the migratory fish season to eliminate attraction flows that could draw migratory fish into the canal system.

Similarly, Boott has undertaken a number of studies relative to fish restoration efforts at the Project that are designed to assess not only direct Project effects on fishery resources, but also to examine the potential cumulative effects of the Project on the overall migratory fish restoration efforts.

Operation of the Project may cumulatively affect migratory fish species including American eel, American shad, river herring (alewife and blueback herring). 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 are currently in place at the Project. To date, there has been no significant mortality observed or documented at the Project. Any mortality that may occur from entrainment or impingement of fish species at the Project would contribute to the cumulative effect of the fisheries in the Merrimack River.

Notably, in its 2007 finding on the petition to list the American eel, the USFWS found that:

- The species is highly resilient.
- The reproductive contribution of eels from coastal and estuarine habitat is substantial, and habitat in the lower reaches of a watershed produces more eels than habitat higher in the watershed.
- Loss of habitat resulting from dams does not threaten the long-term persistence of the American eel.
- American eels are able to navigate many barriers.
- Turbines can affect the regional abundance of eel, but no evidence indicates that turbines are affecting the species at the population level (USFWS 2007).

E.7.3.3 Proposed Environmental Measures

Boott proposes continued operation of the Project with certain environmental PM&E measures consistent with the measures required by the Project's existing license. Boott believes that the continued operation of the Project, as proposed, will limit effects on fish and aquatic resources. Specifically:

Project Facilities and Operations

- Boott proposes to operate the Project in a ROR mode using automatic pond level control of the E.L. Field powerhouse units, for the purpose of protection of fish and wildlife resources downstream from the Project. ROR operation may be temporarily modified for short periods to allow flow management for other project and non-project needs, e.g., downtown canal water level management, raising the crest gates following a high-water event, or for recreational purposes.
- On a seasonal basis during the upstream passage season (i.e., typically from early May through late June/early July – and to be defined annually in consultation with the MRTC), Boott will provide a zone of passage flow of 500 cfs or inflow, whichever is less, into the Project's bypassed reach to provide appropriate fish passage conditions.
- Boott proposes to release a minimum flow of 100 cfs or inflow, whichever is less, to the bypass reach downstream of the Pawtucket Dam during the period outside of the upstream fish passage season. The minimum flow would be provided as spillage over one or more of the crest gate zones.
- Boott proposes to suspend generation and operations of the downtown canal units during fish passage season (which generally occurs between May and November – and to be determined annually in consultation with the MRTC). At the start of the fish passage season, all downtown canal units will be shut off and flows will not be diverted into the downtown canal system (*except as noted below under Canal Water Elevations and Canal Water Flows*). At the end of the fish passage season, when river flows exceed the hydraulic capacity of the E.L. Field

units (6,600 cfs for both units) and the bypass flow, excess flows up to approximately 2,000 cfs may be routed through the downtown canal system and to the canal units.

- Between August 15 and November 15 of each year until the proposed downstream passage protection measures are fully implemented (as discussed more under Exhibit A Section A.2.12 and Exhibit B Section B.1.3.5), Boott is proposing nighttime shutdowns as an interim measure to protect out-migrating adult American eel.
- Boott proposes continued adherence to the requirements of the Project's existing Crest Gate Operation Plan (approved by FERC on March 30, 2015).

Canal Water Flows

Boott is actively collaborating with key stakeholders to finalize the COMP. Once the COMP is finalized, a copy of the Plan will be submitted to FERC for approval and inclusion in the new license. One of the primary components being addressed is the management of canal water flows.

Canal Water Elevations

Boott is actively collaborating with key stakeholders to finalize the COMP. Once the COMP is finalized, a copy of the Plan will be submitted to FERC. One of the primary components being addressed in the COMP is the management of canal water elevations.

Fish Passage

Boott is proposing modifications to the existing upstream and downstream fish passage structures consistent with August 12, 2022, Settlement Agreement for Fish Passage. Since 2022, fish passage technology has continued to advance, and Boott remains open to meeting passage requirements under the Settlement Agreement for Fish Passage through innovative and emerging solutions that may be available or anticipated to enter the market. Boott will continue to collaborate with all relevant stakeholders and FERC in exploring potential options, if any. Proposed fish protection measures include:

- Boott proposes to replace the existing fish lift with a short fish ladder to pass migratory fish from the E.L. Field powerhouse tailrace to the bypass reach, such that fish would be passed upstream of the Project via the existing fish ladder at the Pawtucket Dam. As approved by the MRTC, the proposed fish ladder will be operated on a seasonal basis. In accordance with the Settlement Agreement, Boott will consult with the MRTC member agencies to determine the design and installation schedule for the proposed ladder or approved equivalent.
- Following installation and operation of the proposed upstream fish passage structure, Boott proposes to cease operation of the fish elevator and associated operations described above. Cessation of the fish elevator operations will be determined based on consultation with relevant agencies

and Boott will not continue to incur maintenance costs once the upstream passage structure is constructed and tested.

- Boott proposes to install a new fish exclusion structure or approved equivalent at the E.L. Field Powerhouse to prevent entrainment of fish through the turbines. Downstream passage of fish will continue to be provided via the existing sluice gate in the left forebay wall of the E.L. Field Powerhouse. Boott will consult with the MRTC member agencies to determine the design and installation schedule for the proposed downstream fish exclusion system. Boott reserves the right to seasonally deploy the new exclusion facility only during the downstream fish passage season.
- Between August 15 and November 15 of each year until the proposed downstream fish passage protection measures are fully implemented, Boott is proposing nighttime shutdowns as an interim measure to protect out-migrating adult American eel. Interim nighttime shutdowns will be implemented in accordance with the provisions of the Interim Nighttime Shutdown Plan for Downstream Eel Passage developed in consultation with the MRTC pursuant to Section 4.2 of the Settlement Agreement.
- Additionally, Boott proposes to release a minimum flow of 100 cfs or inflow, whichever is less, to the bypass reach downstream of the Pawtucket Dam during the period outside of the upstream fish passage season. The minimum flow would be provided as spillage over one or more of the crest gate zones. On a seasonal basis during the upstream passage season (i.e., typically from early May through late June/early July – and to be defined annually in consultation with the MRTC), the Licensee will provide a zone of passage flow of 500 cfs or inflow, whichever is less, into the Project's bypassed reach to provide appropriate fish passage conditions.

E.7.3.4 Unavoidable Adverse Impacts

Unavoidable adverse impacts are those effects that may still occur after implementation of PM&E measures. Operation of the Project may continue to result in the delay or entrainment of American eels, American shad, river herring, Atlantic salmon, striped bass, sea lamprey, and other resident species, but these effects are expected to be limited in scope and will not have an effect at the population level.

E.7.4 Terrestrial Resources

The subsections below describe terrestrial resources in the vicinity of the Project and consider the effects of continued operation of the Project as proposed by the Licensee on these resources. Descriptions of the affected environment, the environmental analysis, the proposed environmental measures, and the identification of unavoidable adverse effects were developed based on available data presented in the Licensee's

PAD, other existing information, and from the results of the Recreation and Aesthetics Study performed by Boott (HDR 2021a), included in Appendix B of this exhibit.

E.7.4.1 Affected Environment

The Merrimack River watershed encompasses approximately 5,010 square miles within the states of New Hampshire and Massachusetts. It is the fourth largest watershed in New England. Although the Merrimack River watershed is heavily forested (75 percent of the land area is covered with forest), it also supports all or parts of approximately 200 communities with a total population of 2.6 million people (USEPA 2020b; USACE 2006).

Ecoregions are used to provide general understandings of vegetation, wetland, and terrestrial habitat in an area (USEPA 1997). The Merrimack River watershed is located in both the Northeastern Highlands ecoregion and the Northeastern Coastal Zone. The north and westerly portions of the watershed, located in the Northeastern Highlands, are characterized by low mountains and mostly ungrazed forest and woodland. The southern portion of the watershed is located in the Northeastern Coastal Zone, which is characterized primarily as modified woodland and forest. However, the states of New Hampshire and Massachusetts report that undeveloped open space along the Merrimack River watershed generally decreases further downstream as riverfront communities are more industrialized (MEOEEA 2001; NHDNCR 2018).

Along the upper northern boundary of the Merrimack River watershed, the relatively undeveloped White Mountain National Forest in New Hampshire provides almost 800,000 acres of protected land; this region also provides over one million acres of private forest and agricultural land (NHDNCR 2018). The Project dam is located at RM 41 on the Merrimack River, and the impoundment extends upstream approximately 23 miles almost to the City of Manchester in New Hampshire. The Project impoundment is characterized by the urban/industrialized cities of Nashua, New Hampshire and Lowell, Massachusetts. In the vicinity of the Project in Lowell, Massachusetts, the Merrimack River flows through a region of rapid population growth and development stemming from the 1800s that is still heavily influenced by the growing Boston urban metropolitan area (Figure E.7-17).

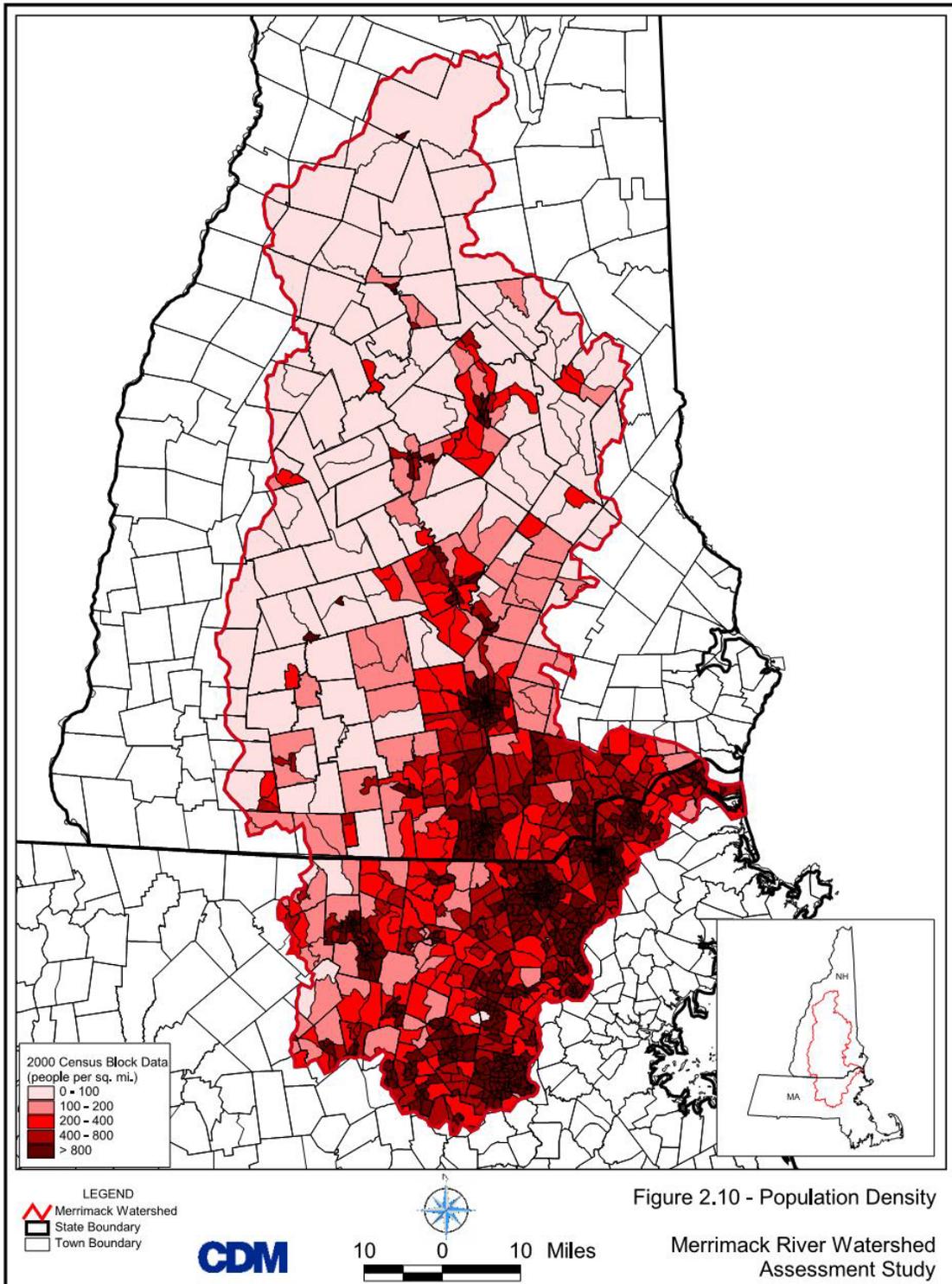
The area near the Project's dam and E. L. Field powerhouse is urban in nature and the vegetation found within the project area is typical of an urbanized setting in this region. The project area has sparsely vegetated shorelines and a narrow riparian corridor consisting of grasses, weeds, and scattered wild shrubs. Early successional/young forest/shrub lands cover types occur in scattered patches along the shoreline of the river intermixed with small stands of mature forest and disturbed sites (fill slopes and millwork areas adjacent to developed sites) (FERC 2011). The developed lands nearby include the University of Massachusetts - Lowell, a variety of housing and residential subdivisions and an extensive network of roads and highways. The area south of these primary power-generating facilities includes several industrial sites, and the bisecting 5.5-mile downtown canal system.

The Merrimack River watershed's land use composition, from the relatively undeveloped White Mountain National Forest in northern New Hampshire to highly urbanized areas

along the mainstem of the Merrimack River, is reflected in the basin's general land use and terrestrial resources (Figure E.7-18).

For purposes of describing the existing condition of terrestrial wildlife and botanical resources, this discussion has been divided into the following subsections: (1) botanical resources, (2) wetland, riparian, and littoral habitat, and (3) wildlife. As appropriate, these subsections describe other germane studies conducted by Boott relative to their resource areas.

Figure E.7-17. Population Density in the Merrimack River Basin



Source: USACE 2002

Source: Merrimack River Watershed 2018.

E.7.4.1.1 Recreation and Aesthetics Study

In accordance with the Commission's SPD, Boott conducted a Recreation and Aesthetics Study to determine the adequacy and capacity of existing recreational facilities, assess potential effects of water levels and flow rates on existing recreational facilities, other forms of recreational assessments, and identify areas within the canal system where vegetation growth on historic canal walls are a concern. Methods and results of the Recreation and Aesthetics Study are described in detail in Boott's Recreation and Aesthetics Study report (HDR 2021a) which was filed with the Commission on February 25, 2021. A portion of the results of this study were used to help form the baseline characterization of terrestrial habitat and wildlife within the Project area; as such the study methods are summarized in this section, with the relevant results discussed in the subsections below.

Boott conducted a Recreation and Aesthetics Study, in part, to identify areas within the canal system where vegetation growth on historic canal walls are a concern, including background literature reviews, desktop analyses, and field investigations.

The visual survey for vegetation growth was conducted between September 25 and 27, 2019. The survey was conducted to identify vegetation growth along the canal walls within the study area. Technicians identified the relative quantity and spatial distribution of each vegetation type using aerial photography and observations of habitat and specific plant species occurrences. Terrestrial vegetation types occurring in the study area were described based on a review of existing information, an inspection of aerial photography, a review of the USGS 7.5-minute quadrangles, and observations of habitat and specific vegetation type occurrences during the field surveys.

For the purposes of examining vegetation type distribution, the study area was divided into the six canals associated with the Lowell Project canal system including: 1) Pawtucket Canal, 2) Northern Canal, 3) Western Canal, 4) Merrimack Canal, 5) Eastern Canal, and 6) Hamilton Canal.

Visual qualitative surveys were conducted in the study area by foot along the shorelines of the canals, or via an NPS boat for the surveys conducted in the Pawtucket Canal from the Swamp Locks and Dam to the Merrimack River. Vegetation was characterized by dominant type (i.e., Herbaceous, Scrub-Shrub, Trees, Forested, or Mixed). The vegetation type assessments were based on overall dominant vegetation characteristics at the time of the survey that may have variations within small areas. In addition, the shoreline/canal was characterized by dominant features (i.e., Block Wall, Concrete, Earthen/Terrestrial Cultural, Stone Wall, Block Wall/Concrete/Stone Wall Mix).

Mapped Vegetation Polygons and Vegetation Points (VPs)¹⁴ were located using an EOS Positioning Systems Arrow 100™ GNSS receiver linked to an iPad™ Air 2 or Android device operating Collector for ArcGIS™ hand-held Global Positioning System (GPS) unit (equipped with a data dictionary aiding in feature attribution). The presence and extent of

¹⁴ Vegetation points were used to identify areas along canal walls where a single vegetation type point was recorded. Vegetation points generally identify where a single species (e.g., shrub, tree) was located.

cover of the vegetation on/along the canal walls observed at the time of the field survey was evaluated based on photographs and field observations. Geospatial vegetation data were transferred to a Geographic Information System (GIS) format and used to develop both visual maps depicting vegetation presence boundaries and VPs along the canal walls as well as tabular information quantifying the abundance and distribution of dominant vegetation types in the study area. Vegetation polygons were then analyzed to calculate the percentage represented by each vegetation category within each canal; VPs were not included in vegetation category percentage calculations because they represent a single point on the canal wall.

Relevant study results are discussed in the subsections below. As noted above, these subsections also describe other germane studies conducted by Boott relative to their resource areas.

E.7.4.1.2 Botanical Resources¹⁵

As presented in Section E.7.1, the Project is located in both the Northeastern Highlands ecoregion and the Northeastern Coastal Zone. The north and westerly portions of the watershed, located in the Northeastern Highlands, are characterized by low mountains and mostly ungrazed forest and woodland. The southern portion of the watershed is located in the Northeastern Coastal Zone, which is characterized primarily as modified woodland and forest. The Project is also located in the New England Physiographic Province. The Taconic, Green, and White Mountain ranges are distinct features of the New England Physiographic Province. The Taconic Mountains are a north-south trending mountain range along the western edge of the province and are thought to be formed by erosion of an upper block of a large thrust fault. Also, north-south trending, the Green Mountains exist primarily in Vermont and are made of Precambrian gneisses. The White Mountains are an exhumed mass of Paleozoic granite and include Mt Washington in New Hampshire, the tallest mountain in the region at 6,288 feet (NPS undated a).

The Lowell Project is located in the Seaboard Lowlands Section of the New England Physiographic Province. The Seaboard Lowlands Section is lower in elevation and less hilly than the adjacent New England Upland Section. Fenneman considered the Seaboard Lowlands Section as the sloping margin of the uplands, although it also roughly coincides with the area inundated by the ocean and areas of large proglacial lakes during the last glacial retreat (Stone and Borns 1986 as cited in Flanagan et al. 1999). In the vicinity of the Project, the Merrimack River flows through a region of rapid population growth and development that is heavily influenced by the Lowell metropolitan area. The local relief in the Merrimack River Valley in the Project vicinity is generally characterized as low, open hills.

Botanical resources in the Merrimack River corridor vary between urban areas and nonurban areas. In the vicinity of the Lowell Project, botanical resources are dominated by hemlock-hardwood-pine, Appalachian oak-pine, and grasslands (NHDFG 2015). These habitat types are discussed below in further detail.

¹⁵ State-listed RTE plant species are discussed in Section E.7.5 of this Exhibit.

Hemlock-Hardwood-Pine Forest

Hemlock-hardwood-pine forest is a wide-spread habitat in the lower Merrimack River corridor. It is a transitional forest between Appalachian oak-pine and northern hardwood found at elevations less than 400 feet and greater than 1,500 feet, respectively. White pine (*Pinus strobus*) and eastern hemlock (*Tsuga canadensis*) are the dominant trees, but American beech (*Fagus grandifolia*) and patches of sugar maple (*Acer saccharum*), white ash (*Fraxinus americana*), and red oak (*Quercus rubra*) contribute to a variable species mix of this forest type. The understory contains small trees and shrubs such as witch hazel (*Hamamelis virginiana*), maple-leaved viburnum (*Viburnum acerifolium*), black birch (*Betula nigra*), black cherry (*Prunus serotina*), and ironwood (*Ostrya virginiana*). Typical plants found on the forest floor include starflower (*Trientalis borealis*), Canada mayflower (*Maianthemum canadensis*), and wild sarsaparilla (*Aralia nudicaulis*).

Most white pine stands that have grown up from abandoned pastures are examples of this type of hemlock-hardwood pine forest habitat. On fertile soils, white pine is replaced by hemlock or hardwoods over time. Older forests that have succeeded to later stages contain patches of larger diameter trees (>18 inches) hemlock or beech in the canopy, layers of young trees and shrubs in the understory, many standing dead trees, and abundant decaying wood on the forest floor. Large-sized cavity trees, pockets of wetlands, patches of acorn-rich oaks, seeps, and tall pine trees make some patches of this forest type especially rich for wildlife (NHDFG 2015; Swain 2020).

Appalachian Oak-Pine Forest

Appalachian oak-pine forests, with their abundance of nut-bearing oaks such as red oak, white oak (*Quercus alba*), and black oak (*Q. velutina*), and hickories such as shagbark (*Carya ovata*), pignut (*C. glabra*), and sweet pignut (*C. ovalis*), provide a rich food source for wildlife such as ruffed grouse (*Bonasa umbellus*), turkey (*Meleagris gallopavo*), gray squirrels (*Sciurus carolinensis*), and eastern chipmunks (*Tamias striatus*). Common understory shrubs and smaller trees of this forest type include black birch (*Betula lenta*), bigtooth aspen (*Populus grandidentata*), sassafras (*Sassafras albidum*), and yellow birch (*Betula alleghaniensis*). Blueberries (*Vaccinium angustifolium* and *V. pallidum*), black huckleberry (*Gaylussacia baccata*), sheep laurel (*Kalmia angustifolia*), and Pennsylvania sedge (*Carex pennsylvanica*), are typical understory plants. Raptors such as northern goshawk (*Accipiter gentilis*) feed on small mammals and find nesting and perching sites in white pines in the tree canopy. White pines adjacent to the Merrimack River provide key nest and perch sites for bald eagles (*Haliaeetus leucocephalus*), great blue herons (*Ardea herodias*), and osprey (*Pandion haliaetus*) (NHDFG 2015).

Many stands of Appalachian oak-pine forest are of the same age, approximately 80-100 years. They grew after farms were abandoned throughout the last century. Many wildlife species found in this forest type are attracted to patches of old or young trees within the larger forested landscape. Historically, the dry soils and warm temperatures in this region allowed occasional low-intensity fires to burn in these forests. Without fire, these forests have a higher proportion of white pine, hemlock, sugar maple and birch species (*Betula* spp.), than nut-bearing trees. Mature Appalachian oak-pine forests may also be denser due to a lack of low ground fires to maintain an open understory (NHDFG 2015).

Grasslands

The most common grassland habitats in the lower Merrimack River corridor are agricultural fields such as hayfields, pastures, and fallow fields. Grassland vegetation is a mixture of grass species, or a combination of grasses, sedges, and wildflowers. Most plants found in grasslands are non-native grasses, introduced for agricultural use. These include timothy (*Phleum pratense*), Kentucky bluegrass (*Poa pratensis*), orchard grass (*Dactylis glomerata*), and perennial ryegrass (*Lolium perenne*). Common native plants include big bluestem (*Andropogon gerardi*), little bluestem (*Schizachyrium scoparium*), and a variety of species of the wildflower genera including goldenrod species (*Solidago* spp.) and various Aster. Vegetation growing in grassland habitat ranges from less than 6 inches to over four feet in height. Vegetation height plays an important role in determining which wildlife species will use it. Few, if any, trees or shrubs are found in grasslands. Unless maintained, most grasslands will return to forest habitat (NHDFG 2015).

Major-River Floodplain Forest

The immediate shoreline of the Merrimack River and some portions of the canals within the Project area (e.g., the Pawtucket Canal near the confluence of the Merrimack River) include areas of floodplain forest and some of these areas have characteristics of Major-river Floodplain Forest as described by Swain (2020). Major-river floodplain forests are deciduous forested wetland communities, which develop next to rivers and streams and receive annual (or semi-annual) overbank flooding and alluvial silt deposition. Soils are predominantly sandy loams without soil mottles and without a surface organic layer. Flooding at these sites occurs annually and can be severe. An island variant of Major-river Floodplain Forests occurs on elevated sections of riverine islands and riverbanks of major rivers, where there are high levels of both natural and human disturbance. All floodplain forest communities in Massachusetts have silver maple (*Acer saccharinum*) as the defining tree, but associated plant species vary depending on the intensity and duration of the flooding and on geographic location. Common plant species occurring with silver maple include cottonwood (*Populus deltoides*), American elm (*Ulmus americana*), and/or slippery elm (*U. rubra*) in the subcanopy and shrubs are generally lacking. The herbaceous layer is usually dominated by a 3-6 ft. (1-2 m) tall, dense cover of wood-nettles (*Laportea canadensis*) and ostrich fern (*Matteuccia struthiopteris*) is sometimes abundant (Swain 2020). Other species growing along the upland margins include tree of heaven (*Ailanthus altissima*), staghorn sumac (*Rhus typhina*), the non-native bittersweet (*Celastrus orbiculatus*), riverbank grape (*Vitis riparia*), Virginia creeper (*Parthenocissus quinquefolia*), scattered Siberian elm (*Ulmus pumila*), purple loosestrife (*Lythrum salicaria*), poison ivy (*Toxicodendron radicans*), Boston ivy (*Parthenocissus tricuspidata*), mullein (*Verbascum thapsus*), and common ragweed (*Ambrosia artemisiifolia*) (HDR 2021a).

Ruderal Herbaceous/Scrub-Shrub/Forested

Ruderal Herbaceous/Scrub-Shrub/Forested areas in the Project vicinity are largely anthropogenic communities of herbaceous or mixed scrub-shrub and forested vegetation

resulting from succession following complete or partial removal of native woody cover. These communities are found in areas where the native forest vegetation has been cleared or partially cleared, in old fields, hedgerows, pedestrian walkways, along Project canals, roadways, etc. Characteristic species can include red maple, American elm, Siberian elm, bush honeysuckles (*Lonicera* spp.), tree of heaven, Boston ivy, poison ivy, goldenrods (*Solidago* spp.), and various grass species (HDR 2021a).

2019 Visual Survey for Vegetation Growth

In September 2019, a visual survey was conducted to identify vegetation growth along the canal walls within the Project area. A wide variety of vegetation types, occurrences, and distribution, ranging from herbaceous, non-woody plants to forested areas of trees and underbrush, and shoreline/canal types, ranging from earthen embankments to placed, uniformly sized blocks were observed during the study. In total, 96 Vegetation Polygons (representing 80 percent of the total survey data collected in the study area) and 24 VPs (representing 20 percent of the total survey data collected in the study area) were mapped between September 25 and September 27, 2019. As shown in Table E.7-25, the total study area encompassed approximately 44 acres and mapped vegetation on/along canal walls accounted for approximately 5 acres (11 percent) of the study area¹⁶. The Pawtucket Canal (19.63 acres; 44 percent of the total study area), Northern Canal (11.67 acres; 26 percent of the total study area), and Western Canal (5.51 acres; 13 percent of the total study area) represent more than 80 percent of the total study area (Table E.7-25).

At the time of the study, most mapped VPs within the total study area had a dominant vegetation type of Scrub-Shrub (46 percent of the total VP count), followed closely by Trees (38 percent of the total VP count). The majority of mapped Vegetation Polygons within the total study area had a dominant vegetation type of Mixed (41 percent of the total mapped vegetation area) at the time of the study. Mapped vegetation polygons with a dominant vegetation type of Forested were only recorded within the Western Canal (53 percent of the Western Canal study area), and the Northern Canal (28 percent of the Northern Canal study area) at the time of the study (HDR 2021a).

Maps showing the results of the vegetation assessment and mapping within the study area are illustrated in a 21-sheet, 11 by 17-inch vegetation type map set with numbered polygons (e.g., 1, 2) and VPs (e.g., VP1, VP2) for each vegetation polygon and/or VP, respectively in Appendix G of the Recreation and Aesthetics Study Report (HDR 2021a). Additionally, results from the canal wall vegetation mapping are compiled in Appendix H and field reconnaissance data is summarized in Appendix I of the Recreation and Aesthetics Study Report.

¹⁶ VPs are not included in mapped vegetation acreage calculations because they represent a single point(s) on a canal wall.

Table E.7-25. Percent total acreage and mapped vegetation acreage of the six major canals associated with the Lowell Project Canal system

Canal	Area (acres)	Percentage (%) of Total Study Area	Mapped Vegetation Area (acres)	Percentage (%) of Total Study Area with Mapped Vegetation
Eastern Canal	4.03	9%	0.93	2%
Hamilton Canal	2.01	5%	0.35	1%
Merrimack Canal	1.40	3%	0.38	1%
Northern Canal	11.67	26%	0.89	2%
Pawtucket Canal	19.63	44%	1.33	3%
Western Canal	5.51	13%	0.90	2%
Total	44.25	100%	4.78	11%

Source: HDR 2021a

E.7.4.1.3 Invasive Plant Species

Invasive species are defined as non-indigenous plant or animal species that aggressively compete with native species. These species often out-compete local native species, impacting biodiversity, recreation, and human health. Invasive plants tend to appear on disturbed ground, and the most aggressive have the ability to invade existing ecosystems.

Non-native invasive species and noxious weeds are typically prolific pioneering species that have the ability to quickly outcompete native vegetation. These species grow rapidly, mature early, and effectively spread seeds that can survive for significant periods in the soil until site conditions are favorable for growth. Invasive plant species are prevalent throughout the Merrimack River Valley, as indicated by the IPANE (IPANE Undated), and have been observed along the banks of the Merrimack River, the Project's canals, and in some vegetation communities within the Project area. Of the 2,263 plant species in Massachusetts that have been documented as native or naturalized, about 725 (32 percent) are naturalized. Of these, the Massachusetts Invasive Plant Advisory Group (MIPAG) recognized 69 species as "Invasive," "Likely Invasive," or "Potentially Invasive" (Commonwealth of Massachusetts 2020). In accordance with the Invasive Species Act, HB 1258-FN, the New Hampshire Department of Agriculture, Markets & Food, Division of Plant Industry is the lead state agency responsible for the evaluation, publication and development of rules on invasive plant species for the purpose of protecting the health of native species, the environment, commercial agriculture, forest crop production, or human health in New Hampshire. New Hampshire's Prohibited Invasive Plant Species List identifies 35 species. These invasive species are provided in Table E.7-26 and include non-native species that have spread into native or minimally managed plant

systems and can cause economic or environmental harm by developing self-sustaining populations and becoming dominant and/or disruptive to those systems.

Table E.7-26. Invasive Plant Species in Massachusetts and Prohibited Invasive Plant Species in New Hampshire

Common Name	Scientific Name	Common Name	Scientific Name
Norway maple	<i>Acer platanoides</i>	Creeping jenny	<i>Lysimachia nummularia</i>
Sycamore maple	<i>Acer pseudoplatanus</i>	Purple loosestrife	<i>Lythrum salicaria</i>
Bishop's goutweed	<i>Aegopodium podagraria</i>	Variable water-milfoil	<i>Myriophyllum heterophyllum</i>
Tree of heaven	<i>Ailanthus altissima</i>	European water-milfoil	<i>Myriophyllum spicatum</i>
Garlic mustard	<i>Alliaria petiolata</i>	Reed canary-grass	<i>Phalaris arundinacea</i>
Japanese barberry	<i>Berberis thunbergii</i>	Common reed	<i>Phragmites australis</i>
Carolina fanwort	<i>Cabomba caroliniana</i>	Japanese knotweed	<i>Polygonum cuspidatum</i>
Oriental bittersweet	<i>Celastrus orbiculatus</i>	Crisped pondweed	<i>Potamogeton crispus</i>
Black swallow-wort	<i>Cynanchum louiseae</i>	Lesser celandine	<i>Ranunculus ficaria</i>
Autumn olive	<i>Elaeagnus umbellata</i>	Common buckthorn	<i>Rhamnus cathartica</i>
Winged euonymus	<i>Euonymus alatus</i>	Black locust	<i>Robinia pseudoacacia</i>
Leafy spurge	<i>Euphorbia esula</i>	Multiflora rose	<i>Rosa multiflora</i>
European buckthorn	<i>Frangula alnus</i>	Water-chestnut	<i>Trapa natans</i>
Sea or horned poppy	<i>Glaucium flavum</i>	European black alder	<i>Alnus glutinosa</i>
Dame's rocket	<i>Hesperis matronalis</i>	European barberry	<i>Berberis vulgaris</i>
Yellow iris	<i>Iris pseudacorus</i>	Spotted knapweed	<i>Centaurea stoebe ssp. micranthos</i>
Broad-leaved pepperweed	<i>Lepidium latifolium</i>	Pale swallow-wort	<i>Cynanchum rossicum</i>
Japanese honeysuckle	<i>Lonicera japonica</i>	Giant hogweed	<i>Heracleum mantegazzianum</i>

Common Name	Scientific Name	Common Name	Scientific Name
Morrow's honeysuckle	<i>Lonicera morrowii</i>	Ornamental jewelweed	<i>Impatiens glandulifera</i>
Bell's honeysuckle	<i>Lonicera x bella</i>	Japanese stilt grass	<i>Microstegium vimineum</i>
Amur honeysuckle	<i>Lonicera maackii</i>	Blunt-leaved privet	<i>Ligustrum obtusifolium</i>
Tartarian honeysuckle	<i>Lonicera tatarica</i>	Common privet	<i>Ligustrum vulgare</i>
Mile-a-minute weed	<i>Persicaria perfoliata</i>	Bohemia knotweed	<i>Reynoutria x bohemica</i>
Kudzu	<i>Pueraria montana</i>	Reed sweet grass	<i>Glyceria maxima</i>
Giant knotweed	<i>Reynoutria sachalinensis</i>	--	--

Sources: Commonwealth of Massachusetts 2020; New Hampshire Department of Agriculture, Markets & Food, Division of Plant Industry 2017; IPANE Undated

As part of the 2019 and 2020 relicensing studies, ten plant species, which are designated as invasive or prohibited species (Commonwealth of Massachusetts 2020; New Hampshire Department of Agriculture, Markets & Food, Division of Plant Industry 2017), were incidentally observed in the Project's vicinity:

- Tree of heaven
- Japanese barberry
- Japanese knotweed
- Oriental bittersweet
- Autumn olive
- Winged euonymus
- Japanese honeysuckle
- Purple loosestrife
- Common buckthorn, and
- Black locust

E.7.4.1.4 Wetland, Riparian, and Littoral Habitats

Wetlands are generally defined as those areas that are inundated or saturated by surface or ground water at a frequency and duration sufficient to support vegetation typically adapted for life in saturated soil conditions. Most formal wetland definitions emphasize three primary components that define wetlands: the presence of water,

unique soils, and hydrophytic vegetation. The USFWS (Cowardin et al. 1979) defines wetlands as follows:

...lands transitional between terrestrial and aquatic systems where the water table is usually at or near the surface or the land is covered by shallow water. For purposes of this classification wetlands must have been one or more of the following three attributes: (1) at least periodically, the land supports predominately hydrophytes; (2) the substrate is predominantly undrained hydric soil; and (3) the substrate is nonsoil and is saturated with water or covered by shallow water at some point during the growing season of the year.

Riparian habitats are areas that support vegetation found along waterways such as lakes, reservoirs, rivers, and streams. The boundary of the riparian area and the adjoining uplands is gradual and not always well defined. However, riparian areas differ from the uplands because of their high levels of soil moisture, frequency of flooding, and unique assemblage of plant and animal communities (Virginia State University 2000). These habitats can range from mature forests to areas covered by emergent vegetation and shrubs. Riparian habitats are unique because of their linear form and because they process large fluxes of energy and materials from upstream systems (Mitsch and Gosselink 1993). Riparian areas and the associated vegetation provide important habitat for wildlife and often contain a higher number of species, both plant and animal, than surrounding upland areas due to the proximity to water. These areas are also important avian habitats for resident and migratory birds. Riparian habitats typically function as travel corridors for migratory wildlife species. The riparian zone serves as the primary interface between riverine and upland habitats, influencing both the primary productivity and food resources within a river. Primary wildlife resources associated with riparian habitats include early spring plant growth in lowland riparian habitats, which provide food sources for migrating birds, white-tailed deer, and other wildlife species.

The USFWS, MADEP, and the NHDES have jurisdiction over wetlands within the Project area. The MADEP's and NHDES's wetland definition is consistent with the USFWS' wetland definition.

Terrestrial habitat conditions in the Project area and upstream along the Merrimack River are largely a result of land use, especially of urban and suburban development (Boott Mills 1980). Based on USFWS National Wetland Inventory (NWI) mapping, wetlands along the Merrimack River primarily consist of low-lying areas near and adjacent to the river, with other isolated wetlands farther away from the river proper. The USEPA has designated the Merrimack River from Franklin, New Hampshire, to Lowell, Massachusetts, as a Priority Waterbody/Wetland due to its importance to waterfowl and fish populations (Carley 2001 as cited in USACE 2003).

There are MADEP and NHDES wetlands and NWI wetlands encompassed within, adjacent to, or in close proximity to the Project boundary. Most of the MADEP, NHDES, and NWI mapped wetland boundaries overlay each other¹⁷. Within the current Project boundary there are approximately 739.2 acres of MADEP wetland, approximately 6.4

¹⁷ The NHDES wetland data GIS layer only included data for the Palustrine System within the Project boundary.

acres of NHDES wetland, and approximately 1,659 acres of NWI wetlands. The 745.6 acres of MADEP and NHDES wetlands are mostly encompassed within the 1,659 acres of NWI wetlands (MassGIS 2018; NH GRANIT undated).

Wetlands currently mapped by the USFWS NWI within the proposed Project boundary are presented in Figure E.7-19 and are summarized in Table E.7-27.

Table E.7-27 provides mapping code descriptions for the NWI codes found on the wetland base maps (USFWS 2020a). The wetlands directly surrounding the Lowell Project are largely considered riverine wetlands with an unconsolidated bottom (Figure E.7-19). Riverine wetlands include all wetlands and deepwater habitats contained within a channel, with two exceptions: (1) wetlands dominated by trees, shrubs, persistent emergents, emergent mosses, or lichens, and (2) habitats with water containing ocean-derived salts of 0.5 parts per thousand (or greater (Cowardin et al. 1979)).

According to a review of GIS data (Massachusetts Bureau of Geographic Information [MassGIS]), there are no Massachusetts Natural Heritage and Endangered Species Program certified vernal pools within the Project boundary. Potential vernal pools were also identified using GIS data. According to MassGIS (2018), two potential vernal pools are located within 100 feet of the Project boundary, but not within the Project boundary.

No formal survey data on wetlands at or near the Project is available. However, based on observations made during the Recreation and Aesthetics Study, as well as during other relicensing studies, riparian vegetation within the Project area appears to be consistent with these areas of New Hampshire and Massachusetts. Where steep banks present themselves, the riparian corridor is narrow with wetland vegetation only occurring immediately adjacent to the river/land interface. Where the shoreline is more gradual and the Merrimack River floodplain extends away from the current river course, palustrine wetlands cover areas of former oxbows, floodplain, and low-lying areas.

Massachusetts floodplain communities are typically dominated by river birch (*Betula nigra*) associations (USACE 2003). Development activity is contributing to the decline of these riparian communities in Massachusetts (Carley 2001 as cited in USACE 2003). The palustrine forested wetland habitats located within and adjacent to the Project boundary are primarily dominated by broad-leaved deciduous subclasses located along forested floodplains. These areas are characterized by their flood regime; lower areas are annually flooded in spring, whereas higher areas are flooded irregularly. Common trees include silver maple, red maple, green ash (*Fraxinus pennsylvanica*), and American elm. The shrub layer may include silky dogwood (*Cornus amomum*) and buttonbush (*Cephalanthus occidentalis*). Common herbaceous species may include sensitive fern (*Onoclea sensibilis*), false nettle (*Boehmeria cylindrica*), water hemlock (*Cicuta maculata*), swamp candles (*Lysimachia terrestris*), and water parsnip (*Sium suave*) (Swain 2020).

Figure E.7-19. Wetlands in the Vicinity of the Lowell Hydroelectric Project and Proposed Project Boundary

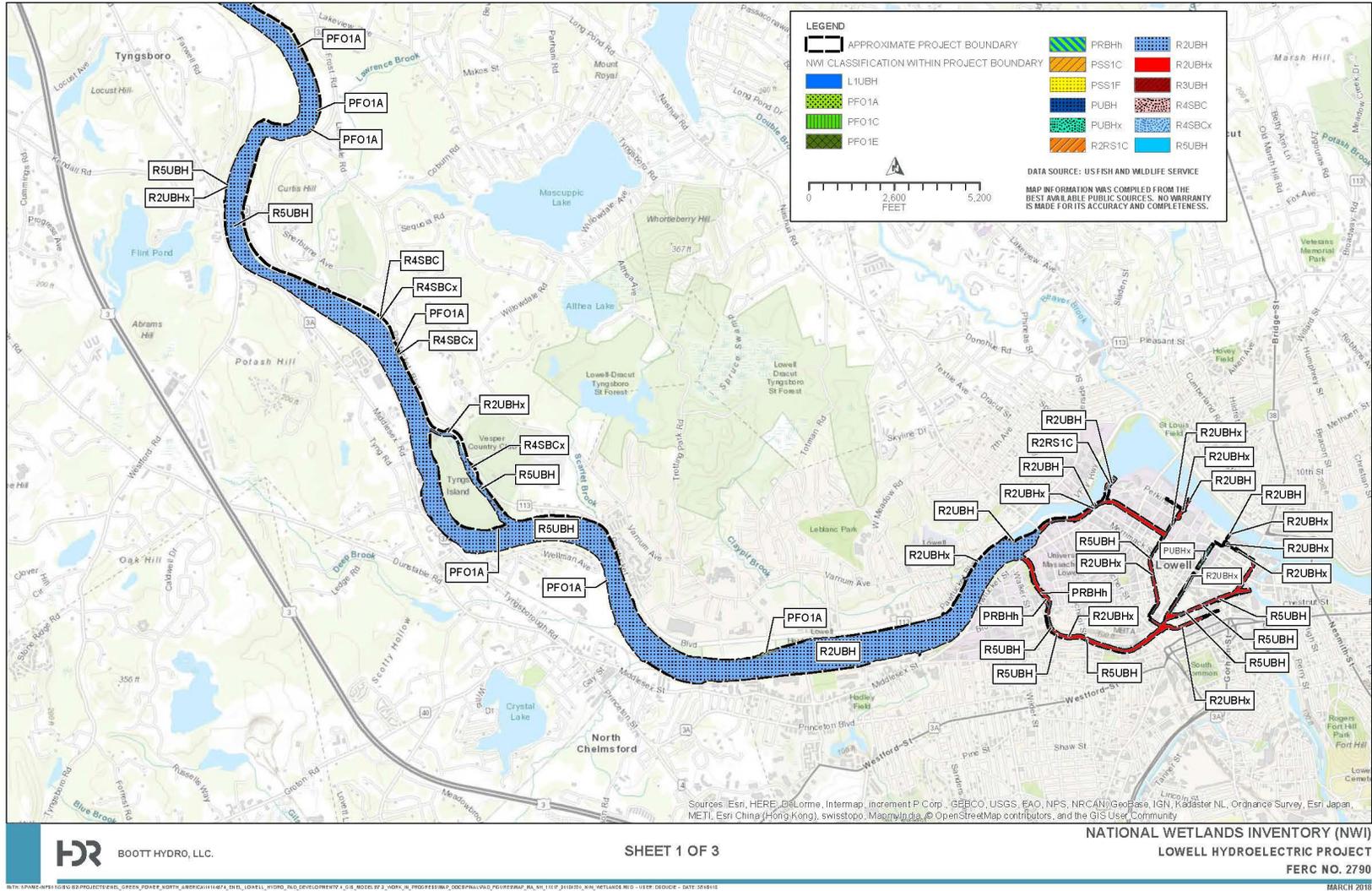


Figure E.7-19 continued

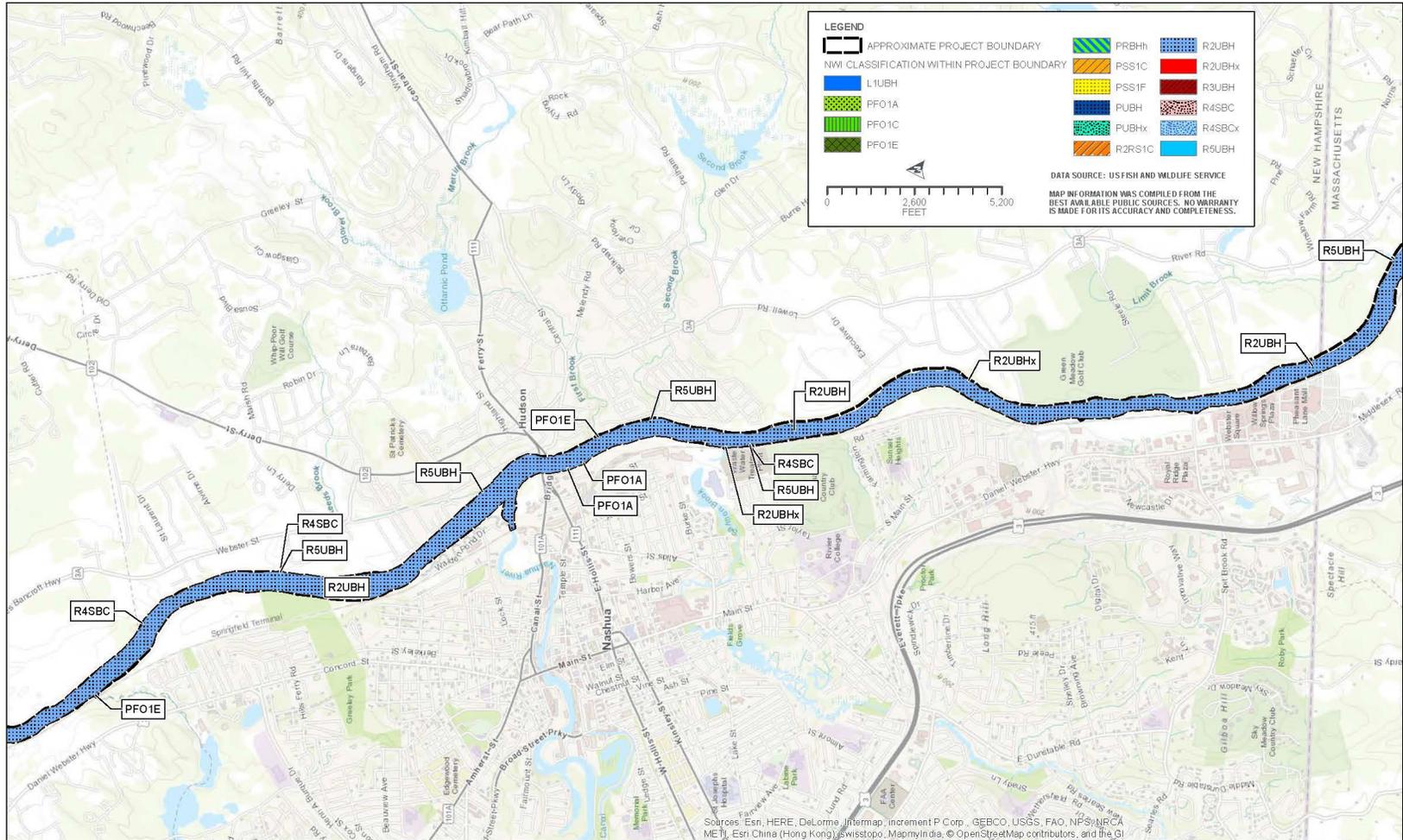


Exhibit E Environmental Report (18 C.F.R. § 5.18)
 Lowell Hydroelectric Project

Figure E.7-19 continued

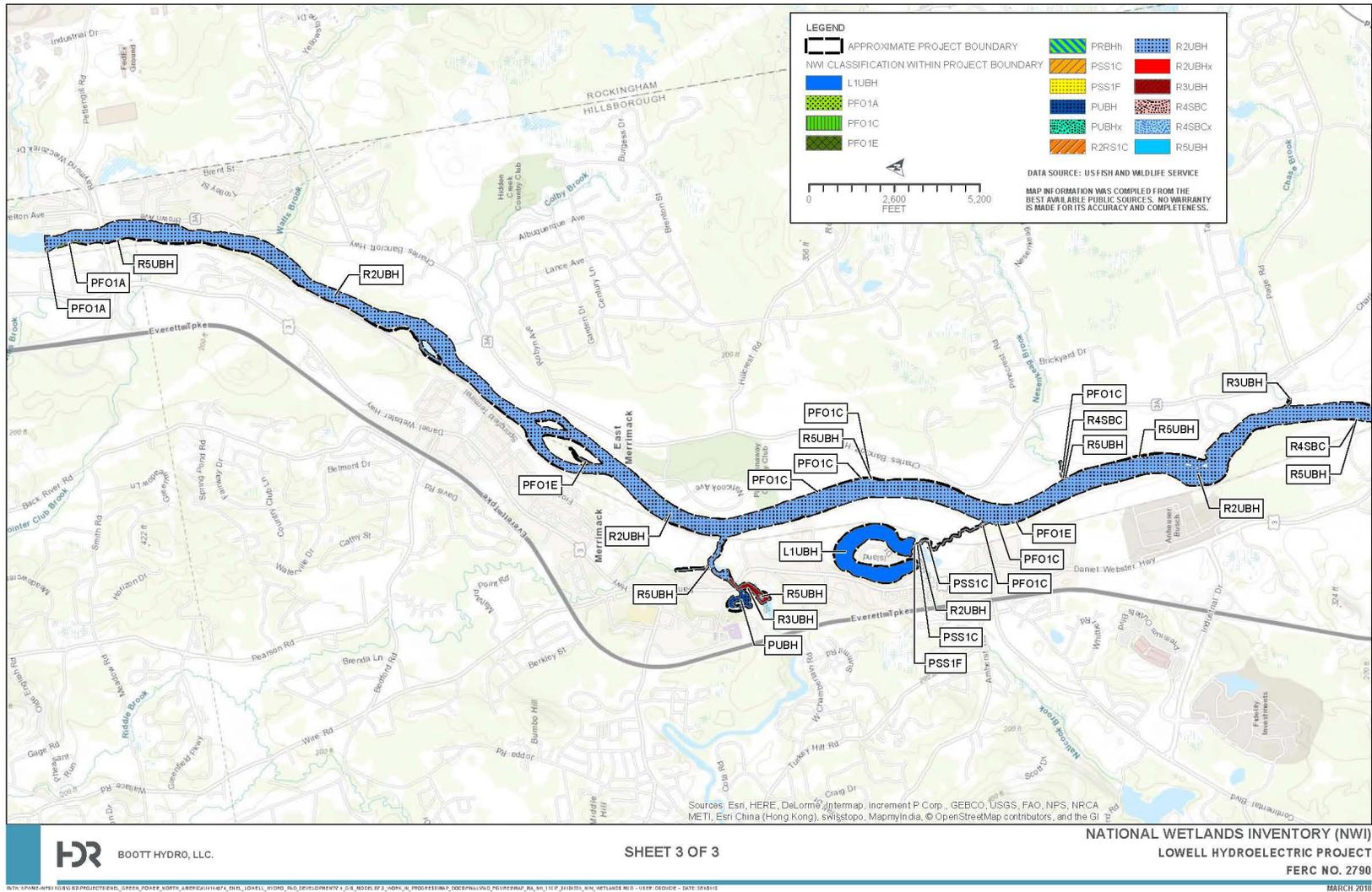


Table E.7-27. National Wetlands Inventory Classification System

Wetlands Code	System	Subsystem	Class	Subclass	Water Regime	Qualifier	Acres
R2UBH	Riverine	Lower Perennial	Unconsolidated Bottom	--	Permanently Flooded	--	1147.42
R2UBHx	Riverine	Lower Perennial	Unconsolidated Bottom	--	Permanently Flooded	Excavated	5.59
R3UBH	Riverine	Upper Perennial	Unconsolidated Bottom	--	Permanently Flooded	--	0.01
R2RS1C	Riverine	Lower Perennial	Rocky Shore	Bedrock	Seasonally Flooded	--	5.60
R4SBC	Riverine	Intermittent	Streambed	--	Seasonally Flooded	--	0.02
R4SBCx	Riverine	Intermittent	Streambed	--	Seasonally Flooded	Excavated	0.10
R5UBH	Riverine	Unknown Perennial	Unconsolidated Bottom	--	Permanently Flooded	--	0.56
PFO1A	Palustrine	--	Forested	Broad-leaved Deciduous	Temporarily Flooded	--	2.61
PFO1E	Palustrine	--	Forested	Broad-leaved Deciduous	Seasonally Flooded/ Saturated	--	0.38
PRBHh	Palustrine	--	Rock Bottom	--	Permanently Flooded	Diked/ Impounded	0.12

Source: USFWS 2020a.

E.7.4.1.5 Wildlife

The Merrimack River corridor provides habitat for a diversity of wildlife species. Diverse habitats such as wetlands, forests, fields, as well as the river and associated tributaries support a variety of species. The quality and types of habitat that the Merrimack River corridor provides is what dictates which wildlife species occupy and use it. The Merrimack River mainstem is categorized as a large/great river habitat (Olivero and Anderson 2008). Large river habitats such as the Merrimack River support a diverse wildlife community which includes many of the mammalian, reptilian, and amphibian species found in northeastern North America.

Mammals

Mammals present in the vicinity of the Lowell Project are those commonly found throughout the region that are adapted to living near humans and urban areas. Some large mammal species that require extensive habitat areas, or species that require solitude, such as moose (*Alces alces*) and black bear (*Ursus americanus*), typically prefer less developed environments that are scarce in the lower Merrimack River corridor and the Lowell Project. White-tailed deer (*Odocoileus virginianus*) is the most common big game species in the Project vicinity, occurring in a wide variety of habitats ranging from forests to agricultural land. This species is most prevalent along forest edges characterized by brushy and woody vegetation, swamp borders, and areas interspersed with fields and woodland openings (DeGraaf and Yamasaki 2001; Doutt et al. 1977). Raccoon (*Procyon lotor*) are also common, especially along the riparian corridor associated with the Merrimack River within the Project vicinity. Other mammals present in the Project vicinity include furbearers, small game species, rodents, and bats. These wildlife species reside in many different habitat types such as woodland, scrub-shrub or early successional areas, and grassland areas; use of these areas may shift during different life stages and/or times or year (DeGraaf and Yamasaki 2001; Doutt et al. 1977).

Mammals typically found in woodland and riparian areas include northern raccoon, long-tailed weasel (*Mustela frenata*), eastern gray squirrel (*Sciurus carolinensis*), American mink (*Mustela vison*), and marten (*Martes martes*). Bat species may include the red bat (*Lasiurus borealis*), silver haired bat (*Lasionycteris noctivagans*), hoary bat (*Lasiurus cinereus*), and little brown bat (*Myotis lucifugus*). These mammals are normally found in woodland/riparian areas due to food requirements, predator/prey relationships, and a preference by several species for trees as den or nest sites (DeGraaf and Yamasaki 2001; Doutt et al. 1977).

Mammals typically found in grassland areas include the meadow vole (*Microtus pennsylvanicus*), house mouse (*Mus musculus*), and the deer mouse (*Peromyscus maniculatus*). Several species of bats also are likely to use these areas or manmade structures within these areas of the Project vicinity. Additionally, several species typical of grassland mammals can be found in multiple habitat types due to their generalized requirements. Coyotes, for example, use woodlands, wetlands, and grasslands in addition to scrub-shrub areas for foraging, dens, and travel corridors (DeGraaf and

Yamasaki 2001; Doutt et al. 1977). Table E.7-28 lists the mammalian species potentially occurring in the vicinity of the Lowell Project. Those species that were observed during field studies performed at the Project are indicated with an asterisk (*).

Table E.7-28. Mammalian Species Potentially Occurring in the Vicinity of the Lowell Project.

Common Name	Scientific Name
Beaver	<i>Castor canadensis</i>
Big brown bat	<i>Eptesicus fuscus</i>
Black bear	<i>Ursus americanus</i>
Black rat	<i>Rattus rattus</i>
Bobcat	<i>Lynx rufus</i>
Coyote	<i>Canis latrans</i>
Deer mouse	<i>Peromyscus maniculatus</i>
Eastern chipmunk*	<i>Tamias striatus</i>
Eastern red bat	<i>Lasiurus borealis</i>
Ermine	<i>Mustela ermina</i>
Fisher	<i>Pekania pennanti</i>
Gray fox	<i>Urcyon cinereoargenteus</i>
Gray squirrel*	<i>Sciurus carolinensis</i>
Hairy-tailed mole	<i>Parascalops breweri</i>
Hoary bat	<i>Lasiurus cinereus</i>
House mouse*	<i>Mus musculus</i>
Little brown bat	<i>Myotis lucifugus</i>
Long-tail weasel	<i>Mustela frenata</i>
Long-tailed shrew	<i>Sorex dispar</i>
Masked shrew	<i>Sorex cinereus</i>
Meadow jumping mouse	<i>Zapus hudsonicus</i>
Meadow vole	<i>Microtus pennsylvanicus</i>
Mink	<i>Mustela vison</i>
Moose*~	<i>Alces alces</i>
Muskrat	<i>Ondatra zibethicus</i>
Northern flying squirrel	<i>Glaucomys sabrinus</i>
Northern short-tailed shrew	<i>Blarina brevicauda</i>
Norway rat	<i>Rattus norvegicus</i>
Porcupine	<i>Erethizon dorsatum</i>
Pygmy shrew	<i>Sorex hoyi</i>
Raccoon*	<i>Procyon lotor</i>
Red fox	<i>Vulpes vulpes</i>
Red squirrel*	<i>Tamiasciurus hudsonicus</i>
River otter	<i>Lontra canadensis</i>
Silver-haired bat	<i>Lasionycteris noctivagans</i>
Small-footed bat	<i>Myotis leibii</i>
Smoky shrew	<i>Sorex fumeus</i>

Common Name	Scientific Name
Snowshoe hare	<i>Lepus americanus</i>
Southern bog lemming	<i>Synaptomys cooperi</i>
Southern flying squirrel	<i>Glaucomys volans</i>
Southern red-backed vole	<i>Clethrionomys gapperi</i>
Star-nosed mole	<i>Condylura cristata</i>
Striped skunk	<i>Mephitis mephitis</i>
Tricolored bat	<i>Perimyotis subflavus</i>
Virginia opossum	<i>Didelphis virginiana</i>
Water Shrew	<i>Sorex palustris</i>
White-footed mouse	<i>Peromyscus leucopus</i>
White-tailed deer	<i>Odocoileus virginianus</i>
Woodchuck*	<i>Marmota monax</i>
Woodland jumping mouse	<i>Napaeozapus insignis</i>
Woodland vole	<i>Microtus pinetorum</i>

Sources: NHDFG 2015; DeGraaf and Yamasaki 2001.

Note: * A moose was tranquilized and relocated by Massachusetts Environmental Police officers from the Northern Canal on June 11, 2020 (CBS Boston News Undated).

Avifauna

The diversity of habitats in the Lowell Project and lower Merrimack River corridor provide breeding, migratory stopover, and wintering habitat for a high diversity of avifauna including neotropical songbirds, resident species, waterbirds, and waterfowl. Species such as the black capped chickadee (*Poecile atricapillus*), blue jay (*Cyanocitta cristata*), and northern flicker (*Colaptes auratus*), and an assortment of woodpeckers occur within the wooded areas of the Project vicinity. Birds that inhabit non-forested areas within the Project's area include American robin (*Turdus migratorius*) and mourning dove (*Zenaida macroura*). The Merrimack River corridor, including the Project's impoundment and adjacent wetlands, attracts a variety of waterfowl. Four species of waterfowl were observed throughout the area while conducting various relicensing studies associated with the Project: Canada goose (*Branta canadensis*), mallard (*Anas platyrhynchos*), black duck (*Anas rubripes*), and double-crested cormorant (*Phalacrocorax auritus*). Double-crested cormorants were observed on several occasions within the bypass reach as well as in the vicinity of the Pawtucket Dam. Mallards were also seen along the Project canals as well at the confluence of the Pawtucket Canal and Merrimack River.

The ruderal herbaceous/scrub-shrub/forested areas in the Project vicinity are typically utilized by common species that are adapted to a variety of habitat types and are tolerant of human disturbance (i.e., generalist species). Common species of these habitats include rock pigeon (*Columba livia*), mourning dove, blue jay, common crow (*Corvus brachyrhynchos*), black-capped chickadee, northern cardinal (*Cardinalis cardinalis*), chipping sparrow (*Spizella passerina*), tree sparrow (*S. arborea*), mockingbird (*Mimus polyglottos*), starling (*Sturnus vulgaris*), and house finch (*Carpodacus mexicanus*) (DeGraaf and Yamasaki 2001). Incidental species observations, documented by

environmental scientists during site visits conducted during 2019 and 2020 relicensing studies, supports this.

Great egret (*Ardea alba*) and great blue heron (*Ardea herodias*) observations were noted while conducting various relicensing studies associated with the Project. These species were usually noted feeding in the bypass reach or flying in the general vicinity of the E.L. Field Powerhouse. Table E.7-29 lists bird species potentially occurring in the vicinity of the Lowell Project. Those species that were observed during field studies performed at the Project are indicated with an asterisk (*).

Table E.7-29. Avian Species Potentially Occurring in the Vicinity of the Lowell Project.

Common Name	Scientific Name
Alder flycatcher	<i>Empidonax alnorum</i>
American bittern	<i>Botaurus lentiginosus</i>
American black duck*	<i>Anas rubripes</i>
American coot	<i>Fulica americana</i>
American crow*	<i>Corvus brachyrhynchos</i>
American goldfinch*	<i>Carduelis tristis</i>
American kestrel	<i>Falco sparverius</i>
American redstart	<i>Setophaga ruticilla</i>
American robin*	<i>Turdus migratorius</i>
American woodcock	<i>Scolopax minor</i>
Bald eagle	<i>Haliaeetus leucocephalus</i>
Baltimore oriole	<i>Icterus galbula</i>
Barn swallow	<i>Hirundo rustica</i>
Belted kingfisher	<i>Megaceryle alcyon</i>
Black-billed cuckoo	<i>Coccyzus erythrophthalmus</i>
Blackburnian Warbler	<i>Dendroica fusca</i>
Black-capped chickadee*	<i>Poecile atricapillus</i>
Black-throated Blue Warbler	<i>Dendroica caerulescens</i>
Black-crowned night heron	<i>Nycticorax nycticorax</i>
Black-throated Green Warbler	<i>Dendroica virens</i>
Blue jay*	<i>Cyanocitta cristata</i>
Blue-gray gnatcatcher	<i>Poliophtila caerulea</i>
Blue-headed Vireo	<i>Vireo solitarius</i>
Bobolink	<i>Dolichonyx oryzivorus</i>
Broad-winged hawk	<i>Buteo platypterus</i>
Brown creeper	<i>Certhia americana</i>
Brown-headed cowbird	<i>Molothrus ater</i>
Brown thrasher	<i>Toxostoma rufum</i>
Bufflehead	<i>Bucephala albeola</i>
Canada goose*	<i>Branta canadensis</i>
Canvasback	<i>Aythya valisineria</i>
Carolina Wren	<i>Thryothorus ludovicianus</i>

Exhibit E Environmental Report (18 C.F.R. § 5.18)
 Lowell Hydroelectric Project

Common Name	Scientific Name
Cedar waxwing	<i>Bombycilla cedrorum</i>
Chestnut-sided Warbler	<i>Dendroica pensylvanica</i>
Chimney Swift	<i>Chaetura pelagica</i>
Chipping Sparrow*	<i>Spizella passerina</i>
Common goldeneye	<i>Bucephala clangula</i>
Common grackle	<i>Quiscalus quiscula</i>
Common Merganser	<i>Mergus merganser</i>
Common nighthawk	<i>Chordeiles minor</i>
Common raven	<i>Corvus corax</i>
Common redpoll	<i>Acanthis flammea</i>
Common Yellowthroat	<i>Geothlypis trichas</i>
Cooper's hawk	<i>Accipiter cooperii</i>
Dark-eyed junco	<i>Junco hyemalis</i>
Double-crested cormorant*	<i>Phalacrocorax auritus</i>
Downy Woodpecker	<i>Picoides pubescens</i>
Eastern Bluebird	<i>Sialia sialis</i>
Eastern Kingbird	<i>Tyrannus tyrannus</i>
Eastern phoebe	<i>Sayornis phoebe</i>
Eastern screech owl	<i>Megascops asio</i>
Eastern Wood-Pewee	<i>Contopus virens</i>
European Starling*	<i>Sturnus vulgaris</i>
Evening grosbeak	<i>Coccothraustes vespertinus</i>
Field sparrow	<i>Spizella pusilla</i>
Gadwall	<i>Mareca strepera</i>
Golden-crowned kinglet	<i>Regulus satrapa</i>
Golden eagle	<i>Aquila chrysaetos</i>
Gray catbird	<i>Dumetella carolinensis</i>
Great blue heron*	<i>Ardea herodias</i>
Greater scaup	<i>Aythya marila</i>
Great crested flycatcher	<i>Myiarchus crinitus</i>
Great horned owl	<i>Bubo virginianus</i>
Great egret*	<i>Ardea alba</i>
Green heron	<i>Butorides virescens</i>
Hairy Woodpecker	<i>Picoides villosus</i>
Hermit thrush	<i>Catharus guttatus</i>
Herring gull	<i>Larus argentatus</i>
Horned grebe	<i>Podiceps auritus</i>
House finch*	<i>Carpodacus mexicanus</i>
House sparrow*	<i>Passer domesticus</i>
House Wren	<i>Troglodytes aedon</i>
Indigo Bunting	<i>Passerina cyanea</i>

Exhibit E Environmental Report (18 C.F.R. § 5.18)
 Lowell Hydroelectric Project

Common Name	Scientific Name
Killdeer	<i>Charadrius vociferus</i>
Least bittern	<i>Ixobrychus exilis</i>
Least flycatcher	<i>Empidonax minimus</i>
Long-eared owl	<i>Asio otus</i>
Louisiana Waterthrush	<i>Seiurus motacilla</i>
Magnolia Warbler	<i>Dendroica magnolia</i>
Mallard*	<i>Anas platyrhynchos</i>
Mockingbird*	<i>Mimus polyglottos</i>
Mourning dove*	<i>Zenaida macroura</i>
Mourning warbler	<i>Oporornis philadelphia</i>
Northern cardinal*	<i>Cardinalis cardinalis</i>
Northern flicker*	<i>Colaptes auratus</i>
Northern goshawk	<i>Accipiter gentilis</i>
Northern parula	<i>Setophaga americana</i>
Northern saw-whet owl	<i>Aegolius acadicus</i>
Northern shrike	<i>Lanius borealis</i>
Northern shoveler	<i>Spatula clypeata</i>
Northern waterthrush	<i>Seiurus noveboracensis</i>
Olive-sided flycatcher	<i>Contopus cooperi</i>
Orchard oriole	<i>Icterus spurius</i>
Osprey	<i>Pandion haliaetus</i>
Ovenbird	<i>Seiurus aurocapilla</i>
Pied-billed grebe	<i>Pied-billed grebe</i>
Pileated woodpecker	<i>Dryocopus pileatus</i>
Pine siskin	<i>Spinus pinus</i>
Purple finch	<i>Carpodacus purpureus</i>
Red-bellied woodpecker	<i>Melanerpes carolinus</i>
Red-breasted nuthatch	<i>Sitta canadensis</i>
Red crossbill	<i>Loxia curvirostra</i>
Red-eyed vireo	<i>Vireo olivaceus</i>
Redhead	<i>Aythya americana</i>
Red-shouldered hawk	<i>Buteo lineatus</i>
Red-tailed hawk*	<i>Buteo jamaicensis</i>
Red-winged blackbird	<i>Agelaius phoeniceus</i>
Ring-billed gull	<i>Larus delawarensis</i>
Ring-necked duck	<i>Aythya collaris</i>
Rock pigeon*	<i>Columba livia</i>
Rose-breasted grosbeak	<i>Pheucticus ludovicianus</i>
Ruby-crowned kinglet	<i>Regulus calendula</i>
Ruby-throated hummingbird	<i>Archilochus colubris</i>
Ruddy duck	<i>Oxyura jamaicensis</i>
Ruffed grouse	<i>Bonasa umbellus</i>

Common Name	Scientific Name
Sandhill crane	<i>Antigone canadensis</i>
Savannah sparrow	<i>Passerculus sandwichensis</i>
Scarlet tanager	<i>Piranga olivacea</i>
Sharp-shinned hawk	<i>Accipiter striatus</i>
Short-eared owl	<i>Asio flammeus</i>
Snow bunting	<i>Plectrophenax nivalis</i>
Snow goose	<i>Anser caerulescens</i>
Snowy owl	<i>Bubo scandiacus</i>
Song sparrow	<i>Melospiza melodia</i>
Sora	<i>Porzana carolina</i>
Spotted sandpiper	<i>Actitis macularius</i>
Swainson's thrush	<i>Catharus ustulatus</i>
Swamp sparrow	<i>Melospiza georgiana</i>
Tree sparrow*	<i>Spizella arborea</i>
Tree swallow	<i>Tachycineta bicolor</i>
Tufted titmouse	<i>Baeolophus bicolor</i>
Turkey vulture	<i>Cathartes aura</i>
Veery	<i>Catharus fuscescens</i>
Virginia rail	<i>Rallus limicola</i>
Warbling vireo	<i>Vireo gilvus</i>
White-breasted nuthatch*	<i>Sitta carolinensis</i>
White-winged crossbill	<i>Loxia leucoptera</i>
Wild turkey	<i>Meleagris gallopavo</i>
Wilson's warbler	<i>Cardellina pusilla</i>
Willow flycatcher	<i>Empidonax traillii</i>
Wood duck	<i>Aix sponsa</i>
Wood thrush	<i>Hylocichla mustelina</i>
Yellow warbler	<i>Dendroica petechia</i>
Yellow-bellied flycatcher	<i>Empidonax flaviventris</i>
Yellow-bellied sapsucker	<i>Sphyrapicus varius</i>
Yellow-billed cuckoo	<i>Coccyzus americanus</i>
Yellow-rumped warbler	<i>Dendroica coronata</i>
Yellow-throated vireo	<i>Vireo flavifrons</i>

Sources: NHDFG 2015; DeGraaf and Yamasaki 2001.

* Species observed during field studies performed at the Project.

Amphibians and Reptiles

Amphibians and reptiles are common and well represented in the Project vicinity. However, only three amphibian species were observed throughout the area while conducting various relicensing studies associated with the Project (Table E.7-30). Species typically found in wetland and open water areas include green frog (*Lithobates clamitans*), bullfrog (*L. catesbeianus*), northern spring peeper (*Pseudacris crucifer*), and

the northern water snake (*Nerodia sipedon sipedon*) (DeGraaf and Rudis 1983; Tying 1990; Hunter et al. 1999). These amphibians and reptiles are normally found in wetland and open water areas due to food and reproductive requirements.

Species typically found in woodland areas include: spotted salamander (*Ambystoma maculatum*), eastern newt (*Notophthalmus viridescens*), American toad (*Anaxyrus americanus*), gray treefrog (*Hyla versicolor*), wood frog (*Lithobates sylvaticus*), and the northern two-lined salamander (*Eurycea bislineata*) (DeGraaf and Rudis 1983; Tying 1990; Hunter et al. 1999). These amphibians are normally found in woodland areas due to food and reproductive requirements. A list of herptile species observed, that may occur or may utilize habitat in the vicinity of the Project is included in Table E.7-30. Those species that were observed during field studies performed at the Project are indicated with an asterisk (*).

Table E.7-30. List of Herptile Species Observed or Anticipated to Occur in the Project Vicinity

Common Name	Scientific Name
Amphibians	
American toad*	<i>Anaxyrus americana</i>
Blue-spotted salamander	<i>Ambystoma laterale</i>
Bullfrog*	<i>Lithobates catesbeiana</i>
Dusky salamander	<i>Desmognathus fuscus</i>
Eastern spadefoot	<i>Scaphiopus holbrookii</i>
Four-toed salamander	<i>Hemidactylium scutatum</i>
Fowler's toad	<i>Anaxyrus fowleri</i>
Gray treefrog	<i>Hyla versicolor</i>
Green frog*	<i>Lithobates clamitans melanota</i>
Marbled salamander	<i>Ambystoma opacum</i>
Northern leopard frog	<i>Lithobates pipiens</i>
Northern spring salamander	<i>Gyrinophilus porphyriticus</i>
Pickerel frog	<i>Lithobates palustris</i>
Redback salamander	<i>Plethodon cinereus</i>
Red-spotted newt	<i>Notophthalmus viridescens</i>
Spotted salamander	<i>Ambystoma maculatum</i>
Spring peeper	<i>Pseudacris crucifer</i>
Two-lined salamander	<i>Eurycea bislineata</i>
Wood frog	<i>Lithobates sylvatica</i>
Reptiles	
Black racer	<i>Coluber constrictor</i>
Bog turtle	<i>Glyptemys muhlenbergii</i>
Blanding's turtle	<i>Emydoidea blandingii</i>
Brown snake	<i>Storeria dekayi</i>
Common garter snake	<i>Thamnophis sirtalis</i>
Common musk turtle	<i>Sternotherus odoratus</i>
Eastern box turtle	<i>Terrapene carolina</i>

Common Name	Scientific Name
Eastern gartersnake	<i>Thamnophis sirtalis</i>
Eastern hognose snake	<i>Heterodon platirhinos</i>
Eastern ratsnake	<i>Pantherophis alleghaniensis</i>
Milk snake	<i>Lampropeltis triangulum</i>
Northern water snake	<i>Nerodia sipedon</i>
Painted turtle	<i>Chrysemys picta</i>
Red-bellied snake	<i>Storeria occipitomaculata</i>
Ribbon snake	<i>Thamnophis sauritus</i>
Ringneck snake	<i>Diadophis punctatus</i>
Smooth green snake	<i>Liochlorophis vernalis</i>
Snapping turtle	<i>Chelydra serpentina</i>
Spotted turtle	<i>Clemmys guttata</i>
Wood turtle	<i>Glyptemys insculpta</i>

Source: NHDFG 2015; DeGraaf and Rudis 1983; Jackson et al. 2010.

* Species observed during field studies performed at the Project.

E.7.4.2 Environmental Analysis

FERC’s SD2 identified effects of continued Project operations on terrestrial resources as potential resource issues. Specifically, SD2 identified the following potential resource issues related to terrestrial resources to be analyzed for site-specific effects:

- Effects of continued project operation on riparian, littoral, and wetland habitat and associated wildlife.
- Effects of continued project operation, including maintenance activities (e.g., vegetation management) on wildlife habitat and associated wildlife.
- Effects of continued project operation and maintenance on the introduction and persistence of invasive plants within the Project boundary.

E.7.4.2.1 Effects of Continued Project Operation on Riparian, Littoral, and Wetland Habitat and Associated Wildlife

The types of wetlands bordering the Project generally reflect the expectations for the natural community in this area. The Project operates in ROR mode, and experiences seasonal and annual variations in flows based on natural hydrologic conditions in the Merrimack River Basin. Boott also proposes to continue to adhere to the requirements of the Project’s existing Crest Gate Operation Plan, which provides for a stable impoundment level maintained over a wide range of flows. Therefore, the proposed operation of the Project will have negligible effects on the flow regime and wetland and riparian habitats in the Merrimack River.

Additionally, the occurrence and distribution of wildlife resources in the Project area is generally unrelated to Project operations, and Project operations have little potential to impact wildlife resources within and bordering the Project. Since the Licensee is not

proposing changes to the existing baseline conditions or changes to the operation of the Project, continued operation of the Project as proposed by the Licensee is not expected to have any adverse effects on wetland, riparian, or littoral habitat or associated wildlife.

E.7.4.2.2 Effects of Continued Project Operation on Wildlife Habitat, Associated Wildlife, and the Introduction and Persistence of Invasive Plants

The operation of the Project has very little, if any, effect on the wildlife habitat or resources within and bordering the Project boundary, and the occurrence and distribution of wildlife resources in the Project area is generally unrelated to Project operations. Boott does however, conduct routine Project maintenance activities. Project maintenance activities are generally localized and minor in nature.

Many types of land uses contribute to the invasion and spread of non-native invasive species, including ground-disturbing activities and activities that promote the dispersal of weed seed. Roads, rivers, streams, agriculture, farming/ranching, recreation, residential, and commercial developments all contribute to the spread of invasive species.

Continued Project operations are not expected to contribute to the spread of invasive species. As noted above, the botanical resources located within the Project boundary have developed under the current operating regime and are generally stable, mature, and well established. Boott's routine vegetation management practices typically involve mechanical vegetation removal around Project facilities and the clearing of hazard trees as necessary. Boott is not proposing to conduct additional ground-disturbing activities such as road construction or land-clearing that would facilitate the spread of invasive botanical species within the Project boundary. The continued operation and maintenance of the Project as proposed by the Licensee is not expected to have any adverse effects on the wildlife habitat and associated wildlife, or the introduction and persistence of invasive plants within the Project boundary.

The downtown powerhouses are generally located in an urban area that does not provide significant habitat for terrestrial plant or wildlife species. Boott proposes to maintain water levels and flows in the canals and to implement trash management. Boott's proposal will not require any modifications to existing terrestrial habitat in the Project's vicinity.

E.7.4.3 Proposed Environmental Measures

Boott proposes to continue operations of the Project with certain PM&E as outlined above in Section E.6.2.

E.7.4.4 Unavoidable Adverse Impacts

Continued operation of the Project as proposed by the Licensee will not result in any unavoidable adverse effects on terrestrial botanical or wildlife resources.

E.7.5 Rare, Threatened and Endangered Species

The subsections below describe RTE species in the vicinity of the Project and consider the effects of continued operation of the Project as proposed by the Licensee on these resources. Descriptions of the affected environment, the environmental analysis, the proposed environmental measures, and the identification of unavoidable adverse effects were developed based on available data presented in the Licensee's PAD, and the:

- Fish Assemblage Study (NAI 2021d)
- Downstream American Eel Passage Assessment (NAI 2021a)

These reports are included in Appendix B of this exhibit.

E.7.5.1 Affected Environment

E.7.5.1.1 Federal-listed Species

As part of the environmental evaluation conducted for the Project, the USFWS Information, Planning, and Consultation System (IPaC System) identified a list of species under the USFWS's jurisdiction that are known or expected to be on or near the Project area. Based on a search of the USFWS IPaC system for ESA-listed species, northern long-eared bat (*Myotis septentrionalis*) is ESA-listed as threatened and may occur in the Project area; the habitat requirements and distribution of the species are described below. No ESA-listed aquatic species are identified in the USFWS database as being known or believed to occur in the Project area (USFWS 2020b). In addition to this species, the bald eagle (*Haliaeetus leucocephalus*) is known to occur as a transient in the Project vicinity; this species is protected under the Federal Bald and Golden Eagle Protection Act¹⁸ (and is separately listed by the Commonwealth of Massachusetts and New Hampshire; see below).

Northern long-eared bat

The northern long-eared bat is found across much of eastern and north-central United States, and all Canadian provinces from the Atlantic Ocean west to the southern Yukon Territory and British Columbia (USFWS 2013). It is a medium-sized bat, measuring 3 – 3.7 inches, with a wingspan of 9 or 10 inches. Its fur color can be medium to dark brown on the back and tawny to pale brown on the underside (USFWS 2013). The bat is distinguished by its long ears relative to other bats in the genus *Myotis* (USFWS 2013). The northern long-eared bat spends winters hibernating in caves and mines, preferring hibernacula with very high humidity. During the summer months, the northern long-eared bat prefers to roost singly or in colonies underneath bark, in cavities, or in the crevices of live or dead trees (USFWS 2013). Breeding begins in late summer or early fall when males swarm near hibernacula. After a delayed fertilization, pregnant females migrate to summer colonies where they roost and give birth to a single pup. Young bats start flying

¹⁸ 16 U.S.C. 668, *et seq.*

18 – 21 days after birth, and adult northern long-eared bats can live up to 19 years (USFWS 2013).

Northern long-eared bats emerge at dusk and fly through the understory of forested hillsides feeding on moths, flies, leafhoppers, caddisflies, and beetles. They also feed by gleaning motionless insects from vegetation and water (USFWS 2013).

The most severe and immediate threat to the northern long-eared bat is white-nose syndrome. As a result of this disease, numbers have declined by 99 percent in the northeast. Other significant sources of mortality include impacts to hibernacula from human disturbance. Loss or degradation of summer habitat as a result of highway or commercial development, timber management, surface mining, and wind facility construction and operation can also contribute to mortality (USFWS 2015).

No Biological Opinions have been developed by the USFWS for the northern long-eared bat in the Project area. In addition, no status reports or recovery plans were located for this species in the vicinity of the Project.

The USFWS has not designated critical habitat for the northern long-eared bat in the vicinity of the Project.

E.7.5.1.2 State-listed Species

Listings of the applicable state-listed threatened, endangered, and candidate species, as well as species of special concern, candidate species, and communities (RTE species) were obtained by request from map and database information provided by the Massachusetts Natural Heritage and Endangered Species Program (Massachusetts NHESP) and the New Hampshire Natural Heritage Bureau (New Hampshire NHB). In addition, habitat information was provided by the New Hampshire NHB, Massachusetts NHESP, as derived from the New Hampshire NHB's and Massachusetts NHESP's fact sheets, and flora manuals (e.g., Magee and Ahles 1999). Specific to the Project area, the potential presence of RTE species was determined by consulting with the Massachusetts NHESP and the New Hampshire NHB during development of the PAD. Table E.7-31 lists the state-listed species and communities that the Commonwealth of Massachusetts and the State of New Hampshire list as potentially occurring within the Project area and provides habitat requirements information.

Table E.7-31. State-listed threatened, endangered, species of special concern, candidate species, and communities potentially occurring within the Project vicinity.

Scientific Name	Common Name	Status ^{a,b}	Habitat/Notes
Massachusetts			
<i>Haliaeetus leucocephalus</i>	Bald Eagle	T	Large lakes, rivers; large riparian trees for nesting, roosting (DeGraaf and Yamasaki 2001).
<i>Stylurus amnicola</i>	Riverine Clubtail	E	Riverine clubtails inhabit primarily medium to large rivers. Although most species of <i>Stylurus</i> fly late in the season, riverine clubtails are on the wing from late June through mid-August (Massachusetts NHESP 2015).

Exhibit E Environmental Report (18 C.F.R. § 5.18)
 Lowell Hydroelectric Project

Scientific Name	Common Name	Status ^{a,b}	Habitat/Notes
New Hampshire			
<i>Alasmidonta varicosa</i>	Brook Floater	E	Sections of stream with low to moderate flow and stable substrates (Nedeau et al. 2000).
<i>Anguilla rostrata</i>	American Eel	SC	American eels are opportunistic carnivores, selecting a range of prey items from small aquatic insects and crustaceans to larger macroinvertebrates and fish (Ross et al. 2001). Yellow eels associate with pools or backwater habitats and often have relatively small home ranges (Gunning and Shoop 1962).
<i>Haliaeetus leucocephalus</i>	Bald Eagle	SC	Large lakes, rivers; large riparian trees for nesting, roosting (DeGraaf and Yamasaki 2001).
<i>Emydoidea blandingii</i>	Blanding's Turtle	E	Permanent, shallow, dark waters with abundant vegetation; marshes, bogs, ditches, ponds, swamps, also in slow moving rivers and protected coves (DeGraaf and Yamasaki 2001).
<i>Heterodon platirhinos</i>	Eastern Hognose Snake	E	Where sandy soils predominate, such as beaches, open fields, dry, open pine or deciduous woods (DeGraaf and Yamasaki 2001).
<i>Sturnella magna</i>	Eastern Meadowlark	T	Large grassy fields of intermediate height and density but also uses grassy meadows, hay fields, tall-grass prairies, agricultural fields and open weedy orchards (DeGraaf and Yamasaki 2001).
<i>Ammodramus savannarum</i>	Grasshopper Sparrow	T	Generally prefers moderately open grasslands with patchy bare ground: dry hayfields, especially those with alfalfa and red clover, weedy fallow fields, prairies, and coastal dunes in Massachusetts (DeGraaf and Yamasaki 2001).
<i>Sylvilagus transitionalis</i>	New England Cottontail	E	Brushy areas, open woodlands, swamps, mountains, beaches, and open lands (DeGraaf and Yamasaki 2001).
<i>Lithobates pipiens</i>	Northern Leopard Frog	SC	Wet open meadows and fields and wet woods during summer months, including river floodplains (DeGraaf and Yamasaki 2001).
<i>Petromyzon marinus</i>	Sea Lamprey	SC	In fresh water, sea lampreys use river reaches with gravel substrate for spawning. Spawning habitat is similar to that used by salmon, occurring at the upstream end of riffles and the tail end of pools (NHDFG undated a).
<i>Porzana carolina</i>	Sora	SC	Prefers freshwater marshes with shallow to intermediate water depths and dominated by emergent vegetation (DeGraaf and Yamasaki 2001).

Exhibit E Environmental Report (18 C.F.R. § 5.18)
Lowell Hydroelectric Project

Scientific Name	Common Name	Status ^{a,b}	Habitat/Notes
<i>Poocetes gramineus</i>	Vesper Sparrow	SC	Sparsely vegetated dry uplands such as short-grass meadows, grazed pastures, hayfields, grain fields, dry open uplands, and burned and cutover areas (DeGraaf and Yamasaki 2001).
<i>Viola pedata</i> <i>var. pedata</i>	Bird-foot Violet	T	This species occurs in sandplains, disturbed openings, dry forests, and thin woods. Threats would include direct destruction of the plants or major alterations in their habitat (Magee and Ahles 1999; New Hampshire NHB 2018).
<i>Cenchrus longispinus</i> *	Long-spined Sandbur	E	This species grows in dry, sandy soil of fields, roadsides, waste areas, beaches, river flats, sandplains, and disturbed openings, and is sensitive to disturbances that eliminate its habitat (Magee and Ahles 1999; New Hampshire NHB 2018).
<i>Betula nigra</i>	River Birch	T	This species grows along rivers and streambanks and the population could be deleteriously affected by any project activities that alter the hydrology of its habitat, by increased sedimentation, and by increased nutrients/pollutants in stormwater runoff (Magee and Ahles 1999; New Hampshire NHB 2018).
<i>Lupinus perennis</i> <i>ssp. perennis</i>	Wild Lupine	T	This wildflower grows in extremely dry, sandy openings. It is tolerant of surrounding disturbance and depends upon periodic mowing (or, historically, wildfire) to eliminate trees that would otherwise shade it out (New Hampshire NHB 2018).
<i>Eleocharis diandra</i>	Wright's Spikesedge	E	Wright's spikesedge is found along gently sloping freshwater shorelines and marshes. It commonly occurs in disturbed, saturated soils of river edges, often in small depressions. It is typically found in the zone along the water's edge that undergoes spring flooding and is exposed in the summer. The species is primarily vulnerable to changes to the hydrology of its wetland habitat, especially alterations that change water levels. It may also be susceptible to increased pollutants and nutrients carried in stormwater runoff (Magee and Ahles 1999; New Hampshire NHB 2018; Massachusetts NHESP 2012).
N/A	Hemlock Forest*	--	Hemlock forests typically occur on rocky, coarse, and/or thin soils poor in nutrients, including ravines, gorges, river and kame terraces, and other microsites below 2000 feet in elevation. Soils typically have well-developed E horizons (classic Spodosols), are very acidic, high in exchangeable aluminum, and low in available nitrogen and other nutrients. Threats include logging, introduction of invasive species, and direct destruction due to development (Sperduto and Nichols 2004; New Hampshire NHB 2018).

Scientific Name	Common Name	Status ^{a,b}	Habitat/Notes
N/A	High gradient Rocky Riverbank System	--	Threats are primarily changes to the hydrology of the river, land conversion and fragmentation, introduction of invasive species, and increased input of nutrients and pollutants (New Hampshire NHB 2018).

Sources: New Hampshire NHB 2018; Massachusetts NHESP 2018; MEOEEA 2018.

a: "E" = Endangered, "T" = Threatened, "SC" = Special Concern, "--" = an exemplary natural community, or a rare species tracked by New Hampshire NHB that has not yet been added to the official state list. An asterisk (*) indicates that the most recent report for that occurrence was more than 20 years ago.

b: The request to New Hampshire NHB included lands within the FERC Project boundary but did not specify a maximum linear distance from the Project boundary in which potential RTE species would be identified. Therefore, for the purposes of this Exhibit, the RTE project area in New Hampshire has been defined as all lands within the FERC Project boundary and lands within approximately 500 feet of the Project boundary.

Massachusetts NHESP Priority and Estimated Habitats

The Massachusetts NHESP identifies Priority Habitat based on the known geographical extent of habitat for all state-listed rare species, both plants and animals, and is codified under the Massachusetts Endangered Species Act (MESA). Habitat alteration within Priority Habitat may result in a take of a state-listed species and is subject to regulatory review by the Massachusetts NHESP. Currently, a portion of the Project boundary, and adjacent terrestrial habitats outside the Project boundary, are listed as Massachusetts NHESP Priority Habitat (Priority Habitat 1987). This area extends from approximately 1.03 miles south of the New Hampshire border on the northern end to just south of the Greater Lowell Technical High School on the southern end along the Merrimack River.

The Massachusetts NHESP also identifies Estimated Habitats, which are a sub-set of the Priority Habitats, and are based on the geographical extent of habitat of state-listed rare wetlands wildlife and is codified under the Wetlands Protection Act (WPA), which does not protect plants. State-listed wetland wildlife species are protected under the MESA as well as the WPA. Currently, a portion of the Project boundary, and adjacent terrestrial habitats outside the Project boundary, are listed as Massachusetts NHESP Estimated Habitat (Estimated Habitat 1320). This area extends from approximately 1.03 miles south of the New Hampshire border on the northern end to just south of the Greater Lowell Technical High School on the southern end along the Merrimack River.

E.7.5.1.3 Identified Federal- and State-listed Species in the Project Area

Fish Species

State-listed fish species were identified through two primary studies, the Fish Assemblage Study and the Downstream American Eel Passage Assessment Study. The methods and results of these studies are presented in the Technical Report for the Fish Assemblage Study (NAI 2021d) and the Technical Report for the Downstream American Eel Passage Assessment (NAI 2021a), respectively, which were filed with the Commission on February 25, 2021.

In accordance with the approved study plan, Boott conducted a Fish Assemblage Study in 2019 to characterize the fish assemblage in areas affected by the Lowell Project, specifically the impoundment and bypassed reach. The study area for this fish community survey included 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 bypassed reach (NAI 2021d). Two state-listed species of special concern, the American eel and the sea lamprey, were identified. Boott captured 17 American eel upstream of the Pawtucket Dam by boat electrofishing and experimental gill net and also captured 33 American eel within the bypassed reach downstream of Pawtucket Dam by backpack electrofishing during the spring, summer and fall sampling in 2019. American eel represented 13.8 percent of the total electrofishing catch from the ledge channel habitat located in the lower portion of the Lowell bypassed reach. Additionally, Boott captured 21 sea lampreys upstream of Pawtucket Dam by boat electrofishing and experimental gill net during the spring, summer and fall sampling in 2019 (NAI 2021d).

Wildlife Species

No ESA-listed wildlife species (i.e., northern long-eared bat) were observed during field studies conducted in 2019 or 2020; although no specific surveys were conducted for this species.

E.7.5.1.4 Designated Critical Habitat

When a species is proposed for listing as endangered or threatened under the ESA, the USFWS must consider whether there are areas of habitat believed to be essential to the species' conservation. Those areas may be proposed for designation as Critical Habitat. Critical Habitat is a specific geographic area that contains features essential for the conservation of a threatened or endangered species and that may require special management and protection. No Critical Habitat has been designated under the ESA for terrestrial species in the Project vicinity (USFWS 2020b).

E.7.5.2 Environmental Analysis

FERC's SD2 identified effects of continued Project operations on threatened and endangered species as potential resource issues. Specifically, SD2 identified the following potential resource issues related to threatened and endangered species to be analyzed for site-specific effects:

- Effects of continued project operation and maintenance on the federally threatened northern long-eared bat.

One federally threatened mammal species, the northern long-eared bat, may occur within the Project area. This aerial insectivore may forage adjacent to Project waters in forested habitats in the summer but is not expected to be adversely affected as a result of Project operation. This bat species roosts in upland areas (live or snag trees, caves, etc.), outside of the range of potential Project operational affects. This bat species spends winters months in hibernacula and is not expected to be adversely affected by

Project operations. There are no known hibernacula or roost trees for northern long-eared bat in the immediate vicinity of the Project's facilities. Additionally, the occurrence and distribution of terrestrial wildlife resources in the Project area is generally unrelated to operation of the Project. The operation of the Project as proposed is not expected to have any adverse effects on northern long-eared bat; however, in the event Boott performs maintenance activities at the Projects that could affect bat habitat, Boott will perform the required consultation and protection measures pursuant to applicable federal and state laws and regulations, including the Endangered Species Act.

Bald eagles are known to use the Merrimack River watershed for winter perching, roosting, and feeding activities and have been documented along the Merrimack River mainstem from Franklin to Nashua, New Hampshire, and throughout the Massachusetts portion of the basin (USACE 2003). Continued Project operations as proposed by the Licensee have a very low potential to impact bald eagles or roost trees. The occurrence and distribution of terrestrial wildlife resources in the study area is generally unrelated to Project operations. Boott conducts routine Project maintenance activities and manages formal Project recreation facilities at the Project. Project maintenance activities are generally localized and minor in nature.

Some State wildlife Species of Special Concern may potentially occur within the Project. These include several bird species and one amphibian species (northern leopard frog). All of the wildlife Species of Special Concern that have potential to occur within the Project area are highly mobile and are most likely to occur in the Project area for foraging (and, in some cases, breeding) during temperate months. The Licensee is proposing no fundamental changes in operation. As a result, and given that no RTE species have been documented within the Project boundary, continued operation of the Project is not expected to adversely affect RTE species.

E.7.5.3 Proposed Environmental Measures

Boott proposes continued operations of the Project with environmental PM&E measures which will protect rare, threatened and endangered species and their habitats. These measures include:

- Boott proposes to operate the Project in a ROR mode using automatic pond level control of the E.L. Field powerhouse units, for the purpose of protection of fish and wildlife resources downstream from the Project. ROR operation may be temporarily modified for short periods to allow flow management for other project and non-project needs, e.g., downtown canal water level management, raising the crest gates following a high-water event, or for recreational purposes.
- On a seasonal basis during the upstream passage season (i.e., typically from early May through late June/early July – and to be defined annually in consultation with the Merrimack River Technical Committee (MRTC)) the Licensee will provide a zone of passage flow of 500 cfs or inflow, whichever is less, into the Project's bypassed reach to provide appropriate fish passage conditions.

- Boott proposes to entirely suspend generation and operations of the downtown canal units during the downstream fish passage season (typically May through November – and to be defined annually in consultation with the MRTC). At the start of the downstream fish passage season, all downtown canal units will be shut off and flows will not be diverted into the downtown canal system (*except as noted in E.6.2 under Canal Water Elevations and Canal Water Flows*). At the end of the fish passage season, when river flows exceed the hydraulic capacity of the E.L. Field units (6,600 cfs for both units) and the bypass flow, excess flows up to approximately 2,000 cfs may be routed through the downtown canal system and to the canal units.
- Boott proposes to release a minimum flow of 100 cfs or inflow, whichever is less, to the bypass reach downstream of the Pawtucket Dam during the period outside of the upstream fish passage season. The minimum flow would be provided as spillage over one or more of the crest gate zones.
- Boott proposes to replace the existing fish lift with a short fish ladder to pass migratory fish from the E.L. Field powerhouse tailrace to the bypass reach, such that fish would be passed upstream of the Project via the existing fish ladder at the Pawtucket Dam. As approved by the MRTC, the proposed fish ladder will be operated on a seasonal basis. In accordance with the Settlement Agreement, Boott will consult with USFWS and NMFS to determine the design and installation schedule for the proposed ladder. Boott may consult with the MRTC to discuss the possibility of requesting a reevaluation of new technology in the future.
- Following installation and operation of the proposed upstream fish passage structure, Boott proposes to cease operation of the fish elevator and associated operations described above. Cessation of the fish elevator operations will be determined based on consultation with relevant agencies and Boott should not have to continue to incur maintenance costs once the upstream passage structure is constructed and tested.
- Boott proposes to install a new fish exclusion structure or approved equivalent at the E.L. Field Powerhouse to prevent entrainment of fish through the turbines. Downstream passage of fish will continue to be provided via the existing sluice gate in the left forebay wall of the E.L. Field Powerhouse. The Licensee will consult with the MRTC member agencies to determine the design and installation schedule for the proposed downstream fish exclusion system. Boott reserves the right to seasonally deploy the new exclusion facility only during the downstream fish passage season.
- Between August 15 and November 15 of each year until the proposed downstream fish passage protection measures are fully implemented, Boott is proposing nighttime shutdowns as an interim measure to protect out-migrating adult American eel. Boott will consult with the MRTC on the nighttime shutdowns.
- Boott proposes continued adherence to the requirements of the Project's existing Crest Gate Operation Plan (approved by FERC on March 30, 2015).

E.7.5.4 Unavoidable Adverse Impacts

The occurrence and distribution of terrestrial wildlife and RTE resources in the study area is generally unrelated to Project operations. The continued operation of the Project as proposed by the Licensee is not expected to have any adverse effects on the northern long-eared bat. Routine Project maintenance activities that could affect bat habitat are generally localized. Bat foraging may take place over the impoundment and along the shoreline; however, the ROR operation of the Project will not affect the ability of bats to access foraging habitat or limit potential prey species (e.g., invertebrates).

E.7.6 Recreation and Land Use

The subsections below describe recreation and land use in the vicinity of the Project and consider the effects of continued operation of the Project as proposed by the Licensee on these resources. Descriptions of the affected environment, the environmental analysis, the proposed environmental measures, and the identification unavoidable adverse effects were developed based on available data presented in the Licensee's PAD, and the:

- Recreation and Aesthetics Study Report (HDR 2021a)
- Water Level and Flow Effects on Historic Resources Study Report (HDR 2021b)
- Resources, Ownership, Boundaries and Land Rights Study Report (HDR 2021c)
- Whitewater Boating and Access Study Report (HDR 2024)

In accordance with the Commissions SPD, Boott filed the Resources, Ownership, Boundaries, and Land Rights Study Report on February 25, 2021, and the Water Level and Flow Effects on Historic Resources Study Report was filed with the Commission on November 1, 2021. On March 1, 2022, the Commission issued a Determination on Requests for Study Modifications for the Lowell Hydroelectric Project. In response to this issuance, on May 31, 2022, Boott filed the Recreation and Aesthetics Study Report. On May 31, 2022, Boott filed the Initial Whitewater Boating and Access Study Report. On January 23, 2023, Boott filed the updated Whitewater Boating and Access Study Report, and on December 23, 2024, Boott filed the Final Whitewater Boating and Access Study Report.

E.7.6.1 Affected Environment

E.7.6.1.1 Project Recreation Facilities

Pursuant to existing License Article 38 and the FERC-approved Recreation Plan, Boott maintains one formal recreation area at the Project:

E.L. Field Powerhouse Visitor Center (Visitor Center)

The Visitor Center, located along the mainstem of the Merrimack River, offers a secured view of the interior of the turbine gallery and an interpretive display that provides information regarding the development, history, and operation of the Project, and nearby historic, natural, cultural, recreational resources, and other items of interest.

E.7.6.1.2 Recreation in the Project Area

The Project's primary features are located along the Merrimack River in the City of Lowell, Massachusetts. The Merrimack River watershed supports all or parts of approximately 200 communities with a total population of 2.6 million people (USEPA 2020b; USACE 2006). The Merrimack River provides numerous recreational opportunities including boating, canoeing, kayaking, rowing, fishing, and swimming to the residents of the communities along its banks. The river is also utilized by residents of major cities in the region, particularly residents from Boston (Nashua Regional Planning Commission [NRPC] 2008; NHDES 2019a; USACE 2006).

The Project dam is located at RM 41 on the Merrimack River, and the impoundment extends upstream approximately 16 miles to Cromwell's Falls in Litchfield and Merrimack, New Hampshire. The Project impoundment is characterized by the urban/industrialized cities of Nashua, New Hampshire and Lowell, Massachusetts. Several parks and conservation areas in the vicinity of the Project afford additional recreation opportunities that include hiking, cross country skiing, picnicking, and bird watching. Recreational opportunities differ closer to the larger, more populated cities along the river.

Several project facilities are located within overlapping locally, state, and nationally designated parks and historic properties/preservation districts. Non-Project related recreational facilities and opportunities in the Project's vicinity include:

- Depot Street Boat Ramp
- Greely Park and Boat Ramp
- Lowell National Historic Park (LHNP)
- Lowell Heritage State Park
- Lowell-Dracut Tyngsborough State Forest
- Flints Pond Access
- Merrill Park
- Twin Bridge Park
- Moore's Falls Conservation Area
- John Bryant River Access
- Thornton's Ferry Boat Launch
- Litchfield State Forest

- Horse Hill Nature Preserve
- Leslie Bockes Memorial Forest
- New Hampshire Heritage Trail
- Chelmsford Boat Access
- Great Brook Farm State Park
- Warren H. Manning State Forest
- Billerica State Forest
- Carlisle State Forest
- Governor Thomas Dudley State Park
- Merrimack River Boat Access.

These and other non-Project related facilities are not owned or operated by Boott but are popular Merrimack River recreational areas. In addition, there are numerous informal access areas on Lowell Hydroelectric Project lands that are used by the public for access to the Merrimack River. Figure E.7-20 depicts the wide range of recreational opportunities in the vicinity of the Project, which are described in more detail below.

Figure E.7-20. Recreation Opportunities in the Vicinity of the Lowell Hydroelectric Project

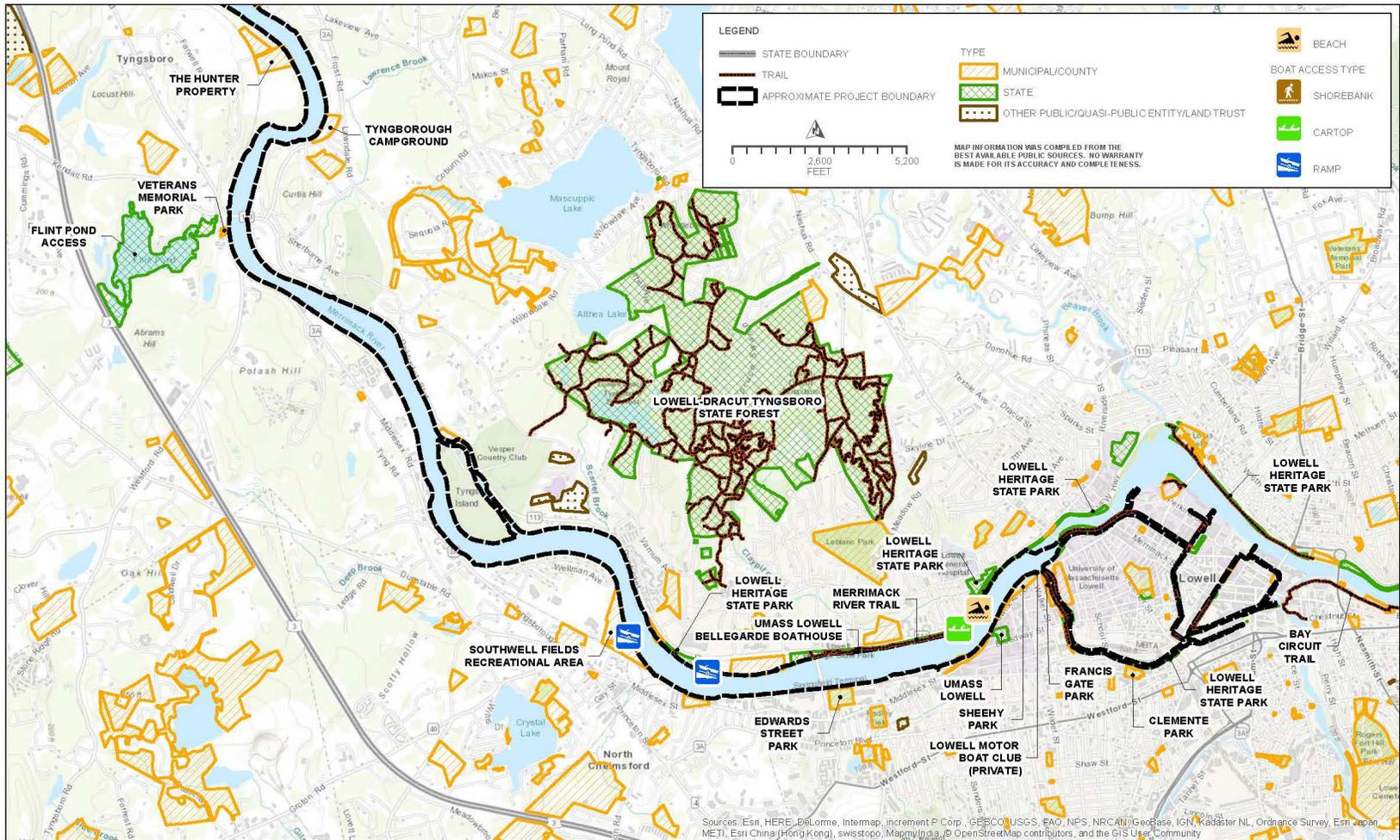


Exhibit E Environmental Report (18 C.F.R. § 5.18)
 Lowell Hydroelectric Project

Figure E.7-20 continued

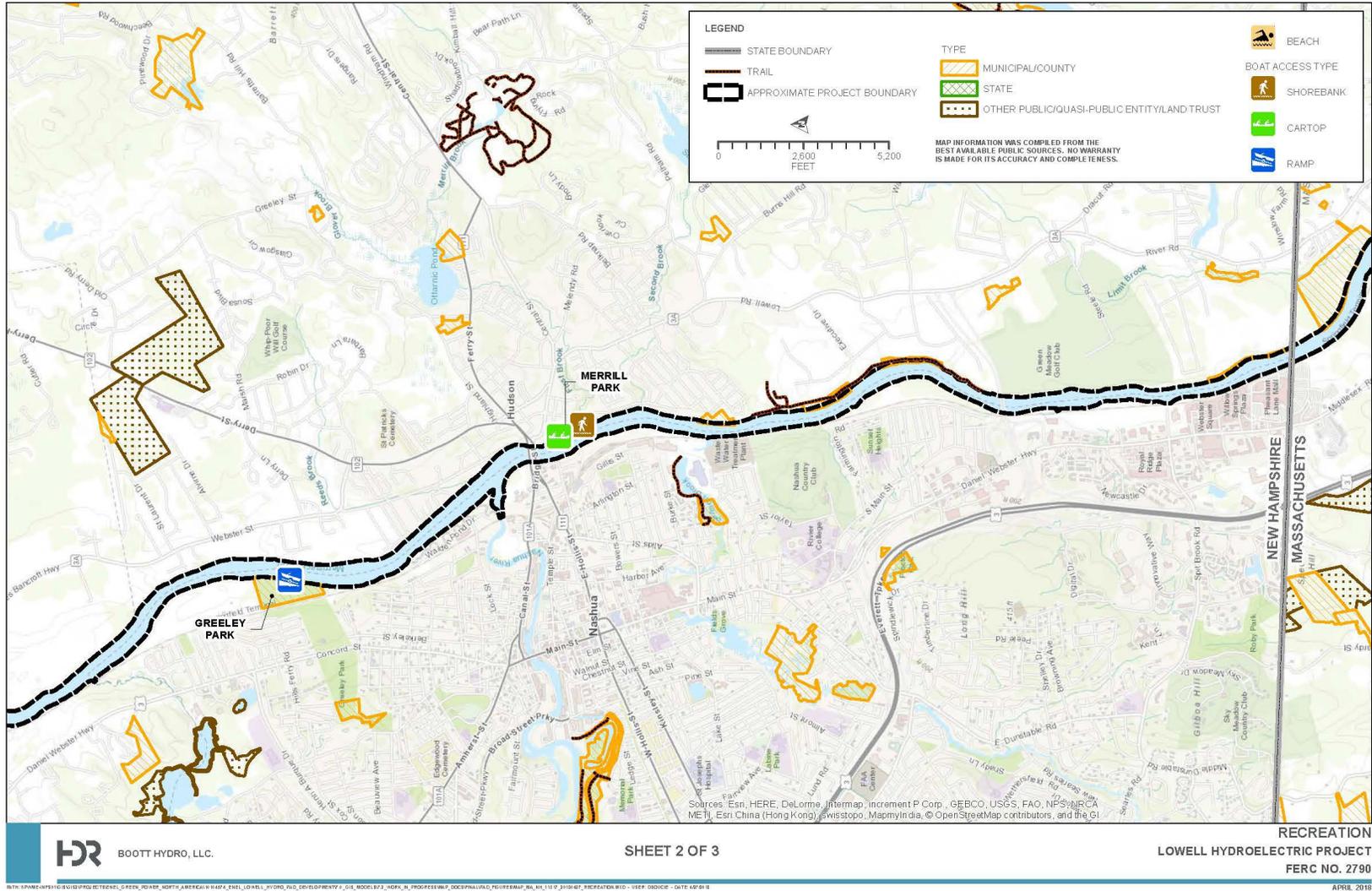
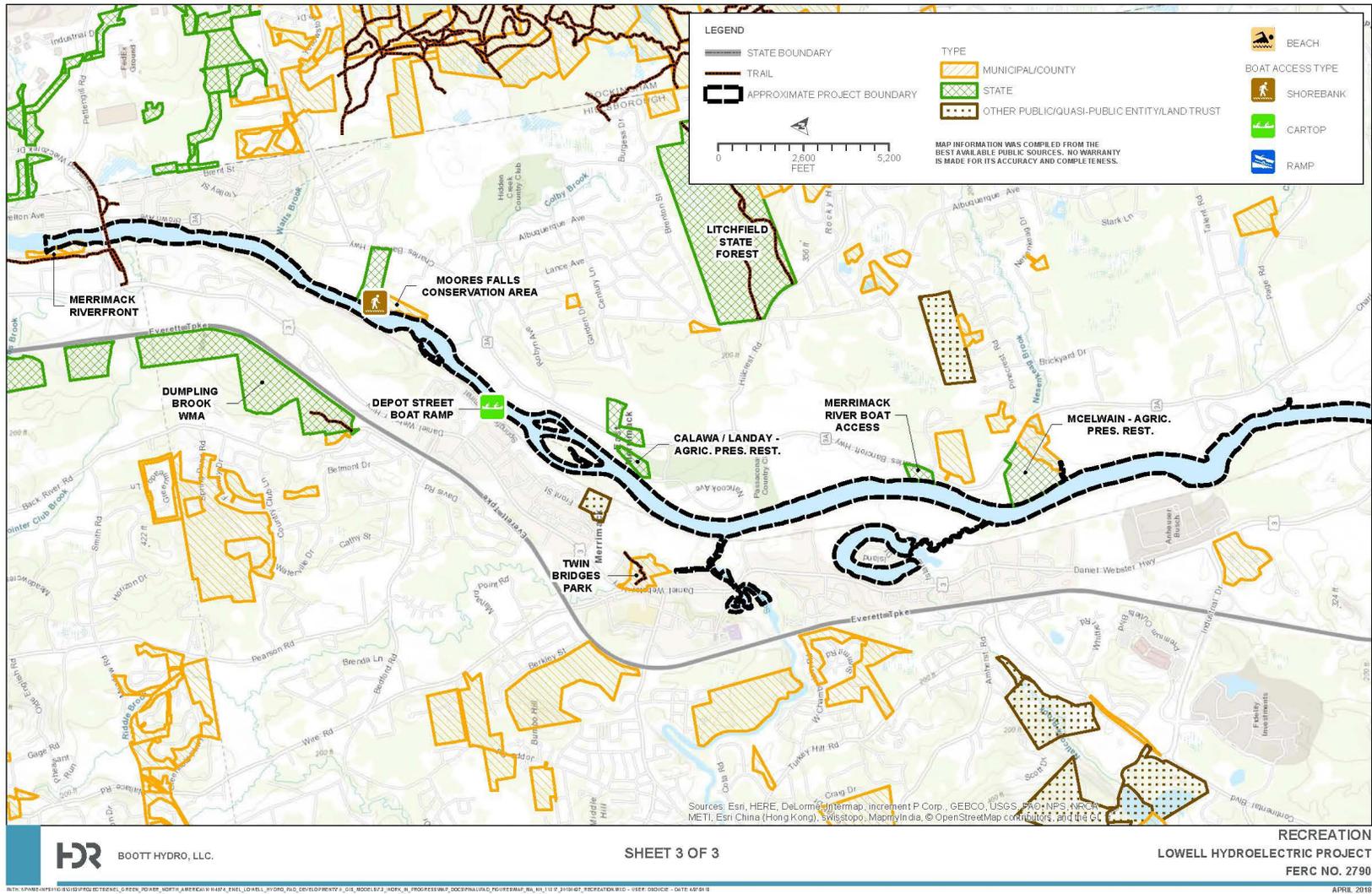


Figure E.7-20 continued



E.7.6.1.3 Recreation Opportunities in New Hampshire

The State of New Hampshire reports many recreational uses of the Project impoundment, including fishing, canoeing, kayaking, rowing, and motor boating. Much of the Project impoundment is in Hillsborough County, New Hampshire, which has approximately 54,480 acres of recreation lands and 116 public access sites to the water (New Hampshire Department of Natural and Cultural Resources [NHDNCR] 2018). Most of the shore lands along the Merrimack River in New Hampshire are privately owned; therefore, recreation activities take place immediately on the Merrimack River (NRPC 2008). There are six known boat access facilities in New Hampshire with direct access to the Project impoundment. These facilities range in design from concrete ramps to shoreline access and are described below:

Moore's Falls Conservation Area: Moore's Falls Conservation Area offers shoreline fishing and car-top boating access to Moore's Falls upstream of the Project impoundment. Moore's Falls are a length of rapids on the Merrimack River which drop 6 feet in elevation over 650 feet in distance, which define the upstream extent of the Project impoundment. There are also walking trails through the woods, an old trolley track trail, multiple access points to the Merrimack River for fishing, educational information regarding environmental conservation, and birdhouses. Running along the east bank of the river are the remains of a historic lock structure constructed in the early 1800s. NHDES recommends this conservation area for angler fishing, as small and large mouth bass are often caught, as well as rainbow and brook trout, both of which are stocked by the NHFGD in the Lower Merrimack River (Middlesex Canal Association 2009; NHDES 2019a).

Depot Street Boat Ramp: The Depot Street Boat Ramp offers a carry-in boat ramp and fishing access to the Merrimack River and is managed by the Town of Merrimack. The trail to the river runs under railroad tracks. This access is suitable for motorboats, as the river slows from the rocky rapids upstream (NHDES 2019a; Merrimack Parks and Recreation 2020). There is also a scenic picnic area.

John Bryant River Access: The John Bryant River Access is a canoe/kayak car top facility managed by the Litchfield Recreation Commission. It provides fishing access, scenic views of the river, and birdwatching. It is available only to Town of Litchfield, New Hampshire residents (Litchfield Recreation Commission 2020).

Thornton's Ferry Boat Launch: Thornton's Ferry Boat Launch is owned by the Town of Merrimack and offers cartop carry-in boating and fishing access to the Merrimack River (NHFGD undated).

Greeley Park & Boat Ramp: Greeley Park is a 125-acre city park located in Nashua, New Hampshire. Greeley Park offers many recreation amenities/facilities including baseball/softball fields, historical sites, picnic areas, playgrounds, restrooms, tennis courts, trails, and wading pools (NHFGD undated; City of Nashua 2020). In 2019, the City of Nashua issued an invitation to bid for reconstruction of the Greeley Park Boat Ramp, as well as construction of a gravel parking lot, placement of new signs, and three biological retention ponds. The work was completed in July 2020 (NHFGD undated; City of Nashua 2019; The Telegraph 2020). A paved ramp at the north end of Greeley Park in

Nashua also allows access to the river for boaters. NHDES recommends this conservation area for angler fishing (NHDES 2019a).

Merrill Park: Merrill Park is a 9.3-acre city park located in Hudson, New Hampshire. It is adjacent to the east riverbank and Project boundary. The park is mostly forested with a few walking paths and picnic benches. It has a path which leads down to the Merrimack River, allowing hand-carry access for canoes or kayaks, or fishing (Town of Hudson undated).

In addition to the facilities mentioned above, the following facilities are within a 30-minute drive from the Project boundary and provide outdoor activities that include wildlife observation, driving for pleasure, sightseeing, day hiking, and jogging/running/walking.

Litchfield State Forest: The Litchfield State Forest is a 450-acre forest in Litchfield managed by the State of New Hampshire. It is located about 1.5 miles east of the Project boundary. The 1.3-mile Litchfield State Forest Trail provides comfortable walking and biking trails. Off trails provide an additional four miles of hiking, wildlife observation, and scenic opportunities. The trails are often used for cross country skiing in the winter (Litchfield Recreation Commission 2020; ExploreYourSpaces 2020).

Flints Pond Access: Flints pond is a 50-acre, warm water pond located in the Town of Hollis, New Hampshire. The pond is open to the public for fishing, kayaking, and canoeing in the summer. In the winter, ice fishing, snowshoeing, and snowmobiling are also popular. A boat ramp is available at the north end of the pond (Flints Pond Improvement Association 2015). Flints Pond Access is approximately 0.2 miles west of the Project boundary.

Horse Hill Nature Preserve: Horse Hill Nature Preserve is a 560-acre property owned by the Town of Merrimack, located about three miles west of the Project Boundary. It is primarily a mixed hardwood forest, with a series of streams, ponds, swamps, and numerous wetlands. Old logging roads form the basis of what is today a trail network used by hikers, bikers, cross country skiing, snowshoeing, hunters, snowmobilers, and horseback riders. This trail network covers most of the property, however, there are still large areas without defined access.

Leslie Bockes Memorial Forest: Forest Society owns and manages this approximately 226-acre forest located in Londonderry, New Hampshire (five miles east of the Project Boundary). Nearly four miles of old logging roads provide hiking, skiing, and snowshoeing with numerous access points. The trails are on well-maintained woods roads that enable easy walking and generally good footing. The tract is a known spot for bird and nature-watching (Forest Society 2020).

Twin Bridge Park: Twin Bridge Park is in Merrimack, New Hampshire, and features a baseball field, playground, picnic area, and extensive hiking trails through 27 acres of woods along Baboosic Brook (Town of Merrimack undated). Twin Bridge Park is approximately 0.2 miles west of the Project Boundary.

New Hampshire Heritage Trail: The completed trail system will connect trail segments along the Lower Merrimack River and ultimately extend south into Massachusetts, and north along the Merrimack, Pemigewasset, and Connecticut Rivers to the Canadian border. Several trail sections have been completed along this part of the river and

northward, with existing segments in Nashua, Hooksett and Manchester, New Hampshire (NHDES 2019a).

E.7.6.1.4 Recreation Opportunities in Massachusetts

The state of Massachusetts reports that recreation along the Project impoundment changes as open space generally decreases further downstream and riverfront communities are more industrialized (MEOEEA 2001). Water-based recreation (boating, fishing, canoeing, and swimming) is provided on the downstream portion of the Project impoundment by multiple boat ramps and waterfront parks. There are many additional recreational opportunities in and surrounding Lowell, including networks of trails, thousands of acres of nearby state forest, and urban passive parks for walking, jogging, dog-walking, and picnicking (City of Lowell 2018; MADCR 2014; LNHP 2017).

As part of the LNHP or Lowell Heritage State Park, different sites in and around the city of Lowell are related to the historical era of textile manufacturing and offer museum exhibits, walking tours, and interpretive/interactive displays (LNHP 2017; MADCR 2014). Boat tours led by NPS guides also provide access to the historic canal system and the Project impoundment. The canal boat tours highlight some of the Lowell Hydroelectric Project facilities by travelling through the historic navigation locks (NPS undated c). Although portions of the LNHP are within the Project boundary, it is not a FERC-approved recreation facility. Additional recreational opportunities provided by NPS at the LNHP include trolley rides available for touring the city.

The downstream portion of the Project impoundment is accessible for water-based recreation by the following recreational facilities:

Lowell National Historical Park: The LNHP was established in 1978 and is operated by the NPS. This National Historic Park is made up of a group of different sites in and around the city of Lowell, Massachusetts, related to the era of textile manufacturing that relied on hydroelectric power to operate during the Industrial Revolution of the early 1800s. It is a primary recreation attraction for the City of Lowell and the Lowell Hydroelectric Project. While the majority of the Project facilities, canals, gatehouses, dams, locks, and powerhouses, are necessary components of its operations, they serve a dual purpose as a NPS attraction for which it is maintained and preserved as a historic property (NPS undated c). As noted above, LNHP is not a FERC-approved recreation facility despite the canal system and many of the Project's facilities being located within the Project Boundary. Section 102 of the Lowell Act (16 U.S.C. § 410cc-12) requires FERC to: (a) make findings of whether a proposed maintenance activity will have an adverse effect on the resources of the Lowell NHP or Lowell Historic Preservation District; and (b) determine whether a proposed maintenance activity "will be conducted in a manner consistent with" the Standards for Rehabilitation and Construction Standards (Standards) established under section 302 of the Lowell Act (16 U.S.C. § 410cc-32(e)) and set forth at 46 Fed. Reg. 24000 (1981).

Lowell Heritage State Park: The 83-acre Lowell Heritage State Park occupies a 2-mile long stretch along the north bank of the Project impoundment, upstream of the Pawtucket Dam. The park features historical exhibits that were created in partnership

with the NPS to educate the public regarding the network of canals and mills constructed in the 19th century to power Lowell's then bustling textile industry. Activities available include biking, boating (non-motorized and motorized), canoeing and kayaking, swimming, fishing, hiking, and educational programs. Facilities include a paved bike path and walking esplanade, picnic area, a beach, restrooms, scenic viewing area, an outdoor concert stage, and visitors center (Commonwealth of Massachusetts 2018a). Also located within the park boundary is the University of Massachusetts Lowell Bellegarde Boathouse, which also houses the Merrimack River Rowing Association, a non-profit rowing club.

Rourke Brothers Boat Ramp (part of the Lowell Heritage State Park): The park provides a trailered boat launch, located on the north bank of the impoundment about 2 miles upstream of the Pawtucket Dam. Adjacent to the boat launch is an access dock for boating and fishing.

Chelmsford Boat Access: The park provides a trailered boat launch, shoreline fishing access, picnic areas, athletic fields, and trails.

In addition to the facilities mentioned above, these facilities are located within a 30-minute drive from the Project Boundary.

Lowell-Dracut Tyngsborough State Forest: The Lowell-Dracut Tyngsborough State Forest is approximately one mile north of the Project boundary. The Lowell-Dracut Tyngsborough State Forest spreads across three towns and features over 1,140 acres of protected land, including 180 acres of open water or wetlands and 457 acres of land in the city of Lowell. Popular activities include hiking, fishing, hunting, cycling, birding, picnicking, nature walking, mountain biking, and playing various field sports. In the winter, people sled, ice skate, and cross-country ski (Commonwealth of Massachusetts 2018c).

Great Brook Farm State Park: Located seven miles south of the Project, this park is a working dairy farm connected to miles of trails that can be used for a variety of recreational activities. The park also includes historic buildings and resources, interpretive programming, and a cross-country ski concession.

Warren H. Manning State Forest: Located five miles south of the Project, this state forest is a largely wooded property with a small recreation area, complete with a spray deck, picnic area, water playground, and fitness trail.

Billerica State Forest: Located six miles south of the Project, this state forest offers rustic, multi-use trails and wooded areas for walking and wildlife viewing.

Carlisle State Forest: Located ten miles south of the Project, this state forest provides over a mile of trails through wooded property protected from forestry activities at the turn of the 20th century. The forest includes an older stand of exceptionally large eastern white pines.

Governor Thomas Dudley State Park: Located ten miles south of the Project, this 11-acre park is a small, wooded parcel, that provides access to the Concord River and links to other protected open spaces.

E.7.6.1.5 Existing Shoreline Management Plans

There is no formal Shoreline Management Plan or permitting policy for the shoreline of the Lowell Hydroelectric Project.

E.7.6.1.6 Existing Shoreline Buffer Zones

At normal pool elevation of 92.2 feet NGVD, there are approximately 32 shoreline miles bordering the current impoundment of the Pawtucket Dam. Both New Hampshire and Massachusetts have established shoreline buffer zones. Per New Hampshire's Comprehensive Shoreland Protection Act (CSPA), which contains minimum standards to protect public surface waters and their immediate environs, any disturbance activity greater than 50,000 feet² occurring within 250 feet of the Merrimack River requires an Alteration-of-Terrain permit (LMRLAC 2008). In Massachusetts, the Wetlands Protection Act (Massachusetts General Laws Chapter 131, Section 40) protects important water-related lands and other areas from destruction or alteration. Generally implemented by the local Conservation Commission in each municipality, the Act establishes a 100-foot buffer zone around all coastal banks, inland banks, freshwater wetlands, coastal wetlands, tidal flats, beaches, dunes, marshes, and swamps, and a riverfront area within 200 feet of rivers and streams (or 25 feet of some urban rivers) that flow year round. The canals in Lowell are specifically defined as not having a riverfront area [310 CMR 10.58 (2)1.g] (MACC undated).

E.7.6.1.7 National Wild and Scenic River System, National Trail System, and Wilderness Areas

The Merrimack River is not designated as a National Wild and Scenic River or under study for inclusion in the National Wild and Scenic River System. The Lowell Hydroelectric Project is not located within or adjacent to lands included in, or under study for inclusion in, the National Trails System or designated as, or under study for inclusion as, a Wilderness Area.

E.7.6.1.8 Nationwide Rivers Inventory

The upper portion of the impoundment was listed under the National Rivers Inventory in 1995. The full classified reach is 16 miles long from Amoskeag Dam in Manchester to the confluence with Pennichuck Brook in Merrimack. The reach is considered notable due to fish, historic, recreational, and wildlife values (NPS undated *b*).

E.7.6.1.9 State-protected Rivers

The lower reach of the Merrimack River, which includes the upstream impoundment of the Project in New Hampshire, is designated as a "Community River" under the New Hampshire Rivers Management and Protection Program (NHDES 2017). Community rivers are defined as "those rivers or river segments which flow through populated areas of the state and which possess actual or potential resource values. Such rivers have some residential or other building development near their shorelines, are readily accessible by road or railroad, and may include some impoundments or diversion."

(NHDES 1990). The LMRLAC provides an advisory role on matters pertaining to the management of the river, and comments on development plans which might affect the river's resource values. The LMRLAC also maintains a river corridor management plan pursuant to NH RSA 483:10 (NHDES 2008).

E.7.6.1.10 Regionally or Nationally Significant Recreation Areas

The Lowell Hydroelectric Project is located within the LNHP, a regionally and nationally significant recreation area.

E.7.6.1.11 Recreation Use and Need

Recreation Studies

Recreation and Aesthetics Study

Pursuant to the approved study plan, Boott conducted a Recreation and Aesthetics Study to identify existing recreation use as well as recreation resources and activities that may be affected by the continued operation of the Project. The methods and results of the Recreation and Aesthetics Study are described in detail in Boott's Recreation and Aesthetics Study Report (HDR 2021a) filed with the Commission on February 25, 2021. The Commission's March 1, 2022, Determination on Requests requested the Recreation and Aesthetics Study Report be updated with new information to identify Project effects on recreation. Boott filed a Recreation and Aesthetics Updated Study Report with FERC on May 31, 2022 (Boott 2022).

Field Inventory

Boott inventoried non-Project recreation facilities within the Project's vicinity in the fall of 2019, including the Chelmsford Boat Access, Depot Street Boat Ramp, Greeley Boat Ramp, Lowell Heritage State Park, LNHP, Merrill Park, Merrimack Trail System, Moore's Falls Conservation Area, NPS Canal Walkway, Pawtucket Falls Overlook, and Rourke Brothers Boat Ramp. The Visitor Center (the only-FERC approved recreation facility) was closed on the days of inventory, but the external features (e.g. parking lot) were also inventoried. Pursuant to the RSP, Boott collected information regarding each facility including the type and location of existing recreation facilities, the type of recreation provided (e.g., boat access, angler access, picnicking, etc.), existing amenities and sanitation, the type of vehicular access and parking (if any), the suitability of facilities to provide recreational opportunities and access for persons with disabilities (i.e., compliance with current Americans with Disabilities Act [ADA] standards for accessible design), GPS location data, and representative photographic documentation of recreation facilities. The results of the field inventory are presented in Appendix B to the Recreation and Aesthetics Study Report. A map of inventoried facilities is presented as Figure E.7-21.

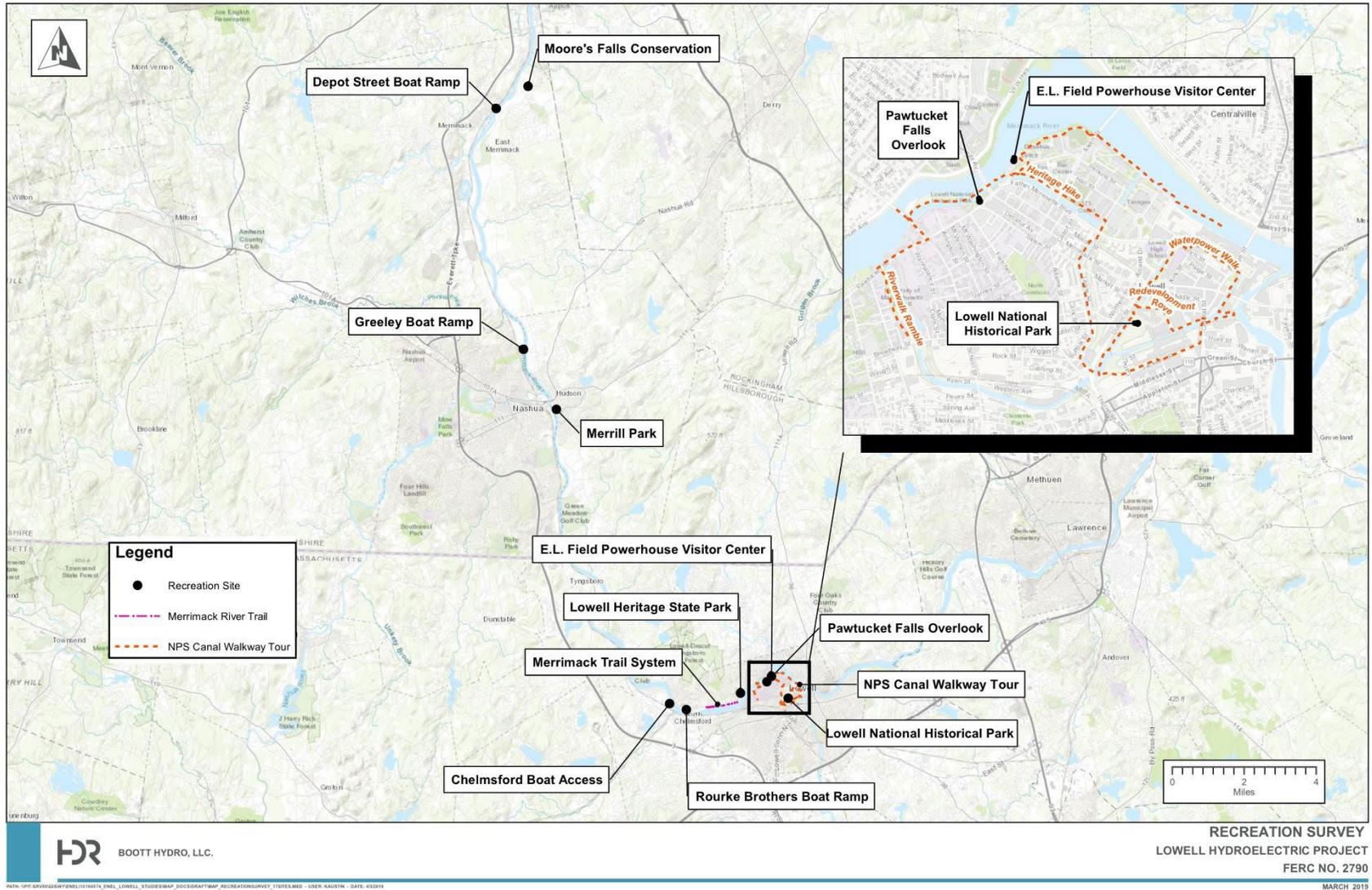
Visitor Use Data and Field Reconnaissance

As provided in the approved study plan, Boott conducted personal interviews (visitor intercept surveys) and field reconnaissance activities at recreation facilities in the Project's vicinity between May and October 2019. Boott developed survey questions based on general concepts and guidance from the U.S. Forest Service's (USFS)

National Visitor Use Monitoring Handbook (USFS 2007) and questions that were asked during recreation studies for other relevant hydropower relicensings. The survey questions that were asked during the personal interviews are included in Appendix A of the Recreation and Aesthetics Study Report. Boott consulted with the NPS, MADCR, and American Whitewater (AW) to identify specific recreation survey locations.

In May 2019, Boott began conducting personal interviews at the Lowell Heritage State Park, Merrimack Trail System, Pawtucket Falls Overlook, NPS Canal Walkways, LNHP Visitor Center, Chelmsford Boat Access, Rourke Brothers Boat Ramp, Merrill Park, and Whitewater takeout location. The surveys were conducted on random weekdays and weekend days throughout the months of May, June, July, August, September, and October of 2019. Personal interviews and field reconnaissance were conducted on four days of each month on both weekdays, weekend days, and holidays. A team of two technicians traveled between each of the aforementioned recreation sites and spent approximately one hour at each site conducting the personal interviews and collecting field reconnaissance data including (a) the various types of recreation activities, (b) an estimation of the number of vehicles, and (c) the approximate numbers of recreationists observed at each site. Field reconnaissance data is summarized in Appendix D of the Recreation and Aesthetics Study Report.

Figure E.7-21. Recreation Facilities Inventoried During Recreation and Aesthetics Study



For the personal interviews, individual recreationists and groups were interviewed, including visitors using boat launches and LNHP-managed facilities. Respondents answered questions verbally while a technician recorded their responses using the Qualtrics® offline survey platform to record and submit answers.¹⁹ The personal interview questions included topics such as: general user information; age group, resident/visitor; purpose and duration of visit; distance traveled; history of visiting the site or area; types of recreational activities respondents participated in or planned to participate in during their visit; other recreational sites that respondents visited or intended to visit during their trip; general satisfaction with recreational opportunities, flow conditions, facilities, and the respondents overall visit and/or areas that need improvement; accessibility of facilities or areas; economic aspects, including dollars spent during their trip; and day use/overnight lodging during their visit. Before rotating to the next site, technicians also recorded the date, time, and weather conditions observed.

A total of 53 individuals participated in the interviews. Personal interviewees travelled an average of 7.3 miles to the recreation area, with a range of 0.1 miles to 3,000 miles. The most common recreational activities survey respondents participated in were trail related activities (walking, dog-walking, hiking, running, or jogging), bank and/or boat fishing, and kayaking. Walking was the most common primary recreation activity. The majority (77 percent) of personal interview respondents rated their overall experience of recreational activities at the Project as “totally acceptable” or “acceptable.”

According to respondents, the most frequently visited recreational facilities in the Project area were the Lowell Heritage State Park, the Rourke Brothers Boat Ramp, Chelmsford Boat Access, Merrimack Trail System, and LNHP-facilities. Participants were asked several questions regarding their general opinions of recreation in the vicinity of the Project, potential issues with the recreation facilities (i.e., crowding, safety), and recommendations for improvements to existing facilities. In general, the participants did not experience much crowding at the recreational facilities, parking issues, or lack of accessibility to the specific recreational facilities. Respondents tended to rate their overall experience at specific recreation facilities as “totally acceptable.” The most common recommendations for recreational enhancements were: (1) bathrooms/porta potty (2) improving/maintaining the existing structures such as the boat ramps, and (3) the addition of trash cans/trash control measures.

Field reconnaissance data obtained during personal interviews indicates the recreation facilities are well-utilized for many different activities. Walking (and dog-walking) and jogging/running were by far the most common activities observed by technicians. Additional common activities included bicycling, boating, picnicking, and fishing. The Merrimack Trail System and the Lowell Heritage State Park were highly utilized for many different recreational opportunities; these are connecting facilities, so it was common for recreationists to visit both. The Rourke Brothers Boat Ramp and the Chelmsford Boat

¹⁹ While the survey questions in the approved study plan were utilized for these interviews, the numbering and specific wording was adapted during the interview to better facilitate the interview and to accommodate the Qualtrics® survey platform.

access were predictably mostly used for boating, but also commonly utilized for walking, dog-walking, fishing, and picnicking. The Chelmsford Boat Access adjoins a series of softball fields, and technicians reported softball tournaments with hundreds of attendees during the summer weekends. At all facilities, technicians generally reported less activity during the early daylight hours, and during rainy, cool times of the day.

Results from the personal interviews are compiled in Appendix C of the Recreation and Aesthetics Study Report.

Online Survey

In addition to the personal interviews and visitor use data collection, Boott developed a version of the interview questions to allow respondents to provide survey responses online. In accordance with the approved study plan, the survey was made available for one year, from June 2019 to June 2020, on the Project's relicensing website (www.lowellprojectrelicensing.com). The online survey was developed using the Qualtrics® survey platform. Boott posted a brief description of the purpose and intent of the survey and the website address at popular recreation access areas at the Project. During personal interviews and field reconnaissance, Boott provided handouts to recreationists with the relevant information on how to access the online survey. Boott notified the Commission and stakeholders of the availability of the online survey in the Second Quarterly Study Progress Report filed with the Commission on October 1, 2019. The survey questions developed for the online survey are also included in Appendix A of the Recreation and Aesthetics Study Report.

A total of 96 respondents completed the online survey. Online respondents stated they travelled on average around 11 miles to the Project area. The majority (92 percent) of online respondents rated their overall experience of recreational activities at the Project as "totally acceptable" or "acceptable." Of the online recreation surveys completed (76 percent of online respondents), the respondents thus far are typically regular visitors who visit three or more times per year and the remaining respondents identified themselves as first-time visitors or infrequent visitors. Most respondents stated they do not stay overnight in the Project area in accommodations other than their primary residence (90 percent of online respondents).

According to respondents, the most frequently visited recreational facilities in the Project area were the Lowell Heritage State Park, the Rourke Brothers Boat Ramp, Chelmsford Boat Access, Merrimack Trail System, and LNHP-facilities. Online respondents tended to rate their overall experience at specific recreation facilities as "totally acceptable." The most common recommendations for recreational enhancements were: (1) bathrooms/porta potty (2) improving/maintaining the existing structures such as the boat ramps, and (3) the addition of trash cans/trash control measures.

Results from the online surveys are compiled in Appendix E of the Recreation and Aesthetics Updated Study Report (Boott 2022).

Expansion of Recreational Access to Project Canals

In the Commission's March 1, 2022, Determination on Requests, staff requested an analysis of the effects of Project operation on NPS boat tours and recreational rights. FERC also requested an evaluation of the potential for expanding public access to the

canals for recreation (including NPS boat tours) in light of the results of the Operation Analysis of the Lowell Canal Study and in consideration of Project operation under normal and high flow conditions.

Boott reviewed many sources to understand the recreational rights to the Lowell canal system, including the MOU, the 1984 Great Deed between Proprietors and Boott (Proprietors 1984), the 1986 Order of Taking (Commonwealth of Massachusetts 1986), and the 1995 Grant of Easement from the Commonwealth of Massachusetts to the LNHP (Commonwealth 1995). These documents form the basis of the Resources, Ownership, Boundaries, and Land Rights Study filed with the Commission on November 1, 2021. The 1984 Great Deed details the sale of portions of the Project from the Proprietors to the current owner (Boott), and provides the metes, bounds, and elevations of all the structures conveyed, as well as associated easements, access and repair rights (Proprietors 1984). The 1986 Order of Taking details the take of properties, rights, and responsibilities from Boott to the Commonwealth, operating through MADCR (Commonwealth 1986). The 1995 Grant of Easement describes the properties and parcels that were leased from the Commonwealth to the NPS and the rights and responsibilities of both parties with respect to those properties and parcels (Commonwealth 1995).

The review of these documents indicates that the 1984 Great Deed conveyed all canals (exterior plane of walls and floors) throughout the canal system to Boott for the explicit use of power generation, except for the Pawtucket Canal and the Lower Pawtucket Canal. Proprietors instead retained ownership of the Pawtucket Canal and Lower Pawtucket Canal and granted Boott an easement for the right to operate the structures of these canals, to “install conduits, pipes, and wiring and the right to maintain, repair, or replace the existing structures for power generation usage solely. (Proprietors 1984).

Based on the review of the MOU, the 1984 Great Deed between Proprietors and Boott, the 1986 Order of Taking, and the 1995 Grant of Easement from the Commonwealth of Massachusetts to the LNHP, Boott currently does not have any right to expand recreational opportunities throughout the Lowell canal system. MADCR purchased all recreational rights over all the canals and canal walls (even canals owned by Boott), including exclusive navigational rights such as boating or canoeing. MADCR maintains an exclusive and permanent easement throughout the entire canal system to install access points such as boat ramps, wharves, and docks. Boott and other stakeholders are not permitted to use the canals as recreational resources, as those rights are exclusively held by MADCR. Boott describes recreational rights and responsibilities in more detail in the Resources, Ownership, Boundaries, and Land Rights Study Report filed with FERC on November 1, 2021.

Historical and Current NPS Boat Tours

In their letter dated March 1, 2022, the Commission recommended (1) an evaluation of the effects of Project operation on NPS boat tours in the Northern Canal; (2) an evaluation of the effects of Project operation on NPS boat tours, in relation to Boott's prior intermittent proposal to remove the majority of the canal system from the Project boundary; and (3) an evaluation of the potential for expanding access to the canals for

recreation (including NPS boat tours) in light of the results of the Operation Analysis of the Lowell Canal Study and in consideration of Project operation under normal and high flow conditions including an assessment of surge gate and shut down options).

On April 14, 2022, Boott held a conference call with NPS to obtain information on their historical and current canal boat tour operations. The information discovered through this literature review is consistent with NPS operations staff's understanding of historical boat operations during this time frame. NPS states they do not ever recall successful navigation on the Western Canal (as originally conceived), and infrequent use, if any, of the Merrimack Canal for boat tours. As reported by NPS, between the late 1980s through 1994, NPS boat tours would run in either direction from Swamp Locks up through Guard Locks Locking Gatehouse (Guard Locks Complex), continuing north onto the Merrimack River and through the Pawtucket Gatehouse, using the Pawtucket Gatehouse Lock Chamber to enter onto the Northern Canal. Navigation on the Northern Canal continued through Hydro Locks to the Aiken Street dock before turning around to loop back to Swamp Locks. NPS staff would usually end the tour at Swamp Locks or lock down Swamp Locks to the Lower Locks Complex. NPS staff report they usually did not lock down Lower Locks to access the Concord River.

As noted previously and to be consistent with the requests from the Commission in 2022, Boott is no longer considering the removal of canals from the Project Boundary and thus point number two from above is no longer applicable.

Northern Canal

NPS operated boat tours on the Northern Canal from the late 1980s to 1994, spending up to a half hour per tour navigating the Northern Canal from the Pawtucket Gatehouse, turning around at the Aiken Street dock, and navigating back through Hydro Locks to the Pawtucket Gatehouse. In 1994 NPS ceased boat tours on the Northern Canal after overtopping and failure of the bayboard section of the Great River Wall. The FERC New York Regional Office expressed their concerns by letter to the NPS on March 31, 1994, recommending that NPS discontinue both the Northern Canal boat tours and walking along the Northern Canal Walkway until further studies were conducted (FERC 1994; Enel 2008). In their September 1994 Environmental Inspection Report, FERC stated "the existence of a boat tour in a power canal is a practice that normally would be discouraged. Aside from the obvious hazards associated with power production it can also present unforeseen dangers. The Project, however, was designed with the idea that tour boats would operate in the canal. Recent events seem to indicate that this practice be revisited in terms of "public safety" (FERC 1994).

In recent years, NPS held boat tours on the Northern Canal only on special occasions mostly due to the locking issues at Hydro Locks that arose around 1996. NPS staff recently report that Hydro Locks is inoperable as pins were bent as they were frozen in at one point. Based on drawings these pins may be the hinge pins or the pins that lock the gates together in the closed position. The pins can no longer be moved or removed. Since they were frozen, they do not lock tight enough and there is leakage. Additionally, NPS reports that Hydro Locks is mired in mud (NPS 2018). As reported to FERC in their March 31, 2022, Response to Additional Information Request, Boott intends to install a downstream fish exclusion system including a new trashrack structure in the E.L. Field

powerhouse forebay. During the installation of the downstream fish exclusion system, the Northern Canal will be dewatered, providing Boott the opportunity to inspect and repair as needed Hydro Locks and its locking mechanisms, as well as to determine whether the Hydro Locks gates are mired in mud. Additionally, the proposed trashrack overlay may cause changes in navigable accessibility or changes in operations.

Given Boott's canal elevation agreement with NPS, Boott regularly coordinates on water elevations with the NPS and other stakeholders. As reported in their November 1, 2021, Response to Additional Information Request, Boott is proposing to maintain specific water levels throughout the canal system as determined in consultation with NPS.

Northern Canal Walkway

The Northern Canal Walkway opens seasonally (May 15 through October 15) when flow rates in the Merrimack River and Northern Canal are lower than 3,500 cfs. This threshold was determined in a study demonstrating that a surge wave above 3,500 cfs in the Northern Canal poses a risk of overtopping the Great River Wall. In 1999, the Licensee completed construction of the Surge Gate, designed to attenuate the surge wave in the canal that occurs during sudden plant shutdown. A test of the Surge Gate revealed that the gate did attenuate the resulting transient wave. However, as reported to FERC, the test indicated when fully opened, the significant volume of discharge through the Surge Gate is hazardous to any persons in the riverbed below or near the gate. FERC directed Boott to design a Public Safety Plan to warn the public of this hazard, which included warning signs, sirens and beacons installed at various locations along and in the Merrimack River (FERC 2000). Accordingly, to be conservative and assure public safety, the 3,500 cfs threshold to open the Northern Canal Walkway remained despite the installation of the Surge Gate and is a part of the Public Safety Plan.

Within one year of license issuance, Boott will develop a Recreation Access and Facilities Management Plan in consultation with the stakeholders to: a) evaluate opportunities for increasing pedestrian access to the Northern Canal Walkway under certain conditions; b) define flow management practices needed to enhance recreational opportunity in the project vicinity; and c) continue to manage the Project's recreation facility, the E.L. Field Powerhouse Visitor Center.

Pawtucket Canal

As reported in Section E.6, Boott is actively collaborating with key stakeholders to finalize the COMP. Once the COMP is finalized, a copy of the Plan will be submitted to FERC for approval and inclusion in the new license. One of the primary components being addressed is the management of canal water elevations and canal flows.

Water Level and Flow Effects on Historic Resources Study

In accordance with the Commission's SPD, Boott conducted a Water Level and Flow Effects on Historic Resources Study. The objective of this study was to analyze the potential effects of water level fluctuations from Project operations in the headpond, Northern Canal, and the Upper Pawtucket Canal (extending upstream from the Guard Lock Gate Complex to the mainstem of the Merrimack River) on historic structures with a focus on the Pawtucket Gatehouse, the Northern Canal Waste Gatehouse, the Guard

Lock and Gatehouse Complex, and the Great Wall. Methods and results are described in detail in Boott's study report (HDR 2021b) which was filed with the Commission on March 5, 2021.

The results indicated the magnitude of fluctuation in the Project's headpond and the Pawtucket Canal has been significantly reduced by the implementation of the pneumatic crest gates, as shown by post crest gates operations presented in Figure E.7-22 and pre crest gate operations shown in Figure E.7-23 below. Water levels in the Pawtucket Canal upstream of the Guard Locks complex are essentially the same as the Project impoundment and remained below the normal headpond level of 92.2 ft NGVD29 throughout the 2020 study period except for one occasion. The elevation of the Guard Locks complex walkway (92.45 ft), the clapboard siding (92.45 ft), and the bottom of the mid-level windows (94.08 ft) are all above the normal water level of the Upper Pawtucket Canal. Only river flows in excess of 35,000 cfs could cause the Upper Pawtucket Canal to inundate the wooden structural elements of the Guard Locks complex; however, these conditions are outside of the ability of the Project to control the impoundment water level and therefore not attributable to Project operations.

The operation of the Northern Canal has caused periodic inundation of the sill at the Northern Canal Waste Gatehouse (Figure E.7-24). This inundation may be one factor in the continued deterioration of the gatehouse's southern sill. Spray from the canal spillway may also be contributing to deterioration along the eastern end of the northern sill.

Figure E.7-22. Project Headpond Water Surface Elevation During 2020 Monitoring Period.

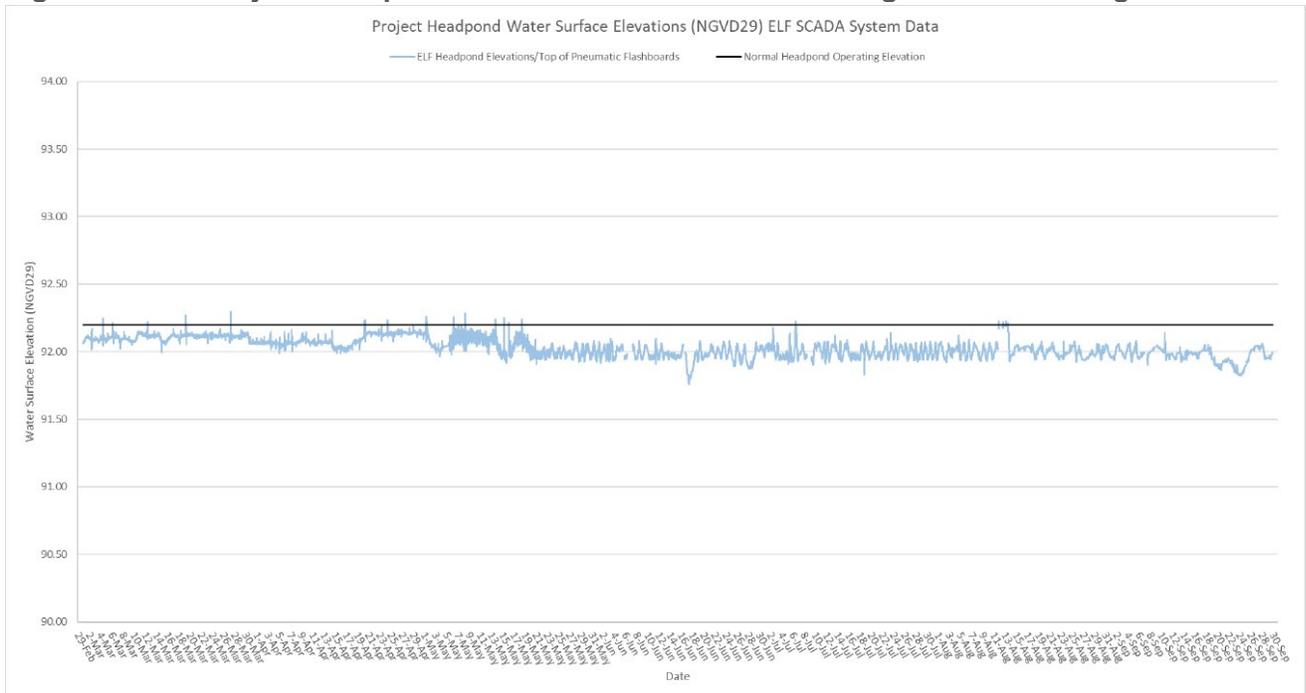
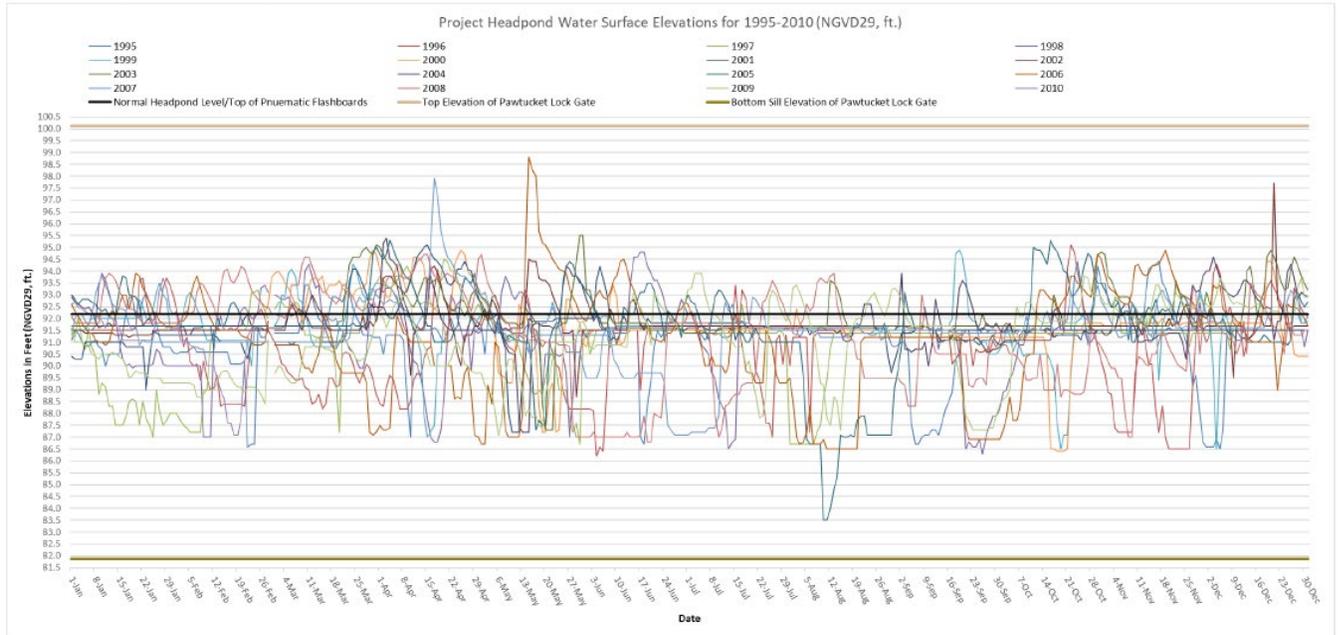
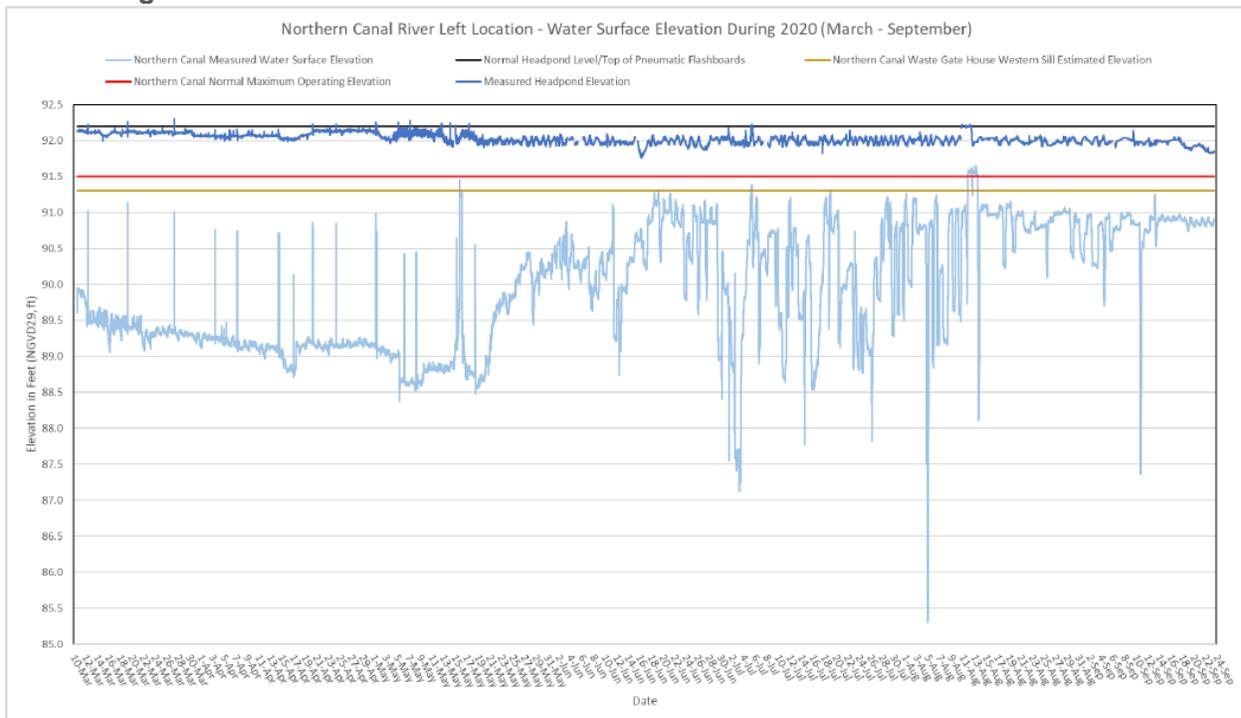


Figure E.7-23. Merrimack River – Pawtucket Dam Headpond Elevations for Period of Record (1995-2010)¹



¹Period of Record Data 1995-2010 was recorded with 5-foot high wooden flash boards in operation and prior to the installation of the automated pneumatic flashboards along the crest of the Pawtucket Dam.

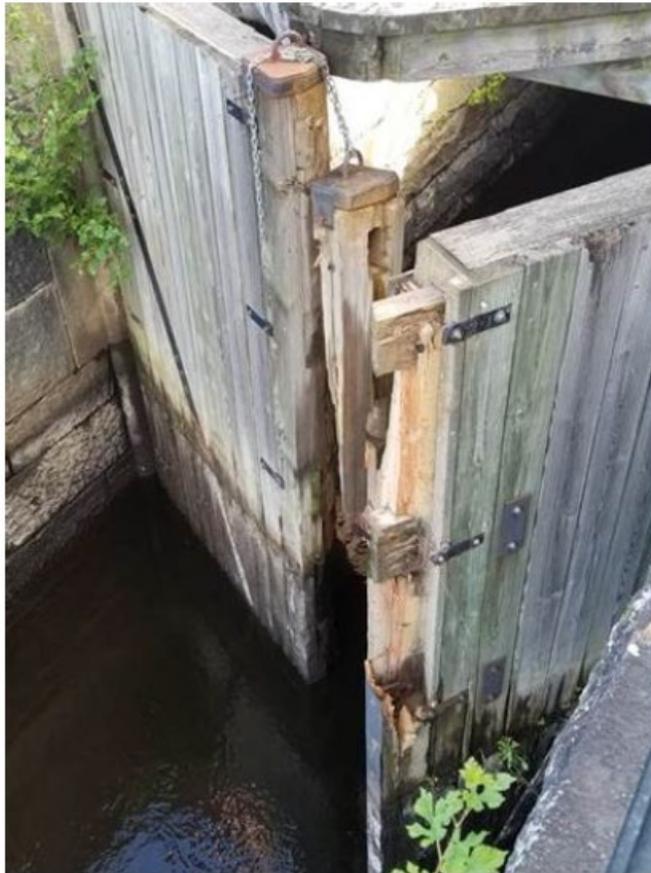
Figure E.7-24. Northern Canal River Left Location – Water Surface Elevation During 2020 Monitoring Period



The results of the study indicate the wooden structural elements of the historic resources located along the Upper Pawtucket and Northern Canals appear most susceptible to damage from submergence, periodic inundation, and waterborne trash. While the magnitude of fluctuation in the Project's headpond and the Pawtucket Canal has been significantly reduced by the implementation of the pneumatic crest gates, the Merrimack River is subject to routine seasonal high flow events. High flow events can also mobilize waterborne trash and debris that have the potential to damage wooden structural elements; however, neither high flow events nor the presence of waterborne trash and debris in the Merrimack River are attributable to Project operations.

While normal Project operations do not appear to be adversely affecting the Pawtucket Gatehouse Lock Structure beyond normal wear, at least one incident appears to have contributed to recorded damage to the upstream miter gate (Figure E.7-25). The canal surge event that occurred in 2018 was caused by the malfunction of a water level transducer. The effect of the resulting surge was exacerbated by the practice of chaining the gates closed. This anomalous incident does not represent normal Project operations, and Boott is repairing the damage to the gate.

Figure E.7-25. Damage to the Northern Canal Lock Timber Gate



Canal Water Level Monitoring

E.L. Field Headpond/Northern Canal Lock

Water surface elevations within the Project headpond at the Northern Canal Lock during the study period (March 10 – September 29, 2020) range from a minimum of 91.76 ft to a maximum of 92.30 ft for a range of 0.54 ft.

Northern Canal

Water surface elevations within the Northern Canal collected during the study period ranged from a minimum of 85.30 ft to a maximum of 91.64 ft with a range of 6.34 ft at the Northern Canal River Left (RL) location near the Emergency Surge Gate and from a minimum of 85.71 ft to a maximum of 92.14 ft for a range of 6.43 ft at the Northern Canal River Right (RR) location, near the canal's mid-point between the Pawtucket Gatehouse and the E.L. Field powerhouse.

Based on the level logger data collected in the Northern Canal at the RL location, water surface elevations within the Northern Canal reached elevations greater than 91.5 ft (the normal maximum operating elevation of the Northern Canal) on one occasion during the monitoring period. Beginning on August 11 at approximately 9:45 PM through August 13 at approximately 3:45 p.m. the water surface elevation in the Northern Canal was greater than 91.5 ft reaching a maximum elevation of 91.64 ft.

Based on the level logger data collected in the Northern Canal at the RR location, water surface elevations within the Northern Canal reached elevations greater than 91.5 ft (the normal maximum operating elevation of the Northern Canal) on three occasions. On March 19, 2020, at approximately 9:00 a.m. the water surface reached a maximum elevation of 91.52 ft for less than 15 minutes. On May 15, 2020, at the RR location, the water surface elevation within the Northern Canal rose above 91.5 ft for approximately 10 hours and reached a maximum elevation of 91.62 ft. Beginning on August 11, 2020, at approximately 9:45 p.m. through August 13 at approximately 3:45 p.m. the water surface elevation in the Northern Canal at the RR location was greater than 91.5 ft reaching a maximum elevation of 91.64 ft.

Upper Pawtucket Canal

Water surface elevations within the Upper Pawtucket Canal during the study period ranged from a minimum of 91.69 ft to a maximum of 92.35 ft for a maximum range of 0.66 ft and are consistent with the impoundment level data. Within the Lower Pawtucket Canal levels ranged from a minimum of 79.53 ft to a maximum of 86.21 ft for a range of 6.68 ft. Water surface elevation data downstream of the Guard Lock Gate Complex were not collected following the June 12 download event due to loss of the downstream level loggers (Lower Pawtucket Canal).

On one occasion during the study period, the water surface elevation within the Upper Pawtucket Canal reached an elevation greater than 92.2 ft (the normal operating elevation of the Project headpond). This event occurred from March 27, 2020, at approximately 11:30 a.m. and lasted for less than 15 minutes, reaching a maximum elevation of 92.29 ft.

The Lower Pawtucket Canal was drawn down approximately 6.5 ft from April 2 through April 7, 2020, to facilitate bridge reconstruction in downtown Lowell, but generally remained between elevations 88.25 ft and 89.47 ft, a range of 1.22 ft during the remaining study period.

Analysis of Potential Project Related Effects

Northern Canal Lock and Pawtucket Gatehouse

The Northern Canal Lock and the Pawtucket Gatehouse are located at the southern abutment of the Pawtucket Dam and controls flow into the Northern Canal. It is principally constructed of dressed masonry with concrete over lintels and contains ten 8-foot-wide by 15-foot-high, motor-operated, timber sliding gates which feed the Northern Canal. Another small intake opening feeds a presently unused wheel, which formerly powered the gate mechanisms through a line shaft. The structure's water passages are nearly 80 ft in length. A small navigation lock is located at the southerly end of the Pawtucket Gatehouse (Boott 2017).

The Project is operated in a ROR where outflow approximates inflow, generally maintaining the Project headpond at or near elevation 92.2 ft. When flows exceed the 6,600 cfs combined hydraulic capacity of the E.L. Field generating units, it has been Boott's practice to divert up to 2,000 cfs to the downtown canal units when they are operable. Flows higher than 8,600 cfs (the combined capacity of the E.L. Field Powerhouse and the canal units) are spilled over the Pawtucket Dam spillway and into the Project's bypass reach. The pneumatic crest gate system has a control system which maintains a constant upstream water level during increasing flows, by automatically lowering the crest gate panels as the spillway flow increases.

The concrete and masonry gatehouse show normal wear from exposure to the natural river conditions and Project water level fluctuation. Based on a review of existing documentation and consultation with the NPS, Boott did not identify potential Project-related effects on the gatehouse.

Potential Project-related effects have been documented at the Northern Canal lock structure. The lock structure is controlled by a set of timber miter gates, with one set of gates at the upstream entrance/exit and a second set at the downstream entrance/exit. The gates are subject to routine water level that can deteriorate wooden and metal elements. While the magnitude of fluctuation in the Project's headpond has been significantly reduced by the implementation of the pneumatic crest gates, the gates are subject to routine seasonal high flow events. Portions of the gates are also continuously submerged, which contributes to natural deterioration of wooden and metal elements over time.

Other factors which have likely contributed to the deterioration of the miter gates include, but are not limited to, high flows in the Merrimack River and natural deterioration of the submerged portions of the wooden gate structure, neither of which are attributable to Project operations.

Northern Canal Waste Gatehouse

The Northern Canal Waste Gatehouse is a single-story, heavy-timber-framed building, built circa 1872 atop the Great River Wall which houses gate operators for four canal

release gates. Based on consultation with the NPS, Boott identified potential Project-related effects on certain wooden structural elements of the Northern Canal Waste Gatehouse. The wooden sills of the gatehouse have experienced deterioration. Boott reviewed Northern Canal water level data recorded in 2020 to determine if Northern Canal water levels could be a contributing factor to the deterioration of the sill.

The Northern Canal Waste Gatehouse has wooden sill which overhangs the Northern Canal, with a bottom elevation of approximately 91.3 ft NGVD29. The normal maximum operating elevation of the Northern Canal is 91.5 ft. The Northern sill of the Waste Gatehouse has also deteriorated, due to natural exposure to the nearby river and atmospheric conditions, as well as its proximity to the spillway immediately to the east. It is possible that splashing water from the adjacent spillway may have contributed to the deterioration of the eastern third of the northern sill timber. Repeated inundation and drying of the timber sill can be a contributing factor to deterioration. Other factors, including the age of the wooden timbers, general maintenance, weathering, and atmospheric conditions are also likely to have contributed to the deterioration of the southern sill, and the eastern portion of the northern sill. The age of the sills is not known, i.e., it is not known if the existing sills are the original timbers from the 1872 construction of the gatehouse.

Guard Lock and Gates Facility

The Upper Pawtucket Canal branches off the Merrimack River a few hundred feet upstream of the Pawtucket Dam and feeds water into the downtown canal system via the Guard Lock and Gates Facility (“Guard Locks”). The facility consists of the following structures: 1) the Guard Gatehouse which houses 5 sluice gates to convey flow to the Lower Pawtucket Canal; 2) a 24 ft wide granite masonry Lock Canal with two pairs of wooden lock gates; 3) the timber and wood framed Lock House located above the upstream lock gate; 4) the Francis Gatehouse (or Great Gatehouse) timber and wood framed structure over the Lock Canal which houses the 25' high x 25' wide Francis (or Great) Gate. The Guard Gatehouse is separated from the Lock Canal and associated Lock House and Francis Gatehouse by an island with walls of granite, ledge, or concrete.

In its consultation comments, the NPS identified potential Project-related effects on the Guard Lock and Gates Facility. Specific issues identified by the NPS included damage to the upstream side of the gatehouse (including the upstream wooden walkway), erosion of the steps leading to the gatehouse, and damage to the entry door on the east side of the Gate House. Boott reviewed the available information regarding the condition of the Guard Locks Facility with respect to the potential impacts identified by the NPS.

Water levels in the Pawtucket Canal upstream of the Guard Locks complex are essentially the same as the project impoundment and remained below the normal headpond level of 92.2 ft NGVD29 throughout the study period except for one occasion. On March 27, 2020, between 11:30 a.m. and 12:00 p.m. the water level in the Pawtucket Canal upstream of the Guard Locks reached 92.29 ft.

Water levels in the Upper Pawtucket Canal remained below the walkway at the base of the Guard Lock Gatehouse for the entire study. The elevation of the walkway (92.45 ft), the clapboard siding (92.45 ft), and the bottom of the mid-level windows (94.08 ft) are all

above the normal water level of the Upper Pawtucket Canal. Under normal operating conditions, these features are rarely inundated. However, high flow events that are beyond Boott's control can cause water levels to exceed normal operating conditions and may inundate the walkway, clapboard siding, and mid-level windows. As described above, the pneumatic crest gate control system maintains a constant upstream impoundment elevation under elevated flow conditions by automatically adjusting the height of the crest gate panels. The crest gates would be fully lowered at river flows of approximately 35,000 cfs, above which the impoundment and Upper Pawtucket Canal level would rise uncontrolled. Thus, river flows in excess of 35,000 cfs could cause the Upper Pawtucket Canal to inundate the wooden structural elements of the gatehouse; however, these conditions are outside of the ability of the project to control the impoundment water level and therefore not attributable to Project operations.

While normal Project operating conditions do not appear to be having a significant effect on the wooden structural elements of the gatehouse, the presence of waterborne trash and debris may adversely affect the gatehouse. Trash and debris accumulate upstream from Guard Lock Gatehouse, including large logs and timbers. While trash and debris that accumulate upstream from the gatehouse have the potential to damage exterior wooden elements and windows under such high flow conditions, natural high flow events and waterborne trash are not related to Project operations. Boott retains a crane service to remove the trash and debris from in front of the Pawtucket Gatehouse once or twice each year.

Boott notes that the top of the steps (104.87 ft) leading to the lower level door of the Guard Gatehouse and the bottom sill of the lower level door itself (100.34 ft) are significantly above the maximum recorded Project headpond elevation for the recent period of record. According to the historic data for the period of record (1995 – 2010) the maximum elevation of the Project headpond was 98.8 ft in 2006. As such, apparent damage to these structural elements are not related to Project operations. The flood of March 20, 1936, was the only event high enough to inundate the gatehouse stairs, reaching a peak elevation of 107.3 ft at a flow of 173,000 cfs.

All structures within the Guard Lock and Gates Facility are owned by the Proprietors of Locks and Canals and the Commonwealth of Massachusetts, under the administration of the MADCR. In general, the Proprietors own the substructure of each building while the Commonwealth owns the buildings and fixtures above the foundations. Boott generally has easement rights to operate and maintain the water control equipment within each structure. NPS also retains rights to access and implement improvements such as walkway surfaces, lighting, railings, decking, benches, and landscaping. As owners, Proprietors and the Commonwealth have a right and a duty to maintain properties under their ownership, but they do not have an obligation to enhance or upgrade their properties. Similarly, an easement, such as that issued to Boott and/or NPS, allows the holder to conduct routine maintenance of the property under easement.

Additional information is provided in the Water Level and Flow Effects on Historic Resources Study Report (Boott 2021).

Resources, Ownership, Boundaries and Land Rights Study

Pursuant to the approved study plan, Boott conducted a Resources, Ownership, Boundaries, and Land Rights Study to determine current ownership of resources within the canal system and existing Project Boundary, and document maintenance responsibilities, access rights, and FERC jurisdiction. The methods and results of the Resources, Ownership, Boundaries, and Land Rights Study filed with the Commission on February 25, 2021.

Ownership, easement rights, and use of the canal system in Lowell are complex, with intersecting roles between public agencies and private entities at the local, State, and Federal level. Boott conducted desktop research and a literature review to compile and review available ownership and rights documentation to obtain a better understanding of the rights and responsibilities related to resources within the Project Boundary. As appropriate and relevant, public guidance and conceptual planning and/or management documentation was reviewed by Boott including the 1977 Report of the LHCD, the 1980 Details of the Preservation Plan, the 1981 FGMP, and the 1990 Preservation Plan Amendment. Additionally, Boott reviewed and analyzed the three legal documents that establish most of the ownership, responsibilities, and land rights to the Lowell canal system. The 1984 Deed, Bill of Sale and Grant of Easements, also known as the “Great Deed” details the sale of portions of the Project from the Proprietors of the Locks and Canals on the Merrimack River (Proprietors) to Boott, as well as associated access and repair easements. The 1986 Order of Taking details the take of properties, rights, and responsibilities from Boott and Proprietors to the Commonwealth, operating through MADCR. The 1995 Grant of Easement describes the easement rights provided to the NPS from MADCR for specific properties and parcels around the canal system.

The conceptual framework for the rights and responsibilities for management of the Lowell canal system remain consistent within the 1977 Report of the LHCD, the 1980 Details of the Preservation Plan, the 1981 FGMP, and the 1990 Preservation Plan Amendment. MADCR and NPS are presented as the main parties responsible for developing, renovating, and maintaining the major elements of the canal system. In the 1977 Report of the LHCD, agency responsibilities were characterized and are shown below in Table E.7-32.

Table E.7-32. Agency Responsibilities Identified in 1977 Report of the LHCD

Agency	Responsibilities
NPS	Interpretation, park wide downtown "cross-section" of 19th Century Lowell (including preservation, building and open space improvements, transportation, and visitor services)
MADCR	Canals, riverbanks, and related recreational areas gatehouses, locks and dams barge system

Ownership of the Lowell canal system is largely determined by the 1984 Great Deed and 1986 Order of Taking. Components of the canal system are owned by Proprietors, Boott, and MADCR. Proprietors owns most of the Pawtucket Canal and Lower Pawtucket Canal, as well as all or portions of associated structures in those canals (e.g. Swamp Locks Dam, Lower Locks Dam, and the Guard Locks and Francis Gate). Boott is not known to own any structures of or within the Pawtucket or Lower Pawtucket Canal.

With respect to the canals themselves, the FERC license for the Project encompasses only the canal beds, bottoms, and walls, up to and encompassing the exterior plane of the canal walls, caps, and bottoms. References in this Exhibit E to the “Lowell canal system” does not include Pawtucket Dam, nor does it include any lands, sidewalks, pathways, buildings, powerhouses, gatehouses, or other infrastructure above the canals or adjacent to the exterior planes of the canal walls, caps, and bottoms, both horizontally and vertically.

Boott has an usage easement for power generation for the Northern Canal, Western Canal, Merrimack Canal, Eastern Canal, and Hamilton Canal. Boott has an usage easement for power generation for specific dams, gate structures, and hydroelectric equipment within the canals. The specific structures to which Boott holds easements within these canals include Hall Street Dam, Lawrence Dam, Boott Dam, Rolling Dam, Merrimack Dam, Merrimack Gates, YMCA Gates, and the Moody Street Feeder. Boott owns equipment to support hydroelectric development located inside most gatehouses, such as the Boott Dam Gatehouse and Tremont Gatehouse, but Boott does not own the gatehouse buildings.

MADCR owns most of the gatehouses throughout the canal system (e.g. Pawtucket Gatehouse, Lower Locks Gatehouse, and Swamp Locks Gatehouse, Rolling Dam Gatehouse, Hamilton Gatehouse, and Massachusetts Wasteway Gatehouse) and this is largely determined based on elevation.

Easement rights to structures of the Lowell canal system are held by Proprietors, Boott, MADCR, and NPS. In the 1984 Great Deed, Boott obtained easement rights, in common with Proprietors, to the Pawtucket Canal and structures of the Pawtucket Canal. These easement rights allow Boott to access, operate, maintain, repair, and replace the Pawtucket Canal (exterior plane of the walls and floors) and structures of the Pawtucket Canal, as well as easements to structures to support hydropower generation. In the 1986 Order of Taking, MADCR obtained a permanent and exclusive easement to structures of the canal system, including canal walls, beds, and bottoms, for purposes including conservation, preservation, maintenance, and other uses consistent with the use of the system as a park. NPS obtained similar easement rights through the 1995 Grant of Easement from MADCR, including the right to maintain, repair, conduct grounds maintenance, and operate boat tours.

An exclusive easement allows the easement holder to control and implement specific purposes as if they are the owner. MADCR has a permanent and exclusive easement over most of the canal system for the following purposes, which include the following enhancements and upgrades:

- a) Support of all fixtures or structures of the Commonwealth now or hereafter attached;

- b) Preservation and conservation;
- c) Supplemental maintenance in addition to that performed by the Condemnees (the prior or current owner) and their successors and assigns;
- d) Landscaping and erection of exhibits and structures;
- e) Placement of barriers and fences;
- f) Placement and attachment of docks, wharves, walls, and boat ramps of a temporary or permanent nature;
- g) Placement of lighting and other utilities;
- h) Operation and maintenance of boat locking chambers, if any, for any and all purposes; and
- i) Any and all other uses consistent with the operation of the canal system as a park.

Given that MADCR's exclusive easement is throughout most of the canal system, it overlaps significantly with Boott and Proprietors' owned property. It is understood that Boott, Proprietors, and MADCR have a duty and right to maintain properties under their ownership to achieve a standard of reasonable care. Owners do not have an obligation or duty to upgrade or enhance their property. However, MADCR's exclusive easement throughout most of the Lowell canal system gives them the right to implement any of the purposes noted above, which include enhancements and upgrades.

The Resources, Ownership, Boundaries, and Land Rights Study also determined different resource rights. The results indicated that recreational resource rights are exclusively owned by MADCR. In early conceptual planning documents, MADCR was presented as the party that would own, implement, and manage any recreational resources. MADCR obtained such rights in the 1986 Order of Taking, including the exclusive right to use water for recreational, educational, or navigational purposes, and permanent and exclusive rights to build wharves, docks, and boat ramps. The two other identified resources are air resource rights, and water and flowage rights. Air resource rights have been owned by MADCR since issuance of the 1986 Order of Taking. Water and flowage rights are owned by Boott and Proprietors, as established in the 1984 Great Deed.

Whitewater Boating and Access Study

Boott conducted the Whitewater Boating and Access Study at the Lowell Project following the methods in *Flows and Recreation: A Guide to Studies for River Professionals* (Whittaker, 2005). In 2019, Boott performed primary planning and preparation activities for the study which included: (1) formation of a Whitewater Study Working Group (hereafter 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 methods 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. Boott conducted a review of any existing online information and anecdotal evidence regarding whitewater conditions.

Boott coordinated with representatives from AW, NPS, City of Lowell Parks Department, City of Lowell Emergency Management, Lowell Parks and Conservation Trust, and Zoar Outdoor to form the Study Working Group. Coordination between Boott and the Study Working Group included study planning, identification of potential put-in and take-out locations, discussion on safety concerns, and identification of potential volunteers to participate in controlled flow releases. The Study Working Group identified a need to visually document a range of flows in the Project's bypassed reach to assist participant selection of flows for the controlled flow releases. Since the Study Working Group participants had limited experience boating the bypass reach, participants could not make informed choices on which flows would be appropriate for boating.

In consultation with stakeholders, Boott developed a Whitewater Flow Documentation Plan that described the methods and approach for (a) documenting the range of flow conditions in the bypass reach, and (b) consulting with the Study Working Group to identify flows suitable for this study.

After reviewing the Whitewater Flow Documentation Report and consultation with stakeholders, the Study Working Group selected three bypass flows ranging from 2,500 cfs to 8,600 cfs. The first flow was estimated at 6,600 cfs (and later verified at 5,750 cfs [middle flow]), the second flow was estimated at 8,000 cfs (and later verified at 6,700 cfs [high flow]), and the third was estimated at 2,500 cfs (and later verified at 2,750²⁰ cfs [low flow]). The Project is ROR with no usable storage capacity. The maximum hydraulic capacity of the E.L. Field Powerhouse is 6,600 cfs. Flows up to 6,600 cfs are directed to the station for power generation. In addition, a portion of river flow (e.g., a 100 cfs minimum flow) is directed to the Project's canal system. Assuming the Project is operating at maximum capacity, the Study Working Group determined that the ideal Merrimack River flow range to perform the study was between approximately 8,000 cfs and 10,000 cfs.

Boott coordinated with AW to monitor site and flow conditions to schedule the controlled whitewater releases. In early November 2022, Boott and the Study Working Group coordinated to identify a date to conduct the Whitewater Boating and Access Study with the understanding that given that the Project was offline²¹, the study would be performed under two flow conditions: middle and high flows. All participants were required to review and adhere to the Safety Code of American Whitewater and applicable safety policies established in the Whitewater Boating and Access Study Safety Plan. The volunteer boaters for the controlled release evaluations were required to be experienced and have the skills necessary to boat the reach. Participants were required to sign a liability waiver prior to taking part in on-water evaluations.

Based on the river and anticipated precipitation, Boott and the Study Working Group determined that the predicted flows for November 19, 2022, were within the desired range to perform the field activities. The first flow consisted of the available ROR flow,

²⁰ The third flow assessment had a flow range between 2,500 and 3,000 cfs, with this range taken as the approximate median for both the starting and ending flows of the assessment.

²¹ On September 2, 2022, Boott notified the Commission that the Project was offline and filed an incident report on September 19, 2022.

and the second flow consisted of an increased flow with limited duration provided by lowering of one of the Pawtucket Dam crest gates.

The third and final flow was conducted on a later date (i.e., November 24, 2024), once the Project returned to operation and flows were within the desired range. The third controlled flow release was characterized as the available ROR flow, with a portion of the flow directed through the operable units in the powerhouse and then into the bypassed reach (approximately 610 cfs). Through ongoing coordination between Boott and the Study Working Group, the third controlled flow assessment was performed on November 24, 2024.

Boott provided each of the controlled releases for up to 3 hours to allow participants the opportunity to boat the reach and make multiple passes at each flow, if desired. Boott developed pre, post, and comparative survey forms in consultation AW that would be completed by participants during this portion of the study. After completing the controlled flow releases, Boott held two focus group discussions: one focused on the medium and high flow trials in 2022, and the other on the low flow trial in 2024. These meetings aimed to review the study results and gather feedback on the feasibility and quality of various boating opportunities across different flow conditions within the Project's bypassed reach.

The on-water boating assessment for the first and second flows were performed on November 19, 2022, between 9:30 am and 3:00 pm and assessed flows of 5,750 cfs and 6,700 cfs. Participants convened at the UMass Lowell Campus Recreation Center for a health and safety meeting and study overview. Study participants included intermediate and advanced level boaters, generally corresponding to Class III-IV whitewater experience.

The on-water boating assessment for the third flow and final flow was conducted on November 24, 2024, from 9:30 am to 1:30 pm, with flows evaluated at approximately 2,500 cfs at the start of the assessment. Before launching, participants gathered at the staging area for a health and safety briefing, followed by an overview of the study by Boott. Of the six participants, only three had also partaken in the 2022 assessment. All six of the study participants identified themselves as an advanced Class IV boater.

Study participants completed pre-run, post-run, and comparative analysis survey forms following both the 2022 and 2024 sessions. One participant was unable to attend the focused group discussion during the 2024 session. The three participants who took part in the 2022 session provided comparative feedback between the three controlled flow releases. Further details of the whitewater study can be found in the Final Whitewater Boating and Access Study (HDR 2024).

Summarized Results²²

Boott conducted a Whitewater Boating and Access Study at the Project to evaluate the feasibility of whitewater boating in the 3,500-foot-long stretch of the Merrimack River

²² The summarized results include data from the 2022 and 2024 Pre-run and Post-run survey forms, Flow Comparison Survey forms, Focus Group Discussions, and Whitewater Flow Determination Report. For more

between the Project's Pawtucket Dam and the confluence below the powerhouse. To support this evaluation, Boott followed the Whittaker et al. (2005) methodology and conducted a stepwise study.

In alignment with the SPD, Boott completed all planning and preparation activities for the Whitewater Boating and Access Study, as detailed in the preceding section.

The literature review documented there are 52 whitewater opportunities within 60 miles of the Project, including a reach on the Concord River which is in the immediate Project area and has three major class III-IV rapids: Twisted Sister, Three Beauties, and The Middlesex Dam. The Concord River is an urban whitewater gem that has a high utilization rate for which UMass Lowell- Outdoor Adventure uses as well as a private boating company, Zoar, as a recreational feature in downtown Lowell (UMass Lowell). It appears whitewater rafting is located at 650 Suffolk Street in Lowell, MA, which is approximately half an hour north of Boston. There is parking available in a side parking lot, across a little bridge, specifically designed for guest parking.

The Concord River in Lowell, MA offers a unique urban whitewater rafting experience, particularly popular in the spring due to snowmelt and rainfall. Trips run on weekends during April and May, with Zoar Outdoor and the Lowell Parks & Conservation Trust partnering to operate them. This one-mile stretch features Class III-IV rapids like "Middlesex Dam," "Three Beauties," and "Twisted Sister."

Key Aspects of Concord River Rafting:

- **Location:** Northeastern Massachusetts, about a half-hour north of Boston.
- **Season:** Primarily spring, with trips typically offered from April to May.
- **Difficulty:** Class III-IV rapids, suitable for intermediate rafters.
- **Rapids:** The trip features three main rapids: Middlesex Dam, Three Beauties, and Twisted Sister.
- **Experience:** An urban whitewater rafting experience in Lowell, MA, with the river flowing through the "Concord River Greenway".
- **Outfitter:** Zoar Outdoor, which also offers other outdoor adventure trips.
- **Partnership:** Trips are run in collaboration with the Lowell Parks & Conservation Trust (LP&CT).
- **Conservation:** Proceeds from the trips support the LP&CT's conservation efforts, including the "Concord River Greenway Park".

The flow analysis analyzed and reviewed hydrology information as it relates to whitewater and any operational constraints and safety concerns as the Merrimack River in this stretch is known for large debris, metal rebar, and sharp metal objects.

After review of the Whitewater Flow Documentation Report and consultation with stakeholders, the Study Working Group decided to focus on bypass flows ranging from 2,500 cfs to 8,600 cfs. Assuming the Project is reaching its maximum hydraulic capacity

details, refer to the FERC-filed Whitewater Boating and Access Study Report, available under Accession No. 20241223-5016 at <https://elibrary.ferc.gov/eLibrary/search>.

of 6,600 cfs, the ideal Merrimack River flow range to perform the study was approximately 8,000 cfs to 10,000 cfs. It was found that the Project experiences average Merrimack River flows within this range in early to late spring, and during the recreation season (May-October), May, June, July, and October have at least a 10 percent exceedance of these flows.

In the 2022 assessment, participants generally found the take-out facility to be acceptable and in good condition. However, the put-in at the Northern Canal Walkway Island was rated as acceptable to marginal, with suggestions for improvements such as better parking, stairs, and a more accessible path. During the 2024 assessment, participants rated the takeout as marginal to acceptable, while the put-in at Northern Canal Walkway Island was unanimously rated as marginal. It is important to note that since the three new participants in 2024 did not attend the 2022 on-water boating assessment, they did not complete the flow comparison survey form. However, feedback on the need for upgrades at both the put-in and take-out locations was mentioned in the 2024 pre- and post-run assessment forms.

Participants were unanimous in requesting additional parking availability during the 2024 session. They expressed concerns that parking is extremely limited and insufficient for medium to large groups of boaters at the Blacksmith's Shop and near the staging area. Specifically, one participant inquired whether parking at the powerhouse could be made available. For security reasons, this is not an option, as it provides access to other Project features and areas that should be restricted to the public for safety and security reasons. Another participant highlighted the lack of parking at the take-out site during regular periods (i.e., outside of planned whitewater boating studies). Boott reminded the participants that parking in the surrounding neighborhood of Edward A. Lelcheur Park involves public roadways and lots, which are not directly affiliated with UMass Lowell. These areas are already designated and available for parking within the city limits.

Based on the results from the on-water assessments conducted on November 19, 2022, and November 24, 2024, participants indicated that the whitewater opportunities in the Lowell bypassed reach would be ideal for intermediate boaters (at least Class III whitewater), depending on the craft used and the location within the reach. Boott plans to install signage at the put-in location to inform boaters of the hazards that may exist within the Project's bypassed reach. The signage program may include standard warnings of potential hazards including fall hazards, rising water levels, and possible debris in the river. The Project will adhere to its Emergency Action Plan, as standard practice required by the FERC for all federally licensed hydropower projects.

Overall, participants found the bypassed reach to be enjoyable at the 6,700 cfs flow and indicated they would likely return in the future if this flow were available. For boaters who participated in both the 2022 and 2024 assessments, the third flow was described as offering good playboating opportunities, while the first and second flows were better suited for boaters looking to "run" laps in this short reach. Boater preferences for flow levels varied significantly, as each boater has unique preferences for their experience levels. As a result, the optimal flow was seen as different for each participant. Some participants preferred the features offered at the first and second flows for riding their "line," while others favored playboating during the third flow.

The 2024 participants unanimously agreed that the low-flow conditions were unsuitable for beginners, citing the increased difficulty and risk associated with rescue operations under such circumstances. One participant identified specific hazards, discussing several areas within this section of the reach with potential foot entrapment points along their navigation line. This observation was the focus of the boaters concerns that this flow could pose significant risks for inexperienced boaters. For experienced paddlers, however, the flow offered a technically challenging and engaging experience.

Boaters compared the Project's bypassed reach to the reaches found on the Concord River; Weston Project/Kennebec River; Winnepesaukee; and Turners Falls/Connecticut River. One participant from the 2024 assessment noted that the Lowell bypassed reach reminded them of the Mill City Park at Franklin Falls urban engineered whitewater park in Franklin, NH. This comparison was further explored during the subsequent 2024 Focus Group Discussion.

Boaters in both the 2022 and 2024 assessments collectively requested the opportunity for scheduled or "forecasted" flows during weekends and weekdays, access to real-time flow condition data from a flow gauge, and extended access to the walkway beyond the times outlined in the schedule above. If Boott were to provide special access for whitewater boaters to the put-in via the Northern Canal Walkway Island, it would need to request from and coordinate with NPS and MADCR as they are the entities that are responsible for access, vegetation management, and trail maintenance. For scheduled whitewater releases this coordination would likely not be a problem in most situations. However, unscheduled, ad hoc access is less feasible, because leaving the walkway access gates open would defeat the existing public safety measures described above.

Participants from both sessions frequently referenced the Concord River when comparing it to other boating rivers in the area. The Concord River was widely favored by focus group members for its whitewater features, convenient location, and proximity to work or home. In contrast, a participant in the 2024 assessment described the Lowell bypassed reach as an ideal location, emphasizing its personal benefits. The participant noted that in their opinion, this location is likely the only whitewater spot in the area accessible via public transportation.

Participants generally agreed that the City of Lowell is the premier whitewater location within close proximity to Boston, offering access to both the Concord and Merrimack Rivers. Participants indicated that the Concord River was their preferred choice of the two options; however, they agreed that when the Concord is unavailable, the Project's bypassed reach could be an excellent alternative. However, in the past 10-15 years the Project has not observed more than a few kayakers. They also concurred that it could serve as an appealing after-work option during days with longer daylight hours and could act as a substitute when the Concord River is not running. However, it is likely that lower flows on the Merrimack River coincide with the lower flow periods on Concord River. Additionally, participants expressed an interest in access to real-time flow data to monitor the flows within the Project's bypassed reach.

Safety concerns highlighted were the weirs and the sharp shale bedrock with the potential to overturn boats or trapping a boater via recirculation. Although the put-in and take-out locations were rated as generally marginal to acceptable, the put-in is in a

restricted area and would only be available to boaters from May 15 – October 15 when flows in the Merrimack River are less than 3,500 cfs and subject to NPS operations. Other put-in options were discussed, and their difficulties were identified, mainly Boott's lack of access, discussed above. Boaters described the take-out location as steep and littered with debris, including broken glass and hypodermic needles, posing risks to both their health and their equipment.

On January 21, 2025, Boott and AW held a virtual meeting to outline the next steps for whitewater boating at the Project. During the discussion, the group reached a consensus to initiate coordination with NPS to address access issues and to facilitate access to real-time flow data in order to monitor conditions within the Project's bypassed reach.

Land Use

Land use in the immediate vicinity of the Project is shown in Figure E.7-26. There are limited Project lands within the Project Boundary and only facilities needed for operation of the Project are included within the Project Boundary. Land use at the Project facilities is primarily Developed, High Intensity.

Land use along the impoundment of the Lowell Hydroelectric Project varies. The land use at the southern reach of the impoundment, in the Nashua area, and near Manchester is predominantly Developed, High Intensity. Elsewhere along the impoundment, where there are suburban and rural areas, land use is predominantly Developed, Low Intensity, except at the northern reach of the impoundment where other significant land uses include forest, hay/pasture, and crops.

Figure E.7-26. Land Use in the Vicinity of the Lowell Hydroelectric Project and Proposed Project Boundary

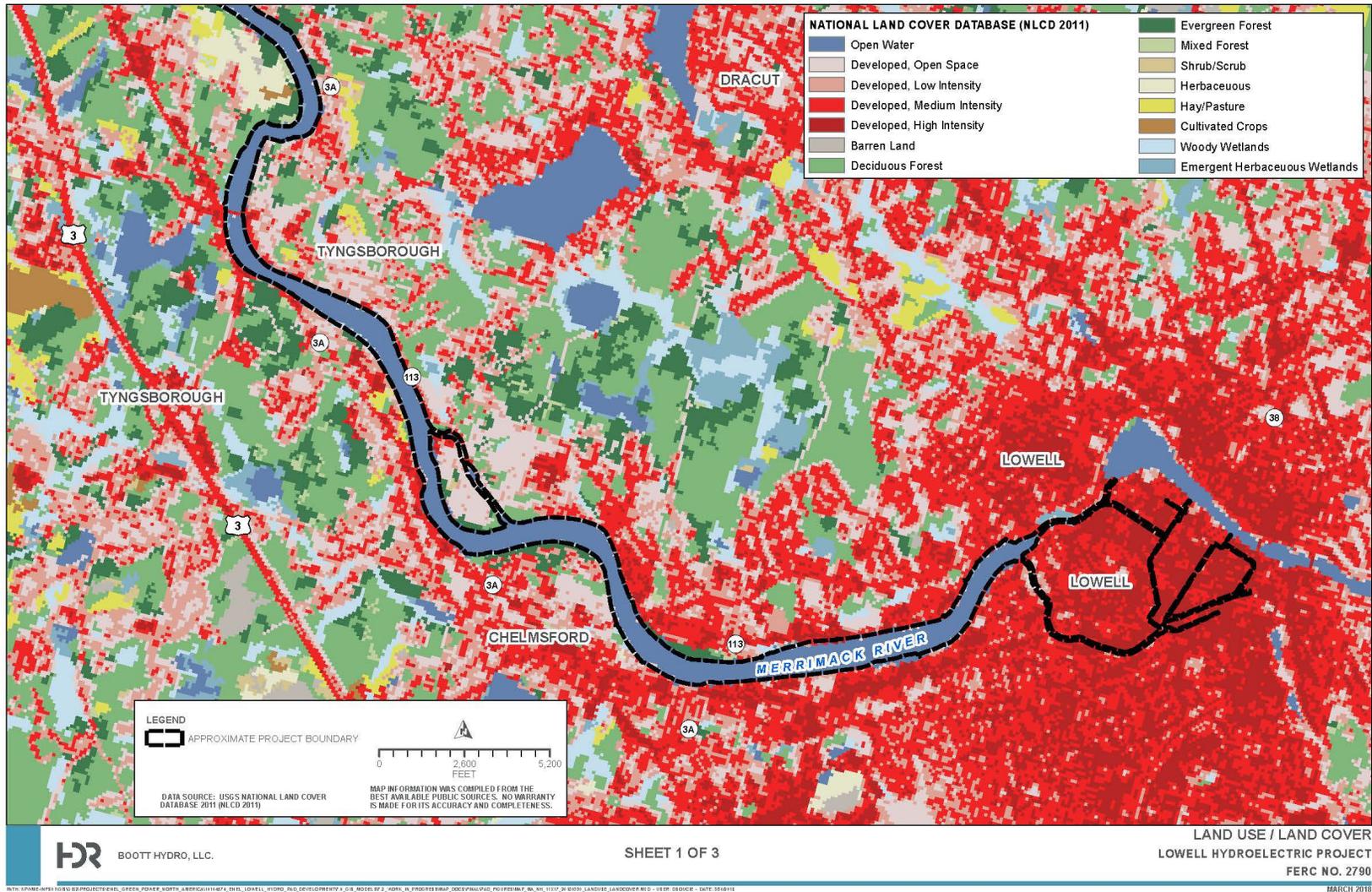


Figure E.7-26 continued

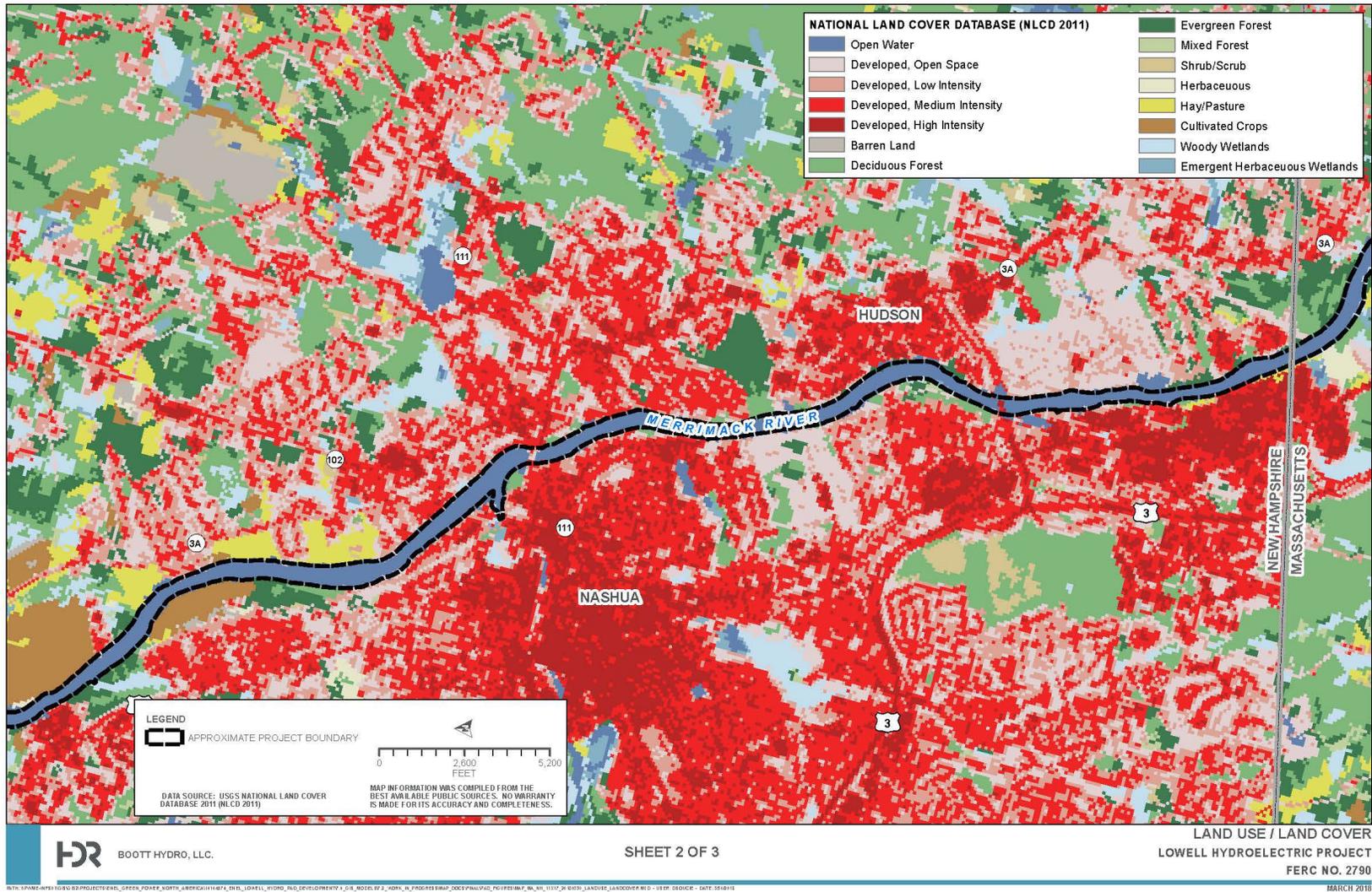
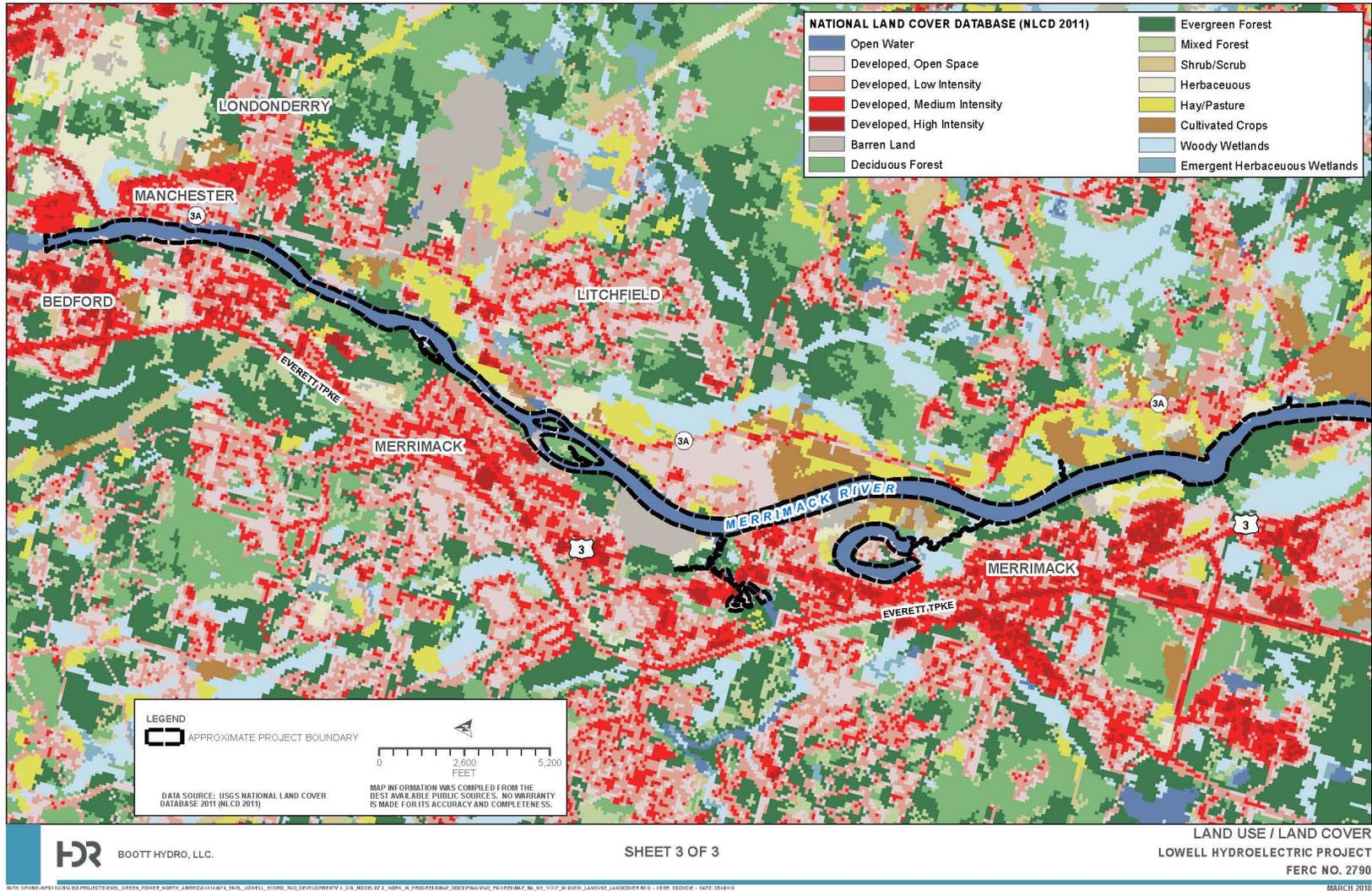


Figure E.7-26 continued



E.7.6.2 Environmental Analysis

FERC's SD2 identified effects of continued Project operations on recreation and land use as potential resource issues. Specifically, SD2 identified the following potential resource issues related to recreational use and land use to be analyzed for site-specific effects:

- 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.
- Effects of continued project operation on land use in the project area.

E.7.6.2.1 Recreational Resources

As described in the Recreation and Aesthetics Report (HDR 2021a), more than 145 recreationists participated in interview or online surveys to share their opinions of and experiences with existing non-Project recreation facilities within the Project's vicinity. Most sites inventoried were reported in good condition, with parking lots, ample signage, and educational exhibits. Respondents both in-person and online overwhelmingly rated their overall experience as "totally acceptable" or "acceptable". Overall, the visitor use data indicates that non-Project recreation facilities within the Project's vicinity provide an "acceptable" or "totally acceptable" recreation experience for visitors.

While walking was the most common primary recreation activity, other trail-related activities (dog-walking, hiking, running, or jogging), bank and/or boat fishing, and kayaking all ranked high among activities that respondents participated in while visiting Project recreation facilities. The most frequently visited recreational facilities in the Project area were Lowell Heritage State Park, the Rourke Brothers Boat Ramp, Chelmsford Boat Access, Merrimack Trail System, and LNHP-facilities. Potential issues with the recreation facilities included crowding and safety; however, in general, respondents did not experience much crowding at the recreational facilities, parking issues, or lack of accessibility to the specific recreational facilities.

As part of the Recreation and Aesthetics Study, Boott conducted an evaluation of expanded recreational access in the Project canals. Boott's primary concerns were the recreational rights to the canal system and understanding public safety issues associated with providing recreational access in the Project's canal system. Boott reviewed many sources to understand the recreational rights to the Lowell canal system, including the Memorandum of Understanding (MOU), the 1984 Great Deed between Proprietors and Boott (Proprietors 1984), the 1986 Order of Taking (Commonwealth of Massachusetts 1986), and the 1995 Grant of Easement from the Commonwealth of Massachusetts to the LNHP (Commonwealth 1995).

By letter dated May 14, 1980, MADCR stated that they were currently in the process of negotiating purchase rights to the Lowell canal system which would allow for recreational boating in the canals, stating further that use of the canals and implementation of the boating program were key elements of the Lowell Heritage State Park (MADEM 1980). Through the 1986 Order of Taking, MADCR purchased all air rights over the canals,

including over the canal walls and dams, and the exclusive right to use water in the entire canal system for recreational, educational, and navigational purposes, unless said purposes interfere with Boott's hydroelectric generation (Commonwealth 1986). Included in the 1986 Order of Taking is a permanent and exclusive easement to MADCR for all canal walls, beds, or bottoms throughout the canal system for purposes consistent with the use of the canal system as a recreational park. These purposes specifically include placement and attachment of docks, wharves, walls, and boat ramps of a temporary or permanent nature (Commonwealth 1986). The 1995 Grant of Easement from MADCR to LNHP did not convey these exclusive recreation rights to LNHP (Commonwealth 1995).

Based on the review of the MOU, the 1984 Great Deed between Proprietors and Boott, the 1986 Order of Taking, and the 1995 Grant of Easement from the Commonwealth of Massachusetts to the LNHP, Boott currently does not have any right to expand recreational opportunities throughout the Lowell canal system. MADCR purchased all recreational rights over all the canals and canal walls (even canals owned by Boott), including exclusive navigational rights such as boating or canoeing. MADCR maintains an exclusive and permanent easement throughout the entire canal system to install access points such as boat ramps, wharves, and docks. Boott and other stakeholders are not permitted to use the canals as recreational resources, as those rights are exclusively held by MADCR.

Additionally, while Boott does not have recreational or navigational rights to the canal system, Boott believes that providing access for the general public to the Northern Canal between the Pawtucket Gatehouse and the E.L. Field powerhouse would present a number of significant safety concerns. The current velocities in the Northern Canal are too high for safe navigation by non-powered boats when the E.L. Field powerhouse is operating, and the steep canal walls restrict the ability of public safety officials to respond to any emergency situations. Allowing recreationists access to or near to these Project facilities poses significant and unacceptable safety and security risks.

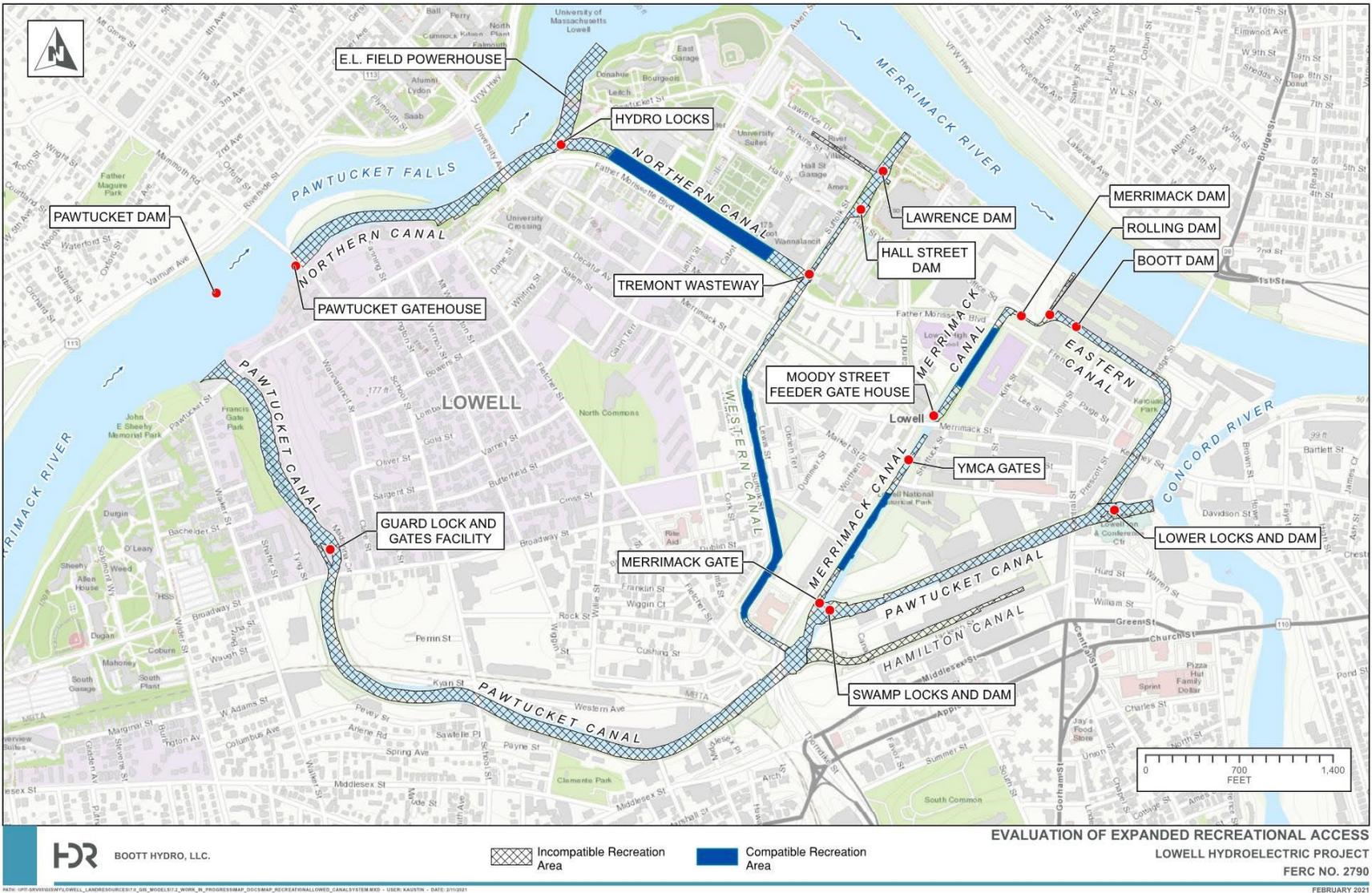
As reported in the Recreation and Aesthetics Study Report, Boott conducted an analysis of any effects of the crest gate and water levels and flows on NPS boat tours and access to the Northern Canal Walkway. The effect of the crest gate system on NPS boat tours appears to be minimal, as flows in the Merrimack River are generally not that high (8,600 cfs) during the boat tour season, and even under those flow conditions Boott does not always raise the crest gates. Boott's surge gate operations have the potential to affect access to the Northern Canal Walkway. Due to safety reasons with the surge gate, the Northern Canal Walkway opens seasonally (May 15 through October 15) when flow rates in the Merrimack River and Northern Canal are lower than 3,500 cfs.

The dewatering of the Northern Canal for construction of downstream fish passage facilities may temporarily affect recreation on the Northern Canal Walkway during the recreation season from May 15 – October 15, but Boott will work with stakeholders to mitigate the effects to recreation under the proposed Canal Drawdown Plan and the proposed Recreation Access and Facilities Management Plan. The Northern Canal Walkway is currently open to the public from May 15 – October 15 from 9:00 AM to 5:00 PM, as long as flows in the Merrimack River are under 3,500 cfs (as determined each morning from the United States Geological Survey gage readings). Boott proposes to manage the canal structures, water levels and flows, and trash as described in Section

E.6.2, which is expected to result in positive impacts on recreation within the canal system.

Continued Project operations as proposed by the Licensee will not result in any changes to the adequacy, availability, and accessibility of the non-Project related recreational facilities within the Project's vicinity.

Figure E.7-27. Identified Recreation Areas Potentially Compatible with Project Operations



E.7.6.2.2 Resources, Ownership, Boundaries and Land Rights

The NHPA establishes the statutory responsibility of federal agencies to consider historic properties under their jurisdiction. Section 106 requires federal agencies to consider the effects of their undertakings on historic properties listed in or eligible for inclusion in the NRHP. The Commission's issuance of a new license for the Project is defined as an undertaking under the NHPA and is, therefore, subject to the provisions of Section 106 and its implementing regulations at 36 C.F.R. Part 800.

FERC's SD2 identified effects of continued Project operations on cultural and historical resources as potential resource issues. Specifically, SD2 identified the following potential resource issues related to cultural and historical resources to be analyzed for site specific effects:

- Effects of continued project operation and maintenance on historic resources, archeological resources, and traditional cultural properties that are included or may be eligible for inclusion in the National Register of Historic Places.
- Effects of continued project operation and maintenance on properties of traditional religious and cultural importance to an Indian tribe.

During the previous relicensing, Boott consulted extensively with the Massachusetts SHPO and NPS to avoid destroying historic Waste Gates on the Northern Canal and to fund repairs to the Northern Canal Gates to restore them to their original condition. The proposed powerhouse was relocated, and fish passage facilities were modified to avoid any impacts to the Northern Canal Gatehouse. In addition, the Owner constructed a new set of locks in the Northern Canal to provide boat passage, to avoid any loss of historic use of the canal system. Furthermore, additional mitigative measures were undertaken by the Licensee to minimize impacts of new structures introduced into the historic district (Cleantech Analytics 2017).

Current Project operations may be a contributing factor to the continued deterioration of the Northern Canal Waste Gatehouse's southern and northern sills. The Northern Canal periodically inundates the southern sill, and spray from the Northern Canal spillway may be contributing to the deterioration of the northern sill. Repeated inundation and drying of timber sills has the potential adversely affect the integrity of the Northern Canal Waste Gatehouse; however, other factors unrelated to Project operations have also likely contributed to the ongoing deterioration of the sills, including the age of the wooden timbers, general maintenance, weathering, and atmospheric conditions.

Boott has not identified any other historic properties that are adversely affected by the ongoing operation and maintenance of the Project. As noted above, Boott determined at least one incident that appears to have contributed to recorded damage to the upstream miter gate at the Pawtucket Gatehouse. This anomalous incident does not represent normal Project operations, and Boott is repairing the damage to the gate.

Boott is not currently proposing modifications to the Project's operations or any land-clearing or land-disturbing development activities within the area of potential effects (APE) that would result in an impact to any archaeological sites, historic architectural

resources, or areas that have been identified as having moderate to high potential for containing archaeological sites.

In addition, only one tribe, the Mashpee Wampanoag Tribe, responded to FERC's initial tribal consultation letter dated April 26, 2017, and did not identify any concerns related to the Project pertaining to cultural resources.

As reported in the Resources, Ownership, Boundaries, and Land Rights Study Report (HDR 2021c), Boott owns the canal and MADCR and NPS have various easement rights to the downtown canal system for purposes of preservation, conservation, and other uses consistent with that of a park. MADCR has a permanent and exclusive easement to the entire canal system for all uses consistent with the operation of the canal system as a park, which gives MADCR the right to implement preservation and conservation measures as if they were the owner of the structures. Boott does have certain easement rights to these structures they do not own, but those easement rights are mostly limited to hydropower maintenance and operation.

E.7.6.2.3 Whitewater Recreation and Access

Boott conducted a Whitewater Boating and Access Study (HDR 2024) at the Project to evaluate the feasibility of whitewater boating in the 3,500-foot-long stretch of the Merrimack River between the Project's Pawtucket Dam and the confluence below the powerhouse.

Based on the results from the on-water assessments conducted on November 19, 2022, and November 24, 2024, participants indicated that the whitewater opportunities in the Lowell bypassed reach would be ideal for intermediate boaters (at least Class III whitewater). For boaters who participated in both the 2022 and 2024 assessments, the third flow (2,750 cfs) was described as offering good playboating opportunities, while the first and second flows (5,750 and 6,700 cfs respectively) were better suited for boaters looking to "run" laps in this short reach. Boater preferences for flow levels varied significantly, as each boater has unique preferences for their experience levels. The Project offers various boating experiences in the bypassed reach at different flow levels; an "ideal flow" was not identified.

Participants of the study frequently referenced the Concord River when comparing it to other boating rivers in the area. The Concord River was widely favored by focus group members for its whitewater features, convenient location, and proximity to work or home. Participants indicated that the Concord River was their preferred choice of the two options. They also concurred that the Project could serve as an appealing after-work option during days with longer daylight hours and could act as a substitute when the Concord River is not running.

However, the literature review performed for the study documented that there are 52 other established whitewater opportunities within 60 miles of the Project that could serve as a substitute for whitewater when it is not available on the Concord River. Additionally, the Recreation and Aesthetics Study (HDR 2021a) surveyed 149 individuals for their feedback on recreation in the Project area and results did not indicate an interest in or demand of whitewater recreation at the Project. As documented in the Whitewater Boating and Access Study Report (HDR 2024), only two of the eleven study participants

were located within 30 miles of the Project. While Boott understands interest in a “whitewater backup” when the Concord is not running, there is no evidence of a demand for the features provided by the Lowell Project and there are upwards of 52 other already established whitewater experiences within 60 miles of the Project. Therefore, continued operation of the Project as proposed is not expected to adversely affect whitewater recreation in the Project area, and Boott is not proposing any measures specific to whitewater recreation.

Additionally, as documented in the Recreation and Aesthetics Study (HDR 2021) and the Whitewater Boating and Access Study Report (HDR 2024), specific hazards were identified. Under any flow, emergency rescue operations do not have a clear point of access. Access to the bypassed reach from river right (looking downstream) is only provided from the Northern Canal Walkway and would have to be non-vehicular. Access along river left is not provided and is limited by the Massachusetts Department of Transportation’s management of Varnum Ave/VFW Highway (e.g. fencing along the highway). The 2024 participants unanimously agreed that the low-flow conditions were unsuitable for beginners, indicating that clear emergency rescue options are important, but not available. Hazardous conditions in the bypassed reach include the weirs, sharp bedrock, debris and remaining rebar embedded in the river rock. The significant amount of flow that is released through the Surge Gate when opened poses an extreme risk to anyone below on the rocky shore or in the riverbed below despite installed public safety signage and measures.

When flows in the Merrimack River are below 3,500 cfs, the Northern Canal Walkway is open to the public and therefore can be used as a put-in. If Boott were to provide special access for whitewater boaters to the put-in via the Northern Canal Walkway Island (e.g. when flows are above 3,500 cfs), it would need to request from and coordinate with NPS and MADCR. However, such ad hoc access is not feasible, because leaving the walkway access gates open would defeat the existing public safety measures developed in consultation with Boott, FERC and NPS to protect the public (HDR 2021a).

E.7.6.2.4 Land Use

The facilities of the Lowell Hydroelectric Project are situated in an intensely developed urban landscape. The historic use of the Merrimack River in the vicinity of the Project for navigation, transportation, and industrial applications remain as the primary feature guiding its current use as a tourism attraction, municipal and industrial infrastructure element, and recreational asset. The City of Lowell was built by hydropower during the Industrial Revolution and hydropower is consistent with the current land use as an urban, industrial city. Continued Project operations as proposed by the Licensee are not expected to result in any changes to land use.

Recreational boating is not permitted on the canal system, and the MADCR retains exclusive rights with respect to recreation on the canals. As noted above, MADCR also holds an exclusive and permanent easement throughout the entire canal system to install access points such as boat ramps, wharves, and docks. Boott and other stakeholders are not permitted to use the canals as recreational resources, as those rights are exclusively held by MADCR. Boott is not proposing to remove or otherwise modify the

features of the canal system, and Boott will maintain the structural integrity of the canal system consistent with its obligations under FERC's project safety regulations. Boott's proposal to maintain the canal water levels as described in Section E.5.8.4 and E.6.2 will continue to support the NPS's seasonal canal boat tours.

Boott is not proposing any modifications to existing land use at the Project. For these reasons, the Project is not expected to adversely affect recreation or land use.

E.7.6.3 Proposed Environmental Measures

Project Facilities and Operations

- Boott proposes to operate the Project in a ROR mode using automatic pond level control of the E.L. Field powerhouse units, for the purpose of protection of fish and wildlife resources downstream from the Project. ROR operation may be temporarily modified for short periods to allow flow management for other project and non-project needs, e.g., downtown canal water level management, raising the crest gates following a high-water event, or for recreational purposes.
- On a seasonal basis during the upstream passage season (i.e., typically from early May through late June/early July – and to be defined annually in consultation with the Merrimack River Technical Committee (MRTC))²³, Boott will provide a zone of passage flow of 500 cfs or inflow, whichever is less, into the Project's bypassed reach to provide appropriate fish passage conditions.
- Boott proposes to release a minimum flow of 100 cfs or inflow, whichever is less, to the bypassed reach downstream of the Pawtucket Dam during the period outside of the upstream fish passage season. The minimum flow would be provided as spillage over one or more of the crest gate zones.
- From May 15 to October 15, Boott maintains an operating agreement with the NPS to allow tour boat operations to navigate the canal system. Boott maintains canal water levels within appropriate limits during the May 15 to October 15 tour boat operating season, and typically will not be operating the downtown canal units, due to flow conditions and fish passage considerations.
- In support of the NPS's canal boat operations and additional recreational activities (provided by others), as well as for aesthetics, canal wall integrity, and vegetation control, Boott will make a good-faith effort to maintain the water elevations within the canal system consistent with the elevations established in the COMP. See below for Boott's proposed operations as they pertain to *Canal Water Elevations* and *Canal Water Flows*.
- Boott proposes continued adherence to the requirements of the Project's existing Crest Gate Operation Plan (approved by FERC on March 30, 2015).

²³ The Merrimack River Technical Committee is comprised of the following state and federal agencies: New Hampshire Department of Fish and Game (NHDFG), Massachusetts Division of Fisheries and Wildlife (MADFW), Massachusetts Division of Marine Fisheries (MADMF), United States Fish and Wildlife Service (USFWS), United States Forest Service (USFS), and National Marine Fisheries Service (NMFS).

Canal Water Elevations

Boott is actively collaborating with key stakeholders to finalize the COMP. Once the COMP is finalized, a copy of the Plan will be submitted to FERC for approval and inclusion in the new license. One of the primary components being addressed is the management of canal water elevations.

Canal Water Flows

Boott is actively collaborating with key stakeholders to finalize the COMP. Once the COMP is finalized, a copy of the Plan will be submitted to FERC for approval and inclusion in the new license. One of the primary components being addressed is the management of canal water flows.

Trash Management

Boott is actively collaborating with key stakeholders to finalize the COMP. Once the COMP is finalized, a copy of the Plan will be submitted to FERC for approval and inclusion in the new license. One of the primary components being addressed is trash management in the canals.

Historic Properties

- Within one year of license issuance, Boott will develop an HPMP for the Project that will describe appropriate management measures to avoid, minimize, or mitigate Project-related adverse effects on historic and archaeological resources over the term of the new license issued for the Project. The measures provided in the HPMP will direct the Licensee's management of NRHP-listed or eligible historic properties within the proposed Project boundary. Boott will develop the HPMP in consultation with the NPS, MHC, NHDHR, and Indian tribes.
- Under the HPMP, Boott will cooperate with NPS, MHC, and other stakeholders to avoid or minimize adverse effects on the Locks and Canals Historic District and the Lowell National Historical Park. With regard to maintenance activities within these areas, section 102 of the Lowell Act (16 U.S.C. § 410cc-12) requires FERC to: (a) make findings whether a proposed maintenance activity will have an adverse effect on the resources of the Lowell NHP or Lowell Historic Preservation District; and (b) determine whether a proposed maintenance activity "will be conducted in a manner consistent with" the Standards for Rehabilitation and Construction Standards (Standards) established under section 302 of the Lowell Act (16 U.S.C. § 410cc-32(e)) and set forth at 46 Fed. Reg. 24000 (1981). The HPMP will include procedures to inform FERC's findings and determinations required under the Lowell Act.

Recreation

- Within one year of license issuance, Boott will develop a Recreation Access and Facilities Management Plan in consultation with the stakeholders to continue to manage the Project's recreation facility, the E.L. Field Powerhouse Visitor Center.

E.7.6.4 Unavoidable Adverse Impacts

Continued Project operations as proposed by the Licensee are not expected to result in any unavoidable adverse impacts to recreation or land use.

E.7.7 Aesthetics and Socioeconomic Resources

The subsections below describe aesthetic and socioeconomic resources in the vicinity of the Project and consider the effects of continued operation of the Project as proposed by the Licensee on these resources. Descriptions of the affected environment, the environmental analysis, the proposed environmental measures, and the identification of unavoidable adverse effects were developed based on available data presented in the Licensee's PAD, other existing information, and from the results of the Recreation and Aesthetics Study performed by Boott in 2020.

E.7.7.1 Affected Environment

E.7.7.1.1 Aesthetic Resources

The Lowell Project is located within the Seaboard Lowlands Section of the New England Physiographic Province. The Taconic, Green, and White Mountain ranges are distinct features of the New England Physiographic Province. The Seaboard Lowlands Section is lower in elevation and less hilly than the adjoining New England Upland Section (Flanagan et al. 1999). The local relief in the Merrimack River Valley in the Project vicinity is generally characterized as low, open hills. The Merrimack River watershed encompasses approximately 5,010 square miles within the states of New Hampshire and Massachusetts. It is the fourth largest watershed in New England. Although the Merrimack River watershed is heavily forested (75 percent of the land area is covered with forest), it also supports all or parts of approximately 200 communities with a total population of 2.6 million people (USEPA 2020b; USACE 2006).

Along the upper northern boundary of the Merrimack River watershed, the relatively undeveloped White Mountain National Forest in New Hampshire provides almost 800,000 acres of protected land; this region also provides over one million acres of private forest and agricultural land (NHDNCR 2018). The Project dam is located at RM 41 on the Merrimack River, and the impoundment extends upstream approximately 23 miles almost to the City of Manchester in New Hampshire. The Project impoundment is characterized by the urban/industrialized cities of Nashua, New Hampshire and Lowell, Massachusetts. In the vicinity of the Project in Lowell, Massachusetts, the Merrimack River flows through a region of rapid population growth and development stemming from the 1800s that is still heavily influenced by the growing Boston urban metropolitan area (Figure E.7-26).

The Project facilities are generally bordered to the north by Route 113 and VFW Highway, and to the south by Pawtucket Street in the heavily populated City of Lowell, MA. The Project's impoundment is largely visible from Route 113 to the north and east and from Route 3A (Tyngsboro Road) to the south and west. One of the best views of

the dam is from the Pawtucket Gatehouse which is located at the southern abutment of the Pawtucket Dam that controls flow into the Northern Canal. The Project's facilities can also be seen from the pedestrian trail located along the Northern Canal, from the University Avenue Bridge crossing, and from VFW Highway. The Project's bypass reach, located north of Mammoth Road and extending down below the Project's powerhouse, offers scenes of jumbles of rocks near the Pawtucket Dam, bedrock outcroppings, and ledges at low water periods, and contains strips of forest vegetation along the streambanks typical of the region. Scenic intrusions and topographical alterations resulting from original Project construction have long since disappeared, and the Project area has become integrated with the environmental and visual setting of the surrounding area.

The aesthetic resources of the Lowell Project largely reside in the historic infrastructure that the Project is a part of. The multiple historic textile mills, gatehouses, locks, canals, and walkways that are part of the Lowell National Historical Park are the primary aesthetic attraction of the Lowell Project (Figure E.7-28 through Figure E.7-32). Tourists are drawn to the city of Lowell to witness the historic site of the Industrial Revolution in the United States. Lowell is essentially a living exhibit of the process and the consequences of the American Industrial Revolution. In addition, the Project's immediate shoreline, associated canals, and river corridor offer a scenic backdrop in an intensely urbanized setting (Figure E.7-30 and Figure E.7-31).

Figure E.7-28. Pedestrian Walk with View of the Northern Canal (left) and Bypass Reach (right).



Figure E.7-29. Guard Lock and Gates Facility.



Figure E.7-30. Upstream View of Bypass Reach Near University Avenue



Figure E.7-31. Westerly View of Pawtucket Canal Near the Confluence with the Merrimack River



During the original licensing of the Project, NPS and other stakeholders stated that the powerhouse architecture should not mimic the nineteenth-century structures nearby. It was stated by officials that the modern nature of the new facility would be apparent and that it would harmonize well with the Northern Canal, the local neighborhood, and the river. The Licensee agreed to coordinate final exterior building design with the NPS and

other interested agencies to help achieve this aim. Landscaping of the powerhouse area was also discussed in the prior application and the following proposals were made (Boott Mills 1980):

- Riverbank vegetation near the site to be protected to the extent feasible.
- Steep, riverside areas disturbed during construction are to be planted with native plant material.
- Street-level areas to compliment state and federal park design.
- Transmission lines from station to adjacent highway bridge to be inconspicuous.

Figure E.7-32 and Figure E.7-33 depict the Pawtucket Dam and E.L. Field Powerhouse, respectively. The E.L. Field Powerhouse is located in the vicinity of more modern architecture such as the University of Massachusetts Lowell dormitories.

Figure E.7-32. Westerly View of Pawtucket Dam from the Pawtucket Gatehouse



Figure E.7-33. E.L. Field Powerhouse with University of Massachusetts Lowell in the Background



E.7.7.1.2 Recreation and Aesthetics Study

Pursuant to the RSP, on April 9, 2020, Boott mapped areas within the canal system owned or under the control of Boott where waterborne trash may be a potential concern. The amount and type of waterborne trash that accumulates within the Project boundary can vary according to several factors including the season, Project operations, and the magnitude and duration of the flow events (HDR 2021a).

The surveys for waterborne trash have shown that waterborne trash accumulates within the Project's canal system, and these accumulations are somewhat dependent on the level of the water within the canals as well as the required operation of some of the NPS gates within the study area. For example, NPS gates that are operated on a routine basis had minimal signs of waterborne trash associated with them, while others that are largely in the closed position tended to have accumulations of waterborne trash behind them at varying densities (HDR 2021a).

Accumulated waterborne trash includes material floating on the impoundment surface and/or found on the surface of the canal system. Most of the waterborne trash accumulation within the Lowell Canal system appears to be derived from upstream inputs (the Merrimack River) as well as direct canal inputs (accidental and intentional

littering) and from runoff events (also likely from accidental and intentional littering) (HDR 2021a).

In total, eight (8) areas of waterborne trash totaling 0.21 acres were mapped on April 9, 2020, as well as three additional areas of accumulated trash on the canal bed and a single area with a waterborne sheen. The total study area encompassed approximately 44 acres and the mapped areas within the canals were 3.531 acres or approximately 154,000 square feet (HDR 2021a).

Waterborne trash consisted of common materials such as foam board pieces, plastic cups, foam plates, foam bait containers, shoes, plastic bottles, organic debris, etc. (see Figure E.7-34 and Figure E.7-35).

Figure E.7-34. Waterborne trash on the Pawtucket Canal at Guard Lock and Gates Facility.



Figure E.7-35. Waterborne trash on the Merrimack River upstream of the Northern Canal Gatehouse



E.7.7.1.3 Socioeconomic Resources

The Lowell Project is located in Middlesex County, Massachusetts and Hillsborough County, New Hampshire. The population of Middlesex County in 2023 was approximately 1,622,896 resulting in an approximate 1.7 percent increase in population from the 2018 (U.S. Census Bureau 2023a). The population of Hillsborough County in 2023 was 424,732 resulting in a 3.2 percent increase in population from 2018 (U.S. Census Bureau 2023a).

According to the U.S. Census Bureau, the median household income in Middlesex County (in 2023 inflation adjusted dollars) from 2019 to 2023 was estimated to be \$126,779. There is an estimated 7.5 percent living below the poverty line in Middlesex County (U.S. Census Bureau 2023b). The most common employment sectors for Middlesex County are professional, scientific, and management, and administrative and waste management services; and educational services, and health care and social assistance (U.S. Census Bureau 2023b).

According to the U.S. Census Bureau, the median household income in Hillsborough County (in 2023 inflation adjusted dollars) from 2019 to 2023 was estimated to be \$100,436. There is an estimated 6.5 percent living below the poverty line in Hillsborough County (U.S. Census Bureau 2023b). The most common employment sectors for Hillsborough County are healthcare and social assistance, manufacturing, and retail trade (U.S. Census Bureau 2023b).

The Lowell Project is located within the Greater Boston metropolitan area, which is primarily composed of urban and suburban towns and cities. The City of Lowell's estimated population in 2023 was 114,799, making it the fourth largest city in Massachusetts. The population of Lowell grew an estimated 3.1 percent since the previous 2018 survey. The median household income in Middlesex County (in 2023 inflation adjusted dollars) from 2019 to 2023 was estimated to be \$126,779, while the Lowell household annual income (in 2023 inflation adjusted dollars) from 2019 to 2023 was \$76,205. An estimated 16 percent of people were below the poverty line in 2023 (U.S. Census Bureau 2023b).

The economy of Lowell employs approximately 62,349 people. The largest industries in Lowell are educational services, and health care and social assistance and manufacturing.

Educational, scientific, and technical services are also notable contributing industries to the Lowell economy.

The City of Lowell's Healthy and Sustainable Local Economy 2025 Master Plan targets multiple facets of the local economy and the well-being of its citizens. One facet is to continue to support the urban revitalization plan of the Hamilton Canal District which includes properties adjacent to Lowell Project facilities. A second facet of the City of Lowell's plan is to attract and maintain environmentally sustainable businesses, institutions, and industry. Hydropower is a suitable industrial energy supplier that satisfies this local economic development goal (City of Lowell 2013).

E.7.7.2 Environmental Analysis

FERC's SD2 identified the following potential resource issue related to aesthetics and socioeconomic effects:

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

E.7.7.2.1 Aesthetic Resources

As described above, the facilities of the Lowell Hydroelectric Project are situated in an intensely developed urban landscape. The Project dam is located at RM 41 on the Merrimack River, and the impoundment extends upstream approximately 23 miles almost to the City of Manchester in New Hampshire. The Project impoundment is characterized by the urban/industrialized cities of Nashua, New Hampshire and Lowell, Massachusetts. In the vicinity of the Project in Lowell, Massachusetts, the Merrimack River flows through a region of rapid population growth and development stemming from the 1800s that is still heavily influenced by the growing Boston urban metropolitan area.

The aesthetic resources of the Lowell Project largely reside in the historic infrastructure of the Project. The multiple historic textile mills, gatehouses, locks, canals, and walkways that are part of the Lowell National Historical Park are the primary aesthetic attraction of the City of Lowell, portions of which are included in the Lowell Project (Figure E.7-28 through Figure E.7-32).

Pursuant to the approved study plan for the Recreation and Aesthetics Study, Boott reviewed several sources to summarize historical and current practices for maintaining aesthetics (vegetation and waterborne trash management) in the Project Area. Following establishment of the LNHP in 1978, MADCR²⁴, NPS, and Proprietors entered into an agreement in 1979 regarding management of the Lowell canal system and other historic structures. This agreement establishes MADCR as the lead party responsible for the maintenance of canal structural components, including canal banks and walls. As the lead party, MADCR was responsible for "landscaping and damage repair" to canal banks and walls, with assistance provided by NPS if needed. NPS was charged with the operation of the canal-related exhibits and services, and Proprietors were responsible for the operation and maintenance of the hydroelectric and hydromechanical parts of the Lowell canal system (NPS 1981). NPS developed and issued a Final General Management Plan (FGMP) in August 1981 to provide a basis for visitor use, resource management, and general development within the LNHP. The FGMP states that management of the Lowell canal system will be accomplished through cooperative agreements between private and public entities, but MADCR is the lead agency responsible for maintaining, developing, and renovating the major elements of the canal system (NPS 1981).

²⁴ The signatory of the 1979 agreement was the Massachusetts Department of Environmental Management, the predecessor agency to MADCR.

In 1991, MADCR, the NPS, and Boott executed a MOU for the purpose of maintaining and operating the Lowell Canal System.²⁵ The MOU assigned specific responsibilities to each party and was filed with the Commission²⁶ on April 25, 1991 (MOU 1991). Article IV of the MOU directed NPS to assist MADCR in the removal and control of vegetation along the canal system, (“particularly that growing on and in the canal walls”) and to assist MADCR in performing ground maintenance. Article IV also directed NPS to assist MADCR in the removal of litter and other waterborne trash from the Lowell Canal System, and states NPS is solely responsible for maintaining and cleaning, (“including removal of trash”) all existing trash booms and safety lines/booms on the Lowell Canal System (MOU 1991).

Responsibilities assigned to MADCR under Article V of the MOU include serving as the lead agency for all grounds maintenance, keeping all grass, trees, and shrubs neatly trimmed and in a healthy condition, removing dead or diseased plants, fertilizing, pruning, and thinning of plants (as required), and approving ground maintenance or improvement plans as proposed by NPS. Article V also directs MADCR to assist NPS in the removal and control of destructive vegetation along the canal system, and to cooperate with the NPS on developing a litter removal program for waterborne litter and trash on the canals. (MOU 1991). This article also directed MADCR to reimburse NPS for time and materials for work done on the canal system.

Article VI of the MOU directed NPS and MADCR to hold a joint annual meeting to develop an annual destructive vegetation clearing program and canal surface water cleanup program. The annual programs were to be developed in accordance with each agency’s budget and seasonal staffing level. Under Article VI, MADCR was also directed to consult with NPS to develop a long-term capital improvement program for the canal system. The minutes of this annual meeting between MADCR and NPS were to be provided to Boott and the Proprietors each year (MOU 1991).

Article IX stated that the MOU would expire five years from the date of signing, with an option for renewal. Efforts to renew the MOU apparently stalled around 1996, as MADCR issued a Grant of Easement²⁷ to the NPS in late 1995 (FERC 2001; Boott 2001; Lowell Sun 2006). This Grant of Easement provided NPS rights to implement construction and maintenance improvements at forty-two MADCR-owned parcels around the canal system. Such rights include landscaping, decking, and lighting. The Grant of Easement did not exclusively limit NPS’s rights, only stating that construction and maintenance improvements must be consistent with the use of the area as a park. The Grant of Easement did not relinquish MADCR’s waterborne trash and vegetation management responsibilities provided by the FGMP or MOU, as described above.

In the Resource Management Plan (RMP) for the Lowell/Great Brook Planning Unit, MADCR elaborates the agency was directed by the Commonwealth in 1993 to “concentrate on maximizing the riverfront component and minimizing, but not eliminating,

²⁵ Proprietors of the Locks and Canals on the Merrimack River was included as a party in the MOU but did not execute the agreement.

²⁶ The 1991 Memorandum of Understanding is available on FERC’s eLibrary (<https://elibrary.ferc.gov/eLibrary/search>) under docket number p-2790.

²⁷ The 1995 Grant of Easement is also generally referred to as LNHP Deed No. 40.

[its] position in the downtown.” Under a lower annual budget, MADCR states it has since focused its resources on the riverfront portion of the Lowell Heritage State Park system and less on the downtown canal system (MADCR 2014).

Boott annually removes accumulated river-borne debris from the upstream side of the Northern Canal Gatehouse under an MADCR permit. This effort is performed as necessary, typically two to three times annually. Boott also removes debris that accumulates from the upstream side of the Guard Locks and Gatehouse in the Pawtucket Canal on an as necessary basis, both for aesthetics and to ensure that debris does not interfere with the proper functioning of the Guard Gates. Boott will continue these practices under the new FERC license as described in Section E.6.2.

The combination of past and present land use activities in and around the Project area have contributed and will likely continue to contribute to the accumulation of waterborne trash within the Project’s canal system that occur in the study area today (e.g., industrialization, commercial development, residential areas in close proximity to canals, etc.). However, the complexity and diversity of historical and current land use activities in the study area create a problem for tracing and identifying the sources of waterborne trash and its movement and distribution within the study area. Waterborne trash consisted of common materials such as foam board pieces, plastic cups, foam plates, foam bait containers, shoes, plastic bottles, and organic debris. It is well known that many types of land uses contribute to the accumulations of waterborne trash including stormwater drainage systems, upstream sources, inappropriately discarded trash, natural events (woody debris), densely populated areas, etc. Roads, construction, recreation, residential developments, and commercial and industrial developments all can contribute to the problem. Ongoing Project operation and maintenance has very little potential to cause and/or significantly contribute to the waterborne trash accumulation areas observed during the study.

Existing Project facilities are an integral part of the river’s ecologic and aesthetic character. The Licensee is not proposing to modify Project operations. Current Project operations do not involve activities that directly affect aesthetics. Continued operation of the Project will help maintain the aesthetic quality of the Merrimack River by providing a continuous flow in the Project’s bypassed reach and downstream areas. Boott also proposes to maintain water elevations and flows in the canal system and manage trash as described in Section E.6.2. No impacts on aesthetic resources are expected as a result of continued Project operations.

E.7.7.2.2 Socioeconomic Resources

As previously described in this application, the Project is located within the historic infrastructure of the LNHP. Tourists are drawn to the city of Lowell to witness the historic site of the Industrial Revolution of the United States. Boott is not proposing to modify Project operations in manner that would affect regional tourism. As such, the continued operation of the Project as proposed by the Licensee is not expected to have any adverse effects on socioeconomic resources.

E.7.7.2.3 Environmental Justice

At this time, Boott is not proposing any changes to Project operations and will continue to operate in ROR mode. As the Project operates in ROR mode, seasonal and annual variations in flow within the Project area are based on natural hydrologic conditions. As the Project has historically met water quality standards, continued ROR operation is not expected to have negative effects on water quality. Additionally, Boott will provide a year-round minimum flow of 100 cfs or seasonal bypass flow of 500 cfs into the Project's bypassed reach for the purposes of aquatic habitat and water quality protection, which also provide direct and indirect benefits to Environmental Justice (EJ) communities as described below.

Boott is also proposing to install an upstream tailrace fish ladder, modify the existing upstream fish ladder, modify the bypass reach zone of passage, and install a downstream fish protection system. These measures are designed to improve fish passage and support fish populations in the Merrimack River. Support of these populations positively impacts EJ communities that may fish for river herring, shad, and other species for recreation or subsistence. Potential erosion and sedimentation, air quality, traffic, and noise impacts resulting from the construction of fish passage and protection measures will be short-term and are expected to be identified and mitigated during environmental permitting and design. The proposed enhancements are expected to provide EJ communities with improved fishing opportunity in the Merrimack River.

Boott is proposing to continue to manage the canal structures and facilities, water levels, and flows in line with current and future agreements with stakeholders. Maintenance of these structures will preserve the aesthetics and cultural values associated with the historical canal system and mill powerhouses.

Recreational resources of the portions of the canal system have been a subject of the facilitated discussions with Project stakeholders. The potential effects of flows through the canals on aspects like aesthetics, trash accumulation, and recreation have been addressed through these discussions. Also, an understanding of current water quality within the canal system, and the continued maintenance of water quantity and quality, are important management goals for Boott and participants. Boott is proposing to develop a Recreation Access and Facilities Management Plan in consultation with the stakeholders within one year of license issuance. This plan is expected to provide local communities with increased access and recreational opportunities at the Project. As reported in the Recreation and Aesthetics Study Report, Boott does not have any recreational rights to the canal system as those rights were acquired by MADCR. Therefore continued operation of the Project is not expected to impact EJ community access to the canal system. Boott proposes to develop a HPMP that will establish procedures for consultation with NPS, MHC, and other stakeholders for avoidance and minimization of adverse effects on the Locks and Canals Historic District and the Lowell National Historical Park.

Section 102 of the Lowell Act (16 U.S.C. § 410cc-12) requires FERC to: (a) make findings of whether a proposed maintenance activity will have an adverse effect on the resources of the Lowell NHP or Lowell Historic Preservation District; and (b) determine whether a proposed maintenance activity "will be conducted in a manner consistent with"

the Standards for Rehabilitation and Construction Standards (Standards) established under section 302 of the Lowell Act (16 U.S.C. § 410cc-32(e)) and set forth at 46 Fed. Reg. 24000 (1981).

As described in Section E.6.2 of this Exhibit, Boott is proposing to maintain canal water levels and flows and manage trash. Boott is proposing to maintain flows in the canal system to maintain the aesthetics of the canals that attract tourists and visitors to the City of Lowell. Boott is also proposing to continue to maintain canal facilities consistent with existing rights, responsibilities, and existing or new agreements developed among the concerned stakeholders. The proposed maintenance of canal water levels will continue to support the NPS's canal boat operations that attract visitors to the LNHP. Relicensing and continued operation of the Project is not expected to have adverse effects on EJ communities. Boott proposes to operate the Project in the same way it has been historically operated, continuing to supply low-cost electricity and jobs, which benefits all communities within the region.

E.7.7.3 Proposed Environmental Measures

Boott proposes to continue operations of the Project with certain PM&E as outlined above in Section E.6.2.

E.7.7.4 Unavoidable Adverse Impacts

The continued operation of the Project as proposed by the Licensee is not expected to have any unavoidable adverse impacts on aesthetic or socioeconomic resources.

E.7.8 Cultural Resources

The subsections below describe cultural resources in the vicinity of the Project and consider the effects of continued operation of the Project as proposed by the Licensee on these resources.

In considering a new license for the Project, the Commission has the lead responsibility for compliance with applicable Federal laws, regulations, and policies pertaining to historic properties, including the NHPA, as amended (NHPA)²⁸. Section 106 of the NHPA (Section 106)²⁹ requires federal agencies to consider the effects of their undertakings on historic properties and to afford the ACHP a reasonable opportunity to comment.

The term “historic property” is defined in the implementing³⁰ regulations as any precontact or historic period district, site, building, structure, or individual object included in or eligible for inclusion in the NRHP, including any artifacts, records, and remains that are related to and located within historic properties, and properties of traditional religious

²⁸ 54 U.S.C. §300101 et seq.

²⁹ 54 U.S.C. §306108

³⁰ 36 C.F.R. Part 800 – The Protection of Historic Properties

and cultural significance that meet the NRHP criteria. The criteria for evaluating properties for inclusion in the National Register (36 C.F.R. Part 60) has been established by the Secretary of the Interior. In accordance with the criteria, properties are eligible if they are significant in American history, architecture, archaeology, engineering, or culture. The quality of significance is present in historic properties that possess integrity of location, design, setting, materials, workmanship, feeling, association, and:

1. That are associated with events that have made a significant contribution to the broad patterns of our history;
2. That are associated with the lives of persons significant in our past;
3. That embody the distinctive characteristics of a type, period, or method of construction, or that represent the work of a master, or that possess high artistic values, or that represent a significant or distinguishable entity whose components may lack individual distinction; and/or
4. That have yielded or may be likely to yield information important in prehistory or history.

The regulations implementing Section 106 are intended to accommodate historic preservation concerns with the needs of federal undertakings through a process of consultation among agency officials, Federally recognized Native American tribes, SHPO, THPO, and other parties, including the public, as appropriate. By letter dated April 26, 2017, the Commission initiated consultation under Section 106 with Federally recognized Native American tribes, including the Mashpee Wampanoag Tribe, Narragansett Indian Tribe, Stockbridge Munsee Tribe of Mohican Indians, and Wampanoag Tribe of Gay Head (Aquinnah).

The Commission designated Boott as its non-federal representative for purposes of conducting informal consultation pursuant to Section 106 via the June 15, 2018, NOI to file a License Application for a New License and Commencing Pre-filing Process.

E.7.8.1 Affected Environment

E.7.8.1.1 Area of Potential Effects

The APE for any undertaking is defined in 36 C.F.R. §800.16(d) as the geographic area or areas within which an undertaking may directly or indirectly cause alterations in the character or use of historic properties, if any such properties exist. The APE is influenced by the scale and nature of an undertaking. Although the Project's potential effects are limited by the nature of this undertaking (the relicensing and continued operation and maintenance of existing hydroelectric facilities), the Project has the potential to affect historic properties directly or indirectly (should any such properties exist). As described in the PAD, Project-related effects on historic properties may potentially result from (1) the Project's operations, (2) potential enhancement measures at the Project, and (3) routine maintenance activities. Potential enhancement measures at the Project (e.g., development of new recreation access areas) could result in ground disturbance which has the potential to disturb intact archaeological deposits, should any be present.

Routine maintenance activities at the Project could result in ground disturbance and could also affect the integrity of historic buildings and structures.

Consistent with the scope of potential effects on historic properties, Boott proposed to define the APE for relicensing the Project as the following:

The APE for the Lowell Hydroelectric Project is the lands within the defined FERC Project boundary.

Since the Project boundary encompasses all lands that are necessary for the Project's purposes, the definition of the APE is consistent with the 36 C.F.R. §800.16(d) and the manner in which the Commission has defined the APE for similar hydroelectric projects. The existing Project boundary is presented in Figure E.1-1.

E.7.8.1.2 Cultural Context

Precontact Period

For several thousand years, the Pawtucket Falls was a thriving center of Native American economic and cultural activity. The annual run of anadromous fish drew Pennacook Native Americans from a wide area of northern New England, and two subtribes, the Pawtuckets and Wamesits, established villages on the flats near the bend of the Merrimack below the falls. Salmon, sturgeon, shad, and alewives were harvested with nets, spears, and barbed arrows. The fish provided not only a large portion of the Native Americans' yearly protein intake, but also served as fertilizer for the nearby agricultural fields. The site retains its Native American name today, for "Pawtucket" means rapids or falls in the Algonquin dialect of its early settlers (Boott Mills 1980).

There are three pre-Contact archaeological sites recorded in the area of Lowell Park, however, many more exist along the Merrimack River both upstream and downstream of the Project. Many Archaic Period village sites, camp sites, and fishing grounds are documented in the vicinity of the Project (MADCR 2014). Boott distributed PAD questionnaires to the MHC and the NHDHR; however, no responses were received.

According to the MHC's survey map of prehistoric sites in Lowell, a major Native American archeological site is on the flood plain beyond the bluff. Much of this area, site of Native American campgrounds and cultural activities associated with fishing, has been disturbed by a series of construction projects for roads and buildings. The likely locations of artifactual remains lie northeast of the path followed by the intake channel (Boott Mills 1980).

E.7.8.1.3 Historical Context

This section provides an historical context of the Project Area from early Anglo-European settlement through the Industrial Revolution.

Anglo-European settlers gradually acquired Native American homelands, and private ownership divided the once common land into scattered farms. Proprietors of riverbank properties even acquired legal title to the fishing rights on sections of the rapids. Although remnants of former Native American bands made annual trips to fish at the

Pawtucket Falls as late as the 1840s, they were considered a quaint curiosity in the growing industrial community (Boott Mills 1980).

Background of Industrial Lowell

A number of circumstances are responsible for Lowell becoming America's first industrial city, particularly, the existence of the great waterpower potential at the Pawtucket Falls. Although a transportation canal around the rapids at Lowell was completed in 1796, the manufacturing potential of the site was not fully appreciated until 1821. The Boston Associates chose the site of the Pawtucket Falls for their new textile manufacturing community (Boott Mills 1980). The Boston investors acquired control of Proprietors of the Locks and Canals on Merrimack River, the company that had built the Pawtucket navigation canal and that, due to the success of the competing Middlesex Canal (direct route to Boston), was not doing well financially. The Boston investors and other industrialists formed a series of textile corporations in Lowell. The old canal company was set up to build canals, sell mill sites, manufacture machinery, and lease waterpower to the textile manufacturers (Boott Mills 1980). The Pawtucket Canal became the feeder for a complex system of power canals beginning in 1822. By 1826, two canals branched from the Pawtucket and four additional canals were already envisioned. Ten years later, the expanded system was complete. Water drove the machinery of mills located on two distinct levels, with the tailraces of mills on the upper level emptying into canals leading to lower level mills. By 1846, when a second major expansion of the canal system began, ten textile mill complexes and a machine shop received their power from Proprietors of the Locks and Canals on Merrimack River (Boott Mills 1980).

General History of the Northern Canal Area

Since 1826, engineers had been able to increase the flow into the Lowell Canal system by constructing dams at Pawtucket Falls. The first was a crude wooden structure; but by 1830, a masonry dam seated on heavy wooden cribbing was helping to maintain a "pond" behind the falls. Three years later, workmen added two more courses of granite headers and raised wooden flashboards. This raised the level of the upper river and diminished its current for over 18 miles upstream. However, the dam did not meet the water needs of the growing industrial city for long as the demand for waterpower continued to increase yearly as the textile corporations expanded their manufacturing operations. Power was continually scarce in the dry summer months; and by the 1840s, shortages were common throughout the year. One problem was the severe friction losses in the canals created by greater flow rates. When mills needed more water, the current had to increase to supply this demand. Increased current produced friction, which actually dropped the level of water in the canals and reduced the head, or potential to generate power. Thus, the mills could only get a greater flow of water by giving up some of the head that they also needed. In times of freshets, river water entering the tailraces of mills impeded their wheels. Such backwater conditions placed excessive demands on the canal system (Boott Mills 1980).

James B. Francis, the British-born chief engineer of Proprietors, proposed the construction of a second feeder canal. This huge waterway would bring additional water into the system and allow a reduction of current in most of the canals. To make such a

plan effective, however, two conditions had to be met. First, Locks and Canals would have to prohibit the use of water for manufacturing at night, so that the river's flow could be ponded until the morning. Second, the power company would have to control the outlets of the major lakes that fed the Merrimack River. Using the lakes as reservoirs, Lowell would then have a source of extra water in dry seasons (Boott Mills 1980).

With booming economic conditions in American textile manufacturing in the 1840s, the Essex Company of Lawrence and the Locks and Canals acquired control of over 100 square miles of lake surface in New Hampshire. James B. Francis selected a new route for a second feeder canal. The route ran parallel to the river for over 2,000 feet, then turned inland to join the Western Canal. The route required Francis to build a "Great River Wall" to hold his canal above the Merrimack rapids and also required him to (1) rebuild a large part of the Pawtucket Dam, (2) construct sophisticated gate controls, and (3) modify the existing canal system to integrate it with the new canal (Boott Mills 1980).

The construction of the Northern Canal, under the supervision of James B. Francis in 1846-1847, was one of the most impressive achievements in the history of American engineering. The vast undertaking was the culmination of efforts to harness the flow of the Merrimack River at Pawtucket Falls to drive the textile machinery of the Boston investors. When completed, the project set new standards in civil and hydraulic engineering and introduced the famous "Francis" turbine to the world (Boott Mills 1980). The Northern Canal brought water into the system with a higher head than had been previously possible, and it reversed the current in the Western Canal from the junction to the Swamp Locks Basin. Water from the Northern Canal supplied the demands of the Tremont, Suffolk, and Lawrence Mills. Once Francis had completed the Moody Street Feeder in 1848, the Northern Canal also fed the Merrimack Canal through three brick vaulted tunnels. A smaller underground passage, known as the Boott Penstock, transferred some of this flow from the Merrimack Canal to the end of the Eastern Canal, where an adequate water level had always been hard to maintain (Boott Mills 1980). After testing the results of his physical improvements to the system, Francis arranged for redistribution of power and an increase in the number of "mill powers" leased to each company. Because of the limitations of the old Pawtucket Canal as the sole feeder, only 91 mill powers had been leased up to that time. The Northern Canal enabled the chief engineer to lease 139 mill powers, a gain of more than 50 percent. These were "permanent mill powers" to be supplied in all seasons; for most of the year, the corporations could also purchase "surplus" mill powers at an inexpensive rate. The mill complexes were assured of almost 12,000 gross horsepower, even in summer (Boott Mills 1980).

Francis, acting as "The Chief of Police of Water," tried to prevent waste in the system and developed techniques to monitor the water use by individual corporations. When the flow in the river was low, he even closed the gates of the Northern Canal during the noon break. His 1846 tests of Uriah Boyden's outward-flow turbines in the Appleton Mills led to the development of the first "Francis" turbine, which was used to raise and lower the headgates within the Pawtucket Gatehouse. The original Francis turbine and drive belts remain in the Pawtucket Gatehouse but are no longer used. This work convinced Francis that the corporations should switch from breastwheels to more efficient hydraulic

turbines. In this way, they could produce more net horsepower from each “mill power” delivered to their sites. Also, turbines, which ran well underwater, could generate during the “backwater” conditions that ruined the efficiency of breastwheels. The widespread conversion to turbines in Lowell took place during and immediately following the construction of the Northern Canal. Francis’ Northern Canal and its associated structures remain one of the most important historic engineering resources in the Northeast (Boott Mills 1980).

Historic Resources

In 1976 the Locks and Canals Historic District was listed on the National Register of Historic Places. The Locks and Canals Historic District includes the City of Lowell’s canal system, surviving millyards, and other industrial-related resources. In 1977, the Locks and Canals Historic District was designated a National Historic Landmark (NHL), the nation’s highest level of historic significance and recognition. In 1978, Congress passed the Lowell Act, which recognized the historical value of this industrial area and established the Lowell Park and Lowell Historic Preservation District, stating:

“...certain sites and structures in Lowell, Massachusetts, historically and culturally the most significant planned industrial city in the United States, symbolize in physical form the Industrial Revolution...”

The Lowell Historic Preservation District surrounds Lowell Park as a buffer zone and enables federal assistance in the preservation and revitalization of the City of Lowell, while Lowell Park consists of the areas indeed for intensive visitor use in the interpretation of the City of Lowell and its canal system. The intention of the establishment of the Lowell Park and Lowell Historic Preservation District is to preserve and interpret the nationally significant historical and cultural sites, structures, and districts in Lowell, Massachusetts.

A Cultural Resources Inventory of the Lowell National Historical Park and Preservation District was prepared for the NPS in 1980. This inventory was completed in response to the 1978 legislation establishing the Lowell National Historical Park and the Lowell Historic Preservation District. This legislation was two-fold in that it created a park as well as a historic preservation district. The legislation outlined broad policies and goals of the federal commitment and required careful planning. To address this need for planning, the cultural resources inventory was conducted to assess the resources and aid in future planning. The defining features of the Locks and Canals Historic District and Lowell National Historic District are discussed in further detail below.

Locks and Canals Historic District

The Locks and Canals Historic District was listed on the National Register in 1976 and became a National Historic Landmark in 1977. The Locks and Canals Historic District encompasses all the canals in Lowell (built between 1793 and 1848), their associated locks, and the mills that were powered by the canals. This district contains features of the Lowell Project. There are approximately five miles of canals, and the associated mill yards increase the acreage of the district to approximately 100 acres. The canals are contiguous and meander throughout the city. The mill buildings and yards are all

associated directly with a canal, and three boarding houses, not contiguous to the canals but built by mill owners for their workers, are also included in the district. The main components of the Locks and Canals Historic District are:

- Lock House
- Francis Gate and House
- Sluice Gate House
- Northern Canal Gatehouse
- Locks and Canals Blacksmith Shop
- Gate Keeper's Cottage
- Northern Canal
- Northern Canal Walk and Great River Wall
- Suffolk Millyard
- Tremont Gatehouse
- Tremont Yard
- Lawrence Yard
- Moody Street Feeder
- Moody Street Feeder Gatehouse
- Boott Mills
- Massachusetts Mills
- Boot Mills Boarding House
- Massachusetts Mills Boarding House
- Lower Locks, Pawtucket Canal
- Bigelow Yard
- Hamilton Yard
- Eastern canal
- Lower Pawtucket Canal
- Appleton Mills
- Hamilton Canal
- Swamp Locks
- Merrimack Canal
- Lowell Machine Shop

- Proprietors of Locks and Canals Yard
- Western Canal
- Upper Pawtucket Canal
- Pawtucket Dam
- Suffolk Manufacturing Company Boarding Houses

The Locks and Canals Historic District is significant for its contributions to the development of Lowell as the first great industrial city in the United States.

Lowell National Historical Park

The LNHP and Preservation District was listed on the National Register in 1978. The LNHP Preservation District includes within its boundaries an approximate 5-mile power canal system, a portion of the central business district, and three major mill complexes. The area within the park boundaries totals 134 acres, but with only NPS ownership of a handful of buildings with other property privately owned. The Lowell Historic Preservation District includes the mills or mill sites of most of the rest major textile corporations, the remainder of the historic central business district, and areas along the Concord River where smaller factories flourished outside the main waterpower system. There are 895 properties within Lowell Park and the Lowell Historic Preservation District and are classified as follows:

- 307 residential buildings
 - 147 single family
 - 62 duplexes
 - 99 multiple family
- 210 commercial buildings
- 130 buildings within textile mill complexes
- 27 other industrial structures
- 16 schools
- 9 churches
- 24 government buildings
- 92 vacant lots
- 33 components of the canal system
- 11 bridges
- 37 miscellaneous structures (theaters, parking garages, playgrounds, etc.)

In terms of the condition, the properties (excluding the canals) are classified according to 1979 data as follows: 56 in excellent condition, 412 in good condition, 244 need minor repair, 70 need major repair, and 8 are derelict. In terms of period, the structures range

in period from pre-1820 to post-1950 with the greatest number of structures dated in the 1890s and from 1900-1925.

Lowell Park and the LHPD's most important historical resources are the canal system, the remaining major mill complexes, and the central business district's nineteenth century commercial buildings. The District also includes elements of other historic industrial enterprises, particularly along the Concord River. Residential properties within the District represent most of the range of styles, forms, and periods of Lowell's architectural history, but these houses generally fall short of Lowell's historic houses outside the Lowell Historic Preservation District's in quantity, quality, and concentration.

Section 102 of the Lowell Act (16 U.S.C. § 410cc-12) requires FERC to: (a) make findings of whether a proposed maintenance activity will have an adverse effect on the resources of the Lowell NHP or Lowell Historic Preservation District; and (b) determine whether a proposed maintenance activity "will be conducted in a manner consistent with" the Standards for Rehabilitation and Construction Standards (Standards) established under section 302 of the Lowell Act (16 U.S.C. § 410cc-32(e)) and set forth at 46 Fed. Reg. 24000 (1981).

Lowell Canal System

The Lowell Canal System has also been recognized for its significance within the field of engineering. The American Society of Civil Engineers designated the "Lowell Waterpower System" as a Historic Civil Engineering Landmark in 1984, and the American Society of Mechanical Engineers designated the "Lowell Power Canal System and Pawtucket Gatehouse" as a Historic Mechanical Engineering Landmark in 1985 (MADCR 2014).

E.7.8.1.4 Cultural and Historical Resource Studies

Pursuant to the approved RSP and SPD, Boott filed with the Commission the following studies relating to historical and cultural resources:

- Water Level and Flow Effects on Historic Resources Study (HDR 2021b),
- Historically Significant Waterpower Equipment Study (Gray & Pape 2021), and
- Resources, Ownership, Boundaries and Land Rights Study (HDR 2021c).

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. The Lowell National Historical Park and Historic Preservation District Cultural Resources Inventory (Shepley, 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 until now.

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 NHL District. The canal system and many Project facilities are also located within the LNHP 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, 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.

Water Level and Flow Effects on Historic Resources Study

In accordance with the Commission's SPD, Boott conducted a Water Level and Flow Effects on Historic Resources Study. The objective of this study was to analyze the potential effects of water level fluctuations from Project operations in the headpond, Northern Canal, and the Upper Pawtucket Canal (extending upstream from the Guard Lock Gate Complex to the mainstem of the Merrimack River) on historic structures with a focus on the Pawtucket Gatehouse, the Northern Canal Waste Gatehouse, the Guard Lock and Gatehouse Complex, and the Great Wall. Methods and results are described in detail in Boott's study report (HDR 2021b) which was filed with the Commission on March 5, 2021.

The results indicated the magnitude of fluctuation in the Project's headpond and the Pawtucket Canal has been significantly reduced by the implementation of the pneumatic crest gates, as shown by post crest gates operations presented in Figure E.7-37 and pre crest gate operations shown in Figure E.7-38 below. Water levels in the Pawtucket Canal upstream of the Guard Locks complex are essentially the same as the Project impoundment and remained below the normal headpond level of 92.2 ft NGVD29 throughout the 2020 study period except for one occasion. The elevation of the Guard Locks complex walkway (92.45 ft), the clapboard siding (92.45 ft), and the bottom of the mid-level windows (94.08 ft) are all above the normal water level of the Upper Pawtucket Canal. Only river flows in excess of 35,000 cfs could cause the Upper Pawtucket Canal to inundate the wooden structural elements of the Guard Locks complex; however, these conditions are outside of the ability of the Project to control the impoundment water level and therefore not attributable to Project operations.

The operation of the Northern Canal has caused periodic inundation of the sill at the Northern Canal Waste Gatehouse (Figure E.7-39). This inundation may be one factor in the continued deterioration of the gatehouse's southern sill. Spray from the canal spillway may also be contributing to deterioration along the eastern end of the northern sill.

Figure E.7-36. Project Headpond Water Surface Elevation During 2020 Monitoring Period

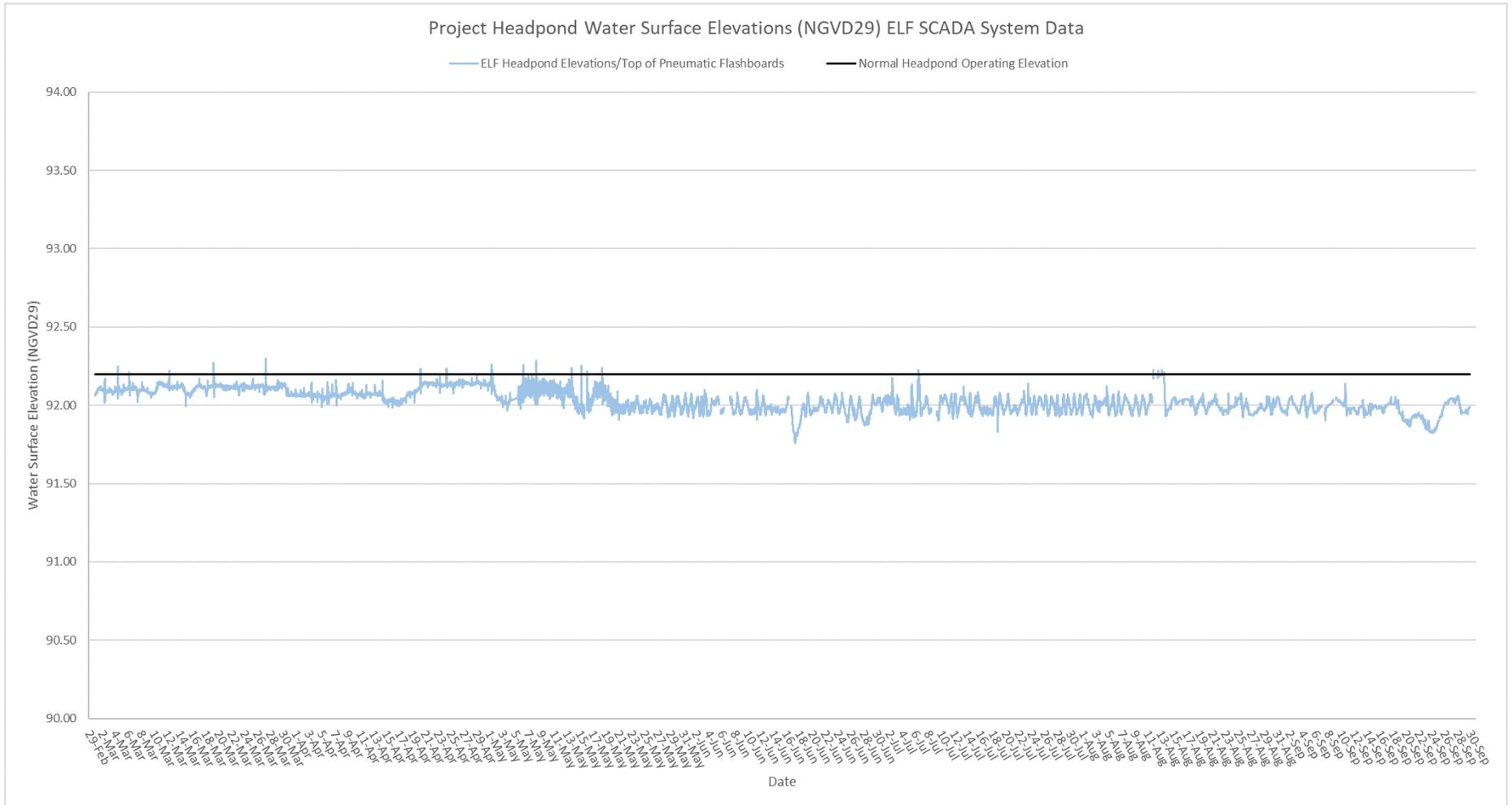


Figure E.7-37. Merrimack River – Pawtucket Dam Headpond Elevations for Period of Record (1995-2010)

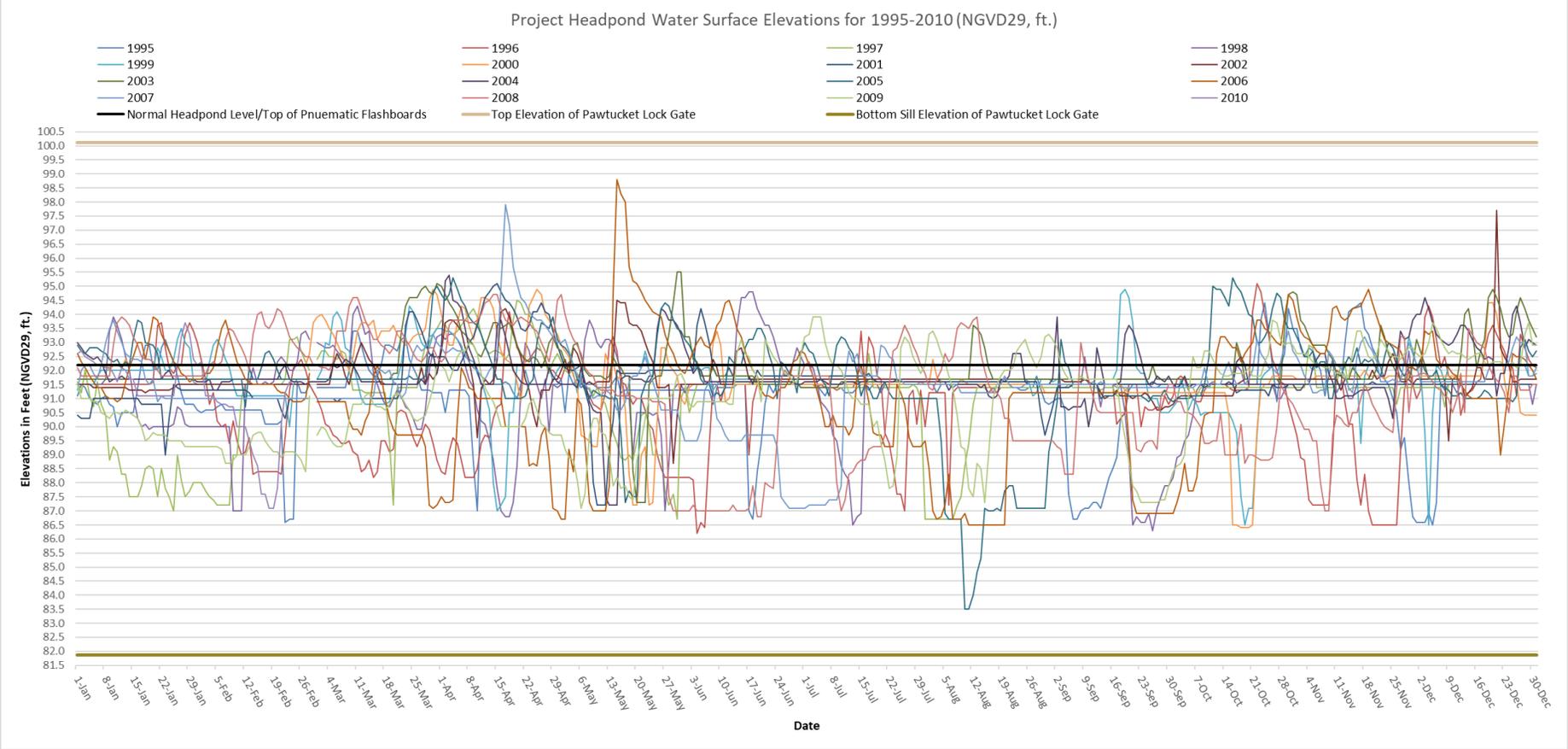
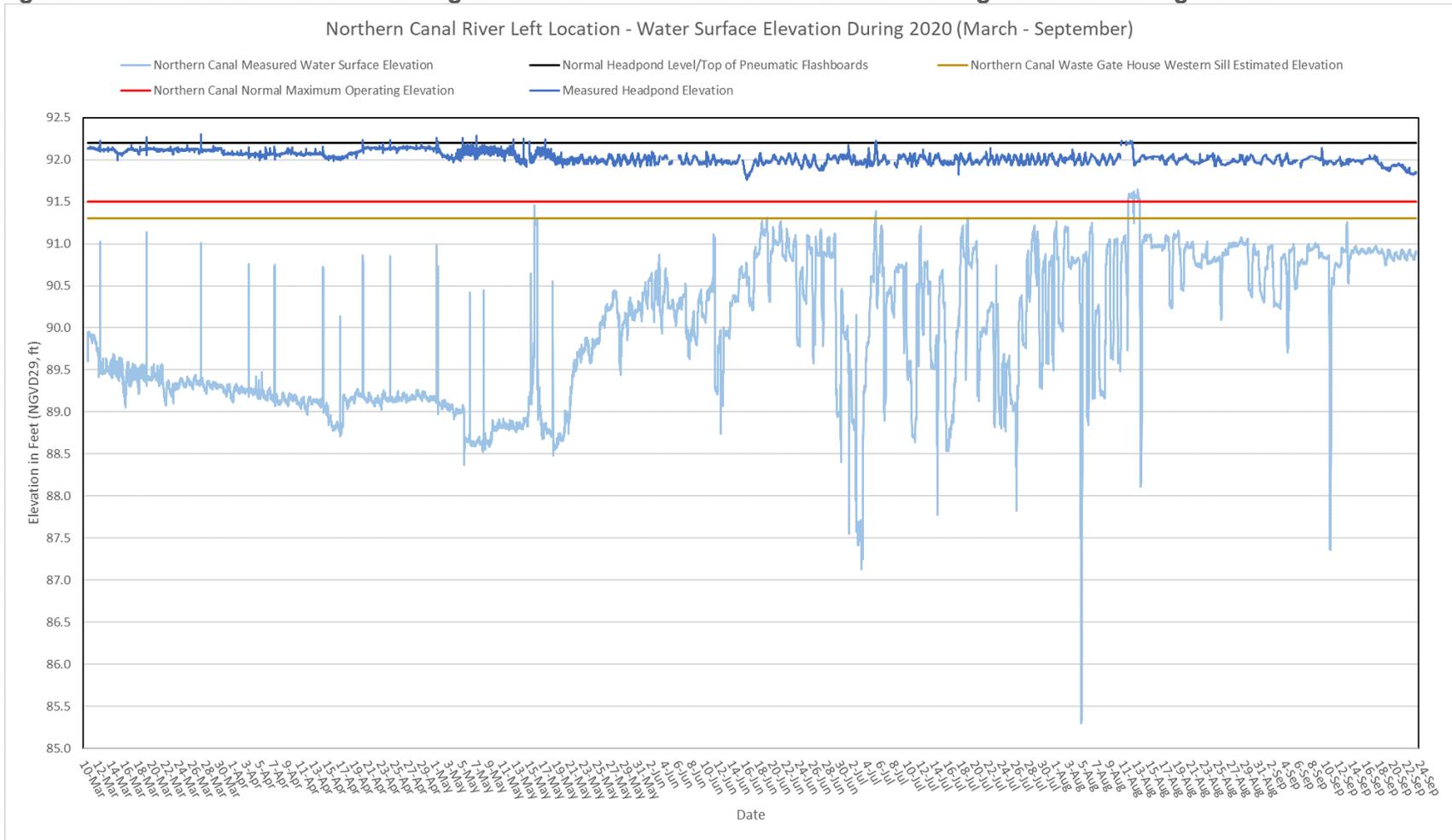


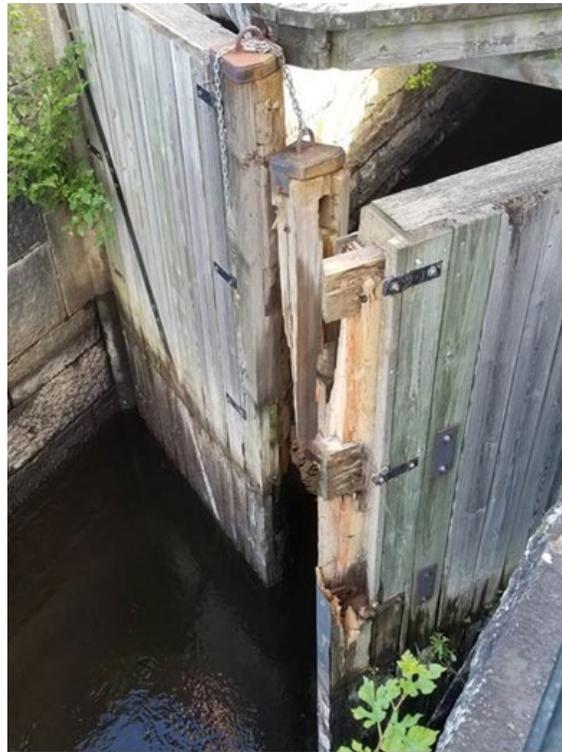
Figure E.7-38. Northern Canal River Right Location - Water Surface Elevation During 2020 Monitoring Period



The results of the study indicate the wooden structural elements of the historic resources located along the Upper Pawtucket and Northern Canals appear most susceptible to damage from submergence, periodic inundation, and waterborne trash. While the magnitude of fluctuation in the Project's headpond and the Pawtucket Canal has been significantly reduced by the implementation of the pneumatic crest gates, the Merrimack River is subject to routine seasonal high flow events. High flow events can also mobilize waterborne trash and debris that have the potential to damage wooden structural elements; however, neither high flow events nor the presence of waterborne trash and debris in the Merrimack River are attributable to Project operations.

While normal Project operations do not appear to be adversely affecting the Pawtucket Gatehouse Lock Structure beyond normal wear, at least one incident appears to have contributed to recorded damage to the upstream miter gate (Figure E.7-39). The canal surge event that occurred in 2018 was caused by the malfunction of a water level transducer. The effect of the resulting surge was exacerbated by the practice of chaining the gates closed. This anomalous incident does not represent normal Project operations, and Boott is repairing the damage to the gate.

Figure E.7-39. Damage to the Northern Canal Lock Timber Gate



Historically Significant Waterpower Equipment Study

In accordance with the Commission's SPD, Boott conducted a Historically Significant Waterpower Equipment Study to identify historically significant waterpower equipment for potential future interpretation, exhibition, or as scrap equipment to maintain and operate other historic machinery. Methods and results are described in detail in Boott's study report (Gray and Pape 2021) which was filed with the Commission on February 25, 2021.

The results indicated that it is the totality of the system of waterpower and water-control machinery at Lowell that is historically significant. Removal and replacement of individual pieces of equipment was nearly continual, from the day the system first became operational. Removal or alteration of existing equipment would constitute an adverse effect upon the qualities that make the existing system historically significant if they prevented or precluded the system from operating. Several pieces of equipment appear to be historically significant, distinct from their role as a part of the larger system. These pieces of equipment include the surviving 1870 hydraulic gate hoist system at the Pawtucket Canal Guard Locks, and the Francis turbine powered belt-and-line shafting gate operating system at the Pawtucket Gatehouse. The extant gate operating system at the Moody Street Feeder Gatehouse is likely also historically significant.

Resources, Ownership, Boundaries, and Land Rights Study

Pursuant to the approved study plan, Boott conducted a Resources, Ownership, Boundaries, and Land Rights Study to determine current ownership of resources within the canal system and existing Project Boundary, and document maintenance responsibilities, access rights, and FERC jurisdiction. The methods and results of the Resources, Ownership, Boundaries, and Land Rights Study filed with the Commission on February 25, 2021.

Ownership, easement rights, and use of the canal system in Lowell are complex, with intersecting roles between public agencies and private entities at the local, State, and Federal level. Boott conducted desktop research and a literature review to compile and review available ownership and rights documentation to obtain a better understanding of the rights and responsibilities related to resources within the Project Boundary. As appropriate and relevant, public guidance and conceptual planning and/or management documentation was reviewed by Boott including the 1977 Report of the LHCD, the 1980 Details of the Preservation Plan, the 1981 FGMP, and the 1990 Preservation Plan Amendment. Additionally, Boott reviewed and analyzed the three legal documents that establish most of the ownership, responsibilities, and land rights to the Lowell canal system. The 1984 Deed, Bill of Sale and Grant of Easements, also known as the “Great Deed” details the sale of portions of the Project from the Proprietors of the Locks and Canals on the Merrimack River (Proprietors) to Boott, as well as associated access and repair easements. The 1986 Order of Taking details the take of properties, rights, and responsibilities from Boott and Proprietors to the Commonwealth, operating through MADCR. The 1995 Grant of Easement describes the easement rights provided to the NPS from MADCR for specific properties and parcels around the canal system.

The conceptual framework for the rights and responsibilities for management of the Lowell canal system remain consistent within the 1977 Report of the LHCD, the 1980 Details of the Preservation Plan, the 1981 FGMP, and the 1990 Preservation Plan Amendment. MADCR and NPS are presented as the main parties responsible for developing, renovating, and maintaining the major elements of the canal system. In the 1977 Report of the LHCD, agency responsibilities were characterized and are shown below in Table E.7-33.

Table E.7-33. Agency Responsibilities Identified in 1977 Report of the LHDC

Agency	Responsibilities
NPS	interpretation, park wide downtown "cross-section" of 19th Century Lowell (including preservation, building and open space improvements, transportation, and visitor services)
MADCR	canals, riverbanks, and related recreational areas gatehouses, locks and dams barge system

Ownership of the Lowell canal system is largely determined by the 1984 Great Deed and 1986 Order of Taking. Components of the canal system are owned by Proprietors, Boott, and MADCR. Proprietors owns most of the Pawtucket Canal and Lower Pawtucket Canal, as well as all or portions of associated structures in those canals (e.g. Swamp Locks Dam, Lower Locks Dam, and the Guard Locks and Francis Gate). Boott is not known to own any structures of or within the Pawtucket or Lower Pawtucket Canal.

Boott owns the Northern Canal, Western Canal, Merrimack Canal, Eastern Canal, and Hamilton Canal, including their beds, bottoms, and walls, up to and encompassing the exterior plane of the canal walls, caps, and bottoms, but does not own any lands, sidewalks, pathways, buildings, powerhouses, gate houses, or other infrastructure above the canals or adjacent to the exterior planes of the canal walls, caps, and bottoms, both horizontally and vertically. Boott owns specific dams, lock structures, and hydroelectric equipment within the canals they own. The specific structures fully owned by Boott within these canals include Hall Street Dam, Lawrence Dam, Boott Dam, Rolling Dam, Merrimack Dam, Merrimack Gates, YMCA Gates, and the Moody Street Feeder. Boott owns hydroelectric equipment located inside most gatehouses, such as the Boott Dam Gatehouse and Tremont Gatehouse, but Boott does not own the gatehouse buildings.

MADCR owns most of the gatehouses throughout the canal system (e.g. Pawtucket Gatehouse, Lower Locks Gatehouse, and Swamp Locks Gatehouse, Rolling Dam Gatehouse, Hamilton Gatehouse, and Massachusetts Wasteway Gatehouse) and this is largely determined based on elevation.

Easement rights to structures of the Lowell canal system are held by Proprietors, Boott, MADCR, and NPS. In the 1984 Great Deed, Boott obtained easement rights, in common with Proprietors, to the Pawtucket Canal and structures of the Pawtucket Canal. These easement rights allow Boott to access, operate, maintain, repair, and replace the Pawtucket Canal and structures of the Pawtucket Canal. In the 1986 Order of Taking, MADCR obtained a permanent and exclusive easement to structures of the canal system, including canal walls, beds, and bottoms, for purposes including conservation, preservation, maintenance, and other uses consistent with the use of the system as a park. NPS obtained similar easement rights through the 1995 Grant of Easement from MADCR, including the right to maintain, repair, conduct grounds maintenance, and operate boat tours.

An exclusive easement allows the easement holder to control and implement specific purposes as if they are the owner. MADCR has a permanent and exclusive easement over most of the canal system for the following purposes, which include the following enhancements and upgrades:

- a) Support of all fixtures or structures of the Commonwealth now or hereafter attached;
- b) Preservation and conservation;
- c) Supplemental maintenance in addition to that performed by the Condemnees (the prior or current owner) and their successors and assigns;
- d) Landscaping and erection of exhibits and structures;
- e) Placement of barriers and fences;
- f) Placement and attachment of docks, wharves, walls, and boat ramps of a temporary or permanent nature;
- g) Placement of lighting and other utilities;
- h) Operation and maintenance of boat locking chambers, if any, for any and all purposes; and
- i) Any and all other uses consistent with the operation of the canal system as a park.

Given that MADCR's exclusive easement is throughout most of the canal system, it overlaps significantly with Boott and Proprietors' owned property. It is understood that Boott, Proprietors, and MADCR have a duty and right to maintain properties under their ownership to achieve a standard of reasonable care. Owners do not have an obligation or duty to upgrade or enhance their property. However, MADCR's exclusive easement throughout most of the Lowell canal system gives them the right to implement any of the purposes noted above, which include enhancements and upgrades, as if they were the owner.

The Resources, Ownership, Boundaries, and Land Rights Study also determined different resource rights. The results indicated that recreational resource rights are exclusively owned by MADCR. In early conceptual planning documents, MADCR was presented as the party that would own, implement, and manage any recreational resources. MADCR obtained such rights in the 1986 Order of Taking, including the exclusive right to use water for recreational, educational, or navigational purposes, and permanent and exclusive rights to build wharves, docks, and boat ramps. The two other identified resources are air resource rights, and water and flowage rights. Air resource rights have been owned by MADCR since issuance of the 1986 Order of Taking. Water and flowage rights are owned by Boott and Proprietors, as established in the 1984 Great Deed.

E.7.8.2 Environmental Analysis

The NHPA establishes the statutory responsibility of federal agencies to consider historic properties under their jurisdiction. Section 106 requires federal agencies to consider the effects of their undertakings on historic properties listed in or eligible for inclusion in the NRHP. The Commission's issuance of a new license for the Project is defined as an undertaking under the NHPA and is, therefore, subject to the provisions of Section 106 and its implementing regulations at 36 C.F.R. Part 800.

FERC's SD2 identified effects of continued Project operations on cultural and historical resources as potential resource issues. Specifically, SD2 identified the following potential resource issues related to cultural and historical resources to be analyzed for site-specific effects:

- Effects of continued project operation and maintenance on historic resources, archeological resources, and traditional cultural properties that are included or may be eligible for inclusion in the National Register of Historic Places.
- Effects of continued project operation and maintenance on properties of traditional religious and cultural importance to an Indian tribe.

During the previous relicensing, Boott consulted extensively with the Massachusetts SHPO and NPS to avoid destroying historic Waste Gates on the Northern Canal and to fund repairs to the Northern Canal Gates to restore them to their original condition. The proposed powerhouse was relocated, and fish passage facilities were modified to avoid any impacts to the Northern Canal Gatehouse. In addition, the Owner constructed a new set of locks in the Northern Canal to provide boat passage, to avoid any loss of historic use of the canal system. Furthermore, additional mitigative measures were undertaken by the Licensee to minimize impacts of new structures introduced into the historic district (Cleantech Analytics 2017).

Current Project operations may be a contributing factor to the continued deterioration of the Northern Canal Waste Gatehouse's southern and northern sills. The Northern Canal periodically inundates the southern sill, and spray from the Northern Canal spillway may be contributing to the deterioration of the northern sill. Repeated inundation and drying of timber sills has the potential to adversely affect the integrity of the Northern Canal Waste Gatehouse; however, other factors unrelated to Project operations have also likely contributed to the ongoing deterioration of the sills, including the age of the wooden timbers, general maintenance, weathering, and atmospheric conditions.

Boott has not identified any other historic properties that are being adversely affected by the ongoing operation and maintenance of the Project. As noted above, Boott determined at least one incident that appears to have contributed to recorded damage to the upstream miter gate at the Pawtucket Gatehouse. This anomalous incident does not represent normal Project operations, and Boott is repairing the damage to the gate.

Boott is not currently proposing modifications to the Project's operations or any land-clearing or land-disturbing development activities within the APE that would result in an impact to any archaeological sites, historic architectural resources, or areas that have been identified as having moderate to high potential for containing archaeological sites.

In addition, only one out of the nine tribes, the Mashpee Wampanoag Tribe, responded to FERC's initial tribal consultation letter dated April 26, 2017, and did not identify any concerns related to the Project pertaining to cultural resources.

As noted above, the downtown canals are located within the LNHP, the Locks and Canals Historic District (a National Historic Landmark) and the Lowell National Historical Park and Preservation District, which are listed in the National Register of Historic Places.

As reported in the Resources, Ownership, Boundaries, and Land Rights Study Report (HDR 2021c), Boott owns all the canals except the Pawtucket Canal and Lower Pawtucket Canal, but MADCR and NPS have various easement rights to the downtown canal system for purposes of preservation, conservation, and other uses consistent with that of a park. MADCR has a permanent and exclusive easement to the entire canal system for all uses consistent with the operation of the canal system as a park, which gives MADCR the right to implement preservation and conservation measures as if they were the owner of the structures. Boott does not own most of the historic gatehouses, dams, and locks; these are mostly owned by MADCR and Proprietors. Boott does have certain easement rights to these structures they do not own, and those easement rights are mostly limited to hydropower maintenance and operation.

As noted in Section E.6.2, Boott is proposing to decommission the Assets power station and remove it from the new FERC license. Within one year of license issuance, Boott will file a decommissioning plan with the Commission including measures to avoid, minimize, or mitigate Project-related effects during decommissioning. Boott has ceased operation of all three units at Assets, installed stoplogs at the entrance, and disconnected all live electrical connections. In general, Boott is proposing to install a concrete plug in each penstock opening at the canal wall to prevent the flow of water. Boott is proposing to disconnect turbines, generators, and other electrical equipment at the Assets power station—this equipment is obsolete and poses little risk of danger to the public without the flow of water.

Continued operation of the powerhouses as proposed by Boott will not adversely affect the integrity of the LNHP, Locks and Canals Historic District, or the Lowell National Historical Park and Preservation District. Boott will continue to provide flows into the canal system and maintain water levels consistent with the measures proposed in Section E.6.2. Boott will also maintain canal facilities consistent with existing rights, responsibilities, and existing or new agreements developed among the concerned stakeholders. For these reasons, Boott does not think that the proposed continued operation of the canal facilities and the downtown powerhouses will have an adverse effect on historic or archaeological resources.

E.7.8.3 Proposed Environmental Measures

- Within one year of license issuance, Boott will develop an HPMP for the Project that will describe appropriate management measures to avoid, minimize, or mitigate Project-related adverse effects on historic and archaeological resources over the term of the new license issued for the Project. The measures provided in

the HPMP will direct the Licensee's management of NRHP-listed or eligible historic properties within the Project's APE, which is preliminary defined as the proposed Project boundary. Boott will develop the HPMP in consultation with the NPS, MHC, NHDHR, and Indian tribes.

- Through this consultation, the Licensee will develop historic properties management measures to be incorporated into the HPMP. Boott has outlined the following two goals for managing historic resources within the Project's APE:
 - Support continued normal operation of the Project while maintaining and preserving the integrity of historic properties; and
 - To the fullest extent possible, avoid, minimize, or mitigate adverse effects on historic properties within the APE.

To address these goals, the Licensee will develop an HPMP for the Project in accordance with the *Guidelines for the Development of Historic Properties Management Plans for FERC Hydroelectric Projects* promulgated by FERC and the ACHP on May 20, 2002. The HPMP will describe measures for the management of and protection of historic properties within the Project's APE through the term of the new license. As such, continued operation of the Project as proposed by the Licensee is not expected to adversely affect historic or archaeological resources.

Canal Water Elevations

Boott is actively collaborating with key stakeholders to finalize the COMP. Once the COMP is finalized, a copy of the Plan will be submitted to FERC for approval and inclusion in the new license. One of the primary components being addressed is the management of canal water elevations.

Canal Water Flows

Boott is actively collaborating with key stakeholders to finalize the COMP. Once the COMP is finalized, a copy of the Plan will be submitted to FERC for approval and inclusion in the new license. One of the primary components being addressed is the management of canal water flows.

Trash Management

Boott is actively collaborating with key stakeholders to finalize the COMP. Once the COMP is finalized, a copy of the Plan will be submitted to FERC for approval and inclusion in the new license. One of the primary components being addressed is trash management in the canals.

Vegetation Management

Boott is actively collaborating with key stakeholders to finalize the COMP. Once the COMP is finalized, a copy of the Plan will be submitted to FERC for approval and inclusion in the new license. One of the primary components being addressed is vegetation management in the canals.

E.7.8.4 Unavoidable Adverse Impacts

The continued operation of the Project as proposed by the Licensee is not expected to have any unavoidable adverse impacts on historic or archaeological resources.

E.8 Economic Analysis

This section identifies estimated costs specific to proposed PM&E measures. Overall Project cost and value information is provided in Exhibit D of the license application.

Table E.8-1. Annual Costs of Proposed PM&E Measures

	Capital Cost	Annual Cost	Levelized Cost
Cost of capital (debt and equity)	\$0	\$0	\$0
Annual operations and maintenance	\$0	\$222,686	\$202,442
Annual insurance, taxes, and administrative costs	\$0	\$999,666	\$908,787
Cost of Relicensing	\$1,900,000	\$0	\$148,256
Downstream fish protection	\$5,200,000	\$10,000	\$302,573
Upstream fish passage	\$2,600,000	\$10,000	\$186,849
Decommission fish lift	\$75,000	\$0	\$4,693
Existing fish ladder and weir improvements	\$100,000	\$5,000	\$11,701
Historic Properties Management Plan	\$75,000	\$5,000	\$9,619
Recreation Plan	\$50,000	\$10,000	\$12,422
Total	\$10,000,000	\$1,262,352	\$1,787,342

E.9 Consistency with Comprehensive Plans

Section 10(a)(2) of the FPA, 16 U.S.C. section 803(a)(2)(A), requires the Commission to consider the extent to which a project is consistent with federal and state comprehensive plans for improving, developing, or conserving a waterway or waterways affected by a project. Under 18 CFR §5.18(b)(5)(ii)(F) each license application must identify relevant comprehensive plans and explain how and why the proposed project would, would not, or should not comply with such plans. In addition, the license application must include a description of any relevant resource agency or Native American Tribe determination regarding the consistency of the project with any such comprehensive plan.

The Commission's SD2 identified twenty-eight comprehensive plans for New Hampshire and Massachusetts that are potentially relevant to the Lowell Hydroelectric Project. On December 19, 2018, the NPS filed five additional comprehensive plans, and by letter dated March 20, 2019, the Commission accepted four of the five plans. Boott has reviewed the Commission's list of the available comprehensive plans. Listed below are the comprehensive plans applicable to the Project. For the reasons noted in this application, Boott has determined that the proposed operation of the Project, as proposed in this Final License Application, is consistent with these plans.

E.9.1 Federal Plans

Atlantic States Marine Fisheries Commission. 1998. Amendment 1 to the Interstate Fishery Management Plan for Atlantic sturgeon (*Acipenser oxyrinchus oxyrinchus*). (Report No. 31). July 1998.

Atlantic States Marine Fisheries Commission. 1999. Amendment 1 to the Interstate Fishery Management Plan for shad and river herring. (Report No. 35). April 1999.

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Atlantic States Marine Fisheries Commission. 2008. Amendment 2 to the Interstate Fishery Management Plan for American eel. Arlington, Virginia. October 2008.

Atlantic States Marine Fisheries Commission. 2009. Amendment 2 to the Interstate Fishery Management Plan for shad and river herring, Arlington, Virginia. May 2009.

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MRTC. 2021. MERRIMACK RIVER WATERSHED COMPREHENSIVE PLAN FOR DIADROMOUS FISHES. Filed with the Federal Energy Regulatory Commission.

E.9.2 Massachusetts Comprehensive Plans

Massachusetts Department of Environmental Management. n.d. Commonwealth connections: A greenway vision for Massachusetts. Boston, Massachusetts.

Massachusetts Department of Fish and Game. 2006. Comprehensive wildlife conservation strategy. West Boylston, Massachusetts. September 2006.

Massachusetts Executive Office of Energy and Environmental Affairs. Statewide Comprehensive Outdoor Recreation Plan (SCORP): Massachusetts Outdoor 2006. Boston, Massachusetts.

E.9.3 New Hampshire Comprehensive Plans

Merrimack River Policy and Technical Committees. 1990. Strategic plan for the restoration of Atlantic salmon to the Merrimack River, 1990 through 2004. Concord, New Hampshire. April 1990.

New Hampshire Office of Energy and Planning. 2007. New Hampshire Statewide Comprehensive Outdoor Recreation Plan (SCORP): 2008-2013. Concord, New Hampshire. December 2007.

New Hampshire Office of State Planning. 1977. Wild, scenic, & recreational rivers for New Hampshire. Concord, New Hampshire. June 1977.

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E.10 Consultation Documentation

In accordance with 18 C.F.R § 5.18(b)(5)(G), a list of containing the name, and address of every Federal, state, and interstate resource agency, Indian tribe, and member of the public with which the Licensee consulted in preparation of Exhibit E is presented in the transmittal letter. In addition, Boott is providing a consultation log of relevant correspondence with the contacts of the distribution list and copies of relevant documentation, presented in Appendix C.

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