GREAT RIVER HYDRO, LLC

Wilder Hydroelectric Project
(FERC Project No. 1892-026)

Bellows Falls Hydroelectric Project
(FERC Project No. 1855-045)

Vernon Hydroelectric Project
(FERC Project No. 1904-073)

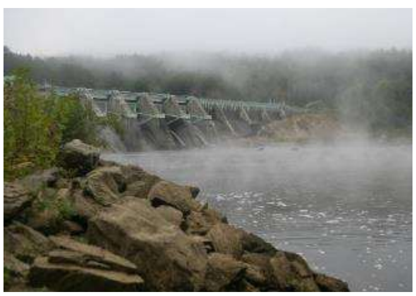
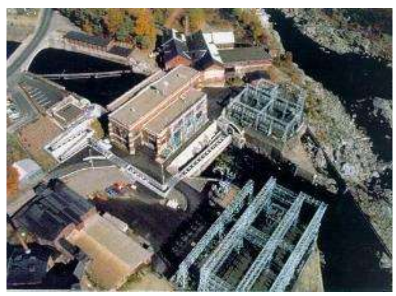


EXHIBIT E

December 7, 2020

June 2023 Revision

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ACRONYMS AND ABBREVIATIONS

μS/cm	microsiemens per centimeter
1D	one-dimensional
2D	two-dimensional
acre-ft	acre-feet
ACHP	Advisory Council on Historic Preservation
A.D.	Anno Domini
APE	area of potential effects (as pertains to Section 106 of the National Historic Preservation Act)
ASMFC	Atlantic States Marine Fisheries Commission
AWS	area weighted suitability
B.C.	Before Christ
B.P.	Before Present
CCA	claimed capacity audits
C.F.R.	Code of Federal Regulations
cfs	cubic feet per second
cm	centimeter
CRASC	Connecticut River Atlantic Salmon Commission
CSO	combined sewer overflow
CTDEEP	Connecticut Department of Energy and Environmental Protection
CWA	Clean Water Act
°C	degrees Celsius
DA	drainage area
DO	dissolved oxygen
DOI	U.S. Department of the Interior
EFH	Essential Fish Habitat
EIS	Environmental Impact Statement
El.	elevation
EO	element occurrence
EPA	U.S. Environmental Protection Agency
ESA	Endangered Species Act

°F	degrees Fahrenheit
FCA	Forward Capacity Auction
FERC	Federal Energy Regulatory Commission
FirstLight	Power Resources
FLA	Final License Application
FMF	Fifteen Mile Falls Hydroelectric Project
FPA	Federal Power Act
ft	foot or feet
ft/s	feet per second
FWS	U.S. Department of the Interior, Fish and Wildlife Service
GIS	Geographic Information System
Great River Hydro	Great River Hydro, LLC
HI-Z	HI-Z Turb'N
HPMP	Historic Properties Management Plan
IEO	inflow equals outflow
ILP	Integrated Licensing Process
IPANE	Invasive Plant Atlas of New England
ISO-NE	New England Independent System Operator
ISR	Initial Study Report
KOP	key observation point
kV	kilovolt
kVA	kilovolt-ampere
kW	kilowatt
kWh	kilowatt-hour
m^2	square meter
mgd	million gallons per day
mg/L	milligram(s) per liter
mg/m^3	milligrams per cubic meter
mL	milliliter
m.s.l.	mean sea level
MW	megawatt
MWh	megawatt-hour
National Register	National Register of Historic Places

NEIWPCC	New England Interstate Water Pollution Control Commission
NEPA	National Environmental Policy Act
NGVD29	National Geodetic Vertical Datum of 1929
NAVD88	North American Vertical Datum of 1988
NHA	New Hampshire Audubon
NHDES	New Hampshire Department of Environmental Services
NHFGD	New Hampshire Fish and Game Department
NHNHB	New Hampshire Natural Heritage Bureau
NHPA	National Historic Preservation Act
NHSHPO	New Hampshire State Historic Preservation Officer
NITHPO	Narragansett Indian Tribal Historic Preservation Officer
NMFS	National Marine Fisheries Service
NOAA	National Oceanic and Atmospheric Administration
NOI	Notice of Intent
NPDES	National Pollutant Discharge Elimination System
NRCS	Natural Resources Conservation Service
NTU	nephelometric turbidity unit
NWI	National Wetlands Inventory
O&M	operation and maintenance
PAD	Pre-Application Document
PGA	peak ground acceleration
PHABSIM	Physical Habitat Simulation
PIT	passive integrated transponder
PLP	Preliminary Licensing Proposal
PM&E measures	protection, mitigation, and enhancement measures
Projects	Wilder (FERC No. 1892), Bellows Falls (FERC No. 1855), and Vernon (FERC No. 1904) Hydroelectric Projects
PSP	Proposed Study Plan
PURPA	Public Utility Regulatory Policies Act of 1978
REC	Renewable Energy Credit
RPD	reactive power demonstrations
RPM	revolutions per minute
RM	river mile

R.S.A.	New Hampshire Revised Statutes Annotated
RSP	Revised Study Plan
RTE	rare, threatened, or endangered
§	Section of a statute such as 18 C.F.R. § 5.6 (c)
SD1	Scoping Document 1
SD2	Scoping Document 2
SGCN	Species of Greatest Conservation Need
SHPO	State Historic Preservation Office
Sound	Long Island Sound
SPD	Study Plan Determination
sq. mi.	square mile(s)
TCP	Traditional Cultural Property
TMDL	total maximum daily load
TransCanada	TransCanada Hydro Northeast Inc.
USACE	U.S. Army Corps of Engineers
U.S.C.	United States Code
USGS	U.S. Geological Survey
USR	Updated Study Report
VAR	volt-ampere-reactive
VANR	Vermont Agency of Natural Resources
VDEC	Vermont Department of Environmental Conservation
VFWD	Vermont Fish & Wildlife Department
VTNHI	Vermont Natural Heritage Inventory
VTSHPO	Vermont State Historic Preservation Officer
VY	Vermont Yankee Nuclear Power Plant
WAP	Wildlife Action Plan
WSE	water surface elevation
WUA	weighted usable area
YOY	young-of-year

1. INTRODUCTION

Great River Hydro, LLC (Great River Hydro), in accordance with 18 Code of Federal Regulations (C.F.R.) § 5.17 and § 5.18 is filing with the Federal Energy Regulatory Commission (FERC) Amended Applications for New License for Major Project – Existing Dam for the existing Wilder (FERC No. 1892), Bellows Falls (FERC No. 1855), and Vernon (FERC No. 1904) Hydroelectric Projects (Projects). Great River Hydro is following the Integrated Licensing Process (ILP). These applications supersede applications filed on May 1, 2017, a statutorily specified filing date. These amended applications incorporate ILP actions completed after the original filing, including completion of three study review cycles and continuation of stakeholder consultation.

On October 31, 2012, TransCanada Hydro Northeast Inc. (TransCanada), the previous Licensee, filed Notices of Intent (NOIs) to seek new licenses for the Wilder, Bellows Falls, and Vernon Projects, along with a Pre-Application Document (PAD) for each Project with FERC. The previous licensee also filed a Preliminary Licensing Proposal (PLP) for the three Projects on December 1, 2016. Current licenses for the Projects were issued in 1979 and expired on April 30, 2019, but were authorized to continue project operation until a new license is issued or other disposition.[1] The Projects are located on the Connecticut River in New Hampshire and Vermont (Figure 1.0-1). No federal lands are located within the Project boundaries. Table 1.0-1 summarizes general Project information.

Table 1.0-1. Summary of general Project information.

	Wilder	Bellows Falls	Vernon
FERC Project No.	1892	1855	1904
Current license term	12/10/1979–4/30/2019	08/03/1979–4/30/2019	06/25/1979–4/30/2019
Project location (state: town, county)	Vermont: Hartford, Windsor New Hampshire: Lebanon, Grafton	Vermont: Rockingham, Windham New Hampshire: Walpole, Cheshire	Vermont: Vernon, Windham New Hampshire: Hinsdale, Cheshire
Dam location (river mile [RM])	217.4	173.7	141.9
Authorized generating capacity (megawatt [MW])	35.6	40.8	32.4

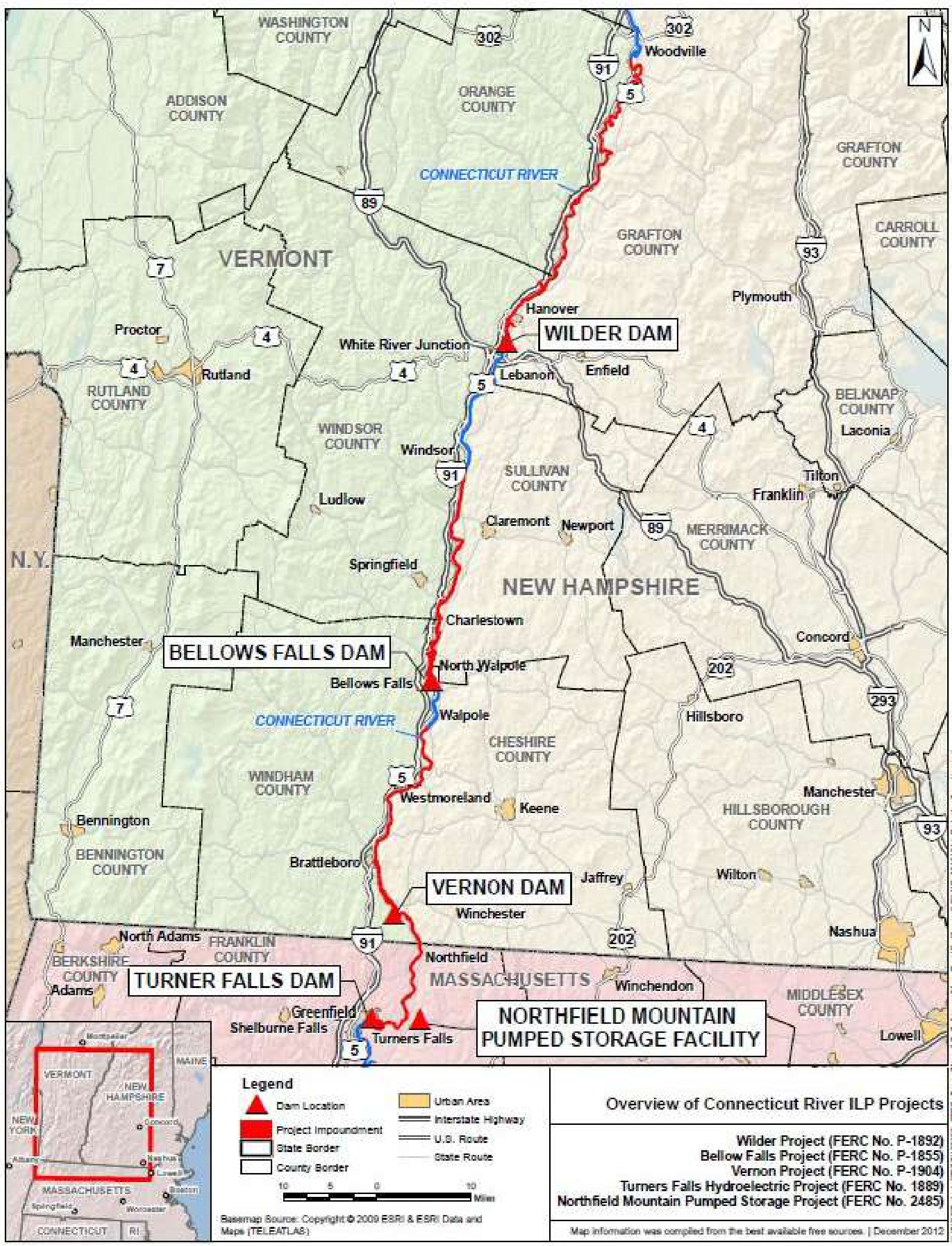
[1] On January 16, 2015, a request was filed with FERC to extend for 1 year the current terms of the licenses for Wilder, Bellows Falls, and Vernon Projects. On July 22, 2015, the Director granted the request, and Project licenses expired on April 30, 2019. Subsequently, by notice dated May 9, 2019, the Commission issued from year-to-year an annual license under the terms and conditions of the present license until a new license is issued, or the project is otherwise disposed of as provided in Section 15 or any other applicable section of the FPA.

	Wilder	**Bellows Falls**	**Vernon**
Dependable capacity ISO-NE average summer-winter capacity supply obligation for the 11th Forward Capacity Auction (FCA #11, 2020-2021) (kilowatt [kW])	41,000 kW	49,000 kW	35,000 kW
Annual energy production (gross megawatt-hour [MWh])	156,303 MWh/year	239,070 MWh/year	158,028 MWh/year

This Exhibit E of the Amended Final License Applications (FLAs) presents Great River Hydro's proposal for the continued operation of the Wilder, Bellows Falls, and Vernon Projects under the terms of new licenses. No new capacity or construction at the Projects is proposed; however, as opportunities arise to examine upgrades and efficiency gains, Great River Hydro has and will continue to evaluate them in the ordinary course of its business.

This Exhibit E considers only Great River Hydro's proposed environmental measures as prescribed in 18 C.F.R. § 5.15(b)(5)(ii)(C). Preliminary indications regarding environmental measures and general recommendations for changes in the Projects have not been formally proposed by federal and state resource agencies, Indian Tribes, non-governmental organizations, or members of the public. In formal comments on the PLP and the continued stakeholder discussions regarding instream flow habitat enhancement and possible operational alternatives that have taken place since the May 1, 2017, submission of License Applications, these stakeholders suggested a run-of-river operation would best mimic a natural river system. Great River Hydro considered this alternative in its May 1, 2017, filing but eliminated it from further analysis because run-of river operation of these Projects it is not reasonable. due to the critical need for large, dispatchable hydroelectric resources in the New England regional power system to support further penetration of additional renewable energy, provide much needed energy security in winter peak periods, provide fast-start reserve energy resources and voltage-ampere reactive (VAR)[2] support. Appendix A contains responses to comments on the PLP. Great River Hydro has explored alternatives to the currently proposed and no-action alternatives during the past few years and discusses them further below.

[2] Voltage is regulated through reactive power production and consumption, and resources on the grid may be compensated for providing this reactive power capability. VAR is the unit of measurement for reactive power.



Source: FERC (2013)

Figure 1.0-1. Locations of Connecticut River Projects.[3]

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[3] "The Connecticut River Projects" include five hydroelectric projects undergoing concurrent relicensing: Wilder (FERC No. 1892), Bellows Falls (FERC No. 1855), and Vernon (FERC No. 1904) Projects along with FirstLight's Turners Falls (FERC NO. 1889) and Northfield Mountain Pumped Storage (FERC No. 2485) Projects.

1.1 Purpose of Action and Need for Power

1.1.1 Purpose of Action

FERC must decide whether to issue licenses to Great River Hydro for the Projects and what conditions should be placed in any licenses issued. In deciding whether to issue a license for a hydroelectric project, FERC must determine that the project will be best adapted to a comprehensive plan for improving or developing a waterway. In addition to the power and developmental purposes for which licenses are issued (e.g., flood control, irrigation and water supply), FERC must give equal consideration to the purposes of energy conservation, the protection, mitigation of damage to, and enhancement of fish and wildlife (including related spawning grounds and habitat), the protection of recreational opportunities, and the preservation of other aspects of environmental quality.

Issuing new licenses for the Projects would allow Great River Hydro to continue to generate electricity at the Projects for the term of the new licenses, making electric power from a renewable resource available to serve regional demand, continue to provide critical, fast-start generating resources to the New England Independent System Operator (ISO-NE), address public policy goals of reducing greenhouse gas emissions by enabling and supporting further penetration of variable renewable energy resources (e.g., wind and solar) serving the region.

This Exhibit E was prepared in accordance with 18 C.F.R. § 5.18(b) and generally follows FERC's guidelines in *Preparing Environmental Documents* (FERC, 2008). Herein, Great River Hydro assesses the environmental and economic effects of continuing to operate the Projects under current operations (the no-action alternative) and its Proposed Alternative, which largely reflects a proposed modified operation. Important resource issues that are addressed in the environmental analysis include erosion, aquatic habitat, fish passage, recreation, rare, threatened, and endangered species, and cultural and historic resources.

1.1.2 Need for Power

The Projects are located in the regional electric system that is operated by the ISO-NE and that supplies electric power to the New England states. ISO-NE is responsible for regional grid operation and dispatch of generation, wholesale market administration, and power system analysis and planning to ensure system reliability and adequate generation and transmission resources to meet regional needs. ISO-NE prepares both short- and long-term projections of electricity supply and demand. The 2020–2029 Forecast Report of Capacity, Energy, Loads, and Transmission projects the summer peak demand under typical summer peak weather conditions to rise annually at a rate of 0.9 percent, as well as projecting the winter peak demand under typical winter weather conditions to rise by an average of 1.1 percent, and 0.4 percent in annual overall electricity use from 2020 to 2029 (ISO-NE, 2020).

Table 1.0-1 summarizes the authorized capacity and annual energy production for the Projects. Combined, the Projects provide 125.0 megawatts (MW) of dependable capacity and on average 579369 annual megawatt-hours (MWh) to the regional power grid. Over the term of the new licenses, the Projects will continue to directly provide renewable power and can support and facilitate the further penetration of additional variable energy (wind and solar) resources into the region through reserve capacity and grid stability functionality. Project generation displaces fossil-fired generation, reduces power plant emissions, and provides substantial environmental benefit. The Projects also provide forward capacity, real-time fast-start reserves, VAR support and in the case of Vernon, Renewable Energy Credits (RECs) within the ISO-NE

1.2 Applicable Statutory and Regulatory Requirements

Issuance of new licenses for the Projects is subject to requirements under the Federal Power Act (FPA) and other federal statutes. The following sections summarize requirements applicable to this Exhibit E. Additional requirements, such as those found in FPA Section 18 fishway prescriptions and Section 10(j) recommendations, may be issued by agencies with authority after filing of the FLAs for the Projects.

1.2.1 Clean Water Act

Section 401 of the Clean Water Act (CWA) requires Great River Hydro to obtain certification from the appropriate state pollution control agency verifying compliance with the CWA or to obtain a waiver of certification. The New Hampshire Department of Environmental Services (NHDES) and the Vermont Department of Environmental Conservation (VDEC) are the state agencies responsible for water quality certifications for the Projects. On April 1, 2016, the states of New Hampshire and Vermont issued a letter stating their decision not to issue joint Section 401 water quality certifications for the Projects and requiring submittal of state-specific certification applications for each of the Wilder, Bellows Falls, and Vernon Projects.

Great River Hydro will file requests for water quality certification with the two state agencies in accordance with 18 C.F.R. § 5.23(b) within 60 days of FERC's issuance of notice of acceptance of the FLAs and Ready for Environmental Analysis (REA) notice.

1.2.2 Endangered Species Act

Section 7 of the Endangered Species Act (ESA) requires FERC to consult with the U.S. Department of the Interior, Fish and Wildlife Service (FWS), and the U.S. Department of Commerce, National Oceanic and Atmospheric Administration (NOAA) Fisheries (aka National Marine Fisheries Service or NMFS), to ensure that FERC's licensing 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. Great River Hydro (formerly

TransCanada) is designated as FERC’s non-federal representative for informal consultation under the ESA (in FERC’s NOI to File License Application and Commencing Pre-filing Process issued on December 21, 2012).

Species lists obtained from FWS, NMFS, and the New Hampshire and Vermont Natural Heritage Bureaus were reviewed to develop the applications. Endangered species listed under the ESA that occur or are likely to occur in the Wilder, Bellows Falls, and/or Vernon Projects include dwarf wedgemussel (*Alasmidonta heterodon*) (DWM), Jesup’s milk vetch, and northeastern bulrush. The bald eagle is present in the Project areas and is a protected species under the Bald and Golden Eagle Protection Act (16 United States Code [U.S.C.] § 668-688c). Currently, no federally designated critical habitats occur in New Hampshire or Vermont (FWS, 2020a).

The endangered Puritan tiger beetle was not observed in field surveys conducted in 2014. It was likely extirpated and last observed in the Project areas in 1932. The northern long-eared bat was newly listed as threatened on April 2, 2015. The species may occur within the Project boundaries, but the species was neither requested to be nor was evaluated in relicensing field studies,[4] and the species was not observed in any other relicensing studies.

1.2.3 Coastal Zone Management Act

Section 307(c)(3) of the Coastal Zone Management Act requires that all federally licensed and permitted activities be consistent with approved state Coastal Zone Management Programs. The Projects are not located within New Hampshire’s designated Coastal Management Zone, defined by the state’s 3-mile territorial sea, extending from the Maine-New Hampshire border to the Massachusetts-New Hampshire border and extending inland to include the lands and waters in all or part of 17 coastal towns in Rockingham and Strafford counties. Vermont does not have a Coastal Zone Management Program. The Wilder, Bellows Falls, and Vernon Projects are not located in a state-designated coastal zone management area and, therefore, are not subject to the New Hampshire coastal zone program review. The NHDES Coastal Program’s Federal Consistency Coordinator concurred via email dated April 27, 2020, that Project relicensing is not subject to the state’s federal consistency review. A copy of the request for concurrence and the state’s reply in the affirmative are included in Appendix B, *Coastal Zone Management Act Concurrence*.

[4] The primary threat to the species is white-nose syndrome, a fungal disease that affects bats during hibernation in caves and mines, none of which are located within the Project boundaries. The species is state-listed as threatened in New Hampshire and as endangered in Vermont.

1.2.4 National Historic Preservation Act

Section 106 of the National Historic Preservation Act (NHPA) requires that every federal agency consider how each of its undertakings could affect historic properties. Historic properties are any prehistoric or historic districts, sites, buildings, structures, Traditional Cultural Properties (TCPs), and objects significant in American history, architecture, engineering, and culture that are eligible for inclusion in the National Register of Historic Places (National Register).

Great River Hydro (formerly TransCanada) is designated as FERC's non-federal representative for informal consultation under Section 106. Study plans were developed to identify any adverse effects on historic properties resulting from continued operation of the Projects, and the New Hampshire and Vermont State Historic Preservation Offices (SHPOs), affected Indian Tribes, and other interested parties were given an opportunity to comment prior to FERC's final Study Plan Determination (SPD). The results of those studies are discussed in Section 3.11, *Cultural and Historic Resources*, and provide the basis for the Programmatic Agreement to be executed by the SHPOs, Great River Hydro, and other interested parties, which will likely direct Great River Hydro to develop Historic Properties Management Plans (HPMPs).

1.2.5 Wild and Scenic Rivers Act

Section 7(a) of the Wild and Scenic Rivers Act requires federal agencies to make a determination as to whether the operation of a project under a new license would invade the area or unreasonably diminish the scenic, recreational, and fish and wildlife values present in the designated river corridor. No segments of the Connecticut River have been designated for inclusion in the Wild and Scenic Rivers System. However, three segments are listed in the Nationwide Rivers Inventory, which identifies potential candidates for inclusion in the Wild and Scenic Rivers System. The first is a 28-mile segment from South Newbury, Vermont, to the confluence with the Omponmanoosuc River which overlaps the upper half of Wilder impoundment. Recreation and Scenic were the outstandingly remarkable values identified with this listing in the inventory. The second segment is a 24-mile reach overlapping the upper reservoir of the Bellows Falls Project from Windsor, Vermont, to the confluence of the Williams River across from Charleston, New Hampshire. Hydrology is the outstandingly remarkable value supporting this listing, which incorrectly lists this segment as free flowing. The third segment is a 19-mile reach downstream of the Bellows Falls Project from the Route 123 Bridge in Walpole, New Hampshire, to the Route 9 Bridge in Brattleboro, Vermont, overlapping the upper reservoir of the Vernon Project. Fish, Recreational, Scenic, and historical are the outstandingly remarkable values supporting this segment. All of these segments were listed in 1982 (National Park Service, 2016). Federal agencies are required to assess whether a federal action could diminish the outstandingly remarkable values for which a segment is listed in the Nationwide Rivers Inventory. The Projects were constructed well before the listing of these three segments, and although Great River Hydro proposes to modify operations of the Projects, it is highly likely that the changes proposed will maintain if not enhance the outstandingly remarkable values for which these segments of the Connecticut River were identified and listed in the Nationwide Rivers Inventory.

1.2.6 Magnuson-Stevens Fishery Conservation and Management Act

The Magnuson-Stevens Fishery Conservation and Management Act requires federal agencies to consult with NOAA Fisheries on all actions that may adversely affect Essential Fish Habitat (EFH). EFH was defined for Atlantic Salmon as all aquatic habitats in the watersheds of identified rivers including all tributaries, to the extent that they are currently or were historically accessible for salmon migration in Maine, New Hampshire, Vermont, Massachusetts, Rhode Island, and Connecticut, including the entire Connecticut River watershed. The designation excludes only areas upstream of longstanding naturally impassable barriers (i.e., natural waterfalls in existence for at least several hundred years) (NEFMC, 1998).

Beginning in 1967, the Connecticut River Atlantic Salmon Commission (CRASC) worked to restore Atlantic Salmon to the Connecticut River Basin by hatchery production and stocking, as well as other management and regulatory approaches. Upstream and downstream fish passage facilities at the Wilder, Bellows Falls, and Vernon Projects have provided Atlantic Salmon with passage through the Projects since the 1980s. Because of low adult returns over the years, FWS discontinued culturing salmon for restoration in the Connecticut River Basin in 2012. New Hampshire, Vermont, and Massachusetts also discontinued rearing and stocking programs, yet small numbers of adult salmon have continued to return to the basin. Since 2016, however, only three adult salmon have returned to the Project-affected areas (see Section 3.6, *Fish and Aquatic Resources*). Therefore, Great River Hydro does not anticipate that the Projects will adversely affect EFH for Atlantic Salmon.

1.3 Public Review and Comment

1.3.1 Scoping

On December 21, 2012, FERC issued its Notice of Commencement of Proceedings and Scoping Document 1 (SD1) for its NEPA analysis of the "Connecticut River Projects," which includes the Wilder, Bellows Falls, and Vernon Projects as well the Turners Falls (FERC No. 1889) and Northfield Mountain Pumped Storage (FERC No. 2485) Projects.[5] FERC staff indicated in SD1 its intent to prepare a single Environmental Impact Statement (EIS) for the five Connecticut River Projects to analyze both site-specific and cumulative environmental impacts and reasonable alternatives to the proposed actions. FERC also designated Great River Hydro as its non-federal representative for carrying out informal consultation, pursuant to

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[5] FirstLight Power Resources (FirstLight) is the Licensee of the downstream Turners Falls Hydroelectric Project and the Northfield Mountain Pumped Storage Project. The current licenses for both the Turners Falls Project and the Northfield Mountain Project expire on April 30, 2018. On April 29, 2016, FirstLight filed with FERC a consolidated FLA for the two projects and is seeking to combine the projects into a single new license.

Section 7 of the ESA and pursuant to Section 106 of the NHPA for the Wilder, Bellows Falls, and Vernon Projects.

In January 2013, in various locations near the five Connecticut River Projects in New Hampshire, Vermont, and Massachusetts, FERC staff held six Project-specific scoping meetings and one additional scoping meeting to help identify the cumulative effects of licensing the five Projects. Site visits to the Wilder, Bellows Falls, and Vernon Projects were conducted on October 1–3, 2012, prior to the scoping meetings as a result of FERC's decision to avoid winter conditions that would limit access to the facilities under the scoping schedule.

On April 15, 2013, FERC issued its Scoping Document 2 (SD2), in response to verbal and written comments received at the scoping meetings as well as during the scoping process.

1.3.2 Study Plans and Studies

The Proposed Study Plan (PSP) was filed on April 16, 2013.[6] The PSP included responses to comments received on the PADs and to study requests for the Projects from state and federal agencies, local officials, non-governmental organizations, and other interested parties (collectively, stakeholders).

The PSP filing included a study request responsiveness summary, identifying each study request, the Study Plan's responsiveness to the request, and the rationale for why any particular study request was not adopted. The April 16, 2013, filing also included the schedule for Study Plan meetings. Because a single meeting would not be adequate to clarify and discuss the PSP, a series of meetings were held from May to July 2013 to discuss Study Plan proposals. Many interested stakeholders participated in resource-specific working groups and provided extensive feedback.

Comments on the PSP were due on July 15, 2013 (i.e., within 90 days of the filing of the PSP). The consultation process included receiving, discussing, and reviewing stakeholder comments on the PSP. In addition, in response to comments received and consultation with stakeholders through the Study Plan meetings, the PSP was updated and filed with FERC on July 9, 2013.

The Revised Study Plan (RSP) to address the effects of continued operation of the Projects was filed on August 14, 2013. The RSP included 33 individual studies and data collection efforts (Table 1.3-1). The RSP reflected comments received during the Study Plan meetings and working group discussions as well as formal comments filed by stakeholders with FERC.

On August 27, 2013, Entergy announced plans to decommission the Vermont Yankee Nuclear Power Plant (VY) during the fourth quarter of 2014. VY withdrew cooling water from, and discharged it back into, the Vernon Project impoundment.

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[6] Delays on FERC's eFiling website prevented PSP filing on the due date of April 15, 2013.

The effect of decommissioning VY thus changed the baseline conditions at the Vernon Project.

In a September 13, 2013, SPD, the Director delayed issuing determinations for 20 aquatic resource studies, pending a technical meeting on the issue of VY's decommissioning; however, determinations were issued for the remaining 13 studies unlikely to be affected by VY's continued operation or decommissioning. These studies were approved with, or without, modifications. In addition, 4 requested studies were determined to be not required. On September 24, 2014, TransCanada (now Great River Hydro) filed a request for clarification on specific aspects of the determination, and the Director provided clarification on those aspects in a letter dated October 22, 2013.

Table 1.3-1. Summary of ILP studies.

Study No.	Study Title	Modified from RSP[a]	FERC Filing Date	Citation
1	Historical Riverbank Position and Erosion Study		03/01/2016	Field and Normandeau (2016a)
2–3	Riverbank Transect and Riverbank Erosion Studies	X	Initial Report 08/01/2016 Final Report 02/04/2017 Corrected Supplemental to Final Report 11/20/2017	Field and Normandeau (2016b) Field and Normandeau (2017a) Field and Normandeau (2017b)
4	Hydraulic Modeling Study	X	Initial Report 03/01/2016 Final Report 06/17/2016	GEI (2016)
5	Operations Modeling Study	X	08/01/2016	Hatch (2016)
6	Water Quality Study	X	Initial Report 03/01/2016 Final Report 08/01/2016 Revised Final Report 12/15/2016	Louis Berger and Normandeau (2016a)
7	Aquatic Habitat Mapping Study		Initial Report 09/15/2014 Final Report 03/02/2015	Normandeau (2015a)
8	Channel Morphology and Benthic Habitat Study		Initial Report 03/02/2015 Final Report 05/16/2016 Supplemental Data 08/31/2016	Stantec and Normandeau (2016)
9	Instream Flow Study		Interim Report 03/01/2016 Final Report 03/22/2017	Normandeau (2016a) Normandeau (2017a) Normandeau (2019a)

Study No.	Study Title	Modified from RSP[a]	FERC Filing Date	Citation
			Revised Final Report 05/20/2019	
10	Fish Assemblage Study	X	Initial Report 03/01/2015 Final Report 08/01/2016 Report Supplement 11/30/2016	Normandeau (2016b)
11	American Eel Survey	X	03/01/2016	Normandeau (2016c)
12	Tessellated Darter Survey	X	Initial Report 03/01/2016 Final Report 08/01/2016	Normandeau (2016d)
13	Tributary and Backwater Fish Access and Habitats Study	X	Preliminary Report 09/14/2015 Final Report 06/17/2016	Normandeau (2016e)
14-15	Resident Fish Spawning in Impoundments and Riverine Sections Studies	X	Interim Report 03/01/2016 Final Report 08/01/2016 Revised Final Report 11/30/2016	Normandeau (2016f)
16	Sea Lamprey Spawning Assessment	X	Interim Report 03/01/2016 Final Report 08/01/2016	Normandeau (2016g)
17	Upstream Passage of Riverine Fish Species Assessment	X	Initial Report 05/16/2016 Final Report 11/30/2016	Normandeau (2016h)
18	American Eel Upstream Passage Assessment	X	Initial Report 03/01/2016 Report Supplement 11/30/2016 Report Supplement 02/09/18 Report Supplement 05/20/19	Normandeau (2016i) Normandeau (2018a) Normandeau (2019b)

Study No.	Study Title	Modified from RSP[a]	FERC Filing Date	Citation
19	American Eel Downstream Passage Assessment	X	Initial Report 05/16/2016 Supplemental Data 08/31/2016 Final Report 02/28/2017	Normandeau (2016j) Normandeau (2017c)
20	American Eel Downstream Migration Timing Assessment	X	06/17/2016	Normandeau (2016k)
21	American Shad Telemetry Study - Vernon	X	Initial Report 08/01/2016 Final Report 02/28/2017 Report Supplement 02/09/18	Normandeau (2016l) Normandeau (2017d) Normandeau (2018b)
22	Downstream Migration of Juvenile American Shad - Vernon	X	Initial Report 05/16/2016 Supplemental Data 08/31/2016 Final Report 01/17/2017	Normandeau (2016m) Normandeau (2017e)
23	Fish Impingement, Entrainment, and Survival Study	X	Initial Report 05/16/16 Final Report 11/30/2016 Report Supplement 02/28/2017	Normandeau (2016n) Normandeau (2017f)
24	Dwarf Wedgemussel and Co-occurring Mussel Study		• Phase 1 Report 09/15/2014 • Phase 2 Report 03/02/2015 • Delphi Panel Report 05/16/2016 • Co-occurring Mussel Development of HSC Report 03/22/2017	Biodrawversity and Louis Berger (2014) Biodrawversity and Louis Berger (2015) Normandeau (2016o) Normandeau and Biodrawversity (2017)
25	Dragonfly and Damselfly Inventory and Assessment	X	Initial Report 06/17/2016 Final Report 12/15/2016	Normandeau (2016p) Normandeau (2017b)

Study No.	Study Title	Modified from RSP[a]	FERC Filing Date	Citation
			Supplement to Final Report 07/12/2017	
26	Cobblestone and Puritan Tiger Beetle Survey		06/17/2016	Normandeau (2016q)
27	Floodplain, Wetland, Riparian, and Littoral Vegetation Habitats Study		Preliminary Report 09/14/2015 Final Report 08/01/2016 Report Supplement 11/30/2016	Normandeau (2016r)
28	Fowler's Toad Survey		Study Report 06/17/2016	Normandeau (2016s)
29	Northeastern Bulrush Survey		Study Report 06/17/2016	Normandeau (2016t)
30	Recreation Facility Inventory and Use & Needs Assessment	X	Study Report 03/01/2016 Report Supplement 12/15/2016	Louis Berger and Normandeau (2016b)
31	Whitewater Boating Flow Assessment - Bellows Falls and Sumner Falls	X	Study Report 03/01/2016	Louis Berger and Normandeau (2016c)
32	Bellows Falls Aesthetic Flow Study		Initial Report 03/01/2016 Final Report 08/01/2016	Louis Berger and Normandeau (2016d)
33	Cultural and Historic Resources Study		• Phase 1A Archaeological Reconnaissance Survey Report for Vernon Project 04/10/2008 (filed with SHPOs only) • Phase 1A Archaeological Reconnaissance Survey Reports for Wilder and	Various, see Section 3.11.

Study No.	Study Title	Modified from RSP[a]	FERC Filing Date	Citation
			Bellows Falls Projects 07/01/2013 • Phase 1A Archaeological Reconnaissance Survey Update for Vernon Project 12/23/2014 • Phase IB Archaeological Identification Survey for Wilder, Bellows Falls, and Vernon Projects 03/23/2016 • Phase II Archaeological Determination of Eligibility Lampshire Meadow Site, Wilder Project 08/01/2016 • Phase II Archaeological Site Evaluation Surveys Wilder and Vernon Projects 12/01/2016 • Traditional Cultural Properties (TCP) Study Report 05/16/2016	

a. Modifications included study delays to 2015 due to: the VY closure, FERC SPDs, and/or study plan revisions filed by the Licensee on December 31, 2013.

A technical meeting was held on November 26, 2013, to discuss the effects of the planned VY closure and to identify aquatic resource studies that were: (1) not affected by operation of VY that could be implemented in 2014; (2) likely affected by operation of VY; and (3) might need modification due to the decommissioning of VY.

On December 31, 2013, revisions to 5 Study Plans were submitted based on the VY technical meeting and on follow-up discussions with agencies and stakeholders. Minor revisions were made to the following Study Plans: Study 6, *Water Quality*; Study 13, *Tributary and Backwater Area Fish Access and Habitat*s; Study 18, *American Eel Upstream Passage Assessment*; Study 21, *American Shad Telemetr*y; and Study 23, *Fish Impingement, Entrainment, and Survival*.

On February 21, 2014, the Director issued another SPD for those 20 aquatic resource studies and a "new" Vernon Hydroacoustic Study, that the SPD referred to as a "study requested but not adopted." Of those 20 proposed studies, 15 were deferred until 2015 to allow for the new post-VY baseline condition. Five studies were determined to be not affected by the VY decommissioning and were approved without modification for implementation in 2014. FERC also addressed the December 31, 2013, Study Plan revisions in this SPD.

A request for rehearing filed on March 24, 2014, argued against the need to conduct the newly requested Vernon Hydroacoustic Study; however, stakeholders were consulted, and the Study Plan requested in the SPD was filed on September 15, 2014. A technical meeting was held on November 20, 2014, to discuss issues surrounding the potential use of hydroacoustics at the Vernon Project. Subsequently, on May 14, 2015, the Director issued an order eliminating the requirement to conduct the Vernon Hydroacoustic Study, and approving the updated RSP for Study 22, *Downstream Migration of Juvenile American Shad at Vernon*, that was filed on February 3, 2015.

During 2013 and 2014, several studies were initiated, and the Initial Study Report (ISR) was filed on September 15, 2014. Initial results were presented and discussed at a meeting on September 29, 2014; the meeting summary was filed on October 14, 2014. At the meeting, stakeholders were made aware of some expected study delays because of lack of water in 2014. Written comments on the ISR were received, and a response to comments was filed on December 15, 2014.

In 2015, fishery and water quality studies, which were delayed by the VY closing, were initiated, and several incomplete studies that began in 2014 were continued.

The Updated Study Report (USR) was filed on September 14, 2015. Additional study results were presented and discussed at a meeting on October 1 and 2, 2015, and the meeting summary was filed on October 14, 2015. Written comments on the USR were received and a response to those comments was filed on December 14, 2015. The Director issued an SPD on January 15, 2016, withholding staff determinations on stakeholder-requested study modifications to Studies 3, 5, 13, 14, 15, and 18 pending completion of those studies.

Also, on September 14, 2015, the Director issued a Revised Process Plan and Schedule for the Connecticut River Projects that identified March 1, 2016, as a "target" filing deadline for USRs on studies yet to be completed. Any remaining study reports that could not be filed by March 1, 2016, would be identified along with a respective filing date for each study.

A second USR was filed on March 1, 2016. Additional study results were presented and discussed at a meeting on March 17 and 18, 2016, and the meeting summary was filed on March 31, 2016. Written comments on the second USR were received, and a response to those comments was filed on May 31, 2016, with a response supplement filed on June 2, 2016. The Director issued an SPD on the second USR on June 29, 2016.

On May 5, 2016, the Director issued a Revised Process Plan and Schedule for the Connecticut River Projects that identified May 15, 2016 (a Sunday, May 16 being the next business day) as the filing deadline for USRs on most studies not completed by the March 1, 2016, filing; and August 1, 2016, as the filing deadline for the remaining studies that are not yet complete. Because of the need to conduct additional analysis of hydraulic and operations model data, not all reports listed in FERC's current schedule for filing as part of the third USR on May 16, 2015, were filed at that time, although 7 study reports were filed. On June 1, 2016, a meeting was held to discuss the associated results, and the meeting summary was filed on June 14, 2016. Written comments on the May 16, 2016, USR were received, and a response to those comments was filed on August 15, 2016 (the business day following the August 13, 2016, Saturday due date). The Director issued an SPD on the third USR on September 12, 2016.

FERC staff was consulted about study reports that could not be filed by May 16, 2016, and a target date of June 17, 2016, was proposed for the completion and distribution of those reports to provide the reports to stakeholders for review and consultation prior to the Final Study Report filing deadline of August 1, 2016.

The fourth USR was filed on June 17, 2016, that included 6 study reports and 1 revised report in response to comments on the USR filed on March 1, 2016. In consultation with FERC staff and stakeholders, a meeting was held on July 15, 2016 (after the 15-day due date), to discuss results, and the meeting summary was filed on August 1, 2016.

The fifth USR was filed on August 1, 2016, that included the 5 study reports that were incomplete for the May 16, 2016, USR filing; 2 final study reports for which interim reports were filed March 1, 2016; and 4 revised (final) study reports in response to comments received during the comment period for the March 1, 2016, USR. Two other study reports were initially to be included in the fifth USR, but further consultation with stakeholders and analysis was necessary to complete these studies. The associated USR meeting was held on August 25, 2016, and the meeting summary was filed on August 31, 2016. In consultation with FERC staff, the comment period for the fourth (June 17, 2016) and fifth (August 1, 2016) USRs remained open until September 30, 2016, the deadline for study reports filed on or before the August 1, 2016, USR filing. Written comments on the June 17 and August 1, 2016, USRs were received, and a response to those comments was filed on October 31, 2016 (the business day following the October 30, 2016, Sunday due date) with a response supplement filed on December 5, 2016. The Director issued an SPD on the fourth and fifth USRs on November 29, 2016.

Additional revised study reports or report supplements were filed on November 30, 2016 (6 studies), December 15, 2016 (3 studies), January 17, 2017 (1 study), and February 4, 2017 (1 study) (see Table 1.3-1).

On February 22, 2017, the Director issued a Revised Process Plan and Schedule that identified March 15, 2017, as the deadline for USRs on studies not previously filed. Two study reports and 1 report supplement were filed on February 28, 2017. FERC staff was consulted about study reports that could not be filed by March 15, 2017, and reports for 2 studies were filed on March 22, 2017 (see Table 1.3-1). The associated USR meeting was held on March 30, 2017, for all 16 study reports filed between November 30, 2016, and March 22, 2017, and the meeting summary was filed on April 14, 2017. Written comments were received and a response to those comments was filed on June 13, 2017, noting that 5 studies remained open, 2 in consultation with stakeholders and 3 in supplemental study or evaluation. One of the studies under further evaluation was filed on July 12, 2017. The Director issued an SPD on July 21, 2017, requiring additional analysis for 2 studies. That analysis was filed on November 15, 2017.

As required by 18 C.F.R. §§ 5.17(a), Great River Hydro filed license applications on May 1, 2017, stating that key resource studies had not been completed, however, and therefore a complete licensing proposal could not be developed. Amended license applications were proposed to be filed after completing additional field work, consultation, and analyses for multiple studies. On May 15, 2017, the Commission issued public notice of the license applications, stating that a revised procedural schedule with target dates for the post-filing milestones would be issued after Great River Hydro completes and files the remaining study reports and amends the license applications.

On February 15, 2018, the Director issued a Revised Process Plan and Schedule for 5 remaining studies and a progress reporting schedule for 2 studies under consultation with stakeholders. A USR meeting was held on March 8, 2018, for 5 supplemental reports filed between July 12, 2017, and February 15, 2018, the associated meeting summary was filed on March 23, 2018. Written comments on the supplemental reports were received, and a response to those comments was filed on May 22, 2018. The Director issued an SPD on June 21, 2018, accepting the 5 studies as complete.

Progress reports for the two remaining studies were filed on May 15, 2018; August 13, 2018; November 13, 2018; and February 11, 2019. On February 19, 2019, the Director issued a Revised Process Plan and Schedule for the 2 studies, and a USR was filed on May 20, 2019; that included supplemental reports for 2 additional studies. The USR meeting was held on June 4, 2019, followed by a meeting summary on June 18, 2019. Written comments were received and a response to those comments filed on August 19, 2019. There were no disagreements to the meeting summary and no additional studies or study modification requests; therefore, under FERC's ILP procedures, Great River Hydro completed its study phase under the ILP.

On February 5, 2020, Great River Hydro filed a schedule for filing amended FLAs on July 31, 2010. However, based on the series of discussions and timeline detailed below, Great River Hydro delayed its filing of amended applications and communicated to FERC licensing staff the intended delay. On October 7, 2020, FERC issued a letter Order requesting FLA materials be filed with the Commission within 60 days.

On December 20,2019, the aquatics working group requested to meet with Great River Hydro to discuss project operations. Due to weather delays, the initial meeting did not take place until March 2, 2020. At that meeting, Great River Hydro and the federal and state agencies and NGO's stakeholder attending informally agreed to continue discussions regarding alternative operations under a new license, to the extent they were productive. The conceptual framework for the discussions centered on developing an alternative in which significant environmental protection could be achieved much of the time without sacrificing limited but very important, energy, capacity, and ancillary resources that are critical to the regional power grid at times of year or when certain power system conditions require it. Great River Hydro and the stakeholders held a total of 21 joint meetings between June 4 and November 4, 2020. In its amended applications filed on December 7, 2020, Great River Hydro proposes a preferred alternative to current operations based on these discussions. Stakeholder support for the proposal is provided together with the Proposed Alternative Operation in Exhibit B, Appendix B-1.

Additional consultation with Abenaki Tribal representatives continues in developing, a Programmatic Agreement, and an Historic Properties Management Plan (see Section 3.11, *Cultural and Historic Resources*). Pursuant to 18 C.F.R. § 5.18(b)(5)(ii)(G), consultation documentation related to all studies is included in Section 6, *Consultation Documentation*.

Results from all studies are identified and included in Section 3, *Environmental Analysis*, of this Exhibit E.

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2. PROPOSED ACTION AND ALTERNATIVES

2.1 No-action Alternative

The no-action alternative is the baseline from which to compare the proposed action (i.e., relicensing of the Wilder, Bellows Falls, and Vernon Projects) and all action alternatives that are assessed. Under the no-action alternative, the Projects would continue to operate under the terms and conditions of the current licenses and current measures that are implemented voluntarily. Thus, the no-action alternative includes the existing facilities and current operations. The no-action alternative is described for each Project in the subsections below.

2.1.1 Wilder Project

2.1.1.1 Existing Project Facilities

The Wilder Project dam and powerhouse are located on the Connecticut River at river mile (RM) 217.4, approximately 1.5 miles upstream of the White River confluence and 7 miles downstream of the Ompompanoosuc River in the town of Hartford, Windsor County, Vermont, and in the city of Lebanon, Grafton County, New Hampshire (see Figure 1.0-1 above). The Project consists of a rolled earthen embankment and earthen dike dam with a concrete gravity spillway; an approximate 45-mile long impoundment; a powerhouse, a garage/service building, and buildings used for offices; fish passage facilities; and appurtenant facilities (Figure 2.1-1). Project information is summarized in Table 2.1-1 and additional detail is included in Exhibit A.

The dam is a concrete gravity structure extending across the Connecticut River from Hartford, Vermont, to Lebanon, New Hampshire. The dam structures include an earthen embankment that is about 400 feet (ft) long, a non-overflow gravity concrete bulkhead wall that is 232 ft long, a concrete forebay intake that is 208 ft long, a gravity concrete spillway that is about 526 ft long and 59 ft in maximum height, and another earthen embankment that is about 180 ft long. The south embankment is 13 ft in maximum height and the north embankment is primarily a natural bank to which protection has been added. The spillway portion of the dam is divided into four sections: skimmer gate, 6 tainter gates, 4 stanchion flashboards, and another skimmer gate. The various bays are separated by concrete piers supporting a steel and concrete bridge.

The Project impoundment extends upstream about 45 miles to a point about 4.0 miles below the Wells River-Woodsville Bridge. The Project has limited storage capacity because of the relatively flat terrain from the upper extent of the Project impoundment to the dam. The impoundment has a surface area of 3,100 acres and about 105 miles of shoreline and a total volume of 34,600 acre-feet (acre-ft) at elevation (El.) 385.0[7] ft at the top of the stanchion boards. The usable storage amounts to about 13,350 acre-ft in 5 ft of drawdown to El. 380 ft; however, the typical impoundment operating range under non-spill conditions is 2.5 ft, between El. 382.0 and El. 384.5 ft providing about 7,350 acre-ft of storage.

The powerhouse contains three turbine generating units. Unit Nos. 1 and 2 are adjustable blade Kaplan units with a maximum hydraulic capacity of 6,000 cfs and minimum hydraulic capacity of 400 cfs. Nameplate capacity for Unit Nos. 1 and 2 is 18,000 kilovolt-amperes (kVA) at 0.9 power factor, or 16,200 kilowatts (kW), for each unit. Unit No. 3 is a vertical Francis unit with maximum hydraulic capacity of 700 cfs and minimum hydraulic capacity of 400 cfs. Unit No. 3 nameplate capacity is 3,555 kVA at 0.9 power factor, or 3,200 kW.

At full load, with inflow equaling a maximum station discharge of at least 10,700 cfs, the Project has the capability of producing 43.4 megawatts (MW) and 10-year average annual generation (2007–2016) of approximately 161,739 MWh.

The Project also includes upstream and downstream fish passage facilities (see Section 2.1.1.5, *Existing Environmental Measures*), and recreation areas and facilities including a boat launch, portage, picnic areas, hiking trail, fish ladder viewing area, and fishing access (see Section 3.9, *Recreation Resources and Land Use*).

[7] All elevations in Chapter 2 are stated in National Geodetic Vertical Datum of 1929 (NGVD29).

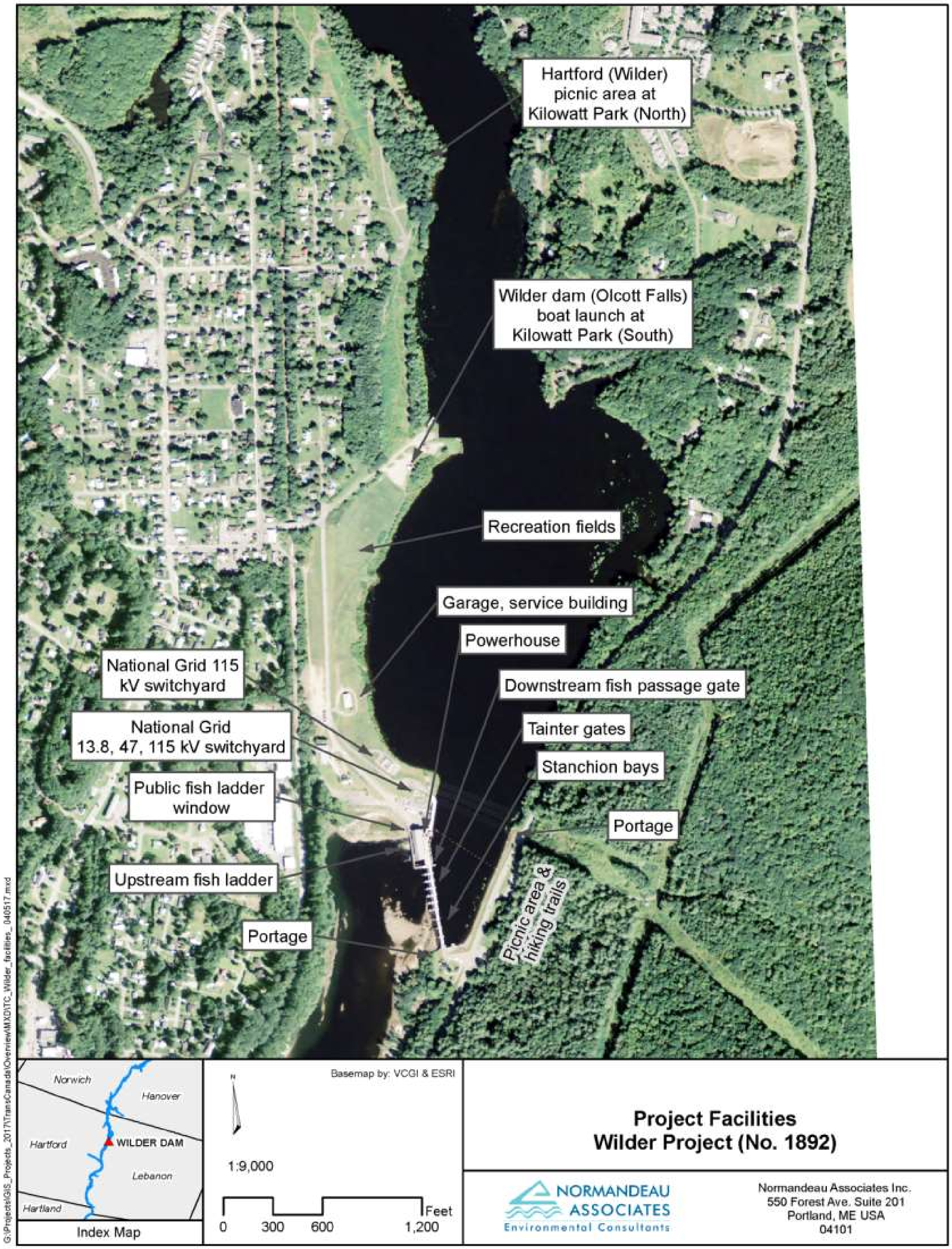

Figure 2.1-1. Primary Wilder Project facilities.

Table 2.1-1. Wilder Project summary.

General Information	
Owner	Great River Hydro, LLC
FERC Project Number	P-1892
Current license term	December 10, 1979–April 30, 2019
Authorized generating capacity	35.6 MW
Location of dam	Connecticut River at RM 217.4
Nearest towns/counties	Hartford, Windsor County, VT Lebanon, Grafton County, NH
Drainage area	3,375 square miles
Major tributaries	NH—Ammonoosuc River VT—Wait and Ompompanoosuc rivers
Operating range elevation (all elevations in NVGD29)	380.0–385.0
Normal current range elevation[a]	382.0–384.5
Normal tailwater elevation	332.0
Impoundment length	45 miles (Haverhill, NH / Newbury, VT)
Gross storage	34,350 acre-ft
Useable storage	13,350 acre-ft (at 5-ft drawdown)
Surface area at full pond	3,100 acres
Average annual inflow at the Project	Approximately 6,400 cfs
Required minimum flow	675 cfs or inflow, whichever is less
Generated minimum flow	700 cfs
Major Structures and Equipment	
Dam	Rolled earth embankment, reinforced concrete gravity non-overflow section, powerhouse, concrete spillway, earth dike, 1,541 feet long with a maximum height of 59 feet and net head of 51 feet.
Spillway gates	6 tainter gates, 2 skimmer gates, 4 stanchion bays
Powerhouse	Steel frame and brick masonry construction with reinforced concrete substructure.
Turbine generating units	3
Turbine type	Units 1–2: Kaplan adjustable blade Unit 3: vertical Francis
Turbine capacities	Units 1–2: 19 MW, 6,000cfs @ 49 ft head Unit 3: 3 MW, 700 cfs @ 58 ft head
Generator capacities	Units 1–2: 16,200 kW Unit 3: 3,200 kW
Total discharge capacity, including spill	157,600 cfs
Fish ladder	Reinforced concrete, overflow weir fish ladder approximately 450 ft long with 58 pools and 54 ft of vertical rise, collection facility, and viewing windows.

a. Reflects typical non-spill, non-emergency operation.

2.1.1.2 Project Boundary

The Wilder Project boundary includes the powerhouse and dam, the impounded portion of the river (approximately 45 miles from the dam upstream), a limited amount of fee-owned Project land, and a significant amount of private lands adjacent to the river upon which Great River Hydro retains sufficient flowage rights to operate the Project. The Project boundary (maps and boundary shapefiles are provided in Exhibit G) encompasses the areas necessary to operate the Project.

Great River Hydro holds fee ownership of 123 acres of land for the Wilder Project. Of this acreage, 43 acres are associated with the dam and generation, 59 acres are currently dedicated to public outdoor recreation use, 10 acres have been licensed to Dartmouth College for recreation use, and 11 acres of other lands along the shoreline just upstream and downstream of the dam on the New Hampshire side, and downstream of the dam on the Vermont side.

2.1.1.3 Project Safety

The Project has been operating for more than 37 years under the existing license and during this time, FERC staff have conducted operational inspections focusing on the continued safety of the structures, identification of unauthorized modifications, efficiency and safety of operations, compliance with the terms of the license, and proper maintenance. In addition, the dam is considered a high-hazard structure and has been inspected and evaluated every 5 years by an independent consultant and a consultant's safety report has been submitted for FERC review under 18 C.F.R. Part 12.

2.1.1.4 Existing Project Operations

Project operations are automated and controlled from a consolidated hydro operations control center located in Wilder, Vermont. Great River Hydro typically operates the Project in a coordinated manner with other Great River Hydro hydroelectric generating facilities on the Connecticut River, taking into consideration variations in electricity demand as well as natural flow in order to maximize the efficient use of available water. When inflows are within the Project's generating capacity, Great River Hydro uses the limited impoundment storage at the Project to dispatch generation as required to meet the generation schedule managed by ISO-NE. During the course of any day, generation can vary between the required minimum flow and full generating capacity, depending on inflow and impoundment storage. Over the course of a day, the Project generally passes the average daily inflow.

High flows occur routinely throughout the year at the Project, most often during the spring freshet, the fall rainy season, and significant rainfall events impacting the Connecticut River watershed below Moore dam. Annually, flows at the dam exceed Project station approximately 12 percent of the time. During periods of sustained high flows, Great River Hydro dispatches Project generation in a must-run status to use available water for generation. Once flows exceed powerhouse capacity, it operates the Project in a "river profile" manner. Additional detail on Project operation is included in Exhibit B and in Section 3.5.1.1, *Water Quantity*.

2.1.1.5 Existing Environmental Measures

Water Level and Flow Management

The licensed minimum flow (Article 35) at the Wilder Project is 675 cubic ft per second (cfs) or a discharge flow equal to the inflow if less. Minimum flow is provided primarily by generation from Unit No. 3 at an efficient operating flow of about 700 cfs. Discharge from Unit No. 3 also serves as the attraction flow for the fish ladder. Additional non-generation flows have been provided seasonally for Atlantic Salmon upstream and downstream fish passage on a schedule provided annually by CRASC based on fish counts at downstream projects (see below). For the past several years, the number of Atlantic Salmon returning to the Connecticut River has been low and therefore upstream and downstream passage flows have not occurred.

Impoundment WSE as measured at the dam is typically within a 2.5-ft range between El. 382.0 and 384.5 ft above mean sea level (m.s.l.) under normaloperation (non-spill conditions).[8] The overall operating range is between El. 380 ft and 385 ft, but this full range is used during high water events that require spill through tainter gates as specified in the Operating Procedures, which were developed as required under Article 32 of the current Project license. In extreme flood events, where flood flows increase beyond the capacity of tainter gates, stanchion bays would be removed, which would require the elevation be just below the concrete crest at 365 ft in order to reinstall the beams and boards. Such an event has never occurred since the Wilder Project has been in operation. Under Article 32, a Coordination Agreement was developed with the U.S. Army Corps of Engineers (USACE) that specifies how the Project is operated during high flow events. Operating Procedures also restrict impoundment drawdown rates to typically 0.1 to 0.2 ft per hour and to not exceed 0.3 ft per hour. A flow of approximately 3,000 cfs per hour results in about 0.1 ft of elevation change.

During the summer recreation season, beginning on the Friday before Memorial Day and continuing through the last weekend in September, a self-imposed minimum impoundment level at El. 382.5 ft as measured at the dam is maintained from Friday at 4:00 p.m. through Sunday at midnight and on holidays during this period, unless the Project is experiencing high flows above station capacity.

Recreation

The Project includes the following formal recreation areas and facilities: (1) the Hartford (Wilder) picnic area at Kilowatt Park (North); (2) Wilder dam (Olcott Falls)

[8] Throughout the Exhibit E the use of 'normal' refers to operations of the hydropower project at flows Great River Hydro can control. Flows above station generation capacity result in spill and are no longer considered 'normal'.

boat launch at Kilowatt Park (South); (3) Wilder dam fish ladder and angler parking; (4) Lebanon (Wilder dam) picnic area, vista, and hiking trails; (5) Wilder dam portage and downstream natural areas; and (6) Gilman Island including primitive campsites and Titcomb Cabin (see Section 3.9, *Recreation Resources and Land Use*).

Upstream Fish Passage

Upstream fish passage facilities are operated in accordance with an annual *Fish Passage Notification Schedule* provided by CRASC which sets the dates for upstream passage for all dams on the Connecticut River. Typically, the upstream fish ladder operates from May 15 through July 15 and in fall from September 15 through November 15 for Atlantic Salmon; however, in recent years fish ladder operation has been suspended because of low returns and abandonment of the program by FWS and the states. Details on the fish ladder are included in Exhibit A and Exhibit F.

Downstream Fish Passage

As of February 11, 2016, CRASC no longer requires downstream passage operations at Wilder for Atlantic Salmon smolts (see Section 3.6, *Fish and Aquatic Resources*). CRASC's annual *Fish Passage Notification Schedule* set the dates for downstream passage for all dams on the Connecticut River. Downstream passage flows were provided by the skimmer gate (trash/ice sluice) located between Unit No. 3 and the fish ladder entrance gallery bay and spillway for adult Atlantic Salmon from October 15 to December 31 if 50 or more adults were documented as having passed upstream.

Existing License Requirements

In addition to Standard Articles 1 through 28 set forth in Form L-3 (Revised October 1975) titled "Terms and Conditions of License for Constructed Major Project Affecting Navigable Waters of the United States," the Wilder Project license includes the requirements summarized in Table 2.1-2.

Table 2.1-2. Summary of Wilder Project license and amendment requirements.

License Article	Summary of Requirement
29	Requires establishment and maintenance of amortization reserves based on a specified reasonable rate of return upon the net investment in the Project.
30 (December 11, 1985, amendment)	Requires payment of annual charges to FERC for the cost of administration of the license, based on the authorized installed capacity (including the 1985 addition of Unit No. 3) for that purpose of 47,500 horsepower.
31	Requires implementing and modifying when appropriate, the Emergency Action Plan on file with FERC designed to provide an early warning to upstream and downstream inhabitants and property owners if an impending or actual sudden release of water is caused by an accident to, or failure of, Project works.
32	Requires entering into an agreement with USACE to provide for the coordinated operation of the Project in the interest of flood control and navigation on the Connecticut River.
33	Requires installation and operation of signs, light, sirens, barriers, or other devices that may be reasonably needed to warn the public of fluctuations in flow from the Project and to protect the public in its recreational use of Project lands and waters.
34 (December 15, 1980, amendment)	Gives authority to the Licensee to grant permission for certain types of use and occupancy of Project lands and waters and to convey certain interests in project lands and waters for certain types of use and occupancy, without prior FERC approval.
35	Requires the Licensee to maintain a continuous minimum flow of 675 cfs (approximately 0.20 cfs per square mile (sq. mi.) of drainage basin) or a discharge flow equal to the inflow of the impoundment, whichever is less, from the Project into the Connecticut River. These flows may be modified temporarily: (1) during and to the extent required by operating emergencies beyond the control of the Licensee; and (2) in the interest of recreation and protection of the fisheries resources upon mutual agreement between the Licensee and the Fish and Game Departments of New Hampshire and Vermont.
36	Requires undertaking consultation and cooperation with the appropriate SHPO(s) prior to the commencement of any construction or development of any Project works or other facilities at the Project.
37	Requires filing with FERC a feasibility analysis of installing additional generating capacity at the Project.
38	Required filing revised Exhibit K drawings clearly delineating the limits of the lands over which the Licensee holds flowage rights for the Project.

2.1.2 Bellows Falls Project

2.1.2.1 Existing Project Facilities

The Bellows Falls Project dam is located on the Connecticut River at RM 173.7, about 1 mile upstream of the confluence of Saxtons River and 3 miles downstream of the Williams River at the upper end of a sharp bend of the Connecticut River at Bellows Falls, Vermont, in the town of Rockingham, Vermont, and in the town of Walpole, New Hampshire (see Figure 1.0-1 above). The Project consists of a concrete gravity dam, spillway, and bypassed reach; an approximate 26-mile long impoundment; a power canal and powerhouse; a substation, line garage, and storage building located near the powerhouse; fish passage facilities; and appurtenant facilities (Figure 2.1-2). Project information is summarized in Table 2.1-3 and additional detail is included in Exhibit A.

The dam is a concrete gravity structure extending across the Connecticut River between Rockingham, Vermont and Walpole, New Hampshire. Virtually all of the dam structure is located in New Hampshire. It is 643 ft long with a maximum height of about 30 ft and is divided by concrete piers into 5 bays. Two bays contain steel roller-type flood gates and the 3 other bays contain stanchion flashboards.

The Project impoundment extends upstream about 26 miles to Chase Island at Windsor, Vermont, about 1 mile below the Windsor Bridge. The Project has limited storage capacity because of the relatively flat terrain from the upper extent of the Project impoundment to the dam. The impoundment has a surface area of 2,804 acres, about 74 miles of shoreline, and a total volume of 26,900 acre-ft at El. 291.63 ft at the top of the stanchion boards. The usable storage amounts to about 7,476 acre-ft in 3 ft of drawdown to El. 288.63 ft; however, the typical impoundment operating range under non-spill conditions is 1.8 ft between El. 289.6 ft and 291.4 ft providing about 4,642 acre-ft of storage.

A power canal connects the impoundment to the powerhouse. The canal is lined with stone stabilized by a grid of concrete grade beams and walls. The downstream end of the canal is a concrete walled forebay. The canal is 100 ft wide at the upstream end, about 36 ft wide at the downstream end, about 29 ft deep, and approximately 1,700 ft long, including the length of the powerhouse forebay. The canal creates a natural bypassed reach between the dam and the outlet of the powerhouse tailrace. The bypassed reach is about 3,500 ft (0.7 mile) long and receives between 125–300 cfs from leakage at the dam through the roller gates seals and stanchion flashboards and, when conditions dictate, much higher flows through intentional spill through roller gates and stanchion bays.

The powerhouse contains three vertical Francis turbine generating units each with a maximum hydraulic capacity of 3,670 cfs and minimum hydraulic capacity of 700 cfs. Nameplate capacity of each unit is 17,000 kVA at 0.8 power factor, or 13,600 kW. At full load, with inflow equaling a maximum station discharge of at least 11,200 cfs, the Project has the capability of producing 49.0 MW and ten-year average annual generation (2007–2016) of approximately 247,373 MWh.

The Project also includes upstream and downstream fish passage facilities (see Section 2.1.2.5, *Existing Environmental Measures*); and recreation areas and facilities including three boat launches and picnic areas, a portage, and a visitor center with a fish ladder viewing window (see Section 3.9, *Recreation Resources and Land Use*).

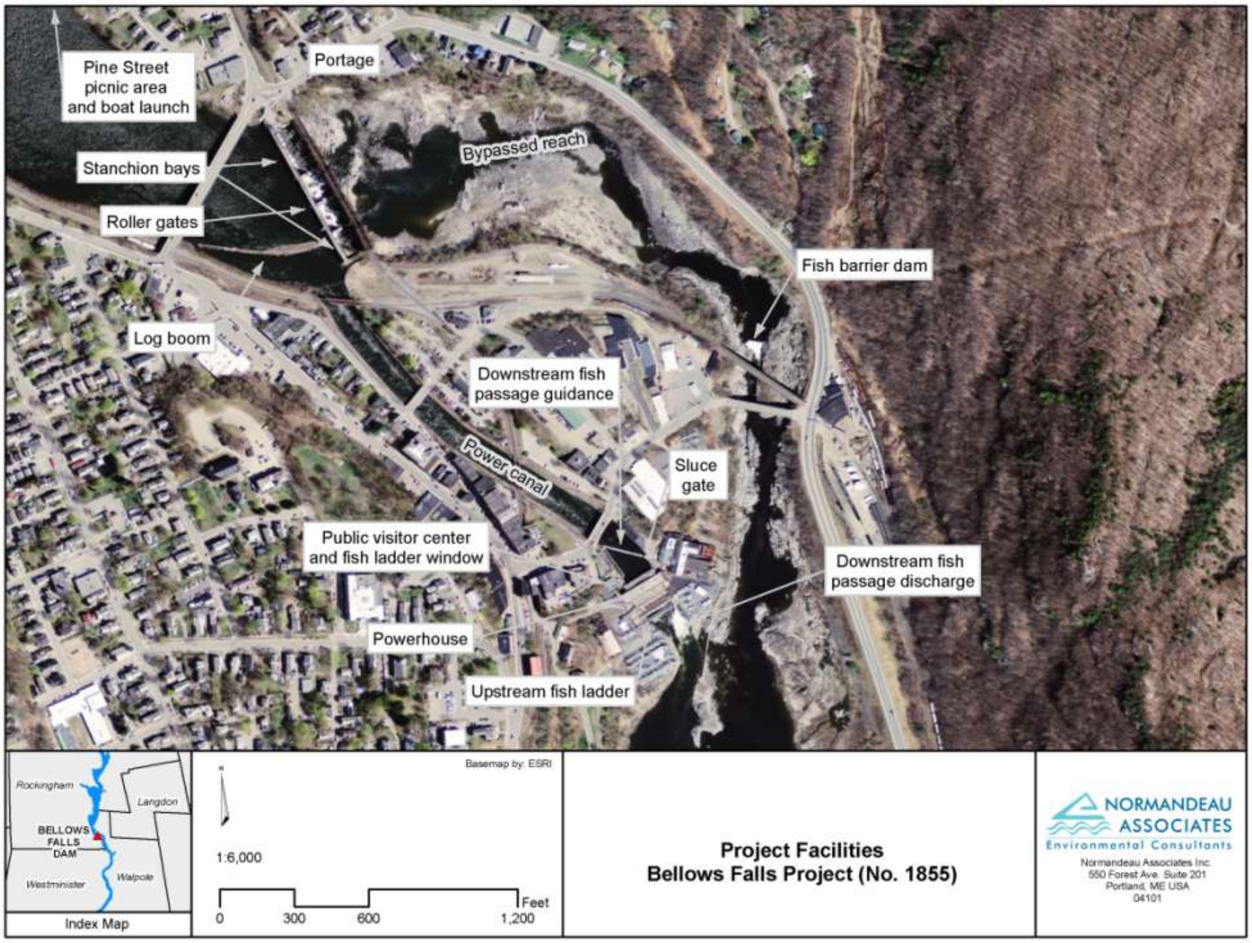

Figure 2.1-2. Primary Bellows Falls Project facilities.

Table 2.1-3. Bellows Falls Project summary.

General Information	
Owner	Great River Hydro, LLC
FERC Project Number	P-1855
Current license term	August 3, 1979–April 30, 2019
Authorized generating capacity	40.8 MW
Location of dam	Connecticut River at RM 173.7
Nearest towns/counties	Rockingham, Windham County, VT Walpole, Cheshire County, NH
Drainage area	5,414 square miles
Major tributaries	NH—Mascoma and Sugar rivers VT—White, Ottauquechee, Black, and Williams rivers
Operating range elevation (all elevations in NVGD29)	288.6–291.6
Current range elevation[a]	289.6–291.4
Normal tailwater elevation	229.0
Impoundment length	26 miles (Cornish, NH/Windsor, VT)
Gross storage	26,900 acre-ft
Useable storage	7,476 acre-ft (at 3-ft drawdown)
Surface area at full pond	2,804 acres
Average annual inflow at the Project	Approximately 10,500 cfs
Required minimum flow	1,083 cfs or inflow, whichever is less
Generated minimum flow	1,300 cfs
Major Structures and Equipment	
Dam	Concrete gravity type construction, 643 ft long, with maximum height of 30 ft and net head of 60.5 ft
Spillway gates	2 steel roller gates, 3 stanchion bays, 1 forebay sluice gate
Bypassed reach	Natural riverbed approximately 3,500 ft long, minimal flow from leakage
Powerhouse intake canal	Paving stones stabilized by a grid of concrete grade beams and walls with a concrete walled forebay, 1,700 ft long
Powerhouse	Steel frame and brick construction
Turbine generating units	3
Turbine manufacturer/type	vertical Francis
Turbine capacities	Each—16 MW, 3,670 cfs @ 57 ft head
Generator capacities	Each—13,600 kW
Total discharge capacity, including spill	119,785 cfs
Fish ladder	Reinforced concrete; vertical slotted weir fish ladder 920 ft long with 67 pools and 60 ft of vertical rise, collection facility, and viewing windows

a. Reflects typical non-spill, non-emergency operation.

2.1.2.2 Project Boundary

The Bellows Falls Project boundary includes the powerhouse, canal and dam, the impounded portion of the river (approximately 26 miles upstream from the dam), a limited amount of fee-owned Project land, and a significant quantity of private lands adjacent to the river upon which Great River Hydro retains sufficient flowage rights to operate the Project. The Project boundary (maps and boundary shapefiles are provided in Exhibit G) encompasses the areas necessary to operate the Project.

Great River Hydro holds fee ownership of 835 acres of land in the Project. Of this, 62 acres are used for plant and related facilities; 86 acres for public outdoor recreational use; 60 acres of other shoreline lands in Charlestown, New Hampshire; and the remaining 627 acres currently support local agriculture, farming, and wildlife management.

2.1.2.3 Project Safety

The Project has been operating for more than 37 years under the existing license, and during this time, FERC staff have conducted operational inspections focusing on the continued safety of the structures, identification of unauthorized modifications, efficiency and safety of operations, compliance with the terms of the license, and proper maintenance.

2.1.2.4 Existing Project Operations

Project operations are automated and controlled from a consolidated hydro operations control center located in Wilder, Vermont. Great River Hydro typically operates the Project in a coordinated manner with other Great River Hydro hydroelectric generating facilities on the Connecticut River, taking into consideration variations in electricity demand as well as natural flow in order to maximize the efficient use of available water. When inflows are within the Project’s generating capacity, Great River Hydro uses the limited impoundment storage at the Project to dispatch generation as required to meet the generation schedule managed by ISO-NE. During any day, generation can vary between the required minimum flow and full generating capacity, depending on inflow and impoundment storage. Over the course of a day, the Project generally passes the average daily inflow.

High flows occur routinely throughout the year at the Project, most often during the spring freshet, the fall rainy season and significant rainfall events impacting the Connecticut River watershed below the Moore dam. Annually, flows at the dam exceed station capacity approximately 28 percent of the time. During periods of sustained high flows, Great River Hydro dispatches Project generation in a must-run status to use available water for generation. Once flows exceed powerhouse capacity, it operates the Project in a “river profile” manner. Additional detail on Project operation is included in Exhibit B and in Section 3.5.1.1, *Water Quantity*.

2.1.2.5 Existing Environmental Measures

Water Level and Flow Management

The licensed minimum flow (Article 33) provides for a constant 1,083 cfs or a discharge flow equal to the inflow if less, through the powerhouse. Minimum flow is provided primarily through generation at a minimum efficient operating flow of about 1,300 cfs. There is no minimum flow requirement through the dam, but leakage provides some flow in the bypassed reach (flows range between 125–300 cfs as calculated or estimated over the course of various studies). Additional non-generation flows related to fish passage are provided seasonally on a schedule provided annually by CRASC based on fish counts at downstream projects (see below).

Impoundment WSE as measured at the dam is typically within a 1.8-ft range between El. 289.6 and 291.4 ft under current operation (non-spill conditions). The overall operating range is between El. 288.63 ft and 291.63 ft, but this full range is used during high water events that do not require removal of stanchion boards as specified in the Operating Procedures, which were developed as required under Article 32 of the current Project license. In extreme flood events, where flood flows increase beyond the capacity of the roller gates requiring stanchion boards to be removed, the elevation would drop to just below the concrete crest at 278.6 ft in order to reinstall the beams and boards. Whenever possible, if flows exceed 50,000 cfs (maximum roller gate capacity plus station discharge), top portions of stanchion boards are removed rather than tripping the beams and removing all boards down to the concrete crest. The most recent event in which stanchion beams were removed was during Tropical Storm Irene in late August 2011. Under Article 32, a Coordination Agreement was developed with USACE that specifies how the Project is operated during high flow events. Operating Procedures also restrict impoundment drawdown rates to typically 0.1 to 0.2 ft per hour and to not exceed 0.3 ft per hour. A flow of approximately 3,000 cfs per hour results in about 0.1 ft of elevation change.

During the summer recreation season, beginning the Friday before Memorial Day and continuing through the last weekend in September, a self-imposed minimum impoundment level of El. 289.6 ft as measured at the dam is maintained from Friday at 4:00 p.m. through Sunday at midnight and on holidays during this period, unless the Project is experiencing high flows above station capacity.

Recreation

The Project includes the following formal recreation areas and facilities:
(1) Charlestown boat launch and picnic area; (2) Herrick's Cove boat launch and picnic area; (3) Pine Street boat launch and portage trail take-out; (4) Bellows Falls fish ladder visitor center; and (5) the informal boat-in campsite at Lower Meadow in Charlestown, New Hampshire (see Section 3.9, *Recreation Resources and Land Use*).

Upstream Fish Passage

Upstream fish passage facilities are operated in accordance with an annual *Fish Passage Notification Schedule* provided by CRASC which sets the dates for upstream passage for all dams on the Connecticut River. Typically, the upstream fish ladder operates from May 15 through July 15 and in fall from September 15 through November 15 for Atlantic Salmon; however, in recent years, fish ladder operation has been suspended because of low returns and abandonment of the program by FWS and the states. Details on the fish ladder are included in Exhibit A and Exhibit F.

Downstream Fish Passage

As of February 11, 2016, CRASC no longer requires downstream passage operations at Bellows Falls for Atlantic Salmon smolts (see Section 3.6, *Fish and Aquatic Resources*). CRASC's annual *Fish Passage Notification Schedule* set the dates for downstream passage for all dams on the Connecticut River. Downstream passage flows were provided for adult Atlantic Salmon from October 15 to December 31 if 50 or more adults were documented as having passed upstream. Downstream migrating fish are attracted to the forebay sluiceway/skimmer gate by a solid, partial depth diversion boom across the canal. A small auxiliary gate located on the east side of the powerhouse is opened to direct fish that may get under the diversion boom to the sluiceway.

Existing License Requirements

In addition to Standard Articles 1 through 28 set forth in Form L-3 (Revised October 1975) titled "Terms and Conditions of License for Constructed Major Project Affecting Navigable Waters of the United States," the Bellows Falls Project license includes the requirements summarized in Table 2.1-4.

Table 2.1-4. Summary of Bellows Falls Project license and amendment requirements.

License Article	Summary of Requirement
29	Requires establishment and maintenance of amortization reserves based on a specified reasonable rate of return upon the net investment in the Project.
30	Requires payment of annual charges to FERC for the cost of administration of the license, based on the authorized installed capacity for that purpose of 54,400 horsepower.
31	Requires implementing and modifying when appropriate, the Emergency Action Plan on file with FERC designed to provide an early warning to upstream and downstream inhabitants and property owners if an impending or actual sudden release of water is caused by an accident to, or failure of, Project works.
32	Requires entering into an agreement with USACE to provide for the coordinated operation of the Project in the interest of flood control and navigation on the Connecticut River.

License Article	Summary of Requirement
33	Requires the Licensee to maintain a continuous minimum flow of 1,083 cfs (0.20 cfs per sq. mi. of drainage basin) or a discharge flow equal to the inflow of the impoundment, whichever is less, from the Project into the Connecticut River. This flow may be modified temporarily: (1) during and to the extent required by operating emergencies beyond the control of the Licensee, or (2) in the interest of recreation and protection of the fisheries resources upon mutual agreement between the Licensee and the Fish and Game Departments of New Hampshire and Vermont.
34	Requires undertaking consultation and cooperation with the appropriate SHPO(s) prior to the commencement of any construction or development of any Project works or other facilities at the Project.
35	Requires installation and operation of signs, light, sirens, barriers, or other devices that may be reasonably needed to warn the public of fluctuations in flow from the Project and to protect the public in its recreational use of Project lands and waters.
36 (December 15, 1980 amendment)	Gives authority to the Licensee to grant permission for certain types of use and occupancy of Project lands and waters and to convey certain interests in project lands and waters for certain types of use and occupancy, without prior FERC approval.
37	Requires filing with FERC a feasibility analysis of installing additional generating capacity at the Project.

2.1.3 Vernon Project

2.1.3.1 Existing Project Facilities

The Vernon Project dam and powerhouse are located on the Connecticut River at RM 141.9, about 2 miles upstream of the confluence of the Ashuelot River and 7.4 miles downstream of the West River, in the town of Vernon, Vermont, and the town of Hinsdale, New Hampshire (see Figure 1.0-1 above). The Project consists of a concrete gravity dam; an approximate 26-mile long impoundment; a powerhouse, storage/maintenance building and yard; fish passage facilities; and appurtenant facilities (Figure 2.1-3). Project information is summarized in Table 2.1-5 and additional detail is included in Exhibit A.

The dam is a composite overflow and non-overflow ogee-type, concrete gravity structure extending across the Connecticut River between Hinsdale, New Hampshire, and Vernon, Vermont. The dam is 956 ft long with a maximum height of 58 ft. It consists of the integral powerhouse with a sluice gate block section that is about 356 ft long and a concrete overflow spillway section about 600 ft long. The spillway portion of the dam is divided into 12 bays containing, from west to east, a trash/ice sluice, 4 tainter gates, 2 hydraulic flashboard bays, 3 stanchion bays, and 2 tainter gates. In addition, 8 submerged hydraulic flood gates are located below the ogee spillway and the 10-ft by 50-ft tainter gates. The various bays are separated by concrete piers supporting a steel and concrete bridge that runs the length of the dam for access and for operation of flashboards. The trash sluice is a skimmer gate that passes logs and other debris deflected away from the powerhouse by a log and ice boom in the powerhouse forebay.

The Project impoundment is approximately 26 miles long and extends upstream approximately to the Walpole Bridge (Route 123 Bridge) at Westminster Station, Vermont. The Project has limited storage capacity because of the relatively flat terrain from the upper extent of the Project impoundment to the dam. The impoundment has a surface area of 2,550 acres, about 69 miles of shoreline, and a total volume of about 40,000 acre-ft at a full impoundment El. of 220.13 ft at the top of the stanchion boards. Maximum drawdown to the spillway crest (at El. 212.13 ft) if hydraulic and stanchion flashboards are lowered or removed under high flow, equates to a maximum usable storage capacity of 18,300 acre-ft. The more typical impoundment operating range under non-spill conditions is between El. 218.3 and El. 220.1 for usable storage capacity of 4,489 acre-ft.

The powerhouse contains 10 turbine generating units. Unit Nos. 1–4 are single runner vertical Francis units each with a maximum hydraulic capacity of 1,465 cfs and minimum hydraulic capacity of 400 cfs. Nameplate capacity for Unit Nos. 1–4 is 2,500 kVA at 0.8 power factor, or 2,000 kW for each unit. Unit Nos. 5–8 are vertical axial flow Kaplan units each with a maximum hydraulic capacity of 1,800 cfs and minimum hydraulic capacity of 300 cfs. Nameplate capacity for Unit Nos. 5–8 is 5,000 kVA at 0.9 power factor, or 4,000 kW for each unit. Unit Nos. 9 and 10 are single runner vertical Francis units each with a maximum hydraulic capacity of 2,035 cfs and minimum hydraulic capacity of 500 cfs. Nameplate capacity for Unit Nos. 9 and 10 is 6,000 kVA at 0.7 power factor, or 4,200 kW for each unit.

At full load, with inflow equaling a maximum station discharge of at least 14,500 cfs, the Project has the capability of producing 32.0 MW. Nine-year average annual generation, accounting for 2008 as first full year of re-developed Units 5-8 operation (2008–2016) is approximately 162,557 MWh.

The Project also includes upstream and downstream fish passage facilities (see Section 2.1.3.5, *Existing Environmental Measures*), and recreation areas and facilities including a boat launch, portage, picnic areas, hiking trail, fish ladder viewing area, and fishing access (see Section 3.9, *Recreation Resources and Land Use*).

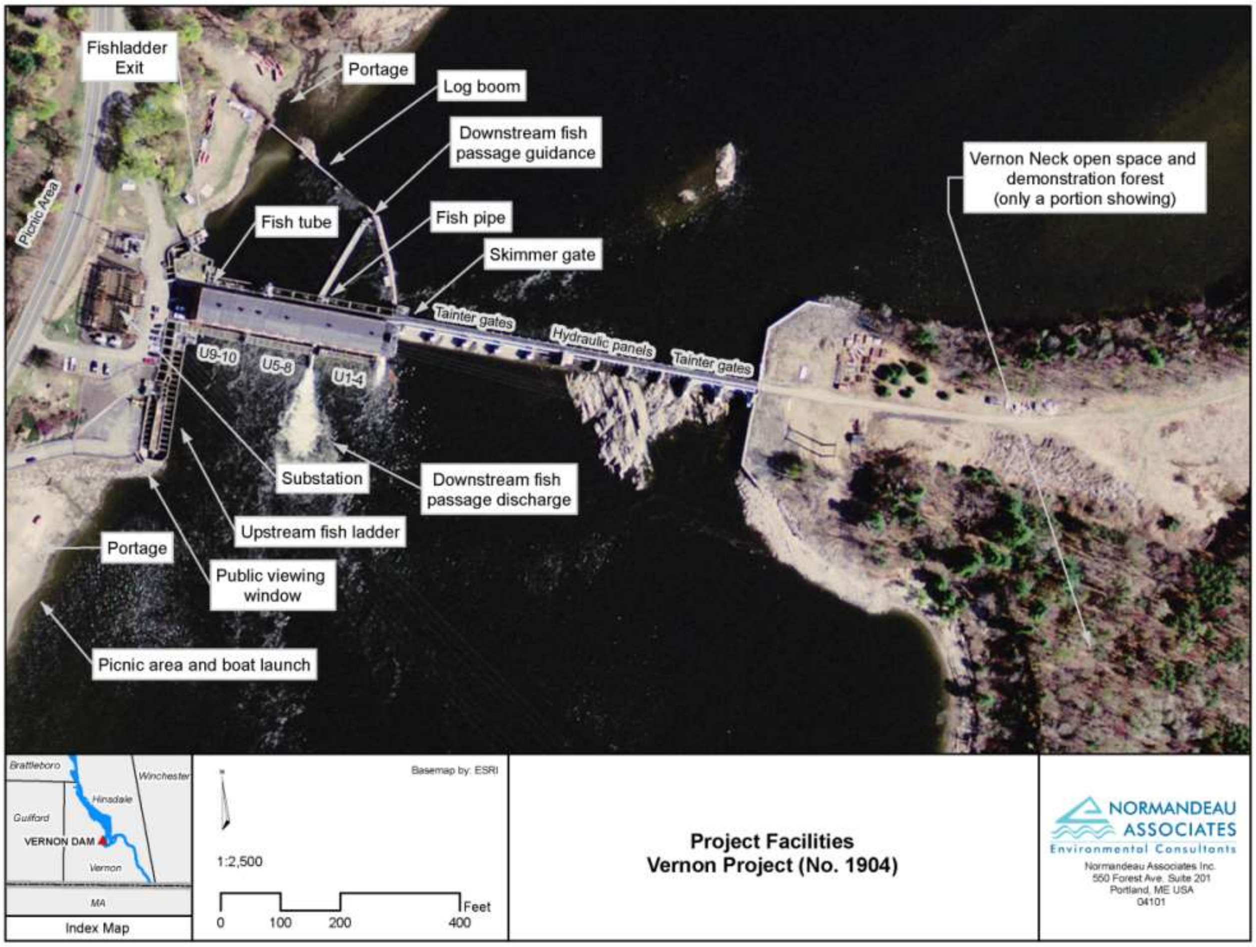

Figure 2.1-3. Primary Vernon Project facilities.

Table 2.1-5. Vernon Project summary.

General Information	
Owner	Great River Hydro, LLC
FERC Project Number	P-1904
Current license term	June 25, 1979–April 30, 2019
Authorized generating capacity	32.4 MW
Location of dam	Connecticut River at RM 141.9
Nearest towns/counties	Vernon, Windham Count, VT Hinsdale, Cheshire County, NH
Drainage area	6,266 square miles
Major tributaries	NH—Cold River VT—Saxtons and West rivers
Operating range elevation (all elevations in NVGD29)	212.0–220.0
Current range elevation[a]	218.6–219.8
tailwater elevation	184.63
Impoundment length	26 miles (Walpole, NH/Westminster, VT)
Gross storage	40,000 acre-ft
Usable storage	18,300 acre-ft (at 8-ft drawdown)
Surface area at full pond	2,550 acres
Average annual inflow at the Project	Approximately 12,200 cfs
Required minimum flow	1,250 cfs or inflow, whichever is less
Generated minimum flow	1,600 cfs
Major Structures and Equipment	
Dam	Composite overflow and non-overflow, ogee-type concrete gravity structure, 956 ft long with a maximum height of 58 ft and net head of 33.5 ft.
Spillway Gates	6 tainter gates, 2 hydraulic panel bays, 8 hydraulic flood gates, 3 stanchion bays, 1 sluice gate
Powerhouse	Reinforced concrete substructure with a structural steel and brick superstructure, 336 ft long by 55 ft wide
Turbine generating units	10
Turbine manufacturer/type	Units 1–4: vertical Francis Units 5–8: vertical Kaplan Units 9–10: vertical Francis
Turbine capacities	Units 1–4: 2.5 MW, 1,465 cfs @ 35 ft head Units 5–8: 4.0 MW, 1,800 cfs @ 32 ft head Units 9–10: 4.2 MW, 2,035 cfs @ 34 ft head
Generator capacities	Units 1–4: 2,000 kW Units 5–8: 4,000 kW
Total discharge capacity, including spill	119,785 cfs
Fish Ladder	Reinforced concrete: overflow weir lower section comprised of 26 pools, and collection facility; viewing window; serpentine vertical slot upper section with 25 pools. Overall 35 ft of vertical rise, 984 ft long.

a. Reflects typical non-spill, non-emergency operation.

2.1.3.2 Project Boundary

The Project boundary includes the powerhouse and dam, the impounded portion of the river (approximately 26 miles upstream from the dam), a limited amount of fee-owned project land, and a significant quantity of private lands adjacent to the river upon which Great River Hydro retains sufficient flowage rights to operate the Project. The Project boundary encompasses the areas necessary to operate the Project.

Great River Hydro holds fee ownership of 287 acres of land in the Vernon Project. Of this, 16 acres are used for plant and related facilities; 34 acres are for public outdoor recreational use; 14 acres currently support local agriculture; and the remaining 223 acres are presently natural forest areas.

2.1.3.3 Project Safety

The Project has been operating for more than 37 years under the existing license and during this time, Commission staff have conducted operational inspections focusing on the continued safety of the structures, identification of unauthorized modifications, efficiency and safety of operations, compliance with the terms of the license, and proper maintenance.

2.1.3.4 Existing Project Operations

Project operations are automated and controlled from a consolidated hydro operations control center located in Wilder, Vermont. Great River Hydro typically operates the Project in a coordinated manner with other Great River Hydro hydroelectric generating facilities on the Connecticut River, taking into consideration variations in electricity demand as well as natural flow in order to maximize the efficient use of available water. When inflows are within the Project's generating capacity, Great River Hydro uses the limited impoundment storage at the Project to dispatch generation as required to meet the generation schedule managed by ISO-NE. During the course of any day, generation can vary between the required minimum flow and full generating capacity, depending on inflow and impoundment storage. Over the course of a day, the Project generally passes the average daily inflow.

High flows occur routinely throughout the year at the Project, most often during the spring freshet, the fall rainy season and significant rainfall events impacting the Connecticut River watershed below the Moore dam. Annually, flows at the dam exceed station capacity approximately 22 percent of the time. During periods of sustained high flows, Great River Hydro dispatches Project generation in a must-run status to use available water for generation. Once flows exceed powerhouse capacity, it operates the Project in a "river profile" manner. Additional detail on Project operation is included in Exhibit B and in Section 3.4.1.1, *Water Quantity*.

2.1.3.5 Existing Environmental Measures

Water Level and Flow Management

The licensed minimum flow (Article 34) at Vernon is 1,250 cfs or a discharge flow equal to the inflow if less, and is provided primarily through generation at an efficient operating flow of about 1,600 cfs. Additional non-generation flows are provided seasonally on a schedule provided annually by CRASC based on fish counts at downstream projects (see below).

Impoundment WSE as measured at the dam is typically within a 1.8-ft range between El. 218.3 and 220.1 ft under normal operation (non-spill conditions). The overall operating range is between El. 212.13 ft and 220.13 ft, but this full range is only used during high water events that do not require removal of stanchion boards as specified in the Operating Procedures, which were developed as required under Article 32 of the current Project license. In extreme flood events, where flood flows increase beyond the capacity of the tainter gates, hydraulic floodgates and hydraulic flashboards requiring stanchion bays would be removed, the elevation would drop to just below the concrete crest at 212.6 ft in order to reinstall the beams and boards. Whenever possible, if flows exceed approximately 80,000 cfs, top portions of stanchion boards are removed rather than tripping the beams and removing all boards down to the concrete crest. The most recent event in which stanchion beams were removed was during Tropical Storm Irene in late August 2011. Under Article 32, a Coordination Agreement was developed with USACE that specifies how the Project is operated during high flow events. Operating Procedures also restrict impoundment drawdown rates to typically 0.1 to 0.2 ft per hour and to not exceed 0.3 ft per hour. A flow of approximately 3,000 cfs per hour results in about 0.1 ft of elevation change.

During the summer recreation season, beginning the Friday before Memorial Day and continuing through the last weekend in September, a self-imposed minimum impoundment level at El. 218.6 ft as measured at the dam is maintained from Friday at 4:00 p.m. through Sunday at midnight and on holidays during this period, unless the Project is experiencing high flows above station capacity.

Recreation

The Project includes the following formal recreation areas and facilities: (1) Vernon Glen picnic area; (2) Governor Hunt Recreation Area and boat launch including fishing access, and a fish ladder viewing area; (3) boat portage; (4) Vernon Neck open space; and (5) informal boat-in campsites in Hinsdale, New Hampshire, and on Stebbins Island (see Section 3.9, *Recreation Resources and Land Use*).

Upstream Fish Passage

Upstream fish passage facilities are operated in accordance with an annual *Fish Passage Notification Schedule* provided by CRASC which sets the dates for upstream passage for all dams on the Connecticut River. As of 2016 and if required, upstream passage is provided in spring from April 15 through July 15 (actual start date depends on passage counts at Turners Falls and Holyoke) for Atlantic Salmon and American Shad (and for Blueback Herring, although none have passed since 2000; See Section 3.5, *Fish and Aquatic Resources*) and in fall from September 15 through November 15 for Atlantic Salmon. Details on the fish ladder are included in Exhibit A and Exhibit F.

Downstream Fish Passage

CRASC's annual *Fish Passage Notification Schedule* sets the dates for downstream passage for all dams on the Connecticut River. Downstream fish passage facilities consist of a "fish pipe" that discharges about 350 cfs through the powerhouse, and a 156-ft-long louver array that extends from the forebay to the fish pipe entrance. The angled louver array consists of stainless steel panels with 3/8-inch x 2-inch louver vanes placed 3 inches on center and angled 60 degrees from the direction of the panels. Panels extend to a depth of 12–14 ft below the current impoundment WSE. The louver intercepts and directs downstream-migrating fish that enter the forebay from mid-river and from the east (New Hampshire) shoreline into the fish pipe. A second smaller "fish bypass" (or "fish tube") is located near Unit No. 10. It discharges about 40 cfs and functions as a secondary passage route for fish that are not intercepted by the louver array and are able to enter the western end of the forebay. Downstream passage is provided for:

- Adult American Shad from April 15 (or the same date as upstream passage begins) through July 31;
- Juvenile American Shad from August 1 through November 15;
- Adult American Eels from September 1 through November 15; and
- Adult Atlantic salmon from October 15 through December 31, if 50 or more adults are documented passing upstream.

As of February 11, 2016, CRASC no longer requires downstream passage operations at Vernon for Atlantic Salmon smolts (see Section 3.5, *Fish and Aquatic Resources*).

Existing License Requirements

In addition to Standard Articles 1 through 28 set forth in Form L-3 (Revised October 1975) titled "Terms and Conditions of License for Constructed Major Project Affecting Navigable Waters of the United States," the Vernon Project license includes the requirements summarized in Table 2.1-6.

Table 2.1-6. Summary of Vernon license and amendment requirements.

License Article	Summary of Requirement
29	Requires establishment and maintenance of amortization reserves based on a specified reasonable rate of return upon the net investment in the Project.
30	As revised June 16, 2007, requires payment of annual charges to FERC for the cost of administration of the license, based on the authorized installed capacity for that purpose of 32.4 MW.
31	Requires implementing and modifying when appropriate, the Emergency Action Plan on file with FERC designed to provide an early warning to upstream and downstream inhabitants and property owners if an impending or actual sudden release of water is caused by an accident to, or failure of, Project works.
32	Requires entering into an agreement with USACE to provide for the coordinated operation of the Project in the interest of flood control and navigation on the Connecticut River.
33	Required providing potable water at Vernon Glen and the Governor Hunt picnic area, and completing all improvements to the Governor Hunt boat launch area and all recreation facilities detailed in the license Exhibit R. The Vernon Neck Demonstration Forest Area shall be designated as a natural area, with only limited public use. The northern portion of the Vernon Glen may continue in existing agriculture use, subject to its reservation for future recreational development that may be determined necessary during the license period.
34	Requirement to maintain a continuous minimum flow of 1,250 cfs (0.20 cfs per sq. mi. of drainage basin) or a discharge flow equal to the inflow of the impoundment, whichever is less, from the Project into the Connecticut River. This flow may be modified temporarily: (1) during and to the extent required by operating emergencies beyond the control of the Licensee; and (2) in the interest of recreation and protection of the fisheries resources upon mutual agreement between the Licensee and the Fish and Game Departments of New Hampshire and Vermont.
35	Requires undertaking consultation and cooperation with the appropriate SHPO(s) prior to the commencement of any construction or development of any Project works or other facilities at the Project.
36	Requires installation and operation of signs, light, sirens, barriers, or other devices that may be reasonably needed to warn the public of fluctuations in flow from the Project and to protect the public in its recreational use of Project lands and waters.
37 (December 15, 1980, amendment)	Giving authority to the Licensee to grant permission for certain types of use and occupancy of Project lands and waters and to convey certain interests in Project lands and waters for certain types of use and occupancy, without prior FERC approval.

License Article	Summary of Requirement
38	Required filing for approval a revised Exhibit K and (1) clearly delineating its flowage rights for Project lands, as well as fee ownership, and (2) incorporating all information denoted on Exhibit Drawing K-2, Sheet 3A of 14, which was a part of the application for amendment of license filed May 31, 1968.
39	Required filing with FERC a feasibility analysis of installing additional generating capacity at the Project.
40	Required filing a copy of a report with FERC within 30 days after USACE issues its final report on its study of erosion on the Connecticut River.
301, 302, 303 (June 12, 1992, amendment)	Required commencing construction of the revised Project works within 2 years, and completing construction of the project within 4 years from the date of amendment; revising and submitting drawings, specifications and exhibits.
304 (June 12, 1992, amendment)	Requires continuing to allow the New England Power Pool's regional central dispatching system (NEPEX) to coordinate operation of the Vernon Project with the Northfield Mountain Project (Project No. 2485) and Turners Falls Project for generation output. In the event that NEPEX will no longer continue to adequately coordinate the Projects' operation, the Licensee must enter into a reasonable agreement with Northeast Utilities Service Company (NUSCO, then owner of Northfield Mountain and Turners Falls) to coordinate the operation of the three Projects.
401 (June 12, 1992, and July 28, 2006, amendments)	Required preparing and filing for Commission approval at least 90 days before commencing construction, a final plan and schedule to control erosion, slope stability, and fugitive dust and to minimize the quantity of sediment resulting from project construction and operation. Further, the Licensee must implement its plan and schedule for minimizing impacts on migrating anadromous fish during excavation and construction.
402 (June 12, 1992, and July 28, 2006, amendments)	Required preparing and filing for FERC approval at least 90 days before commencing construction, a final plan and schedule for upstream fish passage and for monitoring the effectiveness of the passage of Atlantic Salmon, American Shad, and other anadromous fishes.
404 (June 12, 1992, amendment)	Required preparing National Register registration forms consistent with the Secretary of the Interior's Standards and Guidelines for Historic Preservation for the Vernon powerhouse; and documenting the components proposed for replacement according to the standards of the Historic American Engineering Records of the National Park Service, prior to commencing any Project-related construction activities, that would affect the characteristics of the Vernon powerhouse that make it eligible for the National Register.

License Article	Summary of Requirement
405 (July 28, 2006, amendment)	Requirement to comply with the conditions of the water quality certificate, issued by NHDES, pursuant to Section 401 of the CWA. Those provisions included developing and implementing the following plans: Operations Plan, Flow Release Monitoring Plan, Dissolved Oxygen and Temperature Monitoring Plan, Erosion Monitoring Plan, and Debris Removal Plan.
Additional Provision	An additional provision of the July 28, 2006, license amendment required the Licensee to implement the "Memorandum of Agreement Regarding the Proposed Amendment to the License of the Vernon Hydroelectric Project Vernon, Vermont and Hinsdale, New Hampshire" Memorandum of Agreement. The Memorandum of Agreement included filing of the HPMP for the Project and the following provisions: (1) conduct photographic documentation of the powerhouse; (2) conduct digital video documentation at key stages of the Project to record the removal of the original equipment and installation of the new equipment; (3) conduct archaeological investigations to identify known archaeological sites and areas within project boundaries that have a likelihood of containing archaeological deposits; (4) prepare an HPMP for the Project; and (5) offer, and if accepted, donate generating and electrical equipment removed from the powerhouse to museums and educational organizations.

2.2 Great River Hydro's Proposal

In this amended FLA, Great River Hydro offers an applicant proposal that addresses the importance and need to continue to operate the three hydroelectric projects as critical and essential renewable energy generation resources. It will continue to manage its Projects in a responsible manner, ensuring high dam safety and operating standards; operate and expand fish passage facilities as needed; manage its public recreation facilities, including access to public waters within fee-owned Project lands; and protect and expand awareness of historic and cultural resources within the Project boundaries.

Great River Hydro proposes to operate the Wilder, Bellows Falls, and Vernon Projects fundamentally different than current operation also referred to as the no-action alternative. The proposed operation comprises the major enhancement and mitigation element and represents the most significant element associated with the Great River Hydro proposal. The proposed operation addresses many resource concerns both holistically and specifically, adopting many operational preferences stated by active stakeholders in the scoping and study phase of the ILP.

At the same time, the proposed operation maintains Great River Hydro's capability to be flexible and responsive to current wholesale energy, forward capacity, reserve, and other ancillary services markets managed by ISO-NE. The proposed operation will also remain responsive to ISO-NE system emergencies when ISO-NE requires operation for reserves, security, system stability, system over-supply conditions, and critical events or other emergencies involving dam and public safety. The proposed operation ensures the Projects' ability to address future regional energy demands and system needs as those evolve over time.

Proposed operation, under conditions when inflow to the Project at the dam is within the range of the Project powerhouse hydraulic capacity, focuses on creating more stable impoundment water surface elevations by reducing the average frequency, average duration, and average range of impoundment fluctuation. It also will reduce the magnitude and frequency of sub-daily operational changes in discharge from each Project by increasing the amount of time that the Projects are operated in an inflow equals outflow mode and maintain a stable impoundment elevation at the dams.

Great River Hydro, state and federal fishery agencies held consultation meetings throughout 2021 and part of 2022 with the goal of reaching agreement on fish passage enhancements at Vernon, Bellows Falls and Wilder under respective new licenses. On August 2, 2022, an executed Settlement Agreement on Fish Passage between these parties was filed with the Commission. The Settlement Agreement resolves all issues related to the appropriate prescriptions for fish passage at the Projects under the new licenses pursuant to Section 18 of the Federal Power Act ("FPA")1 and the Parties' recommended terms and conditions related to fish passage under Sections 10(a) and 10(j) of the FPA. It specifies a schedule for implementation of passage measures and enhancements as well as pre-construction design and consultation tasks and post-construction effectiveness evaluations. In the August 2, 2022 filing, updated Exhibit D Table D-1's were submitted that reflect the measures and schedule. Section 18 prescriptions as well as recommendations under Sections (10(a) and 10(j) are expected to correspond with those provided in the Settlement Agreement and are expected to be filed within 60 day of FERC's notice that the application is ready for environmental analysis.

In addition, within 60 days of notice from FERC that the application is ready for environmental analysis, Great River Hydro will be filing applications with both NH and VT for Water Quality Certification. Also, shortly after filing the application, Great River Hydro will be initiating development of a Programmatic Agreement managing historic property (PA) with the NH and VT State Historic Preservation Offices that includes the development of a Historic Properties Management Plan (HPMP) for the three Projects. Abenaki tribal leaders and representatives will be invited to participate in developing both the PA and the HPMP. No Project effects on traditional cultural properties have been identified at this time; however, any additional information provided by Tribal interests could, to the extent suitable, be incorporated into the HPMP.

Proposed Project operation will predominantly maintain a specified Target Water Surface Elevation (Target WSE) at each dam and as a result, maintain flow below the Project equal to the approximate inflow as measured or calculated at the dam (IEO). A Target WSE will be maintained at each dam within a Target WSE

Bandwidth of 0.5-ft above and below the Target WSE to account for potential differences between anticipated inflow and actual instantaneous inflow. The buffer will absorb these sub-daily imbalances (positive or negative) and reduce the frequency and need for constant minor adjustments, reduce wear and tear on station turbine generators, and maintain ability to follow the ISO-NE planned Day Ahead generation schedule. To maintain a relatively stable impoundment at the Target WSE at the dam, inflow as measured or determined at the dam will be passed downstream through station discharge or spill. Although primarily maintaining an IEO Operation, the Projects will also maintain some, albeit restricted, discretionary Flexible Operation capability to respond to high energy demand. The Projects will continue to maintain unrestricted capability to respond to Emergencies and ISO-NE transmission and power system requirements (system Operation Requirements). Elements associated with the proposed Project operations including modes of operation, capabilities, restrictions, requirements, and allowances, are more fully specified, defined, and described in Exhibit B, Section B.1.3.2 (see also Appendix B-1) for each Project.

A continuous minimum of 300 cfs, measured instantaneously, will be provided below the Bellows Falls dam, in the bypassed reach at all times. The combined total flow in the bypassed reach and flow below Bellows Falls station as a result of both generation discharge and downstream fish passage will comprise total project discharge for the purposes of compliance with the Proposed Operation described in Section 2.2.1 below. The minimum flow of 300 cfs will be maintained in the bypassed reach and provided under non-spill and non-emergency periods through the proposed 680kW minimum flow unit at the dam described in more deatil in Exhibit A, Section A3. During maintenance or emergencies, when the unit is out of service, spilling over the dam crest or through gates will provide the required minimum flow into the bypassed reach.

Subsequent sections summarize the operational and non-operational measures such as monitoring, compliance, and consultation, included with Great River Hydro's proposal.

2.2.1 Proposed Operation

All three Projects will comply with IEO Operation and maintain stable impoundment conditions at Project-specific Target WSE within Target WSE Bandwidths specified below, unless:

- Flexible Operation along with Transition Operation is applied as specified below;
- IEO Operation is suspended due to either High Water Operation (see Exhibit B, *Operations during Adersse, Mean, and High Water Years and Emergency Conditions)*, or Emergency and System Operation, Requirements and Audits; or

- IEO Operation is suspended due to non-emergency Maintenance Requirements that mandate deviating from IEO Operation, but only after consultation with relevant state and federal resource agencies prior to initiating a necessary deviation and developing a suitable refill plan and schedule.

Target WSE is the Project-specific elevation at each dam to be maintained under IEO Operation by adjusting station discharge (Table 2.2-1). The Target WSE would be monitored no less frequently than hourly, and station discharge would be adjusted as frequently as reasonably possible to ensure accurate WSE. Station discharge is calculated and adjusted based on unit discharge curves and formulas within the accuracy and capability of unit control systems.

Target WSE Bandwidth is the maximum range, 0.5 ft above and 0.5 ft below the Target WSE, available for use during IEO Operation, to absorb unanticipated changes in inflow at the dam or slight deviations or imbalances between hourly inflow and hourly discharge due to miscalculation of inflow or unit discharge (Table 2.2-1). Rates of change in station discharge to maintain a Target WSE (matching inflow with outflow) will be limited to reasonable changes necessary to continue or adjust the actual WSE to the Target WSE within the Target WSE Bandwidth, largely dependent upon rate of change in inflow, the degree of flow control using MW setpoints on the generator and the monitoring accuracy of WSE at the dam. Changes in station discharge necessary to match inflow should not occur more than once per hour (unless rate of change in inflow is rapidly accelerating or declining) and would not be greater than reasonably necessary to restore a balanced IEO condition at the Target WSE.

Table 2.2-1. Target WSEs and Target WSE Bandwidths for each Project (elevations are m.s.l., NGVD29)

	Wilder Project	Bellows Falls Project	Vernon Project
Target WSE	384.5 ft *	291.1 ft *	219.63 ft
Target WSE Bandwidth	Between 385.0 and 384.0 ft, representing 0.5 ft above and below the Target WSE	Between 291.6 and 290.6 ft, representing 0.5 ft above and below the Target WSE	Between 220.13 and 219.13 ft, representing 0.5 ft above and below the Target WSE

* Except during DWM pre-winter habitat protection operation period, triggered and maintained as water temperatures drop from 15° Celsius (°C) to10° C within identified DWM habitats within the Projects.

Flexible Operations are when the Projects are operated at the Licensee's discretion and deviate from operation at IEO and stable pond. Flexible Operations are limited, in part, by a maximum number of flexible operation hours specified below, which are allocated on a monthly basis to reflect the seasonal criticality of instream aquatic resources as well as the criticality and fuel security concerns associated with winter peaking loads in New England:

- December, January, February, March: no more than 65 hours in each month; this represents an average of 9 percent of hours in each month.
- April, May, June: no more than 10 hours in each month; this represents an average of 1.4 percent of the hours in each month.
- July: A total of 20 hours with no more than 10 hours from July 1 through July 15; this represents 2.7 percent of the hours in July.
- August, September, October: a total of no more than 20 hours in each month; this represents an average of 2.7 percent of the hours in each month.
- November: a total of 42 hours with no more than 10 hours from November 1 through 15; this represents 5.8 percent of the hours in November.

Flexible Operation Hours are the hours of flexible operation that will count towards the maximum number of flexible operation hours allowed each month. Determination of the number of flexible operation hours that have been used each month for comparison to the maximum number of flexible operation hours allowed, will be as follows:

- The minimum duration of a Flexible Operation event is one hour.
- For any event less than an hour for any reason, the event will be counted as one hour. ISO-NE is responsible for the dispatch of a unit or station and as such Great River Hydro is not able to precisely determine or dictate when a unit starts or stops. ISO-NE typically dispatches units at or near the top of the hour (e.g., 1:00, 2:00) under non-emergency situations. If an event lasts more than 15 minutes past the top of the hour, that event will be considered to have lasted and counted as if it were for that entire hour. Examples are provided in Table 2.2-2:

Table 2.2-2. Examples showing how flexible operation hours will be calculated.

Approximate Time Flexible Operation Event Begins*	Time Flexible Operation Event Ends and Down-ramping Begins	Number of Flexible Operation Hours
2:00 pm	2:57 pm	1
2:00 pm	3:15 pm	1
2:00 pm	3:16 pm	2

* ISO-NE dispatches units near the top of the hour.

Flexible Operations will maintain impoundment elevations within and comply with the Project-specific Flexible Operating Impoundment Ranges that are provided in Table 2.2-3:

Table 2.2-3. Project -specific flexible operating impoundment WSE ranges.

Project	WSE Range (m.s.l. NGVD29)	Maximum Fluctuation During Any Flexible Operation Event (feet)
Wilder	383.0 and 384.5	1.5
Bellows Falls	Oct 1 – May 31: 289.6 and 291.1 June 1-Sept 30: 290.1 and 291.1	Oct 1 – May 31: 1.5 June 1-Sept 30: 1.0
Vernon	218.3 and 219.63	1.33

To protect DWM from freezing in the winter, the Wilder and Bellows Falls Project Target WSE will be temporarily lowered in the fall of each year, intended to create overwintering habitat that is protected from potential water drawdown that could expose mussel beds to freezing air temperatures. Mussels reduce their mobility and settle into the substrate for the winter as water temperatures drop below 15°C. By lowering the WSE, the habitat they occupy will remain submerged over the winter, protecting largely immobile mussels from exposure and freezing air temperatures. To accomplish this, Great River Hydro will lower the WSE at the Wilder and Bellows Falls dams to an elevation at or above the low limit of each of the respective Flexible Operating Impoundment Ranges (see table above) and maintain that WSE for the limited period of time during which water temperatures consistently drop from 15°C to 10°C. This period is typically 10-21 days, occurring in the late-October to early-November timeframe. Once water temperatures are consistently below 10°C within identified DWM habitats within the Wilder and Bellows Falls Project impoundments, the WSE can be adjusted upward to the Target WSE and use the elevation range above the low limit described above for Flexible Operations. The WSE at each the Wilder and Bellows Falls dams will remain at or above this DWM habitat winter protection WSE throughout the subsequent period when water temperatures are at or below 10°C and no earlier than March 1 unless inflow exceeds respective station capacity and inflow levels require flood profile operation WSE at the dams (see Exhibit B, *Operations during Adverse, Mean, and High Water Years and Emergency Conditions*).

Additionally, the Flexible Operating Impoundment Range is narrowed between June 1 and September 30 to reduce the potential for dewatering at-risk DWM habitat and individuals within portions of the Bellows Falls Project.

Flexible Operation Maximum Discharge is the maximum station discharge during Flexible Operation and is based upon the inflow at the hour in which the Flexible Operation will occur as follows:

- When inflow is about 1,800 cfs or less, Flexible Operation Maximum Discharge is 4,500 cfs.

- When inflow is greater than about 1,800 cfs, the Flexible Operation Maximum Discharge is limited to 2.5 times the calculated inflow and will not exceed the maximum station generating capacity.
- Inflow to each Project is estimated based on anticipated inflow arriving at the dam from upstream. In real-time it is calculated and monitored through actual change in WSE measured at the dam.

There are no limitations on the number of Flexible Operation events per day or the duration of Flexible Operation events other than those indirect limitations due to inflow and Transition Operation requirements as specified herein.

Transition Operations are actions required to precede Flexible Operation in some cases and follow Flexible Operation in all cases. Three elements are associated with Transition Operation:

- Up-ramping: A flow increase for the hourly period that would precede most (exceptions specified below) initial Flexible Operation hours at a specified flow depending upon the Project, so that the overall flow difference between the IEO flow and the scheduled Flexible Operation flow is gradual and not instantaneous. Up-ramping rates are specific to each Project and would only apply when Flexible Operation is scheduled in advance (i.e., in the Day-Ahead market) and not when Flexible Operation is initiated in Real-Time or for claimed capacity audits (CCA) and reactive power demonstrations (RPD). Up-ramp rates are specified at each Project as:
  - Wilder Project: the lesser of discharge from one of the larger units (Unit 1 or Unit 2) (approximately 5,000 cfs) or the flow half-way between current IEO flow and the Flexible Operation;
  - Bellows Falls Project: the lesser of 5,414 cfs (representing 1 cfs/square mile of drainage area or cfsm) or the flow half-way between current IEO flow and the Flexible Operation flow;
  - Vernon Project: the lesser of 1 cfsm (approximately 6,266 cfs) or half-way between current IEO flow and the Flexible Operation flow.
- Down-ramping: A flow decrease at a specified rate for the period following Flexible Operation until the flow is equal to inflow at the dam. Decreases will occur on an hourly basis, as a percentage of the previous hourly flow. The first hour after the Flexible Operation hour will be no greater than approximately 70 percent of the Flexible Operation flow and each successive hour will be approximately 70 percent of the previous hour.
- Refill: A maximum 48-hour period subsequent to post-Flexible Operation Down-ramping when the impoundment WSE is restored to the stable Target WSE by passing a fraction of the inflow at the dam and retaining the remaining fraction as impounded water above the dam. The hourly flow rate below each Project dam during refill will be the greater of

approximately 70 percent of inflow or the required minimum base flow as shown in Table 2.2-4. Note that Project flows may be less than specified in the table when a Project is operating IEO and calculated inflow is less than the required minimum base flow.

Table 2.2-4. Project-specific required minimum base flows.

Wilder	Bellows Falls*	Vernon
Oct 1 - March 31: 1,500 cfs April 1 - May 31: 2,000 cfs June 1 - Sept 30: 1,100 cfs	Oct 1 - March 31: 1,600 cfs April1 - May 31: 3,000 cfs June 1 - Sept 30: 1,400 cfs Bypass Reach below dam: 300 cfs year round	Oct 1 - March 31: 1,600 cfs April 1 - May 31: 3,000 cfs June 1 - Sept 30: 1,400 cfs

* Minimum Base Flow is the combined flow below dam and station.

The 48-hour maximum refill period begins immediately following Down-ramping after a Flexible Operation event and ends no more than 48 hours later unless the reservoir is within 0.1 ft of the Target WSE (Table 2.2-1). The 48-hour period includes any temporary interruptions during refill (e.g., purposely pausing refill and passing all inflow, or decisions to implement another Flexible Operation event prior to the impoundment reaching a WSE equal to the Target WSE minus 0.1 ft). Great River Hydro expects to only pause refill for extended periods as needed when participating in the Real-Time Market, as described above. Based on analysis of Flexible Operation simulations, Great River Hydro expects that the number and duration of pauses will be minimal especially during the critical spawning months spanning from April through July 15.

Scheduled Flexible Operation will require one hour of Transition Operation Up-ramping. Unscheduled (in response to Real-Time price signals) Flexible Operation, and Emergency and System Operation, Requirements, and Audits will not require Up-ramping.

All Flexible Operation events will require Transition Operation Down-ramping and Refill as specified.

The three Transition Operation elements will be applied at the Projects as described in Table 2.2-5.

Table 2.2-5. Application of Transition Operation elements by operating condition.

	Up-Ramping	Down-Ramping	Refill
IEO Operations	Not Applied	Not Applied	Not Applied
Flexible Operations, Scheduled	Applied during the hour prior	Applied as Defined	Applied as Defined
Flexible Operations, Un-Scheduled	Not Applied	Applied as Defined	Applied as Defined

	Up-Ramping	Down-Ramping	Refill
High Water Operations	Not Applied	Not Applied	Not Applied
CCA and RPD Audits	Not Applied	Applied as Defined	Applied as Defined
Emergencies and System Emergencies	Not Applied	Not Applied	Not Applied

Specifics of Great River Hydro's proposal will be included in the operation compliance and monitoring plans (OCMPs) expected to be required by the §401 water quality certifications and subsequently required under the FERC licenses. If any information submitted to the relevant resource agencies pursuant to the OCMPs indicates that operation of any Project is not complying with proposed operations, Great River Hydro will consult with the state and federal resource agencies to discuss their concerns and, if necessary, will identify and implement appropriate corrective actions.

2.2.2 Proposed Non-Operational Protection, Mitigation, and Enhancement Measures

In addition to the significant modification to project operations described above, Great River Hydro proposes to continue many of the existing non-operational Project protection, mitigation, and enhancement (PME) measures consistent with the no-action alternative. Those measures include:

- Continuing to manage, maintain, and enhance as demand and use requires the various recreation areas and facilities associated with the three projects.
- Continuing to manage undeveloped land through cooperative agreements with farmers to maintain prime agricultural lands productive but also managed for critical wildlife habitat such as grassland bird nesting.
- Continue to implement the Historic Resource Management Plan (HPMP) for the Vernon Project
- Continue to maintain and operate fish passage facilities. and operate as requested in Schedule of Operations letters issued annually by the Connecticut River Salmon Restoration Commission (CRASC).

Great River Hydro proposes the following additional PME measures:

- Operate fish ladders at the three Projects from April 1 thru July 15 to support upstream passage for resident early spring spawners such as White Sucker and Walleye and diadromous species as adult Sea Lamprey and juvenile American Eel.

- Develop and sign a Programatic Agreement for Managing Historic Resources with State Historic Preservation Officers in consultation with Abenaki tribal leaders agrees to:
    - Develop new HPMPs or the Wilder and Bellows Falls Project and update the current HPMP for Vernon;
    - Continue attempts to secure landowner permission to conduct Phase IB on remaining identified locations and if permission allows, conduct Phase II surveys as appropriate;
    - Expand and support educational and cultural programs, activities and outreach for Abenaki tribal groups and interests
- Incorporate into their respective Projects three canoe campsites, currently non-project recreation areas on Great River Hydro fee-land; Lower Meadow Campsite in Charlestown NH (Bellows Falls Project); Wantastiquet-Hinsdale canoe rest area in North Hinsdale, and Stebbins Island in Hinsdale New Hampshire (Vernon Project);
- Great River Hydro and resource agencies with prescriptive authority under Section 18 of the Federal Power Act along with state fish and wildlife agencies have initiated discussion of upstream and downstream fish passage at the Wilder, Bellows Falls and Vernon Projects and will continue those discussions after filing amended FLAs. In those discussions, Great River Hydro will work with resource agencies and FWS fishway engineers to identify appropriate structural and operational improvements to existing or new facilities for safe, efficient upstream and downstream passage of migratory fish species at each of the Projects. GRH intends to reach agreement on fish passage requirements, passage study needs, designs and implementation plans and schedules. GRH would expect provisions in any such agreement, if reached, would be included in the FWS recommendation for Terms and Conditions. GRH would implement the of such an agreement under the terms the new Licenses.
- Design, install and implement tools, equipment, and resources as needed, within the Project boundary, portions of the river affected by project operations and in the hydro operations control center to assist in inflow monitoring, inflow forecasting and manage the impoundment to Target WSE in order to successfully operate the Projects under the proposed operation.

2.3 Alternatives Considered but Eliminated from Further Analysis

Great River Hydro considered several action alternatives but eliminated them from further analysis because they are not reasonable in the circumstances of the

Wilder, Bellows Falls, and Vernon Projects. Those alternatives are: (1) issuing a non-power license; (2) federal government takeover of the Projects; and (3) retiring the Projects. Each is discussed below.

2.3.1 Non-Power License

A non-power license is a temporary license that FERC issues when it determines that a project should no longer be used to generate power. In SD2, FERC stated that this is not an appropriate alternative for the Projects.

> A non-power license is a temporary license the Commission would terminate whenever it determines that another governmental agency is authorized and willing to assume regulatory authority and supervision over the lands and facilities covered by the non-power license. At this time, no governmental agency has suggested a willingness or ability to take over any of these five projects. No party has sought a non-power license, and we have no basis for concluding that the TransCanada[9] and FirstLight projects should no longer be used to produce power. Thus, we do not consider a non-power license a reasonable alternative to relicensing the projects.

In addition, power from the three Projects is needed (see Section 1.1.2, *Need for Power*) and new licenses can be issued that satisfy the requirements of Sections 4(e) and 10(a)[10] of the FPA, which require FERC to give equal consideration to all uses of the waterway on which a project is located. Therefore, Great River Hydro concurs with FERC that this alternative is not a reasonable one.

2.3.2 Federal Government Takeover

Great River Hydro has not analyzed federal government takeover of the Projects and concurs with FERC's perspective stated in SD2:

> In accordance with § 16.14 of the Commission's regulations, a federal department or agency may file a recommendation that the United States exercise its right to take over a hydroelectric power project with a license that is subject to sections 14 and 15 of the FPA.[11] We do not consider federal takeover to be a reasonable alternative. Federal takeover of the project would require congressional approval. While that fact alone would not preclude further consideration of this alternative, there is currently no evidence showing that federal takeover should be recommended to Congress. No party has suggested

[9] Now the Great River Hydro projects.

[10] 16 U.S.C. § 797(e) (2000), and 16 U.S.C. § 803(a)(1) (2000), respectively

[11] 16 U.S.C. §§ 791(a)-825(r).

> that federal takeover would be appropriate, and no federal agency has expressed interest in operating any of these five projects.[12]

2.3.3 Retiring the Projects

Great River Hydro has not analyzed retiring (decommissioning) the Projects and concurs with FERC's perspective on potentially retiring these projects as summarized in SD2. Several commenters to FERC's SD1 recommended that FERC include decommissioning as an alternative action. As summarized in SD2, FWS, The Nature Conservancy, and Two Rivers-Ottauquechee suggested that "eliminating project decommissioning from further review, prior to scoping is pre-mature. Two Rivers-Ottauquechee requests that decommissioning of the Wilder Project is considered in the Commission's NEPA document, and FWS states, in general, that decommissioning should be evaluated for the Connecticut River projects." FERC's response to these comments in SD2 states:

> Decommissioning some or all of [the] Connecticut River projects would require denying the relicense applications and surrender or termination of the existing licenses with appropriate conditions. There would be significant costs involved with decommissioning the projects and/or removing project facilities. The projects provide a viable, safe, and clean renewable source of power to the region. Based on the 17 factors (to be considered when determining whether a more thorough analysis of decommissioning is warranted), outlined in The Interagency Task Force Report on NEPA Procedures in FERC Hydroelectric Licensing,[13] we do not consider decommissioning to be a reasonable alternative for the Connecticut River projects, at this time.

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12 The five projects refer to the Wilder, Bellows Falls, Vernon, Turners Falls, and Northfield Mountain Pumped Storage projects, or collectively, the "Connecticut River projects" for purposes of relicensing.

13 http://www.ferc.gov/industries/hydropower/indus-act/itf/nepa_final.pdf.

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3. ENVIRONMENTAL ANALYSIS

3.1 General Setting

3.1.1 Overview of the Basin

The Connecticut River originates in the Fourth Connecticut Lake in Pittsburg, New Hampshire, near the Canadian border. It flows in a southerly direction for about 407 miles to Long Island Sound (the Sound) at Old Saybrook, Connecticut. The river flows 255 miles between New Hampshire and Vermont and forms the state border from Stewartstown, New Hampshire, and Canaan, Vermont, to the Massachusetts border at Hinsdale, New Hampshire, and Vernon, Vermont. The New Hampshire-Vermont state border is designated as the ordinary low-water mark on the western (Vermont) shore, without reference to extreme droughts[14] and prior to inundation by impoundments of dams after 1933 when the US Supreme Court issued its decision on the state boundary location as a result of boundary lawsuit filed by Vermont against New Hampshire in 1915.

The river has a drainage area (DA) of 11,250 square miles (sq. mi.). The upper Connecticut River Basin[15] (Figure 3.1-1) has a DA of 7,751 sq. mi. and is about 271 miles long. It includes the Wilder, Bellows Falls, and Vernon Project areas and the area downstream to the Turners Falls Project.

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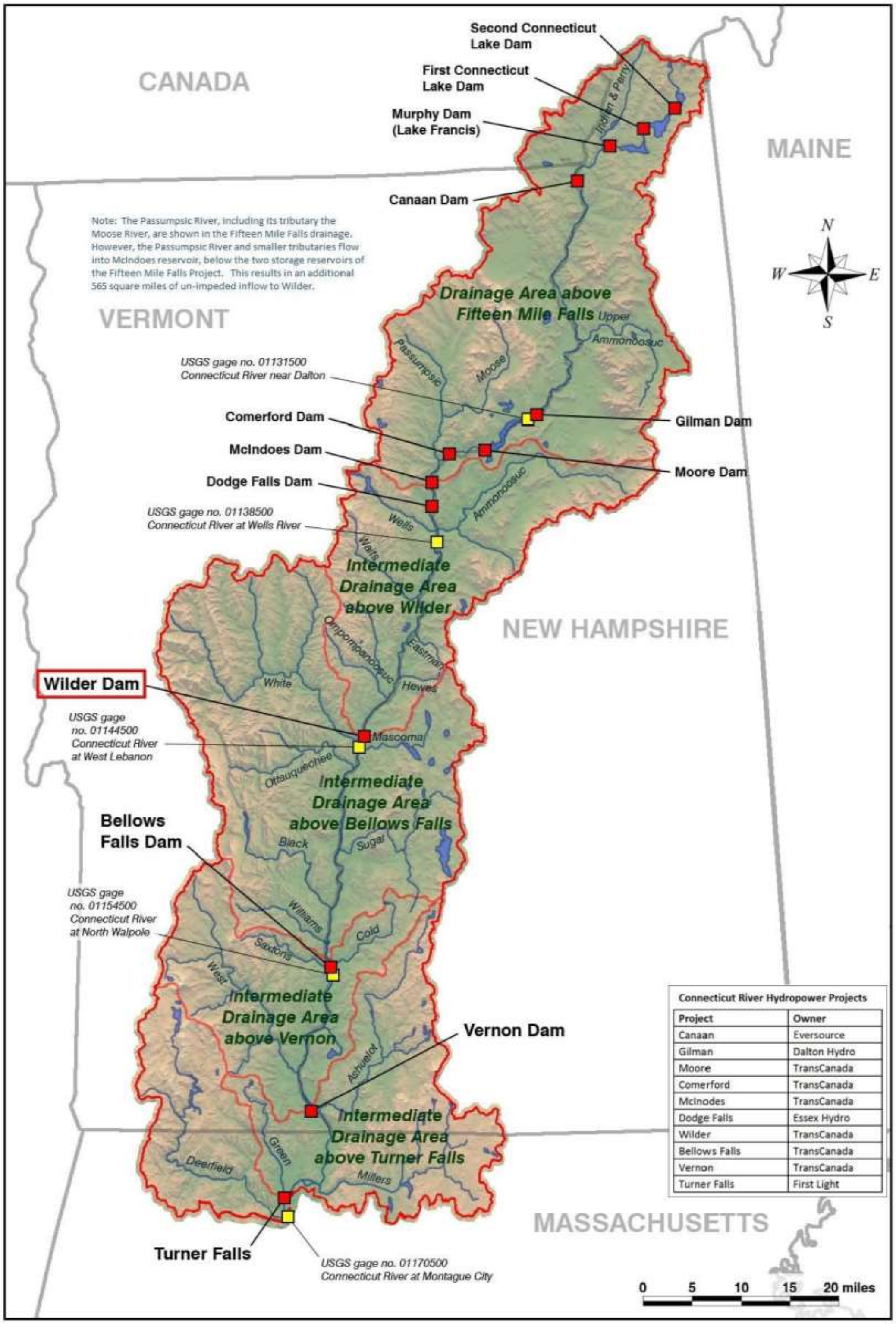
[14] Vermont v. New Hampshire. 1933. State of Vermont v. State of New Hampshire 289 U.S. 593. May 29, 1933. Available at: https://www.law.cornell.edu/supremecourt/text/289/593#writing-type-1-STONE. Accessed September 19, 2016.

[15] The upper Connecticut River Basin is defined as the northern part of the watershed from the headwaters to the confluence of the Deerfield River, near Greenfield, Massachusetts.



Source: EPA (2012, as modified by Great River Hydro)

Figure 3.1-1. The upper Connecticut River basin.

3.1.1.1 Tributaries

Twelve major tributaries (stream order 5 or greater) enter the Connecticut River and provide direct inflow to the Projects (Table 3.1-1) as described below.[16] More than 140 smaller tributaries (stream order 4 or less) also enter the Connecticut River within the approximate 122-mile length encompassing the Project areas (Figure 3.1-2 through Figure 3.1-4).

Table 3.1-1. Major tributaries (fifth order stream or higher) draining to the Wilder, Bellows Falls, and Vernon Project areas.

Tributary	Connecticut River Confluence Location	Stream Order	Drainage Area (sq. mi.)	Enters Mainstem at River Mile
Between Dodge Falls and Wilder Dams				
Ammonoosuc River[a]	Woodsville (Haverhill), NH	5	395	266.3
Waits River	Bradford, VT	5	158	246.8
Ompompanoosuc River	Pompanoosuc, VT	5	136	224.3
Between Wilder and Bellows Falls Dams				
White River	White River Junction, VT	7	710	215.1
Mascoma River	West Lebanon, NH	5	194	214.2
Ottauquechee River	North Hartland, VT	5	222	210.2
Sugar River	West Claremont, NH	6	275	195.2
Black River	Springfield/Gould Mill, VT	5	204	183.1
Williams River	Rockingham, VT	5	118	176.4
Between Bellows Falls and Vernon Dams				
Saxtons River	North Westminster, VT	5	78	172.5
Cold River	Cold River, NH	5	100	171.9
West River	Brattleboro, VT	6	423	149.3
Downstream of Vernon Dam				
Ashuelot River[b]	Hinsdale, NH	6	421	139.6

Source: USGS (2016a, 2016b)

a. The Ammonoosuc River enters the mainstem upstream of the Wilder impoundment and just upstream of the Wells River (fourth order stream tributary and not listed here).

b. The Ashuelot River enters the mainstem just downstream of the Vernon Project-affected riverine reach.

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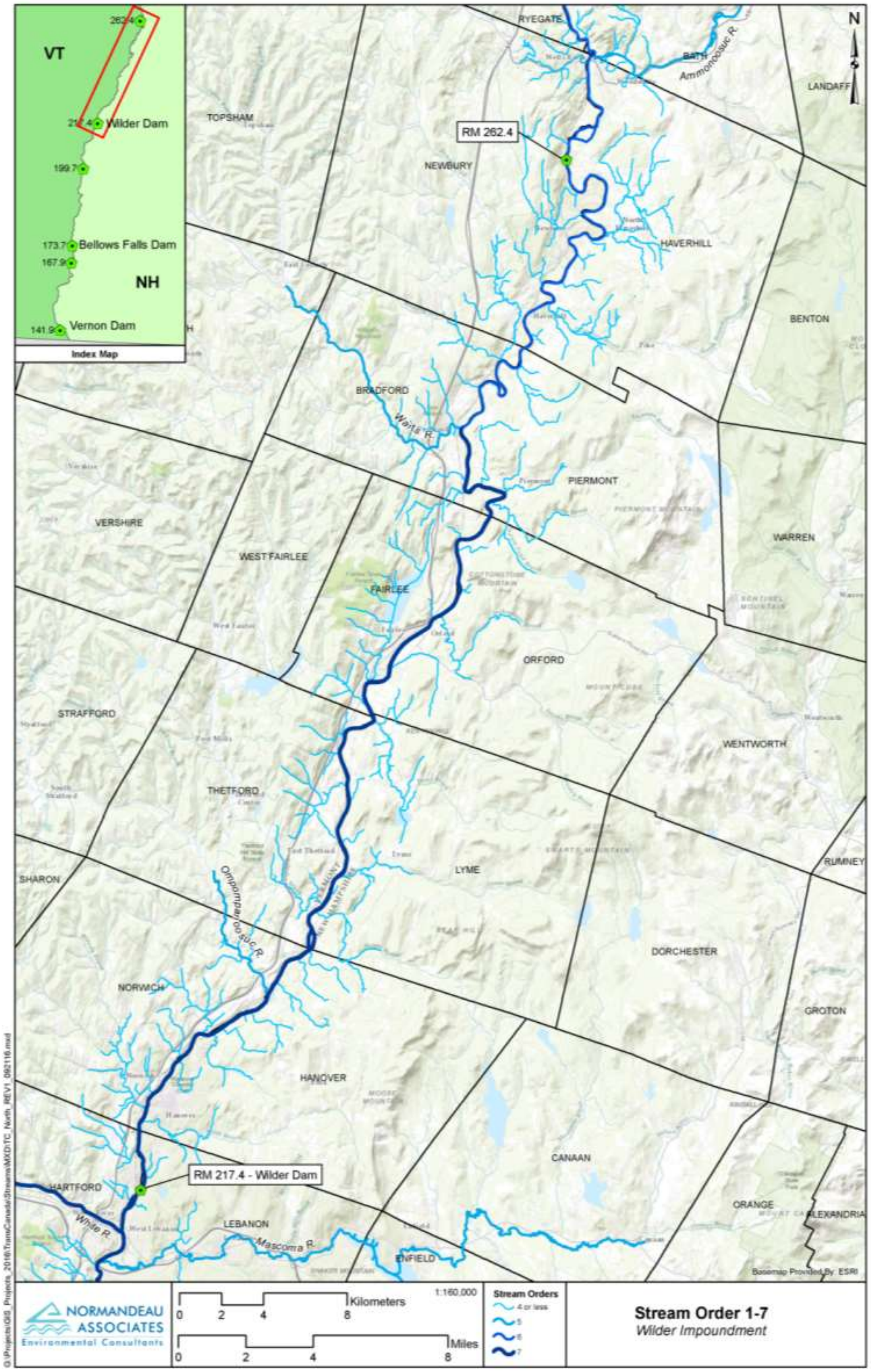
16 Stream order is a hierarchical ordering of streams based on the degree of branching. A first order stream is an unbranched stream and combines with another first order stream to form a second order stream, two second order streams combine to form a third order stream, etc. (Armantrout, 1998).

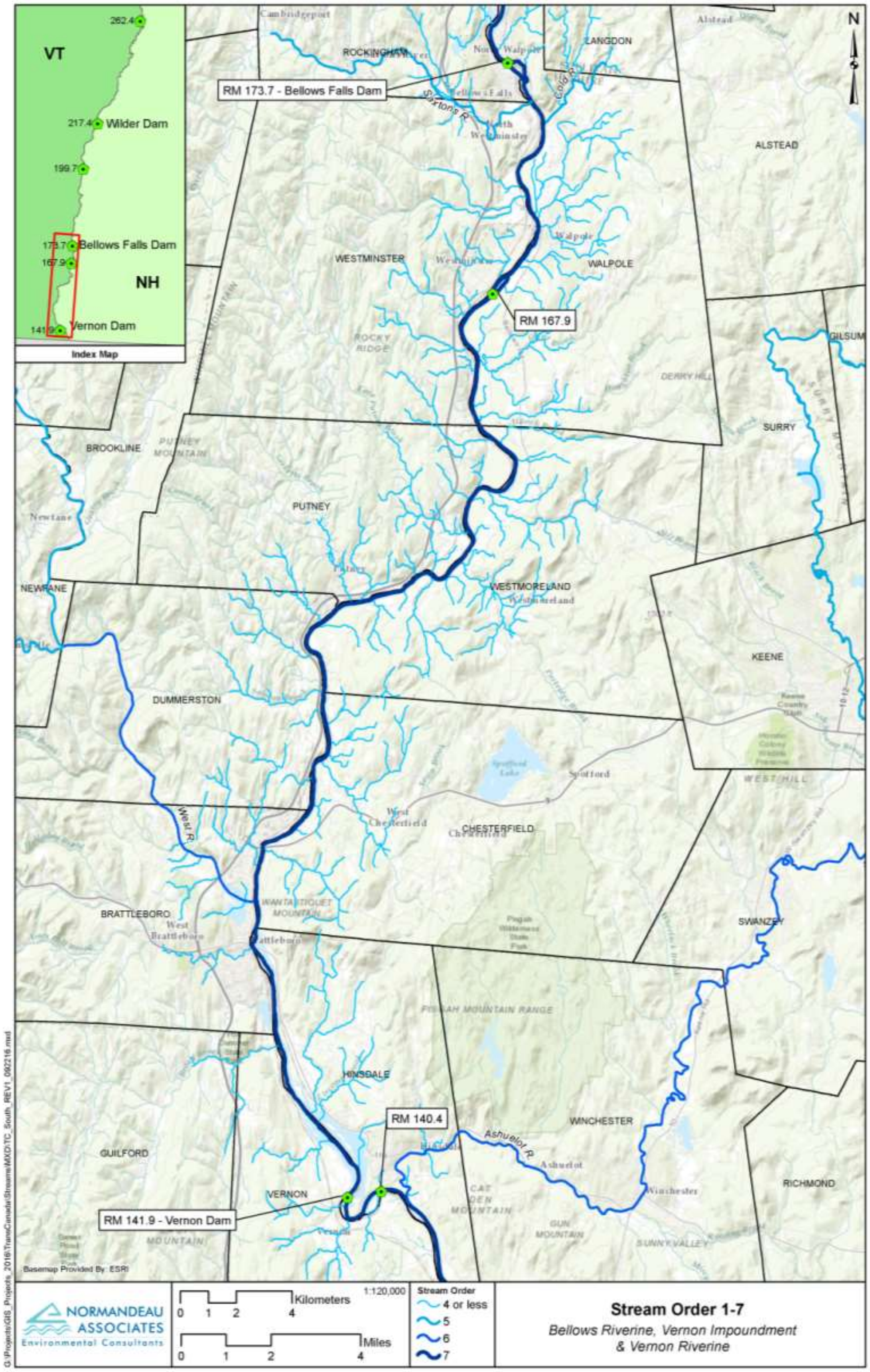


Source: USGS (2016b, as modified by Great River Hydro)

Figure 3.1-2. Tributaries to the Wilder Project.

Source: USGS (2016b, as modified by Great River Hydro)

Figure 3.1-3. Tributaries to the Bellows Falls Project.



Source: USGS (2016b, as modified by Great River Hydro)

Figure 3.1-4. Tributaries to the Vernon Project.

3.1.1.2 Major Water Uses

The river was used as a means of log conveyance mostly in the spring for the timber industry from the mid-1800s until 1915 when the last major log drives occurred; however, pulpwood was floated down the river until 1949 (Brown, 2009). Similarly, dams constructed for industrial mill power and transportation also pre-dated large-scale hydroelectric development. The Connecticut River has long been used for recreational purposes including power boating, canoeing, kayaking, rowing, sport fishing, and ice fishing.

Both surface water from tributaries and groundwater in the vicinity of the Connecticut River and tributaries within the Wilder, Bellows Falls, and Vernon Project areas are used for drinking water, irrigation, mining, and industrial purposes. Based on available information, there is little use of surface water from the Connecticut River for non-power purposes within the Project areas. Three New Hampshire-registered withdrawals[17] taken directly from the Connecticut River in Hanover, Plainfield, and Westmoreland are used for irrigation or institutional purposes. The only major withdrawal from Vermont waters of the Connecticut River was for cooling and service water for VY, which ceased commercial operation in 2014; however, VY continues to withdraw service water at a much reduced quantity and rate from the river for non-commercial purposes (non-contact cooling service water, plant heating boiler blowdown, and strainer and traveling screen backwash). Treated wastewater from private, commercial, municipal, and industrial sources in New Hampshire and Vermont discharges to the Connecticut River and its tributaries and is permitted under CWA § 402 implementing regulations at 40 C.F.R. 122.

3.1.1.3 Dams

Dams on the mainstem of the Connecticut River include Second Connecticut Lake, First Connecticut Lake and Murphy dam, all without hydropower production, and 12 hydroelectric developments. The Canaan and Gilman Projects, the Fifteen Mile Falls (FMF) Hydroelectric Project (Moore, Comerford, and McIndoes developments), and Dodge Falls Project are located upstream of the Wilder, Bellows Falls, and Vernon Projects. Downstream are the Turners Falls and Holyoke Projects all located in Massachusetts (Table 3.1-2). Numerous licensed and exempt hydropower projects and hundreds of small non-powered dams are located on tributaries to the Connecticut River in New Hampshire and Vermont. Most notably is the Northfield Mountain Pumped Storage Project, which uses the impoundment above Turners Falls dam and below Vernon dam for its lower reservoir. Information about the Great River Hydro Project dams and impoundments follows:

- Wilder dam is located at RM 217.4. The impoundment extends upstream approximately 45 river miles to Haverhill, New Hampshire, and Newbury,

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[17] New Hampshire requires registration of water withdrawals more than 20,000 gallons per day averaged over 7 days or a total of more than 600,000 gallons per day in a 30-day period. Vermont requires permits for water withdrawals from in-state waters but does not have a system for tracking permitted withdrawals.

Vermont. The downstream Project-affected riverine reach is approximately 17.7 miles long.

- Bellows Falls dam is located at RM 173.7. The impoundment extends upstream approximately 26 river miles to Cornish, New Hampshire, and Windsor, Vermont. The downstream Project-affected riverine reach is approximately 5.8 miles long.
- Vernon dam is located at RM 141.9. The impoundment extends upstream approximately 26 river miles to Walpole, New Hampshire, and Westminster, Vermont. The downstream Project-affected riverine reach is approximately 1.5 miles long to the downstream end of Stebbins Island.

Building of the large mainstem hydroelectric dams on the Connecticut River in New Hampshire and Vermont started with the completion of the Vernon Project in 1909, followed by the Bellows Falls Project in 1928. The upstream FMF Project was constructed between the 1930s and 1950s. The Wilder Project, constructed in 1950, was a redevelopment of a site occupied by a paper mill and hydroelectric plant.

Table 3.1-2. Mainstem Connecticut River dams and hydropower projects.

Project Name	Owner	FERC No.	River Mile	Storage Capacity (acre-ft)
Second Connecticut Lake	Great River Hydro	NA	389.5	11,613
First Connecticut Lake	Great River Hydro	NA	382.2	73,493
Murphy Dam (Lake Francis)	State of NH	NA	374.2	99,306
Canaan	Canaan Resource Partners NH	P-7528	370	200
Gilman	Ampersand Gilman Hydro LP	P-2392	300	705
Moore	Great River Hydro	P-2077	283.5	223,722
Comerford	Great River Hydro	P-2077	275.2	32,270
McIndoes	Great River Hydro	P-2077	268.6	5,988
Dodge Falls (exempt)	Dodge Falls Associates LP	P-8011	264.6	Run of river
Wilder	Great River Hydro	P-1892	217.4	13,350 (at 5-ft drawdown)
Bellows Falls	Great River Hydro	P-1855	173.7	7,476 (at 3-ft drawdown)
Vernon	Great River Hydro	P-1904	141.9	18,300 (at 8-ft drawdown)
Northfield Mountain	FirstLight	P-2485	127	12,318
Turners Falls	FirstLight	P-1899	122	16,150
Holyoke	Holyoke Gas and Electric	P-2004	87	Run of river

Source: Great River Hydro Operations Department; FirstLight (2016b); NHDES (2016); VDEC (2016a).

USACE operates flood control dams on four of the major tributaries to the Wilder, Bellows Falls, or Vernon Project areas (Table 3.1-3). In accordance with Article 32 of each Project license, an agreement with USACE is maintained that provides for the coordinated operation of the Projects in the interest of flood control and navigation on the Connecticut River. Under the agreement, operating procedures stipulate the lowering of WSEs at the dams in anticipation of inflows greater than maximum generating capacity at each respective Project. These high water operations are initiated to manage upstream water elevations throughout critical locations in the impoundment in order to operate within certain flowage right restrictions and reduce the potential for waters to exceed bank full conditions (see Section 3.4.1.1, *Water Quantity*).

Table 3.1-3. USACE dams in the vicinity of the Wilder, Bellows Falls, and Vernon Projects[a]

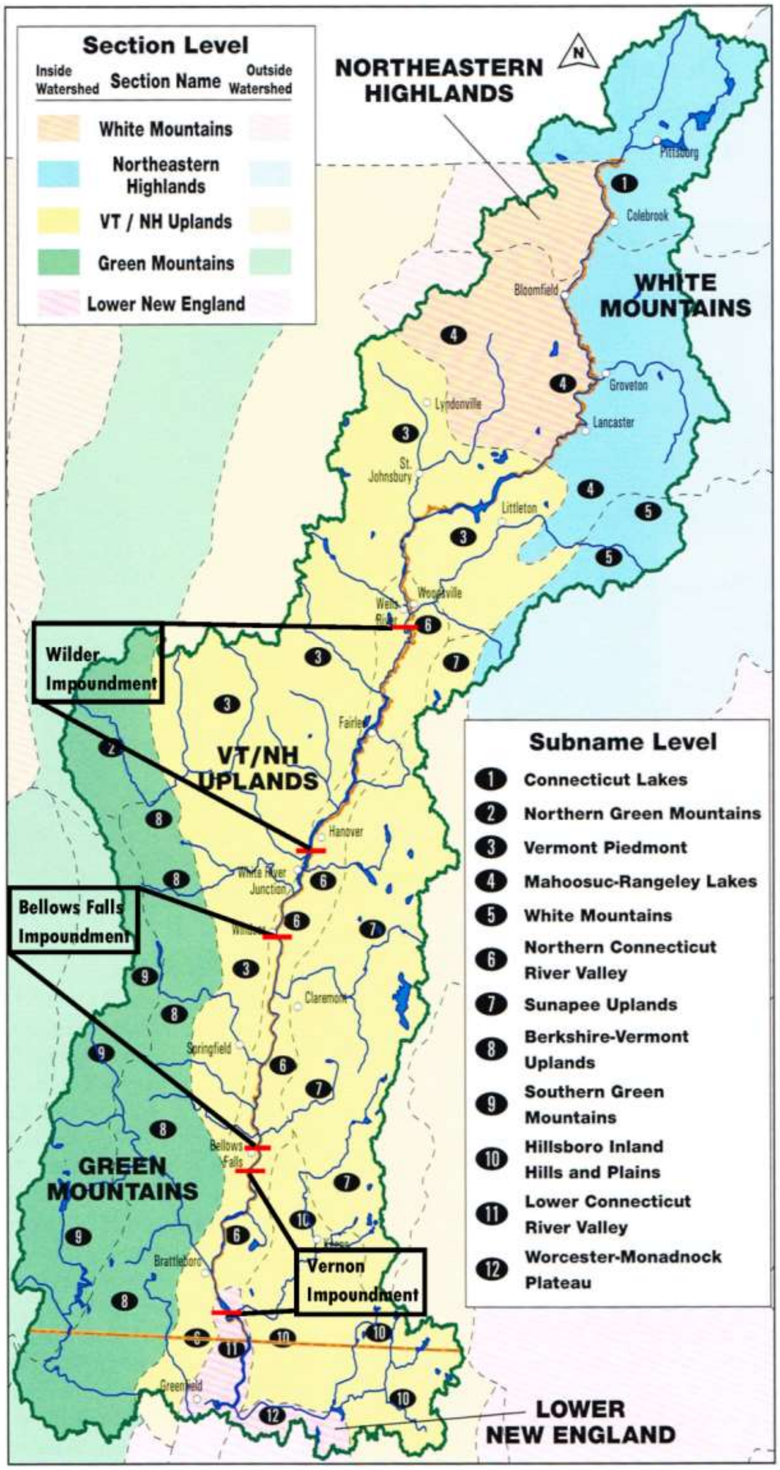
USACE Project Name	Tributary	Discharges to Connecticut River Impoundment	Flood Storage Capacity (acre-ft)
Union Village	Ompompanoosuc	Wilder	7,365
North Hartland	Ottauquechee	Bellows Falls	71,198
North Springfield	Black	Bellows Falls	51,250
Ball Mountain	West	Vernon	54,626
Townshend	West	Vernon	33,757

Source: USACE (2016)

a. USACE operates two additional flood control dams in New Hampshire on the Ashuelot River, which enters the Connecticut River 2.1 river miles downstream of Vernon dam.

3.1.2 Topography

The Projects are located primarily within the Vermont/New Hampshire Uplands section of the New England Physiographic Province, although the lower portion of the Vernon impoundment is located in the Lower New England region (Figure 3.1-5). Within the smaller biophysical regions of eastern Vermont and western New Hampshire, the Projects lie in the Southern Vermont Piedmont. The region comprises low rolling foothills dissected by many rivers and streams draining to the Connecticut River. The lowlands comprise fertile farmland and the hills are covered with hardwood forests (Thompson and Sorenson, 2000).



Source: Brown (2009, as modified by Great River Hydro)

Figure 3.1-5. Physiographic regions of New Hampshire and Vermont encompassing the Wilder, Bellows Falls, and Vernon Projects.

The word piedmont, which means "at the foot of the mountains," is used to describe an area of foothills, and this area comprises rolling hills and valleys at the foot of the Green Mountains that extend into western New Hampshire, and at the foot of the White Mountains in New Hampshire to the east. The most notable feature of the piedmont landscape is a number of mountains that rise above the surrounding landscape. These isolated mountains are called monadnocks, a word believed to originate in Abenaki that means "island mountain place" (Vermont Geographic Alliance, 2016) and consist of resilient granite outcrops. Mount Ascutney in Windsor and Weathersfield, Vermont, is such a monadnock and was formed by plutonic activity that resulted from the Alleghenian Orogeny, when subsurface magma was melted and reformed (see Section 3.3, *Geologic and Soil Resources*). This magma cooled and became very hard rock, and it has resisted the erosion that has lowered the softer sedimentary rocks that surround it. Elevations in the Southern Vermont Piedmont range from less than 300 ft at Vernon to 3,144 ft at the top of Mount Ascutney (Thompson and Sorenson, 2000).

3.1.3 Climate

The climate within the Wilder, Bellows Falls, and Vernon Project areas consists of mild and humid summers and cold winters. Average temperatures tend to be slightly warmer, and precipitation somewhat higher (although snowfall tends to be lower) at the southern end of the area near Vernon, Vermont, than at the northerly upstream end of the Wilder impoundment at Haverhill, New Hampshire. Precipitation is relatively evenly distributed throughout the year. Table 3.1-4 provides a summary of average climate data throughout the approximate 122-mile area that encompasses the Projects.

Table 3.1-4. Average annual climate data for the Wilder, Bellows Falls, and Vernon Project areas.

		Upper Wilder Impoundment Haverhill, NH	Wilder Dam Hanover, NH	Bellows Falls Dam Walpole, NH	Vernon Dam Vernon, VT
Temp. (°F)	January low	6	10	11	11
	January high	26	28	29	32
	July low	55	59	59	59
	July high	77	82	80	84
Ave. annual (inches)	Precipitation	40.0	40.1	44.9	47.0
	Snowfall	71	61	57	55[a]

Source: U.S. Climate Data (2020)

a. Snowfall data from Keene, New Hampshire.

3.1.4 Major Land Uses

Land use in the Connecticut River Valley is predominantly rural and agricultural, and a considerable portion of the land is undeveloped and forested. Much of the land in the valley has been preserved by property owners using various conservation easements for agriculture, open space, and habitat protection. Bottomland agriculture in the area is used for dairy, vegetable, and hay farming. Along the New Hampshire and Vermont sides of the Connecticut River, most of the land is zoned for limited residential use with infrequent commercial and industrial sites (NHDES, 1991). This development pattern was established in early settlement days that continues today. and consists of mosaic villages and small cities surrounded by rural areas. The juxtaposition of dense villages with working forestlands and agricultural fields defines the character of the Connecticut River Valley. While industrial land use is rare near the river, railroad tracks are commonly found along the banks of both sides of the river and in proximity to the Projects. The primary land uses adjacent to the Project boundaries are recreation, agriculture, and wildlife habitat.

See Section 3.9, *Recreation Resources and Land Use*, for additional information about the recreation resources and land uses within the Wilder, Bellows Falls, and Vernon Project areas.

3.1.5 Major Economic Activities

The primary industry sector in each of the six counties within the Project areas is the educational services/healthcare/social assistance market, accounting for between 29 and 34 percent of total jobs in each of the counties in the area. The next largest industries in each of these counties are manufacturing and retail trade, making up between 9 and 19 percent of total jobs in each county (U.S. Census Bureau, 2014a). The Cheshire Medical Center and Dartmouth Hitchcock Clinic-Keene in Cheshire County employs 1,200 persons, while the Dartmouth Hitchcock Medical Center/Hitchcock Clinic employs 6,900 people in Grafton County. Dartmouth College employs 3,200 people in Grafton County as well. In Sullivan County, the largest employer is Sturm Ruger & Co., a sporting firearms company, which employs 1,455 people (NHES, 2016). In Vermont, the Veterans Administration Hospital and the Community College of Vermont also support a number of jobs (Hartford Chamber, 2016). VY formerly employed approximately 600 people; however, since commercial operation of the facility ended in December 2014 and as it is currently being decommissioned, employment at VY has decreased substantially. See Section 3.12, *Socioeconomics*, for additional information about the economy with the Wilder, Bellows Falls, and Vernon Project areas.

3.2 Scope of Cumulative Effects Analysis

3.2.1 Cumulatively Affected Resources

According to the Council on Environmental Quality's regulations for implementing NEPA (40 C.F.R. 1508.7), a cumulative effect is the effect on the environment that results from the incremental effect of the action when added to other past, present and reasonably foreseeable future actions, regardless of what agency (federal or non-federal) or person undertakes such other actions. Cumulative effects can result from individually minor but collectively significant actions taking place over a period of time, including hydropower and other land and water development activities.

FERC issued SD2 on April 15, 2013, which identified the cumulative effects to consider in its environmental analysis of the Wilder, Bellows Falls, and Vernon Projects as well as FirstLight's Turners Falls (Project No. 1889) and Northfield Mountain (Project No. 2485) Projects located downstream of the Vernon Project on the Connecticut River.

> Based on information in the Pre-Application Documents and staff analysis of the written comments submitted from agencies and other stakeholders on the SD1 document and comments from the January 2013 public scoping meetings, we identified the following resources that may be cumulatively affected by the proposed operation and maintenance of the five Connecticut River Projects: water quality and quantity[18] (including power generation), fishery resources (including anadromous and catadromous fish and fish passage), floodplain communities, freshwater mussels, sediment movement, recreational uses, and rare, threatened, and endangered species (FERC, 2013).

The geographic and temporal scope of the cumulative effects analysis, including past, present, and reasonably foreseeable future actions considered in the analysis for these resources, is summarized below.

3.2.2 Geographic Scope of Analysis for Cumulatively Affected Resources

The geographic scope of analysis for cumulatively affected resources defines the physical limits or boundaries of the proposed Project operations and maintenance under new licenses. Because the proposed actions (e.g., continued operation of the Projects) would affect different resources differently, the geographic scope for each resource may vary.

In SD2, FERC describes the geographic scope for cumulatively affected resources and Great River Hydro has included this geographic area in the cumulative effects

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[18] From FERC SD2: Water quantity is defined as flow magnitude, flow frequency, flow duration, flow timing, and rate of change.

analysis for these resources as applicable to the Wilder, Bellows Falls, and Vernon Projects. In addition to these three Projects and the two FirstLight Projects that are the subject of FERC's cumulative effects analysis, 10 additional mainstem dams on the Connecticut River and tributary dams are located throughout the watershed (Section 3.1.1.3, *Dams*). Collectively, all of these dams as well as the myriad other non-dam-related activities and resource uses within the river corridor and watershed cumulatively affect the resource areas identified by FERC.

3.2.3 Temporal Scope of Analysis for Cumulatively Affected Resources

The temporal scope of the cumulative effects analysis includes past, present, and reasonably foreseeable future actions and their effects on each cumulatively affected resource. Because the term of new licenses for the Wilder, Bellows Falls, and Vernon Projects is expected to range from 30 to 50 years, the temporal scope of analysis includes reasonably foreseeable actions over that timeframe. Because Great River Hydro is not proposing changes to current Project operations or maintenance at this time, future effects from Project operation, are not expected to change from present conditions over the term of new licenses.

3.2.3.1 Water Quantity and Water Quality

Because of the extensive seasonal storage capacity at Moore impoundment (part of the FMF Project located upstream of the Wilder Project), FERC identified the geographical extent of cumulative effects on water quantity and water quality to include the Connecticut River from the base of Moore dam to the mouth of the Connecticut River at the Sound. FERC chose this geographic area to "recognize the cumulative operational influences of the upstream water storage, and the operations of the five Connecticut River projects on water quantity throughout this area and subsequently on water quality that could occur downstream to mouth of the Connecticut River at Long Island Sound." Section 3.5.3 discusses cumulative effects of the Wilder, Bellows Falls, and Vernon Projects on water quantity and water quality.

3.2.3.2 Migratory Fish Species

Because hydroelectric dams influence both upstream and downstream fish migration within river systems, FERC identified the geographical extent of potential cumulative effects on anadromous, catadromous, and diadromous fish species to include the Connecticut River from the Sound upstream to each species' historical habitat range. Section 3.6.3 discusses cumulative effects of the Wilder, Bellows Falls, and Vernon Projects on migratory fish species that occur within the Project areas.

3.2.3.3 Resident Fish Species, Freshwater Mussels, and Sediment Movement

FERC identified the geographical extent of cumulative effects on resident fish species, freshwater mussels, and sediment movement to include the upper extent of the Wilder impoundment downstream to the Route 116 Bridge in Sunderland,[19] Massachusetts. FERC chose this geographic area because "the operation of the five projects could be a contributing factor to sediment movement within the river and cumulative effects on resident fisheries and freshwater mussel habitat in this area." Section 3.6.3 discusses cumulative effects of the Wilder, Bellows Falls, and Vernon Projects on resident fish species and freshwater mussels that occur within the Project areas. Section 3.7.3 discusses the cumulative effects of the Projects on the federally endangered DWM, and Section 3.4.3 discusses cumulative effects of the Projects on sediment movement.

3.2.3.4 Terrestrial and Floodplain Communities

FERC identified the geographic scope of cumulative effects on terrestrial and floodplain communities to include the 100-year floodplain (as defined by the Federal Emergency Management Agency) adjacent to the Project-affected areas from the upstream extent of the Wilder impoundment downstream to the Route 116 Bridge in Sunderland, Massachusetts. FERC chose this geographic area because the operation of the five projects, "in combination with other land uses in the Connecticut River Basin, may cumulatively affect floodplain communities adjacent to project impoundments and downstream riverine reaches in this area." Section 3.7.3 discusses cumulative effects of the Wilder, Bellows Falls, and Vernon Projects on terrestrial and floodplain communities that occur within the Project areas.

3.2.3.5 Recreation (Multi-day Paddle Trips)

The presence of multiple dams on the Connecticut River may cumulatively affect multi-day paddle trips. In its SD2, FERC identified the geographic scope of the cumulative effects on recreation for multi-day paddling trips on the Connecticut River as extending possibly as far upstream as Murphy dam (RM 383) in Pittsburg, New Hampshire, where the natural riverine reaches become navigable (CRWC, 2007; American Whitewater, 2013) and downstream to the Holyoke dam, the most downstream dam, in Holyoke, Massachusetts. Section 3.9.3 discusses the cumulative effects of the Wilder, Bellows Falls, and Vernon Projects on multi-day paddling trips on the Connecticut River within the Project areas.

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[19] From FERC SD2: The Route 116 Bridge is located at the approximate upstream extent of the Holyoke Project impoundment.

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3.3 Great River Hydro Proposed Operation Overview of Environmental Effects

Great River Hydro's proposed operation is based on a concept that significant environmental protection can be achieved much of the time without sacrificing limited but very important, energy, capacity, and ancillary resources that are critical to the regional power grid at times of year or when certain power system conditions require it. Proposed operations would provide environmental protection through an Inflow equals Outflow (IEO) operation the majority of the time and discretionary generation for a limited number of hours each month (between 1.4 and 9 percent of the total hours in a month), fewer hours in the April-October period, and more in the late fall-early spring months. That distribution would protect critical aquatic resource sensitive months between April and September and allow for more hydro operational flexibility during the less sensitive winter months, often dormant periods for many aquatic resources.

Environmental effects of the proposed operation were evaluated using a combination of an hourly time-step spreadsheet simulation model, the Study 5 Operations model, recent hydrologic datasets, and historic operations data. Between March and November 2020, Great River Hydro consulted with relevant state and federal resource agencies and participating non-governmental organizations (collectively referred to as proposal stakeholders). Numerous meetings and discussions were held between March and November 2020 in which analysis, evaluation and responses to data requests were exchanged between Great River Hydro and stakeholders. Great River Hydro provided evaluations for stakeholders to gain better understanding of how the proposal would function and reach a level of confidence its ability to provide significant resource protection necessary to support it as the proposed operation scenario in this application (see Exhibit B, Section 1.3).

The evaluations compared actual historic operation at the three projects with simulated IEO operation and IEO/Flexible Operation using the same inflow from a representative set of calendar years the accounted for high, high-medium, low-medium, and low water and corresponding energy generation as well as the corresponding energy clearing price for each hour. Those years were 2009 (high), 2017 (high-medium), 2014 low-medium and 2015 low) of water the years 2009 (high). Because of the manual, intensive labor associated the spreadsheet simulation model, representative months were selected for evaluation and comparison purposes representing the maximum number of available hours for flexible operation: February (65); June (10); August (20); November (42 hours; maximum of 15 between Nov 1 and Nov. 15).

Initially, the simulation process routed inflow (through) the 46-mile Wilder Project and discharges IEO in one case, and IEO plus Flexible operation (using allocated hours) in a second case. Flex hours were generally selected based upon available inflow, proximity to the Target WSE and higher energy prices than subsequent hours. The Wilder Project discharge is routed downstream through the 17 miles of riverine habitat and the 26 miles of the Bellows Falls Impoundment. Similarly, the routed inflow arriving at the Bellows Falls dam was discharged in the IEO operation case, and in the second case passing IEO plus available flexible operation hours if it made economic sense to do so. The discharge was routed downstream using the Study 5 operations model as it is much more realistic and sophisticated in terms of routing functionality and adding intermediate inflows at various downstream points below the dam.

It must be pointed out that the simulation model provided valuable insight and knowledge related to what would result from a decision to use a flexible operation hour. The transition requirements and specifications stipulated in the Great River Hydro operations proposal for up-ramping, down-ramping and refilling impoundment to the Target were adhered to in the simulation. Simulating flexible operation together with the Transition operation requirements would indicate whether the gain in energy value over the amount derived from IEO, was greater than the energy value lost in comparison to IEO due to refilling the impoundment to the Target WSE by discharging 70 percent of inflow. Because the decision making process was in the hands of the simulation operator, running the simulation on an hour-to-hour decision basis, it is likely that the simulation did not always determine or produce the absolute best solution to capitalizing on both available inflow and energy price. Due to the fact that forward-looking inflow and energy prices were "visible" in the simulation spreadsheet, Great River Hydro believes that the simulation may have inflated or overstated flexible operation opportunity. In real-time operation of the project under the proposed operation, one would not have this degree of perfect foresight, rather would have to rely on forecasting and inflow prediction to make such decisions. Therefore, the evaluation of project operation using the model must be considered weighted in the worst-case direction as opposed to being overly conservative.

Many of the resource specific evaluations or analyses desired by the proposal stakeholders and Great River Hydro relied on the WSE nodal results at various locations within each impoundment or below the dam in riverine reaches. The nodes and node-specific flow-to-WSE relationship originates from the Study 4 HEC-RAS model cross-sections and has been used in many of the resource studies performed in this relicensing effort. To ensure accurate nodal WSEs, the routed flow need to accurately reflect attenuation and intermediate tributary and riparian drainage area inflow into the 46-mile long Wilder impoundment, the 26-mile long Bellows Falls and Vernon impoundments, as well as the 17 and 6-mile long sections of non-impounded river downstream of Wilder and Bellows Falls projects. To calculate WSE's above each dam impoundment and riverine sections, multiple iterations of a 3-stage process were required. For example, to accurately determine WSE's with the Wilder impoundment based on the attenuated inflow affected by the Wilder project operation, one had to first create an attenuated inflow routing through the Wilder impoundment to the dam based on the stable Target WSE elevation (mimicking IEO) using the Study 5 model. The IEO/Flexible Operation simulation spreadsheet model was utilized to determine how the WSE at the dam might deviate from the Target WSE (under constant IEO) due to Flexible Operation hours. The WSE at the dam dataset that would show the change in WSE at the dam when flexible operation, together with up-ramping and down-ramping, would discharge flow in excess of inflow and draw down the impoundment which would then subsequently rise during the refill period. The Wilder discharge from the simulation run would be routed and attenuated downstream to the Bellows Falls dam. The previously developed attenuated inflow to the Wilder dam and the WSE data set at Wilder reflecting the simulation of IEO and Flexible Operation would then be inputs into the Study 5 model to produce nodal WSE's within the Wilder impoundment. The same process was repeated again for the river reaches and impoundments above Bellows Falls and again for the same above Vernon dam. No attenuated flow or nodal WSE analysis was performed for the 1.5-mile portion below Vernon as it is also affected by the Turners Falls and Northfield Pumped Storage Projects owned and operated by FirstLight Energy.

Because of the amount of effort required to produce accurate nodal WSE's and the challenge associated with comparing actual historic operations that reflect potential unit or station outages with simulated IEO and IEO/Flexible Operations that was absent any unit or station outage, the proposal stakeholders identified, based on outage information provided by Great River Hydro, specific months and years to compare. They represented the spectrum of allowable Flexible Operation hours as well as normal-dry hydrologic conditions. The months-years selected were August 2015, February 2009, November 2017, and June 2016. The proposal stakeholders requested Great River Hydro simulate IEO and Flexible Operations for the month of June 2016 as it was more representative of a low flow June then all of the other previously selected simulation years and therefore would better identify potential resource impacts.

For comparing current operations, representing the no-action alternative, and the proposed operations, in this section we selected 2015 (low water year) and 2009 (high water year) to illustrate the differences between months within the same year. For 2015, project operation in the winter simulation month of February was affected by more than simply unit outages. A substantial portion of the month of February, Vernon station was absent up to 4 units due to planned maintenance. However, February 2015 was also one of the coldest average months in recent years. Temperatures averaged 7.8°F, the coldest month in a 2008-2020 period of record and 14.6° colder than the monthly mean (National Weather Service, 2020). Extremely cold temperatures require hydro stations, particularly Vernon and Bellows, to operate continuously to provide adequate heating in the powerhouse. Such was the case in February 2015 and the historic data indicate that Vernon and Bellows Falls station maintained continuous generation discharge through February at approximately 4,500 and 3,400 cfs, respectively.

While the perfect foresight nature of the simulation model is an important consideration relative to whether or not each flexible operation decision or event would likely take place given a more realistic reliance on inflow and price estimates and forecasting, it would only serve to inflate the number of flexible operation hours rather than understate them. Through the combined use of the Study 5 operations model to attenuate flow routing and determine nodal WSE information, Great River Hydro believes the WSE information to be accurate in terms of evaluation and determining potential effects on aquatic resources due to the Great River Hydro proposed operation. With all the above information developed by Great River Hydro, and the independent analysis performed by the Proposal Stakeholders, both parties were able to developed the specificity, detail and language associated with the final Great River Hydro alternative operations outlined in Exhibit B, Section 1.3; Exhibit E, Section 2.2.1; and included with evidence of proposal stakeholder support in Appendix B-1.

3.3.1 Impoundment Environments

Great River Hydro's proposed operation described in Section 2.2 will result in significant improvements to environmental conditions in impoundment reaches when compared to the no-action alternative. Changes include increased stability of WSEs (decreases in frequency, duration, and range of impoundment WSE fluctuation), and changes in flow and velocity through the impoundments.

Each change will influence responses by aquatic-dependent species. Species-specific effects from proposed operation are discussed later in this exhibit; this section describes the hydrologic attributes of the proposed flows and compares them to attributes under current conditions. As Section 2.2 notes, under current (non-spill) conditions, proposed operation is characterized by two individual elements: (1) discharging station flow equal to inflow (IEO), and (2) discretionary flexible and transition operations, in which discharge can exceed inflow or be reduced under IEO to allow transition-related impoundment refill.

Many impoundment hydrologic attributes and species responses would be affected in a positive manner by proposed operations. The more stable WSE at the Project dams in combination with generally much smoother and higher base inflow as a result of discharge from the three stations, are expected to improve habitat conditions. Effects of the proposed operation at the Wilder Project will carry-over into the Bellows Falls Project, although attenuation of flow and WSE changes over the 17-mile Wilder riverine reach plus any tributary flow will affect inflow into the Bellows Falls Impoundment. Similarly, the proposed operation at the Bellows Falls Project will likewise influence downstream conditions in the Vernon Project.

3.3.1.1 Water Surface Elevations

Stability in WSEs

Proposed operation will provide a more stable environment in project impoundments by maintaining impoundments at a Target WSE by discharging inflow at the dam. Flexible Operation will result in discharge above or below inflow as well as lower impoundment WSE at the dams, but much less frequently and to a much lesser extent than the no-action alternative, where discharge was often not equal to inflow resulting in either a rising or falling WSE. Proposed operation will not alter inflows into the Wilder impoundment, and as a result WSEs in the upper portions of the Wilder impoundment will continue to be affected by upstream projects. Stability in WSEs in most impoundment reaches associated with the projects is expected to benefit many aquatic species, especially fish that are known to spawn in shallow water. As noted above, WSEs in the upper reaches of each impoundment are highly influenced by inflow, and less so by dam management, whereas dam operations will exert more effect in the lower reaches of impoundments. WSEs in the upper portions of the Bellows and Vernon impoundments will benefit from the higher average base flow and the smoother and less frequent change in discharge flows due to the proposed operation. Very high flows exceeding project capacity will affect impoundment WSEs beyond the control of dam operations. Current high flow water management, or reservoir profile operation, when flows are substantially above station capacities, will continue in a similar manner as the no-action alternative.

The proposed flow regime will focus on maintaining and managing to WSE Target WSE requirements for each impoundment: 384.5 ft for Wilder Impoundment, 291.1 ft for Bellows Falls Impoundment, and 219.6 ft for Vernon Impoundment. Note that WSE management under current operations does not include a specific elevation goal; instead WSEs are maintained within a specified range. Nevertheless, comparison of WSEs under current vs. proposed flow regimes will illustrate the increased stability of WSEs under IEO and Flexible Operations. In 2009, a high flow year, current operations represented by historic operations data resulted in a wide range of WSEs in each impoundment, with very little time at or within 0.1 ft of the Target WSEs stipulated under proposed operations in most months and impoundment reaches. Target WSE only occurred between 1 and 10 percent of time, with lowest percentages in Wilder and highest in Vernon (Table 3.3-1). Percentages were slightly higher in a low flow year (2015), but most percentages remained less than 15 percent, except in Vernon. In contrast, under proposed flows, the Target WSE is achieved in both 2009 and 2015 simulations 47 to 100 percent of the time. Figure 3.3-1 shows WSEs in each impoundment in 2009 and 2015 combined across all 4 months (see Table 3.3-1 for monthly percentages). The IEO/Flex data are based on spreadsheet simulations and, as noted above, do not reflect profile operation (reducing WSE at the dam when flows significantly exceed station capacity), whereas the “current” values are based on historic data and account for profile operation. This appears as current data at the lower WSE range in the charts (e.g., below 382 ft at Wilder, 289.6 ft at Bellows, and 218.3 ft at Vernon). Discounting the High Water Operation related WSE at the left side of the graphs, there is clear evidence that IEO Operation will maintain WSE at the dams at higher elevations within a narrower bandwidth more often than current operations.

In addition to maintaining and managing around Target WSE, proposed operations include special WSE management provisions. During the fall months in the Wilder and Bellows Falls impoundments, lowering the Target WSE for several weeks will limit potential dewatering of DWM as they move into overwintering habitat (see Section 3.8.2.5). Additional DWM protection is provided in the Bellows Falls impoundment from June through September by reducing the Flexible Operating WSE Range by 0.5 ft.

Table 3.3-1. Percent of time impoundment WSEs are within 0.1 ft of proposed Target WSE.

Impoundment	Target WSE ft	Year	Flow Scenario	% of Time at Target WSE (±0.1 ft) Feb	June	Aug	Nov
Wilder	384.5	2009	Current	0.3%	0.1%	4.0%	0.4%
			IEO/Flex	55.2%	91.4%	86.0%	79.6%
		2015	Current	5.8%	0.6%	12.5%	16.4%
			IEO/Flex	70.7%	96.4%	88.0%	75.3%
Bellows Falls	291.1	2009	Current	0.4%	1.1%	2.4%	5.7%
			IEO/Flex	62.5%	92.6%	93.7%	94.7%
		2015	Current	2.7%	0.7%	5.0%	10.4%
			IEO/Flex	55.4%	96.1%	85.8%	50.8%
Vernon	219.6	2009	Current	5.2%	9.9%	11.4%	8.5%
			IEO/Flex	63.1%	100%	87.9%	91.5%
		2015	Current	20.2%	31.5%	25.5%	22.7%
			IEO/Flex	46.6%	96.3%	85.6%	76.3%

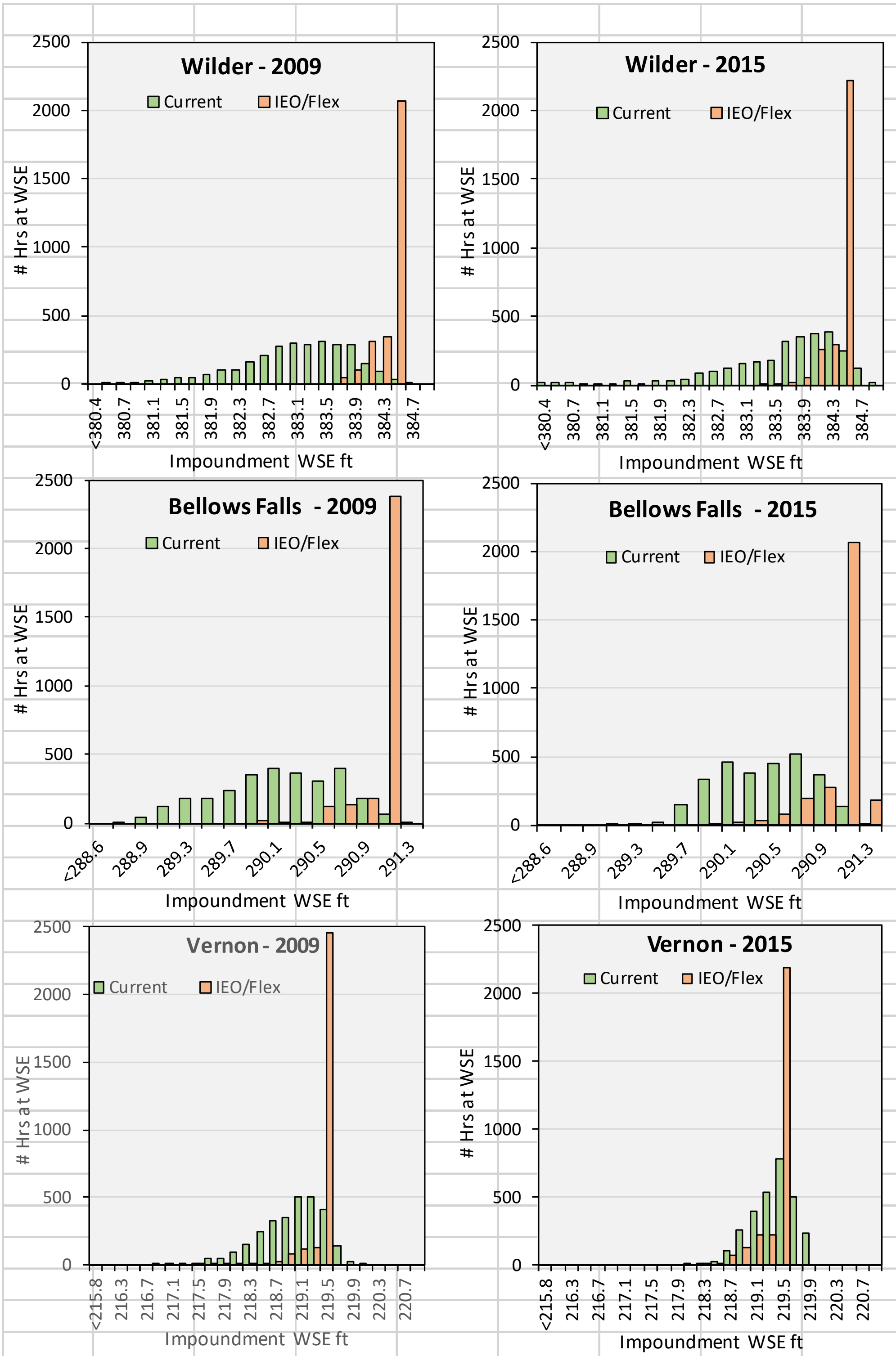

Figure 3.3-1. Number of hours at given WSEs by reach and year (all 4 months combined) according to flow scenario. Note: data may include WSEs under spill conditions.

WSE Fluctuations

Frequency of WSE Fluctuations at Project Dams

Under the proposed flow regime, the frequency of WSE fluctuations due to current (non-spill) dam operations will be dictated by the number of Flexible Operation hours (Section 2.2.1), ranging from 9 percent of the hours in December, January, February, and March to as few as 1.4 percent of the hours in April and May. Current operations have no such limitation on when and how often the generation can be increased. Frequency of WSE changes is expected to decrease substantially under the proposed flow regime because the primary means of insuring inflow equals outflow is through maintaining the Target WSE. This expectation is further described under Section 3.3.2.2 (*Frequency and Magnitude of Flexible Operation*), since the frequency of daily fluctuations in dam discharges (other than to match inflow) will directly result in fluctuations in impoundment WSEs.

Magnitude of WSE Fluctuations at Project Dams

Another measure of WSE stability involves assessing the daily magnitude (or, amplitude) of WSE fluctuations in the vicinity of each project dam (Table 3.3-2). In the Wilder Impoundment, daily WSE changes averaged from 1.03 ft to 1.67 ft under current conditions in both years, whereas the simulation results for IEO/Flexible Operation produced results in which WSE changes were between 0.07 ft and 0.4 ft. Change in WSE under current operations in the Bellows Falls and Vernon impoundments were also significantly greater than IEO/Flexible Operation, although the range of mean daily change varied between 2009 and 2015.

The one aberration in this pattern appears at Vernon in February 2015. However, as described above, the simulation did not reflect any unusual circumstances that actual historic data would reflect. In 2015, a combination unit operation to produce station heat and unit outages related to maintenance resulted in more stable continuous generation than in typical years. Vernon also operates units continuously to produce station heat during extended cold periods. Monthly mean temperatures for Southeastern VT were approximately 8°F (lowest mean between 2000-2020) in February 2015 versus a 20-year average of 22.4°F. Major headgate repair and annual inspections required shutdown of 4 of the station’s 10 generating units for approximately half the month of February 2015. This appears to have limited peaking and resulted in higher than typical sustained discharge than other years, maintaining flow above 4,000-5,000 cfs for most of the month. Figure 3.3-2 clearly shows the large difference in distribution of maximum daily changes in impoundment WSE between current operation or the no-action alternative and the Great River Hydro Proposed Operation, with a much higher frequency of minor (<0.2 ft) fluctuations and a much lower frequency of larger (>0.5 ft) fluctuations under the proposed flow scenario.

The reduction in magnitude of WSE fluctuations under the proposed operation would benefit all shallow-water fish spawners in both mainstem impoundment and backwater habitats, including fallfish, smallmouth bass, sunfish, northern pike, pickerel, and cyprinids, as well as DWM and other mussel species occupying reservoir habitats. Increased WSE stability is also expected to benefit other aquatic-dependent resources, such as cobblestone tiger beetle and odonates.

Table 3.3-2. Mean daily magnitude of WSE changes in impoundments.

		Flow	Mean Daily Change in Impoundment WSE (ft)			
Impoundment	**Year**	**Scenario**	**Feb**	**June**	**Aug**	**Nov**
Wilder	2009	Current	1.50	1.35	1.57	1.67
		IEO/Flex	0.40	0.07	0.15	0.25
	2015	Current	1.14	1.16	1.20	1.03
		IEO/Flex	0.28	0.07	0.12	0.30
Bellows Falls	2009	Current	0.99	1.00	1.10	1.21
		IEO/Flex	0.40	0.11	0.09	0.05
	2015	Current	0.73	0.59	0.86	0.94
		IEO/Flex	0.47	0.05	0.17	0.33
Vernon	2009	Current	1.43	0.89	0.87	1.05
		IEO/Flex	0.47	0.00	0.25	0.11
	2015	Current	0.45[a]	0.52	0.75	0.81
		IEO/Flex	0.65	0.08	0.23	0.38

a. Not representative of typical historic operation due to extreme low temperatures requiring Vernon generation to operate continuously for station heating as well as numerous unit maintenance outages.

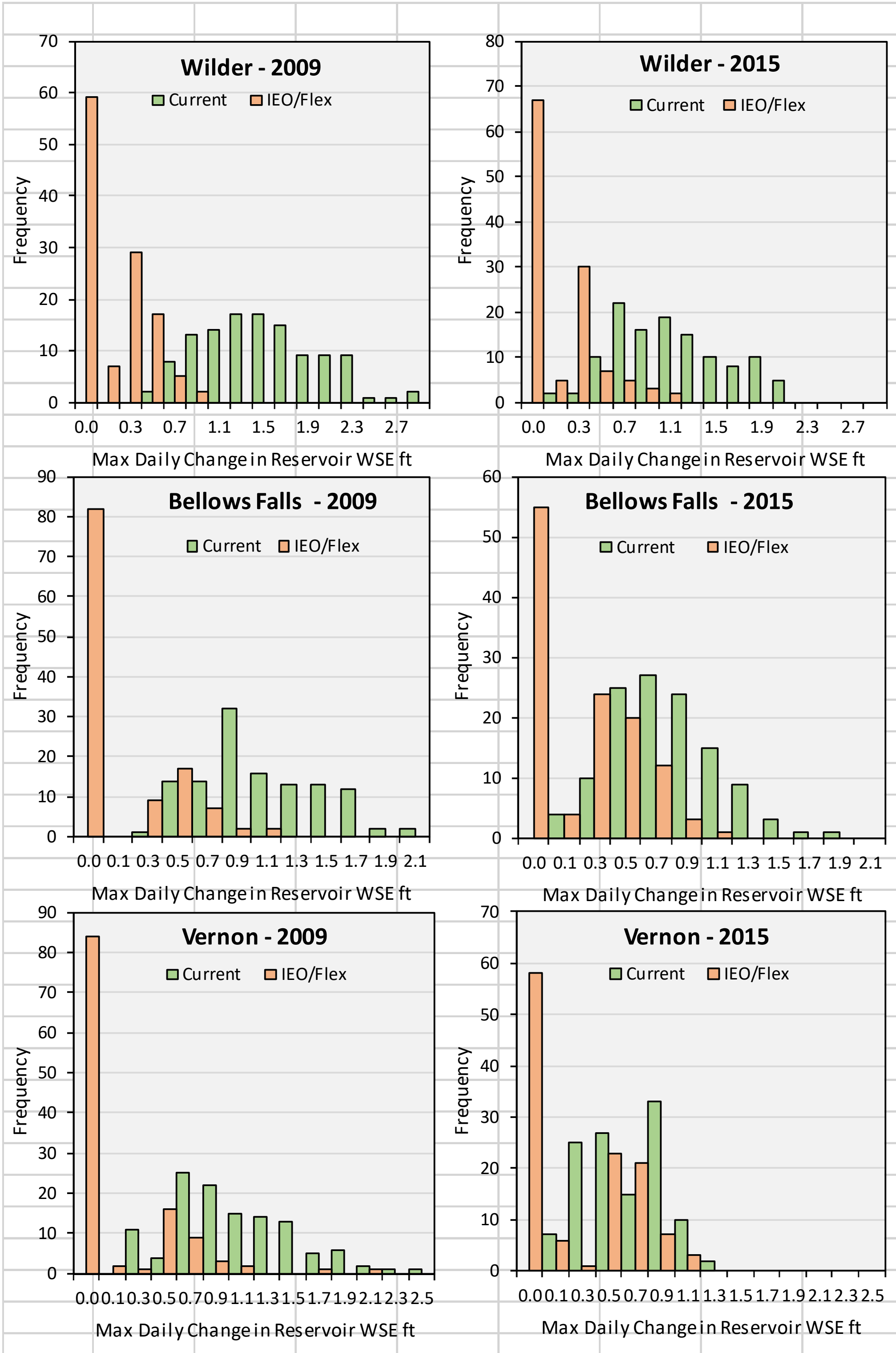

Figure 3.3-2. Magnitude of daily WSE fluctuations in the Wilder, Bellows Falls, and Vernon Impoundments in 2009 and 2015 (all 4 months combined) according to flow scenario.

High Water Profile Operations

The high flow profile operations and associated WSE criteria described in Section 3.1 would remain unchanged under the proposed flow scenario.

3.3.1.2 Velocity Characteristics within Impoundments

Under proposed operations, minor insignificant changes in velocity distributions are expected within project impoundments in comparison to the no-action alternative. Inflow into the Wilder impoundment will not be affected or modified by the proposed operation. For Bellows Falls and Vernon impoundments, the base low flow will be greater because the proposed operation requires a base flow greater than current minimum flows and typically flows will be greater, during to Transition Refill when 70 percent of inflow at the dam must be passed. Other than those two limited circumstances, inflow into these impoundments due to upstream station discharge will either match inflow at the upstream dam or be greater.

Maintaining impoundments at the Target WSE would likely reduce variation in mid-lake velocity patterns. Changes in station discharge may result in minor changes in near-dam velocities; however, most changes would be related to adjusting discharge to match inflow so the most common changes would be small. Flexible Operations can significantly increase discharge over inflow, but the degree of change is tempered by Transition Up-Ramp and Down-ramp Operation as well as Flexible Operation Maximum Discharge limits, which are based upon the rate of inflow. The maximum station discharge will remain unchanged from the no-action alternative; however, the frequency, occurrence, and duration of maximum station discharge will be greatly reduced, particularly from April through November. As a result, resource exposure to the maximum station discharge velocity will be significantly less than current project operation. The proposed operation will not affect the ability to moderate or reduce seasonal runoff or precipitation-related high flows; therefore, natural high flow will continue to remain as the dominant causal agent for higher velocities within impoundments.

3.3.2 Riverine Environments

The proposed operation described in Section 2.2 will result in significant improvements to environmental conditions in riverine reaches affected by project operations when compared to the no-action alternative. Changes include flows largely matching inflow on an instantaneous basis, higher average base flow, less significant flow alteration due to limitations on discretionary Flexible Operation, Transitional up-ramping and down-ramping prior to and subsequent to Flexible Operation, Flexible Operation Maximum Discharge limits, and reserved downstream flow provisions during impoundment refill periods.

Each change will influence responses by aquatic-dependent species. Species-specific effects due to the proposed operation are discussed later in this exhibit; this section describes the hydrologic attributes of the proposed flows and compare them to attributes under current conditions. As noted in Section 2.2, under non-spill conditions, proposed operation is characterized by two individual elements: (1) discharging station flow equal to inflow (IEO) (the dominant condition); and (2) discretionary flexible and transition operations (more limited), in which discharge can exceed inflow or be less than inflow during transition-related impoundment refill.

3.3.2.1 Proportion of Time when Inflow Equals Outflow

A dominant component of the proposed operation is to manage the project reaches so that inflows equal outflows to the maximum extent possible. Under the proposed flow regime, IEO is expected to be achieved except during specific conditions, including periods of Flexible Operation and associated Transition Up-ramp, Down-ramp, and Refill, as well as during Emergency and System Operation. Requirements, and Audits (Exhibit B. Operations during Adverse, Mean, and High Water Years and Emergency Conditions). Note that current operations do not include a goal of achieving IEO; nevertheless, comparing how often the proposed flow regime will operate under IEO in comparison to flow characteristics under the current flow regime will illustrate differences in project operation associated with the no-action and the Great River Hydro proposed alternatives.

As expected, the proportion of time when inflow equaled outflow under current operations was very low in all reaches, years, and months (Table 3.3-3). Outflow was within 100 cfs of inflow less than 6 percent of the time under current operations whereas simulation results of the IEO/Flexible Operation were expected to produce IEO conditions at 70 percent to 100 percent of the time in June, August, and November in both 2009 and 2015. Proportion of time at IEO in February ranged from 39 percent to 60 percent, due to variability in inflows and to the increased frequency of flexible operations during that month. The simulation data suggests that the IEO goal can be achieved under the proposed flow regime throughout most of the year.

Table 3.3-3. Percentage of time when inflow equals outflow.

		Flow	% of Hours when Inflow=Outflow (w/in 100 cfs)			
Impoundment	**Year**	**Scenario**	**Feb**	**June**	**Aug**	**Nov**
Wilder	2009	Current	1%	1%	1%	1%
		IEO/Flex	39%	89%	84%	76%
	2015	Current	0%	5%	1%	1%
		IEO/Flex	60%	97%	86%	67%
Bellows Falls	2009	Current	5%	3%	1%	2%
		IEO/Flex	57%	96%	92%	96%
	2015	Current	1%	2%	1%	1%
		IEO/Flex	44%	97%	77%	68%
Vernon	2009	Current	1%	2%	2%	2%
		IEO/Flex	59%	100%	86%	92%

		Flow	% of Hours when Inflow=Outflow (w/in 100 cfs)			
Impoundment	**Year**	**Scenario**	**Feb**	**June**	**Aug**	**Nov**
	2015	Current	9%[a]	3%	1%	1%
		IEO/Flex	40%	96%	81%	72%

a. Not representative of typical historic operation due to extreme low temperature requiring Vernon generation to operate continuously for station heating as well as numerous unit maintenance outages.

3.3.2.2 Frequency and Magnitude of Flexible Operation

Under current project operation during non-spill conditions, station discharge fluctuates, depending upon the inflow, between minimum flow though Unit 3 and dispatch of Units 1 or 2 during single or double peak hours. Under the proposed operation, monthly limits on Flexible Operation (Section 2.2) will dictate how many hours of Flexible Operation may increase the flow in each downstream riverine reach. Simulation of the proposed IEO/Flexible Operation gives an idea of the frequency and magnitude of flexible operations during a high flow (2009) and low flow (2015) water year over four representative months. As previously noted, simulated IEO/Flexible Operations are based on management responses to known inflow and energy pricing, not predictions and forecasts as would be the case in real-time operation. As a result, the results from the simulation are expected to be somewhat inflated in nature and representative of maximum potential Flexible Operations.

The monthly Flexible Operation limits are expected to result in a dramatic reduction in the frequency of station discharge corresponding to daily peaks in energy demand affecting riverine reaches below the dams, during spring, summer, and fall time periods, as represented by June, August, and November simulations (Table 3.3-4). Frequency of Flexible Operation events are also expected to decrease substantially during winter months (see February) in the Wilder riverine reach, although the number of operational flows in winter may not change notably in the Bellows Falls or Vernon reaches. The differences in number of operational flows in spring, summer, and fall between flow scenarios represent reductions of 58-100 percent, and would produce a dramatic change in flow characteristics in the three riverine reaches during periods when aquatic resources are more active and vulnerable.

Table 3.3-4. Frequency of monthly operational flow events in riverine reaches.

		Flow	Frequency of Operational Flow Events			
Project Reach	**Year**	**Scenario**	**Feb**	**June**	**Aug**	**Nov**
Wilder	2009	Current	49	34	30	33
		IEO/Flex	25	5	7	14
	2015	Current	53	19	39	47
		IEO/Flex	15	1	6	13

		Flow	Frequency of Operational Flow Events			
Project Reach	**Year**	**Scenario**	**Feb**	**June**	**Aug**	**Nov**
Bellows Falls	2009	Current	24	29	18	19
		IEO/Flex	25	2	4	4
	2015	Current	34	9	41	41
		IEO/Flex	24	1	11	17
Vernon	2009	Current	39	20	13	20
		IEO/Flex	20	0	4	5
	2015	Current	14[a]	10	35	40
		IEO/Flex	26	1	9	14

a. Not representative of typical historic operation due to extreme low temperatures requiring Vernon generation to operate continuously for station heating as well as numerous unit maintenance outages.

3.3.2.3 Changes in Discharge Characteristics

In addition to reduced frequency of operational flow events, the proposed operation would alter streamflow characteristics below project dams, including flows largely matching inflow on an instantaneous basis, higher average base flow, a subsequent decrease in the magnitude (amplitude) of Flexible Operation flows above the base [IEO] flow; less significant flow alteration due to limitations on discretionary Flexible Operation, Transitional up-ramping and down-ramping prior to and subsequent to Flexible Operation, Flexible Operation Maximum Discharge limits, and reserved downstream flow provisions during impoundment refill periods. All these elements would provide benefits to aquatic resources through development of a more stable riverine environment.

Seasonal Flow Distributions

Managing to Target WSE resulting in station discharge equal to inflow, along with the limits on Flexible Operation, Transitional Operation requirements, and Flexible Operation Maximum Discharge limits, will result in a smoother and more natural flow regime. Figure 3.3-3 shows the distribution of hourly flows in each riverine reach during August of 2015 (*note: this dataset was selected due to the known lack of unit outages in August 2015, which could otherwise mask representative flow distributions*). The difference in flow distributions between current operations, which showed a highly skewed frequency with many low flows and a low frequency but wide distribution of higher flows, versus the proposed flow regime which would result in a more central and normal distribution of flows, is clearly evident. The relative probability of occurrence shown in the exceedance plots also reveal the wide disparity of flow characteristics, with a decline in periods experiencing minimum base flow, a higher incidence of moderate flows, and a much smoother and gradual decline in probability of high flows. Although other months are not portrayed, increases in minimum flows and decreases in Flexible Operation Maximum Discharge flows under the proposed operations, as discussed in the following sections, indicate that this more normalized distribution of hourly flows is expected to occur in other months and years.

Increase in Base Flows

The proposed flow regime will directly result in higher base flows in each of the riverine reaches than is present under current operations. Under the proposed operation during non-spill conditions, the lowest flows below project dams will occur either as a result of matching inflow or will occur during refilling of the impoundments, in which discharge equals no less than 70 percent of inflow per hour until the impoundment WSE achieves the Target WSE (see Section 2.2). Note that the proposed operation also contains a minimum base flow for each project (Section 2.2). The purpose of the minimum base flow is to determine if a Flexible Operation, including flow requirements for Transition Operation will require a refill that would result in a discharge below the minimum base flow. If it would then the Flexible Operation as proposed should be avoided. The minimum base flow is not a protected minimum flow; if inflow were less than the minimum base flow, the proposed IEO operation would pass inflow.

IEO management will have a cumulative downstream effect, as higher minimum flows in the Wilder reach will lead to higher inflow and minimum flows in Bellows Falls, and thence into the Vernon Project. Due to the limits on Flexible Operation and requiring Transitional Operation, discharge from an upstream Project Flexible Operation event will attenuate significantly as it routes downstream. It will not arrive at the downstream dam with similar hydrologic characteristics. The expected increases in minimum daily flows under the proposed flow regime in the Wilder riverine reach an average of about 100 percent in spring, summer, and fall scenarios of both years, with larger increases (200 to 300 percent) in February (Table 3.3-5). Increases in minimum flows are also expected in the Bellows Falls and Vernon riverine reaches, although the differences are less with average increases ranging from 39 to 50 percent. Figure 3.3-4 illustrates the observed and expected distributions of minimum flows in each project riverine reach during the two representative years (data combined over the four months). As noted in the previous section, these figures also illustrate the comparative lack of very low flows and the more normally distributed pattern of minimum flows under the proposed flow regime. Note that the very high minimum flows shown in the figures below are mostly the result of spill conditions, not managed release flows and will not change under the proposed operation.

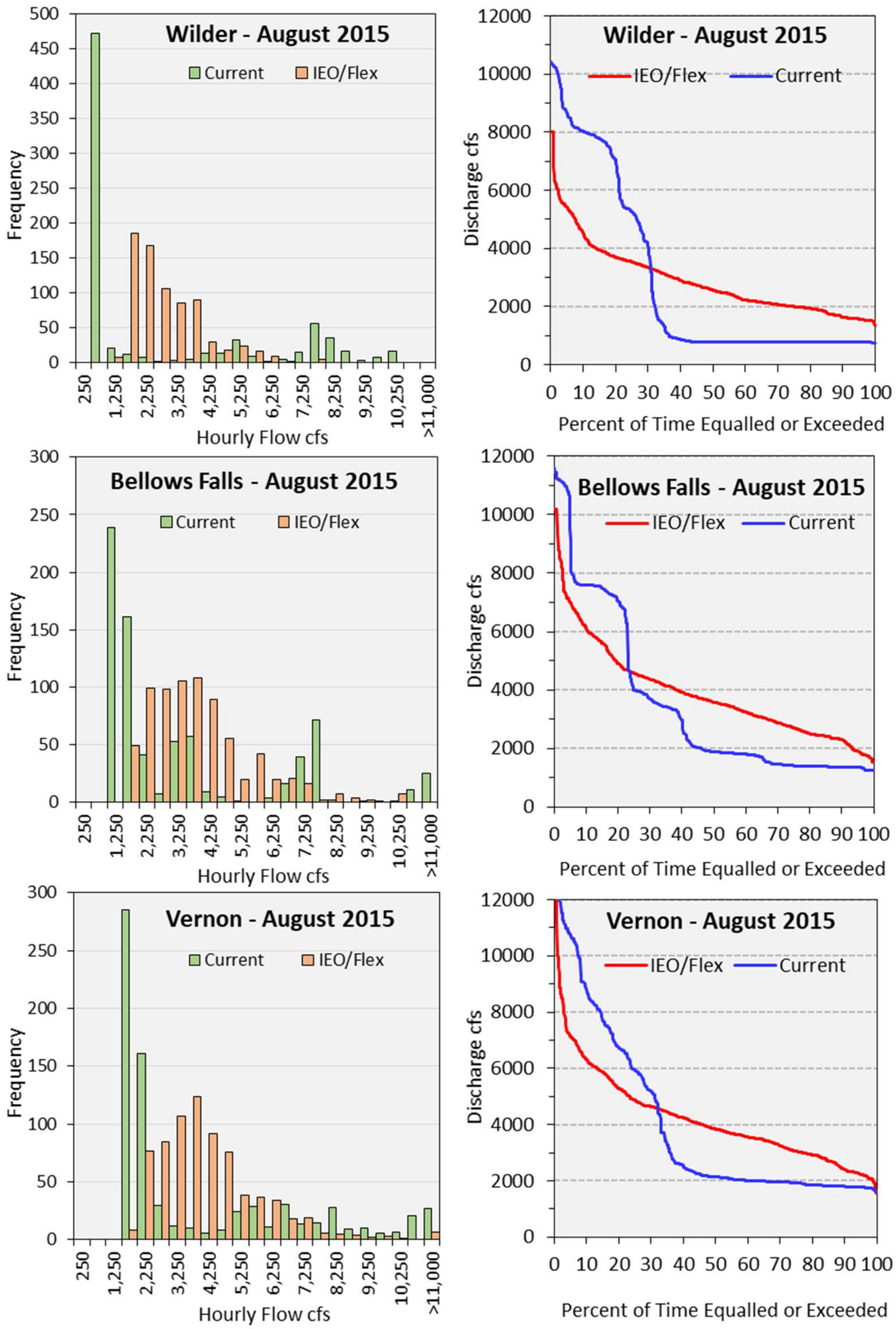

Figure 3.3-3. Frequency distribution and flow exceedance plots of hourly flows in August 2015 according to reach and flow scenario. Note: data may include flows under spill conditions.

Table 3.3-5. Change in mean daily minimum flows in riverine reaches.

		Flow	Mean Daily Minimum Flow (cfs)			
Project Reach	**Year**	**Scenario**	**Feb**	**June**	**Aug**	**Nov**
Wilder	2009	Current	700	1,725	1,660	1,852
		IEO/Flex	2,721	3,530	4,384	4,679
	2015	Current	724	7,866	801	1,360
		IEO/Flex	2,138	9,150	2,071	2,811
Bellows Falls	2009	Current	4,159	5,190	6,029	7,391
		IEO/Flex	4,709	7,048	8,913	10,418
	2015	Current	3,162	12,548	1,500	2,591
		IEO/Flex	3,129	14,476	2,795	4,569
Vernon	2009	Current	2,989	6,128	8,225	8,207
		IEO/Flex	5,049	8,382	10,618	10,967
	2015	Current	4,338*	13,327	1,821	2,796
		IEO/Flex	3,203	14,787	3,170	5,070

*Not representative of typical historic operation due to extreme low temperature requiring Vernon generation to operate continuously for station heating as well as numerous unit maintenance outages.

Decrease in Maximum Flows

Although minimum daily or base flows are expected to increase in all riverine reaches under the proposed flow regime, Flexible Operation Maximum Discharge flows will typically be less than under current operations, due to a number of contributing factors: the Flexible Operation Maximum flow limit, the higher base flow will limit available water, Transitional Operation Requirements less than maximum flow will also utilize available water and require refilling impoundments to Target WSE. The proposed operation (Section 2.2) limits Flexible Operation Maximum Discharge to a maximum of 4,500 cfs when inflows are less than or equal to 1,800 cfs, or to the lesser of either 2½ times the inflow or Maximum Station Discharge Capacity when inflows exceed 1,800 cfs. In contrast, current operations do not restrict the ability to discharge maximum station flow from current, lower minimum flows, and has no Transitional ramping requirements or maximum discharge limits. While under proposed operation there is no reduction in the maximum station discharge capacity, and restrictions do not apply to Emergency and System Operation Requirements, the vast majority of high discharge events will be related to Flexible Operation. Therefore, the aforementioned contributing limiting factors and restrictions, together with limited Flexible Operation Hours will reduce the frequency and occurrence of flows at Maximum Station Capacity in comparison to current operations.

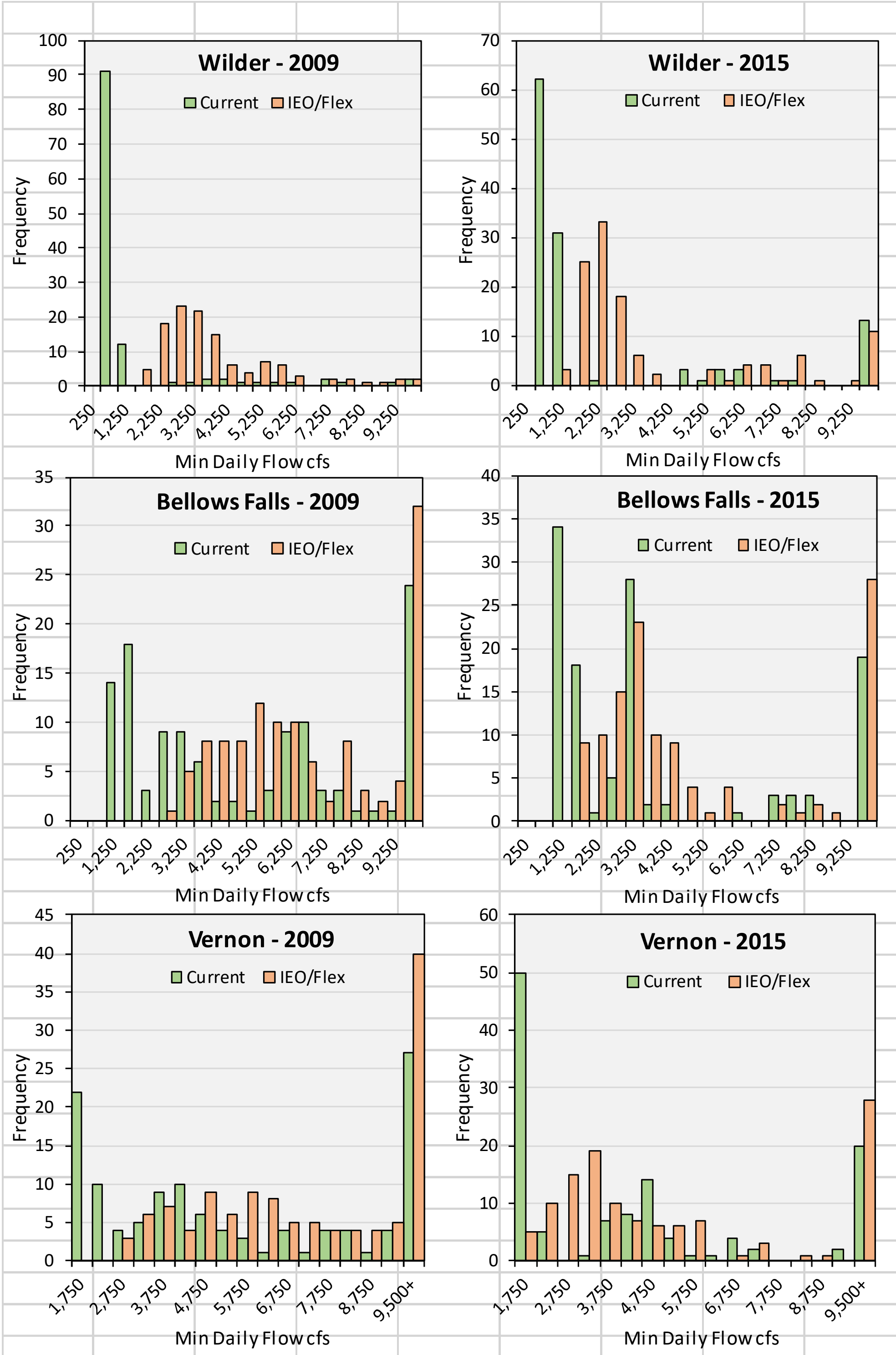

Figure 3.3-4. Minimum daily flows in riverine reaches (all 4 months combined) according to flow scenario. Note: data may include flows under spill conditions.

Decrease in Magnitude of Operations Flows

As a result of increases in the average base flow due to IEO operation and lower frequency and occurrence combined with limitations of maximum flow in Flexible Operation, the magnitude of flow fluctuations in spring, summer, and fall under the proposed flow regime are expected to be roughly 50 percent of the magnitude of flow changes under current operations based on simulation results (Table 3.3-6). As noted for previous metrics, differences between existing and proposed flow characteristics will be less during winter months than during the remainder of the year. Simulation results for February at Bellows and Vernon are overstated as they do not reflect the previously mentioned atypical operation at Vernon (station operation for heating and unit outages), or a similar situation at Bellows Falls, in February 2015. Energy prices and inflow inputs into the simulation model are precise and were considered in Flexible Operation decisions and do not reflect actual uncertainty, variability and forecasting that occurred and affected historic operation decisions. Figure 3.3-5 illustrates the difference in distribution of daily flow changes in each riverine reach in 2009 and 2015 (all 4 months combined), with a higher proportion of small-magnitude changes and a lower proportion of large-magnitude changes (excluding periods of spill) under the proposed flow scenario compared to current operations. Overall, this increase in stability in aquatic habitat, as repeatedly noted above, is expected to provide benefits to many, if not all, aquatic-dependent species.

Table 3.3-6. Mean daily magnitude of flow changes in riverine reaches.

		Flow	Mean Daily Change in Flow cfs			
Project Reach	**Year**	**Scenario**	**Feb**	**June**	**Aug**	**Nov**
Wilder	2009	Current	7,770	7,062	7,437	8,417
		IEO/Flex	4,936	3,143	2,988	3,920
	2015	Current	6,732	5,633	7,612	7,299
		IEO/Flex	3,090	3,636	2,038	2,622
Bellows Falls	2009	Current	3,670	6,014	6,798	7,429
		IEO/Flex	4,934	2,876	3,032	2,676
	2015	Current	3,505	6,448	6,496	6,492
		IEO/Flex	5,465	4,774	3,238	4,144
Vernon	2009	Current	9,061	6,782	6,626	7,492
		IEO/Flex	6,269	2,853	3,828	3,827
	2015	Current	2,312*	6,945	7,165	7,711
		IEO/Flex	7,251	5,222	3,410	5,225

*Not representative of typical historic operation due to extreme low temperature requiring Vernon generation to operate continuously for station heating as well as numerous unit maintenance outages.

Rate of Change in Flow During Operational Flow Events

Transition Operation Up-ramping and down-ramping requirements associated with Flexible Operation are expected to greatly reduce the rapidity and magnitude of both increases and decreases in flow in comparison to current operations. For example, under current conditions there are no up-ramping and down-ramping requirements at the Projects. To illustrate, historic operation data at Wilder dam in 2009 indicate hourly flow changes from 7,000 cfs to over 10,000 cfs occurred in each of the four months. In contrast, under the proposed operation, simulated hourly flow changes in 2009 rarely exceeded 3,000 cfs. Transition Operation ramping and refill limits applied to Flexible Operation will, in addition to attenuation, reduce the magnitude of hourly flow changes in the downstream reaches.

Streamflow Flashiness Index

The reduced number of peaking events and the lower magnitude of daily flow changes under the proposed flow operations leads to a more stable and less “flashy” flow regime. The Richard-Baker Flashiness Index (RBI) is a metric that represents the evenness of flows over a specified time period and under a given flow regime (Baker et al., 2004). The RBI was calculated for each water year, representative month, and flow scenario over both hourly and daily time steps (Table 3.3-7). The hourly-based RBIs are generally 30 to 50 percent smaller under the proposed operations during months representing spring, summer, and fall compared to current operations, but are largely similar during February. Under the daily time step (which is a relatively short time series for this metric), RBIs are also generally smaller for the proposed operations than for current operations, although the differences are less distinct. Comparing the hourly RBIs to the distribution of RBIs based on basin area in Figure 4 of Baker et al. (2004), 50 percent of the RBI scores under current operations appear to fall within the upper-middle or upper quartile (RBI score ~ ≥0.12), whereas 83 percent of hourly RBI scores for the proposed operations appear to fall within the lower or lower-middle quartile, again suggesting a marked improvement in flow stability under the proposed operations.

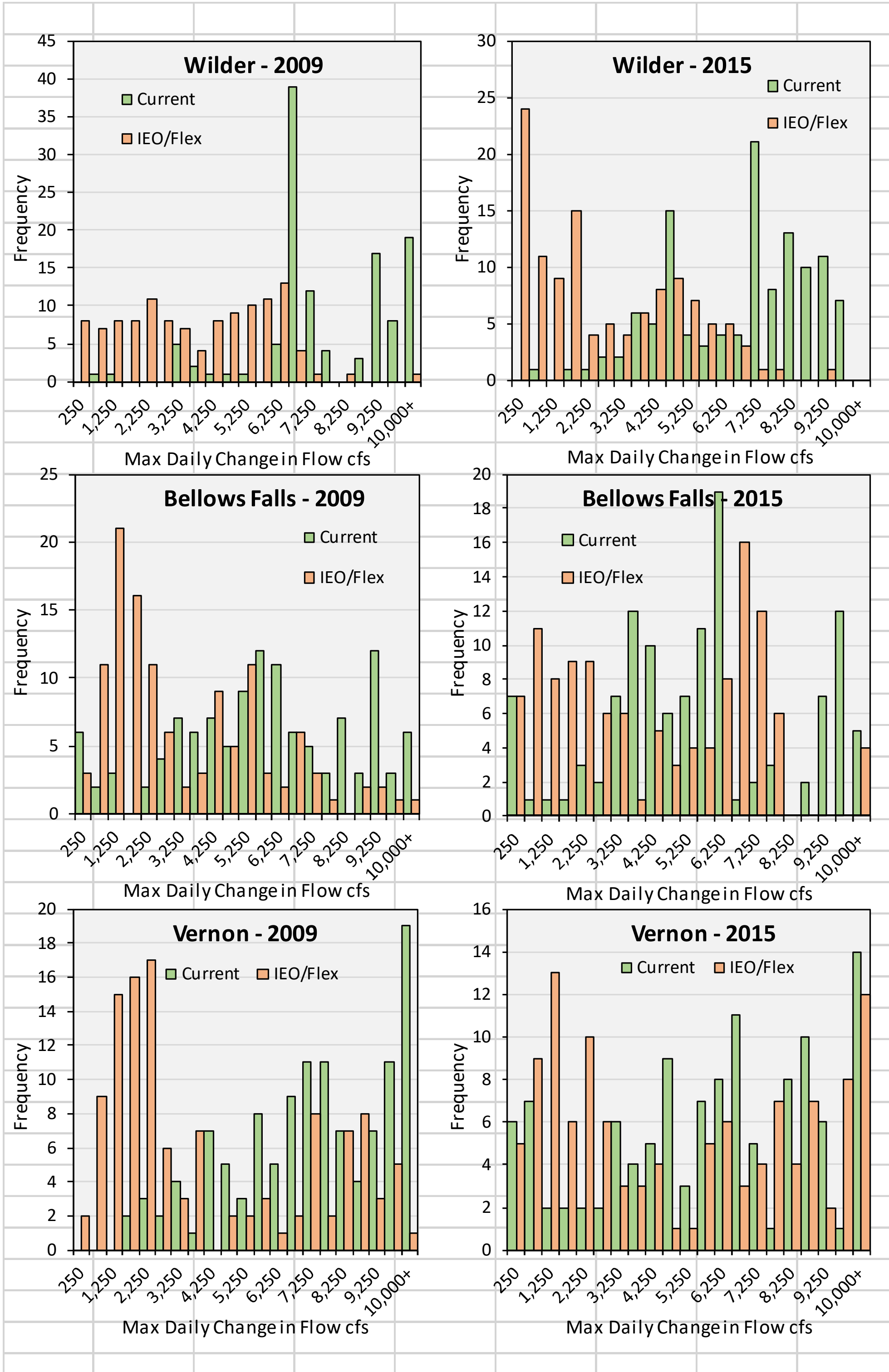

Figure 3.3-5. Mean maximum daily change in flow in each impoundment in 2009 and 2015 (all 4 months combined) according to

flow scenario. Note: many of the largest changes occur during spill events not controlled by the project.

Table 3.3-7. The relative evenness of streamflows in riverine reaches as represented by the Richard-Baker Flashiness Index during hourly and daily time steps.

Project		Flow	Richard-Baker Index (hourly)				Richard-Baker Index (daily)			
Reach	Year	Scenario	Feb	June	Aug	Nov	Feb	June	Aug	Nov
Wilder	2009	Current	0.27	0.14	0.13	0.13	0.18	0.24	0.23	0.20
		IEO/Flex	0.12	0.05	0.05	0.05	0.15	0.20	0.17	0.19
	2015	Current	0.37	0.06	0.28	0.25	0.22	0.22	0.37	0.24
		IEO/Flex	0.09	0.02	0.06	0.06	0.20	0.23	0.28	0.17
Bellows	2009	Current	0.06	0.07	0.06	0.05	0.09	0.20	0.20	0.15
Falls		IEO/Flex	0.08	0.02	0.02	0.02	0.08	0.19	0.16	0.15
	2015	Current	0.11	0.03	0.19	0.14	0.12	0.26	0.35	0.23
		IEO/Flex	0.12	0.01	0.07	0.06	0.19	0.23	0.26	0.15
Vernon	2009	Current	0.14	0.07	0.05	0.05	0.10	0.21	0.19	0.18
		IEO/Flex	0.09	0.02	0.02	0.02	0.11	0.19	0.19	0.17
	2015	Current	0.05*	0.03	0.18	0.14	0.09	0.26	0.25	0.16
		IEO/Flex	0.13	0.01	0.07	0.07	0.21	0.25	0.22	0.15

*Not representative of typical historic operation due to extreme low temperature requiring Vernon generation to operate continuously for station heating as well as numerous unit maintenance outages.

Duration of Flexible Operation

As noted in Section 2.2, a variety of limitations and requirements are associated with Flexible Operation, whereas little to no limitations or requirements apply to operational decisions under current operations. In both cases, general inflow and stream flow levels can often dictate the opportunity and duration of a peaking or discretionary generating level above minimum or base flow conditions. However, under current operation, the base flows are minimum flows, which will in almost every circumstance be lower than IEO flow under the proposed operation. Because the majority of time the project will operate at IEO, the available water for higher generation flow will simply not be available. Transition Operation requirements to up-ramp for the hour preceding the Flexible Operation and, in most cases, at least two subsequent hours of down-ramping, and Re-filling the impoundment to the Target WSE will require water resources prior to and after Flexible Operation that are not required under current operations and represent a volume of water that is also unavailable for discretionary generation given an equal amount of inflow. Another component that affects the duration of Flexible Operation is the requirement to refill the impoundment to the Target WSE. The longer the Flexible Operation occurs, the lower the impoundment is drawn. That translates to a longer refill period when discharging 70 percent of inflow. As a result, the economic impact of generating with only 70 percent of inflow over an extended refill period can detract from the economic benefit associated with the Flexible Operation. Thus, economics also become a factor and serve to reduce the duration of a Flexible Operation.

For illustration, at Wilder in the 2009 simulation, Flexible Operation Hours including the one hour of Transition Operation up-ramping averaged between 3 and 4 hours in length with a maximum of 8 hours. Under current conditions, discretionary high generation flow periods that year averaged about 7.5 hours in length, with many lasting from 15 to 20 hours. Other reaches and years will show similar comparisons, with longer high flow periods under current conditions versus shorter duration Flexible Operation under the proposed operation.

Downstream Attenuation of Streamflows and WSEs

All discharges from Project dams will display attenuation of both flow volume and riverine WSE as flows travel downstream. Such attenuation occurs under current flow operations and would similarly occur under the proposed operations. The level of attenuation will depend on the magnitude of discharge, the rate of change in discharge, distance downstream from the point of discharge, and reach-specific characteristics including channel morphology and tributary inputs. It is expected that the more stable IEO Operations, will result in higher base flows, lower average maximum flows, and the reduced magnitude and duration of high flows under Flexible Operation, plus Transition Operation up-ramping and down-ramping on either end of the Flexible Operation will result in a greater degree of downstream attenuation in flow and WSEs in comparison to current conditions. Increased attenuation will further enhance the stability of the riverine and upper impoundment environments which will benefit aquatic-dependent species.

In conclusion, each of the streamflow metrics described above (seasonal flow distributions, frequency and magnitude of operational flows, changes in minimum and maximum flows, flashiness index, IEO proportion, etc.) illustrate the more stable streamflow environment that will occur in riverine reaches under the proposed operations in comparison to current operations. These changes would be highly beneficial to aquatic-dependent species, particularly during fish spawning, egg incubation, and fry rearing life-stages, as well as terrestrial species such as cobblestone tiger beetles, odonates, and toads.

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3.4 Geologic and Soil Resources

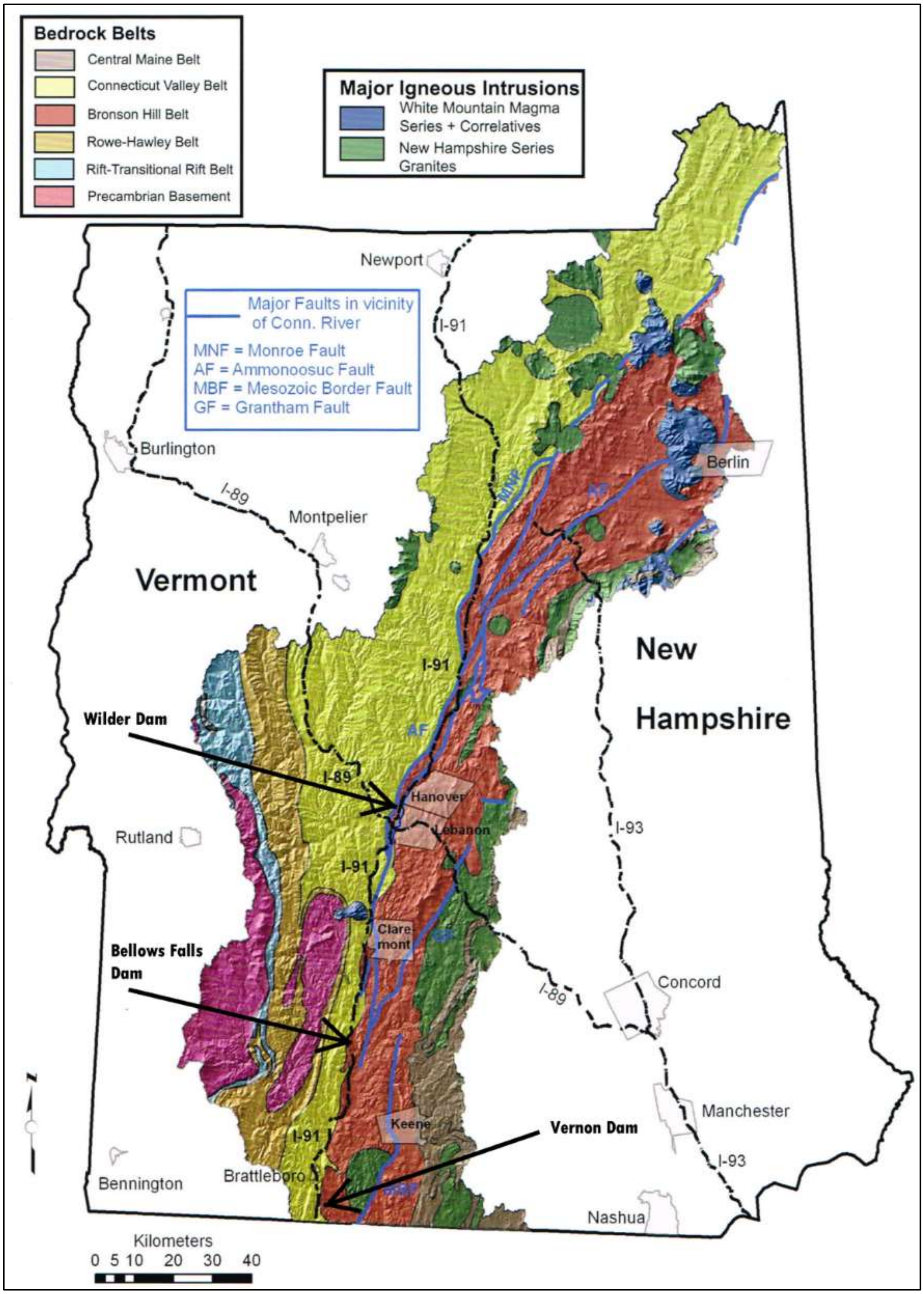
3.4.1 Affected Environment

3.4.1.1 Regional Geology

Bedrock Geology

The bedrock geology in the vicinity of the Wilder, Bellows Falls, and Vernon Projects is broadly similar. The Connecticut River Valley runs along a major tectonic boundary that results in starkly contrasting bedrock geology on either side of the valley (Figure 3.4-1). In the westernmost portion of the watershed in Vermont's Green Mountains are gneisses, marbles, and quartzites that are more than 1 billion years old (i.e., Precambrian Basement) and were originally sediments deposited along the edge of the proto-North American continent known as Laurentia (Van Diver, 1999). This ancient continent began to rift apart (much like the Red Sea rift system today) around 650 million years ago to form a proto-Atlantic Ocean (known as the Iapetus Ocean) into which sediments were deposited to ultimately form the rocks of the Rift-Transitional Rift Belt and Rowe-Hawley Belt in Vermont.

In a reversal of tectonic plate motions around 450 million years ago, the Iapetus Ocean began to close through subduction of the oceanic crust that was formed and attached to the Laurentian continent as a result of the preceding rifting cycle. Similar to the setting of present-day Japan, the partial melting of this subducting Iapetus Ocean crust led to the formation of a volcanic arc now represented by the Bronson Hill Belt in New Hampshire composed of metamorphosed volcanics and granites. Ultimately, through continued subduction, the volcanic arc accreted onto the Laurentian continent at the end of the Taconian Orogeny (i.e., mountain building event) resulting in faulting and metamorphism of both the rocks in the Bronson Hill Belt of New Hampshire and the older rocks to the west in Vermont. Subsequent erosion of the large mountains formed as a result of the Taconian Orogeny shed sediment both to the east and west with the westward directed sediments eventually forming the currently metamorphosed sandstones, shales, and limestones of the Connecticut Valley Belt (Kim and Wunsch, 2009). After almost 50 million years of tectonic quiescence following the Taconian Orogeny, the collision of the Laurentian continent with Avalonia, another ancient continent whose remnants are now primarily found in western Europe, resulted in the Acadian Orogeny that emplaced the granite intrusions of the New Hampshire Series and further faulted, folded, and metamorphosed the preexisting rocks that are now found in the Connecticut River watershed. Further continental collisions between Laurentia and Gondwanaland, an ancient continent whose remnants are now found primarily in Africa, South America, and Antarctica, resulted in the Alleghenian Orogeny from 280 to 300 million years ago and the formation of a single super continent known as Pangea. No rocks from this period are found in the Connecticut River watershed in Vermont and New Hampshire, but the Alleghenian Orogeny did further deform and metamorphose the preexisting rocks.



Source: Brown (2009)

Figure 3.4-1. Bedrock geology in the Project areas.

The breakup of Pangea and ultimate formation of the present day Atlantic Ocean through rifting began approximately 200 million years ago. The White Mountain Series granites formed at this time with the rifting also responsible for the formation of the north-south trending Ammonoosuc Fault that exerts a strong control on the orientation of the Connecticut River Valley from north of the Wilder impoundment to south of Bellows Falls dam. Faults and other fractures in the bedrock formed during the earlier orogenies also control drainage trends in the watershed, especially the rectilinear drainage networks characteristic of many of the river's tributaries in Vermont.

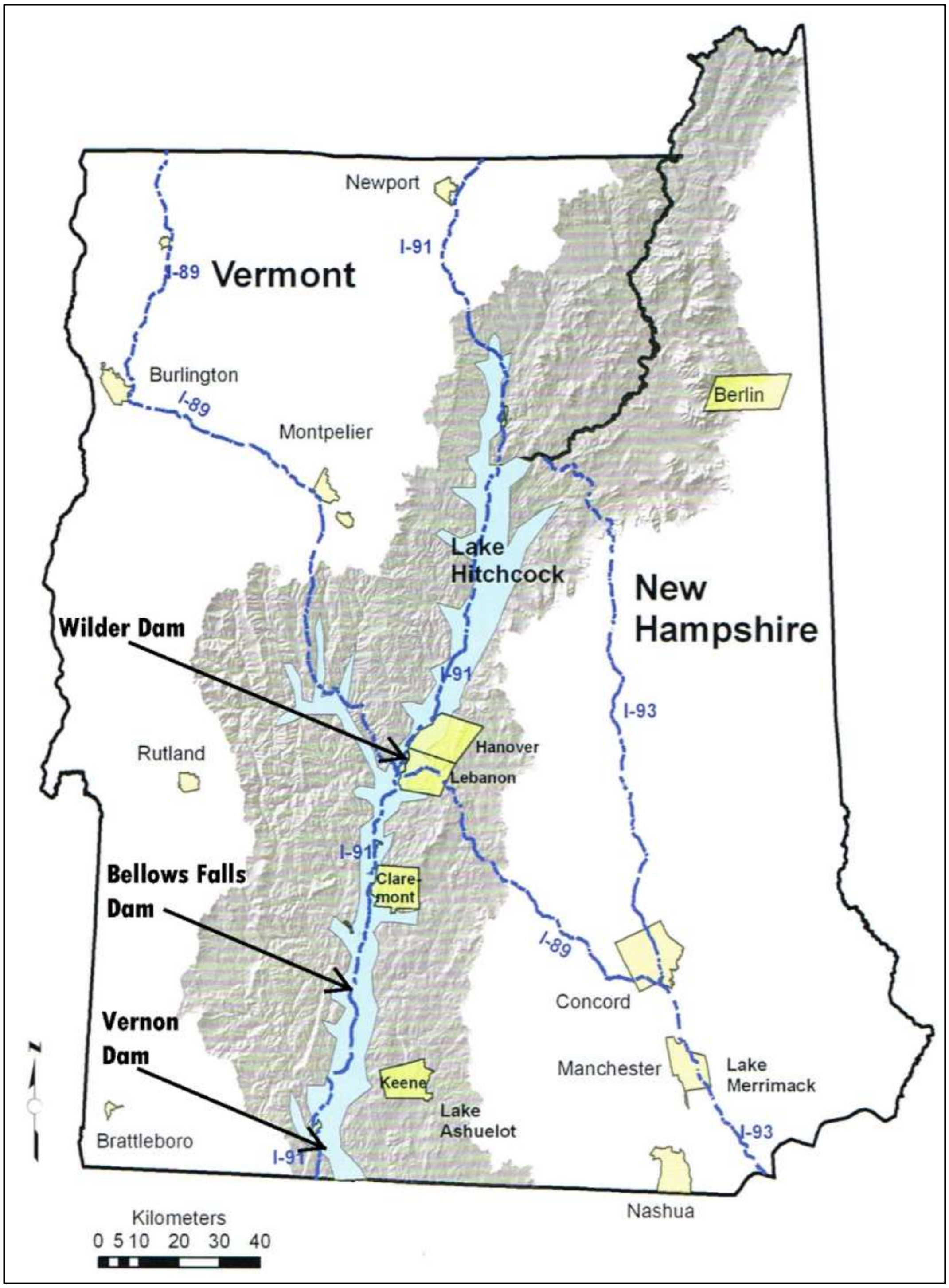
Surficial Geology

The bedrock geology and tectonic processes described above exert a strong control on the topography and physiography of the Connecticut River watershed. The generally north-northeast trending mountain ridges and intervening valleys reflect the underlying orientation of the rock formations and the folds and faults that have deformed them. The ridges are composed of rock types more resistant to erosion with the valleys underlain by less resistant rocks, and the highest peaks of the Green Mountains in Vermont are largely composed of the most erosion-resistant and oldest Precambrian Basement rocks (Kim and Wunsch, 2009). The less resistant rock types found in the Connecticut Valley Belt and Bronson Hill Belt have formed more rolling hills and short ridges compared to the higher more pronounced ridges in the center of the Green Mountains. Isolated dome shaped hills in the watershed such as Mount Ascutney in Windsor, Vermont, are typically underlain by circular granite intrusions of the New Hampshire and White Mountain magma series with radial drainage patterns developed by streams flowing off of the circular peaks in all directions. The upland areas of the watershed are at times draped with a relatively thin veneer of glacial till, but it is only in the Connecticut River and tributary valleys where the effects of glacial action are more pronounced.

The surficial geology of the Wilder, Bellows Falls, and Vernon Project areas is in large part attributable to glacial processes. Although the position of the Connecticut River Valley and watershed more broadly were already well established prior to glaciation, the final Pleistocene advance and retreat of the continental ice mass during the Wisconsin Period eroded and picked up bedrock; realigned some drainages; and deposited till, erratics, and glacial moraines. The retreat of ice from New Hampshire and Vermont about 13,500 years ago left widespread glacial deposits and glacial erosional surfaces. An important part of the deglaciation in this area was the formation of temporary lakes along the margins of the ice fronts. The Connecticut River Valley is situated within the boundaries of Glacial Lake Hitchcock. Glacial Lake Hitchcock formed as glacial meltwaters released from the ice sheet were dammed behind a natural sand, gravel, and till barrier deposited in the area of Rocky Hill, Connecticut, to the south. Continued ice melt resulted in a massive natural lake impoundment north of the Rocky Hill dam, which at its maximum stretched 200 miles from Rocky Hill to St. Johnsbury, Vermont, and reached 20 miles in width (Figure 3.4-2). Glacial Lake Hitchcock persisted in the upper Connecticut River Valley until about 12,300 years ago. The Connecticut River appears to have essentially continued along the same pre-glacial course following the drainage of Glacial Lake Hitchcock.

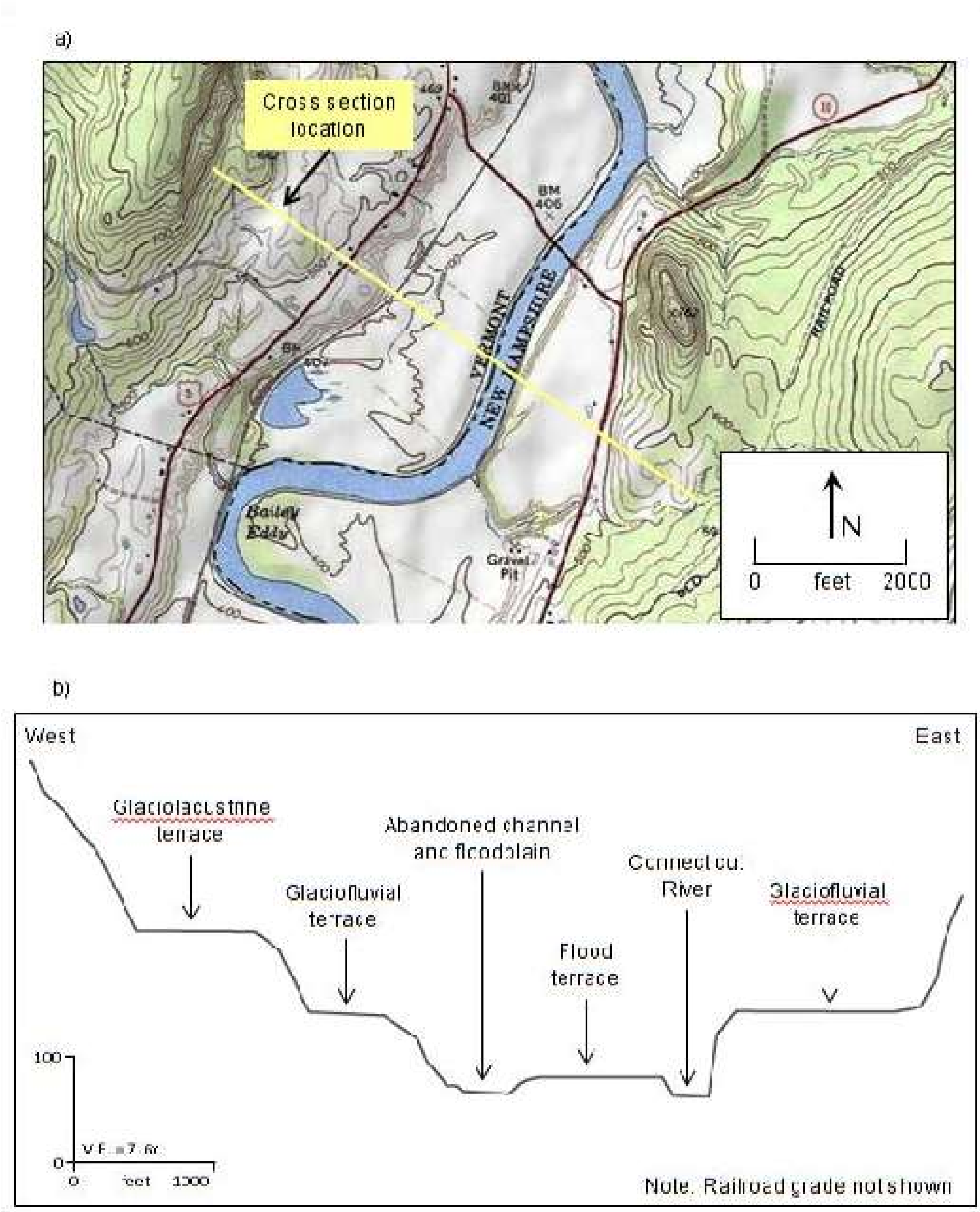
Sandy deltas built out into Glacial Lake Hitchcock at the mouths of tributaries with the tops of these deltaic sediments serving as indicators of the surface elevation of the lake (Brigham-Grett and Rittenour, 2001). While Glacial Lake Hitchcock sediments might be expected along the river given that the lake extended across the valley (Tufts University, 2016), non-glacial lakes at lower elevations persisted after the draining of Glacial Lake Hitchcock (Ridge and Larsen, 1990), so the presence of varved clays or sandy deltaic sediments in the Project areas cannot be immediately attributed to Glacial Lake Hitchcock. In addition, fluvial sediments, inset into the lake and delta terraces, were deposited as the river became fully established from northern New Hampshire to the Sound.

The resulting surficial geology of the Connecticut River Valley consists of a series of terraces stepping up from the river. The river channel's position relative to the various geomorphic surfaces determines the bank heights and bank composition along the length of the river with higher banks encountered where the river flows against older and higher terraces. These terrace and floodplain surfaces, among others, are seen throughout the Project areas. The greatest number, extent, and complexity of surfaces occur where the valley is wide. Much of the Connecticut River Valley in the Project areas is quite narrow such as between Putney and Brattleboro, Vermont, in the Vernon impoundment, but several wider sections exist where a complex assortment of geomorphic surfaces are present (Figure 3.4-3). The widest portion of the valley in the Project areas is in the upper Wilder impoundment upstream of Orford, New Hampshire, with other wide, but much shorter, portions of the valley present in the Bellows Falls impoundment upstream of the Williams River and in the Vernon impoundment between the Cold River confluence and East Putney, Vermont. Surficial geological deposits along the Project areas consist of glaciofluvial, glaciolacustrine, postglacial fluvial sands and gravels, and recent alluvium along the banks of the Connecticut River and glacial till and moraines in the adjacent upland areas.



Source: Brown (2009)

Figure 3.4-2. Extent of Glacial Lake Hitchcock.



Source: ILP Studies 2-3, *Riverbank Transect and Riverbank Erosion Studies*

Figure 3.4-3. Example terrace and floodplain cross section in the Connecticut River Valley.

3.4.1.2 Seismicity

Seismographs and recording stations are located throughout the Northeast with two stations in the Connecticut River Valley within about 50 miles of the Projects (Figure 3.4-4). The Wilder, Bellows Falls, and Vernon Projects are in an area of relatively low seismicity in the Connecticut River Valley. Seismic activity in the Project areas, typical of the Northeast region of North America, is characterized by a low rate of earthquake occurrence. Specific causes of earthquake activity in the Connecticut River Valley are not known.

Historical records of earthquakes in the Northeast date back to the 1500s. Early records indicate several significant earthquakes in New England with some occurring prior to the establishment of seismographs and recording stations. The earliest damaging seismic event is documented to have occurred in 1638 in central New Hampshire, although the damage levels and location of the earthquake are uncertain (Weston Observatory, 2016). In 1755, an earthquake with an estimated magnitude of 6.2 occurred off the coast of Massachusetts. Beginning in the early 1900s, a number of seismographs was operating, although routine reporting of instrumental data on earthquakes in this region did not begin until the late 1930s. The strongest damaging earthquake with an epicenter in the state of New Hampshire occurred at Tamworth on December 20 and 24, 1940, with a measured magnitude of about 5.5 on both dates. The number of seismic stations in the Northeast increased significantly between 1970 and 1974; by 1974, area seismologists were operating a regional seismic network (Figure 3.4-4).

The amount of direct physical damage from an earthquake depends on several factors including the earthquake intensity, stability of underlying geologic materials, and construction features of structures exposed to seismic vibration, which vary from site to site. To show probabilistic expectations for damaging shaking from earthquakes, the U.S. Geological Survey (USGS) has developed Seismic Hazard Maps, which indicate the earthquake motions that have a certain probability of occurring across the entire United States. The hazard map for the New England vicinity (Figure 3.4-5) indicates a peak horizontal ground acceleration[20] at the Projects of 0.10 to 0.14 g (gravitational force) for a 2 percent probability of exceedance in 50 years (USGS, 2014). Most earthquakes in the vicinity of the Projects are of small magnitude (Figure 3.4-6). Earthquakes with a magnitude lower than 2.5 on the Richter scale[21] are typically not felt by humans.

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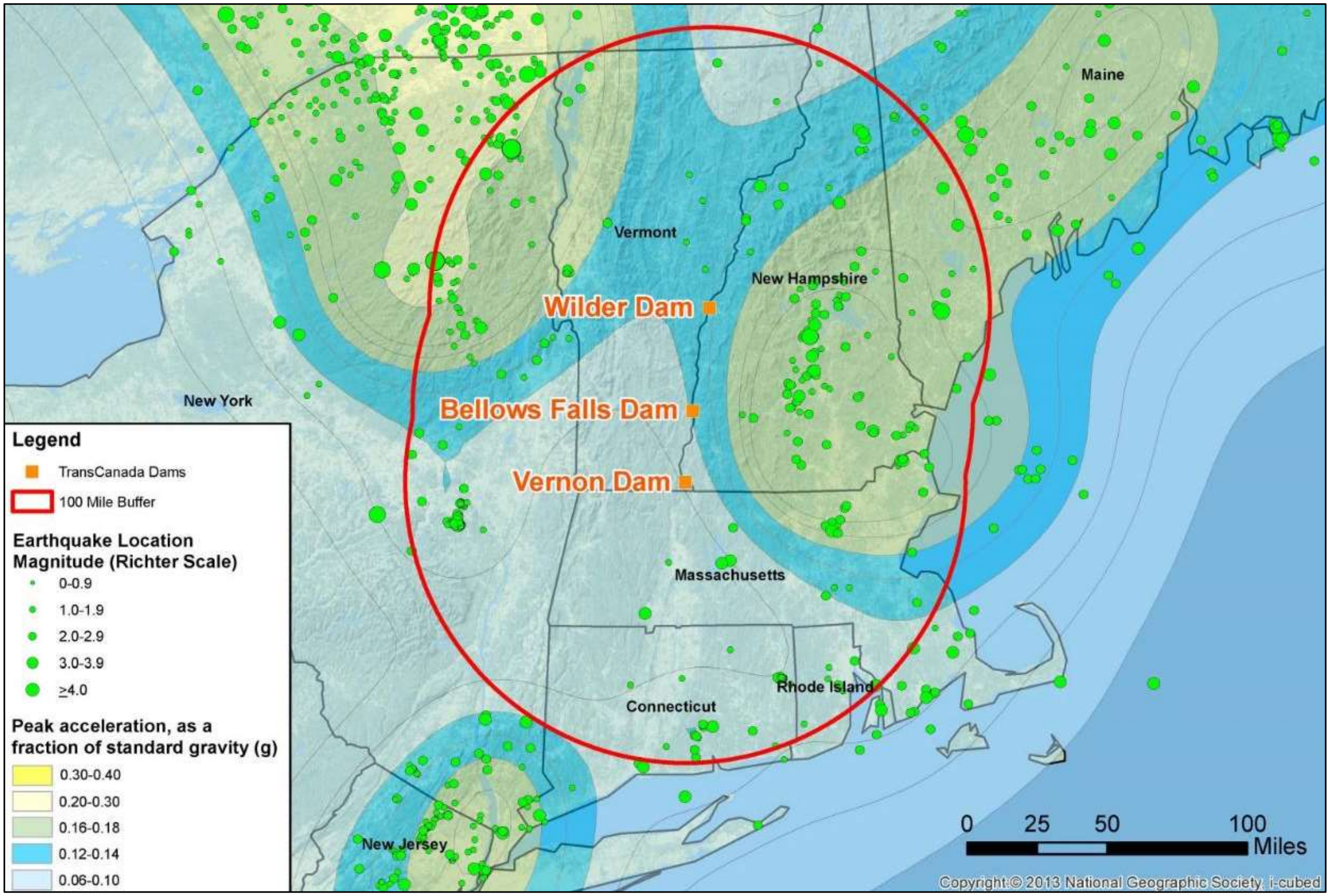
[20] Peak ground acceleration (PGA) is the maximum ground acceleration that occurs during earthquake shaking at a location. The horizontal PGA component is generally larger than the vertical component and is the most commonly used type of ground acceleration in engineering applications. A horizontal PGA of 0.10 to 0.14 g is equal to 3.2 to 4.5 feet/second. The perceived shaking at this PGA level is strong, but the potential damage is light (USGS, 2016c).

[21] The magnitude of earthquakes is described using the Richter scale, which is determined from the logarithm of the amplitude of waves recorded by seismographs.

Source: Weston Observatory (2016)

Figure 3.4-4. Seismic stations in the Northeast.

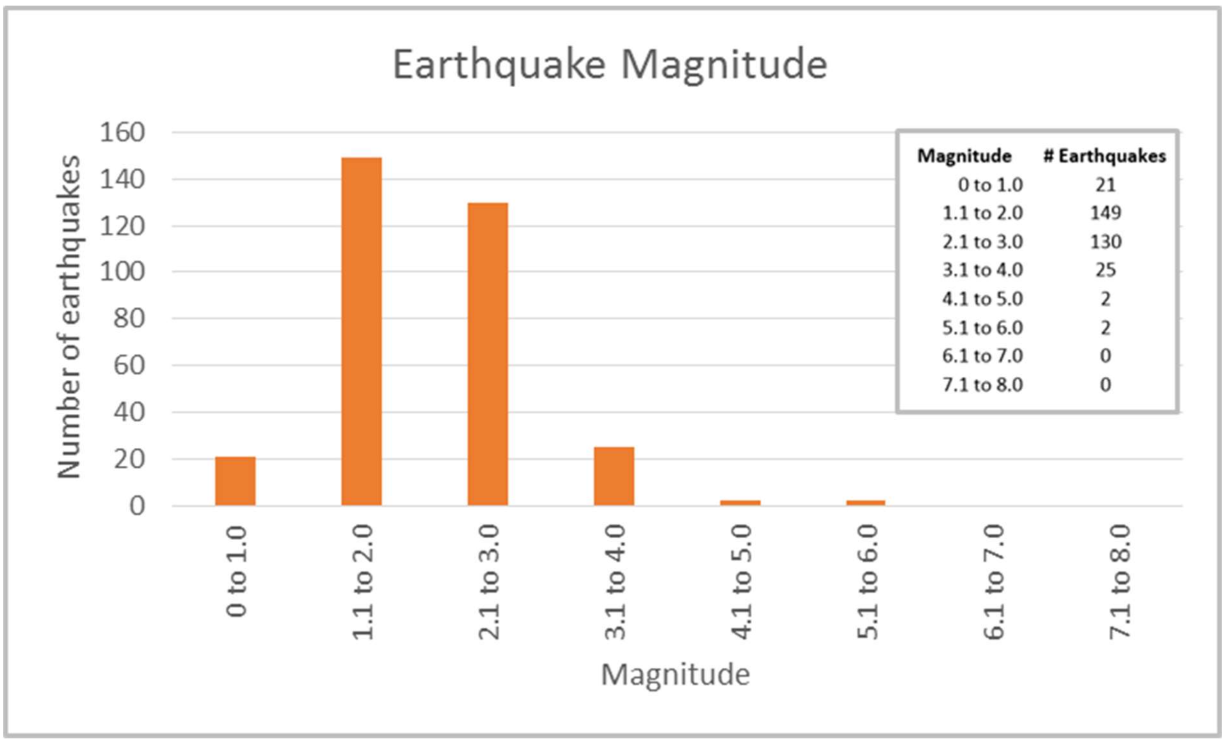


Source: USGS (2014)

Figure 3.4-5. Earthquake locations, 100-mile buffer, and peak acceleration.

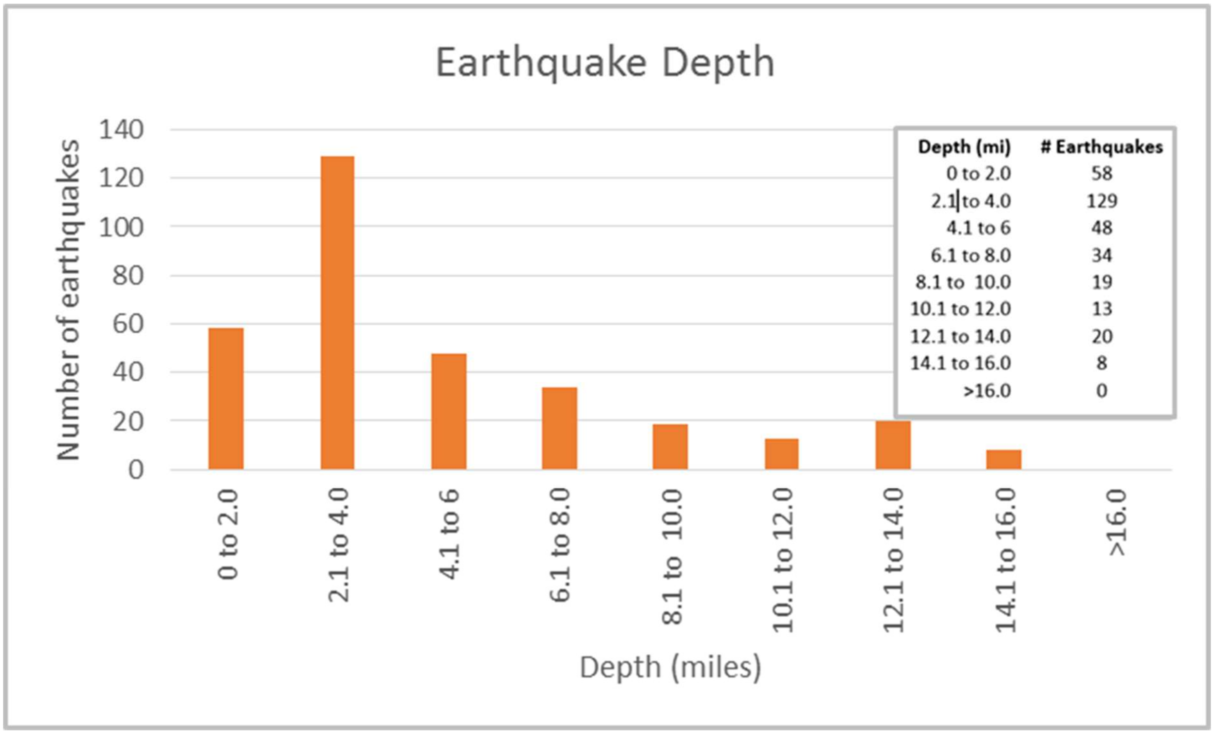
The USGS Earthquake Catalog (USGS, 2016d), a compilation of monitoring station data, indicates that 329 earthquakes are known to have occurred within 100 miles of the Projects since the establishment of a seismic monitoring network in the region in 1974. The largest seismic event since 1974 (magnitude 5.3) occurred on April 20, 2002, in the Adirondack State Park about 91 miles northwest of Wilder dam and 14.6 miles west of Chesterfield, New York. Only 4 of the 329 recorded earthquakes (1 percent) since 1974 had a magnitude higher than 4.0 (Figure 3.4-6), while 300 of 329 recorded earthquakes (91 percent) had a magnitude of 3.0 or lower.

Monitoring stations in the Northeast indicate that seismicity occurs at relatively shallow depths in the upper crust. For earthquakes evaluated within 100 miles of the Projects since 1974, recorded depths ranged from ground surface to a maximum depth of 14.7 miles with an average depth of 4.8 miles. About 80 percent of the earthquakes were recorded occurring at depths of 8.0 miles, or shallower (Figure 3.4-7).



Source: USGS (2016d)

Figure 3.4-6. Frequency of earthquake magnitude within 100 miles of the Wilder, Bellows Falls, and Vernon Projects.



Source: USGS (2016d)

Figure 3.4-7. Frequency of earthquake depth within 100 miles of the Wilder, Bellows Falls, and Vernon Projects.

The spatial and vertical distributions of recorded earthquakes within 100 miles of the Projects suggest a lack of a predominant factor responsible for the seismicity. Earthquakes may be caused by human activity (hydraulic fracturing and nuclear detonations) and by natural sources of crustal deformation such as faulting, magma migration, or by geologic intrusions where deformable material is forced into brittle overlying rocks. With volcanic activity not occurring in the eastern United States, and regular hydraulic fracturing activities being only a recent development and furthermore not occurring in the region, crustal rupture is the principal source of crustal deformation in the northeastern United States.

Several faults are mapped in the Connecticut River Valley in New Hampshire and Vermont (Figure 3.4-1); however, no earthquake focus can be directly related to faults (NHDES, 1994) and no active faults are mapped in New Hampshire or Vermont (USGS, 2014). The bedrock underlying the Project areas ranges from about 1.4 billion to 100 million years of age and is characterized by north-northeast trending belts of metamorphosed sedimentary and igneous rocks (Brown, 2009). Observations of faults in the region near the Projects indicate the faults are healed and have not been active in 90 million years or longer (NHDES, 1994).

3.4.1.3 Soils

Table 3.4-1 summarizes the soil types[22] found in each of the Project areas and the sections below provide more detail for each Project (ILP Study 33, *Cultural and Historic Resources Study, Phase 1A Reports*; Willamette and Normandeau, 2016).

Wilder Project

Numerous soil types are present in the Wilder Project area. Soil types situated on terrace formations along the Connecticut River include loamy sands and sandy loams associated with the Quonset, Windsor, Agawam, Merrimac, and Ninigret series. These soils formed from deposits laid down as glacial outwash. Silt loams associated with the Hitchcock, Belgrade, and Hartland soil series are also present, and formed in glaciolacustrine deposits most likely associated with Glacial Lake Hitchcock. Other terrace soil types consist of units classified as Urban land-Windsor-Agawam complex and pits, sand and pits. The Urban land-Windsor-Agawam complex represents areas where anthropogenically disturbed soils are intermixed with small areas of undisturbed sandy loam Windsor and Agawam series soils. Pits, sand and pits, and gravel represent areas of gravel and sand quarrying or borrow pits.

Soil types along floodplains include moderately erodible sandy loams associated with the Podunk, Rumney, Hadley, and Ondawa soil series, and highly erodible silt loams associated with the Winooski and Limerick soil series. Adjacent upland areas contain sandy loams associated with the Tunbridge, Woodstock, and Colrain soil series, Buckland loam series, and silt loams associated with the Bernardson, Cardigan, and Pittstown soil series. Other soil types present in upland area include the Glover-Vershire complex. These soils can often consist of a rocky to very rocky shallow mantle overlying bedrock and are frequently interspersed with bedrock outcrops. Udorthent and Udipsamment soil types are also present along the Project area and consist of human-transported fill deposits.

Bellows Falls Project

Soil types situated on terrace formations along the Connecticut River include loamy sands and sandy loams associated with the Quonset, Windsor, Agawam, Ninigret series and Warwick series gravelly loam. These soils formed from deposits laid down as glacial outwash. Silt loams associated with the Hitchcock, Belgrade, and Unadilla Variant soil series are also present and formed in glaciolacustrine deposits likely associated with Glacial Lake Hitchcock. Other terrace soil types consist of units classified as Urban land-Windsor-Agawam complex and pits, sand and pits, gravel. The Urban land-Windsor-Agawam complex represents areas where anthropogenically disturbed soils are intermixed with small areas of undisturbed

[22] Detailed soil maps for the Project areas can be generated at http://websoilsurvey.sc.egov.usda.gov/App/HomePage.htm.

sandy loam Windsor and Agawam series soils. Pits, sand and pits, gravel soil types represent areas of gravel and sand quarrying or borrow pits.

Soil types along floodplains include moderately erodible sandy loams associated with the Podunk, Rumney, Hadley, and Ondawa soil series and highly erodible silt loams associated with the Winooski and Limerick soil series. Adjacent upland areas contain sandy loams associated with the Tunbridge, Marlow, Lyman, and Monadnock soil series and silt loams associated with the Dummerston, Macomber, Bernardson, Cardigan, Kearsarge, and Dutchess soil series. Taconic channery loam soils are also present in upland areas. These upland soils can be rocky to very rocky. Other soil types present in upland areas include the Glover-Vershire complex, Lyman-Rock outcrop complex, Macomber-Taconic complex and Vershire-Dummerston complex. These soils can often consist of a shallow mantle overlying bedrock and are frequently interspersed with bedrock outcrops. Udorthent and Udipsamment soil types are also present and consist of human-transported fill deposits.

Vernon Project

The portion of the Vernon Project located in the southeastern part of Windham County, Vermont, is covered by Dummerston-Macomber-Taconic association soils, derived primarily from bedrock-controlled loamy glacial till. These soils are very deep to shallow, gently sloping to very steep, somewhat excessively drained and well-drained soils that formed in loamy glacial till on hills and mountains and have moderate erodibility. The only exception to this soil association is in the vicinity of Vernon dam and the islands just below the dam, which contain Tunbridge-Marlow-Lyman soils. These soils are also very deep to shallow, gently sloping to very steep, somewhat excessively drained to well-drained soils that have formed in loamy glacial till on hills and mountains. Tunbridge soils have low erodibility and Marlow and Lyman soils have moderate erodibility.

The majority of the Project area in Cheshire County, New Hampshire, is made up of Windsor-Agawam-Hoosic soils, which are very deep, on nearly level to very steep land that is excessively drained, well-drained, and somewhat excessively drained. Windsor and Hoosic soils have low erodibility and Agawam soils have moderate erodibility. The soils are loamy and formed in glacial outwash deposits. The only exception to this is in the vicinity of Wantastiquet Mountain State Park in Hinsdale and Chesterfield, New Hampshire, which contains Bernardston-Cardigan-Kearsarge-Dutchess soils. These soils are also very deep, moderately deep, and shallow on gently sloping to very steep land that is well drained to excessively drained and consists of loamy soils that formed in glacial till and have moderate erodibility.

Table 3.4-1. Summary of soil types present in the Wilder, Bellows Falls, and Vernon Project areas.

Associated Land Form/Context	Soil Type	Parent Material	Wilder	Bellows Falls	Vernon
Terraces	Quonset fine sandy loam	Formed in glaciofluvial deposits	X	X	
	Windsor loamy sand or loamy fine sand		X	X	X
	Warwick gravelly loam			X	
	Agawam fine sandy loam		X	X	X
	Hoosic sandy loam				X
	Merrimac sandy loam		X		
	Ninigret fine sandy loam		X	X	
	Hinckley sandy loam				
	Urban land-Windsor-Agawam complex		X	X	
	Pits, sand, and pits, gravel		X	X	
	Hitchcock silt loam	Formed in glaciolacustrine deposits	X	X	
	Belgrade silt loam		X	X	
	Hartland silt loam		X		
	Unadilla Variant silt loam			X	
Floodplains	Podunk fine sandy loam	Formed in alluvium	X	X	
	Rumney fine sandy loam		X	X	
	Hadley very fine sandy loam		X	X	
	Winooski silt loam (highly erodible)		X	X	
	Limerick silt loam (highly erodible)		X	X	
	Ondawa fine sandy loam		X	X	
Uplands (hill, ridges, mountains)	Tunbridge fine sandy loam	Formed in glacial till	X	X	X
	Marlow fine sandy loam			X	X
	Lyman fine sandy loam			X	X
	Buckland sandy loam		X		
	Colrain sandy loam		X		

Associated Land Form/Context	Soil Type	Parent Material	Wilder	Bellows Falls	Vernon
Uplands (hill, ridges, mountains) (cont.)	Dummerston silt loam	Formed in glacial till		X	X
	Macomber silt loam			X	X
	Woodstock sandy loam		X		
	Taconic channery loam			X	X
	Bernardston silt loam		X	X	X
	Cardigan silt loam		X	X	X
	Pittstown silt loam		X		
	Kearsarge silt loam			X	X
	Dutchess silt loam			X	X
	Monadnock fine sandy loam			X	
	Glover-Vershire complex (very rocky fine sandy loams)		X	X	
	Lyman-Rock outcrop complex (very stony fine sandy loam and bedrock outcrops)			X	
	Macomber-Taconic complex (very rocky channery silt loams)			X	
	Vershire-Dummerston complex (rocky fine sandy loams)			X	
Various (infilled contexts)	Udorthents and Udipsamments	Human transported soils	X	X	

Source: ILP Study 33, *Cultural and Historic Resources Study, Phase 1A Reports*

The position of the Connecticut River channel relative to the soils described in Section 3.4.1.3 largely determines riverbank composition throughout the Project areas. Great River Hydro conducted three relicensing studies related to soils and erosion:

- ILP Study 1, Historical Riverbank Position and Erosion Study;
- ILP Study 2, Riverbank Transect Study; and
- ILP Study 3, Riverbank Erosion Study.

Reports for Studies 2-3 were combined into a single document, ILP Studies 2-3, *Riverbank Transect and Riverbank Erosion Studies.* Additionally, a Supplemental Report to Study 3 was completed and included site samples and lab analysis of bank soils and sediments from the 21 erosion monitoring sites.

The preponderance of sandy soils (including loam with admixtures of silt and clay), whether of glacial or alluvial origin is reflected in the riverbank composition throughout the Project areas with 76 percent of the banks mapped as sand in Studies 2-3 (Table 3.4-2). However, the complex glacial and post-glacial history of the valley with advancing and retreating glaciers, lakes impounded behind natural dams, and the formation of multiple floodplain levels as the modern river reached its current position has given rise to a heterogeneous stratigraphy in the sediments that fill the valley such that the composition at the base of the riverbank is often different than the upper bank in the same location, especially where the banks are high. In such instances, the mapped soils, generally reflecting conditions within a few feet of the surface, are not an accurate indication of the bank composition at the bank toe where riverine action is most effective. A typical heterogeneity observed in the banks is sandy glacial outwash or alluvial soils overlaying varved glaciolacustrine clay at the base of the bank. Groundwater seeps are often observed emanating along such contacts where well-draining sands and loams are found above less permeable clay and silt. A more detailed breakdown of bank composition within each Project area is provided below.

Bank heights largely depend on the geomorphic surface along which the river is flowing; bank heights are low where the river flows across the modern floodplain and are higher where the river encounters older glacial surfaces, generally closer to the valley’s edge. In the impoundments, bank heights are generally lower closer to the dams because of the backwatering upstream of the dams. Bank heights immediately upstream of Vernon dam, for example, are less than 1 foot in places because of the inundation of the modern floodplain. In contrast, bank heights of greater than 50 feet are present where the river flows against glacial till along the valley’s edge. The highest bank in the Project areas is greater than 90 feet in Charlestown, New Hampshire, and is composed of glacial outwash sands. A more detailed breakdown of bank heights within each Project area is provided below and summarized in Table 3.4-2.

Table 3.4-2. Percentage of bank characteristics by Project area.

	Project Areas Combined	Wilder Imp.	Wilder Riverine	Bellows Falls Imp.	Bellows Falls Riverine	Vernon Imp.	Vernon Riverine
Bank Height (ft)							
< 1	3.0	5.4	0.4	1.2	0.5	3.2	0.6
1-4.9	9.0	9.6	0.5	16.3	1.0	9.8	0.0
5-7.9	7.1	13.6	1.2	3.3	4.2	5.4	0.3
8-9.9	7.5	9.0	3.8	8.4	1.0	8.4	1.3
10-14.9	19.9	24.0	15.2	20.1	23.6	15.3	30.0
15-19.9	17.2	15.5	30.6	8.8	16.9	17.6	25.2
20-29.9	15.6	15.8	12.3	15.9	16.5	17.2	16.9
30-50	12.6	6.0	17.6	16.7	36.3	11.3	9.9
> 50	8.1	1.2	18.4	9.4	0.0	11.7	15.7
Bank Texture							
Bedrock	4.4	2.1	8.3	3.6	0.9	5.6	17.1
Boulder / fractured	1.3	0.4	0.2	0.9	17.9	0.1	5.5
Cobble	6.3	0.4	24.5	1.6	29.3	2.9	0.0
Glacial clay	2.1	1.2	2.0	3.8	0.0	1.5	19.9
Gravel	10.2	2.0	38.6	12.6	5.6	2.8	0.0
Sand	75.7	93.9	26.4	77.5	46.4	87.1	57.5

	Project Areas Combined	**Wilder Imp.**	**Wilder Riverine**	**Bellows Falls Imp.**	**Bellows Falls Riverine**	**Vernon Imp.**	**Vernon Riverine**
Bank Stability							
Eroding	11.3	13.7	9.5	13.9	4.6	7.9	14.4
Vegetated eroding	22.1	20.9	21.6	20.0	22.5	25.2	33.7
Failing armor	6.4	6.7	8.8	5.9	4.9	5.2	6.1
Unstable banks	***39.8***	***41.3***	***39.9***	***39.8***	***32.0***	***38.2***	***54.2***
Armored	14.4	15.2	7.6	14.8	31.0	14.6	5.1
Stable	41.9	39.4	49.9	39.0	37.0	44.5	35.7
Healed erosion	3.8	4.1	2.6	6.5	0.0	2.7	5.0
Stable banks	***60.2***	***58.7***	***60.1***	***60.2***	***68.0***	***61.8***	***45.8***
Riparian Vegetation							
Present	77.3	69.0	85.1	74.2	80.1	88.1	63.2
Absent	22.7	31.0	14.9	25.8	19.9	11.9	36.8

Source: ILP Studies 2-3, *Riverbank Transect and Riverbank Erosion Studies*

Bank erosion occurs when the sum of the forces driving erosion exceeds the resisting strength of the bank (Parker et al., 2008; Easterbrook, 1993). For these reasons, bank composition and bank height are important controls on the distribution of erosion because the bank's composition is an important determinant of its strength to resist erosion, while gravitational forces, an important driver of erosion, increase with increasing bank height. The bank's resistance to erosion depends on bank material properties (such as grain size and cohesion), vegetation (type and amount), and other bank characteristics such as form roughness (i.e., topographic surface irregularities). The driving forces acting on a bank, regardless of bank height, can also be increased by the removal of the underlying support (e.g., overhanging banks, benches, and beaches), an increase in the surcharge (i.e., weight) on the bank slope accompanying precipitation, or the addition of failed material from upslope, or an increase of lateral stresses that can accompany the formation of ice in cracks or water added to pore spaces.

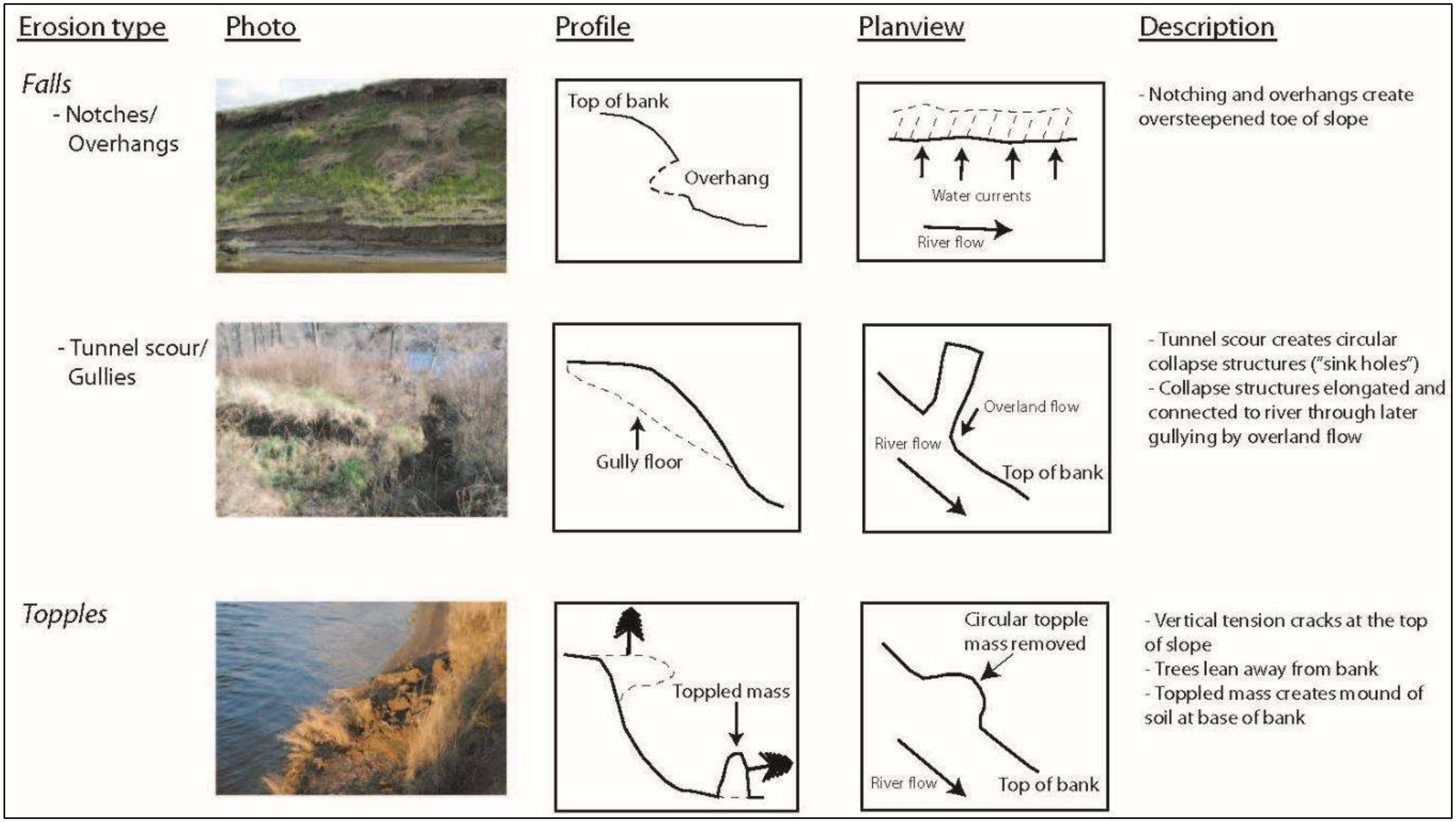
Riparian vegetation can increase a bank's resistance to erosion because roots help to bind soil particles together (Micheli and Kirchner, 2002). While 82 percent of the banks within the Project areas have riparian vegetation, the height of the riverbanks in many locations may limit the stabilizing influence of the roots. On high riverbanks, the roots of the vegetation may penetrate into the soil only a small fraction of the bank's total height while the greatest erosive forces are acting at the base where the river is flowing against the bank or underlying benches at the toe of the slope. In these instances, the stabilizing influence of the vegetation may result after the tree has been undermined by erosion, fallen to the base of the bank, and in that position protect the bank from further erosion until completely dislodged from the bank and washed downstream. The stabilizing influence of even dead trees at the base of the bank may persist for several years (Figure 3.4-8).

Source: ILP Studies 2-3, *Riverbank Transect and Riverbank Erosion Studies*

Figure 3.4-8. Example of riparian vegetation on bank.

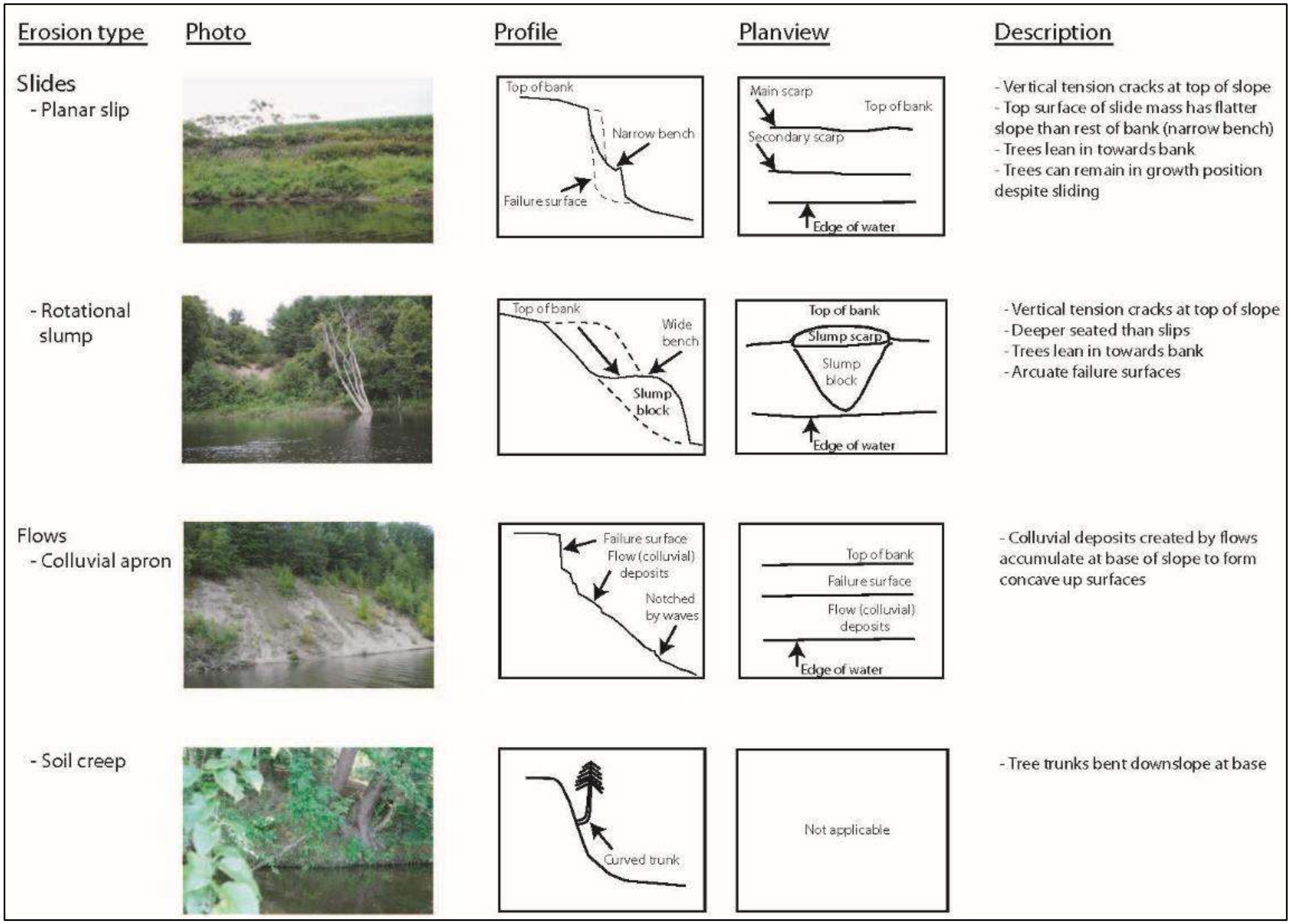
When the driving forces exceed the resisting forces of the banks in the three Project areas, the resulting erosion occurs by four primary processes: falls, topples, slides, and flows (Figure 3.4-9). All four erosion processes often occur at the same place over a period of time in a "cycle of erosion" that leads to the removal of material from the bank and a continuation of the erosion process (Figure 3.4-10).

While falls might typically be considered to involve masses of sediment free falling through the air to the base of the bank, the removal of individual particles by water currents are also categorized as falls because these particles are first dislodged then rolled or carried in suspension away from the bank. Water-driven forces strong enough to erode and transport sediment in the three Project areas could be generated by at least five different mechanisms: tractive forces generated by river flow (primarily above station generation flow), groundwater seeps, overland flow, waves, and water level fluctuations. Currents, by whichever mechanism, acting at the base of the bank over prolonged (although not necessarily continuous) periods can create the notches and overhangs seen along 37 percent of the river's banks over the three Project areas (ILP Studies 2-3).



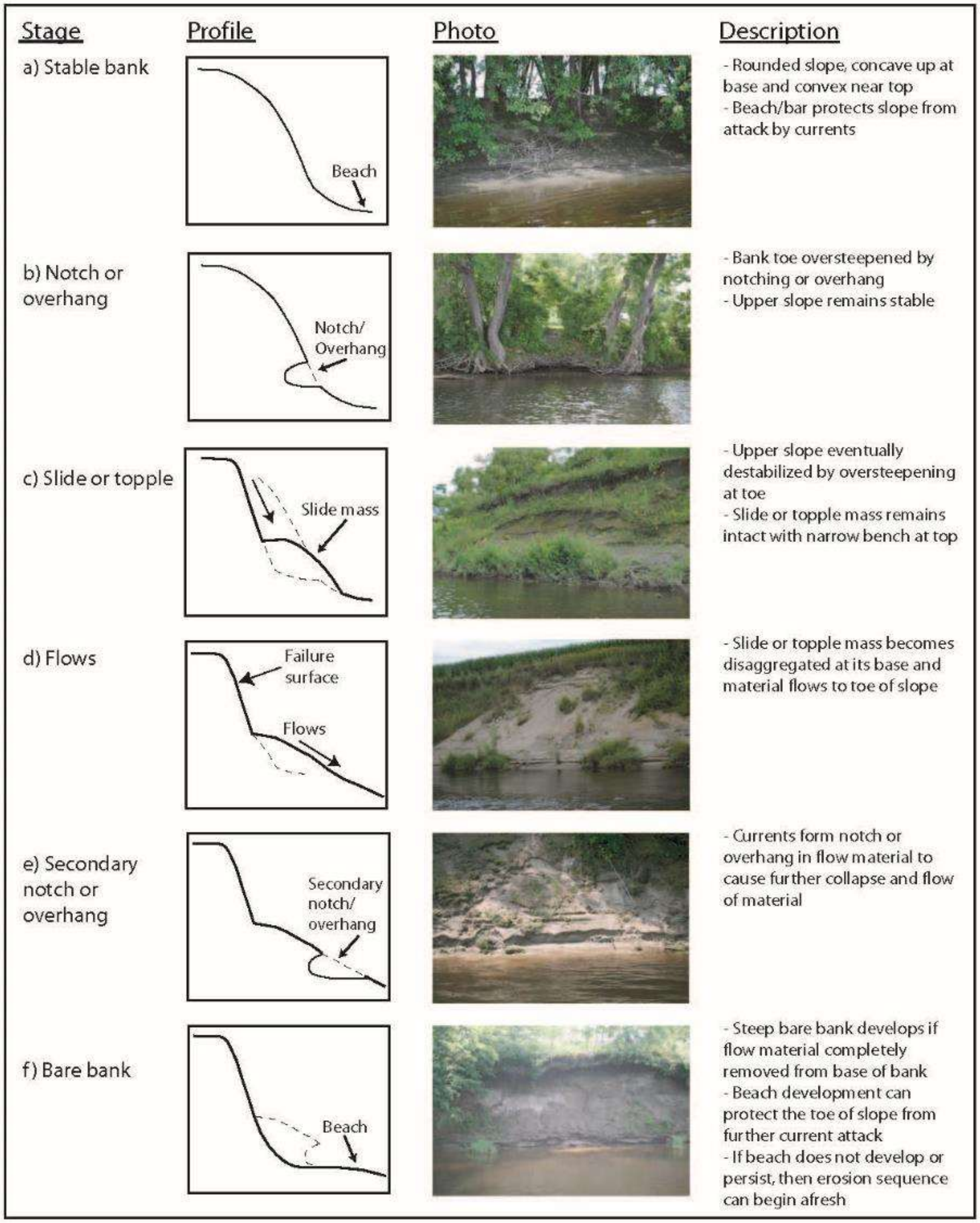
Source: Adapted from Field, 2007, in ILP Studies 2-3, *Riverbank Transect and Riverbank Erosion Studies*

Figure 3.4-9. Types of erosion occurring in the Project areas and their characteristics.



Source: Adapted from Field, 2007, in ILP Studies 2-3, *Riverbank Transect and Riverbank Erosion Studies*

Figure 3.4-9. Types of erosion occurring in the Project areas and their characteristics (continued).



Source: Adapted from Field, 2007, in ILP Studies 2-3, *Riverbank Transect and Riverbank Erosion Studies*
Note: Different stages of erosion can be occurring adjacent to each other along a long, continuously eroding bank.

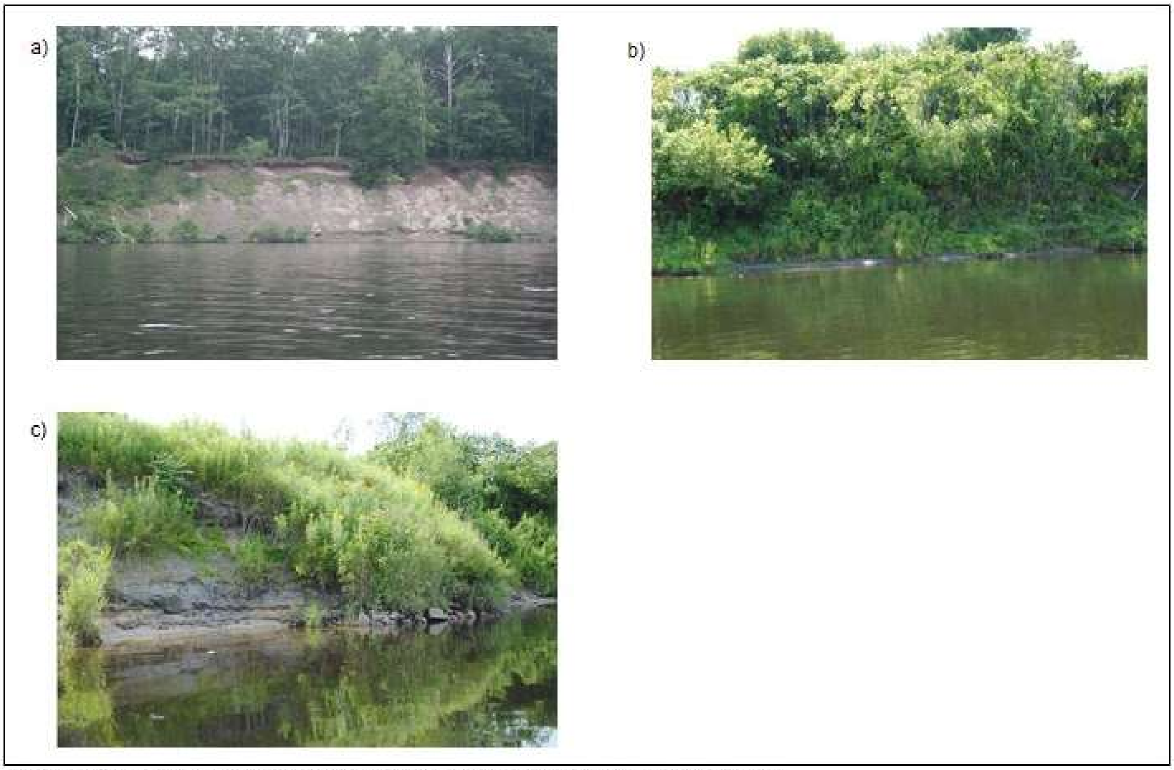
Figure 3.4-10. Model idealizing steps in the cycle of erosion.

Slides are large blocks of the bank that slide along failure surfaces that are either relatively shallow and parallel to the bank line (i.e., planar slips) or deeper seated, arcuate-shaped in planform, and have a concave-up profile (i.e., rotational slumps). Planar slips are the most dominant form of erosion observed other than overhangs created by falls. Topples develop when vertical tension cracks parallel to the top edge of the bank widen to a point where the top portion of cohesive blocks of soil rotate forward about a pivot point near the base of the soil mass. Topples also occur when soil attached to an undermined root system of trees or other vegetation leans over and collapses over the bank. Topples form from either pristine bank material or as larger planar slips and rotational slumps break apart into smaller blocks of soil. Flows form at the base of planar slips, rotational slumps, and topple blocks as the material becomes disaggregated into individual particles at the time of the initial sliding or toppling or at some later point. Dry grain flows or liquefied flows can occur at the same time as the initial sliding/toppling or for some time after an event if the material remains loose, especially on the over-steepened base of the slide masses. Flows are an important mechanism for delivering eroded soil to the base of the bank. If the material accumulating at the base of the bank remains for an extended period, the upper portion of the bank will likely restabilize; however, if flood flows ultimately carry the accumulated material away from the bank, new overhangs can develop at the base of the bank and the cycle of erosion will be restarted afresh to continue the erosion.

The current amount and distribution of erosion in the three Project areas were established by mapping bank stability as part of Studies 2-3. The 250 miles of bank length that were mapped were subdivided into six stability categories: stable, armored, eroding, vegetated eroding, failing armor, and healed erosion. Banks mapped as eroding, vegetated eroding, and failing armor are all unstable banks equally prone to erosion. The reason for discriminating between the three is because of differences in the visual appearance of the banks. Eroding banks are largely devoid of vegetation and have well-exposed bare scarps created where the bank material has slid or toppled downslope (Figure 3.4-11, Photo a). Vegetated eroding banks also have bare scarps—an indicator that erosion is occurring—but such scarps are obscured by vegetation and the evidence for erosion easily missed without careful observation (Figure 3.4-11, Photo b). Past armoring efforts to protect the riverbanks have failed in many locations with erosion once again occurring. The failing armor category was established to reflect this past armoring history, although only barely visible remnants of the armoring remain in some cases (Figure 3.4-11, Photo c).

Banks mapped as vegetated eroding and failing armor were likely not mapped as eroding in earlier efforts that extend back to the 1950s because the typical bare bank face usually associated with erosion is not often present in these locations. Also worth noting is that notching alone was not likely to be considered as eroding in earlier mapping efforts. The cycle of erosion represents a continuum between a stable bank and an eroding bank. A minor notch at the base of the bank does not result in the rest of the bank sliding, falling, or toppling downslope. Notching at the base of a stabilized bank can exist; notching does not necessarily result in deeper notching. In cases where a notch/overhang increases in size, the gravitational driving forces destabilizing the bank continue to increase until eventually the bank begins to erode. The notch/overhang should not in itself be considered unstable or an eroding bank unless accompanied with other evidence.

Taken together, the three bank stability types representing unstable banks represent 40 percent of the bank length through the three Project areas. A more detailed breakdown of erosion within each Project area is provided below and summarized in Table 3.4-3.



Photos of the unstable bank categories: a) eroding, b) vegetated eroding, c) failing armor.

Source: ILP Studies 2-3, *Riverbank Transect and Riverbank Erosion Studies*

Figure 3.4-11. Unstable bank examples of eroding, vegetated eroding, and failing armor categories.

Table 3.4-3. Percentage of bank erosion in 1958, 1978, and 2014.

River Reach	Time period	Bank length (miles)	Stable (miles)	%	Eroding (miles)	%
Entire Project Areas	1958	218.4	190.3	87.1	28.2	12.9
Wilder Impoundment	1958	93.3	88.5	94.8	4.8	5.2
Bellows Falls Impoundment	1958	52.6	37.9	71.9	14.8	28.1
Vernon Impoundment	1958	59.9	53.2	88.8	6.7	11.2
Entire Project Areas	1978	218.4	186.3	85.3	32.1	14.7
Wilder Impoundment	1978	93.3	76.1	81.6	17.2	18.4
Bellows Falls Impoundment	1978	52.6	48.8	92.8	3.8	7.2
Vernon Impoundment	1978	60.0	50.2	83.8	9.7	16.2
Entire Project Areas	2014	251.8	223.3	88.7	28.5	11.3
Wilder Impoundment	2014	90.2	77.9	86.3	12.4	13.7
Bellows Falls Impoundment	2014	49.5	42.6	86.1	6.9	13.9
Vernon Impoundment	2014	57.8	53.2	92.1	4.6	7.9

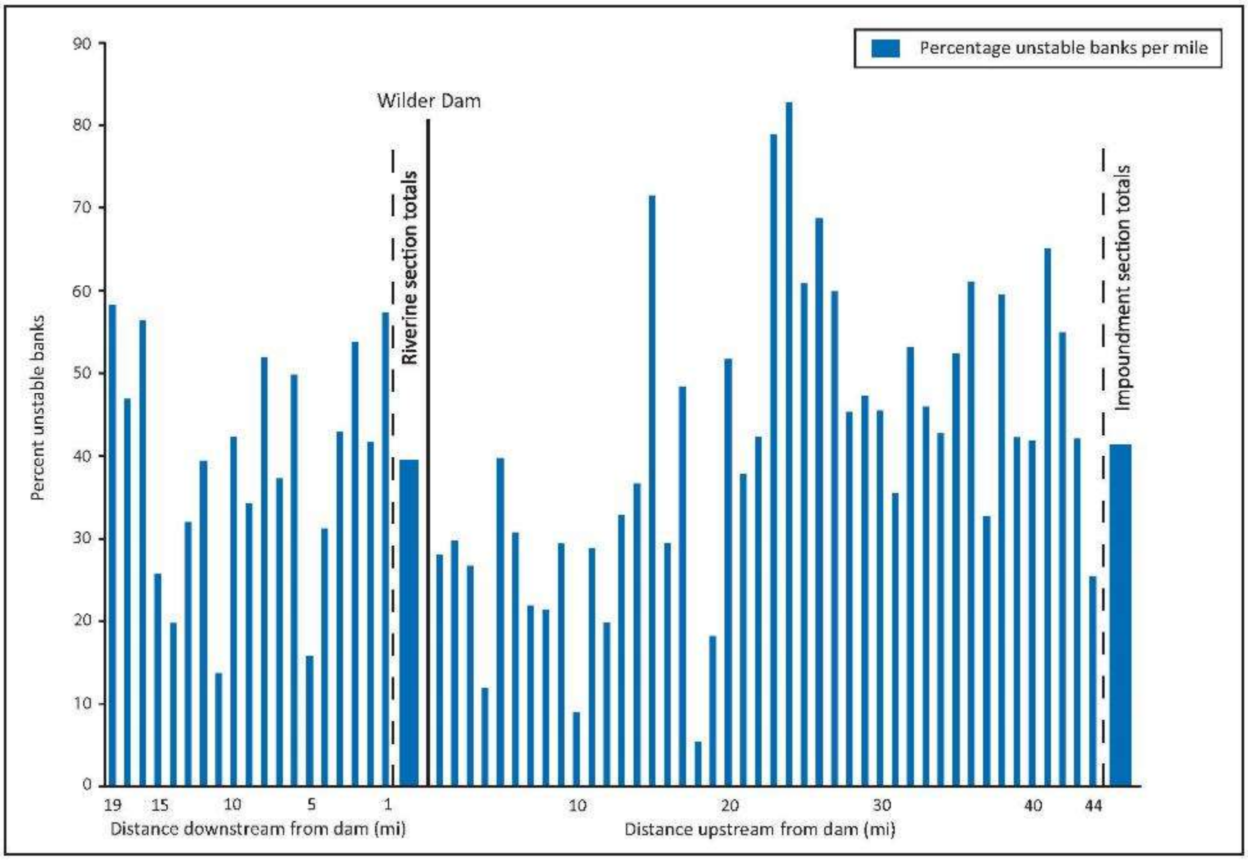
Source: ILP Studies 2-3, *Riverbank Transect and Riverbank Erosion Studies*

Wilder Project

The height, composition, and stability of the banks vary considerably throughout the Wilder impoundment. The upper impoundment flows across wide floodplain areas, so bank heights are generally limited to less than 15 feet north of Bradford, Vermont, and Piermont, New Hampshire. Bank heights exceed 50 feet in portions of the lower impoundment where the river more frequently encounters glacial surfaces. Very low banks of less than 5 feet make up 15 percent of the Wilder impoundment and are typically found at tributary confluences and where old abandoned oxbows intersect the river.

Banks of the upper Wilder impoundment are composed (almost exclusively) of sand (see Table 3.4-1), but gravel is present at the base of the banks in some locations. While loam and sand banks are also prevalent in the lower impoundment, gravel and clay banks are more frequently observed. Bedrock is uncommon in the Wilder impoundment, although bedrock outcrops along 8 percent of the banks in the riverine section downstream of the dam with most of this concentrated in the Sumner Falls area. The large percentage of cobble banks in the Wilder riverine reach compared to the impoundment is consistent with bank heights greater than 15 feet for nearly 80 percent of the bank length.

Slightly greater than 40 percent of the banks in the Wilder impoundment are unstable (i.e., banks designated as eroding, vegetated eroding, or failing armor). Although significant variation exists, bank instability in the impoundment is generally greater with increasing distance from Wilder dam (Figure 3.4-12). The lower levels of erosion closer to the dam may be the result of higher levels of armoring on the riverbanks in the lower impoundment. The highest levels of erosion in the Wilder riverine reach are found in the most downstream portions of the reach but are nearly as high at the upstream end just below the dam. Erosion rates are lowest in the middle portion of the riverine reach where the greatest amount of bedrock is present along the banks. Overall, the percentage of unstable banks in Wilder impoundment is similar to that documented in the Wilder riverine reach.

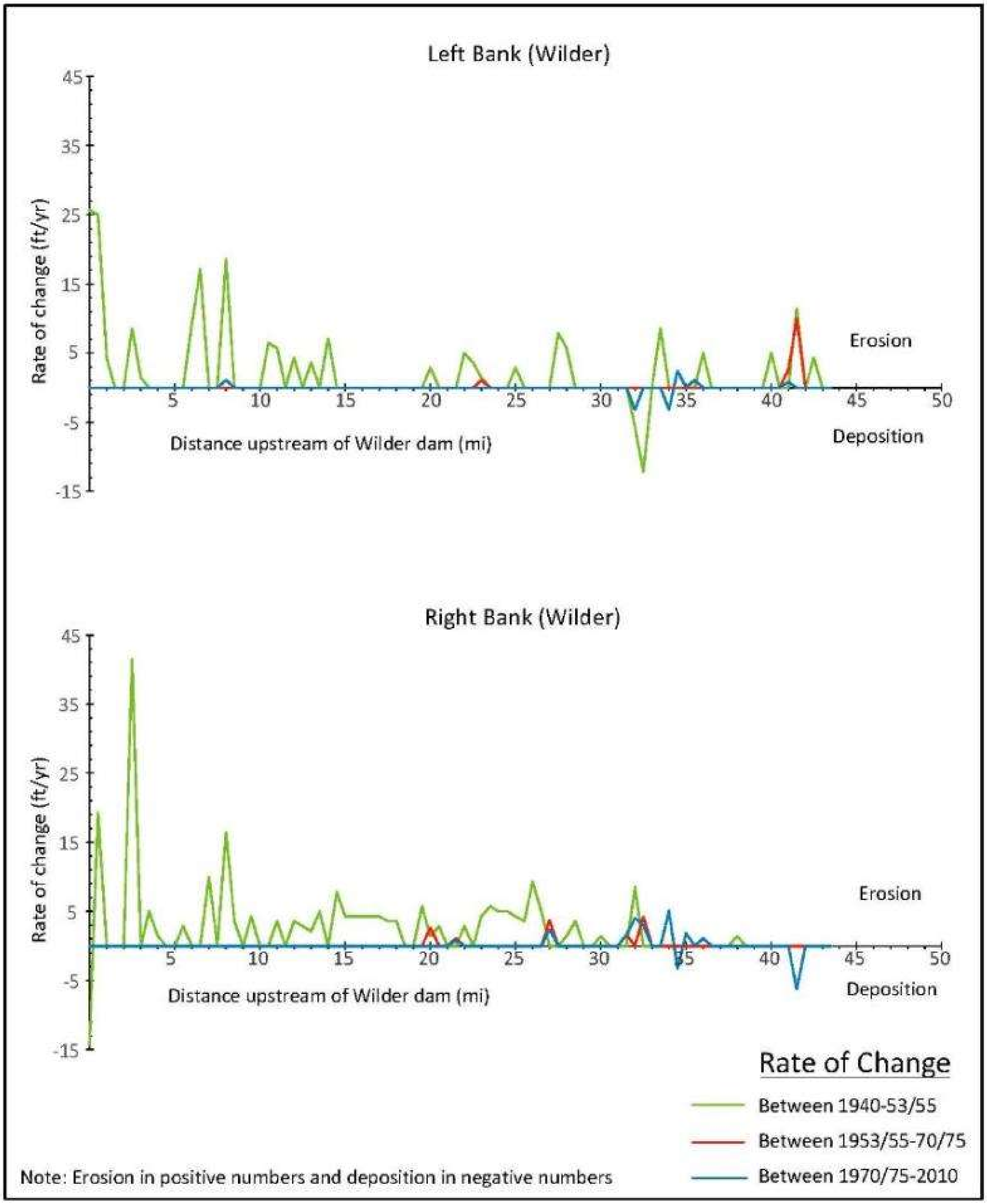


Source: ILP Studies 2-3, *Riverbank Transect and Riverbank Erosion Studies*

Figure 3.4-12. Variation in amounts of erosion with distance from Wilder dam.

The amount of erosion in the Wilder impoundment appears to have increased through time as determined by comparing maps of erosion completed in 1958, 1978, and 2014 (see Table 3.4-3). Between 1958 and 2014, the percentage of bank length that was eroding increased from 5 to 14 percent. Historical comparison is challenging, however, because vegetated eroding and failing armor banks were not likely considered eroding in the earlier mapping efforts. Given that a greater percentage of the lower impoundment is armored, the increase in erosion primarily occurred in the upper impoundment where normal (non-spill) Project operations (i.e., WSE fluctuations at Wilder dam) have little influence on flow conditions. While the impoundment upstream of Wilder dam extends upstream to Haverhill, New Hampshire, and Newbury, Vermont, WSE fluctuations in the upper impoundment are more significantly impacted by inflows from upstream (see Section 3.5.1.1, *Water Quantity, Project Inflows and Outflows – Vernon Projec*t, and Figure 3.5-15).

An analysis of georeferenced historical aerial photographs indicates that the rate of erosion has increased slightly at some locations in upper Wilder impoundment with very little change occurring in the lower impoundment after an initial inundation of the banks after the opening of Wilder dam in 1950. In addition to temporal variations in the rate of erosion, the rate of erosion in Wilder impoundment varies spatially as well (Figure 3.4-13). Limited data sources compiled in Studies 2-3 enabled the calculation of estimated erosion rates at only a few isolated locations and those rates varied from approximately 10 ft per year to less than 1.0 ft per year. However, two years of continuous monitoring at six active erosion sites in the Wilder impoundment as part of Studies 2-3 recorded recession at the top of the bank at one site and no erosion at the other five locations.



Source: ILP Studies 2-3, *Riverbank Transect and Riverbank Erosion Studies*

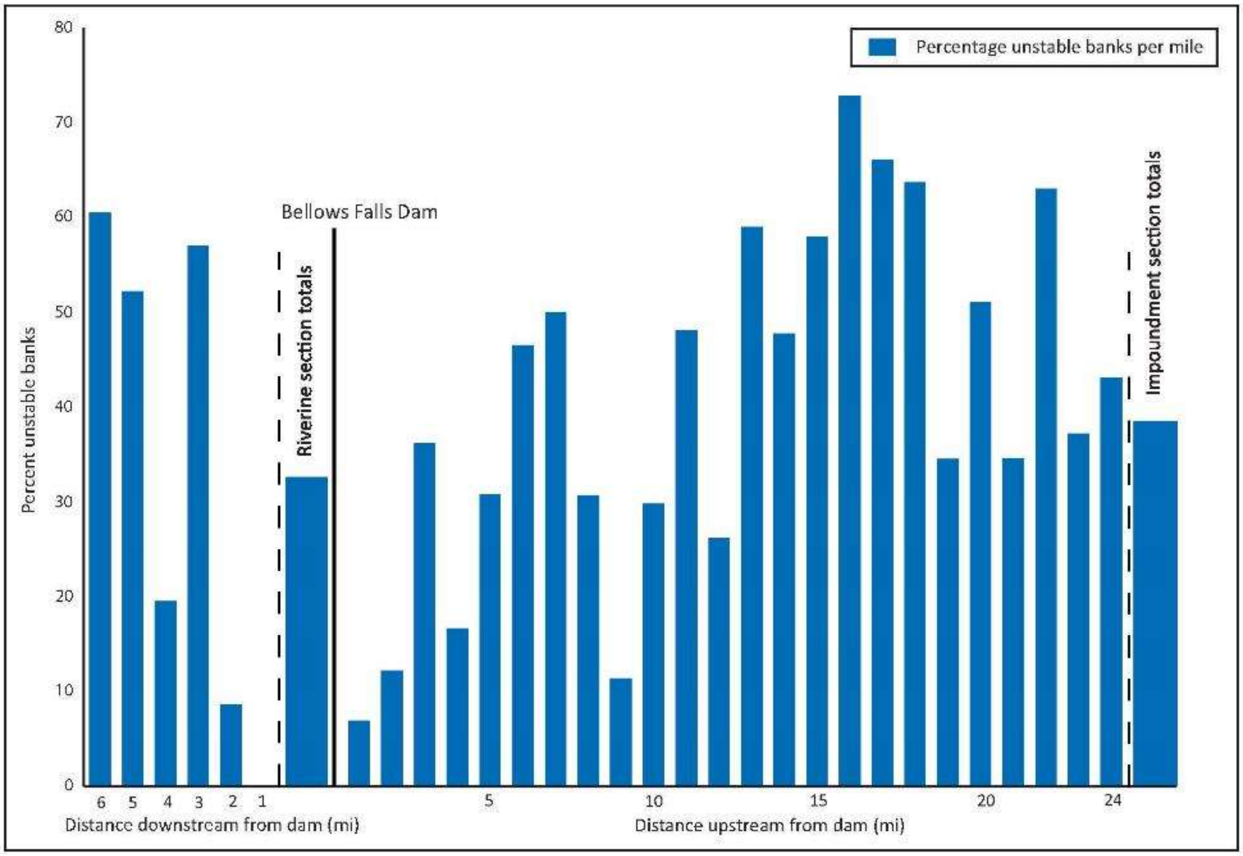
Figure 3.4-13. Rates of erosion in Wilder impoundment with distance upstream of the dam (left and right banks looking downstream).

Bellows Falls Project

The height, composition, and stability of the banks also vary considerably throughout the Bellows Falls impoundment. Higher banks resulting from the river flowing against old river terraces or glacial surfaces are present throughout most of the impoundment but are generally found only along one bank at any given location with a lower floodplain on the opposite bank. In general, banks are less than 15 feet high when the river flows against active floodplains or tributary deltas and greater than 15 feet where the river encounters glacial surfaces or terraces. The nearly 20 percent of the banks less than 5 feet high are concentrated in the lower impoundment, where a number of low floodplain meadows have formed upstream of the Williams River delta that constricts the valley and causes backwatering upstream during floods. The low banks also result from the opening of Bellows Falls dam in 1928 that raised water levels and inundated the lower portions of once higher banks.

Bank composition in the Bellows Falls impoundment is nearly 80 percent sand (see Table 3.4-1). Gravel and cobble are present along less than 15 percent of the bank, largely along portions of the nearly 10 percent of banks that are more than 50 feet high. Bedrock occurs along only 4 percent of banks in the impoundment. While less than 1 percent of the banks have exposed bedrock in the Bellows Falls riverine reach downstream of the dam, nearly 20 percent of the banks are composed of boulders, suggesting bedrock may be present just below the surface. The large percentage of cobble banks in the riverine reach compared to the impoundment is consistent with bank heights greater than 15 feet for 70 percent of the bank length.

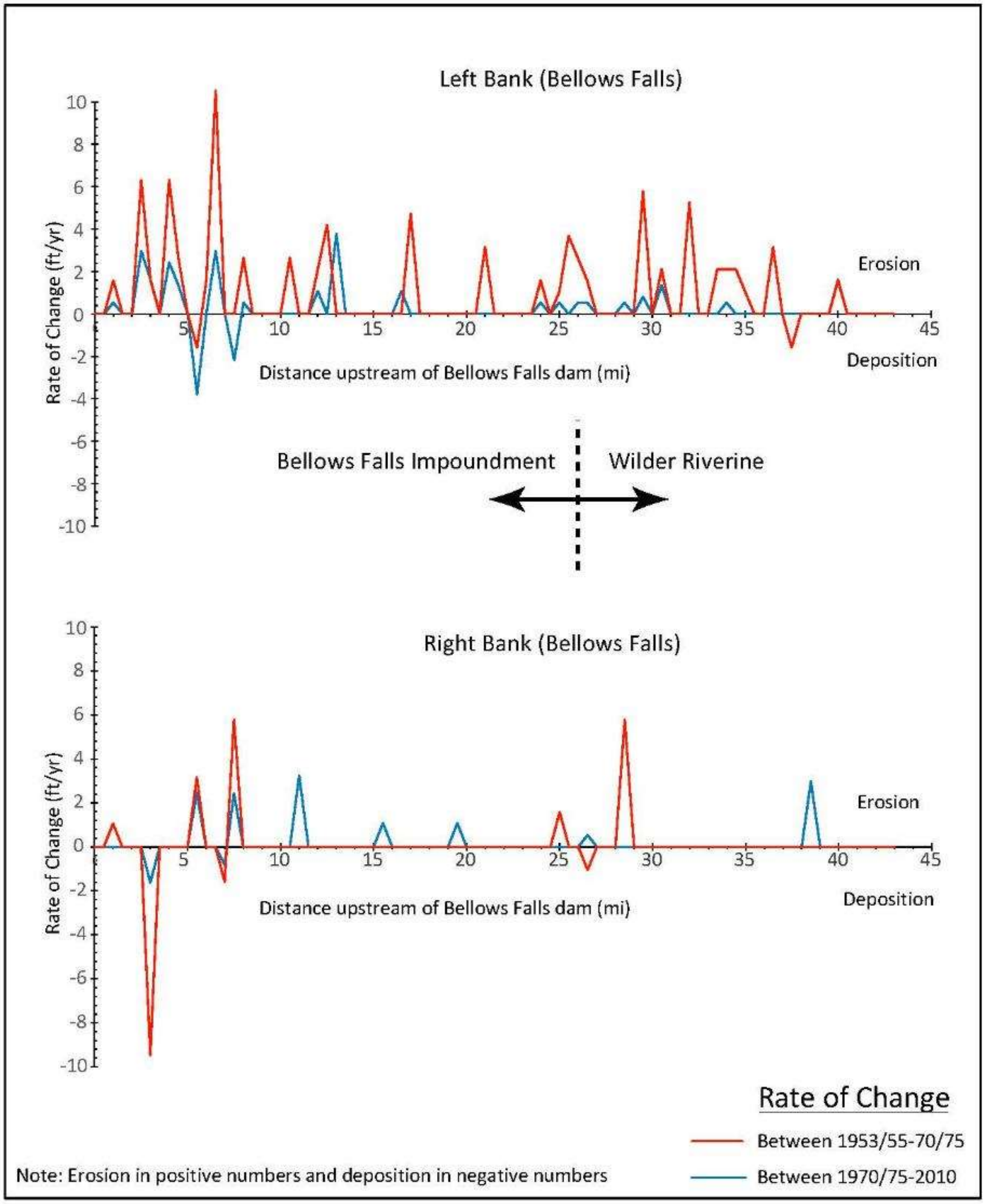
Forty percent of the banks in the Bellows Falls impoundment are unstable (Studies 2-3). Although significant variation exists, bank instability in the impoundment is generally greater with increasing distance from the dam (Figure 3.4-14). The lower levels of erosion closer to the dam may be due to the presence of armoring along the higher banks on the Vermont shore and the low banks on the New Hampshire side. Lower banks have limited gravitational force to drive erosion. The highest levels of erosion in the Bellows Falls riverine reach are found in the most downstream portions of the reach. The percentage of unstable banks in the Bellows Falls riverine reach is approximately 7 percent lower than in the Bellows Falls impoundment, largely because no unstable banks are present in the first mile downstream of Bellows Falls dam where bedrock, boulders, and armoring are prevalent.



Source: ILP Studies 2-3, *Riverbank Transect and Riverbank Erosion Studies*

Figure 3.4-14. Variation in amounts of erosion with distance from Bellows Falls dam.

The amount of erosion in the Bellows Falls impoundment appears to have decreased through time as determined by comparing maps of erosion completed in 1958, 1978, and 2014 (see Table 3.4-3). Between 1958 and 2014, the percentage of eroding banks decreased from 28 to 14 percent. Historical comparison is challenging, however, because vegetated eroding and failing armor banks were not likely considered eroding in earlier mapping efforts. An analysis of georeferenced historical aerial photographs indicates that the rate of erosion has decreased significantly at many locations, particularly in the lower Bellows Falls impoundment (Figure 3.4-15). In addition to temporal variations in the rate of erosion, the rate of erosion in the impoundment varies spatially as well. Two years of erosion monitoring at four sites in the impoundment as part of Studies 2-3 recorded recession at the top of the bank at two sites and no erosion at the other two locations. With 7 ft of bank recession at a monitoring site in Charlestown, New Hampshire, in the lower impoundment, current erosion rates in the Bellows Falls impoundment range from 0 ft per year to as high as 3.5 ft per year.



Source: ILP Studies 2-3, *Riverbank Transect and Riverbank Erosion Studies*

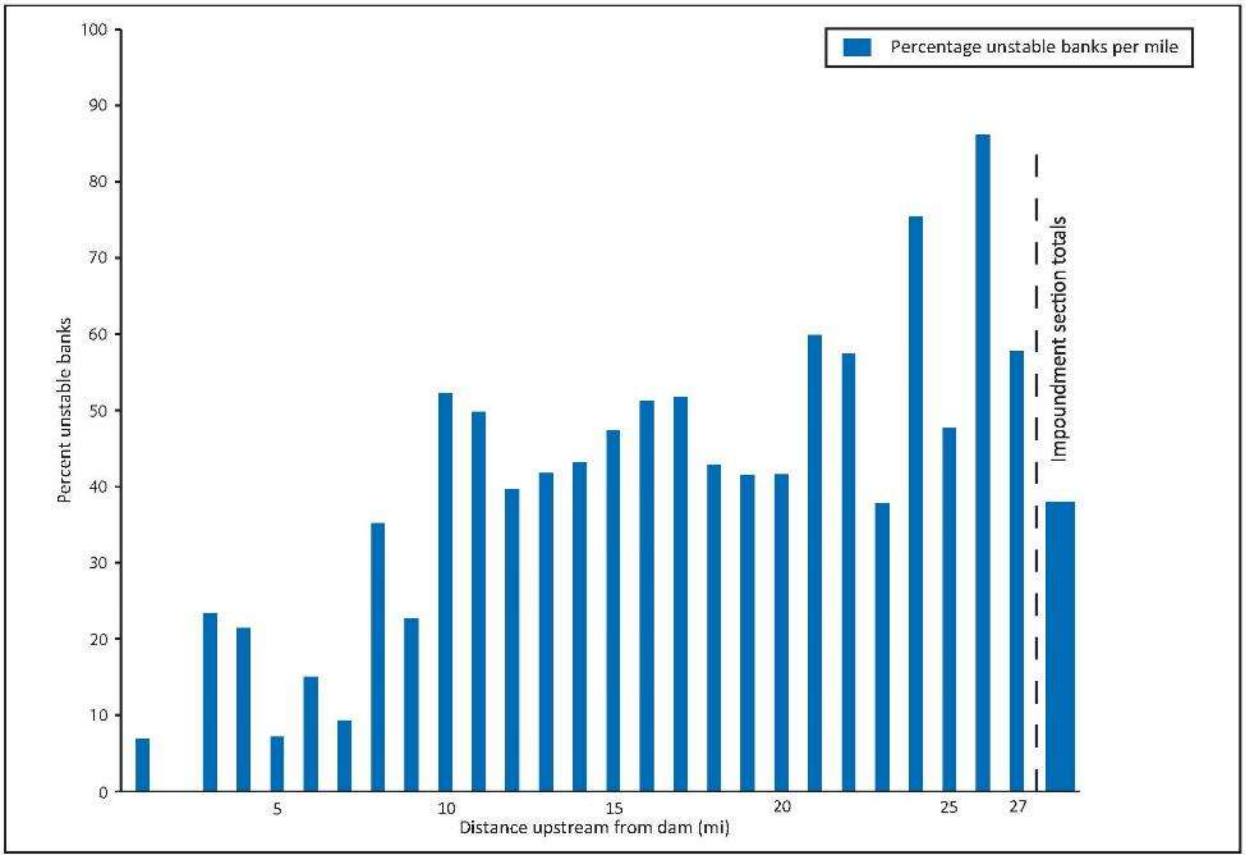
Figure 3.4-15. Rates of erosion in Bellows Falls impoundment with distance upstream of the dam (left and right banks looking downstream).

Vernon Project

Like the Wilder and Bellows Falls impoundments, the height, composition, and stability of the banks vary throughout the Vernon impoundment. Nearly 60 percent of the banks in the impoundment are greater than 15 feet high as more than 10 miles of the impoundment between Putney and Brattleboro, Vermont, pass through a narrow portion of the Connecticut River Valley where very little floodplain is present. Greater than 10 percent of the bank length is less than 5 feet high in large part because of backwater areas inundated upstream of Vernon dam.

Banks in the Vernon impoundment are composed of nearly 90 percent sand (see Table 3.4-1). However, more areas of bedrock outcrop occur along the banks of the Vernon impoundment than in the Wilder or Bellows Falls impoundments, reflecting the long narrow valley between Putney and Brattleboro. While most of the Vernon riverine reach downstream of the dam is composed of sand (58 percent), a considerable percentage of the banks are composed of bedrock (17 percent), and glacial clay (20 percent) as the river flows through the relatively confined valley for the approximate 1.5 miles of river considered part of the Vernon riverine reach for Studies 2-3.

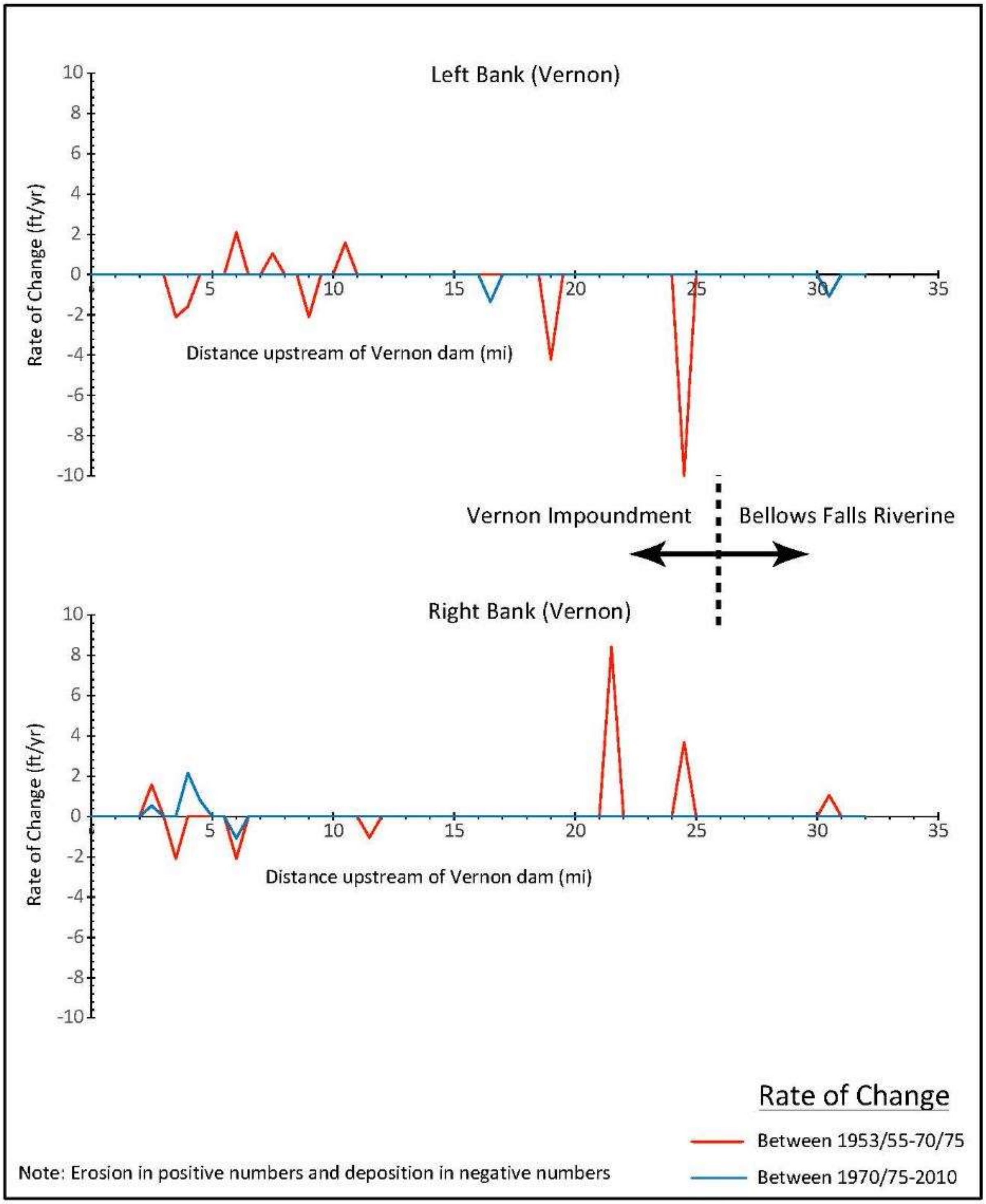
Nearly 40 percent of the banks in the Vernon impoundment are unstable (Studies 2-3). Although some variation exists, bank instability in the impoundment is generally greater with increasing distance from the dam (Figure 3.4-16). The presence of very low banks associated with the raising of Vernon dam in 1909 best explains the lower levels of erosion closer to the dam. Two years of erosion monitoring at three sites in the impoundment as part of Studies 2-3 recorded no recession at the top of the bank at those sites. More than half of the banks in the Vernon riverine reach are unstable with greater amounts of instability in the second mile downstream of the dam compared to the first mile closest to the dam. However, comparisons of erosion levels between the Vernon impoundment and the Vernon riverine reach are unwarranted given the great disparity in length (i.e., only two data points are available from the riverine reach, and data are not shown in Figure 3.4-16).



Source: ILP Studies 2-3, *Riverbank Transect and Riverbank Erosion Studies*

Figure 3.4-16. Variation in amounts of erosion with distance from Vernon dam.

The amount of erosion in the Vernon impoundment appears to have decreased slightly through time as determined by comparing maps of erosion completed in 1958, 1978, and 2014 (see Table 3.4-3). Between 1958 and 2014, the percentage of eroding banks decreased from 11 to 8 percent. Historical comparison is challenging, however, because vegetated eroding and failing armor banks were not likely considered eroding in the earlier mapping efforts. An analysis of georeferenced historical aerial photographs indicates that the rate of erosion has decreased at many locations and increased at others with most of these changes occurring in lower Vernon impoundment (Figure 3.4-17). Few data are available to determine rates of erosion in the Vernon impoundment. Two years of erosion monitoring at three sites in Vernon impoundment as part of Studies 2-3 recorded no bank recession, suggesting the rate of erosion is very slow for at least parts of the impoundment.

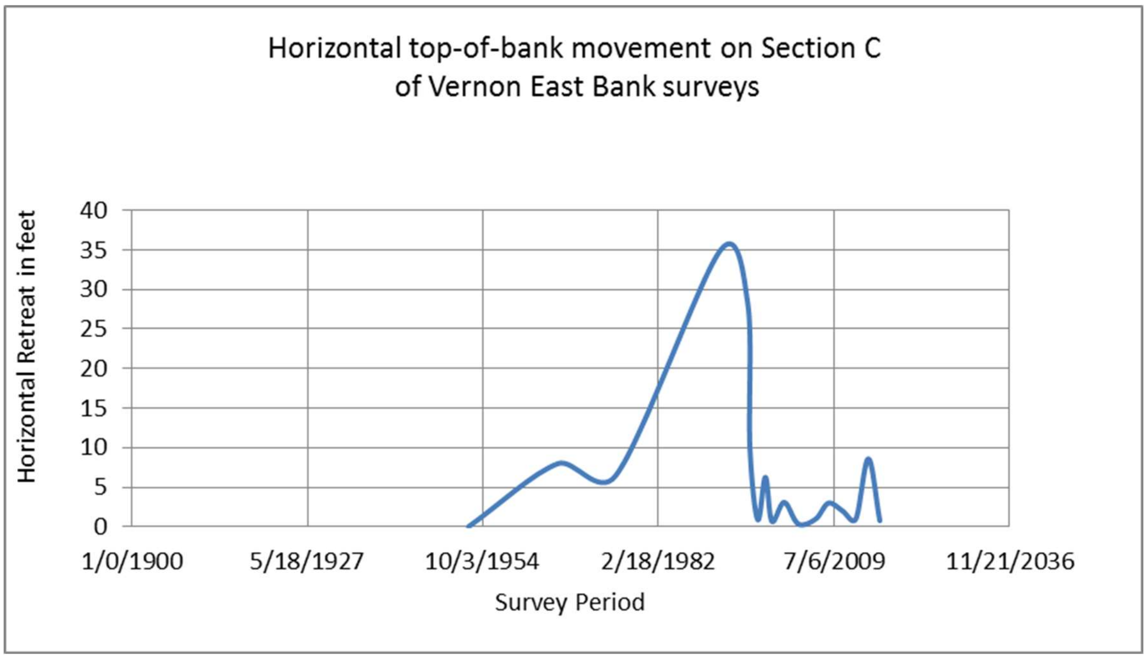


Source: ILP Studies 2-3, *Riverbank Transect and Riverbank Erosion Studies*

Figure 3.4-17. Rates of erosion in Vernon impoundment with distance upstream of the dam (left and right banks looking downstream).

Vernon Neck East Bank Erosion

Twenty-five years of monitoring on a 73-ft high bank immediately downstream of Vernon dam on the left bank (of Vernon Neck so-called) documents an average erosion rate of approximately 2.6 ft per year. Based on aerial photographic evidence indicating the top of bank in 1952, 1966, and 1975 and survey monitoring from 1991 until present, it is apparent that rates of erosion have varied over the 61-year period (Figure 3.4-18). The greatest rate of top-of-bank retreat corresponds with the period between 1975 and 1991. This timeframe corresponds with when the Northfield Mountain Pumped Storage Project commenced operation, which included increasing the Turners Falls impoundment WSE by 5.4 ft. This change in turn, resulted in a 3-5 foot increase of WSE at the base of Vernon dam under normal (non-spill) Vernon operation flows and the Vernon Neck east bank, causing a higher WSE-bank interface.



Source: Great River Hydro

Figure 3.4-18. Vernon East Bank historical top-of-bank movement.

High water events, combined with the higher WSE acting on the high bank are largely responsible for the increased rate of erosion. In 1986, as part of the Vernon Project's spillway crest control and gate modifications, bedrock was removed below the tainter gates on the left bank to re-direct flow into the center river channel and reduce the whirlpool and shear-related effects in the pool below the Vernon Neck east bank. This action may be in part supportive of the development of the significant and seemingly stable beach at the base of the steep bank. Monitoring of the east bank included hydrographic monitoring of the submerged pool below and confirmed the gradual development of a submerged bench and beach at the base. Since 2006, despite annual high flow events with the exception of Tropical Storm Irene in 2011 causing a slight increase in slope failure immediately following that event, biennial surveys indicate little change in the top-of-bank and erosion has remained uniform and slight along the entire length of the bank. The toe-of-slope also shows little change along the entire length of the base of the bank and only minor and normal settling, a common phenomenon in open sloped areas composed primarily of sandy soils.

3.4.2 Environmental Effects

3.4.2.1 No-action Alternative

Analysis of bank erosion data compiled as part of Studies 2-3, bolstered by the supplemental analysis for Study 3 (Field and Normandeau, 2017b) indicates that continued erosion in the Project areas is the result of high flows that exceed the applicable Project's maximum station discharge. Multiple forces act on the riverbanks through time to move the cycle of erosion forward as illustrated in Figure 3.4-10. The continuation of erosion, however, ultimately depends on the removal of sediment that accumulates at the base of the bank from upslope erosion.

Sediment Transport

Evaluations of coarse-grained sediment stability using information collected as part of Study 8 and Study 4 indicate that most coarse-grained substrates are stable at flows within the applicable Project's maximum station discharge. Study 8 concludes that mainstem flows at or greater than the Projects' maximum station discharge and tributary inflows are the dominant factors that lead to transport of coarse-grained sediments in the Project areas. Sediment available for transport is supplied to the river from tributary inputs and bank erosion. Deltas are building out into the Connecticut River at the mouths of numerous tributaries (e.g., the Cold River) and supply fine-grained sediment as well as coarse-grained gravel, cobble, and boulders.

Threshold Velocity for Sediment Entrainment

Comparisons were made between flow velocities generated at various flow levels and the minimum threshold velocity necessary to transport (or entrain) sediment in the Project areas. The threshold velocity depends on a variety of parameters such as grain size, cohesion between the sediment grains, stratification, turbulence in the water, existing turbidity in the water, and vegetative cover. The predominant soils in the Project area consist of fine sandy loam and fine silty loams (see Table 3.4-1). In a publication on thresholds for small channel design, the Natural Resources Conservation Service (NRCS) (2007) recommended a maximum permissible velocity of 1.5 feet per second (ft/s) for fine sand in clear water without any detritus, and 2.5 ft/s in water carrying colloidal silts. For sandy loam, NRCS (2007) recommended a maximum permissible velocity of 1.75 ft/s for clear water and 2.5 ft/s for water carrying colloidal silts. Finally, for silty loam, NRCS (2007) recommended a maximum permissible velocity of 2.0 ft/s for clear water and 3.0 ft/s for water carrying colloidal silts. Because these values are design parameters, they contain a factor of safety. USACE (1991) used an allowable mean velocity for non-scouring flood control channels of 2.0 ft/s for fine sand. Considering these values, a reasonably conservative minimum threshold for sediment entrainment along the Connecticut River is considered to be 2.0 ft/s. Considering that the river carries sediment and vegetative material accumulating at the base of the banks from upslope erosion (thus reducing entrainment potential), a reasonable range for sediment entrainment is estimated at 2.0 to 3.0 ft/s based on velocities provided by NRCS (2007) and USACE (1991).

Flow Velocities and Shear Stress

Flow velocities were measured at three impoundment monitoring sites and three riverine monitoring sites for Studies 2-3 and to compare with the hydraulic model (Study 4) calculated average velocities at those locations, with good agreement between field measurements and calculated velocities. Flow velocities within the impoundments are controlled both by discharge and WSE at the dams as well as upstream inflow. For the same discharge, a drop in WSE at the dams will increase the flow velocity as a result of the increase in water surface slope. When the WSE at the dams is held constant, flow velocity will generally increase with increased discharge or upstream inflow. Velocity, flow, and WSE vary at any given moment within the impoundments unless conditions (WSE, inflow and discharge) are stable for at least 8 continuous hours, which is rare even in a natural, undeveloped river system. Otherwise, increases in inflow can increase WSE at a particular location unless the downstream WSE at the dam is lowered or discharge at the dam is increased, thereby reducing backwater effects on the increasing inflow. Managing flows above station capacity requires managing the WSE at the dam (referred to as river profile operation) to manage WSE within the impoundment within the project boundary and to reduce flood stage upstream. For example, at Wilder dam, under high flow river profile operations (see Section 3.5.1.1, *Water Quantity*), the maximum WSE is reduced when inflow exceeds 10,000 cfs and reaches the bottom of the current operating elevation when flows reach 16,000 cfs. An analysis of hydraulic modeling data indicates that velocity increases in the Wilder impoundment are primarily the result of increases in discharge in direct response to increases in inflow, and only minor increases result from the lowering of WSE at the dam as those discharges increase (Field and Normandeau, 2017a).

At three impoundment erosion monitoring sites (Bellavance, Mudge, and Charlestown) velocities were measured in August 2015 when river flows were at 23 percent, 43 percent, and 75 percent, respectively, of the applicable Project maximum station discharge. Average channel velocities were also calculated, using the HEC-RAS model, for Project minimum flow and maximum station discharge, and for flood flows (30,000, 60,000, and 100,000 cfs) during Study 4 (Table 3.4-4). Both the measured and modeled velocities at the impoundment sites were well below the 2.0 ft/s velocity minimum threshold for sediment entrainment under normal (non-spill) Project operations, indicating that the sediment accumulating at the base of the riverbanks would generally require higher flows and higher velocities to be entrained and removed. In addition, aside from fine sand, silt and clay, some of the sediments at the base of these banks include coarser materials that would have a higher threshold for entrainment. Note that this analysis did not consider localized shear stress on the banks, but rather the overall likelihood of normal (non-spill) Project operations within the impoundments to remove beach or submerged material or lead to channel scour based on average velocities.

Table 3.4-4. Flow velocities measured at corresponding impoundment erosion monitoring sites.

Parameter	Units	Study 2-3 Site ID and Name		
		02-W03	02-W09	02-B07
		Bellavance	Mudge	Charlestown
Project area		Wilder Impoundment	Wilder Impoundment	Bellows Falls Impoundment
Town		Bradford, VT	Lyme, NH	Charlestown, NH
Latitude		44.014852	43.822787	43.220017
Longitude		-72.09461	-72.187887	-72.437683
Streamflow Velocity Measurements in the field				
Date		August 6, 2015		
Measured velocity (mean)	ft/s	0.6	0.7	0.7
Flow at measured velocity	cfs	2,690	4,990	8,560
Max. station discharge	cfs	11,700[d]	11,700[d]	11,400[e]
Percent of total generation		23%	43%	75%
Additional contribution from spill		0%	0%	0%
Modeled Streamflow Velocities				
Velocity at measured flow[a]	ft/s	0.3–0.4	0.7	0.4–0.6
Velocity at minimum flow	ft/s	0.1	0.1	0.1
Velocity at maximum station discharge flow[a]	ft/s	0.7–0.9	1.4-1.5[c]	0.6–0.7
Minimum flow needed for threshold velocity[b]	cfs	100,000	17,000	28,000
Modeled velocity at 30,000 cfs	ft/s	1.7	3.3	2.3
Modeled velocity at 60,000 cfs	ft/s	1.8	5.0	3.4
Modeled velocity at 100,000 cfs	ft/s	2.0	6.6	4.2
Threshold velocity for erosion[b]	ft/s	2.0–3.0		

Source: ILP Studies 2-3, *Riverbank Transect and Riverbank Erosion Studies*

a. Ranges indicate variations due to the range of normal (non-spill) operations WSEs at the downstream dam.
b. Threshold velocity data from NRCS (2007) and USACE (1991). Reasonable range is 2.0–3.0 ft/s.
c. Recently discovered that the study report incorrectly reported velocity at maximum station discharge of 1.3-1.4 at the Mudge site.

d. The maximum station discharge with all three units operating under ideal conditions is approximately 11,700 cfs, although 98 percent of the time flows are less than 10,700 cfs.
e. The maximum station discharge with all three units operating under ideal conditions is approximately 11,400 cfs, although 98 percent of the time flows are less than 11,235 cfs.

Flow velocities were also measured at erosion monitoring sites in the riverine reaches downstream of the Projects (Hartford, Malnati, and Stebbins Island sites) and at the North Walpole USGS gage (no. 01154500) in May 2015. Streamflow values within these riverine reaches represented upstream station discharges plus additional natural tributary inflow, which can be significant at Hartford, Malnati erosion monitoring sites and the North Walpole gage location (Table 3.4-5). Velocities were also modeled for each Project's minimum flow and maximum station discharge, and for flood flows (30,000, 60,000, and 100,000 cfs) during Study 4 (Table 3.4-5). Results indicate that the 2.0 ft/s velocity minimum threshold entrainment velocity is not reached at the Hartford and North Walpole gage sites under the range of normal (non-spill) Project operating discharges but is reached at the Malnati and Stebbins Island sites at above average station discharges, which occurs only when project inflow facilitates such.

The Malnati site is located in the Bellows Falls riverine reach and receives inflow from Bellows Falls as well as from the Saxtons and Cold rivers, both large tributaries (fifth order stream). Threshold entrainment velocity of 2.0 ft/s is reached at 8,000 cfs of flow at that site which occurs most often during the spring freshet and fall rain events. As noted above, an overall reasonable range for sediment entrainment is estimated at 2.0 to 3.0 ft/s. The flow at the Malnati site required for sediment entrainment based on a 3.0 ft/s entrainment velocity rather than the more conservative 2.0 ft/s used in this analysis is approximately 17,000 cfs, well above the maximum station discharge of 11,700 cfs and occurs naturally many times during each year.

At the Stebbins Island site, flow at the time of field measurement was 77 percent of the maximum station discharge, but since the field measurements were taken only in the left channel (New Hampshire side) around Stebbins Island, the measured flow in that channel amounted to approximately 70 percent of total Vernon discharge at that time. The left channel accounted for 70 percent of total discharge from Vernon at the time of field measurement, but that channel is wider and shallower than the right channel so direct proportioning of flow and velocity cannot be made with modeled data. Measured and modeled velocities are difficult to compare at the Stebbins Island site where total river flow is split around the island (modeled velocities are based on average velocity across both channels). Flows in the Vernon riverine reach required to reach the threshold entrainment velocity are further influenced by WSEs at the downstream Turners Falls dam and range from 11,000 to 14,000 cfs within Turners Falls normal (non-spill) operating range (Table 3.4-5), and between 12,000 and 13,000 cfs at the Turners Falls dam median WSE of 181.3 ft (NGVD29). Flows within the range of 11,000 to 14,000 cfs occur primarily during the spring freshet and fall rain events. These various operating WSE at Turners Falls dam influence the Stebbins Island monitoring site by affecting the WSE at the site 2-3 ft. The WSE and flow velocities in the reach below Vernon is further influenced by the operation of Northfield Mountain Pumped Storage project. To provide storage capacity for the Northfield Mountain Pumped Storage Development, the WSE elevation may fluctuate, per the FERC license, 9 ft as measured at the Turners Falls dam. When operating in a pumping mode, the maximum hydraulic capacity (4 pumps) is approximately 15,200 cfs (3,800 cfs/pump) or approximately the maximum discharge of Vernon station (15,400 cfs). Alternatively, when operating in a generation mode, the approximate maximum hydraulic capacity (4 turbines) is approximately 20,000 cfs (5,000 cfs/turbine) (FirstLight, 2016a). Nevertheless, as noted above, the overall reasonable range for sediment entrainment is estimated at 2.0 to 3.0 ft/s. The flow required for sediment entrainment based on a 3.0 ft/s entrainment velocity rather than the more conservative 2.0 ft/s used in this analysis and based on full river flow is nearly 60,000 cfs (Table 3.4-5) which typically occurs at a sustained period at least annually during the spring runoff period. As a result of this and the various downstream project influences on WSE and flow, it is unlikely that Vernon normal (non-spill) operation results in significant velocity and shear stress conditions necessary to cause erosion below the dam.

Table 3.4-5. Flow velocities measured at corresponding riverine erosion monitoring sites and the North Walpole USGS gage.

Parameter	Units	Study 2-3 Site ID and Name			
		02-WR01	NA	02-BR05	02-VR02
		Hartford	USGS Gage N. Walpole	Malnati	Stebbins Island
Project Area		Wilder Riverine	Bellows Falls Riverine	Bellows Falls Riverine	Vernon Riverine
Town		Hartford, VT	Walpole, NH	Walpole, NH	Hinsdale, NH
Latitude		43.6638	43.125964	43.095957	42.770815
Longitude		-72.30636	-72.4 37676	-72.438574	-72.504831
Streamflow Velocity Measurements in the field					
Date		May 9, 2015	May 13, 2015		May 14, 2015
Measured velocity (mean)	ft/s	1.3	2.0	2.6	2.3[a]
Flow at measured velocity	cfs	11,540	11,970	12,040	11,848[a]
Max. upstream station discharge	cfs	11,700[d]	11,400[e]	11,400[e]	15,400
Percentage of max. upstream station discharge		99%	100%	100%	77%[a]
Additional contribution from spill		0%	5%	6%	0%
Modeled Streamflow Velocities					
Velocity at measured flow[b]	ft/s	1.9	1.9	2.5–2.6	1.9–2.1

Parameter	Units	Study 2-3 Site ID and Name			
		02-WR01	NA	02-BR05	02-VR02
		Hartford	USGS Gage N. Walpole	Malnati	Stebbins Island
Velocity at minimum flow[b]	ft/s	0.3	0.5	0.5–0.6	0.4–0.7
Velocity at maximum station discharge flow[b,d,e]	ft/s	1.8	1.8	2.4–2.5	2.1–2.3
Minimum flow needed for threshold velocity[c]	cfs	13,000	13,000	8,000	11,000–14,000
Modeled velocity at 30,000 cfs	ft/s	3.1	3.5	4.0	2.7
Modeled velocity at 60,000 cfs	ft/s	4.3	4.8	5.2	3.1
Modeled velocity at 100,000 cfs	ft/s	5.4	6.0	6.1	3.4
Threshold velocity for erosion[c]	ft/s	2.0–3.0			

Source: ILP Studies 2-3, *Riverbank Transect and Riverbank Erosion Studies*

a. Velocity and flow were measured in the left (New Hampshire side) channel at 8,290 cfs, while Vernon total discharge was 11,848 cfs. Modeled values are based on whole river flows including both left and right (Vermont side) channels.
b. Ranges indicate variations due to the range of normal (non-spill) operations WSEs at the downstream dam.
c. Threshold velocity data from NRCS (2007) and USACE (1991). Reasonable range is 2.0–3.0 ft/s.
d. The maximum station discharge with all three units operating under ideal conditions is approximately 11,700 cfs, although 98 percent of the time flows are less than 10,700 cfs.
e. The maximum station discharge with all three units operating under ideal conditions is approximately 11,400 cfs, although 98 percent of the time flows are less than 11,235 cfs.

Supplemental Flow Velocity and Shear Stress Analysis

In response to the absence of localized shear stress data, FERC requested additional analysis in 2017, otherwise referred to as the Study 3 Supplement. Shear stress is commonly used as a measure of a stream's ability to entrain and transport bed and bank materials. Entrainment occurs only when the shear stress acting upon a particle crosses a threshold that exceeds the resistance of that particle to movement. This threshold value is commonly referred to as the critical shear stress (VANR, 2004).

In response to this request, the supplemental study plan was developed and included monitoring site field work, laboratory analysis of sediment, and hydraulic modeling. Information was collected at the 21 monitoring sites to further characterize site conditions, focusing on the two factors that could influence entrainment and transport of sediment: (1) near-bank shear stress and velocity experienced during project operations, and (2) the critical shear stress and velocity that must be exceeded before sediment entrainment can occur at the 21 monitoring sites. Estimates of near-bank shear stress and velocity were derived from 2D hydraulic modeling conducted for each monitoring site, while the critical shear stress and velocity used in the analysis was based on the average particle size of sediment samples collected at each site. Prior to this supplement, 1D hydraulic estimates of velocity represented averaged velocity for the entire cross section of the river. The supplemental analysis estimated near-bank critical shear stress, velocity, and compared that with bank sediment (sieve size) specific design critical velocity and shear stress thresholds for each sediments type that is affected by the range of project operation (WSE and flow) at the 21 monitoring sites.

A table was prepared for each monitoring site that lists critical shear stresses and near-bank velocities with respect to WSEs corresponding to project operation. Descriptions of river channel features, including stratigraphy, the presence or absence of vegetation, the presence of any visual erosion indicators (e.g., slumps, falls, notching, undercutting), and other notable bank features (e.g., groundwater seeps) were included as observed. Bank sediments were taken at WSEs corresponding to the three project operational conditions, and the composition determined through laboratory analysis to enable determination of an estimated critical shear stress and velocity based on grain size/shape for the site-specific material (Table 3.4-6). The sediment composition associated with the 21 erosion monitoring sites generally corresponds and supports previous identified soil types (Table 3.4-1) and aligns with the conservative minimum threshold of 2.0/ft/s up to 3.0 ft/sec for sediment entrainment along the Connecticut River. Additionally, near-bank shear stress and velocity estimates were interpreted for various project operation conditions using a 2-Dimensional Hydrologic Engineering Center's River Analysis System (HEC-RAS) model. Collectively, comparing the site and bank sediment specific estimated critical shear stress and velocity to potential shear and velocity factors associated with project operating conditions, the ability to entrain and transport sediment under project operations was determined to be absent or if possible, unlikely to be the significant contributing factor when considering the potential due to re-occurring natural high flows.

Table 3.4-6. Sediment composition at corresponding erosion sites.

Site Name	At Minimum Turbine Discharge	At Medium Turbine Discharge	At Maximum Turbine Discharge
Bedell Bridge	silty fine sand	silty fine sand	sandy silt
Bellavance	Silt	silt	silty sand
Tullando	silty fine sand	silty fine sand	fine sand
Mudge	silty sand	silty sand	silty sand
Vaughn	fine sand with silt	fine sand with silt	silty clay
Pine Park	silty fine sand	silty fine sand	silty fine sand
Hartford	medium sand with silt	silty fine sand	gravel with sand and silt

Site Name	At Minimum Turbine Discharge	At Medium Turbine Discharge	At Maximum Turbine Discharge
Edgewater Farm	gravel with sand and silt	gravel with sand and silt	sandy silt
Great River Farm	coarse gravel with sand	coarse gravel with sand and silt	sandy silt
Hartwell	sandy silt	silt with clay	silt
Lipfert	fine gravel	coarse sand	silty fine sand
Jarvis Island	silty fine sand	silty fine sand	sandy silt
Charlestown	sandy silt	sandy silt	sandy silt
North Walpole	medium sand with gravel	medium sand with gravel	silt
Walpole Beach	sandy silt	sandy silt	sandy silt
Malnati	silty fine sand	silty fine sand	silty fine sand
River View Farm (upstream)	silty fine sand	silty fine sand	silty fine sand
River View Farm (downstream)	silty fine sand	silty fine sand	sandy silt
LaCroix	coarse sand with gravel	coarse sand with gravel	medium sand
Vernon	silty coarse gravel	medium sand with gravel	medium sand with gravel
Stebbiins Island	sandy silt	sandy silt	sandy silt

Source: ILP Studies 2-3, *Riverbank Transect and Riverbank Erosion Studies – Supplement to the Final Study Report (Field and Normandeau, 2017b).*

During the March 8, 2018, updated study results meeting on the Study 3 Supplemental Report, concerns were raised about the grain size used in the velocity analysis. All soil samples had a sieve analysis performed to determine grain size distribution and D50 particle size. A hydrometer analysis was also conducted on samples that had a combined silt and clay fraction of more than 5 percent to determine the percentage of each component (i.e., clay and silt) in the given sample. Great River Hydro's erosion study consultant explained the use the average grain size (D50) of the sampled soil is a common practice and reasonable method to calculate the critical threshold velocity and shear stress values representative of the entire soil type; particularly in light of the fact that the values were conservative estimates based on unconsolidated soils, while native bank sediments typically are consolidated and compacted.

A comment was made during the meeting that a substantial proportion of the sediment was other than average size (D50) and a request for corresponding critical velocity and shear stress values for the other representative grain sizes be provided. In its final version of the Supplement to the Final Study Report for ILP Study 2-3, Riverbank Transect and Riverbank Erosion Studies (Field and Normandeau, 2017b), supplemental data for threshold velocities and critical shear stresses for D15, D50, and D85 grain sizes at each of the erosion sites was provided. Selected data from that analysis for the impoundment erosion sites Bellavance, Mudge, and Charlestown is presented in Table 3.4-7 through 3.4-9 below. Similarly, selected data from that analysis for the Hartford, Malnati, and Stebbins Island riverine erosion sites is presented in Table 3.4-10 through 3.4-12 below.

Table 3.4-7. Threshold velocity and critical shear stress data for the Bellavance (impoundment) erosion site.

W03 - Bellavance (Vermont)

Sample characteristics									
Sample elevation (NAVD88 ft)	382.6 (minimum)			383.8 (medium)			387.3 (maximum)		
Sample ID	W03-1			W03-1			W03-2		
Morphological feature	Bench			Bench			Bank		
D15 grain size (mm)	0.0127	Silt		0.0127	Silt		0.0324	Silt	
D50 grain size (mm)	0.0382	Silt		0.0382	Silt		0.0821	Fine sand	
D85 grain size (mm)	0.0666	Silt		0.0666	Silt		0.1517	Fine sand	
Stratigraphy	Compact glacial silt and clay			Compact glacial silt and clay			Colluvium		
Erosion features	Forms resistant shelf at bank toe			Forms resistant shelf at bank toe			Planar slip/topple block		
Presence/character vegetation	None			None			Thick herbaceous growth		
Presence of seeps	None			None			None		
Other characteristics	Large submerged slip block			Large submerged slip block			Large submerged slip block		
Model parameters and outputs									
Dam elevation (NAVD88 ft)	382.6			382.6			382.6		
Model flow (cfs)	700	5000	12000	700	5000	12000	700	5000	12000
Sample station (ft)	2391	2391	2391	2394	2394	2394	2407	2407	2407
Near bank station (ft)	2371	2371	2371	2374	2374	2374	2387	2387	2387
Velocity (ft/sec)	0.085	0.606	1.327	Dry	0.552	1.250	Dry	Dry	0.941
Shear stress (lb/ft^2)	0.0001	0.006	0.026	Dry	0.006	0.024	Dry	Dry	0.016
Threshold analysis									
D15 Threshold velocity (ft/sec)	3.5	3.5	3.5	3.5	3.5	3.5	3.5	3.5	3.5
D15 Velocity threshold passed	No	No	No	No	No	No	No	No	No
D15 Critical shear stress (lb/ft^2)	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04
D15 Shear stress threshold passed	No	No	No	No	No	No	No	No	No
D50 Threshold velocity (ft/sec)	3.5	3.5	3.5	3.5	3.5	3.5	1.8	1.8	1.8
D50 Velocity threshold passed	No	No	No	No	No	No	No	No	No
D50 Critical shear stress (lb/ft^2)	0.04	0.04	0.04	0.04	0.04	0.04	0.021	0.021	0.021
D50 Shear stress threshold passed	No	No	No	No	No	No	No	No	No
D85 Threshold velocity (ft/sec)	2.0	2.0	2.0	2.0	2.0	2.0	1.9	1.9	1.9
D85 Velocity threshold passed	No	No	No	No	No	No	No	No	No
D85 Critical shear stress (lb/ft^2)	0.039	0.039	0.039	0.039	0.039	0.039	0.039	0.039	0.039
D85 Shear stress threshold passed	No	No	No	No	No	No	No	No	No

Source: ILP Studies 2-3, *Riverbank Transect and Riverbank Erosion Studies – Supplement to the Final Study Report (Field and Normandeau, 2017b).*

Table 3.4-8. Threshold velocity and critical shear stress data for the Mudge (impoundment) erosion site.

W09 - Mudge (New Hampshire)

Sample characteristics									
Sample elevation (NAVD88 ft)	382.6 (minimum)			382.8 (medium)			384.6 (maximum)		
Sample ID	W09-1			W09-1			W09-2		
Morphological feature	Beach			Beach			Bank		
D15 grain size (mm)	Unlisted*	Silt		Unlisted*	Silt		0.0386	Silt	
D50 grain size (mm)	0.1113	Fine sand		0.1113	Fine sand		0.0804	Fine sand	
D85 grain size (mm)	0.2038	Fine sand		0.2038	Fine sand		0.1412	Fine sand	
Stratigraphy	Not applicable - below bank			Not applicable - below bank			Colluvium		
Erosion features	None			None			Notching		
Presence/character vegetation	None			None			Moderate herbaceous cover		
Presence of seeps	None			None			None		
Other characteristics	Wood along bank			Wood along bank			Wood along bank		
Model parameters and outputs									
Dam elevation (NAVD88 ft)	382.6			382.6			384.6		
Model flow (cfs)	700	5000	12000	700	5000	12000	700	5000	12000
Sample station (ft)	165	165	165	163	163	163	159	159	159
Near bank station (ft)	185	185	185	184	184	184	179	179	179
Velocity (ft/sec)	0.056	0.402	0.960	Dry	0.385	0.923	0.046	0.329	0.794
Shear stress (lb/ft^2)	0.000	0.003	0.014	Dry	0.002	0.013	0.000	0.002	0.010
Threshold analysis									
D15 Threshold velocity (ft/sec)	3.5	3.5	3.5	3.5	3.5	3.5	3.5	3.5	3.5
D15 Velocity threshold passed	No	No	No	No	No	No	No	No	No
D15 Critical shear stress (lb/ft^2)	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04
D15 Shear stress threshold passed	No	No	No	No	No	No	No	No	No
D50 Threshold velocity (ft/sec)	1.8	1.8	1.8	1.8	1.8	1.8	1.8	1.8	1.8
D50 Velocity threshold passed	No	No	No	No	No	No	No	No	No
D50 Critical shear stress (lb/ft^2)	0.028	0.028	0.028	0.028	0.028	0.028	0.021	0.021	0.021
D50 Shear stress threshold passed	No	No	No	No	No	No	No	No	No
D85 Threshold velocity (ft/sec)	2.0	2.0	2.0	2.0	2.0	2.0	1.9	1.9	1.9
D85 Velocity threshold passed	No	No	No	No	No	No	No	No	No
D85 Critical shear stress (lb/ft^2)	0.052	0.052	0.052	0.052	0.052	0.052	0.036	0.036	0.036
D85 Shear stress threshold passed	No	No	No	No	No	No	No	No	No

Notes:
* D15 grain size listed as "silt" in laboratory results; specific grain size for threshold analysis inferred from nearby samples.

Source: ILP Studies 2-3, *Riverbank Transect and Riverbank Erosion Studies – Supplement to the Final Study Report (Field and Normandeau, 2017b).*

Table 3.4-9. Threshold velocity and critical shear stress data for the Charlestown (impoundment) erosion site.

B07 - Charlestown (New Hampshire)

Sample characteristics						
Sample elevation (NAVD88 ft)	290.2 (minimum and medium)			290.4 (maximum)		
Sample ID	B07-1			B07-2		
Morphological feature	Beach			Bank		
D15 grain size (mm)	0.0241	Silt		0.0241	Silt	
D50 grain size (mm)	0.0624	Silt		0.0619	Silt	
D85 grain size (mm)	0.1118	Fine sand		0.1331	Fine sand	
Stratigraphy	Not applicable - below bank			Colluvium		
Erosion features	None			Planar slip/topple block		
Presence/character vegetation	None			Thick herb and shrub cover		
Presence of seeps	None			None		
Other characteristics	Large slip block along bank			Large slip block along bank		
Model parameters and outputs						
Dam elevation (NAVD88 ft)	290.2			290.2		
Model flow (cfs)	2000	5000	12000	2000	5000	12000
Sample station (ft)	114	114	114	112	112	112
Near bank station (ft)	135	135	135	133	133	133
Velocity (ft/sec)	0.123	0.307	0.730	Dry	Dry	0.692
Shear stress (lb/ft^2)	0.0002	0.001	0.005	Dry	Dry	0.005
Threshold analysis						
D15 Threshold velocity (ft/sec)	3.5	3.5	3.5	3.5	3.5	3.5
D15 Velocity threshold passed	No	No	No	No	No	No
D15 Critical shear stress (lb/ft^2)	0.04	0.04	0.04	0.04	0.04	0.04
D15 Shear stress threshold passed	No	No	No	No	No	No
D50 Threshold velocity (ft/sec)	2.0	2.0	2.0	2.0	2.0	2.0
D50 Velocity threshold passed	No	No	No	No	No	No
D50 Critical shear stress (lb/ft^2)	0.037	0.037	0.037	0.036	0.036	0.036
D50 Shear stress threshold passed	No	No	No	No	No	No
D85 Threshold velocity (ft/sec)	1.8	1.8	1.8	1.9	1.9	1.9
D85 Velocity threshold passed	No	No	No	No	No	No
D85 Critical shear stress (lb/ft^2)	0.029	0.029	0.029	0.034	0.034	0.034
D85 Shear stress threshold passed	No	No	No	No	No	No

Source: ILP Studies 2-3, *Riverbank Transect and Riverbank Erosion Studies – Supplement to the Final Study Report (Field and Normandeau, 2017b).*

Table 3.4-10. Threshold velocity and critical shear stress data for the Hartford (riverine) erosion site.

WR01 - Hartford (Vermont)

Sample characteristics									
Sample elevation (NAVD88 ft)	324.9 (minimum)			328.8 (medium)			332.0 (maximum)		
Sample ID	WR01-1			WR01-2			WR01-3		
Morphological feature	Beach			Beach			Beach		
D15 grain size (mm)	0.1443	Fine sand		0.0805	Fine sand		0.0965	Fine sand	
D50 grain size (mm)	0.5373	Medium sand		0.1535	Fine sand		2.5331	Coarse sand	
D85 grain size (mm)	1.3695	Medium sand		0.4101	Medium sand		28.3358	Coarse gravel	
Stratigraphy	Not applicable - below bank			Not applicable - below bank			Not applicable - below bank		
Erosion features	None			None			Notching on beach		
Presence/character vegetation	None			None			None		
Presence of seeps	None			None			None		
Other characteristics	Trees downed and growing			Trees downed and growing			Trees downed and growing		
Model parameters and outputs									
Dam elevation (NAVD88 ft)	290.2			290.2			290.2		
Model flow (cfs)	700	5000	12000	700	5000	12000	700	5000	12000
Sample station (ft)	594	594	594	604	604	604	607	607	607
Near bank station (ft)	574	574	574	584	584	584	587	587	587
Velocity (ft/sec)	0.287	1.683	2.541	Dry	1.543	2.414	Dry	Dry	2.346
Shear stress (lb/ft^2)	0.001	0.036	0.072	Dry	0.030	0.064	Dry	Dry	0.060
Threshold analysis									
D15 Threshold velocity (ft/sec)	1.9	1.9	1.9	1.8	1.8	1.8	1.8	1.8	1.8
D15 Velocity threshold passed	No	No	Yes	No	No	Yes	No	No	Yes
D15 Critical shear stress (lb/ft^2)	0.037	0.037	0.037	0.021	0.021	0.021	0.025	0.025	0.025
D15 Shear stress threshold passed	No	No	Yes	No	Yes	Yes	No	No	Yes
D50 Threshold velocity (ft/sec)	2.2	2.2	2.2	1.9	1.9	1.9	2.8	2.8	2.8
D50 Velocity threshold passed	No	No	Yes	No	No	Yes	No	No	No
D50 Critical shear stress (lb/ft^2)	0.055	0.055	0.055	0.039	0.039	0.039	0.06	0.06	0.06
D50 Shear stress threshold passed	No	No	Yes	No	No	Yes	No	No	No
D85 Threshold velocity (ft/sec)	2.5	2.5	2.5	2.1	2.1	2.1	6.0	6.0	6.0
D85 Velocity threshold passed	No	No	Yes	No	No	Yes	No	No	No
D85 Critical shear stress (lb/ft^2)	0.05	0.05	0.05	0.042	0.042	0.042	0.42	0.42	0.42
D85 Shear stress threshold passed	No	No	Yes	No	No	Yes	No	No	No

Source: ILP Studies 2-3, *Riverbank Transect and Riverbank Erosion Studies – Supplement to the Final Study Report (Field and Normandeau, 2017b).*

Table 3.4-11. Threshold velocity and critical shear stress data for the Malnati (riverine) erosion site.

BR05 - Malnati (New Hampshire)

Sample characteristics									
Sample elevation (NAVD88 ft)	218.8 (minimum)			220.8 (medium)			224.0 (maximum)		
Sample ID	BR05-1			BR05-2			BR05-3		
Morphological feature	Beach			Bank			Bank		
D15 grain size (mm)	0.0709	Silt		0.0398	Silt		0.0341	Silt	
D50 grain size (mm)	0.1278	Fine sand		0.0801	Fine sand		0.0786	Fine sand	
D85 grain size (mm)	0.2208	Fine sand		0.1597	Fine sand		0.1733	Fine sand	
Stratigraphy	Not applicable - below bank			Colluvium			Colluvium		
Erosion features	None			Planar slip/topple block			Planar slip/topple block		
Presence/character vegetation	None			None			Thick herbaceous cover		
Presence of seeps	Yes, from lower bank			Yes, from lower bank			Yes, from lower bank		
Other characteristics	Large wood, abundant roots			Large wood, abundant roots			Large wood, abundant roots		
Model parameters and outputs									
Dam elevation (NAVD88 ft)	217.6			217.6			217.6		
Model flow (cfs)	2000	5000	12000	2000	5000	12000	2000	5000	12000
Sample station (ft)	163	163	163	156	156	156	145	145	145
Near bank station (ft)	184	184	184	176	176	176	166	166	166
Velocity (ft/sec)	0.711	1.331	2.273	Dry	1.111	2.014	Dry	Dry	1.583
Shear stress (lb/ft^2)	0.008	0.025	0.065	Dry	0.018	0.052	Dry	Dry	0.036
Threshold analysis									
D15 Threshold velocity (ft/sec)	2.0	2.0	2.0	3.5	3.5	3.5	3.5	3.5	3.5
D15 Velocity threshold passed	No	No	Yes	No	No	No	No	No	No
D15 Critical shear stress (lb/ft^2)	0.041	0.041	0.041	0.04	0.04	0.04	0.04	0.04	0.04
D15 Shear stress threshold passed	No	No	Yes	No	No	Yes	No	No	No
D50 Threshold velocity (ft/sec)	1.9	1.9	1.9	1.8	1.8	1.8	1.8	1.8	1.8
D50 Velocity threshold passed	No	No	Yes	No	No	Yes	No	No	No
D50 Critical shear stress (lb/ft^2)	0.033	0.033	0.033	0.020	0.020	0.020	0.020	0.020	0.020
D50 Shear stress threshold passed	No	No	Yes	No	No	Yes	No	No	Yes
D85 Threshold velocity (ft/sec)	2.0	2.0	2.0	1.9	1.9	1.9	1.9	1.9	1.9
D85 Velocity threshold passed	No	No	Yes	No	No	Yes	No	No	No
D85 Critical shear stress (lb/ft^2)	0.056	0.056	0.056	0.041	0.041	0.041	0.044	0.044	0.044
D85 Shear stress threshold passed	No	No	Yes	No	No	Yes	No	No	No

Source: ILP Studies 2-3, *Riverbank Transect and Riverbank Erosion Studies – Supplement to the Final Study Report (Field and Normandeau, 2017b).*

Table 3.4-12. Threshold velocity and critical shear stress data for the Stebbins Island (riverine) erosion site.

VR02 - Stebbins Island (New Hampshire)

Sample characteristics									
Sample elevation (NAVD88 ft)	180.9 (minimum)			182.0 (medium)			184.8 (maximum)		
Sample ID	VR02-1			VR02-1			VR02-2		
Morphological feature	Beach			Beach			Bank		
D15 grain size (mm)	0.0109	Silt		0.0109	Silt		0.0139	Silt	
D50 grain size (mm)	0.0473	Silt		0.0473	Silt		0.0439	Silt	
D85 grain size (mm)	0.0885	Fine sand		0.0885	Fine sand		0.0841	Fine sand	
Stratigraphy	Not applicable - below bank			Not applicable - below bank			Sandy silt*		
Erosion features	None			None			Notching		
Presence/character vegetation	None			None			Moss/sparse herbaceous cover		
Presence of seeps	None			None			None		
Other characteristics	None			None			Abundant roots		
Model parameters and outputs									
Dam elevation (NAVD88 ft)	180.6			180.6			180.6		
Model flow (cfs)	2000	6000	15000	2000	6000	15000	2000	6000	15000
Sample station (ft)	50	50	50	47	47	47	43	43	43
Near bank station (ft)	71	71	71	67	67	67	64	64	64
Velocity (ft/sec)	1.256	2.166	2.333	Dry	2.043	2.249	Dry	Dry	2.149
Shear stress (lb/ft^2)	0.029	0.080	0.082	Dry	0.072	0.077	Dry	Dry	0.072
Threshold analysis									
D15 Threshold velocity (ft/sec)	3.5	3.5	3.5	3.5	3.5	3.5	3.5	3.5	3.5
D15 Velocity threshold passed	No	No	No	No	No	No	No	No	No
D15 Critical shear stress (lb/ft^2)	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04
D15 Shear stress threshold passed	No	Yes	Yes	No	Yes	Yes	No	No	Yes
D50 Threshold velocity (ft/sec)	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0
D50 Velocity threshold passed	No	Yes	Yes	No	Yes	Yes	No	No	Yes
D50 Critical shear stress (lb/ft^2)	0.028	0.028	0.028	0.028	0.028	0.028	0.026	0.026	0.026
D50 Shear stress threshold passed	Yes	Yes	Yes	No	Yes	Yes	No	No	Yes
D85 Threshold velocity (ft/sec)	1.8	1.8	1.8	1.8	1.8	1.8	1.8	1.8	1.8
D85 Velocity threshold passed	No	Yes	Yes	No	Yes	Yes	No	No	Yes
D85 Critical shear stress (lb/ft^2)	0.023	0.023	0.023	0.023	0.023	0.023	0.021	0.021	0.021
D85 Shear stress threshold passed	Yes	Yes	Yes	No	Yes	Yes	No	No	Yes

Notes:
*Sample taken 1.1 ft below contact with sand loam.

Source: ILP Studies 2-3, *Riverbank Transect and Riverbank Erosion Studies – Supplement to the Final Study Report (Field and Normandeau, 2017b).*

Although multiple factors affect sediment entrainment thresholds, these data demonstrate that removal of the material accumulating at the base of the banks along the shore of the impoundments is attributable to high flow events outside of normal Project operations. Along the riverine reaches, removal of material at the base of the banks is attributable mostly to high flow events but may also occur locally to a lesser extent and capability during higher generating flows depending on local bank composition and particle size. As discussed in Section 3.4.2.1, *Threshold Velocity for Sediment Entrainment*, flow velocities at or above the threshold entrainment value do not necessarily mean that erosion is continuously occurring at a given site. Preferential removal of the most easily moved particles (i.e., fine sand) will lead to armoring with coarser particles that are not entrained, and over time, will reduce erosion of finer particles at a given flow velocity. Furthermore, removal of any material accumulating at the base of the riverbanks from upslope erosion caused by the processes described in Figure 3.4-10, as evidenced by the absence of beach or bench material, must occur before further erosion of the bank itself can continue.

Bank Erosion

The erosion data were analyzed with a Geographic Information System (GIS) to identify potential causes of erosion (Studies 2-3). Specifically, bank instability was compared with bank height (and geomorphic surface), position on meander bends, presence of riparian vegetation, and fluctuations in WSEs associated with normal (non-spill) Project operations. The following discussion summarizes the results of the analysis (see the Studies 2-3 report for details).

Bank Height and Composition

The stability of the banks is related to their height and composition. Nine bank height categories were selected to represent the range of geomorphic surfaces the river encounters throughout the Project areas: <1 ft (representing backwater areas inundated by the dams), 1-5 ft (tributary deltas, point bars), 5-8 ft (floodplain), 8–10 ft (floodplain), 10–15 ft (floodplain), 15–20 ft (flood terrace), 20–30 ft (flood terrace), 30–50 ft (glacial terrace), and >50 ft (glacial terrace). Among the various categories, banks that are 15–30 ft high are typically the least stable; these banks are composed of sand and sandy loam. Sand and sandy loam are also characteristic of floodplains, point bars, and many tributary deltas, but these bank height categories are more stable due to their lower height. Banks higher than 30 ft (glacial terraces) are more stable as well, because they are often composed of indurated (i.e., compacted) clay, gravel and cobbles, or bedrock; these materials are less prone to erosion. There is no apparent association between Project operations and bank heights. Normal (non-spill) Project operation fluctuations typically occur on a small portion of total bank heights. Bank height can be a factor influencing rate of erosion at a given location, although heights and composition are largely a result of historic geologic processes, typical river morphology and purposeful manmade channel alterations for logging, agriculture, and transportation. As such, there is no correlation or association with bank height and composition of the banks relative to Project operations.

Meanders and Armoring

Along unaltered meandering alluvial rivers, erosion rates are typically higher on the outside bends of meanders than on the inside bends due to higher shear stresses. However, analysis of unstable banks along both sides of meanders (as well as straight reaches) in the Project areas shows a slight preference for unstable banks on the inside bends as opposed to the outside bends. This finding is likely a result of bank armor that is almost twice as likely to exist along the outside bends of meanders (and along straight reaches) compared to the inside bends causing redirection of force to the opposing bank.

Riparian Vegetation

Bank and riparian vegetation are considered to have a stabilizing influence on riverbanks given that roots tend to bind soil particles together and increase bank resistance to erosion (Micheli and Kirchner, 2002). However, field observations show that erosion in the Project areas is only slightly more likely to occur where vegetation is absent compared to where it is present. The generally weak link between erosion and the absence of vegetation is likely the result of high banks; trees growing on the top of high banks generally do not have root systems that extend down to the base of the bank where they would be most effective at stabilizing the bank. Plant species with different root characteristics (i.e., shallow versus deep or tap rooting) as well as soil type characteristics (compaction, depth, and layer types) can affect the beneficial extent a riparian vegetative provides. Vegetation growing on the bank slope itself could also have a stabilizing influence all the way to the toe of the bank. Ultimately, such vegetation increases the resisting force of erosion, but erosion can still occur if the driving forces are greater even where vegetation is present. Estimates of sheer stress and velocities under high flow conditions demonstrate that such forces exist in the Project area but are natural.

Water Surface Elevations

When considering the role of WSE fluctuation in the erosion process, a distinction must be made between daily range of WSEs associated with normal (non-spill) Project operations and more sustained non-project related WSE conditions resulting from high inflow conditions caused by rainfall events and snow melt in the spring, . Conceptually, given facilitating conditions which would move water into the bank material as a result of the differential hydraulic gradient between the river and the bank, subsequent lowering of WSE can potentially cause erosion by the resulting seepage of water from the. Erosive forces are greatest when the WSE reductions are both rapid and of a large magnitude and when banks have been inundated for an extended period to allow for significant water penetration into bank material. WSE data collected with water level loggers as part of the erosion studies show variations in impoundment levels of over 8 ft in the upper Wilder impoundment during elevated natural high inflow periods. However, the magnitude of the daily fluctuations caused by normal (non-spill) Project operations is far lower than the magnitude of the larger, natural high inflow-induced fluctuations, thereby limiting the hydraulic gradient that could potentially develop between groundwater levels in the bank and the receding river stage.

Within this context, the effect of the magnitude of water level fluctuations on erosion was assessed for normal (non-spill) Project operations. For this analysis, the median WSE fluctuation (i.e., 50th percentile exceedance interval) under no spill conditions was established for each of the more than 1,100 cross sections used in hydraulic modeling (Study 4) and operations modeling (Study 5) of the Project areas. The median WSE fluctuation was chosen for the analysis because frequently experienced WSE fluctuations are the most likely factor associated with erosion. In the impoundments, more than 75 percent of the bank length experiences a median WSE fluctuation of less than 1.5 ft, a range considered ineffective at causing erosion because of the limited hydraulic gradient that would develop between the lowering river level and groundwater that seeps into the bank when the river is at the upper limit of the WSE fluctuation range.

Overall, the magnitude of the median WSE fluctuations from normal (non-spill) Project operations does not correlate well with the location of unstable banks. The magnitude of WSE fluctuations remains relatively constant throughout most of the length of the impoundments, while the levels of erosion sometimes vary substantially from one mile to the next. Although the range of WSE fluctuations is greater in the riverine reaches, the locations of large WSE fluctuations do not align with the areas where the levels of erosion are highest as would be expected if WSE fluctuations exert a strong influence on erosion. In the riverine reaches, WSE fluctuations are influenced by discharge from the dams, simultaneous inflow from tributaries, river channel constrictions, and channel morphology. The low correlation between erosion and the magnitude of WSE fluctuations indicates that other factors, such as bank height and high flow shear stress and velocities exceeding critical thresholds of bank sediment, exert a stronger control on the distribution of erosion than the magnitude of WSE fluctuations (see Section 3.4.2.1, *Current Operation, Sediment Transport*). The impoundment drawdown rate of less than 0.3 ft per hour and typically 0.1–0.2 ft per hour driven by turbine discharge capacities eliminates the potential for Project operation related rapid drawdowns. Use of available storage above the dams to capture smaller, less sustained precipitation events that cause rapid increases in inflow can reduce the potential for sudden spill events downstream of the dams that might otherwise lead to exceedance of sediment entrainment threshold velocities in the riverine reaches.

Other Factors

Several other factors may also play a role in erosion but are considered of only minor importance or could not be analyzed based on data collected as part of the approved study plans. These factors include wind- and boat-generated waves, gullying resulting from overland flow, ice, debris on the riverbanks, and animal activity. Waves are one factor responsible for creating the notches and overhangs that initially destabilize the bank as part of the erosion cycle (Field and Normandeau, 2017a), but a detailed study of their impact was not part of the approved study plan. The anticipated impact would be limited to only one part of the cycle and, absent high flow related erosion of beaches and benches that naturally occurs, the banks would reach a stable state. Anecdotal observations made during fieldwork for Study 3 revealed turbid waters can be generated when waves impinge on the banks indicating at least small-scale erosion is associated with waves. Overland flows cascading over the bank during heavy rains have the potential to erode gullies back from the bank line, but such gullies were rarely observed in the study area, so this action is not considered a significant cause of erosion and, therefore, was not analyzed in detail. Ice, logs, and other debris affecting the riverbanks could potentially scar the riverbank and initiate erosion. Although such impacts were not widely observed in the study area, subsequent slides, slumps, and flows on the bank could obscure such evidence, rendering quantification of this potential cause of erosion difficult in the absence of direct observations. Animals often burrow or slide down the banks, creating bare spots on the banks or conduits through which water can pass, potentially leading to further erosion. However, such animal-generated erosion is not considered a significant cause of bank instability in the study area given the spatial limitation of such activity.

Summary of Effects of No-Action

Bank erosion in the Project areas, where it occurs, is likely the result of multiple causal mechanisms that, in one manner or another, enable specific elements within the cycle of the cycle of erosion (Figure 3.4-10) to proceed. Not all causal mechanisms need to be present at any given site to effect erosion, but where they all are present, they all work in concert to increase bank instability. An attempt to parse out the proportion of erosion attributable to any single process (e.g., WSE fluctuations from normal (non-spill) Project operations) misrepresents the complexity and intertwined nature of the various processes integral to actuating, and more importantly, sustaining the cycle of erosion. The comparison of flow velocities and sediment transport (Table 3.4-5) suggests that bank erosion cannot continue (or the cycle cannot repeat itself) at a given location without the removal of sediment accumulating at the base of the eroding bank by flows exceeding normal operational discharges. The energy available and capacity to impact, entrain, and transport bank sediment during high flows is significantly greater than normal flow and far greater than fluctuation of water level. This underscores the singular importance of floods in perpetuating erosion throughout the Project areas, which is something that is common to all river systems.

Certain conditions appear more closely associated with erosion than others. Erosion in the Project areas is most clearly influenced by bank height and associated geomorphic surface. Erosion preferentially occurs where bank heights are between 15 and 30 ft high. These bank heights generate sufficient gravitational forces to drive erosion and are typically associated with sandy banks that provide limited resistance to erosion. WSE fluctuations associated with normal (non-spill) Project operations are one of several factors along with waves, groundwater seepage, and high flows that can create notching and overhangs that characterize the initial stages in the cycle of erosion. Based on direct observations and calculated WSE fluctuation associated with normal (non-spill) Project operations, there does not appear to be a correlation between project related WSE fluctuation and erosion occurrence in both riverine and impounded reaches. Most importantly, continued erosion in the Project areas depends on high flows to entrain and remove eroding material accumulating at the base of the banks, as described previously in *Sediment Transport*. Water velocities generated at flows near or above the maximum station discharges are the only flows capable of entraining enough accumulated sediment to sustain the cycle of erosion. A statistical analysis included in the revised study report shows bank height has the strongest correlation with erosion, although the relationship is relatively weak. This is best understood by the fact that approximately 40 percent of banks in the Project areas are characterized as being unstable, so there is a 40 percent chance of randomly selecting a point on the banks that is unstable. Knowing the bank height increases the chance of predicting whether the bank is eroding from 40 percent to 43.5 percent. Shear stress at the upper end of the normal Project operational ranges explains a similar level of deviance (3.3 percent), but all other factors explain far less of the deviance, including WSE fluctuation, which explains only 1.1 percent of the deviance from expected erosion.

The substantial changes in the rate and amounts of erosion documented through historical aerial photographs and multiple mapping efforts, and normal Project operations that have trended toward reductions in daily fluctuations over the decades associated with the current licenses, cannot adequately explain the observed patterns of erosion.

Vernon Project operations and maintenance do not appear to cause any adverse effects on the narrow neck of land known as the Vernon Neck, which separates the Vernon impoundment from the tailwater.[23] This was a natural ridge that has been armored at various times on the upstream and downstream slopes to inhibit erosion. A vegetation management plan is in place to limit the growth of potentially dangerous trees and allow regular inspection of this area. No erosion is evident. Surveys have been conducted periodically showing minor changes to the toe of the downstream slope.

3.4.2.2 Great River Hydro Proposal

Great River Hydro proposes to modify the current operation of each of the Wilder, Bellows Falls and Vernon Projects under the terms of a new License, as the preferred alternative over the No-Action Alternative. The proposed alternative focuses on creating more stable reservoir water surface elevations, reducing the magnitude and frequency of sub-daily changes in discharge from the stations, increasing the amount of time that the project is operated as inflow equals outflow and at full reservoir, and reducing the magnitude and rate of change in flows downstream of the dams.

Impoundment Reaches

Similar to the no-action alternative, the lack of a clear correlation between Project related WSE fluctuations and erosion occurrence in impounded reaches would continue to exist under Great River Hydro's proposal. Great River Hydro will continue impoundment drawdown rates (no more than 0.3 ft/hour and typically 0.1–0.2 ft per hour), which serve to limit the rate of impoundment fluctuations and utilize available storage when available to reduce the potential for sudden spill events downstream of the dams which might otherwise lead to entrainment threshold velocities in the riverine reaches. Operations dominated by IEO as described in section 2.2 and characterized from the water resources perspective in section 3.3, would further reduce the factors (e.g. stability in WSE, WSE fluctuations) that influence erosion and result in an overall reduction in erosive forces along project shorelines further minimizing Project related effects on rates of erosion. Periods of increased generation during flex operations would occur; however over dramatically reduced durations, magnitudes, and frequency than

[23] FERC SD2 specifically included this location and potential Project effects on stability.

current operations which would further reduce any adverse effects. Overall, erosion in the Project areas would continue to be driven by high flows that exceed the applicable Project's maximum station discharge.

Riverine Reaches

Similar to impounded reaches, increased stability in flow velocities and reductions in magnitude of changes in flow volumes would reduce erosive forces along riverine reaches. Overall, reduced WSE fluctuations under proposed operations, as well as changes in discharge characteristics as described in section 3.3.2, would reduce adverse effects within riverene sections.

3.4.3 Cumulative Effects

As described in Section 3.2.2, *Geographic Scope of Analysis for Cumulatively Affected Resources*, FERC identified the geographical extent of cumulative effects on sediment movement to include the upper extent of the Wilder impoundment downstream to the Route 116 Bridge in Sunderland, Massachusetts, the approximate upstream extent of the Holyoke Project impoundment. The environmental analysis discussed in Section 3.4.2, *Environmental Effects*, *Geologic and Soil Resources*, indicates that normal Project operations do not affect fine sediment movement or transport within the impoundments. Flow velocities in the riverine reaches downstream of each Project within the upper to highest range of normal generating discharges can entrain fine sediments which could lead to increased levels of suspended sediment and subsequent deposition within those reaches and potentially within the upper portion of the next downstream impoundment. However, as discussed in Section 3.4.2.1, *Current Operation*, *Sediment Transport*, flow velocities above the threshold value do not necessarily mean that erosion is continuously occurring at a given site. Where erosion does take place, preferential removal of the most easily moved particles (i.e., fine sand) will lead to armoring with coarser particles that will over time reduce erosion at a given flow velocity. These processes will continue under the proposed operation of the project, although perhaps to a slightly lesser degree.

3.4.4 Unavoidable Adverse Effects

Current operations contribute, in part, to notching and overhangs that characterize the initial stages in the cycle of erosion are unavoidable, but contribute only a small fraction of the total sediment transported and deposited by the Connecticut River in the impoundments. Under the proposed operation, largely stable impoundments will further that small contribution to a negligible factor. Reduction in Project-related fluctuations would significantly reduce, if not practically eliminate the one of the several factors that can create notching and overhangs that characterize the initial stages in the cycle of erosion. Although under current operation flows within the impoundment did not exhibit velocity and shear stress capable of entraining enough accumulated sediment to sustain the cycle of erosion within impoundments, in general, the proposed operation effect on reducing frequency, occurrence, and average magnitude of maximum flow will have an overall positive impact by reducing potential for erosive forces. Similar to impounded reaches, increased stability in flow velocities and reductions in magnitude of changes in flow will reduce erosive forces along riverine reaches. Overall, changes in discharge characteristics as described in section 3.3.2.2 due to IEO operation with limited Flexible operation and associated Transitional operational requirements of up-ramping and down-ramping and refill under proposed operations, would exert less erosive forces along riverine sections of the Connecticut River below the dams.

High natural flows that cannot be controlled or managed by Project operations do affect sedimentation and/or sediment transport in the impoundments and play a much larger role in causing unavoidable adverse effects on other resources such as protected species, aquatic and wetland habitats, and cultural resources discussed in Sections 3.5–3.11. However, as discussed in those sections, the effects caused by Project operational flows and impoundment fluctuations appear to be minimal to none in most cases. To the extent it can use Wilder Project and upstream Connecticut River Basin reservoir storage and coordinated operation with USACE flood control dams, Great River Hydro tries to reduce the potential unavoidable adverse effects of uncontrolled high natural flows by reducing the peak levels associated with these events.

There do not appear to be any adverse effects caused by Vernon Project operations and maintenance on the narrow neck of land known as the Vernon Neck which separates the Vernon impoundment from the tailwater. There is a vegetation management plan in place that includes measures to limit the growth of potentially dangerous trees and allow regular inspection of this area. No erosion is evident. Surveys have been conducted periodically showing minor changes to the toe of the downstream slope.

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3.5 Water Resources

3.5.1 Affected Environment

3.5.1.1 Water Quantity

Hydrology and Stream Flow

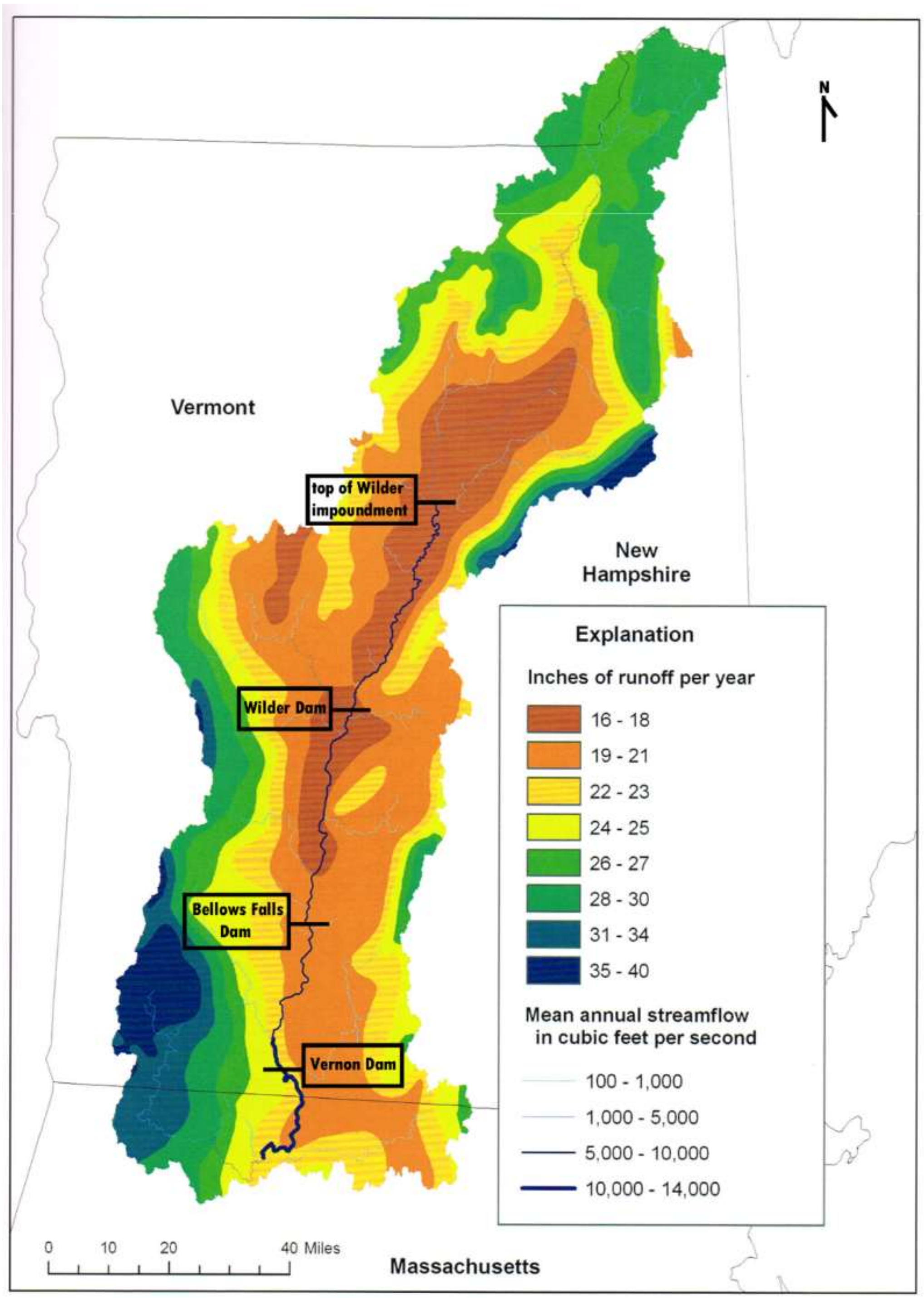
Flows into the Wilder, Bellows Falls, and Vernon Projects are regulated by managed flows from upstream dams and supplemented by tributary inflows including releases from tributary USACE dams (see Section 3.1.1 for basin description). Flows in the Connecticut River and in some major tributaries are measured at USGS gages for the DAs shown in Table 3.5-1. In addition, Great River Hydro records impoundment water levels, generation, and discharges continuously at its Projects.

Table 3.5-1. Active USGS gages in the Project areas.

Location	Drainage Area (sq. mi.)	Gaged Drainage Area (sq. mi.)	USGS Gage No.
McIndoes Dam	2200	---	
Tributary – Ammonoosuc River, NH	395	88	01137500
Connecticut River at Wells River	2,644	2,644	01138500
Tributary - Wells River, VT	100	98	01139000
Tributary - Ompompanoosuc River	136	130	01141500
Wilder Dam	3,375	---	
Tributary - White River, VT	710	690	01144000
Tributary - Ottauquechee River, VT	222	221	01151500
Connecticut River at West Lebanon	4,092	4,092	01144500
Tributary - Sugar River, NH	275	269	01152500
Tributary - Williams River, VT	118	112	01153550
Bellows Falls Dam	5,414	---	
Connecticut River at North Walpole	5,493	5,493	01154500
Tributary - Saxtons River, VT	78	72	01154000
Tributary - Cold River, NH	100	75	01154950
Vernon Dam	6,266	---	
Tributary - Ashuelot River, NH	421	420	01161000

Source: USGS (2016a, 2016e)

Estimated annual runoff varies across the Connecticut River watershed because of topography, regional weather patterns, influences of the Green and White mountains located on either side of the river valley, and annual precipitation variations resulting from latitude and mountain effects. The amount of estimated effective runoff into the Connecticut River (less evapotranspiration estimates and correlated to measured runoff where that data were available) ranges from approximately 16 to 25 inches in the Project areas, increasing from upstream to downstream (Brown, 2009; Figure 3.5-1).



Source: Brown (2009, as modified by Great River Hydro)

Figure 3.5-1. Average annual runoff in the Project areas.

Project Inflows and Outflows

Wilder Project

The Wilder Project has a total DA of 3,375 sq. mi. Inflow is both unregulated (51 percent of DA) and regulated (49 percent of DA). Storage operations associated with the upstream FMF Project reservoirs (58 river miles upstream of Wilder dam) and headwater storage reservoirs (163 river miles upstream of Wilder dam) owned by the State of New Hampshire and Great River Hydro are responsible for flow regulation and augmentation throughout the year. Within the 1,740 sq. mi. of the unregulated portion of the DA below these reservoirs, one USACE flood control project on the Ompompanoosuc River regulates flow during and immediately following precipitation or high runoff periods. All other dams and impoundments located within the DA generally operate in a non-storage, run-of-river mode (see Section 3.1.1, *Overview of the Basin*).

The Wilder impoundment is approximately 45 miles long and extends to Newbury, Vermont, and Haverhill, New Hampshire, about 4 miles downstream of the Wells River-Woodsville Bridge. The impoundment is riverine in character and ranges in depth from several feet to about 60 ft near the dam. Bathymetry in the impoundment changes rapidly as the result of underlying bedrock, channel constriction, deposition, and scour primarily associated with high flows.

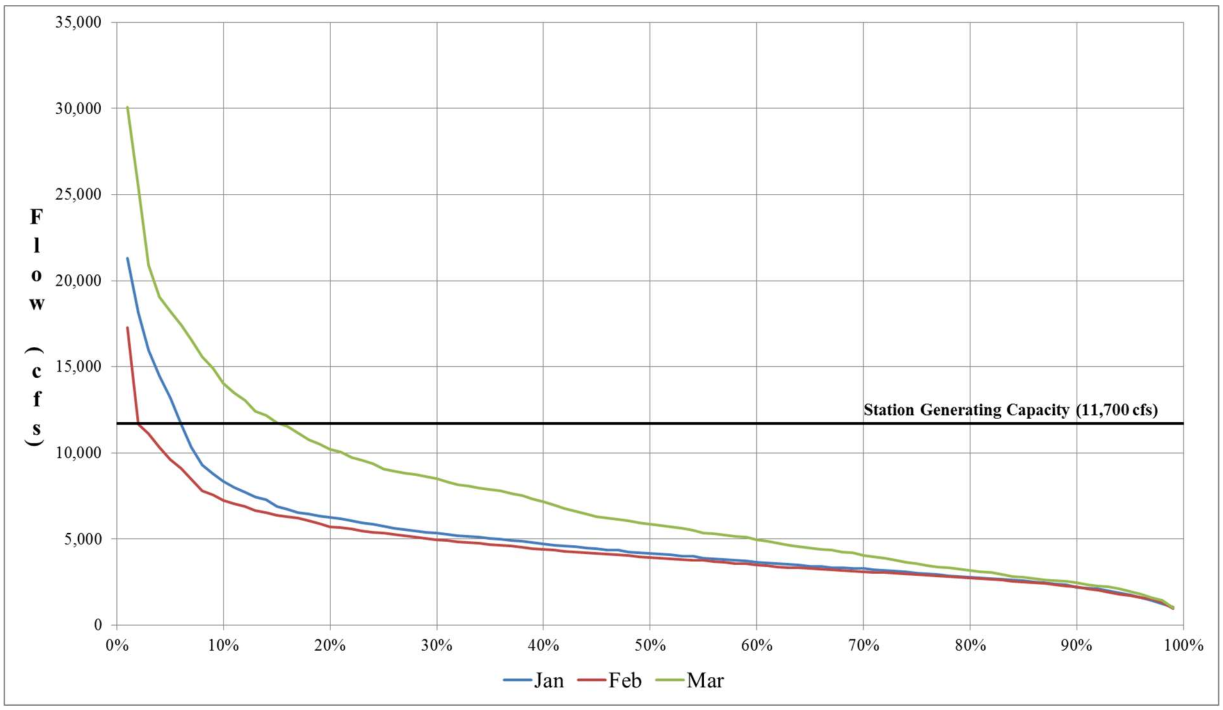
Because of the relatively flat terrain from the upper extent of the Project impoundment to the dam, the Project has limited storage capacity, which is primarily a function of impoundment length and a limited normal range of WSE. Under normal generation conditions, regulated flow from the FMF Project's McIndoes dam reaches Wilder dam on average in about 8 hours. The small run-of-river Dodge Falls Project is located about 51 river miles above Wilder dam and has limited effect on travel times from McIndoes dam.

The Wilder impoundment has a surface area of 3,100 acres and a maximum total volume of 34,600 acre-ft at El. 385 ft NGVD29[24] at the top of the stanchion boards. The overall operating range of the Project, accounting for both low inflow and most high inflows conditions is typically between El. 380.0 ft and 385.0 ft, providing about 13,350 acre-ft of usable storage in the 5-ft operating range. The storage volume associated with the typical operating range, under non-spill conditions, between El. 382.0 ft and 384.5 ft is 7,350 acre-ft, or 55 percent of the overall usable storage.

Figure 3.5-2 through Figure 3.5-5 provide monthly flow exceedance curves for the Wilder Project from January 1, 1979, to December 31, 2015. Data are based on two USGS gages in the project vicinity — USGS gage no. 01144500, Connecticut River at West Lebanon, New Hampshire (subsequently referred to as the West Lebanon gage), located downstream of the confluence with the White River, and USGS gage

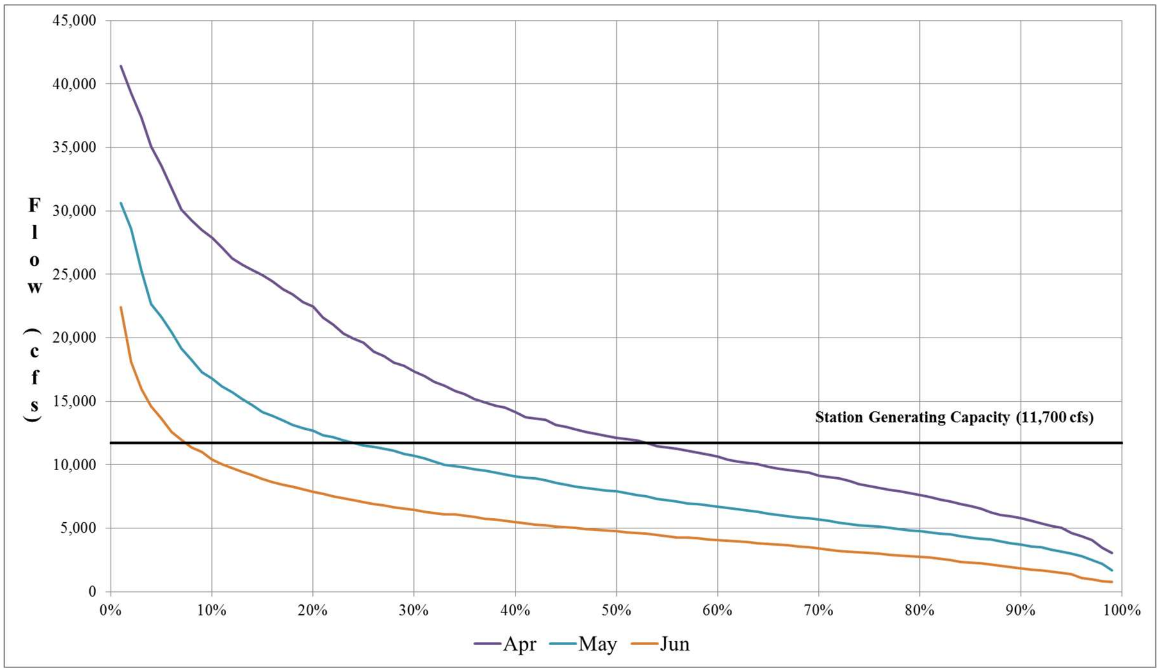
[24] All vertical elevations in Section 3.5 are stated in National Geodetic Vertical Datum of 1929 (NGVD29).

no. 01144000, White River at West Hartford, Vermont (subsequently referred to as the White River gage), located a short distance upstream on the White River. To estimate flow at only the Wilder Project, the daily flow data from the White River gage were prorated by 1.039 based on gaged DAs. These daily prorated flow values were used to account for the small amount of the White River DA that is not captured by the White River gage and for the small tributaries that enter the Connecticut River above the West Lebanon gage. For each day, the daily average flows from the prorated values from the White River gage were then subtracted from the daily West Lebanon gage to estimate flows from the Wilder Project. Table 3.5-2 summarizes the minimum, mean, and maximum values of average monthly flows for the same data set as the exceedance curves.



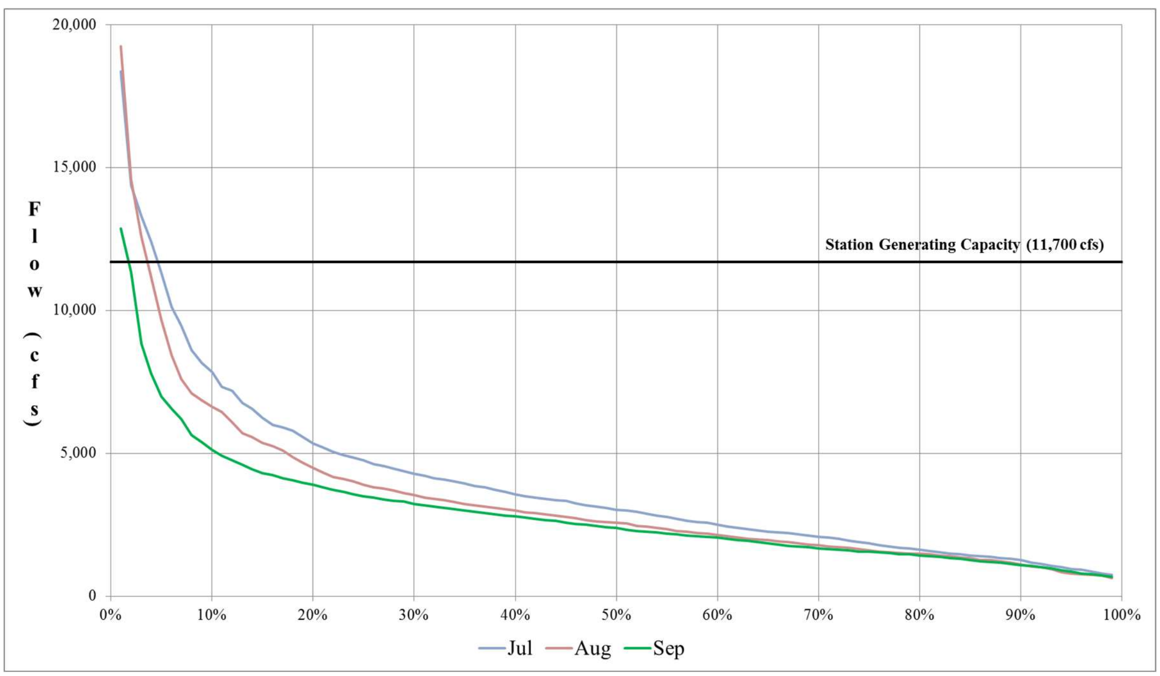
Source: USGS (2016e, as modified by Great River Hydro)

Figure 3.5-2. Wilder flow exceedance curves, January–March (based on flow data from January 1, 1979 to December 31, 2015).



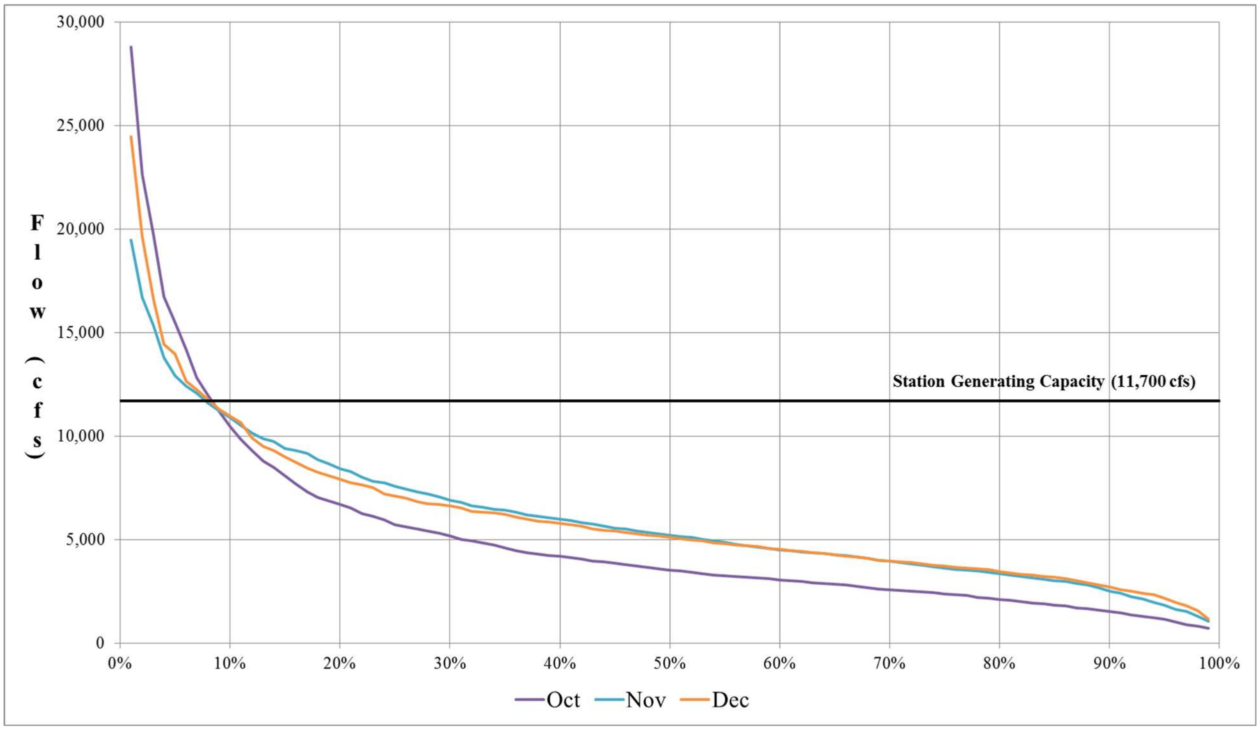
Source: USGS (2016e, as modified by Great River Hydro)

Figure 3.5-3. Wilder flow exceedance curves, April–June (based on flow data from January 1, 1979, to December 31, 2015).



Source: USGS (2016e, as modified by Great River Hydro)

Figure 3.5-4. Wilder flow exceedance curves, July–September (based on flow data from January 1, 1979, to December 31, 2015).



Source: USGS (2016e, as modified by Great River Hydro)

Figure 3.5-5. Wilder flow exceedance curves, October–December (based on flow data from January 1, 197, to December 31, 2015).

Table 3.5-2. Wilder estimated minimum, mean, and maximum average monthly flow values (cfs), January 1979—December 2015.

Month	Minimum	Year	Mean	Maximum	Year
January	2,004	1981	5,111	11,319	2006
February	1,797	1980	4,613	14,011	1981
March	2,733	2015	7,381	18,135	1979
April	4,360	1995	14,824	23,140	2008
May	3,710	1987	9,328	18,428	1996
June	1,991	1999	5,778	12,966	1984
July	1,474	1995	3,996	10,466	1996
August	1,233	2001	3,508	12,949	2008
September	1,131	2001	2,970	7,004	2011
October	1,299	2001	5,176	15,260	2005
November	2,229	2001	6,109	13,416	2005
December	2,555	2001	6,192	13,578	1983

Source: USGS (2016e, as modified by Great River Hydro)

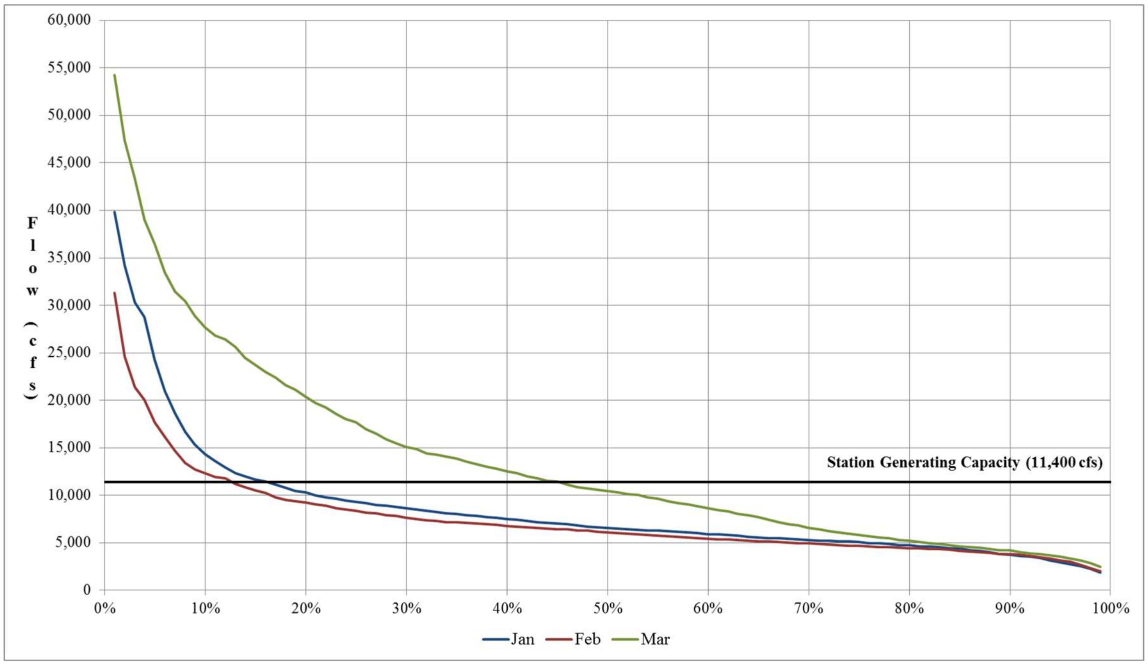
Bellows Falls Project

The Bellows Falls Project has a total DA of 5,414 sq. mi. Inflow is from discharge from the Wilder Project and natural inflow from the 2,039 sq. mi. of intermediate DA downstream of the Wilder Project. More than 42 percent of the total enters as unmanaged flow below the Wilder Project, except under flood flow conditions when the USACE dams on the Ottauquechee and Black rivers store water temporarily (see Section 3.1.1, *Overview of the Basin*).

The Bellows Falls impoundment is approximately 26 miles long and extends upstream to Chase Island at Windsor, Vermont, about 1 mile downstream of the Windsor Bridge. The impoundment is riverine in character and ranges in depth from several feet to about 30 ft near the dam. Bathymetry in the impoundment changes rapidly as the result of underlying bedrock, channel constriction, deposition, and scour primarily associated with high flows, such as those that occurred with Tropical Storm Irene in late August 2011.

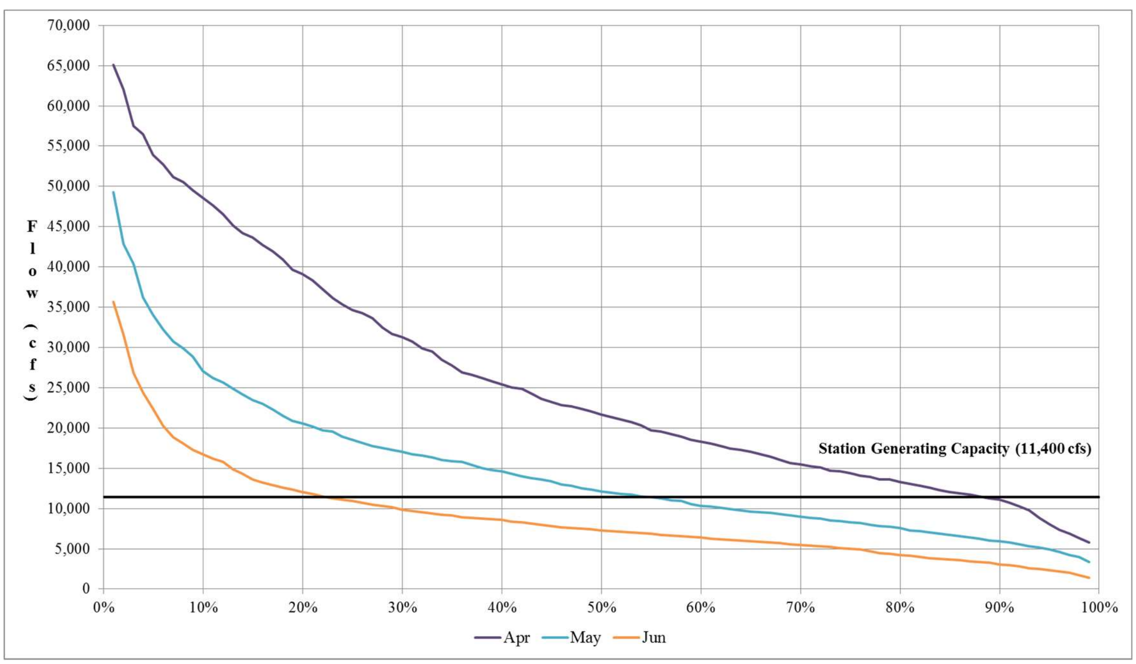
Under normal generation conditions, it takes about 8 hours for flow from Wilder to reach the Bellows Falls dam. The impoundment has a surface area of 2,804 acres at El. 291.63 ft at the top of the stanchion boards. The overall operating range of the Project, accounting for both low inflow and most high inflows conditions, is typically between El. 288.63 ft and 291.63 ft, providing about 7,476 acre-ft of usable storage in the 3-ft range. The storage volume associated with the typical operating range, under non-spill conditions, between El. 289.6 ft and 291.4 ft, is 4,642 acre-ft, or 62 percent of the overall usable storage.

Figure 3.5-6 through Figure 3.5-9 provide monthly flow exceedance curves for the Bellows Falls Project from January 1, 1979, to December 31, 2015. Data are based on the North Walpole gage, located downstream of the confluence with Saxtons River (about 2 miles from Bellows Falls dam). To estimate flow at only the Bellows Falls Project, the daily flow data from the North Walpole gage were prorated by 0.986 based on gaged DA to remove the small effect of inflow from the Saxtons River under most circumstances. Table 3.5-3 summarizes the minimum, mean, and maximum values of average monthly flows for the same data set as the exceedance curves.



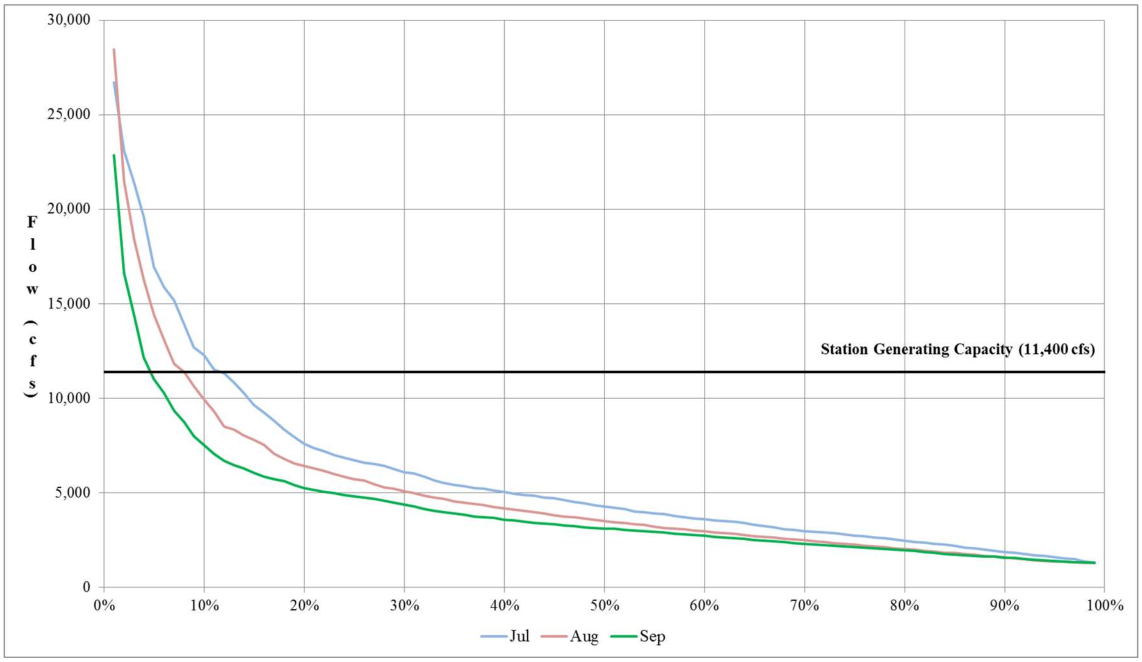
Source: USGS (2016e, as modified by Great River Hydro)

Figure 3.5-6. Bellows Falls flow exceedance curves, January–March (based on flow data from January 1, 1979 to December 31, 2015).



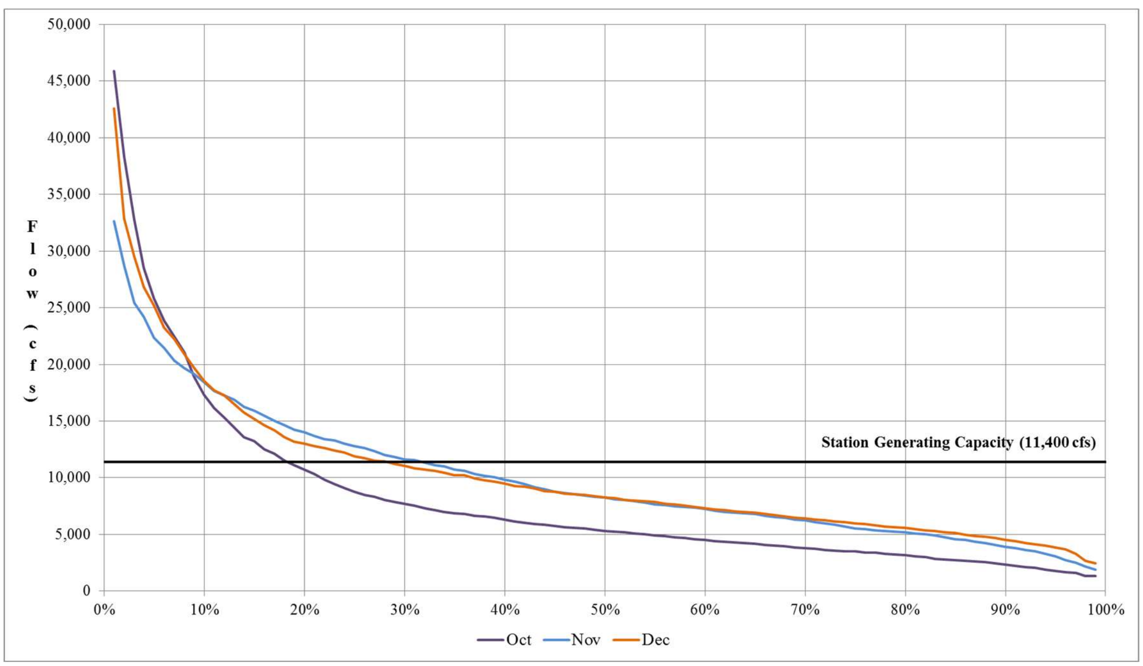
Source: USGS (2016e, as modified by Great River Hydro)

Figure 3.5-7. Bellows Falls flow exceedance curves, April–June (based on flow data from January 1, 1979 to December 31, 2015).



Source: USGS (2016e, as modified by Great River Hydro)

Figure 3.5-8. Bellows Falls flow exceedance curves, July–September (based on flow data from January 1, 1979 to December 31, 2015).



Source: USGS (2016e, as modified by Great River Hydro)

Figure 3.5-9. Bellows Falls flow exceedance curves, October–December (based on flow data from January 1, 1979 to December 31, 2015).

Table 3.5-3. Bellows Falls estimated minimum, mean, and maximum average monthly flow values (cfs), January 1979–December 2015.

Month	Minimum	Year	Average	Maximum	Year
January	2,588	1981	8,666	20,573	2006
February	2,697	1980	7,584	21,499	1981
March	4,405	2015	13,729	33,660	1979
April	7,690	1995	25,776	40,676	2008
May	7,137	1995	14,924	29,404	1996
June	3,038	1999	9,104	20,972	2006
July	1,896	1991	6,011	16,880	2013
August	1,631	2001	5,132	17,803	2008
September	1,533	1995	4,270	13,056	2011
October	1,810	2001	8,167	25,550	2005
November	2,771	2001	10,048	22,794	2005
December	3,558	2001	10,423	22,440	2003

Source: USGS (2016e, as modified by Great River Hydro)

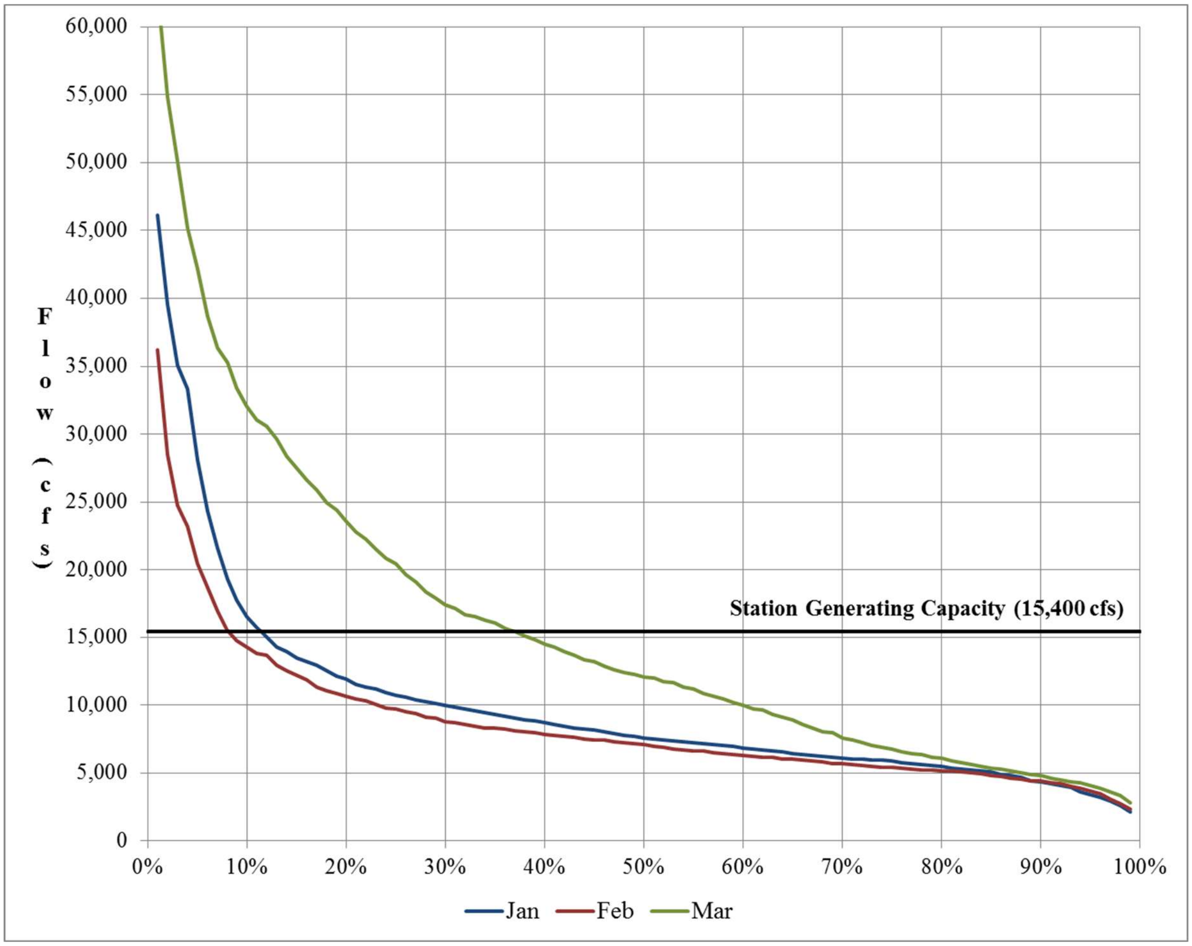
Vernon Project

The Vernon Project has a total DA of 6,266 sq. mi. Inflow is from discharge from the Wilder and Bellows Falls Projects and natural inflow from the 852 sq. mi. of intermediate DA downstream of the Bellows Falls Project. Only 13.5 percent of inflow enters as unmanaged flow below the Bellows Falls Project, except under flood flow conditions when the USACE dams on the West River store water temporarily (see Section 3.1.1, *Overview of the Basin*).

The Vernon impoundment is approximately 26 miles long and extends upstream approximately to Dunshee Island, located downstream of the Walpole Bridge (Route 123) at Westminster Station, Vermont. The impoundment is riverine in character and ranges in depth from several feet to about 50 ft close to the dam. Bathymetry in the impoundment changes rapidly as the result of underlying bedrock, channel constriction, deposition, and scour primarily associated with high flows, such as those that occurred with Tropical Storm Irene in late August 2011.

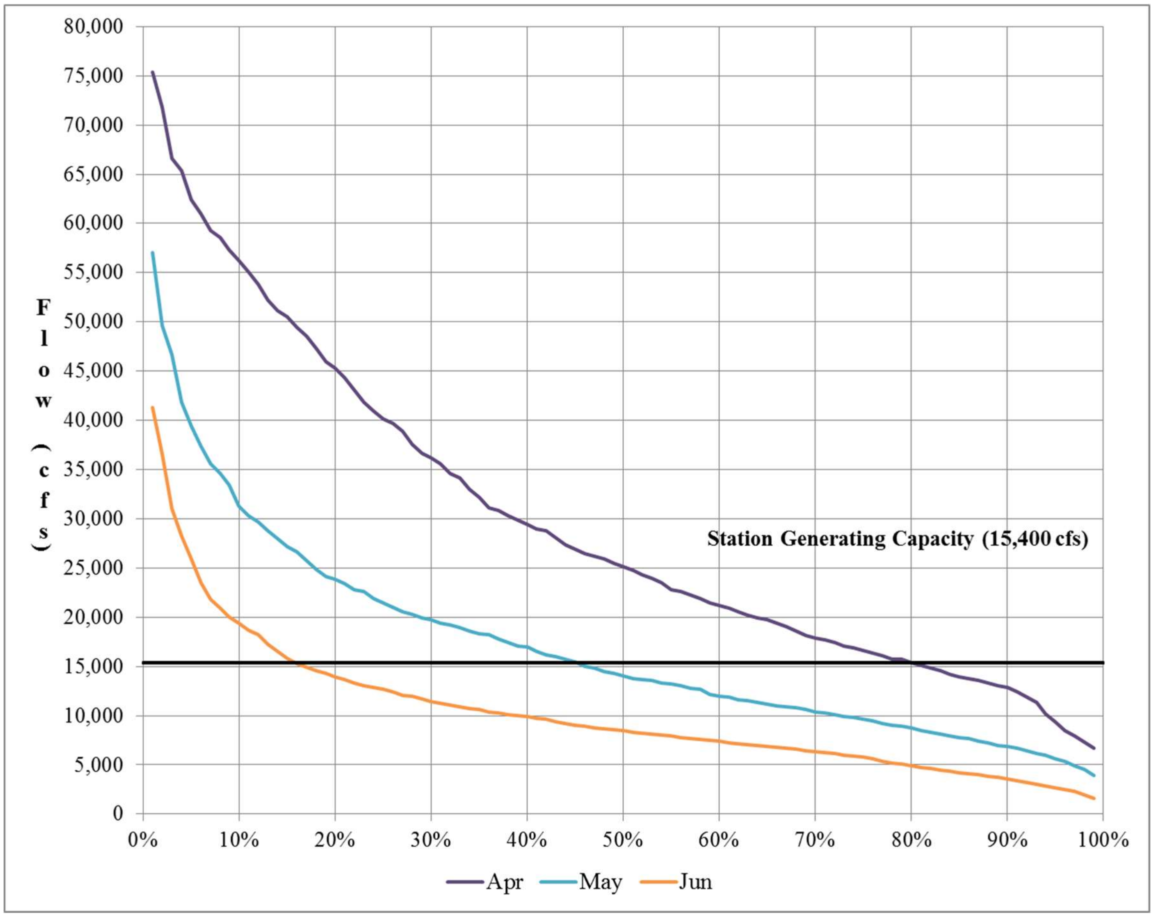
Under normal generating conditions, it takes about 4 hours for flow releases from the Bellows Falls Project to reach Vernon dam. The impoundment has a surface area of 2,550 acres and a total volume of about 40,000 acre-ft at El. 220.13 ft at the top of the stanchion boards. The overall operating range of the Project is from El. 212.13 ft (top of concrete crest) to El. 220.13 ft. Maximum drawdown to the spillway crest, if hydraulic and stanchion flashboards are lowered or removed under high flow, equates to a maximum storage capacity of 18,300 acre-ft. The storage volume associated with the typical operating range, under non-spill conditions is between El. 218.3 and El. 220.1 for a usable storage capacity of 4,489 acre-ft, or 24.5 percent of the overall usable storage.

Figure 3.5-10 through Figure 3.5-13 show monthly flow exceedance curves for the Vernon Project from January 1, 1979, to December 31, 2015. To provide monthly data representative of flow at the Vernon Project, daily flow data from the North Walpole gage were prorated by 1.141 based on gaged DA to produce the monthly flow exceedance curves. This proration was used to account for the normally small amount of inflow from the Cold and West rivers and smaller tributaries that flow into the North Walpole gage. Table 3.5-4 summarizes the minimum, mean, and maximum values of average monthly flows for the same data set as the exceedance curves.



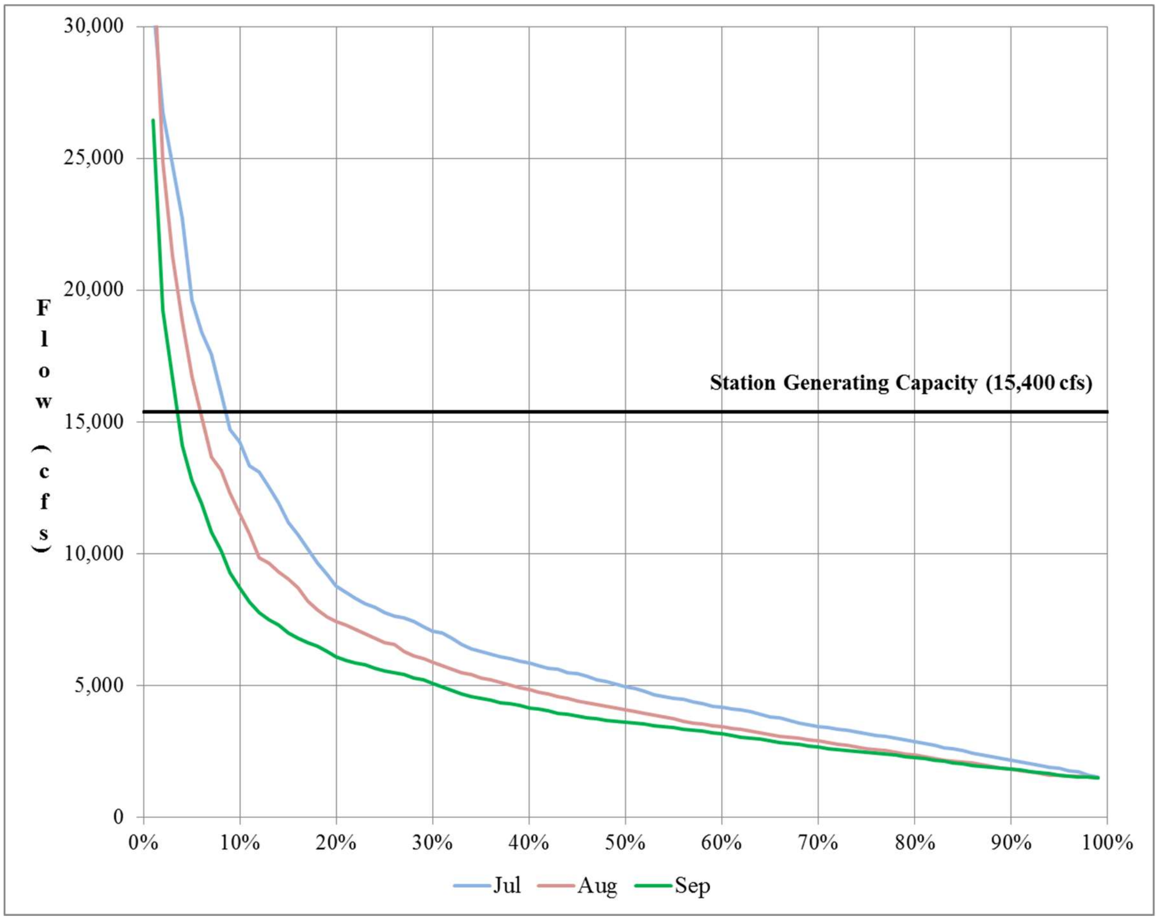
Source: USGS (2016e, as modified by Great River Hydro)

Figure 3.5-10. Vernon flow exceedance curves, January–March (based on flow data from January 1, 1979 to December 31, 2015).



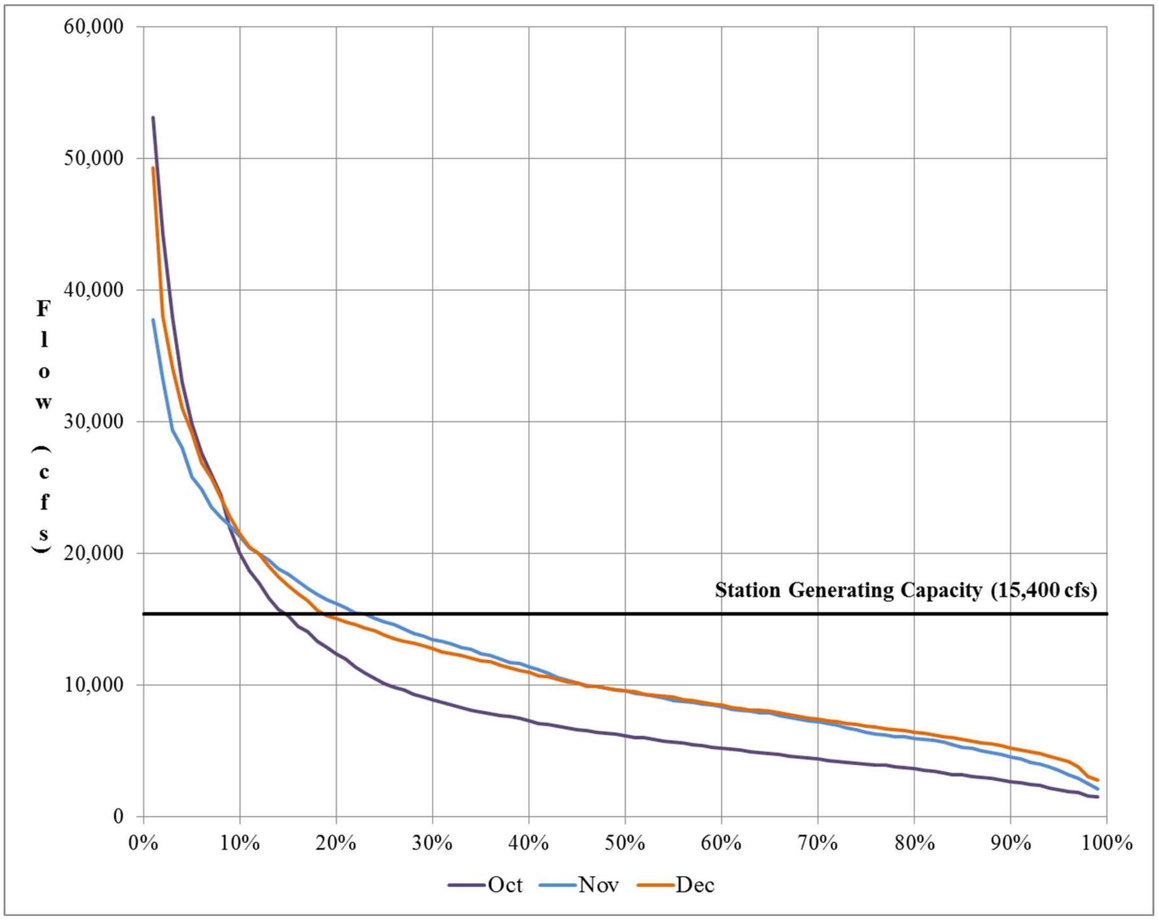
Source: USGS (2016e, as modified by Great River Hydro)

Figure 3.5-11. Vernon flow exceedance curves, April–June (based on flow data from January 1, 1979 to December 31, 2015).



Source: USGS (2016e, as modified by Great River Hydro)

Figure 3.5-12. Vernon flow exceedance curves, July–September (based on flow data from January 1, 1979 to December 31, 2015).



Source: USGS (2016e, as modified by Great River Hydro)

Figure 3.5-13. Vernon flow exceedance curves, October–December (based on flow data from January 1, 1979 to December 31, 2015).

Table 3.5-4. Vernon estimated minimum, mean, and maximum average monthly flow values (cfs), January 1979–December 2015.

Month	Minimum	Year	Average	Maximum	Year
January	2,995	1981	10,029	23,811	2006
February	3,121	1980	8,775	24,882	1981
March	5,123	2015	15,918	38,958	1979
April	8,901	1995	29,832	47,078	2008
May	8,260	1995	17,272	34,032	1996
June	3,516	1999	10,537	24,273	2006
July	2,194	1991	6,957	19,536	2013
August	1,888	2001	5,939	20,604	2008
September	1,774	1995	4,942	15,111	2011
October	2,095	2001	9,453	29,571	2005
November	3,207	2001	11,629	26,381	2005
December	4,118	2001	12,063	25,972	1983

Source: USGS (2016e, as modified by Great River Hydro)

Great River Hydro facilitates flow and real-time operations information with the operators of the downstream Turners Falls Project, owned and operated by FirstLight. Article 304 of the Vernon license requires Great River Hydro to coordinate Project operations with FirstLight. A letter Agreement amending the original 1993 Headwater Benefit Agreement was filed with FERC on June 20, 2003. The Agreement requires Great River Hydro to provide to FirstLight by 10:00 am each day, an estimate of total discharge (cfs-hours) expected the next day at the Vernon Project. As soon as Great River Hydro receives the hourly dispatch schedule for the next day from ISO-New England (ISO-NE), it faxes or emails the schedule for Vernon discharges to FirstLight. Typically, this occurs between 1:30 pm and 2:00 pm. If any subsequent dispatch schedules are received during the day showing changes in the projected hourly release schedules, the revised schedule for Vernon is faxed or emailed to FirstLight.

FirstLight stated in its Final License Application, filed April 20, 2016: "Not having reliable and timely estimates of Vernon's hourly release schedule the day ahead prevents FirstLight from the most efficient management of the TFI [Turners Falls impoundment] for power production." Great River Hydro disagrees with this statement. Article 304 does not require coordination to ensure FirstLight efficiently manages the Turners Falls impoundment because efficient management is largely a function of FirstLight's own coordinated operation of the impoundment that serves two purposes: as the impoundment for the Turners Falls Project and as the lower reservoir for the Northfield Mountain Pumped Storage Project (NMPS). Great River Hydro provides an estimate of total inflow from Vernon early in the day ahead to allow for FirstLight to plan and manage its operations and consider the quantity of inflow it will receive in order to participate in the ISO-NE day ahead energy market, as well as to schedule generation or pumping at NMPS. FirstLight has sufficient operational capability to manage reservoir operations at both Turners Falls and NMPS to accommodate the estimated inflow. Promptly after receiving the hourly dispatch schedule for the next day from ISO-NE, Great River Hydro provides the schedule for Vernon discharges to FirstLight. No other information is available to distribute to FirstLight beyond the ISO-NE schedule. Sharing pre-bid flow or generation forecast information with another wholesale generator participating in the same market is illegal. If flow conditions change, or the ISO-NE dispatch schedule changes, Great River Hydro immediately notifies FirstLight. Lastly, as per the Agreement, FirstLight maintains real-time Vernon tailrace water level monitoring equipment and has the capability to determine precisely what is occurring at Vernon in real time.

With this information, together with their project operations data (unseen by Great River Hydro), FirstLight has the capability to determine Vernon discharge. FirstLight can verify its calculations as Great River Hydro publishes discharge flow information from Vernon, as well as the upstream projects owned by Great River Hydro, in real-time at www.h2Oline.com. Furthermore, Great River Hydro has published travel times for flows between its upstream projects. Great River Hydro estimates the travel time for discharges from Vernon to reach Turners Falls dam to be approximately 4 hours. Collectively, this flow information provides ample flow information for FirstLight to plan, manage, and operate their projects in a coordinated manner as required under Article 304. Therefore, it is Great River Hydro's position that: (1) Great River Hydro is in full compliance with the Agreement filed with the Commission on June 20, 2003; and (2) Great River Hydro provides or facilitates the availability of sufficient anticipated dispatch schedule information, real-time flow, and tailrace information such that FirstLight can, should it choose to, operate their projects in an efficient and coordinated manner with the upstream hydro projects. To the extent that FirstLight seeks additional provisions, the need for such provisions is not a matter of flow and operational coordination but perhaps economic optimization, which is not material to, nor the purpose of, Article 304 in the Vernon license.

Normal Project Operations

Operations at the three Projects are coordinated with other Great River Hydro generating facilities on the Connecticut River, taking into consideration variations in electricity demand as well as natural flow to maximize the efficient use of available water. When inflows are less than maximum generating capacity, Great River Hydro uses the limited impoundment storage at the Projects to coordinate flows between Projects and dispatch generation as required to meet the generation schedule set by ISO-NE through the day-ahead or real-time markets. During the course of any day, generation can vary between the required minimum flow and full generating capacity, depending on inflow and impoundment storage. Over the course of a day, the Projects generally pass the average daily inflow. During periods of sustained high flows, Great River Hydro dispatches Project generation in a must-run status to use available water for generation. Once flows exceed powerhouse capacity, Great

River Hydro operates the Projects in a "river profile" manner, slowly reducing the WSE at the dam as inflows increase (see *High Flow Operations* section below).

At each Project, estimated and anticipated inflow forms the basis for bidding into the day-ahead energy market. Day-ahead hourly bids reflect must-run generation periods associated with minimum flow periods, periods when sustained higher flows are anticipated, and opportunistic generation when inflow and available storage allows and electricity demand is anticipated to be high. Anticipated inflow calculations predict impoundment elevations and determine whether spill gates must be operated to pass flow in excess of Project generating capacities. Estimated inflow is calculated using discharge from the Project plus/minus changes in impoundment elevation measured at the dam on an hourly basis, averaged over a rolling 6-hour period. Impoundment drawdown rates at each Project are typically less than 0.1 to 0.2 ft per hour and do not exceed 0.3 ft per hour based on Great River Hydro's established Operating Procedures. There is approximately 3,000 cfs per hour per 0.1 ft of elevation and 0.3 ft per hour represents a maximum station output. Restricting drawdown under spill conditions to the same maximum as the station prevents higher than typical drawdown rates or downstream flow increases.

Wilder Project

The maximum station discharge with all three units operating is approximately 11,700 cfs, although 98 percent of the time flows are less than 10,700 cfs. The Project itself has a maximum discharge (generation plus spill) capacity of 157,600 cfs, and the flood of record at this site, which occurred in March 1936, was 91,000 cfs. Since then, a USACE flood control structure on the Ompompanoosuc River has been built, the Wilder Project redeveloped, and the Moore dam, which has some flood control capacity, was constructed. All of these facilities have helped to decrease the peak flow at the Wilder Project during flood events. Since the Moore dam began operating in the late 1950s, the highest flow recorded at the Wilder Project has been less than 65,000 cfs.

The licensed minimum flow at the Wilder Project is 675 cfs (or inflow, if less) and is provided primarily by generation from Unit No. 3 at an efficient operating flow of about 700 cfs. Additional non-generation flows are provided seasonally on a schedule provided annually by CRASC based on fish counts at downstream projects. If required, fish passage flows are provided in spring (May 15–July 15) and in fall (September 15–November 15) for upstream fish passage (25 cfs fishway flow plus Unit No. 3 generation flow for attraction water) and for downstream fish passage (512 cfs) from October 15 to December 31. As of 2016, CRASC no longer requires downstream passage operations at Wilder for Atlantic Salmon smolts in spring, and only requires fall downstream passage operations if 50 or more adult salmon are documented passing upstream (see Section 3.6, *Fish and Aquatic Resources*).

During the summer recreation season, beginning on the Friday before Memorial Day and continuing through the last weekend in September, Great River Hydro maintains a self-imposed minimum impoundment level at El. 382.5 ft from Friday at

4:00 p.m. through Sunday at midnight and similar hours for holidays during this period.

Bellows Falls Project

The maximum station discharge with all three units operating is approximately 11,400 cfs, although 98 percent of the time flows are less than 11,235 cfs. The Project itself has a maximum discharge (generation plus spill) capacity of 119,785 cfs, and the flood of record, occurred in March 1936, was 156,000 cfs. Since then, three upstream USACE flood control structures have been built (Union Village, Ompompanoosuc River; North Hartland, Ottauquechee River; and North Springfield, Black River) and the Moore dam, which has some flood control capability, was constructed. These facilities have helped to decrease the peak flow during flood events. Since the Moore dam began operating in the late 1950s, the highest flow recorded at the Bellows Falls Project (as measured at the dam) was 103,397 cfs during Tropical Storm Irene on August 29, 2011.

The licensed minimum flow at the Bellows Falls powerhouse is 1,083 cfs (or inflow, if less) and is provided primarily through generation, typically at least 1,200 cfs. There is no minimum flow requirement through the dam into the bypassed reach, but leakage provides some flow in the bypassed reach (flows range between 125-300 cfs as calculated or estimated over the course of various studies). Additional non-generation flows are provided seasonally at the powerhouse on a schedule provided annually by CRASC based on fish counts at downstream projects. If required, fish passage flows are provided in spring (May 15–July 15) and in fall (September 15–November 15) for upstream fish passage (25 cfs fishway flow and 55 cfs attraction flow) and for downstream fish passage (225 cfs). As of 2016, CRASC no longer requires downstream passage operations at Bellows Falls for Atlantic Salmon smolts in spring, and it only requires fall downstream passage operations if 50 or more adults are documented passing upstream (see Section 3.6, *Fish and Aquatic Resources*).

During the summer recreation season, beginning the Friday before Memorial Day and continuing through the last weekend in September, Great River Hydro maintains a self-imposed minimum impoundment level of El. 289.6 from Friday at 4:00 p.m. through Sunday at midnight and similar hours for holidays during this period.

Vernon Project

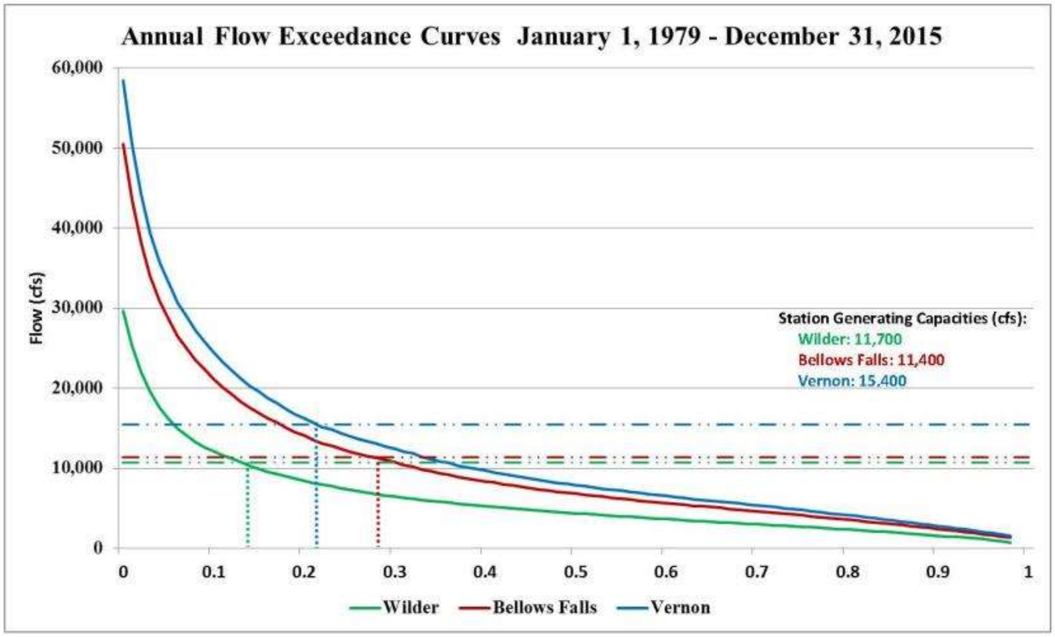
The maximum station discharge with all 10 units operating under ideal or optimum conditions is considered to be about 17,100 cfs, equal to the total sum of each of the turbine unit maximum flow capacities under optimal conditions specific to each unit. This value overstates the total flow through the station when all units are running. The major factor that reduces flow capacity in the all-unit operation is the reduction in net head (headwater elevation behind the trashracks minus tailwater elevation). Net head is significantly reduced during all-unit operation with higher tailwater accounting for most of the loss of head. Actual operating data suggest that total station discharge is rarely, if ever, greater than 15,400 cfs and 98 percent of the time, flows are less than 14,500 cfs. The Project itself has a maximum discharge (generation plus spill) capacity of 127,600 cfs (before the WSE surcharges above maximum WSE), and the flood of record, which occurred in March 1936, was 176,000 cfs. Five USACE flood control structures (Union Village, Ompompanoosuc River; North Hartland, Ottauquechee River; North Springfield, Black River; Ball Mountain and Townsend, West River) along with Moore dam, which has some flood control capability, have helped to decrease the peak flow during flood events. Since Moore dam began operating in the late 1950s and USACE dams were constructed in the 1960s, the highest flow recorded at Vernon dam has been less than 110,000 cfs. The peak discharge from Vernon dam during Tropical Storm Irene reached 102,626 cfs.

The licensed minimum flow at Vernon is 1,250 cfs (or inflow, if less) and is provided primarily through generation and is typically at least 1,500 cfs and above 1,600 cfs approximately 99 percent of the time. Additional non-generation flows are provided seasonally on a schedule provided annually by CRASC based on fish counts at downstream projects. If required, fish passage flows are provided in spring (April 15–July 15) and in fall (September 15–November 15) for upstream fish passage for adult Atlantic Salmon and adult American Shad (65-cfs fishway flow and 200-cfs attraction flow) and for downstream fish passage of several species from April 1–December 31 (350 cfs from the fish pipe and 40 cfs from the fish tube) (see Section 3.6, *Fish and Aquatic Resources*).

During the summer recreation season, beginning the Friday before Memorial Day and continuing through the last weekend in September, Great River Hydro maintains a self-imposed minimum impoundment level at El. 218.6 ft from Friday at 4:00 p.m. through Sunday at midnight and similar hours for holidays during this period.

High Flow Operations

High flows occur routinely throughout the year at each Project, most often during the spring freshet and the fall rainy season. Annually flows at the dams exceed station generating capacity approximately 12 percent of the time at the Wilder Project, approximately 28 percent of the time at the Bellows Falls Project, and approximately 22 percent of the time at the Vernon Project (Figure 3.5-14).



Source: USGS (2016e, as modified by Great River Hydro)

Figure 3.5-14. Wilder, Bellows Falls, and Vernon annual flow exceedance curves.

Spring runoff on the Connecticut River typically occurs in phases based on latitude. For example, normal spring runoff at the Vernon Project occurs distinctly earlier than runoff above Bellows Falls and Wilder dams, but below the FMF Project. The spring runoff from the Connecticut Lakes down to the FMF Project occurs even later in the season. The seasonal storage capability of the FMF Project is limited in comparison to the total amount of inflow it receives. However, the storage capacity at the FMF Project is used during spring runoff to "shave" the maximum anticipated peak flows downstream and refill the impoundments. This operation reduces potential downstream high flow conditions at the Wilder, Bellows Falls, and Vernon Projects, which are typically spilling, and in the case of Bellows Falls and Vernon, often prevents the need to trip stanchion boards.

During periods of ice movement in the spring, frequent upstream observations and river elevation checks are made within the impoundments. When an ice jam occurs upstream of a dam (which is rare), an increased or artificial inflow condition is created by a large swell of water in front of the jam as the water behind the jam pushes the ice and water in front of it. When this condition is observed, Great River Hydro must increase generation or spill gate discharge to pass this temporary situation and to keep the impoundment elevation within its operating pond limits.

When anticipated inflows to each Project impoundment increase above Project generating capacity, Great River Hydro initiates "river profile" operations by lowering the impoundment elevation at each dam. In the case of the Wilder Project, this operational guideline is the result of the engineering design consideration that went into the final Wilder dam re-development when the present day Project was first conceived. The primary consideration for selecting a maximum operating elevation of 385 ft and the high flow "river profile operation" was to limit the extent of tillable agricultural land that would be inundated in the areas around Newbury, Vermont and Haverhill, New Hampshire under high water conditions. In these agricultural fields, the extent of flooding would not increase beyond what had been flooded under high water conditions prior to Project re-development. The February 1949 Indenture and Flowage Easement with the Boston and Maine Railroad and from testimony given before the Federal Power Commission (predecessor of FERC) license hearings prior to the redevelopment of the Wilder Project requires "river profile operation" as necessary to protect railroad infrastructure.

Once anticipated inflows (calculated at the upper extent of the impoundment) exceed Project generating capacity, various combinations of spill gates (see Section 2.1, *No-action Alternative*) are operated together with station discharge to maintain impoundment elevations at the dam at certain set-points until flows exceed the total spill capacity of the Project, at which point the impoundment would rise above the maximum WSE at the dam. Table 3.5-5 lists maximum impoundment elevations that are maintained based on anticipated inflow levels at each Project.

Table 3.5-5. River profile and high flow operations inflows and impoundment elevations.

Project	Anticipated Inflow (cfs)	Maximum Elevation at the Dam (NGVD29)
Wilder	<10,000	385.0
	10,000	384.5
	12,000	384.0
	14,000	383.0
	16,000	382.0
	18,000	381.0
	20,000–85,000	380.0
	85,000–145,000	Impoundment elevation rises from 380.0 and is maintained at 384.0 as long as possible. Stanchion board removal at 145,000 cfs
	> 145,000	All gates are opened, and all stanchion boards removed, impoundment elevation increases dependent upon inflow increases
Bellows Falls	< 11,000	291.6
	11,000–20,000	291.1
	20,000–50,000	290.1 (289.6 if ice is present)
	50,000–90,000	289.6 and partial stanchion board removal at 52,000 cfs

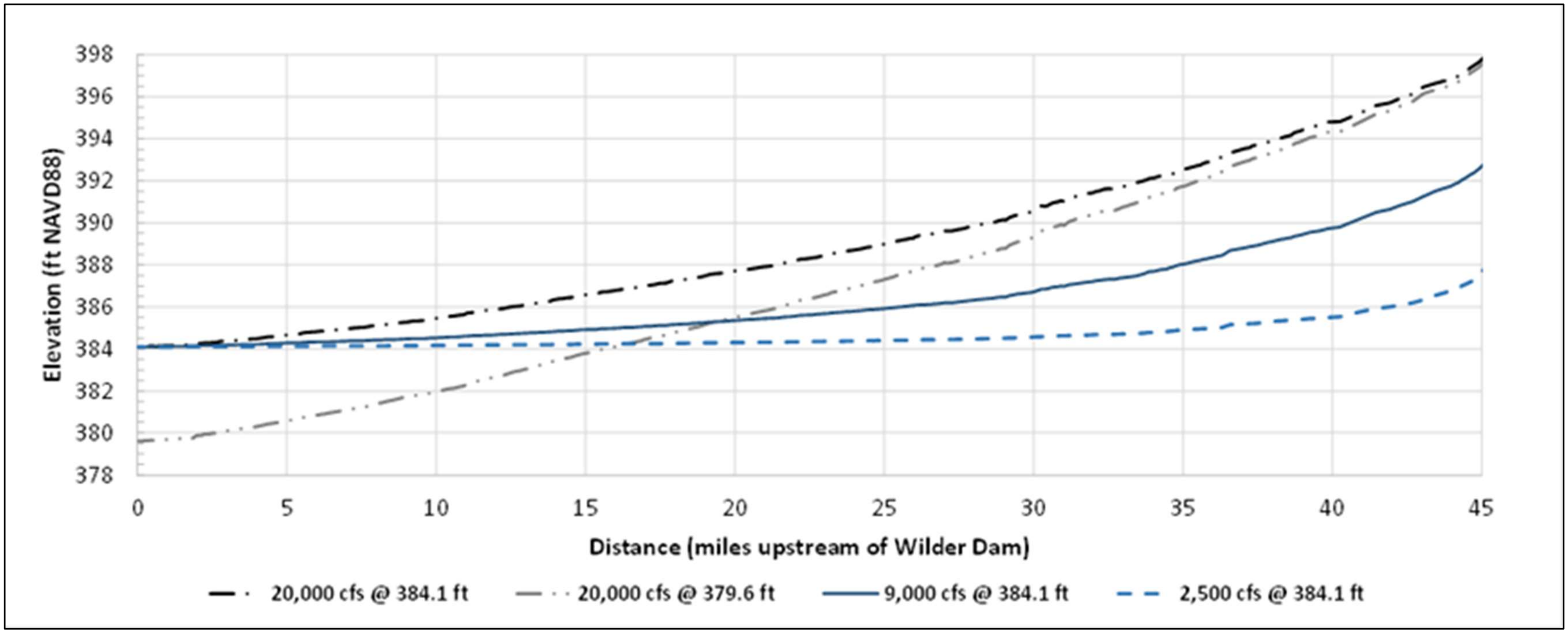
Project	Anticipated Inflow (cfs)	Maximum Elevation at the Dam (NGVD29)
	>90,000	All gates are opened, and all stanchion boards removed, impoundment elevation increases dependent upon inflow increases; impoundment elevation rises from 289.6 and is maintained at 290.6 as long as possible before elevation surcharges as inflow increases
Vernon	< 17,000	220.13
	17,000–45,000	219.6
	45,000–70,100	218.6
	70,100 < 105,000	Impoundment elevation rises from 218.5 and is maintained at 220.1 as long as possible, including partial to full stanchion board removal as needed
	>105,000	All gates, flashboard panels are opened and all stanchion boards removed, impoundment elevation increases dependent upon inflow increases

Source: Great River Hydro

While the impoundment upstream of Wilder dam extends upstream to Haverhill, New Hampshire, and Newbury, Vermont, WSE fluctuations in the upper impoundment are more significantly impacted by inflows from upstream than from operations at Wilder dam. For example, Figure 3.5-15 illustrates a comparison of the river stage across the length the Wilder impoundment under different steady-state flows (i.e., constant flow throughout the impoundment where inflow equals outflow) of 2,500 cfs and 9,000 cfs at WSE equal to 384.1 ft (NAVD 88) at the dam. The increase in inflow from 2,500 cfs to 9,000 cfs, matched by outflow at the dam, within station capacity, changes river stage significantly (by as much as 5 feet) in the upper third extent of the impoundment; more than the normal impoundment operating fluctuation range of 2.5 feet.

This example also illustrates how operating the Wilder Project in a "run-of-river" mode (inflow equal to outflow) would not eliminate WSE fluctuations throughout the impoundment. Further increases in inflow as illustrated by a steady-state flow of 20,000 cfs at WSE equal to 384.1 ft at the dam, expands the effect of increasing river stage due to inflow, both in terms of WSE itself, and to the geographic scope which affects larger, more downstream portions of the impoundment. The effect of high flow "river-profile" operation where flows of 20,000 cfs stipulate a WSE at the dam of 379.6 feet (NAVD88) is also illustrated in Figure 3.5-15.

The plot of this steady-state condition shows how the increase in river stage due to inflow is countered by reducing the WSE at the dam, with the countering effect felt most significantly in a "sweet-spot" middle portion of the impoundment. This "sweet spot", while centered around the mid-impoundment, shifts slightly upstream or downstream during real-time inflows and Project operating conditions.

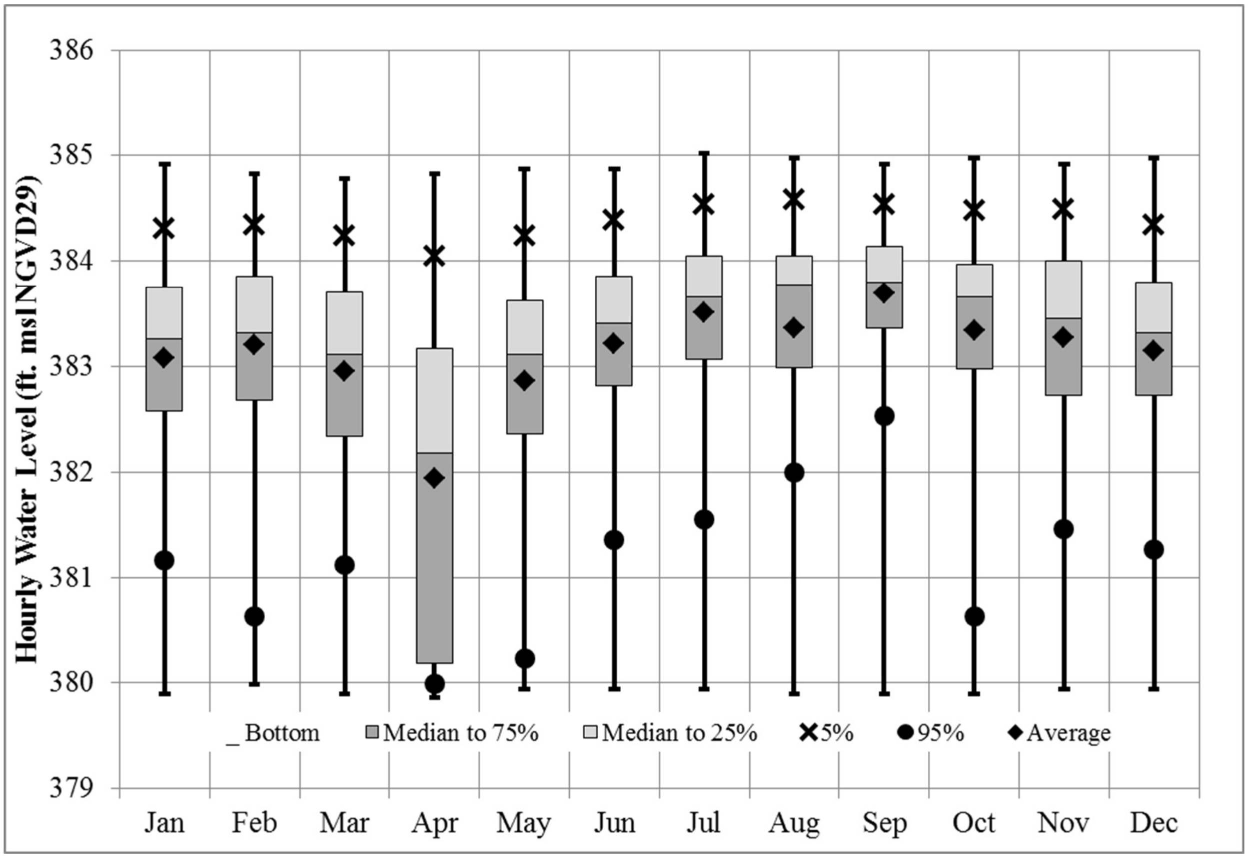


Source: Great River Hydro

Figure 3.5-15. Comparison of river stage with distance from Wilder dam under different steady-state flows.

Wilder Project

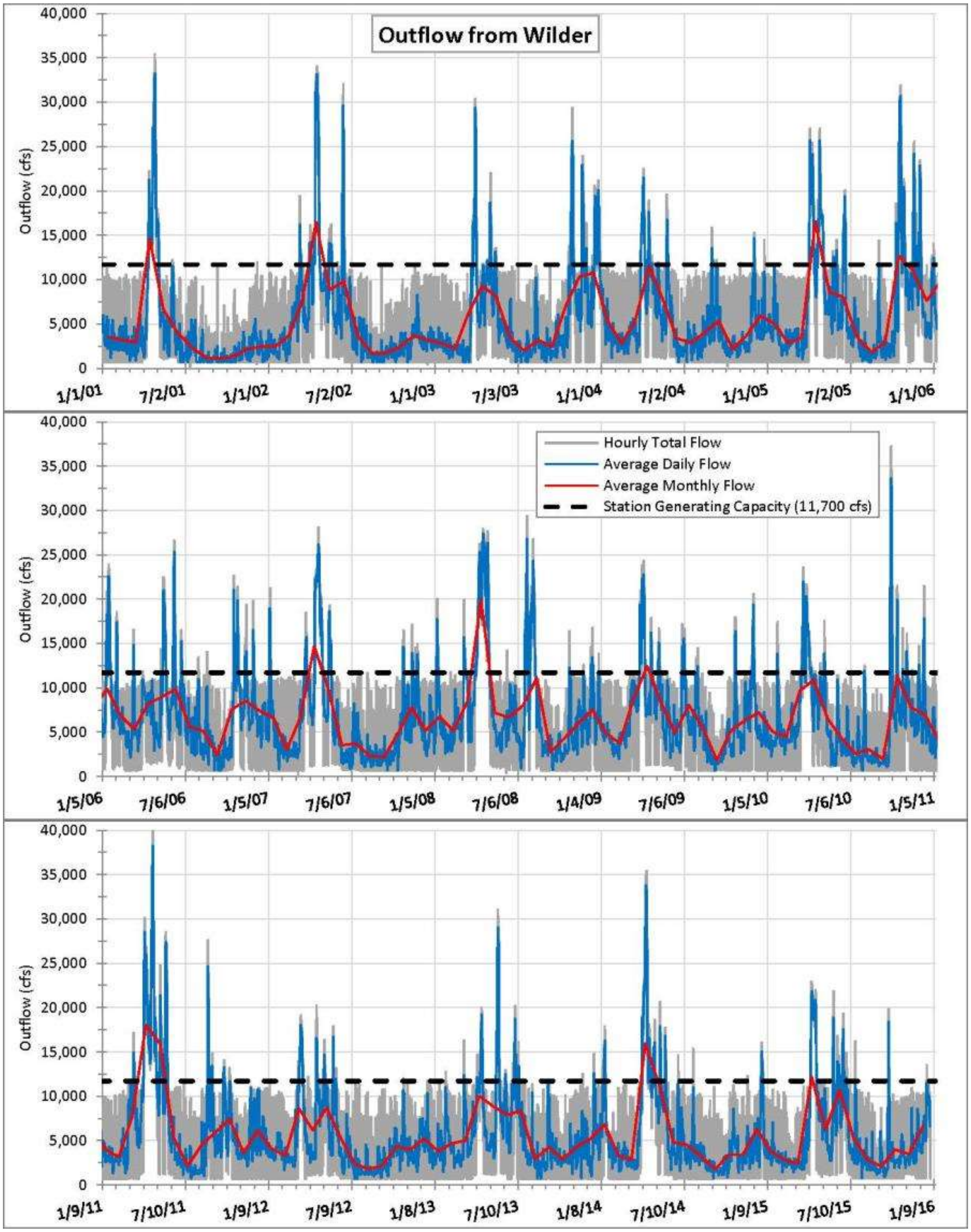
Figure 3.5-16 presents hourly median, average, minimum, and maximum values and the 5, 25, 75, and 95 percent exceedance values for WSEs at Wilder dam from January 1, 2001, to December 31, 2015. This figure illustrates the operational range and high flow operations when the impoundment WSE is lowered at the dam, for example in April when flows in excess of 10,000 cfs are common.



Source: Great River Hydro

Figure 3.5-16. Wilder hourly impoundment water surface elevations January 1, 2001–December 31, 2015.

Figure 3.4-17 presents hourly outflow as compared to the daily and monthly average outflow from January 1, 2001, to December 31, 2015. The figure shows that outflows from the Project are normally between minimum flow and the maximum station discharge of 11,700 cfs under non-spill conditions.

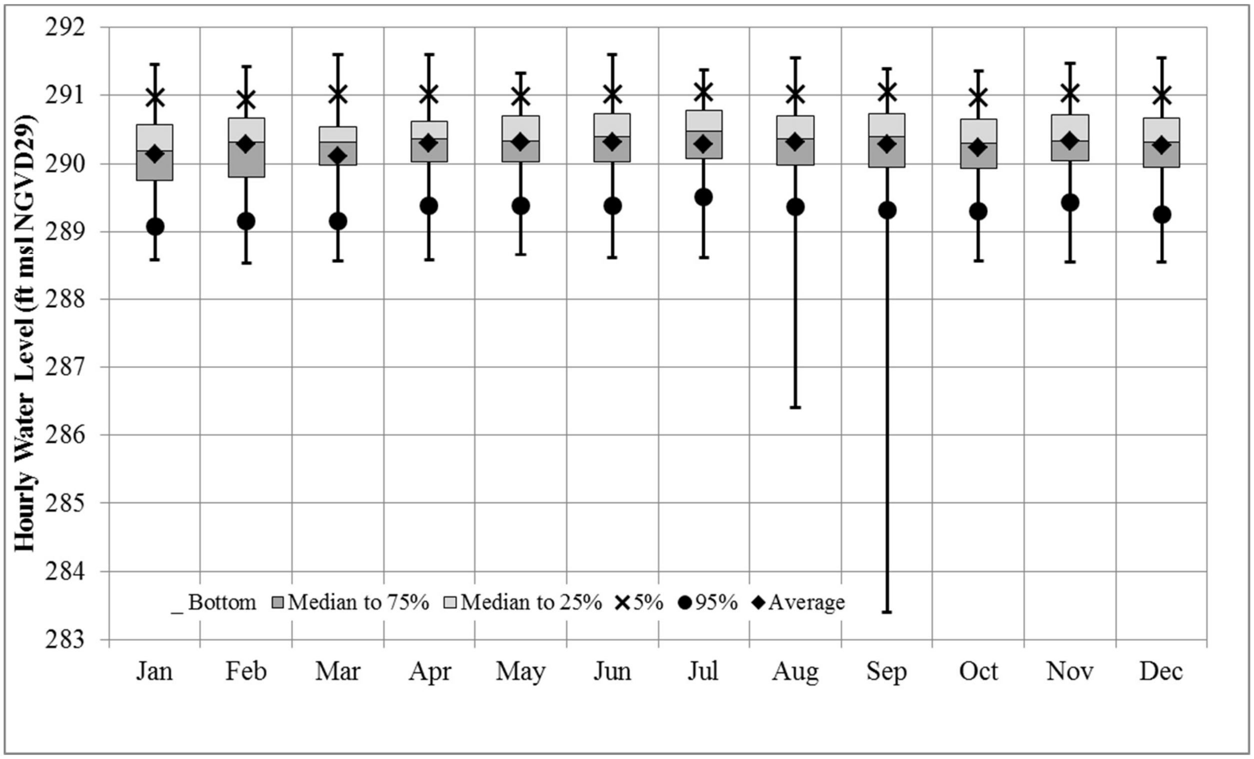


Source: Great River Hydro

Figure 3.5-17. Hourly, average daily, and average monthly outflow from the Wilder Project (January 1, 2001–December 31, 2015).

Bellows Falls Project

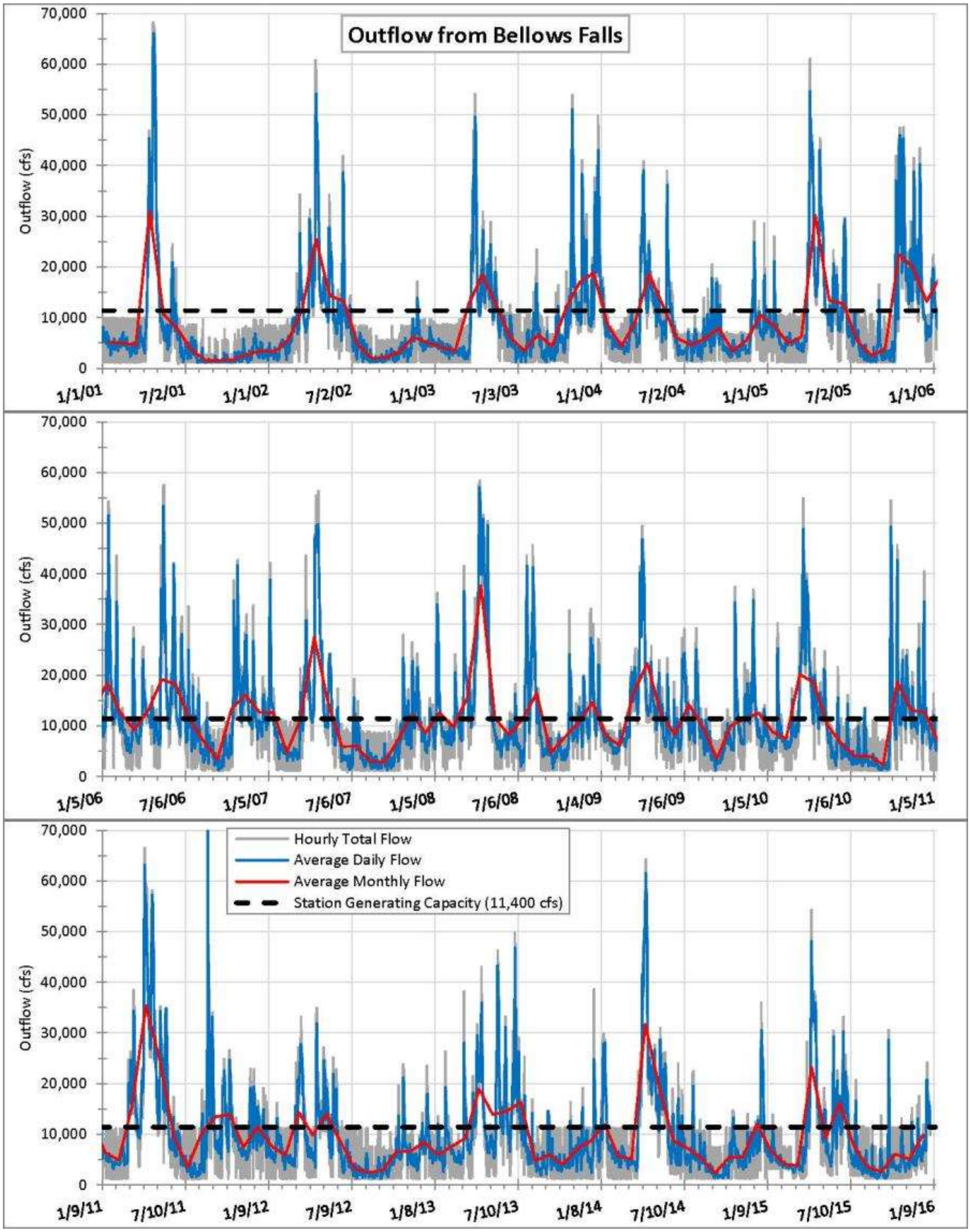
Figure 3.5-18 presents the average hourly median, average, minimum, and maximum values and the 5, 25, 75, and 95 percent exceedance values for impoundment WSEs from January 1, 2001, to December 31, 2015. This figure illustrates the operating range including periods when the WSE dropped below the minimum operational impoundment level in late August and early September 2011 after Tropical Storm Irene, which had peak flows of 103,397 cfs that necessitated pulling two bays of stanchion boards and a portion of boards in a third bay.



Source: Great River Hydro

Figure 3.5-18. Bellows Falls hourly impoundment water surface elevations January 1, 2001–December 31, 2015.

Figure 3.5-19 presents hourly outflow as compared to the daily and monthly average outflow from January 1, 2001, to December 31, 2015. The figure shows that outflows from the Project are normally between minimum flow and the maximum station discharge of 11,400 cfs under non-spill conditions.

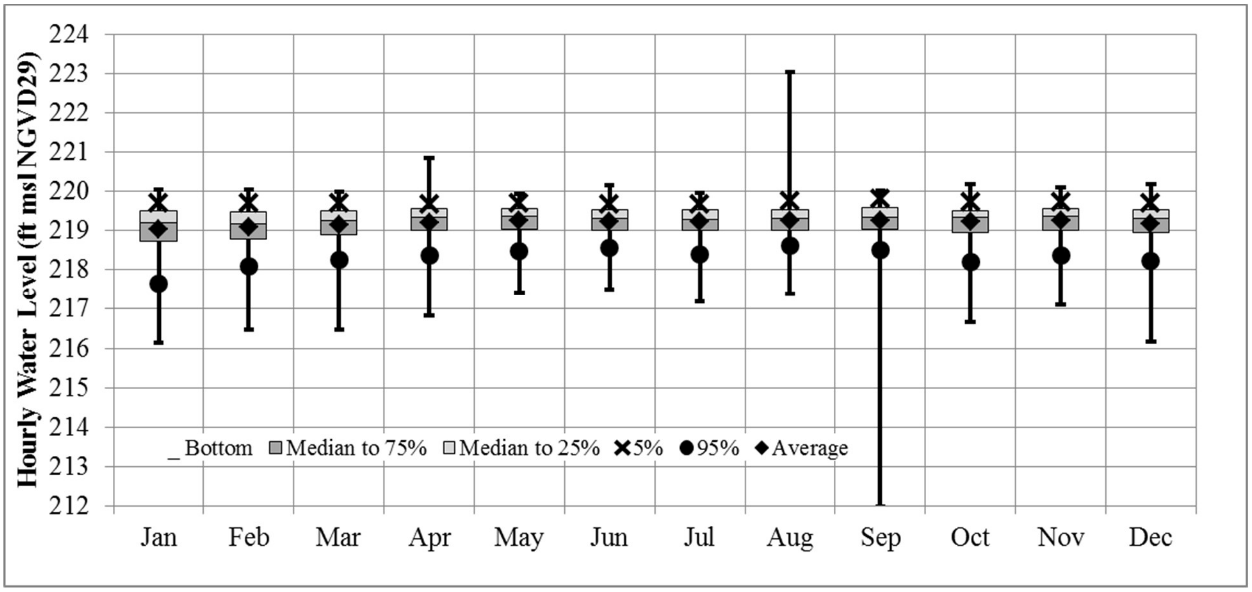


Source: Great River Hydro

Figure 3.5-19. Hourly, average daily, and average monthly outflow from the Bellows Falls Project (January 1, 2001–December 31, 2015).

Vernon Project

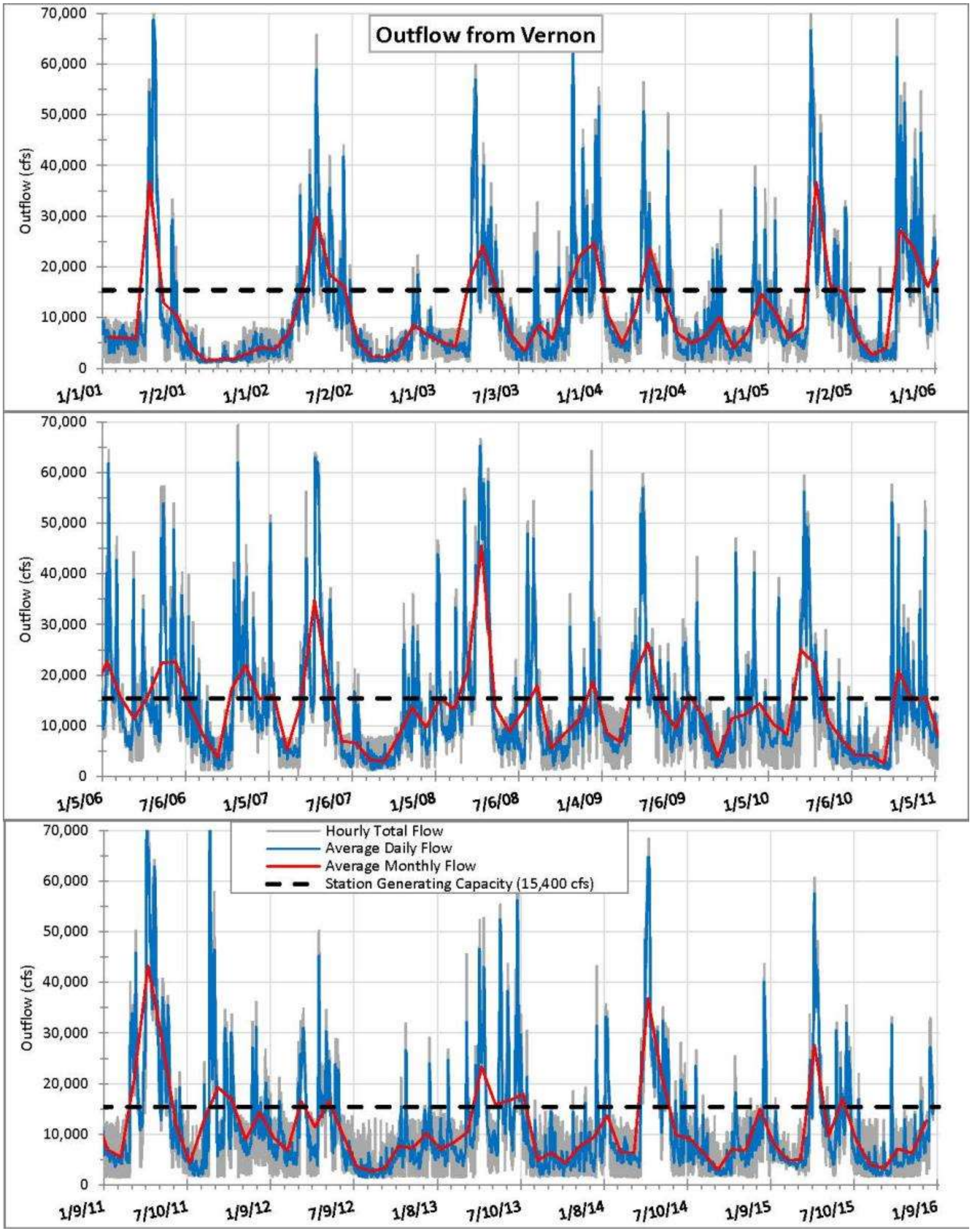
Figure 3.5-20 presents hourly median, average, minimum, and maximum values and the 5, 25, 75, and 95 percent exceedance values for impoundment WSEs from January 1, 2001, to December 31, 2015, and illustrates the operating rage. However, the impoundment reached a peak elevation of 223.04 ft on August 29, 2011, during Tropical Storm Irene and discharge reached a peak flow of 102,626 cfs. The minimum impoundment level during the period shown was El. 212.0 ft on September 14, 2011, also as a result of Tropical Storm Irene.



Source: Great River Hydro

Figure 3.5-20. Vernon hourly impoundment elevations January 1, 2001–December 31, 2015.

Figure 3.5-21 presents hourly outflow as compared to the daily and monthly average outflow from January 1, 2001 to December 31, 2015. The figure shows that outflows from the Project are normally between minimum flow and the maximum station discharge of 15,400 cfs under non-spill conditions.



Source: Great River Hydro

Figure 3.5-21. Hourly, average daily, and average monthly outflow from the Vernon Project (January 1, 2001–December 31, 2015).

3.5.1.2 Water Quality

Surface Water Quality Standards and Designated Uses

The Connecticut River within the Wilder, Bellows Falls, and Vernon Projects is subject to both New Hampshire and Vermont surface water quality standards and designated uses relevant to their respective waterbody classification.

New Hampshire

Through its Surface Water Quality Regulations (Env-Wq 1700, readopted with amendments in 2016), New Hampshire established water quality standards for the state's surface water uses. These water quality standards are intended to protect public health and welfare, enhance the quality of water, and serve the purposes of the CWA and New Hampshire Revised Statutes Annotated (R.S.A.) 485-A. In addition, the surface water quality standards consist of numerical and narrative criteria for the protection and propagation of fish, shellfish, and wildlife and provide for such designated uses as recreation, public water supply, aquatic life integrity, and wildlife. Criteria are established by statute Title L Water Management and Protection, Chapter 485-A, *Water Pollution and Waste Disposal*, and by administrative rules Env-Wq 1700.

Surface waters in New Hampshire are classified as either Class A or Class B. Class A waters are of the highest quality and are managed to be potentially acceptable for water supply uses after adequate treatment. Class B waters are of the second highest quality and are managed to achieve and maintain certain designated uses. The New Hampshire General Court has designated the Connecticut River in the vicinity of the Wilder, Bellows Falls, and Vernon Projects as Class B waters. Tables 3.5-6 and 3.5-7, respectively, present and describe applicable water quality standards and the designated uses for Class B waters in New Hampshire.

Table 3.5-6. Applicable New Hampshire Class B surface water quality standards.

Parameter	Administrative Code	Numeric or Narrative Standard
Temperature	Env-Wq 1703.13	Any increase shall not be such as to appreciably interfere with the uses assigned to this class.
Dissolved oxygen (DO)	Env-Wq 1703.07	Daily average at least 75 percent saturation; instantaneous minimum of 5.0 milligrams per liter (mg/L).
pH	Env-Wq 1703.18	6.5 to 8.0, unless due to natural causes.

Parameter	Administrative Code	Numeric or Narrative Standard
Turbidity	Env-Wq 1703.11	Not exceed naturally occurring conditions by more than 10 nephelometric turbidity units (NTU). If a discharge causes or contributes to an increase equal to or more than 10 NTU of receiving water upstream of the discharge or otherwise outside of the visible discharge, a violation of the turbidity standard shall be deemed to have occurred.
Nutrients	Env-Wq 1703.14	Nitrogen—none in such concentrations that would impair any existing or designated uses, unless naturally occurring. Phosphorus—none in such concentrations that would impair any existing or designated uses, unless naturally occurring.
Bacteria (Escherichia coli)	Env-Wq 1703.06	Geometric mean of three samples over 60-day period shall not contain more than 126 *E-coli* bacteria per 100 milliliters (mL), or no greater than 406 per 100 mL in one sample. For designated beach areas, the geometric mean based on at least three samples over a 60-day period shall not exceed 47 *E-coli* bacteria per 100 mL or 88 per 100 mL in a single sample, unless naturally occurring.

Sources: NHCAR (2016) and NHGC (1998)

Table 3.5-7. Designated uses for Class B New Hampshire surface waters.

NHDES Definition (Env-Wq 1702.17)
(a) Swimming and other recreation in and on the water, meaning the surface water is suitable for swimming, wading, boating of all types, fishing, surfing, and similar activities.
(b) Fish consumption, meaning the surface water can support a population of fish free from toxicants and pathogens that could pose a human health risk to consumers.
(c) Shellfish consumption, meaning the tidal surface water can support a population of shellfish free from toxicants and pathogens that could pose a human health risk to consumers.
(d) Aquatic life integrity, meaning the surface water can support aquatic life, including a balanced, integrated, and adaptive community of organisms having a species composition, diversity, and functional organization comparable to that of similar natural habitats of the region.
(e) Wildlife, meaning the surface water can provide habitat capable of supporting any life stage or activity of undomesticated fauna on a regular or periodic basis.

NHDES Definition (Env-Wq 1702.17)
(f) Potential drinking water supply, meaning the surface water could be suitable for human intake and meet state and federal drinking water requirements after adequate treatment.

Source: NHCAR (2016)

Vermont

Vermont water quality standards serve as the foundation to protect and enhance the quality of Vermont's surface waters (VDEC, 2016b). The current water quality standards became effective January 15, 2017. Surface waters in Vermont are classified as Class A(1), Class A(2), Class B(1) or Class B(2) based on numerical and/or narrative criteria to protect the designated uses. Waters designated as Class A(1) are managed to maintain an essentially natural condition. Class A(2) waters are Public Water Supply waters managed for the natural condition with the exception of withdrawals for public water supplies. Class B(1) waters are managed to achieve and maintain very good biological integrity, and Class B(2) waters are managed to achieve and maintain good biological integrity. The Connecticut River in the vicinity of the three Projects is designated as Class B(2) water in Vermont and as coldwater fish habitat (VDEC, 2016b).[25] Applicable Vermont surface water quality standards and designated uses for the Wilder, Bellows Falls, and Vernon Projects are presented in Table 3.5-8 and Table 3.5-9, respectively.

Table 3.5-8. Applicable Vermont Class B surface water quality standards for coldwater fish habitat.[a]

Parameter	Chapter and Section	Numeric or Narrative Standard
Temperature	29A-302 (1)(A) and (B)(iii)	Change or rate of change in temperature, either upward or downward, shall be controlled to ensure full support of aquatic biota, wildlife, and aquatic habitat uses. The total increase from ambient temperature due to all discharges and activities shall not exceed 1 degree Fahrenheit (°F) (0.56 degrees Celsius [°C]) from ambient temperatures, except for the assimilation of thermal waste as permitted by the Secretary.
DO	29A-302 (5)(ii)	Not less than 6 mg/L and 70% saturation at all times in all other waters designated as a coldwater fish habitat.

[25] Within the mainstem Project areas, the Connecticut River is not explicitly listed as either Class B warmwater fish habitat or Class B coldwater fish habitat; therefore, it is assumed the Connecticut River is a Class B coldwater fishery (see VDEC, 2016b, Appendix A). However, see discussion under Table 3.5-9, note a.

Parameter	Chapter and Section	Numeric or Narrative Standard
pH	29A-303 (6)	pH values shall be maintained within the range of 6.5 and 8.5. Both the change and the rate of change in pH values shall be controlled to ensure the full support of the aquatic biota, wildlife, and aquatic habitat uses.
Turbidity	29A-302 (4)(B)	None in such amounts or concentrations that would prevent the full support of uses, and not to exceed 25 NTU as an annual average under dry weather base-flow conditions.
Nutrients	29A-302 (3) and (c)(iii); 29A-302 (2)(A)	Nitrates shall be limited so that they will not contribute to the acceleration of eutrophication, or the stimulation of the growth of aquatic biota, in a manner that prevents the full support of uses. Nitrates not to exceed 5.0 mg/L as nitrogen (NO_3-N) at flows exceeding low median monthly. Total phosphorus loadings shall be limited so that they will not contribute to the acceleration of eutrophication or the stimulation of the growth of aquatic biota in a manner that prevents the full support of uses.
Bacteria (*Escherichia coli*)	29A-306 (f)(3)(B)	Not to exceed a geometric mean of 126 organisms per 100 mL obtained over a representative period of 60 days, and no more than 10% of samples above 235 organisms/100 mL. In waters receiving combined sewer overflows, the representative period shall be 30 days.

Source: VDEC (2016b)

a. Waters in which one or more applicable water quality criteria are not met because of natural influences shall not be considered in noncompliance with respect to such criteria. In such waters, activities may be specifically authorized by a permit, provided that those activities do not further reduce the quality of the receiving waters and comply with all other applicable criteria.

Table 3.5-9. Designated uses for Vermont Class B surface waters.

Designated Use	Numeric or Narrative Standard[a]
Aquatic Biota, Wildlife, and Aquatic Habitat	Aquatic biota and wildlife sustained by high quality aquatic habitat with additional protection in those waters where these uses were sustainable at a higher level based on Water Management Type designation.
Aesthetics	Water character, flows, water level, bed and channel characteristics, exhibiting good aesthetic value and, where attainable, excellent aesthetic value based on Water Management Type designation.
Public Water Supply	Suitable for use as a source for public water supply with filtration and disinfection.
Irrigation of Crops and Other Agricultural Uses	Suitable, without treatment, for irrigation of crops used for human consumption without cooking and suitable for other agricultural uses.
Swimming and Other Primary Contact Recreation	Suitable for swimming and other forms of water-based recreation where sustained direct contact with the water occurs and, where attainable, suitable for these uses at very low risk of illness based on Water Management Type designation.
Boating, Fishing and Other Recreational Uses	Suitable for these uses with additional protection in those waters where these uses are sustainable at a higher level based on Water Management Type designation.

Source: VDEC (2016b)

a. All Class B waters shall eventually be designated as being either Water Management Type 1, Type 2 or Type 3. The Connecticut River encompassing the Wilder, Bellows Falls and Vernon Projects has no such water management-type designation; therefore, according to Section 3-06 of the Vermont Water Quality Standards, the criteria based on a water management type shall not apply.

Section 303(d) Listing and Total Maximum Daily Load

Under Section 303(d) of the federal CWA, and in adherence with federal water quality planning and management regulations (40 C.F.R. Part 130), all states are required to develop lists of impaired or “Category 5” waters; commonly referred to as the 303(d) list. The list includes lakes, ponds, rivers, and streams whose water quality does not meet state-defined water quality standards. Each state’s list must be updated every 2 years and submitted to the U.S. Environmental Protection Agency (EPA) for approval. The CWA requires the development of total maximum daily loads (TMDLs) for waters on the list and the provision of a schedule indicative of TMDL completion priority.

In 2014, NHDES prepared a draft list of impaired waterbodies for the state (NHDES, 2015). Likewise, in 2014, VDEC prepared a final 303(d) list of impaired waterbodies for which a TMDL is required to be developed (Part A), a list of impaired waterbodies with other pollution control measures in place other than a TMDL (Part B), a list of impaired waterbodies that have a completed TMDL approved by EPA

(Part D), a list of waterbodies that are altered aquatic habitats or designated uses are affected by invasive species (Part E), waterbodies affected by flow alteration (Part F), and other stressed waterbodies that are prevented from attaining higher water quality. Each assessment unit and associated water quality impairments and stresses are discussed below from upstream to downstream by Project for New Hampshire and Vermont.[26] Table 3.5-10 presents the NHDES and VDEC 303(d) listing of impaired or threatened waters in the Wilder, Bellows Falls, and Vernon Project areas for which a TMDL is needed (NHDES, 2015; VDEC, 2016c), tributaries to the Connecticut River are included only if they are impaired at the mouth, adjacent to Project waters.[27] Table 3.5-10 also presents the length of river and designated uses that are impaired, the type of impairment, the TMDL priority, and the source of the impairment.

New Hampshire

Fifteen New Hampshire assessment units encompass the Wilder, Bellows Falls and Vernon Project areas on the mainstem. The assessment units are discussed below in an upstream to downstream direction.

NHRIV801030703-04—Extends 22.2 river miles from the confluence of the Ammonoosuc River in Haverhill and Bath, New Hampshire, just upstream of the Wilder impoundment to the Waits River confluence located in Bradford, Vermont. This segment generally supports aquatic life and drinking water after treatment, but data are lacking to determine whether it supports primary and secondary contact recreation based on Escherichia coli bacteria levels.

NHRIV801040205-06—Extends 7.1 river miles from the Waits River confluence to the Orford and Lyme, New Hampshire, town border. In this assessment unit, drinking water after adequate treatment is fully supported, but data are lacking to determine whether aquatic life, primary and secondary contact recreation, and wildlife designated uses are supported.

NHLAK801040402-03—Extends 21.7 river miles from the Orford and Lyme, New Hampshire, border to Wilder dam and is referred to by NHDES as Wilder Lake. This stretch of river generally supports aquatic life, drinking water after adequate treatment, primary and secondary contact recreation designated uses, but data are lacking to determine whether wildlife uses are met.

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[26] An assessment unit is the basic unit of record for conducting and reporting water quality assessments.

[27] Defined as within 100 ft of the river.

Table 3.5-10. NHDES and VDEC 303(d) listing of impaired or threatened waterbodies in the Wilder, Bellows Falls, and Vernon Project vicinity for which a TMDL is needed.

Waterbody (Unit ID)	Primary Town, State[a]	Project Vicinity	Size	Designated Uses[b]	Impairment Type	TMDL Priority	Pollutant Source[c]
Wilder							
Clark Brook (NHRIV801030703-02)	Haverhill, NH	Impoundment	22.4 miles	AL	Aluminum, fishes bioassessments	Low	Unknown
Grant Brook (NHRIV801040204-02)	Lyme, NH	Impoundment	9.8 miles	AL	Fishes bioassessments	Low	Unknown
Hewes Brook (NHRIV801040402-04)	Lyme, NH	Impoundment	16.1 miles	AL	Benthic macroinvertebrates, fishes bioassessments	Low	Unknown
Mink Brook (NHRIV801040401-05)	Hanover, NH	Impoundment	13.7 miles	AL	Fishes bioassessments	Low	Unknown
Mascoma River (NHRIV801060106-20)	Lebanon, NH	Downstream of dam riverine	1.4 miles	AL	Aluminum	Low	Unknown
Blow-Me-Down Brook (NHRIV801060303-11)	Cornish, NH	Downstream of dam riverine	0.3 mile	AL	Aluminum	Low	Unknown
Bellows Falls							
Sugar River (NHRIV801060407-16)	Claremont, NH	Impoundment	1.7 miles	AL	pH, Aluminum	Low	Unknown
Black River (VT10-11)	Springfield, VT	Impoundment	4.6 miles	1CR	*E. coli*	Low	CSO
Connecticut River, Bellows Falls Impoundment (NHIMP801060703-05)	Charlestown, NH	Impoundment	1,720 acres	AL	pH	Low	Atmospheric deposition (acidity)
Clay Brook (NHRIV801060703-06)	Charlestown, NH	Impoundment	2.4 miles	AL	Fishes bioassessments	Low	Unknown
Commissary Brook (VT13-10)	Rockingham, VT	Impoundment	0.2 mile	AL, AES	Sediment	Low	Erosion

Waterbody (Unit ID)	Primary Town, State[a]	Project Vicinity	Size	Designated Uses[b]	Impairment Type	TMDL Priority	Pollutant Source[c]
Connecticut River, Bellows Falls Bypassed Reach (NHRIV801070501-10-01)	Walpole, NH	Bypassed reach	0.9 mile	AL	pH	Low	Unknown
Cold River (NHRIV801070203-12)	Walpole, NH	Downstream of dam riverine	1.2 miles	AL	pH	Low	Unknown
Vernon							
Partridge Brook (NHRIV801070503-03)	Westmoreland, NH	Impoundment	28.3 miles	AL	pH, Fishes bioassessments	Low	Unknown
Connecticut River, Partridge Brook to West River Confluence (NHRIV801070505-10)	Westmoreland, NH	Impoundment	13.1 miles	AL	pH	Low	Unknown
Crosby Brook (VT13-13)	Brattleboro, VT	Impoundment	0.7 mile	AL	Sediment	Medium	Sedimentation, channelization, buffer loss
Ash Swamp Brook (NHRIV801070507-01)	Hinsdale, NH	Impoundment	14.7 miles	AL	Benthic macro-invertebrate bioassessments	Low	Unknown
Connecticut River, Downstream of Vernon Dam to MA Border (NHRIV802010501-05)	Hinsdale, NH	Downstream of dam riverine	7.6 miles	AL	pH, Aluminum, Copper	Low	Unknown

Source: NHDES (2015); VDEC (2016c)

a. For Vermont, there is no needed and required TMDL for the mainstem Connecticut River that encompasses the Wilder Project vicinity (VDEC, 2016c, 2016d).

b. AL – aquatic life; AES – aesthetics; 1CR – primary contact recreation

c. CSO – combined sewer overflow

NHRIV801040402-13—Extends 2.0 river miles from Wilder dam downstream to the White River confluence in White River Junction, Vermont. This assessment unit supports aquatic life and drinking water after adequate treatment designated uses. Information is lacking to determine whether primary and secondary contact recreation and wildlife designated uses are supported in this reach.

NHRIV801060302-01—Extends from the White River confluence to the Mascoma River confluence in Lebanon, New Hampshire, about 1.4 river miles. In this reach of the mainstem river, aquatic life, drinking water after adequate treatment, and secondary contact recreation are supported; primary contact recreation is impaired because of E. coli bacteria from combined sewer overflows (CSO), but a statewide bacteria TMDL is in place (NHDES, 2010; VDEC, 2011).[28,29] No data are available to determine whether wildlife uses are supported.

NHRIV801060302-05—Extends 14.5 river miles from the Mascoma River confluence to Blow-me-down Brook in Cornish, New Hampshire, and supports drinking water after adequate treatment and secondary contact recreation uses but is impaired for primary contact recreation because of E. coli from CSOs. No data are available to determine whether aquatic life uses are supported.

NHRIV801060305-12—Extends 7.5 river miles from the Connecticut River's confluence with Blow-me-down Brook to its confluence with the Sugar River. This reach of river supports drinking water after adequate treatment and both primary and secondary contact recreation. Aquatic and wildlife uses need data to determine whether they are supported.

NHRIV801060702-12—Extends from the Sugar River confluence 15.4 river miles to the Black River confluence in Springfield, Vermont. This assessment unit supports drinking water after adequate treatment and primary and secondary contact recreation, but aquatic life uses are impaired and wildlife uses cannot be determined. Aquatic life uses are impaired because of invasive aquatic algae and non-native aquatic plants.

NHIMP801060703-05—Encompasses a portion of the Bellows Falls impoundment and extends 12.8 river miles from the Black River confluence to the Bellows Falls dam and powerhouse. This assessment unit supports drinking water after adequate treatment and potentially supports primary contact recreation, but it is undetermined whether this assessment unit supports secondary contact recreation or wildlife uses because of insufficient information. In addition, this assessment unit

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28 Combined sewers are pipes that collect stormwater and municipal wastewater or sewage. If the sewer pipe capacity is exceeded during heavy rains, the sewer overflows.

29 Each statewide TMDL for bacteria-impaired waters applies to all waters impaired by bacteria in Vermont and New Hampshire. However, Assessment Units NHRIV801060302-01 and NHRIV801060302-05 are the only areas of the mainstem Connecticut River in the Project areas where these TMDLs apply based on the 2014 303(d) lists.

is marginally impaired for aquatic life uses due to pH from atmospheric deposition and a TMDL is needed (NHDES, 2015).

NHRIV801070501-10-01—Encompasses the Bellows Falls bypassed reach. In the bypassed reach, aquatic life uses are marginally impaired by pH from atmospheric deposition and a TMDL is needed (NHDES, 2015). Drinking water uses are supported after adequate treatment, while primary and secondary contact recreation as well as wildlife uses are not determined because of insufficient information.

NHRIV801070501-10-02—Extends 10.6 river miles from the Bellows Falls powerhouse to the Houghton Brook confluence in Walpole, New Hampshire. This assessment unit includes a portion of the downstream Bellows Falls riverine and Vernon impoundment areas. The unit supports aquatic life and drinking water uses; however, insufficient information is available to determine whether primary and secondary contact recreation uses and wildlife uses are supported.

NHRIV801070502-06—Extends 5.1 river miles from the Houghton Brook confluence to Partridge Brook in Westmoreland, New Hampshire. The unit supports drinking water uses after adequate treatment, but it is unknown whether aquatic life, primary and secondary contact recreation, and wildlife uses are supported because of insufficient information.

NHRIV801070505-10—Extends 13.1 river miles from the Partridge Brook confluence to the West River confluence in Brattleboro, Vermont. The unit supports drinking water uses after adequate treatment, but it is unknown whether primary and secondary contact recreation and wildlife uses are supported because of insufficient information. Aquatic life is impaired and a TMDL is needed because of pH exceedances. The source of the impairment due to pH is unknown.

NHIMP801070507-01—Extends 11.0 river miles from the West River confluence to Vernon dam (NHIMP801070507-01). The unit supports drinking water after adequate treatment and aquatic life and primary contact recreation. It is unknown whether secondary contact recreation and wildlife uses are supported because of insufficient information.

NHRIV802010501-05—Encompasses Project-affected waters that extend downstream from Vernon dam 7.6 river miles to the New Hampshire/Massachusetts border. This segment supports primary and secondary contact recreation and drinking water uses after adequate treatment; however, the segment is marginally and severely impaired for aquatic life because of aluminum and copper concentrations, respectively, and a TMDL is needed. It is also unknown whether wildlife uses in this reach are met because of insufficient information.

The entire portion of the Connecticut River that encompasses the assessment units above for the Wilder, Bellows Falls, and Vernon Projects is impaired for fish consumption because of mercury from atmospheric deposition (New Hampshire only). A Northeast–wide TMDL was completed for mercury and approved by EPA in

2007 for the entire Northeastern United States, which includes these New Hampshire assessment units (NEIWPCC, 2007).

Vermont

Six Vermont waterbody segments encompass the Wilder, Bellows Falls, and Vernon Project areas. These segments are discussed below in an upstream to downstream direction.

VT16-07—Extends 48.9 river miles from the Connecticut River confluence with the Wells River to Wilder dam. Vermont's 2016 303(d) list of impaired waterbodies and associated parts identifies a portion of this segment that extends from Wilder dam to Bradford, Vermont as impaired because of fluctuating flows and water levels associated with hydropower generation and destabilized/eroding streambanks. The only uses affected in these reaches because of fluctuating flows and water levels are aquatic life support uses (VDEC, 2016e). In addition, VDEC (2016f) reports segment VT13-02 as, "CT RIVER, HOYTS LNDNG, WILDER DAM, TRANSCANADA LAUNCH." However, Hoyts Landing is located in Springfield, Vermont, at the Connecticut River's confluence with the Black River in Springfield, Vermont, within the Bellows Falls impoundment and is managed by the Vermont Fish & Wildlife Department (VFWD). Segment VT16-07 is the river segment that encompasses Wilder dam. No other impairments are identified within this waterbody segment.

VT13-01—Extends 21.4 river miles from Wilder dam to the Connecticut River's confluence with the Sugar River. Vermont's 2016 303(d) list of impaired waterbodies and associated parts lists a portion of this segment that ranges from Wilder dam downstream 20.5 miles to Ascutney Village, Vermont, as impaired because of fluctuating flows and water levels associated with hydropower generation. No other impairments are identified within this waterbody segment.

VT13-02—Extends 21.6 river miles from the confluence with Sugar River downstream to Bellows Falls dam. This segment of the Connecticut River is impaired because of fluctuating flows and water levels associated with hydropower generation and dewatered shorelines/wetlands (VDEC, 2016e). Flow regulation within this segment impacts aquatic life support and aesthetics (VDEC, 2016e). In addition, the area near and around the Hoyts Landing boat ramp [as identified by the state, see VT16-07 above] is stressed because of abundant Eurasian milfoil (VT13-02) (VDEC, 2016g). The presence of Eurasian milfoil impacts aesthetics, aquatic life support, and both primary and secondary contact recreation. No other impairments are identified within this waterbody segment.

VT13-03—Extends from Bellows Falls dam downstream about 25.0 miles to the confluence with the West River in Brattleboro, Vermont, is Waterbody Segment VT13-03. This segment encompasses riverine reaches downstream of Bellows Falls dam as well as the Vernon impoundment. VDEC (2016e) lists VT13-03 from Bellows Falls dam 24 miles downstream (including much of the Vernon impoundment) as altered by flow regulation from hydroelectric generation, which impacts aquatic life support. No other impairments are identified within this waterbody segment.

VT13-04—Vermont's 2016 303(d) list of impaired waterbodies and associated parts identifies Waterbody Segment VT13-04, which extends 7.4 river miles from the Connecticut River confluence with the West River to Vernon dam, as impaired because of fluctuating flows and water levels associated with hydropower generation and dewatered shorelines/wetlands affecting aquatic life support (VDEC, 2016e). No other impairments are identified within this waterbody segment.

VT13-05—Includes riverine reaches downstream of Vernon dam as well as impoundment areas of the Turner's Falls Project. This waterbody segment also serves as the lower reservoir for the Northfield Mountain Pumped Storage Project. This waterbody segment extends 5.7 river miles downstream of Vernon dam, but only 5.5 river miles from Vernon dam downstream is listed as impaired because of fluctuating flows and water levels associated with hydropower generation affected aquatic life support (VDEC, 2016e). In addition, tritium has been identified has a possible pollutant within segment VT13-05 as a result of underground leakage from the now decommissioned VY (VDEC, 2016g).[30] No other impairments are identified within this waterbody segment.

Vermont does not have a specific needed, required, or completed and approved TMDL on the mainstem Connecticut River encompassing the Wilder, Bellows Falls, or Vernon Project areas (VDEC, 2016c, 2016d). However, Connecticut River waters are included in the Northeast-wide TMDL for mercury (NEIWPCC, 2007).

Long Island Sound TMDL

The Long Island Sound (Sound) has a DA of about 16,000 sq. mi. The largest source is the Connecticut River, contributing 70 percent of the total freshwater entering the Sound annually. Nitrogen is the primary limiting nutrient for algal growth in the Sound. Increased nitrogen loading from point and non-point sources has led to hypoxic dissolved oxygen (DO) levels and subsequent loss of designated uses and severe effects on wildlife in the Sound. The Long Island Sound TMDL was developed by the New York Department of Environmental Conservation and Connecticut Department of Environmental Protection and was approved by EPA with the goal of reducing nitrogen loading into the Sound from both point and non-point sources to improve DO levels (NYSDEC and CDEP, 2000).

[30] Tritium is a radioactive isotope of the hydrogen atom.

National Pollutant Discharge Elimination System Permits

Wilder Project

The Wilder Project was issued a National Pollutant Discharge Elimination System (NPDES) permit in the mid-1990s, and the Project has held a valid discharge permit since then. NPDES #VT0000787, permit #3-1393, allows the Project to discharge minor, non-generation related wastewaters, including non-contact cooling water from Units 1, 2, and 3, internal facility drainage, and sump pit waters associated with the generating units. Great River Hydro is required to conduct quarterly sampling of its wastewaters and report the results of the sampling to VDEC, the permitting authority. Permit parameters and limits for temperature, pH, and oil/grease are the same for all discharge outfalls as listed below:

- Temperature (<90°F);
- pH (6.5–8.5); and
- Oil/grease (<20 milligrams per liter [mg/L], not required for non-contact cooling water).

All sources of wastewater from the Wilder Project combine into a single outfall. TransCanada, now Great River Hydro, applied for a 5-year renewal permit in December 2015 (pending at this time) with a daily maximum flow limitation for outfall S/N 001 of 3.13 million gallons per day (mgd), a discharge level only required over a few days for annual dewatering of generating units, average daily discharge is approximately 0.8 mgd.

Bellows Falls Project

The Bellows Falls Project was issued an NPDES permit in the mid-1990s and has held a valid discharge permit since then (NPDES #VT0000795). This permit allows the Project to discharge minor, non-generation-related wastewaters, including non-contact cooling water from turbine bearings and air compressors and internal leakage in wheel pits and sumps. Great River Hydro is required to conduct quarterly sampling of its wastewaters and report the results of the sampling to VDEC, the permitting authority. Permit parameters and limits for temperature, pH, and oil/grease are the same for all discharge outfalls as listed below:

- Temperature (<90°F);
- pH (6.5-8.5); and
- Oil/grease (<20 mg/L, not required for non-contact cooling water).

TransCanada, now Great River Hydro, applied for a 5-year renewal permit in December 2015 (pending at this time) with the following daily maximum flow limits that vary by discharge outfall as noted below:

- 0.023 mgd for S/N 002, S/N 009 and S/N 010: Bearing unit cooling water;
- 0.152 mgd for S/N 003: Air compressor cooling water, sump waters, and other internal drainage waters after treatment via and oil water separator; and

- 1.296 mgd for S/N 004: Wheel pit drainage waters during extremely high river flows.

Vernon Project

The Project was issued an NPDES permit in the mid-1990s and has held a valid discharge permit since then (NPDES No. VT0000868). This permit allows the Project to discharge minor, non-generation-related wastewaters, including non-contact cooling water from turbine bearings and air compressors and internal leakage in wheel pits and sumps. Great River Hydro is required to conduct quarterly sampling of its wastewaters and reporting results to VDEC. Permit parameters and limits for temperature, pH, and oil/grease are the same for all discharge outfalls as listed below:

- Temperature (<90°F);
- pH (6.5-8.5); and
- Oil/grease (<20 mg/L, not required for non-contact cooling water).

TransCanada, now Great River Hydro, applied for a 5-year renewal permit in December 2015 (pending at this time) with daily maximum flow limits that vary by discharge outfall as noted below:

- 0.144 mgd for S/N 001: Bearing cooling water, sump waters, and other internal drainage water;
- "as necessary" for S/N 002: Uncontaminated water during draft tube dewatering of Units 5 through 8; and
- 0.336 mgd for S/N 003: Non-contact bearing cooling water and auto-strainer backwash from Units 5 through 10.

There have been no permit exceedances at the Wilder, Bellows Falls, or Vernon Projects since monitoring commenced.

Other Wastewater Treatment Facilities

Sixty-four wastewater treatment facilities are located in the Connecticut River watershed upstream of the Projects. Table 3.5-11 lists the locations of these facilities.

Table 3.5-11. New Hampshire and Vermont towns in the Connecticut River watershed with wastewater treatment facilities upstream of each Project dam.

New Hampshire		Vermont	
Town	**No. of Facilities**	**Town**	**Number of Facilities**
Upstream of Wilder Dam			
Bethlehem	2	Barnet	1
Colebrook	1	Bradford	1
Groveton	2	Canaan	2
Hanover	1	Danville	1
Lancaster	2	Fairlee	1
Lisbon	1	Lunenburg	1
Littleton	1	Lyndon	2
N. Stratford	2	Newbury	1
Northumberland	1	St. Johnsbury	1
Piermont	1		
Whitefield	1		
Woodsville	1		
Between Wilder and Bellows Falls Dams			
Charlestown	1	Bethel	1
Claremont	1	Cavendish	1
Guild	1	Chelsea	1
Lebanon	1	Hartford	3
Meriden	1	Ludlow	1
Newport	1	Windsor	2
Springfield	1		
Sunapee	1		
West Lebanon	2		
Between Bellows Falls and Vernon Dams			
Westmoreland	1	Brattleboro	3
		Dummerston	1
		Londonderry	1
		Rockingham	1
		Vernon	2

Fish Tissue Contamination and Consumption Advisories

In 2000, a joint federal and state screening level survey was performed to provide baseline fish tissue contaminant data for several fish species present in the Connecticut River (Hellyer, 2006). The study objectives were to better understand the risk to human health from eating Connecticut River fish and to learn what threat eating these fish poses to other mammals, birds, and fishes. For this study, fillet and composite samples of smallmouth bass, white sucker, and yellow perch were collected from three reaches that encompass the Project areas: (1) above Turners Falls dam, Massachusetts, to Vernon dam (Reach 4); (2) above Vernon dam to Wilder dam (Reach 5); and (3) above Wilder dam to Moore dam, New Hampshire (Reach 6) were analyzed for total mercury, polychlorinated biphenyls, organochlorine pesticides (e.g., dichlorodiphenyltrichloroethane), and dioxins. The study determined that: (1) total mercury concentrations in all three species were significantly higher in fish collected from the upstream reaches in higher elevation drainage basins that experience greater air deposition than in downstream reaches, and that mercury in sediments was not found above laboratory reporting limits in any samples collected in the New Hampshire and Vermont section of the river; and (2) mercury contamination, attributed mainly from atmospheric deposition, posed a risk to recreational and subsistence fishers and to fish-eating wildlife. The study concluded that polychlorinated biphenyls, organochlorine pesticides, and dioxins levels in fish tissues could pose a potential risk to human health, but noted: "It is not believed that Connecticut River sediments are a significant source of mercury in fish" (Hellyer, 2006).

The states of New Hampshire and Vermont have freshwater fish consumption advisories, and as discussed above, a TMDL is in place for the entire Northeastern United States to reduce mercury concentrations in fish from atmospheric deposition (NHFGD, 2016a; Vermont Department of Health, 2016; NEIWPCC, 2007).

Historical Water Quality

In 2004, NHDES and EPA conducted a water quality study on the 275 miles of the river between the Canadian and Massachusetts borders in anticipation of the 2005 update of the Connecticut River Management Plan (Connecticut River Joint Commissions, 2008). Samples were collected from June through August, and in some cases, September. Data relevant to the Wilder, Bellows Falls, and Vernon Projects are summarized in Tables 3.5-12, 3.5-13, and 3.5-14, respectively. All sites sampled in the Wilder and Vernon Project areas were found to fully support the designated uses of aquatic life and primary and secondary contact recreation. For the Bellows Falls Project area, most sites sampled were found to be fully supporting the designated uses of aquatic life, and primary and secondary contact recreation; however, the Route 11 Bridge in Charlestown, New Hampshire, Assessment Unit (NHRIV801060702-12) was found not to support aquatic life because of the presence of invasive species, and the Interstate 89 bridge and railroad bridge sites located in Lebanon and West Lebanon, New Hampshire, respectively, were determined not to support primary contact recreation because of impairments from CSOs.

Table 3.5-12. 2004 NHDES Connecticut River water quality assessment data for the Wilder Project area.

Site (Assessment Unit)	Dissolved Oxygen		pH min/max	Temp. (°C) min/max	Bacteria Geometric Mean (#/100 mL)
	(mg/L) min/max	(% Sat.) min/max			
Newbury Road Bridge, Haverhill, NH (NHRIV801030703-04)	7.5 / 8.6	85 / 94	6.9 /7.6	18.5 / 22.0	53
Route 25A Bridge, Orford, NH (NHRIV801040205-06)	7.3 / 8.5	84 / 92	6.6 / 7.6	19.1 / 23.0	43
Wilder Impoundment, West Wheelock Street Bridge, Hanover, NH (NHLAK801040402-03)	7.8 / 8.2	83 / 94	6.8 / 7.7	19.6 / 22.0	17
Route 4 Bridge, West Lebanon, NH (NHRIV801040402-13)	6.8 / 8.3	84 / 95	6.8 / 7.5	19.0 / 21.0	21
Route 89 Bridge, Lebanon, NH (NHRIV801060302-01)	6.6 / 9.4	85 / 97	6.6 / 7.7	16.7 / 23.0	21
Railroad Bridge at Blue Seal, West Lebanon, NH (NHRIV801060302-01)	6.7 / 8.7	85 / 92	6.7 / 7.6	18.0 / 22.0	67
Sumner Falls, Plainfield, NH (NHRIV801060302-05)	7.3 / 8.5	82 / 96	6.5 / 7.8	19.7 / 22.0	66

Source: TransCanada (2012a, 2012b)

Table 3.5-13. 2004 NHDES Connecticut River water quality assessment data for the Bellows Falls Project area.

Site (Assessment Unit)	Dissolved Oxygen		pH min/max[a]	Temp. (°C) min/max	Bacteria Geometric Mean (#/100 mL)
	(mg/L) min/max	(% Sat.) min/max			
Route 12/103 Bridge, Claremont, NH (NHRIV801060305-12)	7.9 / 8.5	86 / 96	6.8 / 7.7	18.3 / 23.0	28
Route 11 Bridge, Charlestown, NH (NHRIV801060702-12)	7.7 / 9.7	89 / 97	7.4 / 7.7	15.5 / 25.0	18
Arch Street Bridge, Walpole, NH (NHIMP801060703-05)	7.2 / 9.5	88 / 97	6.7 / 7.6	15.5 / 25.0	20
Bellows Falls Dam Bypass Reach (NHRIV801070501-10-01)	7.9 / 9.8	90 / 106	7.1 / 8.01	15.2 / 24.0	40

Source: TransCanada (2012b)

a. Values with two digits after the decimal point are those that exceeded state standard(s).

Table 3.5-14. 2004 NHDES Connecticut River water quality assessment data for the Vernon Project area.

Site (Assessment Unit)	Dissolved Oxygen		pH min/max[a]	Temp. (°C) min/max	Bacteria Geometric Mean (#/100 mL)
	(mg/L) min/max	(%Sat.) min/max			
Route 123/Walpole Bridge (NHRIV801070501-10-02)	7.9 / 9.7	91 / 101	6.6 / 7.7	15.4 / 24.0	18
Immediately upstream of confluence with Partridge Brook (NHRIV801070502-06)	6.8 / 9.1	79 / 93	7.0 / 7.6	14.9 / 24.0	19
Route 9 Bridge, Chesterfield (NHRIV801070505-10)	7.5 / 9.7	88 / 96	6.49 / 7.6	15.5 / 23.0	15
Route 119 Bridge Hinsdale (NHIMP801070507-01)	7.8 / 10.3	92 / 106	6.49 / 7.6	15.2 / 23.0	34

Source: TransCanada (2012c)

a. Values with two digits after the decimal point are those that exceeded state standard(s).

In 2008 and 2009, the University of Massachusetts, in cooperation with the Targeted Watershed Initiative, sampled a 14-mile stretch of the Connecticut River for bacteria twice a week during high-use recreation summer months. Ten sampling stations were located between the Hartford (Wilder) picnic area at Kilowatt Park (North) in Hartford, Vermont (0.8 mile upstream of Wilder dam), to the Wilgus State Park in Weathersfield, Vermont (21 miles upstream of Bellows dam). The sites were designated to document the effectiveness of the CSO reductions in Lebanon, New Hampshire, and the elimination of the six CSOs in Hartford, Vermont, in 2007. The geometric means for the 14-mile stretch of water sampled during this study were below the bacterial water quality standard for primary contact recreation of 126 per 100 milliliters (mL), although the water quality standard was exceeded for a single sample at two locations in 2008 and at two locations in 2009 under wet conditions. For all sampling sites except one, wet weather bacterial counts were higher than dry weather counts. At three locations, 1 sample of 27 samples exceeded the New Hampshire water quality standards single sample maximum of 400 per 100 mL: East Wilder boat launch, West Lebanon, New Hampshire (520 per 100 mL); Lyman Point Park launch, Hartford, Vermont (480 per 100 mL); and Blood's Brook launch (Lebanon launch), New Hampshire (416 per 100 mL). No site reported more than one exceedance.

Water quality has also been occasionally measured at three USGS streamflow gages in the Project areas. These gages include the Connecticut River at Wells River, Vermont, (USGS gage no. 01138500), and the West Lebanon and North Walpole gages. The water quality data collected or measured at these gages include temperature (degrees Celsius [°C]), specific conductivity (microsiemens per centimeter [μS/cm]), DO (mg/L; percent saturation), pH (standard units), and various nutrient metrics (Tables 3.5-15, 3.5-16, and 3.5-17).

USGS, in cooperation with the New England Interstate Water Pollution Control Commission (NEIWPCC), also performed a study examining total nitrogen concentrations and nitrogen loading in the Upper Connecticut River basin from December 2002 through September 2005. The study estimated the mean annual load and yield of total nitrogen of the Connecticut River at Wells River, Vermont, was 4.5 million pounds/year and 1,690 (pounds/sq. mi.)/year, respectively. In addition, at North Walpole, New Hampshire, the mean annual load and yield of total nitrogen in the Connecticut River was estimated to be 9.6 million pounds/year and 1,750 (pounds/sq. mi.)/year, respectively (Deacon et al., 2006).

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Table 3.5-15. Water quality data collected or measured at the Connecticut River at Wells River, Vermont, USGS gage no. 01138500 from 2005 through 2007.

Date/Time	Discharge (cfs)	Temperature (°C)	Dissolved Oxygen (mg/L; % saturation)		Specific Conductivity (µS/cm)	pH (standard units)	Total Nitrogen (unfiltered; mg/L)	Nitrite (filtered; mg/L)	Nitrate (filtered; mg/L)	Phosphorus (mg/L)
1/4/2005 12:30 p.m.	6,450	1.8	13.2	92	86	7.0	0.39	0.005[a]	0.187[a]	0.009
2/1/2005 2.00 p.m.	2,060	0.1	13.7	94	92	6.8	0.48	< 0.008	0.261	0.036
3/2/2005 3:15 p.m.	5,930	0.7	13.4	94	77	6.7	0.48	< 0.008	0.266	0.011
3/31/2005 1:45 p.m.	4,510[a]	2.3	15.2	110	119	6.9	0.66	< 0.008	0.261	0.109
4/6/2005 1:45 p.m.	19,100	2.3	13.2	96	84	7.1	0.70	< 0.008	0.242	0.087
4/11/2005 11:45 a.m.	17,300	2.2	13.6	99	63	7.1	0.49[a]	< 0.008	0.196	0.041
4/18/2005 3:45 p.m.	11,900	5.7	11.5	94	85	7.4	0.46	< 0.008	0.203	0.032
5/4/2005 10:00 a.m.	11,200	6.5	12.2	99	58	6.9	0.34	< 0.008	0.148	0.023
6/14/2005 10:15 a.m.	2,280	16.8	9.1	94	71	6.6	0.35	< 0.008	0.112	0.013
7/6/2005 1:15 p.m.	5,090	19.0	8.9	96	90	6.9	0.39	< 0.008	0.116	0.015
7/26/20053:00 p.m.	1,640	23.0	8.4	99	112	7.5	0.36	< 0.008	0.118	0.010
8/8/20053:00 p.m.	2,850	23.2	7.7	91	84	7.2	0.39	< 0.008	0.131	0.007
10/25/2006 10:45 a.m.	10,300	10.3	9.6	86	73	7.0	0.44	< 0.002	0.167	0.015
12/14/2006 9:30 a.m.	5,080	3.6	11.9	90	76	6.8	0.39	0.001[a]	0.202[a]	0.010
2/7/2007 9:30 a.m.	4,480	0.0	---	---	---	6.6	---	0.001[a]	0.271[a]	---
3/28/2007 10:00 a.m.	12,400	---	---	---	79	7.0	0.62	< 0.002	0.344	0.038
4/19/2007 10:15 a.m.	19,900	---	---	---	70	7.0	0.59	< 0.002	0.250	0.051
5/2/2007 10:15 a.m.	17,600	---	---	---	47	6.8	0.48	0.002[a]	0.214[a]	0.026
5/16/2007 10:00 a.m.	4,020	11.0	10.7	101	57	6.6	0.43	0.001[a]	0.203[a]	0.012
6/27/2007 10:30 a.m.	1,590	19.4	7.4	80	102	7.4	0.36	0.002[a]	0.166[a]	0.013
8/1/2007 10:00 a.m.	1,340	22.2	7.4	85	107	7.4	0.39	0.002	0.189	0.006[a]
9/5/2007 9:45 a.m.	1,220	18.8	13.2	92	100	7.4	0.35	0.002[a]	0.164[a]	0.006[a]

Source: USGS (2016f)

Note: "---" indicates no data are available.

a. Value reported is estimated.

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Table 3.5-16. Water quality data collected or measured at the Connecticut River at West Lebanon, New Hampshire, USGS gage no. 01144500 from 2005 through 2007.

Date/Time	Discharge (cfs)	Temperature (°C)	Dissolved Oxygen (mg/L; % saturation)		Specific Conductivity (μS/cm)	pH (standard units)	Total Nitrogen (unfiltered; mg/L)	Nitrite (filtered; mg/L)	Nitrate (filtered; mg/L)	Phosphorus (mg/L)
4/12/2005 7:30 a.m.	23,200	3.0	14.1	105	76	7.3	0.57[a]	< 0.008	0.206	0.059
8/8/2005 8:00 a.m.	1,460	24.0	7.7	92	160	7.6	0.41	< 0.008	0.167	0.006
10/25/2006 2:00 p.m.	14,900	10.8	11.8	104	82	7.2	0.43	< 0.002	0.185	0.015
12/14/2006 11:30 a.m.	9,670	2.8	12.6	94	106	7.4	0.45	0.001[a]	0.257[a]	0.012
2/7/2007 1:00 p.m.	2,740	0.0	---	---	---	7.0	0.54	0.001[a]	0.400[a]	0.011
3/28/2007 1:15 p.m.	22,700	---	---	---	84	7.1	0.78	< 0.002	0.420	0.133
4/19/2007 2:00 p.m.	31,600	---	---	---	81	7.2	0.61	< 0.002	0.286	0.089
5/2/2007 1:00 p.m.	23,400	---	---	---	67	7.1	0.51	0.002[a]	0.252[a]	0.036
5/16/2007 12:45 p.m.	10,600	13.7	10.2	98	84	6.9	0.46	0.001[a]	0.232[a]	0.013
6/27/2007 1:30 p.m.	6,350	22.4	7.1	82	129	7.5	0.42	0.003	0.217	0.008[a]
8/1/2007 1:00 p.m.	1,380	24.8	8.3	100	134	7.6	0.38	0.002	0.188	0.009
9/5/2007 12:15 p.m.	762	22.8	---	---	145	7.2	0.38	0.003	0.198	0.006[a]

Source: USGS (2016g)

Note: "---" indicates no data are available.

a. Value reported is estimated.

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Table 3.5-17. Water quality data collected or measured at the Connecticut River at North Walpole, New Hampshire, USGS gage no. 01154500 from 2005 through 2007.

Date/Time	Discharge (cfs)	Temperature (°C)	Dissolved Oxygen (mg/L; % saturation)		Specific Conductivity (µS/cm)	pH (standard units)	Total Nitrogen (unfiltered; mg/L)	Nitrite (filtered; mg/L)	Nitrate (filtered; mg/L)	Phosphorus (mg/L)
1/5/2005 2:00 p.m.	11,400	0.1	13.4	92	112	7.1	0.39	0.005[a]	0.240[a]	0.010
1/31/2005 12:00 p.m.	10,200[a]	0.1	13.4	92	111	7.0	0.47	< 0.008	0.302	0.011
2/28/2005 11:00 a.m.	10,300	0.2	13.6	98	149	6.9	0.52	< 0.008	0.337	0.013
3/31/2005 5:30 p.m.	26,500	0.2	12.8	89	118	6.9	0.57	< 0.008	0.240	0.078
4/7/2005 2:15 p.m.	46,700	3.9	13.9	106	88	7.2	0.56	< 0.008	0.214	0.121
4/12/2005 7:00 p.m.	30,100	---	---	---	83	7.1	1.40	< 0.008	0.208	0.048
4/18/2005 8:00 a.m.	15,200	7.2	11.9	98	108	7.2	0.41	< 0.008	0.236	0.019
5/3/2005 2:30 p.m.	24,400	7.9	11.4	96	85	7.5	0.33	< 0.008	0.168	0.022
6/7/2005 5:00 p.m.	10,300	---	---	---	101	7.3	0.36	< 0.008	0.142	0.009
7/5/2005 4:00 p.m.	7,340	---	---	---	125	7.5	0.38	< 0.008	0.159	0.015
7/25/2005 11:30 a.m.	3,350	25.7	7.0	86	120	7.5	0.34	< 0.008	0.147	0.011
8/10/2005 1:30 p.m.	1,630	26.4	7.8	97	151	7.8	0.39	< 0.008	0.167	0.009
8/11/2005 3:45 p.m.	6,400	26.7	6.9	86	141	7.4	0.36	< 0.008	0.161	0.006
10/25/2006 5:15 p.m.	22,200	9.5	9.8	84	87	7.0	0.44	< 0.002	0.194	0.018
12/14/2006 3:00 p.m.	10,700	2.6	13.1	97	116	6.9	0.47	0.001[a]	0.281[a]	0.010
2/7/2007 4:30 p.m.	9,090	0.0	---	---	---	7.0	0.57	0.002[a]	0.408[a]	0.012
3/28/2007 4:30 p.m.	35,500	---	---	---	86	7.0	0.84	0.001[a]	0.371[a]	0.152
4/19/2007 5:00 p.m.	49,900	---	---	---	81	6.6	0.64	< 0.002	0.267	0.194
5/2/2007 4:30 p.m.	30,400	---	---	---	73	6.8	0.49	0.002[a]	0.262[a]	0.028
5/16/2007 4:15 p.m.	11,300	14.5	9.5	93	96	6.9	0.44	0.002[a]	0.252[a]	0.011
6/27/2007 4:30 p.m.	8,710	23.5	---	---	142	7.4	0.42	0.003	0.203	0.011
8/1/2007 4:30 p.m.	8,360	25.9	8.0	98	125	7.2	0.38	0.001[a]	0.169[a]	0.007[a]
9/5/2007 2:45 p.m.	1,390	22.3	---	---	136	7.7	0.42	0.003	0.178	0.009

Source: USGS (2016h)

Note: "---" indicates no data are available.

a. Value reported is estimated.

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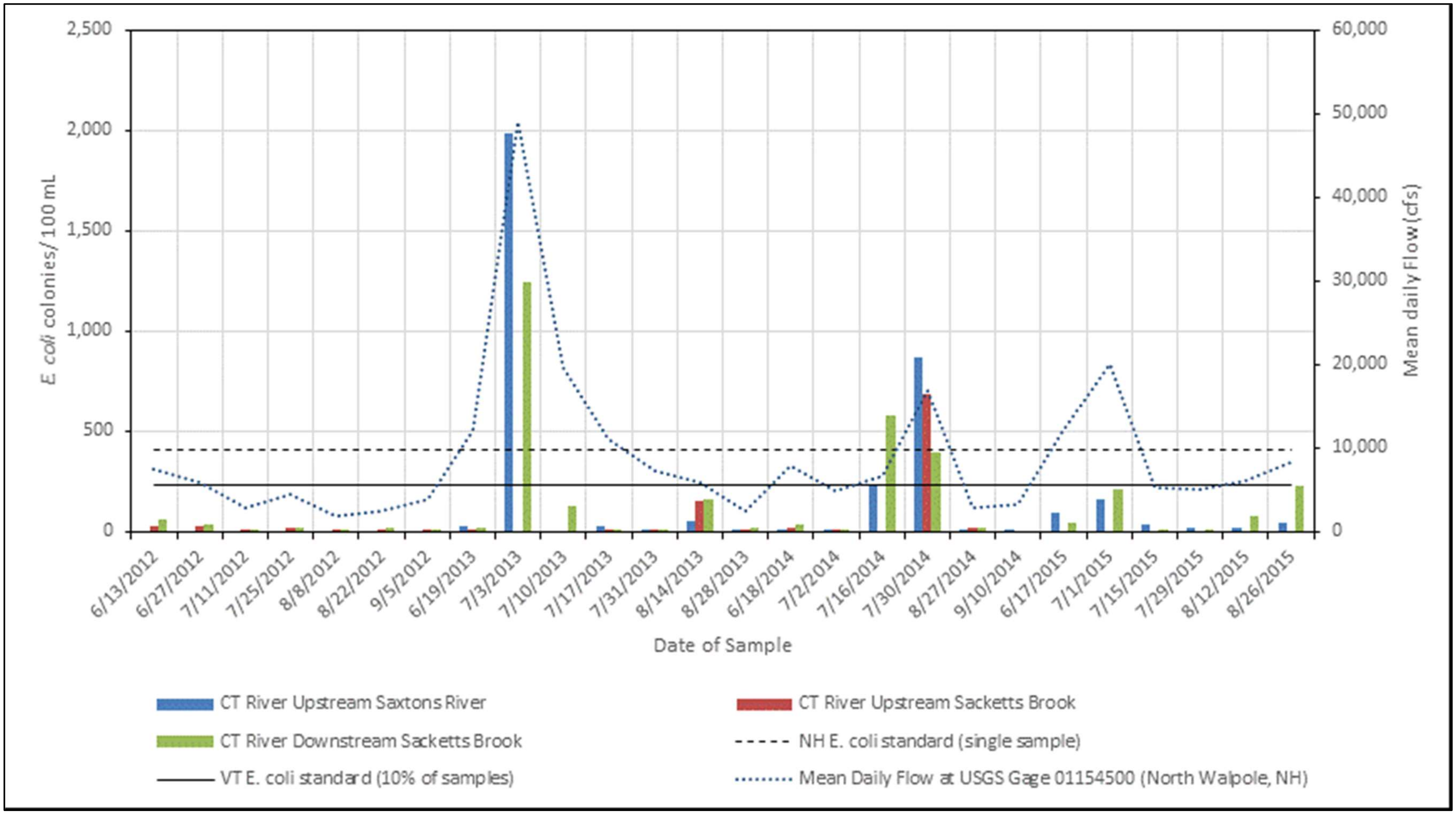
Escherichia coli

The Connecticut River Watershed Council in cooperation with the Pioneer Valley Planning Commission conducts volunteer bacteria monitoring throughout the Connecticut River basin (Connecticut River Watershed Council and Pioneer Valley Planning Commission, 2016). Throughout the Wilder, Bellows Falls, and Vernon Project areas, Connecticut River Watershed Council and its volunteers collected water samples from only the Vernon Project area for bacteria analyses. Water samples were collected upstream and downstream of the Sacketts Brook confluence in Putney, Vermont, and upstream of the Saxtons River confluence. Figure 3.5-22 presents the results of the analyses for 2012 through 2015. Water samples for bacteria analysis were also collected from several main tributaries, including the White, Ottauquechee, Black, Williams, Saxtons, and West Rivers.

Water Quality Studies

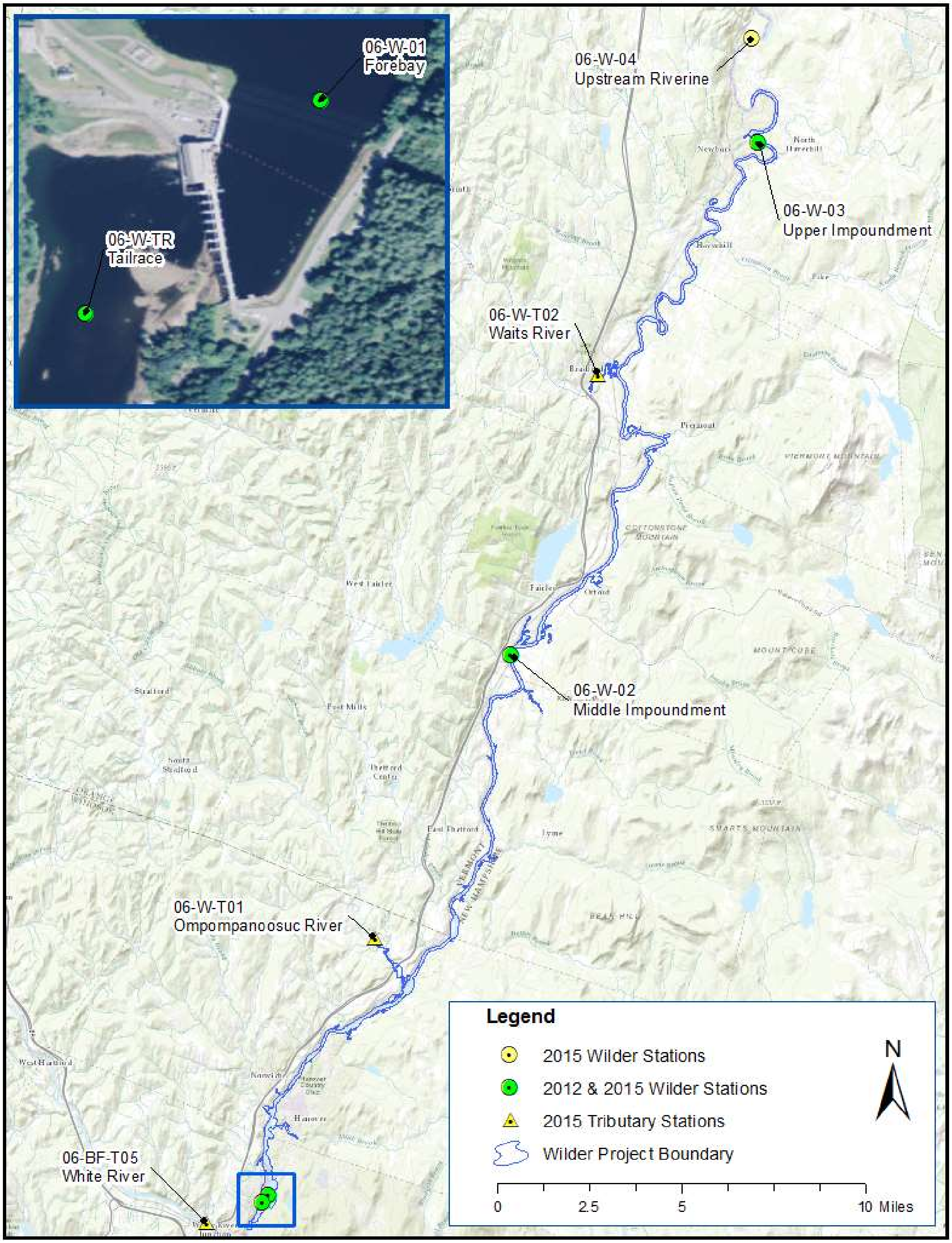
In 2012 and 2015, two baseline water quality studies were conducted in support of the Wilder, Bellows Falls, and Vernon Project relicensing proceedings (Normandeau, 2013a; ILP Study 6, *Water Quality Monitoring and Continuous Temperature Monitoring;* Louis Berger and Normandeau, 2016a). Water quality data collected during the 2012 Baseline Water Quality Study were collected during the summer of 2012 and are representative of conditions during a low-flow, warm-weather period. Measured parameters during the 2012 study consisted of temperature (°C), DO (mg/L, percent saturation), specific conductivity (µS/cm), pH (standard units), nutrients, and chlorophyll-*a*. Data were collected at various locations throughout the Project areas and included stations in the upper impoundments, middle impoundments, forebays, tailraces, and the Bellows Falls bypassed reach (Figure 3.5-23 through Figure 3.5-25). Temperature, DO, specific conductivity, and pH were continuously measured in each Project forebay and tailrace, as well as the Bellows Falls bypassed reach. Vertical profiles were collected at all impoundment stations. Nutrients and chlorophyll-*a* were only collected at each Project forebay from water column composite samples.

As a part of the ILP, additional water quality monitoring (Study 6) was conducted during spring, summer, and fall 2015 using similar methods as the 2012 study, but with the following additions: (1) turbidity monitoring, (2) continuous recording of water temperature at all stations, (3) addition of a riverine station upriver of the upper extent of each Project's impoundment, (4) continuous water temperature monitoring in the 10 largest tributaries, and (5) all water quality parameters were continuously recorded, except for nutrient and chlorophyll-*a*, over a 10-day, low-flow period during the summer (Figure 3.5-23 through Figure 3.5-25). The 2015 study, conducted between April 1 and November 15, was performed under representative flow and weather conditions. Grab samples of water quality parameters, such as temperature, DO, pH, turbidity, and specific conductivity, were also collected at specific study sites in most fisheries studies. Results of those sampling events are included in applicable study reports (i.e., Studies 10 through 16 and Study 21).



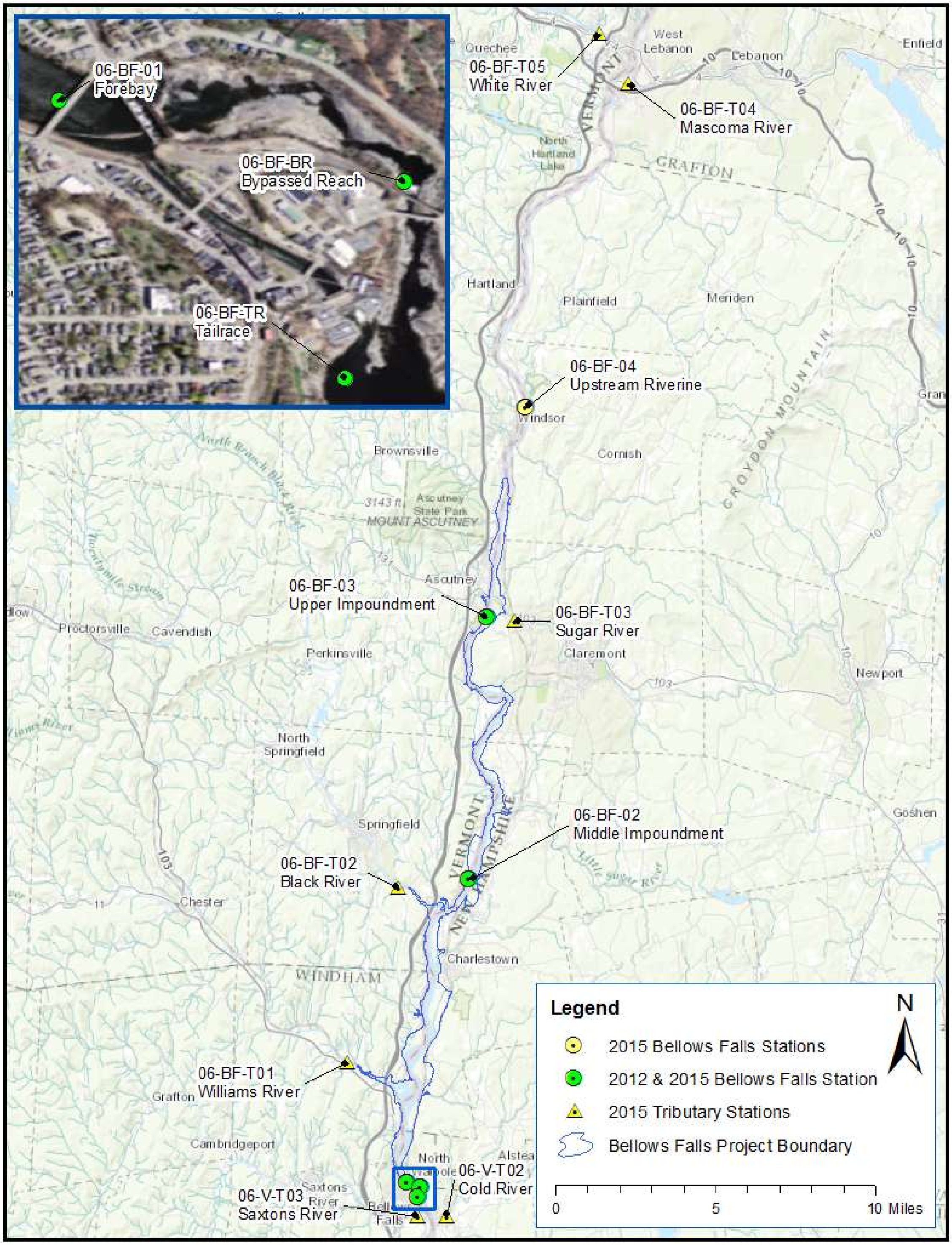
Source: Connecticut River Watershed Council and Pioneer Valley Planning Commission (2016, as modified by Great River Hydro)

Figure 3.5-22. *E. coli* colony bacteria counts in the Vernon Project area.



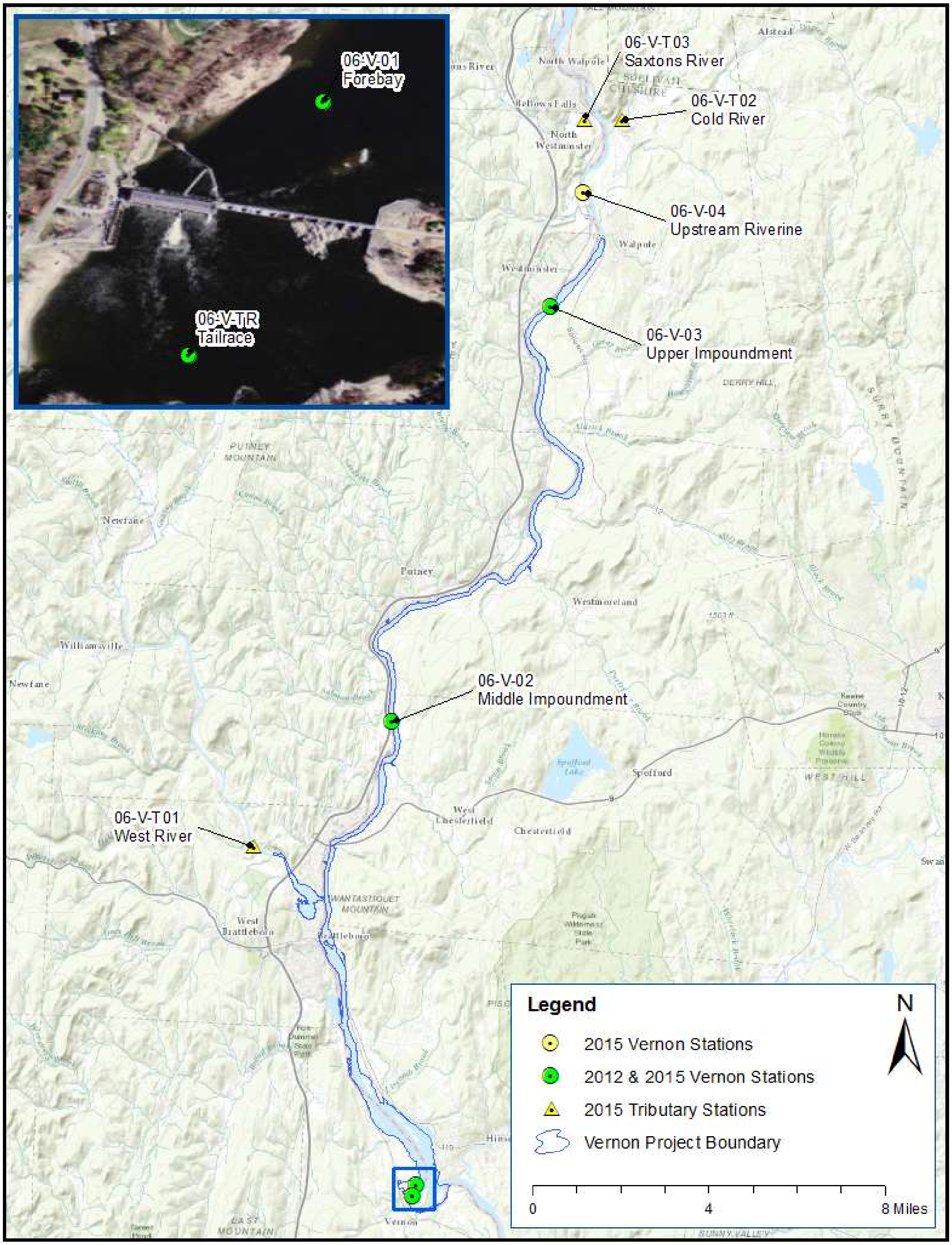
Source: modified from ILP Study 6, *Water Quality Monitoring and Continuous Temperature Monitoring Study* (Louis Berger and Normandeau, 2016a)

Figure 3.5-23. 2012 and 2015 Wilder water quality monitoring stations.



Source: modified from ILP Study 6, *Water Quality Monitoring and Continuous Temperature Monitoring Study* (Louis Berger and Normandeau, 2016a)

Figure 3.5-24. 2012 and 2015 Bellows Falls water quality monitoring stations.



Source: modified from ILP Study 6, *Water Quality Monitoring and Continuous Temperature Monitoring Study* (Louis Berger and Normandeau, 2016a)

Figure 3.5-25. 2012 and 2015 Vernon water quality monitoring stations.

Wilder Project

Temperature and Dissolved Oxygen

Continuous water temperature and DO data were recorded at the Wilder forebay and tailrace, and vertical profiles of water temperature and DO were collected at all Wilder impoundment stations in 2012 from June through September (Normandeau, 2013a). Overall, water temperatures gradually warmed, peaked in early August, and then began to cool. Over the study period, temperatures ranged from 17.3°C (upper impoundment) to 26.5°C (forebay) (Table 3.5-18). DO concentrations (continuous measurements and vertical profiles) in the forebay and tailrace ranged from 5.7 to 9.7 mg/L and 6.5 to 9.3 mg/L, respectively (Table 3.5-18). The low DO level of 5.7 mg/L, which corresponds to 69 percent saturation, occurred during a period of weak stratification in the water column.

In 2015, water temperature, measured continuously throughout the Wilder study area, exhibited seasonal warming and cooling. As the weather warmed in the spring, water temperatures increased rapidly, followed by a steady increase through the summer until late-summer when water temperatures reached their maximum and began to gradually decrease through the fall (Figure 3.5-26). Throughout the Wilder Project area, continuous water temperature readings ranged from 6.4 to 25.8°C. The coolest temperatures were observed at the upper impoundment and upstream riverine stations during the spring and fall, and the warmest temperatures were observed at the middle impoundment and forebay stations in late-August, suggesting a gradual warming over the 46-river mile study area from the upstream riverine area to the Project dam and tailrace (Table 3.5-19). Diel temperature fluctuations occurred at all stations but were more prominent at the shallower upstream and upper impoundment areas than the deeper lower impoundment area and the tailrace where water temperatures were similar between the stations and diel fluctuation were attenuated. The 2015 seasonal trend in the DO concentrations and saturation levels over the study period was as follows (Figure 3.5-27 and Figure 3.5-28): DO levels were relatively high in June, then decreased through the summer because of lower oxygen solubility at higher water temperatures. DO reached its lowest level in mid-September of 6.6 mg/L (78 percent saturation) in the Wilder forebay subsequently increasing with falling water temperatures in early fall. Overall, DO concentrations measured continuously in the Wilder forebay ranged between 6.6 and 10.2 mg/L and percent saturation ranged between 78 and 111 percent. The DO concentrations continuously monitored in the Wilder tailrace ranged from 6.9 to 9.8 mg/L and 81 to 106 percent saturation (Tables 3.5-20 and 3.5-21).

Vertical profiles of water temperature and DO measured at all mainstem Wilder stations indicate that the water column was generally thermally uniform with some surface warming during the summer and was well oxygenated throughout the study period (see Study 6, Appendix H). DO levels based on instantaneous vertical profile measurements ranged from 7.2 mg/L (forebay) to 10.4 mg/L (upper impoundment), and 82 (forebay) to 102 (upper impoundment) percent saturation (Table 3.5-22).

Table 3.5-18. Water temperature, dissolved oxygen, specific conductivity, and pH statistics for the Wilder Project in 2012.

Statistic	Station				
	Upper Impound. 06-W-03 (profile)	Middle Impound. 06-W-02 (profile)	Forebay 06-W-01 (profile)	Forebay 06-W-01 (cont.)	Tailrace 06-W-TR (cont.)
Water Temperature (°C)					
Maximum	22.6	24.1	26.0	26.5	25.4
Minimum	17.3	19.8	19.8	21.1	19.2
Median	20.7	21.8	22.8	24.1	23.6
Mean	20.3	21.9	22.7	24.0	23.2
Dissolved Oxygen (mg/L)					
Maximum	9.1	8.8	9.0	9.7	9.3
Minimum	7.9	7.4	6.0	5.7	6.5
Median	8.7	7.9	7.8	7.6	7.3
Mean	8.5	8.1	7.7	7.6	7.5
Dissolved Oxygen (% saturation)					
Maximum	103	102	108	119	110
Minimum	89	85	71	69	76
Median	94	91	89	91	87
Mean	94	92	90	92	89
Minimum 24-hour mean	---	---	---	78	79
Specific Conductivity (µS/cm)					
Maximum	106	141	137	132	134
Minimum	88	81	85	88	80
Median	93	95	103	109	109
Mean	94	100	108	110	109
pH (standard units)[a]					
Maximum	7.7	7.6	7.5	7.8	7.7
Minimum	5.72	6.37	6.6	7.0	7.1
Median	7.0	7.2	7.2	7.2	7.3
Mean	6.9	7.2	7.2	7.2	7.3

Source: TransCanada (2012a)

Note: "---" indicates no data are available.

a. Values with two digits after the decimal point are those that exceeded state standard(s).

Intensive continuous water temperature and continuous DO monitoring occurred at all Wilder impoundment and upstream riverine stations during a 10-day, high-temperature, low-flow monitoring event (Study 6). During this intensive sampling event, temperature was continuously recorded at three different locations across the river channel at each station (referred to as river left, mid-channel, and river right) and at up to three different depths.[31] Table 3.5-23 presents statistics for each station and deployment depth. Mean temperatures among all stations and deployment depths ranged between 22.1°C at the upstream riverine station and 24.0°C at the Wilder forebay station. Mean temperatures at river left, mid-channel, and river right locations at both upstream and upper impoundment stations were similar. At the middle impoundment, station temperatures were similar among deployment depths (1.0 meter below the water surface, mid-depth, and 1.0 meter above river bottom) and among the river left, mid-channel, and river right locations; mean bottom temperatures were 0.4°C cooler than those on the surface. The Wilder forebay station showed the greatest temperature difference of 0.9 to 1.0°C between surface and bottom temperatures where depths ranged from 6.9 meters at river left to 13.0 meters at river right. Mean DO levels were higher at the upstream and upper impoundment stations than at the middle and forebay stations (Table 3.5-24). Mean DO concentrations at the upstream and upper impoundment stations were both 8.4 mg/L, and percent DO saturation levels were 96 and 97 percent, respectively. The minimum daily mean ranged from 94 to 95 percent DO saturation. Mean DO concentrations at the middle impoundment and forebay stations were slightly lower, ranging from 7.9 to 8.1 mg/L. Mean percent DO saturation levels were 93 percent and 94 percent, and minimum daily mean percent DO saturation levels ranged between 87 to 98 percent at the forebay station, and 92 to 96 percent at the middle impoundment station.

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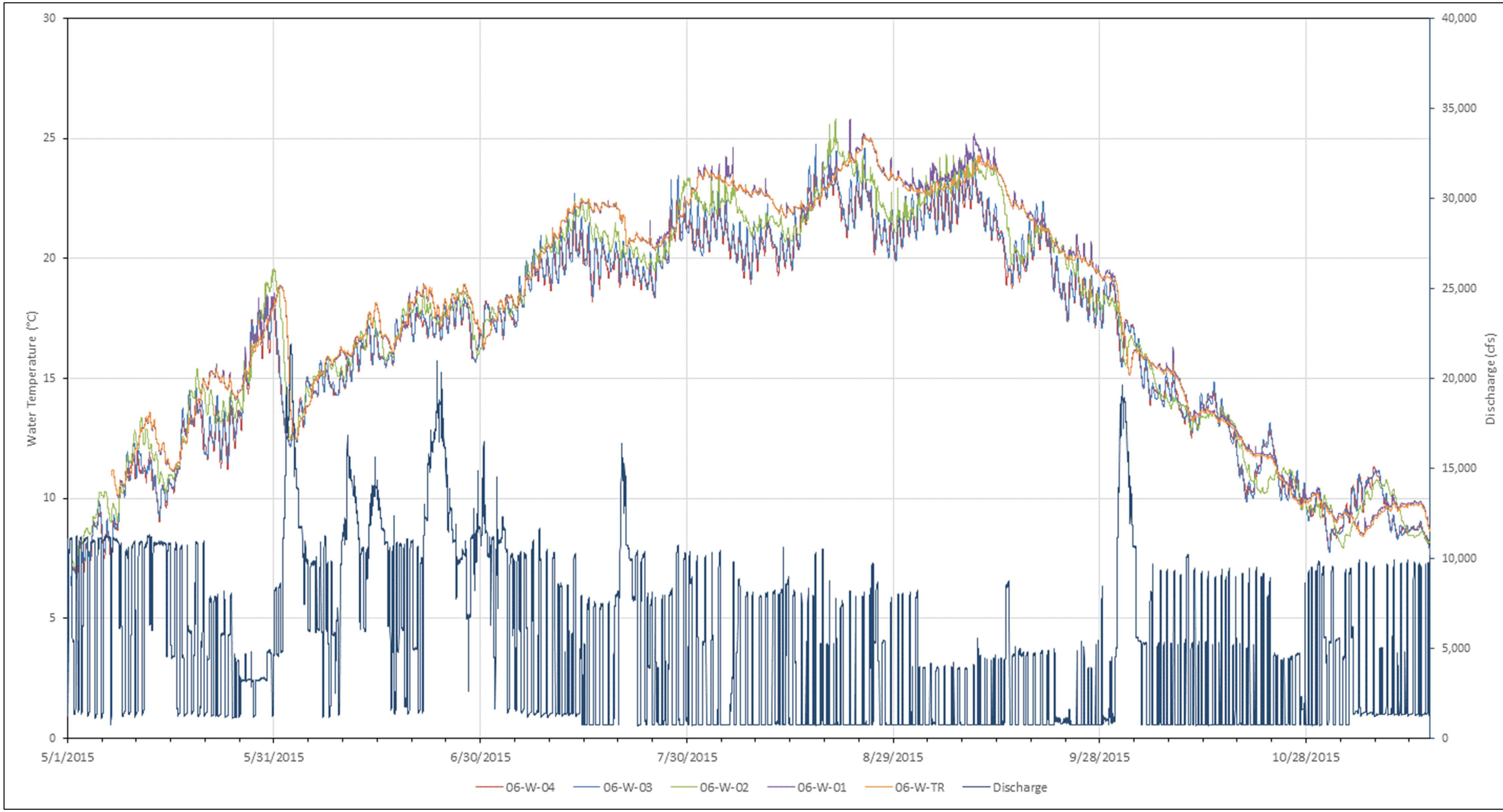
[31] River left and river right are the left-hand or right-hand sides of the river, respectively, as viewed facing downstream.



Source: ILP Study 6, *Water Quality Monitoring and Continuous Temperature Monitoring Study* (Louis Berger and Normandeau, 2016a)

Figure 3.5-26. Wilder continuous water temperatures observed during spring, summer, and fall 2015 with Wilder discharge.

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Table 3.5-19. Monthly water temperatures for Wilder Project in 2015.

Temperature (°C)	May	Jun	Jul	Aug	Sep	Oct	Nov	All
Upstream Riverine (06-W-04)								
Maximum	18.3	18.4	22.9	24.1	23.9	17.5	11.3	24.1
Minimum	6.6	12.2	16.6	18.9	15.9	7.8	6.8	6.6
Median	11.5	16.3	19.7	21.3	20.7	12.9	8.8	17.3
Mean	11.8	16.0	19.6	21.4	20.5	12.6	9.2	16.4
Upper Impoundment (06-W-03)								
Maximum	18.5	18.4	23.5	25.1	24.4	17.3	11.2	25.1
Minimum	6.4	12.1	16.8	19.1	16.3	7.8	6.6	6.4
Median	11.7	16.3	19.8	21.4	20.8	13.0	8.9	17.3
Mean	12.0	16.0	19.7	21.5	20.6	12.6	9.2	16.5
Middle Impoundment (06-W-02)								
Maximum	19.6	18.8	23.4	25.8	24.6	17.5	10.8	25.8
Minimum	7.1	12.4	17.4	20.7	17.2	9.1	7.6	7.1
Median	12.5	16.7	20.4	22.1	21.2	13.1	8.9	17.8
Mean	12.7	16.4	20.4	22.4	21.2	12.6	9.2	16.9
Forebay (06-W-01)								
Maximum	18.9	19.0	23.8	25.8	25.2	17.7	10.2	25.8
Minimum	10.1	12.4	16.8	21.7	17.7	9.2	7.9	7.9
Median	14.1	16.8	20.9	23.2	22.2	13.3	9.4	18.2
Mean	13.9	16.7	20.7	23.2	22.0	13.0	9.3	17.7
Tailrace (06-W-TR)								
Maximum	18.8	19.0	23.5	25.1	24.3	17.7	9.8	25.1
Minimum	10.1	12.5	16.8	21.7	17.7	9.1	7.9	7.9
Median	14.0	16.9	20.9	23.1	22.2	13.2	9.3	18.2
Mean	13.8	16.8	20.8	23.1	21.8	12.9	9.2	17.6

Source: ILP Study 6, *Water Quality Monitoring and Continuous Temperature Monitoring Study* (Louis Berger and Normandeau, 2016a)

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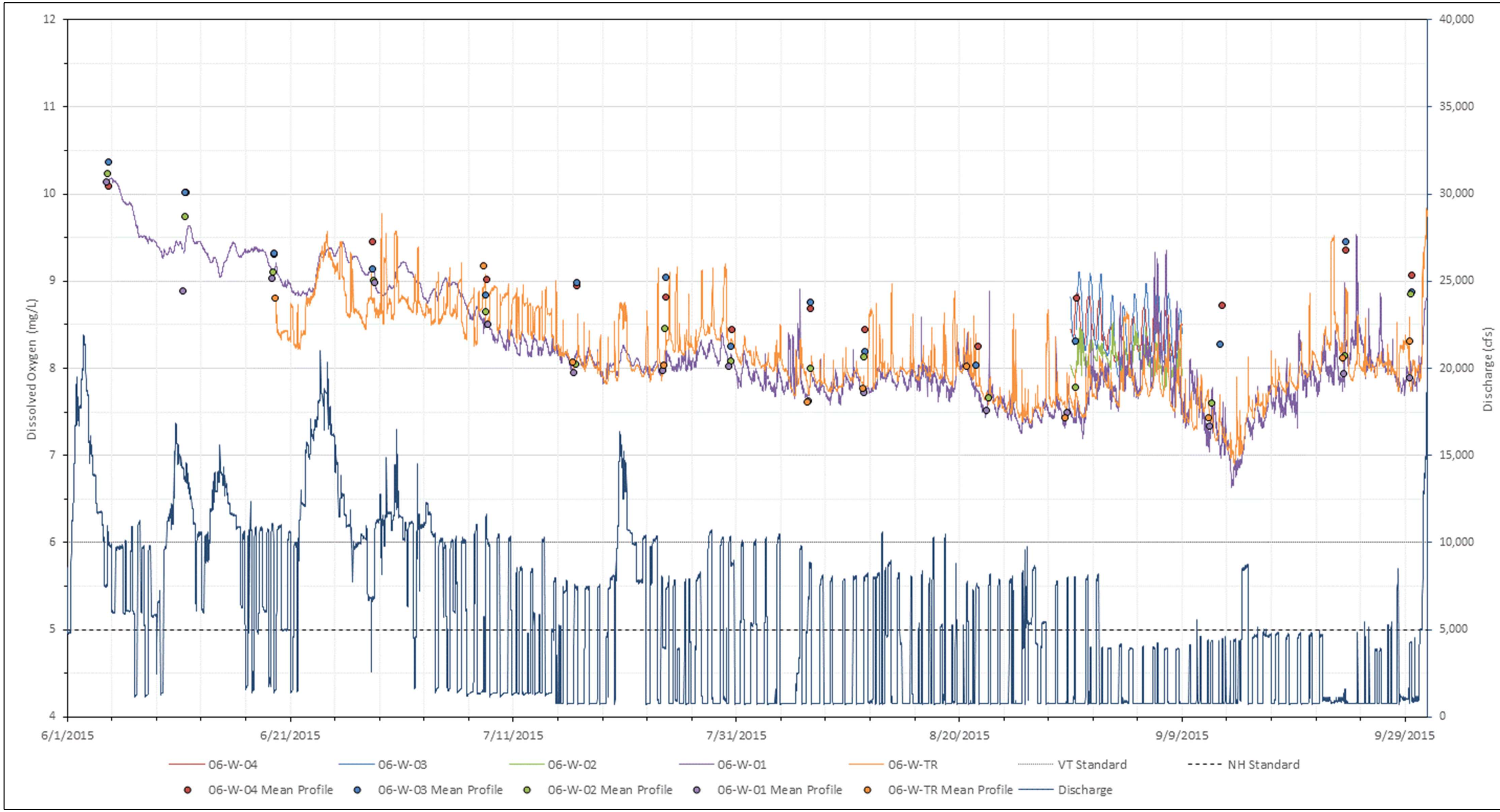

Source: ILP Study 6, *Water Quality Monitoring and Continuous Temperature Monitoring Study* (Louis Berger and Normandeau, 2016a)

Figure 3.5-27. 2015 DO concentrations continuously measured in the Wilder forebay and tailrace, and at all stations during a 10-day, high-temperature, low-flow period with Wilder discharge.

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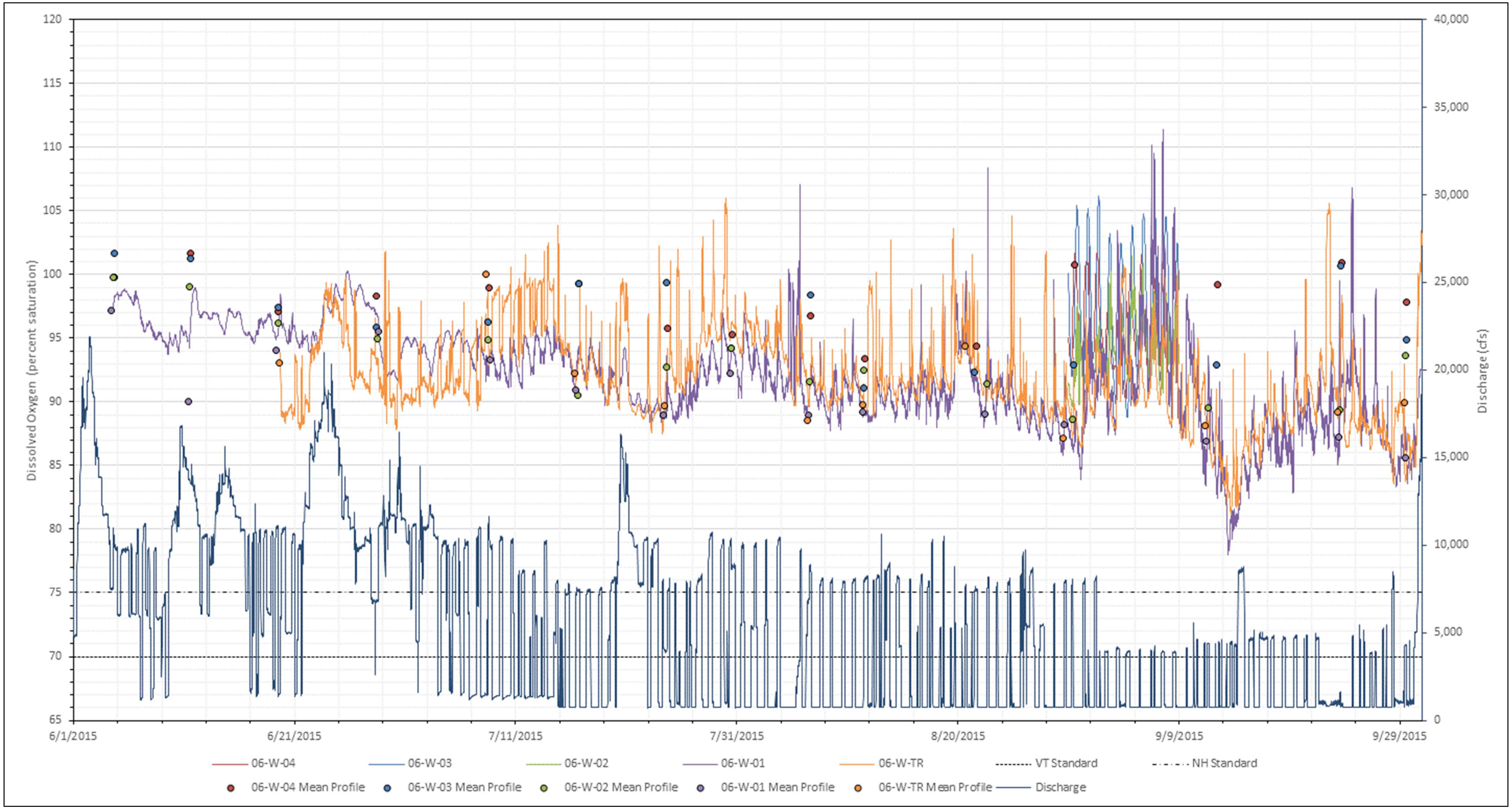

Source: ILP Study 6, *Water Quality Monitoring and Continuous Temperature Monitoring Study* (Louis Berger and Normandeau, 2016a)

Figure 3.5-28. 2015 DO percent saturation continuously measured in the Wilder forebay and tailrace, and at all stations during a 10-day, high-temperature, low-flow period with Wilder discharge.

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Table 3.5-20. Monthly statistics for continuously monitored temperature, specific conductivity, dissolved oxygen, pH, and turbidity in the Wilder forebay in 2015.

Statistic	Jun	Jul	Aug	Sep	All
Temperature (°C)					
Maximum	19.0	23.8	25.8	25.2	25.8
Minimum	13.4	16.8	21.7	17.7	13.4
Median	17.0	20.9	23.2	22.2	21.7
Mean	17.0	20.7	23.2	22.0	20.9
Specific Conductivity (µS/cm)					
Maximum	107	142	142	163	163
Minimum	69	83	105	115	69
Median	78	104	118	134	114
Mean	81	104	120	136	111
Dissolved Oxygen (mg/L)					
Maximum	10.2	9.2	8.9	9.5	10.2
Minimum	8.8	7.8	7.2	6.6	6.6
Median	9.3	8.2	7.8	7.9	8.1
Mean	9.3	8.3	7.8	7.8	8.3
Dissolved Oxygen (% saturation)					
Maximum	100	97	108	111	111
Minimum	92	88	84	78	78
Median	96	93	91	89	92
Mean	96	93	91	90	92
Maximum daily mean	100	95	96	98	100
Min daily mean	92	89	87	81	81
pH (standard units)[a]					
Maximum	7.5	7.6	7.8	8.02	8.02
Minimum	7.3	7.3	7.2	7.4	7.2
Median	7.4	7.4	7.4	7.5	7.4
Mean	7.4	7.4	7.4	7.5	7.4
Turbidity (NTU)					
Maximum	28.3	25.3	7.6	12.1	28.3
Minimum	0.0	0.7	0.3	0.0	0.0
Median	1.9	1.4	0.7	0.6	0.9
Mean	3.4	3.0	0.9	0.6	1.9

Source: ILP Study 6, *Water Quality Monitoring and Continuous Temperature Monitoring Study* (Louis Berger and Normandeau, 2016a)

a. Values with two digits after the decimal point are those that exceeded state standard(s).

Table 3.5-21. Monthly statistics for continuously monitored temperature, specific conductivity, dissolved oxygen, pH, and turbidity collected in the Wilder tailrace in 2015.

Statistic	Jun	Jul	Aug	Sep	All
Temperature (°C)					
Maximum	19.0	23.5	25.1	24.3	25.1
Minimum	16.3	16.8	21.7	17.7	16.3
Median	18.3	20.9	23.1	22.2	22.1
Mean	18.1	20.8	23.1	21.8	21.5
Specific Conductivity (µS/cm)					
Maximum	102	145	145	161	161
Minimum	70	82	105	117	70
Median	84	106	117	131	116
Mean	83	105	119	133	115
Dissolved Oxygen (mg/L)					
Maximum	9.8	9.4	9.0	9.8	9.8
Minimum	8.2	7.8	7.4	6.9	6.9
Median	8.7	8.4	7.9	7.9	8.0
Mean	8.8	8.4	7.9	7.9	8.1
Dissolved Oxygen (% saturation)					
Maximum	102	106	105	106	106
Minimum	88	88	86	81	81
Median	92	94	91	89	91
Mean	93	94	92	90	92
Maximum daily mean	98	98	96	97	98
Minimum daily mean	89	90	89	84	84
pH (standard units)					
Maximum	7.5	7.6	7.6	7.7	7.7
Minimum	7.2	7.2	7.3	7.3	7.2
Median	7.4	7.4	7.4	7.4	7.4
Mean	7.4	7.4	7.4	7.4	7.4
Turbidity (NTU)					
Maximum	64.0	23.8	8.3	14.8	64.0
Minimum	0.3	0.3	0.8	0.1	0.1
Median	3.6	1.6	1.4	1.2	1.3
Mean	7.8	2.8	1.6	1.3	2.5

Source: ILP Study 6, *Water Quality Monitoring and Continuous Temperature Monitoring Study* (Louis Berger and Normandeau, 2016a)

Table 3.5-22. Vertical profile statistics for temperature, dissolved oxygen, specific conductivity, pH, and turbidity for Wilder Project in 2015.

Statistic	Upstream Riverine 06-W-04	Upper Impound. 06-W-03	Middle Impound. 06-W-02	Forebay 06-W-01	Tailrace 06-W-TR
Mean water depth (meters)[a]	0.8	2.2	7.2	10.6	8.6
Temperature (°C)					
Maximum	22.1	22.2	25.7	24.7	23.8
Minimum	14.9	14.5	14.2	13.4	18.0
Median	20.1	19.9	20.9	20.7	22.5
Mean	19.2	19.2	20.3	20.4	21.9
Dissolved Oxygen (mg/L)					
Maximum	10.1	10.4	10.3	10.2	9.2
Minimum	8.3	8.0	7.5	7.2	7.4
Median	8.9	8.9	8.1	8.0	8.0
Mean	9.0	8.9	8.5	8.2	7.9
Dissolved Oxygen (% saturation)					
Maximum	102	102	100	101	100
Minimum	93	91	88	82	86
Median	98	96	93	90	89
Mean	98	97	93	91	90
Specific Conductivity (µS/cm)					
Maximum	121	121	126	139	138
Minimum	62	63	68	74	94
Median	96	95	106	111	130
Mean	96	93	104	109	123
pH (standard units)					
Maximum	7.6	7.5	7.5	7.5	7.5
Minimum	7.2	7.2	7.3	7.3	7.3
Median	7.4	7.3	7.4	7.4	7.4
Mean	7.4	7.4	7.5	7.4	7.4
Turbidity (NTU)					
Maximum	2.7	2.9	5.0	59.3	2.7
Minimum	0.0	0.0	0.0	0.0	0.1
Median	0.9	0.7	0.5	1.2	1.2
Mean	1.0	0.8	0.9	3.1	1.3

Source: ILP Study 6, *Water Quality Monitoring and Continuous Temperature Monitoring Study* (Louis Berger and Normandeau, 2016a)

a. Average of individual depths recorded during each station visit.

Table 3.5-23. Water temperatures for Wilder Project during 10-day, high-temperature, low-flow monitoring period in 2015.

Logger Location	Statistic	Temperature (°C)		
		River Left	Mid-channel	River Right
Upstream Riverine (06-W-04)				
Mid-depth	Maximum	24.8	24.3	23.6
	Minimum	20.3	20.3	20.4
	Mean	22.3	22.3	22.1
Depth to bottom (at first deployment, meters)		0.2	0.3	1.0
Upper Impoundment (06-W-03)				
Mid-depth	Maximum	24.2	24.2	24.2
	Minimum	20.8	20.8	20.7
	Mean	22.4	22.4	22.4
Depth to bottom (at first deployment, meters)		1.5	1.8	2.7
Middle Impoundment (06-W-02)				
1m below surface	Maximum	25.0	24.6	24.9
	Minimum	21.7	21.7	21.8
	Mean	23.1	23.0	23.2
Mid-depth	Maximum	NA	23.6	24.1
	Minimum		21.6	21.7
	Mean		22.7	22.8
1m above bottom	Maximum	23.9	23.4	23.6
	Minimum	21.7	21.6	21.7
	Mean	22.7	22.6	22.8
Depth to bottom (at first deployment, meters)		3.9	6.3	6.2
Forebay (06-W-01)				
1m below surface	Maximum	26.5	26.2	26.3
	Minimum	22.9	22.9	22.9
	Mean	24.0	23.9	23.9
Mid-depth	Maximum	24.4	24.2	23.8
	Minimum	22.7	22.7	22.7
	Mean	23.3	23.2	23.1
1m above bottom	Maximum	23.9	23.5	23.5
	Minimum	22.7	22.7	22.7
	Mean	23.0	23.0	23.0
Depth to bottom (at first deployment, meters)		6.9	10.1	13

Source: ILP Study 6, *Water Quality Monitoring and Continuous Temperature Monitoring Study* (Louis Berger and Normandeau, 2016a)

Note: NA – no logger was deployed because of shallow water depths.

Table 3.5-24. Statistics of temperature, specific conductivity, dissolved oxygen, pH, and turbidity for the Wilder Project during 10-day, high-temperature, low-flow monitoring period in 2015.

Statistic	Station			
	Upstream Riverine 06-W-04	Upper Impound. 06-W-03	Middle Impound. 06-W-02	Forebay 06-W-01
Temperature (°C)				
Maximum	23.6	23.9	24.3	24.8
Minimum	20.4	20.5	21.6	22.6
Median	22.1	22.1	22.8	23.3
Mean	22.1	22.1	22.8	23.4
Specific Conductivity (µS/cm)				
Maximum	120	125	164	151
Minimum	96	101	119	112
Median	112	114	131	132
Mean	111	115	133	133
Dissolved Oxygen (mg/L)				
Maximum	8.9	9.1	8.5	9.4
Minimum	8.0	7.9	7.8	7.2
Median	8.4	8.4	8.1	7.9
Mean	8.4	8.4	8.1	7.9
Dissolved Oxygen (% saturation)				
Maximum	103	106	102	111
Minimum	90	89	90	84
Median	96	96	94	93
Mean	96	97	94	93
Maximum daily mean	99	99	96	98
Minimum daily mean	94	95	92	87
pH (standard units)[a]				
Maximum	7.7	7.7	7.5	8.02
Minimum	7.4	7.3	7.1	7.4
Median	7.5	7.5	7.3	7.6
Mean	7.5	7.5	7.3	7.6
Turbidity (NTU)				
Maximum	3.9	4.2	2.5	1.2
Minimum	1.4	0.7	0.3	0.1
Median	1.8	1.1	0.7	0.6
Mean	1.7	1.0	0.6	0.5

Source: ILP Study 6, *Water Quality Monitoring and Continuous Temperature Monitoring Study* (Louis Berger and Normandeau, 2016a)

a. Values with two digits after the decimal point are those that exceeded state standard(s).

Specific Conductivity

Specific conductivity data collected in 2012 ranged from 80-141 µS/cm (Table 3.5-18), whereas 2015 data showed a wider range of 62-163 µS/cm (Tables 3.5-20, 3.5-21, and 3.5-22). During both studies, specific conductivity was observed to generally increase from upstream areas through the impoundment to the forebay and tailrace, where specific conductivities were generally similar between the two stations. Seasonally, specific conductivity was variable throughout both studies, and was generally lower in late spring and early summer and higher in mid to late summer. No vertical stratification of specific conductivity was observed in either 2012 or 2015, and there was no daily trend in specific conductivity among all stations during the 10-day, high-temperature, low-flow monitoring period in 2015 (Normandeau, 2013a; Study 6).

pH

In 2012, pH was continuously measured in the Wilder forebay and tailrace from June through September and instantaneously measured through the water column during the collection of vertical profiles at the upper impoundment, middle impoundment, and forebay stations. In 2012, pH levels in the Wilder forebay and tailrace ranged between 6.6 and 7.8, and pH through the remainder of the impoundment ranged from 5.7 to 7.7 (Table 3.5-18). Instances when pH levels fell below the lower state surface water quality standard occurred on June 26, 2012, and July 10, 2012. On June 26, 2012, vertical profile pH measurements that exceeded the lower limit were 6.4 at the middle impoundment station and 5.7 to 6.1 at the upper impoundment station. On July 10, 2012, pH ranged from 5.8 to 6.0 at the Wilder upper impoundment station (Normandeau, 2013a; Study 6).

In 2015, pH was also continuously measured in the Wilder forebay and tailrace, and instantaneously measured during the collection of vertical profiles at all impoundment stations and the upstream riverine station. In the Wilder forebay, pH levels ranged from 7.2 to 7.8 from June through August, and the same mean monthly pH level of 7.4, was measured for June, July, and August (Table 3.5-20). In September, the mean pH value increased slightly to 7.5, and the highest pH value of 8.02 was recorded at the forebay station, exceeding the New Hampshire pH standard by 0.02 standard units. In the Wilder tailrace, pH ranged from 7.2 to 7.7 with minor fluctuations, and it did not rise above or fall below the Vermont or New Hampshire surface water quality standards (Table 3.5-21). Vertical profiles indicate that pH throughout the water column was uniform at all Wilder monitoring stations and ranged from 7.2 to 7.6 (Table 3.5-22). During the 10-day, high-temperature, low-flow monitoring period pH was continuously monitored at all mainstem Wilder stations, and exhibited strong diurnal fluctuations at the upstream and upper impoundment stations, but the fluctuations attenuated at the middle impoundment station and forebay and were absent in the tailrace (see Study 6, Appendix J). The lowest pH recorded during the 10-day, high-temperature, low-flow monitoring period was 7.1 at the middle impoundment station and the highest pH recorded was 8.02 at the forebay station, as described above (Table 3.5-24). At no point during the 2015 study was pH observed to exceed the Vermont surface water quality standard.

Turbidity

Turbidity was monitored on a continuous basis from June through September 2015 at the Wilder forebay and tailrace stations (Study 6). Turbidity at the forebay and tailrace stations was generally very low but increased in response to precipitation events that often resulted in spill at the Project dam (Figure 3.5-29). Turbidity at the forebay station ranged from 0.0 to 28.3 nephelometric turbidity units (NTU) with an overall median and mean of 0.9 and 1.9 NTU, respectively (Table 3.5-20). Turbidity at the tailrace station ranged from 0.1 NTU to 64.0 NTU with an overall median and mean of 1.3 and 2.5 NTU, respectively (Table 3.5-21). Vertical profiles of turbidity also depicted a range of values that reflect weather conditions, but overall mean and median turbidity values throughout the Project area ranged from 0.8 to 3.1 NTU and 0.5 to 1.2 NTU, respectively (Table 3.5-22). During low-flow conditions, turbidity was very low in upstream areas and throughout the Wilder impoundment, and generally decreased downstream. Median turbidity values recorded during this period ranged from 1.8 NTU at the upstream riverine station to 0.6 NTU at the forebay with a maximum of 4.2 NTU recorded at the upper impoundment station (Table 3.5-24).

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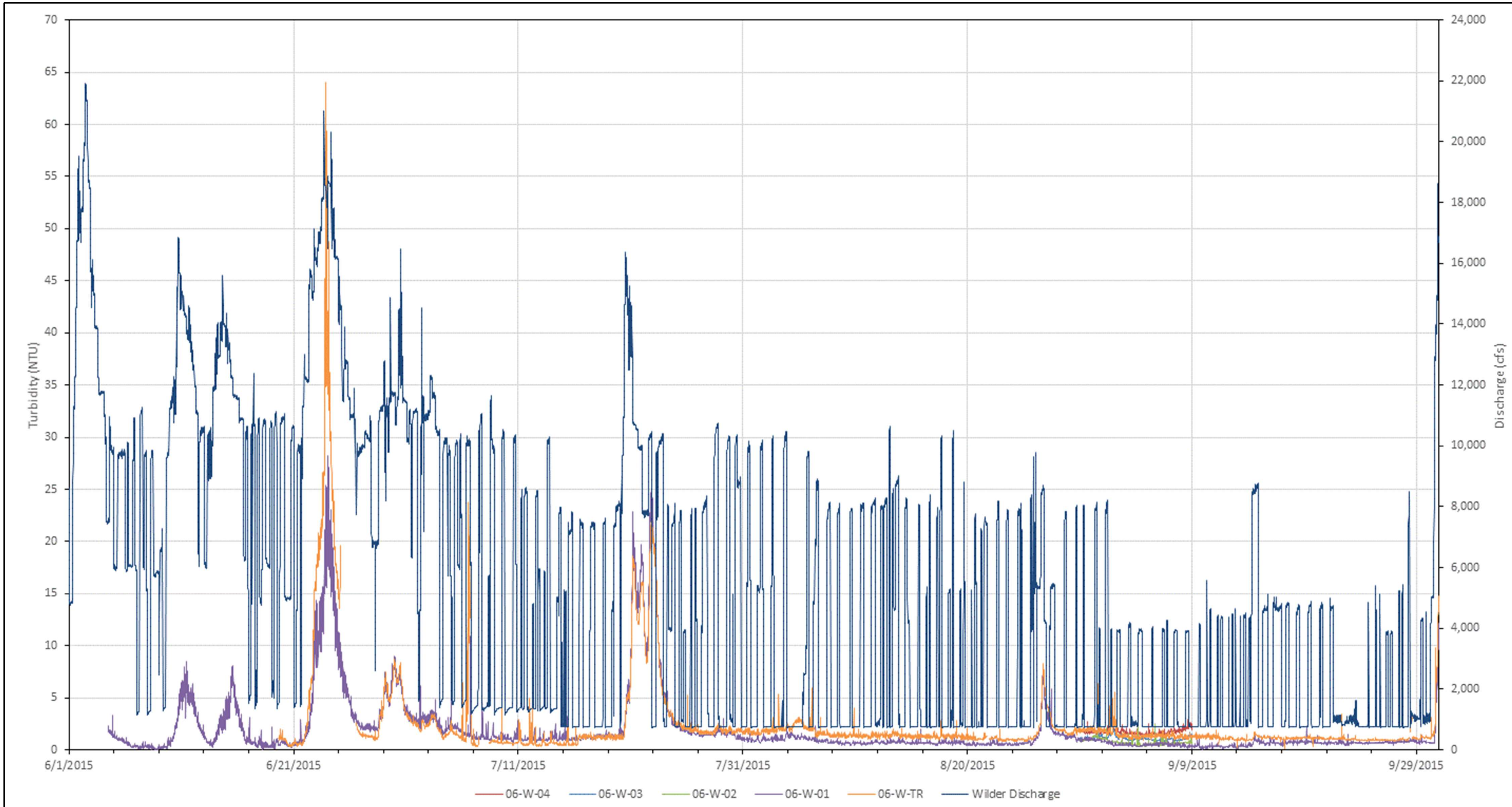

Source: ILP Study 6, *Water Quality Monitoring and Continuous Temperature Monitoring Study* (Louis Berger and Normandeau, 2016a)

Figure 3.5-29. 2015 turbidity measured in the Wilder forebay and tailrace, and at all stations during a 10-day, high-temperature, low-flow period with Wilder discharge.

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Nutrients and Chlorophyll-a

In 2012 and 2015, total nitrogen, total phosphorus, nitrate/nitrite, total Kjeldahl nitrogen, and chlorophyll-*a* concentrations were measured in a water column composite sample in the Wilder forebay (Table 3.5-25 and Table 3.5-26). Nutrients and chlorophyll-*a* generally did not show a seasonal pattern. In 2012, mean nitrate/nitrite and total phosphorus concentrations were 0.19 and 0.019 mg/L, respectively (Table 3.5-25). Chlorophyll-*a* concentrations ranged from 1.6 to 5.8 milligrams per cubic meter (mg/m^3) with a mean of 3.5 mg/m^3. In 2015, concentrations were similar. Mean nitrate/nitrite and total phosphorus concentrations were 0.16 and 0.013 mg/L, respectively (Table 3.5-26). Chlorophyll-*a* concentrations ranged from 0.6 to 4.7 mg/m^3 with a mean of 2.2 mg/m^3.

Table 3.5-25. Nutrient and chlorophyll-*a* concentrations in the Wilder forebay in 2012.

Date	Total Nitrogen (mg/L)	Total Phosphorus (mg/L)	Nitrate/Nitrite (mg/L)	Total Kjeldahl Nitrogen (mg/L)	Chlorophyll-*a* (mg/m^3)
7/10/2012	0.76	0.032	0.16	0.60	4.3
7/17/2012	0.54	0.018	0.17	0.37	5.1
7/24/2012	0.68	0.039	0.21	0.47	5.8
7/31/2012	0.60	0.015	0.22	0.38	3.1
8/7/2012	0.72	0.009	0.22	0.50	2.7
8/14/2012	0.55	0.016	0.18	0.37	4.2
8/22/2012	0.62	0.012	0.18	0.44	2.2
8/28/2012	0.59	0.019	0.19	0.40	3.3
9/4/2012	0.59	0.021	0.20	0.39	2.4
9/11/2012	0.64	0.010	0.17	0.47	1.6
Maximum	0.76	0.039	0.22	0.60	5.8
Minimum	0.54	0.009	0.16	0.37	1.6
Median	0.61	0.017	0.19	0.42	3.2
Mean	0.63	0.019	0.19	0.44	3.5

Source: ILP Study 6, *Water Quality Monitoring and Continuous Temperature Monitoring Study* (Louis Berger and Normandeau, 2016a)

Table 3.5-26. Nutrient and chlorophyll-*a* concentrations in the Wilder forebay in 2015.

Date	Total Nitrogen (mg/L)	Total Phosphorus (mg/L)	Nitrate/Nitrite (mg/L)	Total Kjeldahl Nitrogen (mg/L)	Chlorophyll-*a* (mg/m^3)
6/4/2015	<0.50	0.012	0.14	<0.50	0.7
6/11/2015	<0.50	0.026	0.14	<0.50	1.1
6/19/2015	<0.50	0.011	0.09	<0.50	1.5
6/28/2015	<0.50	0.018	0.09	<0.50	1.5
7/8/2015	<0.50	0.014	0.12	<0.50	1.1
7/16/2015	<0.50	0.009	0.30	<0.50	1.5
7/24/2015	<0.50	0.014	0.11	<0.50	0.6
7/30/2015	0.74	0.022	0.14	0.60	2.8
8/6/2015	<0.50	0.008	0.15	<0.50	3.1
8/11/2015	<0.50	0.009	0.17	<0.50	2.5
8/22/2015	0.77	0.012	0.27	0.50	2.4
8/29/2015	1.50	0.009	0.26	1.20	4.7
9/11/2015	<0.5	0.011	0.16	<0.50	2.5
9/23/2015	<0.5	0.009	0.14	<0.50	3.5
9/29/2015	1.15	0.008	0.15	1.00	3.9
Maximum	1.50	0.026	0.30	1.20	4.7
Minimum	<0.50	0.008	0.09	<0.50	0.6
Median	<0.50	0.011	0.14	<0.50	2.4
Mean[a]	0.46	0.013	0.16	0.40	2.2

Source: ILP Study 6, *Water Quality Monitoring and Continuous Temperature Monitoring Study* (Louis Berger and Normandeau, 2016a)

a. For values below the detection limit of 0.5 mg/L, a concentration of 0.25 mg/L was assumed for calculations of the mean for the associated analyte.

Bellows Falls Project

Temperature and Dissolved Oxygen

In 2012, continuous temperature and DO levels were measured in the Bellows Falls forebay, bypassed reach, and tailrace (Normandeau, 2013a). Vertical profiles of temperature and DO levels were also collected in the Bellows Falls impoundment. Water temperatures gradually increased until mid-August before slowly declining. Strong daily fluctuations in temperature were observed in the shallow, riverine Bellows Falls bypassed reach. Diel fluctuations in temperature were less pronounced in the forebay and tailrace. Temperatures in the forebay, bypassed reach, and tailrace ranged from 21.0 to 27.0°C, 20.9 to 27.2°C, and 21.0 to 26.3°C, respectively, over the summer study period (Table 3.5-27). Overall temperatures in the mainstem (excluding the bypassed reach) ranged from 18.7°C (upper impoundment) to 27.0°C (forebay). Continuous measurements of DO in the forebay, bypassed reach, and tailrace indicated that waters were generally well oxygenated over the study season but fell below state standards in several instances in the forebay and bypassed reach. In the forebay and bypassed reach, DO levels fell below the Vermont surface water quality standard when DO concentrations briefly fell to 5.97 mg/L on July 16, 2012, and to 5.94 mg/L on July 23, 2012, respectively. As measured by vertical profiles, DO levels in the forebay were below state surface water quality standards and ranged between 5.9 mg/L (71 percent saturation) to 3.3 mg/L (39 percent saturation) at depths of 8.0 to 11.7 meters on July 18, 2012. These observations coincided with periods of stratification during high water temperature and low flow and were brief in duration (observed only on 1 day on July 18, 2012; Normandeau, 2013a). DO levels throughout the middle and upper impoundment remained above both Vermont and New Hampshire surface water quality standards throughout the 2012 study.

Table 3.5-27. Water temperature, DO, specific conductivity, and pH statistics for Bellows Falls Project in 2012.

Statistic	Station					
	Upper Impound. 06-BF-03 (profile)	Middle Impound. 06-BF-02 (profile)	Forebay 06-BF-01 (profile)	Forebay 06-BF-01 (cont.)	Bypassed Reach 06-BF-BR (cont.)	Tailrace 06-BF-TR (cont.)
Water Temperature (°C)						
Maximum	24.7	25.6	26.5	27.0	27.2	26.3
Minimum	18.7	19.4	21.0	21.3	20.9	21.0
Median	22.4	23.7	24.1	24.9	25.0	24.4
Mean	22.3	23.1	23.7	24.7	24.8	24.2
Dissolved Oxygen (mg/L)						
Maximum	9.3	9.4	10.6	10.3	9.7	10.7
Minimum	7.4	7.1	3.3[a]	5.9[b]	6.0	6.5
Median	8.1	8.2	8.1	7.9	8.5	8.8
Mean	8.2	8.2	7.9	7.8	8.5	8.8
Dissolved Oxygen (% saturation)						
Maximum	102	103	120	124	121	130
Minimum	88	86	39.0[a]	72.8[b]	74	79
Median	93	96	96	96	103	106
Mean	94	96	94	95	104	106
Minimum 24-hour mean	NA	NA	NA	83	84	93
Specific Conductivity (µS/cm)						
Maximum	183	165	162	168	167	170
Minimum	107	111	118	114	115	118
Median	132	136	141	142	144	145
Mean	133	136	142	142	143	144
pH (standard units)[c]						
Maximum	7.8	7.8	7.7	8.53	8.06	7.6
Minimum	6.08	6.9	6.45	7.2	7.5	7.1
Median	7.2	7.6	7.5	7.7	7.7	7.3
Mean	7.2	7.5	7.4	7.7	7.7	7.3

Source: TransCanada (2012b)

Note: NA — not applicable.

a. Recorded on July 18, 2012, in the hypolimnion.

b. Recorded on July 23, 2013, at 25% depth from surface.

c. Values with two digits after the decimal point are those that exceeded state standard(s).

In 2015, water temperature was continuously monitored from late April through November 15 in the Bellows Falls upstream riverine reach, impoundment, forebay bypassed reach, and tailrace, and along transects and different depth stratum at the impoundment and upstream riverine stations during a 10-day, high-temperature, low-flow monitoring period (Figure 3.5-24). Throughout the Bellows Falls Project area, all stations showed a similar seasonal pattern of warming during the spring and summer and cooling during the fall (Figure 3.5-30). Temperatures ranged from 5.8 to 26.3°C and were, on average, cooler at the upstream riverine stations and warmest at the forebay and tailrace (Table 3.5-28). At the shallower upstream riverine, upper impoundment, and bypassed reach stations, water temperatures had larger diurnal fluctuations whereas at the forebay and tailrace diurnal fluctuations were smaller or sometimes absent.

DO was continuously measured in the forebay, bypassed reach, and tailrace. During the 10-day, high-temperature, low-flow monitoring period, DO was continuously monitored at all mainstem stations. DO levels were relatively high in June then decreased through the summer and began to increase again in September (Figure 3.5-31 and Figure 3.5-32). DO levels ranged from 7.1 to 10.7 mg/L and 84 to 118 percent saturation with the lowest DO levels being observed in August and September (Tables 3.5-29, 3.5-30, and 3.5-31).

Temperature and DO vertical profiles collected throughout the Bellows Falls study area from June to October indicated the water column was generally uniform with some surface warming during the summer but was well oxygenated (see Study 6, Appendix H). Unlike in 2012, no instances of stratification were observed in the forebay; however, weak and very brief stratification was observed at the middle impoundment station when a thermal discontinuity was observed at the surface resulting in a temperature difference between the surface and 1.0 meter depth of about 2.8°C (July 29, 2015). Below the 1.0-meter-depth interval, temperatures were uniform and about 24°C. No other instances of stratification occurred and DO levels never fell below state surface water quality standards (Table 3.5-32).

Intensive continuous water temperature and continuous DO monitoring occurred at all Bellows Falls impoundment and upstream riverine stations during the 10-day, high-temperature, low-flow monitoring period. During this intensive sampling event, temperature was continuously recorded at three different locations across the river channel at each station (referred to as river left, mid-channel, and river right) and at up to three different depths. Mean temperatures at each deployment depth among deployment locations were similar (Table 3.5-33). Locations shallower than 4.5 meters generally had a difference between surface and bottom temperatures of 0.3°C; for locations deeper than 7.9 meters (forebay river right and mid-channel), this difference was greater than or equal to 0.5°C. Mean DO concentrations at the upstream, upper, and middle impoundment stations ranged from 8.6 to 8.7 mg/L, and the mean daily percent DO saturation levels ranged from 97 to 109 percent (Table 3.5-34). The mean DO concentration observed at the Bellows Falls forebay was 8.3 mg/L and the mean daily percent DO saturation ranged from 95 to 109 percent.

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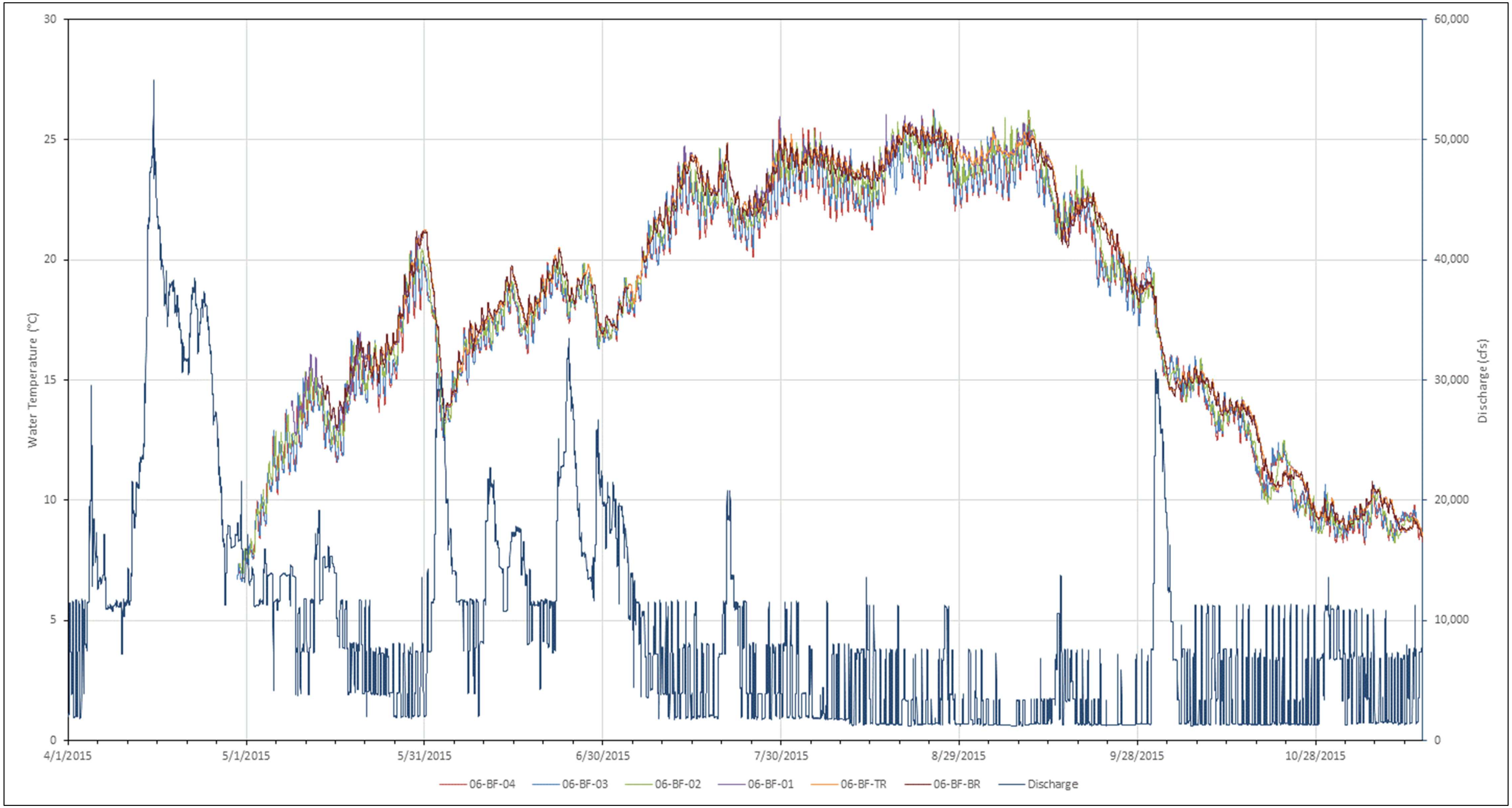

Source: ILP Study 6, *Water Quality Monitoring and Continuous Temperature Monitoring Study* (Louis Berger and Normandeau, 2016a)

Figure 3.5-30. Bellows Falls continuous water temperatures observed during spring, summer, and fall 2015 with Bellows Falls discharge.

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Table 3.5-28. Monthly water temperatures for Bellows Falls Project in 2015.

Temperature (°C)	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	All
Upstream Riverine (06-BF-04)									
Maximum	7.9	20.4	19.9	25.9	26.3	25.9	17.5	10.3	26.3
Min	6.7	7.3	12.5	16.6	21.3	17.6	8.2	5.8	5.8
Median	7.2	14.0	17.4	21.7	23.4	22.2	12.6	8.9	18.0
Mean	7.3	13.9	17.8	21.3	23.5	21.8	12.5	8.7	17.3
Upper Impoundment (06-BF-03)									
Maximum	8.0	20.4	19.8	25.7	26.3	25.8	17.8	10.6	26.3
Minimum	6.6	7.3	12.5	16.7	21.4	17.3	8.4	6.1	6.1
Median	7.2	14.1	17.5	21.8	23.6	22.3	12.8	9.0	18.2
Mean	7.2	14.0	17.2	21.4	23.6	21.8	12.5	8.7	17.5
Middle Impoundment (06-BF-02)									
Maximum	8.15	20.9	20.1	25.2	26.0	26.2	18.1	10.5	26.2
Minimum	6.9	7.6	12.8	16.7	22.3	18.0	8.6	6.1	6.1
Median	7.3	14.4	17.7	22.1	24.1	22.6	12.9	9.0	18.3
Mean	7.4	14.3	17.5	21.7	24.1	22.2	12.5	8.8	17.8
Forebay (06-BF-01)									
Maximum	ND	21.3	20.5	26.	26.1	25.7	18.5	10.4	26.1
Minimum	ND	12.7	13.3	17.1	23.3	18.1	9.0	6.8	6.8
Median	ND	15.7	18.1	22.5	24.3	22.5	13.7	9.1	18.9
Mean	ND	16.0	17.8	22.0	24.4	22.5	12.8	9.1	18.4
Bypassed Reach (06-BF-BR)									
Maximum	ND	21.2	20.5	25.2	25.7	25.3	18.5	10.8	25.7
Minimum	ND	13.0	13.5	17.2	23.0	18.1	9.0	6.8	6.8
Median	ND	16.2	18.2	22.7	24.3	21.5	13.6	9.1	18.8
Mean	ND	16.6	17.9	22.3	24.4	21.5	12.8	9.1	18.2
Tailrace (06-BF-TR)									
Maximum	ND	21.3	20.5	25.4	25.7	25.3	18.4	10.5	25.7
Minimum	ND	15.3	13.4	17.1	23.3	18.1	9.0	6.9	6.9
Median	ND	17.2	18.1	22.5	24.4	22.5	13.7	9.2	19.3
Mean	ND	17.9	17.8	22.0	24.4	22.5	12.8	9.1	18.8

Source: ILP Study 6, *Water Quality Monitoring and Continuous Temperature Monitoring Study* (Louis Berger and Normandeau, 2016a)

Note: ND – no data; high flows and spill conditions in April precluded data collection until May.

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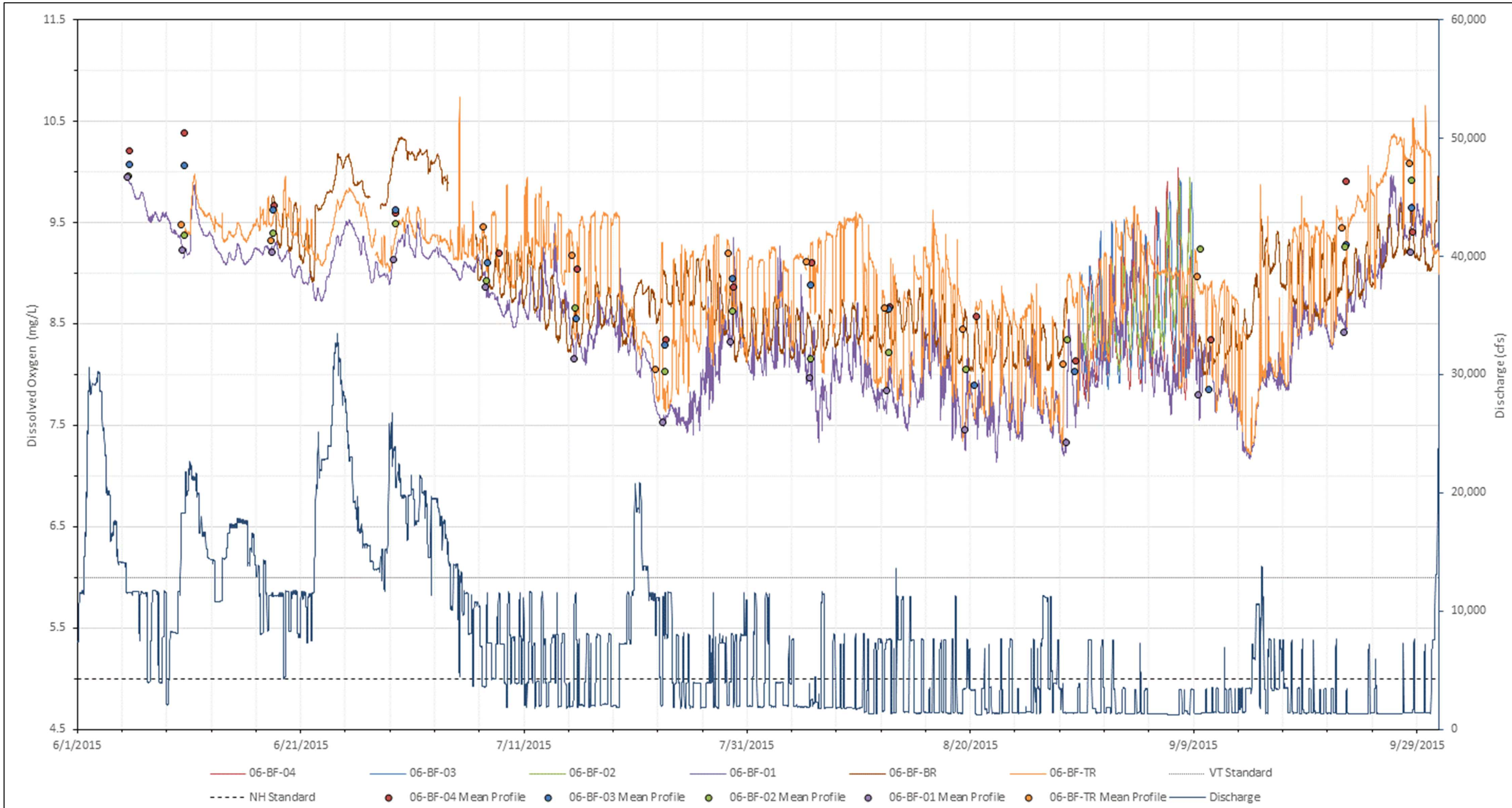

Source: ILP Study 6, *Water Quality Monitoring and Continuous Temperature Monitoring Study* (Louis Berger and Normandeau, 2016a)

Figure 3.5-31. 2015 DO concentrations measured in the Bellows Falls forebay, tailrace, and tailrace, and at all stations during a 10-day, high-temperature, low-flow period with Bellows Falls discharge.

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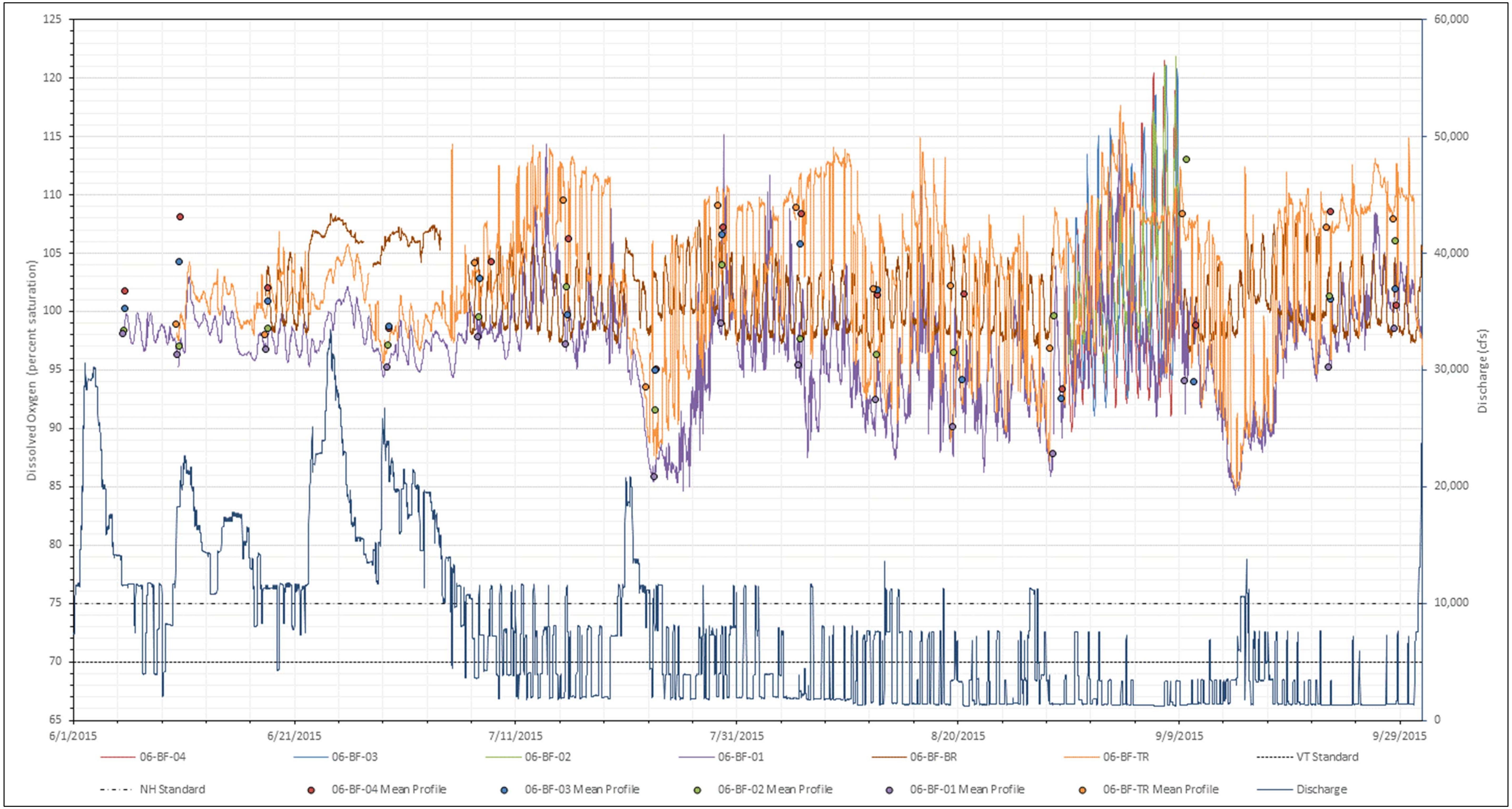

Source: ILP Study 6, *Water Quality Monitoring and Continuous Temperature Monitoring Study* (Louis Berger and Normandeau, 2016a)

Figure 3.5-32. 2015 DO percent saturation measured in the Bellows Falls forebay, bypassed reach, and tailrace, and at all stations during a 10-day, high-temperature, low-flow period with Bellows Falls discharge.

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Table 3.5-29. Monthly statistics for continuously monitored temperature, specific conductivity, dissolved oxygen, pH, and turbidity in the Bellows Falls forebay in 2015.

Statistic	Jun	Jul	Aug	Sep	All
Temperature (°C)					
Maximum	20.5	26.0	26.1	25.7	26.1
Minimum	14.8	17.1	23.8	18.1	14.8
Median	18.2	22.5	24.3	22.5	22.7
Mean	18.2	22.0	24.4	22.5	21.9
Specific Conductivity (µS/cm)					
Maximum	119	158	169	176	176
Minimum	78	95	122	137	78
Median	94	129	146	157	141
Mean	95	127	146	157	133
Dissolved Oxygen (mg/L)					
Maximum	9.9	9.5	9.3	10.0	10.0
Minimum	8.7	7.4	7.1	7.2	7.1
Median	9.2	8.6	7.9	8.4	8.5
Mean	9.3	8.5	7.9	8.5	8.5
Dissolved Oxygen (% saturation)					
Maximum	103	115	112	115	115
Minimum	94	85	86	84	84
Median	98	98	95	98	98
Mean	98	97	95	98	97
Maximum daily mean	101	104	102	109	109
Minimum daily mean	96	87	91	87	87
pH (standard units)[a]					
Maximum	7.7	8.12	8.08	8.28	8.28
Minimum	7.4	7.4	7.5	7.6	7.4
Median	7.5	7.6	7.7	7.8	7.7
Mean	7.5	7.6	7.7	7.8	7.7
Turbidity (NTU)					
Maximum	66.7	9.5	2.4	13.4	66.7
Minimum	0.0	1.0	0.8	0.9	0.0
Median	1.7	1.8	1.2	1.5	1.5
Mean	4.9	2.6	1.2	1.6	2.5

Source: ILP Study 6, *Water Quality Monitoring and Continuous Temperature Monitoring Study* (Louis Berger and Normandeau, 2016a)

a. Values with two digits after the decimal point are those that exceeded state standard(s).

Table 3.5-30. Monthly statistics for continuously monitored temperature, specific conductivity, dissolved oxygen, pH, and turbidity in the Bellows Falls bypassed reach in 2015.

Statistic	Jun	Jul	Aug	Sep	All
Temperature (°C)					
Maximum	20.5	25.2	25.7	25.3	25.7
Minimum	16.9	17.2	23.0	18.1	16.9
Median	18.9	22.7	24.3	21.5	22.9
Mean	18.8	22.3	24.4	21.5	22.3
Specific Conductivity (µS/cm)					
Maximum	118	154	170	174	174
Minimum	51	89	121	146	51
Median	97	130	148	157	143
Mean	94	128	147	159	137
Dissolved Oxygen (mg/L)					
Maximum	10.3	10.2	8.9	10.0	10.3
Minimum	8.9	8.1	8.0	8.0	8.0
Median	9.8	8.8	8.4	8.9	8.7
Mean	9.8	8.9	8.4	8.9	8.9
Dissolved Oxygen (% saturation)					
Maximum	108	108	106	108	108
Minimum	98	97	97	97	97
Median	106	102	100	100	101
Mean	105	102	100	101	102
Maximum daily mean	108	107	102	103	108
Minimum daily mean	100	100	99	99	99
pH (standard units)[a]					
Maximum	7.9	8.07	7.96	8.0	8.07
Minimum	7.5	7.6	7.5	7.5	7.5
Median	7.6	7.8	7.7	7.7	7.7
Mean	7.6	7.8	7.7	7.7	7.7
Turbidity (NTU)					
Maximum	82.3	18.7	8.0	19.8	82.3
Minimum	0.5	0.0	1.4	0.3	0.0
Median	8.2	2.1	1.8	2.0	2.0
Mean	12.5	2.9	1.8	2.1	3.7

Source: ILP Study 6, *Water Quality Monitoring and Continuous Temperature Monitoring Study* (Louis Berger and Normandeau, 2016a)

a. Values with two digits after the decimal point are those that exceeded state standard(s).

Table 3.5-31. Monthly statistics for continuously monitored temperature, specific conductivity, dissolved oxygen, pH, and turbidity in the Bellows Falls tailrace in 2015.

Statistic	Jun	Jul	Aug	Sep	All
Temperature (°C)					
Maximum	20.5	25.2	25.7	25.3	25.7
Minimum	17.0	17.1	23.3	18.1	16.9
Median	18.6	22.5	24.4	22.5	23.0
Mean	18.6	22.0	24.4	22.5	22.2
Specific Conductivity (µS/cm)					
Maximum	117	155	168	175	175
Minimum	77	96	121	135	77
Median	92	127	146	154	140
Mean	93	126	147	154	133
Dissolved Oxygen (mg/L)					
Maximum	10.0	10.7	9.6	10.7	10.7
Minimum	9.0	7.6	7.3	7.2	7.2
Median	9.5	9.2	8.7	9.1	9.1
Mean	9.5	9.0	8.6	9.1	9.0
Dissolved Oxygen (% saturation)					
Maximum	107	114	145	118	118
Minimum	96	87	87	85	85
Median	101	102	104	108	103
Mean	101	103	103	104	103
Maximum daily mean	105	110	112	113	113
Minimum daily mean	97	92	93	88	88
pH (standard units)[a]					
Maximum	7.6	8.0	7.9	8.10	8.10
Minimum	7.5	7.2	7.4	7.6	7.2
Median	7.5	7.6	7.6	7.8	7.7
Mean	7.5	7.6	7.6	7.8	7.7
Turbidity (NTU)					
Maximum	42.6	34.9	21.0	22.8	42.6
Minimum	0.0	0.0	0.0	0.1	0.0
Median	3.3	1.7	0.9	0.9	1.2
Mean	6.1	2.7	1.1	1.2	2.5

Source: ILP Study 6, *Water Quality Monitoring and Continuous Temperature Monitoring Study* (Louis Berger and Normandeau, 2016a)

a. Values with two digits after the decimal point are those that exceeded state standard(s).

Table 3.5-32. Vertical profile statistics for Bellows Falls Project in 2015.

	Upstream Riverine 06-BF-04	Upper Impound. 06-BF-03	Middle Impound. 06-BF-02	Forebay 06-BF-01	Tailrace 06-BF-TR
Mean water depth (meters)[a]	2.1	3.1	3.2	11.0	4.9
Temperature (°C)					
Maximum	25.0	24.4	27.4	25.5	25.0
Minimum	15.2	15.1	14.8	14.7	17.4
Median	21.8	22.0	21.9	21.8	23.6
Mean	21.1	20.7	21.2	21.4	22.3
Dissolved Oxygen (mg/L)					
Maximum	10.4	10.1	10.1	10.0	10.1
Minimum	8.1	7.9	7.9	7.1	8.0
Median	9.1	9.0	8.9	8.3	9.1
Mean	9.1	9.0	8.9	8.4	9.0
Dissolved Oxygen (% saturation)					
Maximum	109	107	117	111	110
Minimum	93	92	91	85	93
Median	102	101	99	96	103
Mean	102	100	100	95	104
Specific Conductivity (µS/cm)					
Maximum	178	182	172	160	160
Minimum	85	58	62	87	92
Median	141	149	129	135	143
Mean	134	139	131	130	137
pH (standard units)[b]					
Maximum	8.19	8.05	8.44	8.0	7.9
Minimum	7.4	7.5	7.4	7.4	7.3
Median	7.8	7.7	7.7	7.6	7.6
Mean	7.8	7.7	7.7	7.6	7.7
Turbidity (NTU)					
Maximum	13.1	17.7	24.9	14.1	13.8
Minimum	0.0	0.0	0.0	0.0	0.0
Median	0.9	0.7	0.5	0.7	0.8
Mean	3.2	3.2	2.5	1.6	1.2

Source: ILP Study 6, *Water Quality Monitoring and Continuous Temperature Monitoring Study*
a. Average of individual depths recorded during each station visit.
b. Values with two digits after the decimal point are those that exceeded state standard(s).

Table 3.5-33. Water temperatures for Bellows Falls during the 10-day, high-temperature, low-flow monitoring period in 2015.

Deployment Depth	Statistic	Temperature (°C)		
		River Left	Mid-channel	River Right
Upstream Riverine (06-BF-04)				
Mid-depth	Maximum	25.7	25.5	26.3
	Minimum	22.4	22.4	21.8
	Mean	23.8	23.6	23.6
Depth to bottom (at first deployment, meter)		0.8	1.3	0.6
Upper Impoundment (06-BF-03)				
Mid-depth	Maximum	25.6	26.0	25.6
	Minimum	22.5	22.7	22.8
	Mean	23.8	24.1	24.0
Depth to bottom (at first deployment, meter)		2.1	0.8	2.9
Middle Impoundment (06-BF-02)				
1 meter below surface	Maximum	26.4	25.5	26.1
	Minimum	23.3	23.4	23.4
	Mean	24.4	24.3	24.4
1 meter above bottom	Maximum	25.2	25.0	25.2
	Minimum	23.3	23.3	23.3
	Mean	24.2	24.1	24.2
Depth to bottom (at first deployment, meter)		3.1	3.3	4.0
Forebay (06-BF-01)				
1 meter below surface	Maximum	26.5	26.2	26.8
	Minimum	25.9	23.9	24.1
	Mean	24.8	24.9	24.9
Mid-depth	Maximum	25.9	25.1	25.3
	Minimum	23.8	23.9	23.9
	Mean	24.6	24.4	24.9
1 meter above bottom	Maximum	25.7	24.7	25.0
	Minimum	23.8	23.8	23.9
	Mean	24.5	24.3	24.4
Depth to bottom (at first deployment, meter)		4.5	10.3	7.9

Source: ILP Study 6, *Water Quality Monitoring and Continuous Temperature Monitoring Study* (Louis Berger and Normandeau, 2016a)

Table 3.5-34. Statistics of temperature, specific conductivity, dissolved oxygen, pH and turbidity for Bellows Falls Project during the 10-day, high-temperature, low-flow monitoring period in 2015.

Statistic	Station			
	Upstream Riverine 06-BF-04	Upper Impound. 06-BF-03	Middle Impound. 06-BF-02	Forebay 06-BF-01
Temperature (°C)				
Maximum	25.5	25.5	25.9	25.7
Minimum	22.4	22.6	23.3	23.8
Median	23.4	23.7	24.3	24.5
Mean	23.6	23.8	24.2	24.5
Specific Conductivity (µS/cm)				
Maximum	185	182	173	160
Minimum	121	127	133	135
Median	153	152	151	148
Mean	153	155	153	148
Dissolved Oxygen (mg/L)				
Maximum	10.0	9.9	10.0	9.5
Minimum	7.8	7.9	8.0	7.6
Median	8.5	8.6	8.6	8.2
Mean	8.6	8.7	8.6	8.3
Dissolved Oxygen (% saturation)				
Maximum	122	121	122	115
Minimum	90	91	95	91
Median	100	101	102	99
Mean	101	103	103	99
Maximum daily mean	104	106	109	109
Minimum daily mean	97	100	99	95
pH (standard units)[a]				
Maximum	8.42	8.30	8.56	8.28
Minimum	7.6	7.5	7.9	7.6
Median	7.9	7.8	8.02	7.7
Mean	7.9	7.8	8.05	7.7

Statistic	Station			
	Upstream Riverine 06-BF-04	**Upper Impound. 06-BF-03**	**Middle Impound. 06-BF-02**	**Forebay 06-BF-01**
Turbidity (NTU)				
Maximum	9.9	3.3	3.2	2.1
Minimum	0.2	0.6	0.5	1.1
Median	1.0	1.0	0.7	1.5
Mean	1.2	1.2	0.8	1.5

Source: ILP Study 6, *Water Quality Monitoring and Continuous Temperature Monitoring Study* (Louis Berger and Normandeau, 2016a)

a. Values with two digits after the decimal point are those that exceeded state standard(s).

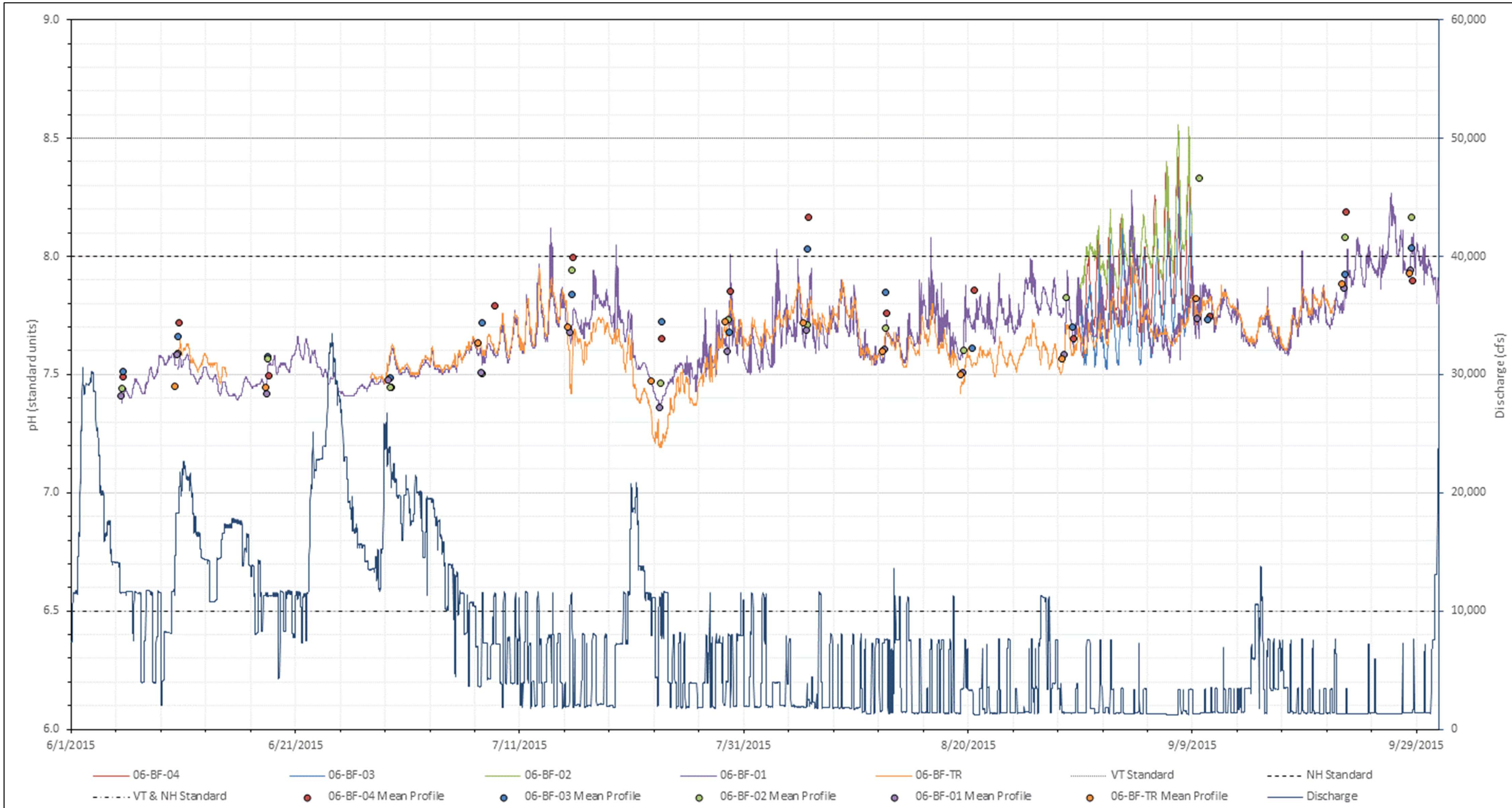
Specific Conductivity

In 2012, specific conductivity ranged between 107 to 183 µS/cm, while during 2015, specific conductivity ranged between 51 to 182 µS/cm. In both study years, specific conductivity readings throughout the Project area were fairly consistent and did not exhibit a spatial trend. Seasonally, however, specific conductivity was variable throughout the study period, but was generally higher in the middle and latter half of this period than the beginning and exhibited no stratification (Normandeau, 2013a; Study 6). In 2015, during the 10-day, high-temperature, low-flow monitoring period specific conductivity exhibited diurnal fluctuations in the shallower upstream riverine station and upper impoundment station, but the diurnal fluctuations attenuated in the deeper middle impoundment and forebay areas.

pH

In 2012, pH was continuously measured in the Bellows Falls forebay, bypassed reach, and tailrace from June through September and instantaneously measured through the water column during vertical profiles at the Bellows Falls upper impoundment, middle impoundment, and forebay stations. As shown in Table 3.5-27, pH ranged between 6.45 and 8.53 in the forebay, between 7.5 and 8.06 in the bypassed reach, and between 7.1 and 7.6 in the tailrace. At the middle impoundment and upper impoundment stations, pH ranged from 6.9 to 7.8 and 6.08 to 7.8, respectively. In the forebay, pH also corresponded well with DO levels and gradually increased from mid-July to mid-September following a decrease in early July (Normandeau, 2013a), and pH levels were uniform throughout the water column. In the bypassed reach, pH exhibited diurnal fluctuations between 7.0 and 8.0, which corresponded well with DO level fluctuations. In the tailrace, pH was relatively high in mid-June, then decreased to about 7.0, and fluctuated between 7.0 and 7.5 from July to mid-September. During the 2012 study, pH occasionally exceeded both New Hampshire and Vermont upper and lower water quality standards (Normandeau, 2013a). The continuous pH data for the forebay indicated exceedances of the upper New Hampshire and Vermont state surface water quality standards that occurred throughout the study. The upper limit of one or both standards was exceeded within the bypassed reach and tailrace forebay, n = 337, range = 8.01 to 8.53 standard units; bypassed reach, n = 35, range = 8.01 to 8.06 standard units; tailrace, n = 72 range = 8.01 to 8.16 standard units.

In 2015, pH was also continuously monitored in the Bellows Falls forebay, bypassed reach, and tailrace from June through September as well as during the 10-day, high-temperature, low-flow monitoring period in late August and early September. In the forebay, pH levels ranged from 7.4 to 8.28, and monthly mean pH levels ranged from 7.5 to 7.8 (Figure 3.5-33; Table 3.5-29). Instances when pH levels in the forebay exceeded the upper limit of the New Hampshire standard but not the Vermont standard were infrequent in July and August but became more frequent in late September. In the bypassed reach, pH levels ranged from 7.5 to 8.07, and July was the only month in which pH levels at that monitoring station were greater than 8.0 (Table 3.5-30). Mean monthly pH levels in the tailrace increased from June through September and pH levels ranged from 7.2 to 8.10; pH levels only exceeded 8.0 in September (Table 3.5-31). Vertical profiles indicate that mean pH levels were slightly higher at the upstream riverine, upper impoundment, and middle impoundment areas than at the forebay or tailrace (Table 3.5-32). The maximum instantaneous pH measurements greater than 8.0 (the New Hampshire standard) but less than 8.5 (the Vermont standard) occurred at the upstream, upper impoundment, and middle impoundment stations; pH levels never were observed to fall below 7.3 at any monitoring stations and were uniform throughout the water column at all mainstem stations during the study period. During the 10-day, high-temperature, low-flow monitoring period all the upstream riverine, impoundment, and forebay stations recorded pH levels greater than 8.0 exceeding the New Hampshire standard, but only the middle impoundment station recorded pH levels greater than 8.5, exceeding also the Vermont standard (Table 3.5-34). The upstream, upper, and middle impoundment stations exhibited strong diel fluctuations, and the peaks of the fluctuations generally occurred during late afternoon; no strong or apparent diel pH trends were observed at the forebay or tailrace stations nor was there evidence of pH stratification among stations (see Study 6, Appendix J).



Source: ILP Study 6, *Water Quality Monitoring and Continuous Temperature Monitoring Study* (Louis Berger and Normandeau, 2016a)

Figure 3.5-33. 2015 pH measured in the Bellows Falls forebay, bypassed reach, and tailrace, and at all stations during a 10-day, high-temperature, low-flow period with Bellows Falls discharge.

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Turbidity

In 2015, turbidity was monitored continuously in the Bellows Falls forebay, bypassed reach, tailrace, and at all impoundment and upstream riverine stations during the 10-day, high-temperature, low-flow monitoring period. In addition, turbidity was also measured throughout the water column at each station (except the bypassed reach) (Study 6). Turbidity at the forebay and tailrace stations was generally very low but increased in response to high flows resulting from precipitation events that often resulted in spill at the Project dam (Figure 3.5-34). At the forebay station, turbidity levels ranged from 0.0 to 67 NTU with an overall median and mean of 1.5 and 2.5 NTU, respectively (Table 3.5-29). Turbidity ranged from 0.0 to 82 NTU in the bypassed reach, but the overall median and mean levels were 2.0 and 3.7 NTU, respectively (Table 3.5-30). Turbidity in the tailrace ranged from 0.0 to 43 NTU and had an overall median of 1.2 NTU and mean of 2.5 NTU (Table 3.5-31). Turbidity levels for each profile were low and uniform throughout the water column, except during or shortly after high flows and precipitation events. Overall, median and mean turbidity levels were all below 1 NTU and 4 NTU, respectively (Table 3.5-32). During the 10-day, high-temperature, low-flow monitoring period, turbidity was generally low; mean and median values were all below 2 NTU, with a maximum of 9.9 NTU at the upstream station (Table 3.5-34).

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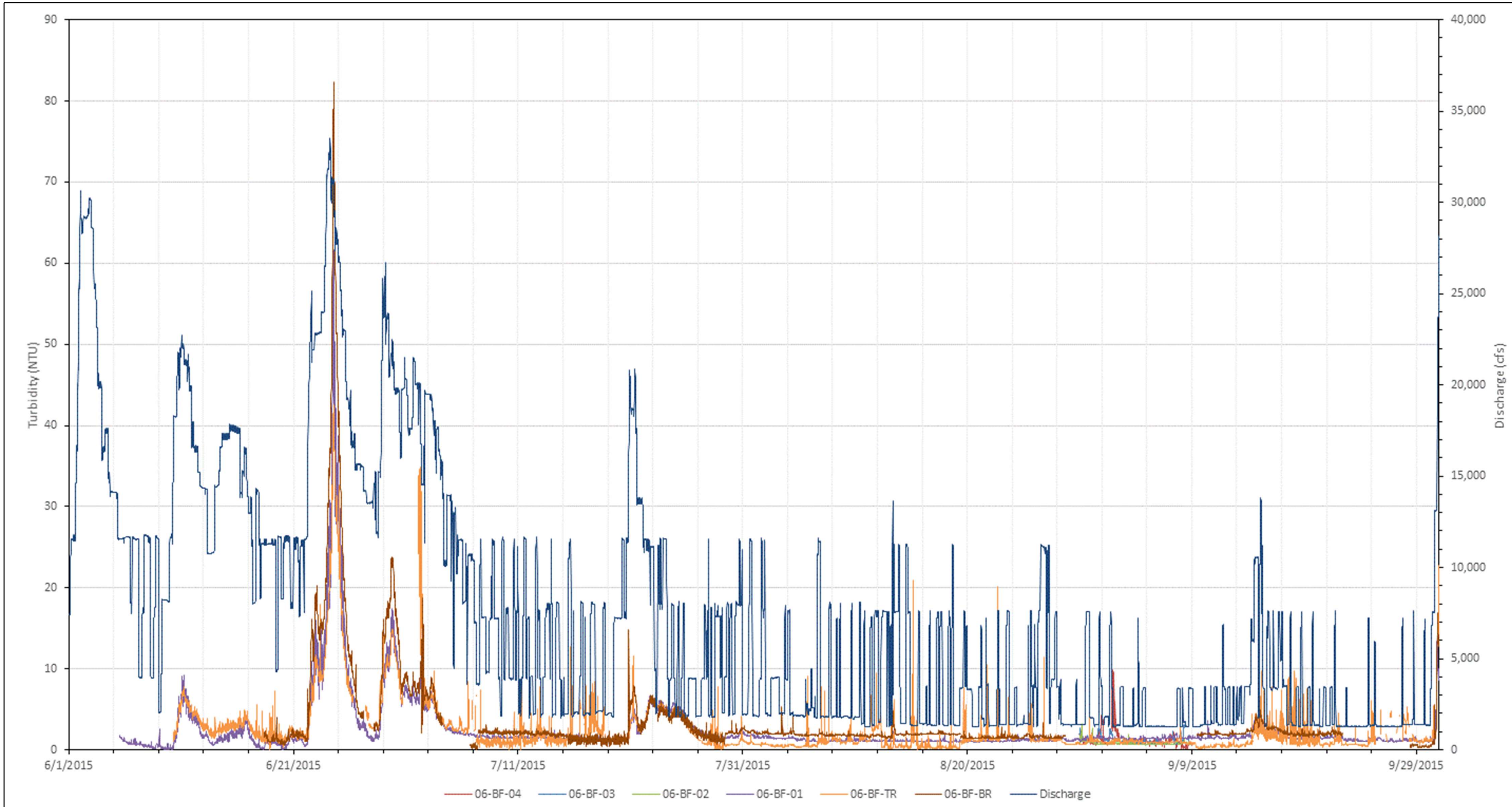

Source: ILP Study 6, *Water Quality Monitoring and Continuous Temperature Monitoring Study* (Louis Berger and Normandeau, 2016a)

Figure 3.5-34. 2015 turbidity measured in the Bellows Falls forebay, bypassed reach, and tailrace, and at all stations during a 10-day, high-temperature, low-flow period with Bellows Falls discharge.

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Nutrients and Chlorophyll-a

In 2012 and 2015, total nitrogen, total phosphorus, nitrate/nitrite, total Kjeldahl nitrogen, and chlorophyll-*a* concentrations were measured in a water column composite sample in the Bellows Falls forebay. The concentrations did not show a strong seasonal pattern. In 2012, the mean nitrate/nitrite and total phosphorus concentrations were 0.19 and 0.020 mg/L, respectively (Table 3.5-35). Chlorophyll-*a* concentrations ranged from 2.7 to 6.6 mg/m^3 with a mean of 3.9 mg/m^3. Concentrations were similar in 2015 with the mean nitrate/nitrite and total phosphorus concentrations of 0.15 and 0.014 mg/L, respectively (Table 3.5-36). Chlorophyll-*a* concentrations ranged from less than 0.5 to 6.8 mg/m^3 with a mean of 3.2 mg/m^3.

Table 3.5-35. Nutrient and chlorophyll-*a* concentrations in the Bellows Falls forebay in 2012.

Date	Total Nitrogen (mg/L)	Total Phosphorus (mg/L)	Nitrate/ Nitrite (mg/L)	Total Kjeldahl Nitrogen (mg/L)	Chlorophyll-*a* (mg/m^3)
7/11/2012	0.53	0.012	0.16	0.37	3.8
7/18/2012	0.66	0.024	0.17	0.49	6.6
7/25/2012	0.61	0.010	0.20	0.41	2.7
8/1/2012	0.66	0.028	0.22	0.44	4.4
8/8/2012	0.83	0.039	0.21	0.62	3.5
8/15/2012	0.69	0.048	0.21	0.48	4.0
8/23/2012	0.58	0.009	0.15	0.43	2.9
8/29/2012	0.59	0.010	0.18	0.41	4.2
9/5/2012	0.56	0.012	0.16	0.40	3.1
9/12/2012	0.61	0.011	0.19	0.42	3.8
Maximum	0.83	0.048	0.22	0.62	6.6
Minimum	0.53	0.009	0.15	0.37	2.7
Median	0.61	0.012	0.19	0.43	3.8
Mean	0.63	0.020	0.19	0.45	3.9

Source: Normandeau (2013a)

Table 3.5-36. Nutrient and chlorophyll-*a* concentrations in the Bellows Falls forebay in 2015.

Date	Total Nitrogen (mg/L)	Total Phosphorus (mg/L)	Nitrate/ Nitrite (mg/L)	Total Kjeldahl Nitrogen (mg/L)	Chlorophyll-*a* (mg/m^3)
6/5/2015	<0.50	0.011	0.14	<0.50	0.7
6/10/2015	1.47	0.012	0.17	1.30	1.4
6/18/2015	<0.50	0.012	0.10	<0.50	2.2
6/29/2015	<0.50	0.036	0.13	<0.50	1.5
7/7/2015	0.73	0.014	0.13	0.60	<0.5
7/15/2015	<0.50	0.009	0.30	<0.50	2.9
7/23/2015	<0.50	0.019	0.14	<0.50	3.6
7/29/2015	<0.50	0.009	0.13	<0.50	4.6
8/5/2015	0.63	0.006	0.13	0.50	3.9
8/12/2015	<0.50	0.012	0.16	<0.50	3.2
8/19/2015	0.69	0.009	0.19	0.50	4.2
8/28/2015	<0.50	0.012	0.17	<0.50	3.1
9/9/2015	0.8	0.024	0.12	0.70	6.8
9/22/2015	<0.50	0.009	0.11	<0.50	4.3
9/28/2015	0.78	0.009	0.08	0.70	5.0
Maximum	1.47	0.036	0.30	1.30	6.8
Minimum	<0.50	0.006	0.08	<0.50	<0.5
Median	<0.50	0.012	0.13	<0.50	3.2
Mean[a]	0.49	0.014	0.15	0.44	3.2

Source: ILP Study 6, *Water Quality Monitoring and Continuous Temperature Monitoring Study* (Louis Berger and Normandeau, 2016a)

a. For values below the detection limit of 0.5 mg/L, a concentration of 0.25 mg/L was assumed for mean calculations for the associated analyte.

Vernon Project

Temperature and Dissolved Oxygen

Continuous temperature and DO levels were recorded in the Vernon forebay and tailrace, and vertical profiles of temperature and DO levels were collected from the Vernon upper impoundment, middle impoundment, and forebay during summer 2012 (Normandeau, 2013a). Surface water temperatures in 2012 demonstrated a typical seasonal pattern of warming in early summer, relatively consistent temperature during mid-summer, and cooling in late-summer and early fall. Overall temperatures ranged from 20.2 to 29.3°C (Table 3.5-37). Based on vertical profile measurements, mean temperatures were cooler at the upper impoundment station and increased toward Vernon dam (Table 3.5-37). The highest temperatures were observed during mid-summer and ranged from about 26 to 29°C. DO was continuously measured in the Vernon forebay and tailrace, and readings were fairly consistent throughout the deployment period ranging from 6.3 to 9.1 mg/L (81 to 115 percent saturation) and 7.4 to 9.8 mg/L (94 to 118 percent saturation) (Table 3.5-37). Based on vertical profiles, mean DO levels decreased from the upper impoundment station toward Vernon dam, but never fell below Vermont or New Hampshire surface water quality standards, despite very weak stratification being observed in late June in the forebay.

In 2015, water temperature was continuously monitored in the Vernon upstream riverine reach, impoundment, forebay, and tailrace. Data from all stations reflect a similar seasonal pattern of warming during the spring and summer, and cooling during the fall (Figure 3.5-35). Over the entire study area, temperatures ranged from 7.2 to 27.2°C and were on average cooler at the upstream riverine site and warmest at the forebay and tailrace (Table 3.5-38). Water temperatures throughout the water column were generally uniform and exhibited only mild surface warming from late-July to mid-September, but no stratification (the maximum decrease in temperature between depth intervals ranged from 0.2 to 0.9°C) (see Study 6, Appendix H).

Intensive continuous water temperature monitoring occurred at the upstream and impoundment stations during the 10-day, high-temperature, low-flow monitoring period at three different locations at each station and up to three different depths (Table 3.5-39). Mean water temperatures ranged from 24.5 to 25.5°C. At the upstream and upper impoundment stations mean water temperatures were similar across the channel (river left, mid-channel, river right) and at the various deployment depths. At the middle impoundment station, temperatures recorded 1 meter above the river bottom and at mid-depth were similar across the channel, but during the afternoon, maximum surface temperatures were warmer by up to about 1°C compared to maximum temperatures recorded at mid-depth. At the forebay, mean temperatures were similar at 1 meter above bottom and mid-depth, but maximum surface temperatures were about 2.0°C warmer than bottom temperatures.

DO was also continuously monitored in the forebay and tailrace areas and at all stations during the 10-day, high-temperature, low-flow monitoring period in late-August and early-September 2015. In the forebay, DO levels initially were at their highest levels in June and gradually decreased to their lowest levels at the beginning of September (Figure 3.5-36 and Figure 3.5-37). DO concentrations measured continuously at the forebay ranged from 6.9 to 10.0 mg/L and percent saturation levels ranged from 82 to 119 percent (Table 3.5-39). In the tailrace, DO levels were fairly consistent throughout the study period and ranged from 7.3 to 10.1 mg/L and 86 to 111 percent, respectively (Table 3.5-40). Even during the 10-day, high-temperature, low-flow monitoring period, DO levels were never observed to decline below state surface water quality standards (Figure 3.5-36 and

Figure 3.5-37; Table 3.5-41). DO vertical profiles collected at all study stations showed that the water column was well oxygenated (Table 3.5-42).

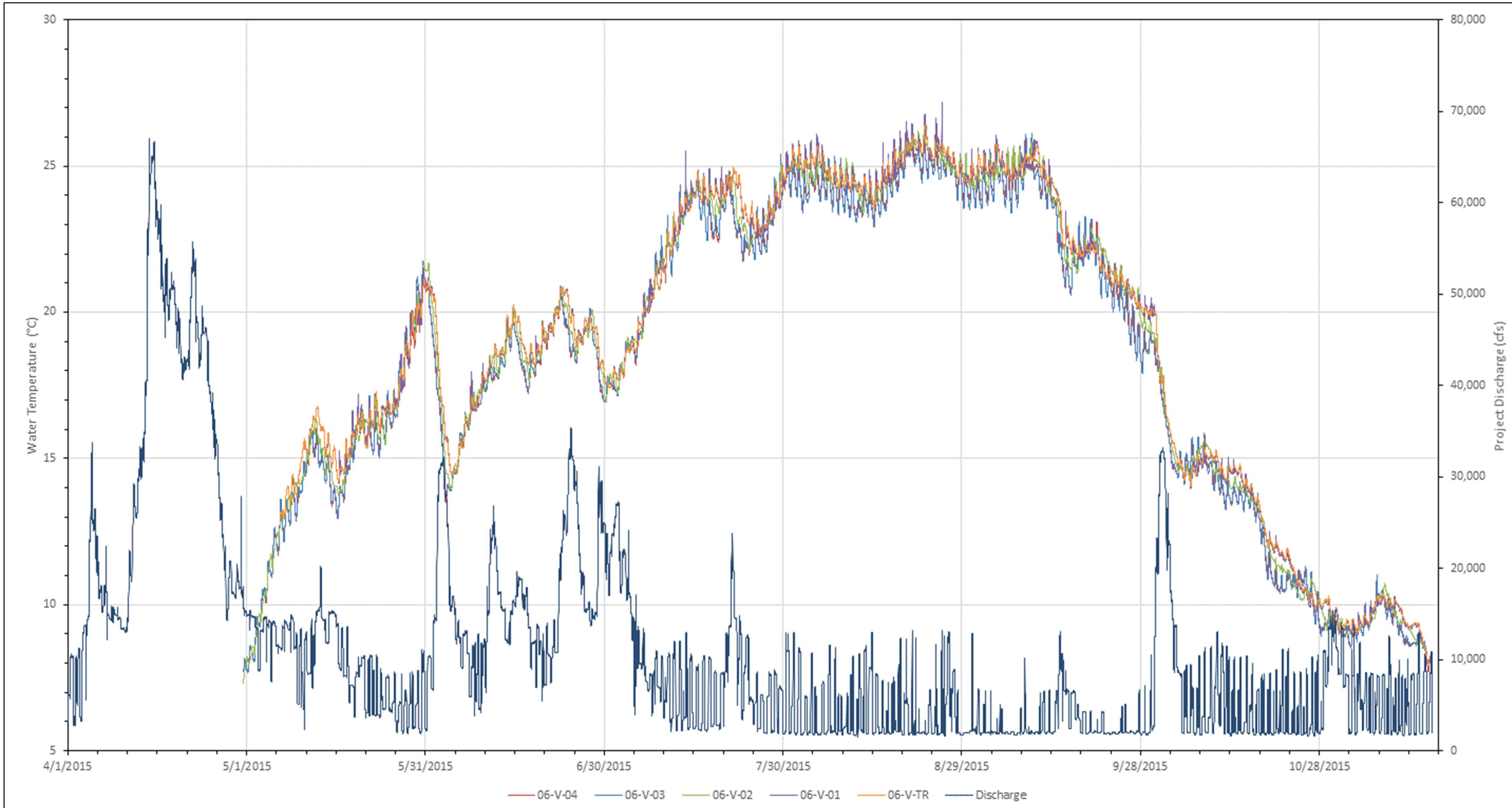
Table 3.5-37. Water temperature, DO, specific conductivity, and pH statistics for Vernon Project in 2012.

Statistic	Station				
	Upper Impound. V-03 (Profile)	Middle Impound. V-02 (Profile)	Forebay V-01 (Profile)	Forebay V-01 (Continuous)	Tailrace V-TR (Continuous)
Water Temperature (°C)					
Maximum	25.1	27.4	28.3	29.3	28.6
Minimum	20.2	21.4	21.6	22.9	22.8
Median	23.8	24.5	25.1	26.7	26.4
Mean	23.5	24.2	24.9	26.6	26.1
Dissolved Oxygen (mg/L)					
Maximum	10.2	9.8	9.6	9.1	9.8
Minimum	7.2	7.0	6.4	6.3	7.4
Median	8.6	8.1	7.8	7.9	8.7
Mean	8.5	8.1	7.9	7.8	8.7
Dissolved Oxygen (% saturation)					
Maximum	120	115	115	115	118
Minimum	87	86	79	81	94
Median	99	95	94	98	107
Mean	100	96	95	98	108
Minimum 24-hour Mean	NA	NA	NA	87	100
Specific Conductivity (µS/cm)					
Maximum	161	164	158	162	163
Minimum	122	113	123	115	116
Median	146	138	141	143	142
Mean	142	139	141	142	141
pH (standard units)[a]					
Maximum	7.6	7.6	7.9	7.8	8.01
Minimum	6.6	7.1	6.7	7.1	7.2
Median	7.2	7.4	7.4	7.4	7.6
Mean	7.2	7.4	7.4	7.4	7.6

Source: TransCanada (2012c)

Note: NA — not applicable.

a. Values with two digits after the decimal point are those that exceeded state standard(s).



Source: ILP Study 6, *Water Quality Monitoring and Continuous Temperature Monitoring Study* (Louis Berger and Normandeau, 2016a)

Figure 3.5-35. Vernon continuous water temperatures observed during spring, summer, and fall 2015 with Vernon discharge.

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Table 3.5-38. Monthly water temperatures for Vernon Project in 2015.

Temperature (°C)	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	All
Upstream Riverine (06-V-04)									
Maximum	8.1	21.3	20.6	25.2	26.2	25.9	18.3	10.8	26.2
Min	7.9	7.7	13.5	17.1	22.9	18.0	8.9	7.2	7.2
Median	8.0	14.9	18.3	22.4	24.4	22.3	13.4	9.0	18.7
Mean	8.0	14.8	17.9	21.9	24.5	22.4	12.7	9.1	18.1
Upper Impoundment (06-V-03)									
Maximum	8.2	21.8	20.7	25.4	26.5	26.1	18.3	11.1	26.5
Min	7.7	7.7	13.7	17.2	22.9	17.9	8.9	7.2	7.2
Median	8.1	15.1	18.2	22.7	24.5	22.3	13.4	9.0	18.8
Mean	8.0	14.9	18.0	22.2	24.5	22.4	12.7	9.1	18.2
Middle Impoundment (06-V-02)									
Maximum	8.1	21.6	20.9	25.6	26.6	25.9	18.3	10.7	26.6
Min	7.3	8.0	14.0	17.2	23.4	18.4	9.1	7.9	7.3
Median	7.8	15.3	18.5	23.1	24.8	22.5	13.6	9.3	19.1
Mean	7.7	15.1	18.1	22.4	24.8	22.8	12.9	9.2	18.5
Forebay (06-V-01)									
Maximum	ND	21.6	20.9	25.8	27.2	26.1	18.3	10.4	27.2
Min	ND	14.2	14.5	17.4	23.5	18.4	9.0	7.7	7.7
Median	ND	16.5	18.7	23.2	24.9	22.4	13.9	9.3	19.7
Mean	ND	16.9	18.4	22.4	24.9	22.9	13.0	9.3	19.0
Tailrace (06-V-TR)									
Maximum	ND	21.2	20.8	25.7	26.4	25.8	18.4	10.4	26.4
Min	ND	12.9	14.4	17.4	23.6	18.4	9.1	7.7	7.7
Median	ND	16.1	18.7	23.4	25.0	22.3	14.0	9.4	19.5
Mean	ND	16.4	18.4	22.5	25.0	22.9	13.1	9.4	18.9

Source: ILP Study 6, *Water Quality Monitoring and Continuous Temperature Monitoring Study* (Louis Berger and Normandeau, 2016a)

Note: ND – no data; high flows and spill conditions in April precluded data collection until May.

Table 3.5-39. Water temperatures for Vernon Project during the 10-day, high-temperature, low-flow period monitoring period in 2015.

Logger Location	Statistic	Temperature (°C)		
		River Left	Mid-channel	River Right
Upstream Riverine (06-V-04)				
1 meter below surface	Maximum	ND	ND	25.9
	Minimum			23.7
	Mean			24.5
Mid-depth	Maximum	27.1	25.9	ND
	Minimum	23.0	23.8	
	Mean	24.6	24.5	
1 meter above bottom	Maximum	ND	ND	26.0
	Minimum			23.8
	Mean			24.6
Depth to bottom (at first deployment, meter)		0.8	2.3	4.1
Upper Impoundment (06-V-03)				
1 meter below surface	Maximum	26.3	ND	ND
	Minimum	22.2		
	Mean	24.5		
Mid-depth	Maximum	ND	26.3	25.9
	Minimum		23.5	23.8
	Mean		24.6	24.7
1 meter above bottom	Maximum	26.2	ND	ND
	Minimum	23.4		
	Mean	24.6		
Depth to bottom (at first deployment, meter)		3.4	2.7	2.1
Middle Impoundment (06-V-02)				
1 meter below surface	Maximum	26.3	26.1	26.1
	Minimum	24.4	24.4	24.4
	Mean	25.0	25.0	25.0
Mid-depth	Maximum	25.3	25.3	25.2
	Minimum	24.4	24.4	24.3
	Mean	24.8	24.8	24.8
1 meter above bottom	Maximum	25.1	25.2	25.3
	Minimum	24.4	24.4	24.4
	Mean	24.7	24.8	24.8
Depth to bottom (at first deployment, meter)		4.8	5.6	6.3

Logger Location	Statistic	Temperature (◦C)		
		River Left	Mid-channel	River Right
Logger Location	**Statistic**	**Temperature (°C)**		
		River Left	**Mid-channel**	**River Right**
Forebay (06-V-01)				
1 meter below surface	Maximum	28.1	27.8	27.9
	Min	24.6	24.6	24.7
	Mean	25.5	25.4	25.5
Mid-depth	Maximum	26.0	26.6	25.6
	Min	24.4	24.6	24.5
	Mean	24.9	25.1	24.9
1 meter above bottom	Maximum	25.3	26.0	25.2
	Min	24.2	24.5	24.4
	Mean	24.6	24.9	24.7
Depth to bottom (at first deployment, meter)		6.9	5.4	17.2

Source: ILP Study 6, *Water Quality Monitoring and Continuous Temperature Monitoring Study* (Louis Berger and Normandeau, 2016a)

Note: ND – no data; no logger was deployed due to shallow water depths.

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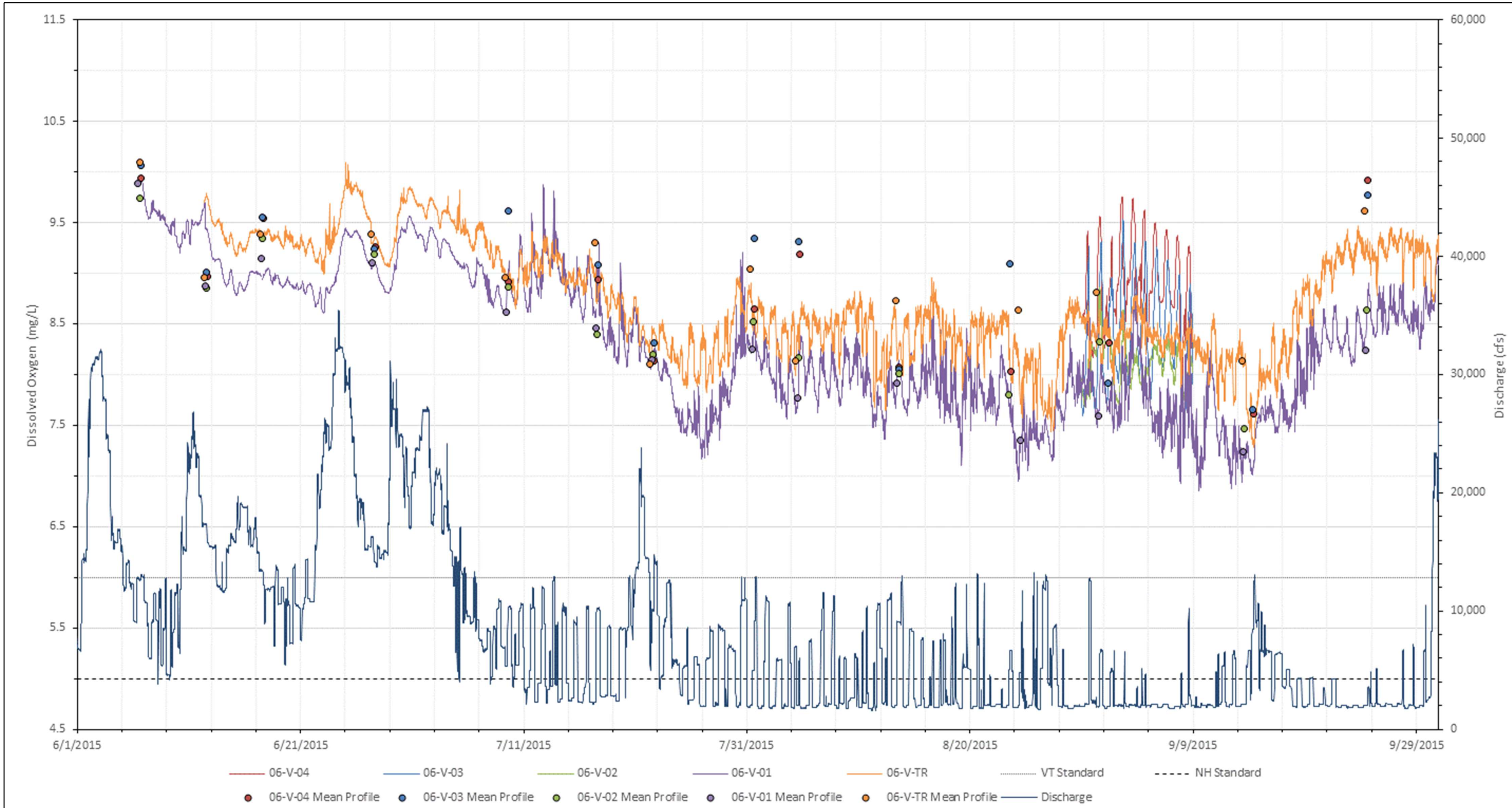

Source: ILP Study 6, *Water Quality Monitoring and Continuous Temperature Monitoring Study* (Louis Berger and Normandeau, 2016a)

Figure 3.5-36. 2015 DO concentrations continuously measured in the Vernon forebay and tailrace, and at all stations during a 10-day, high-temperature, low-flow period with Vernon discharge.

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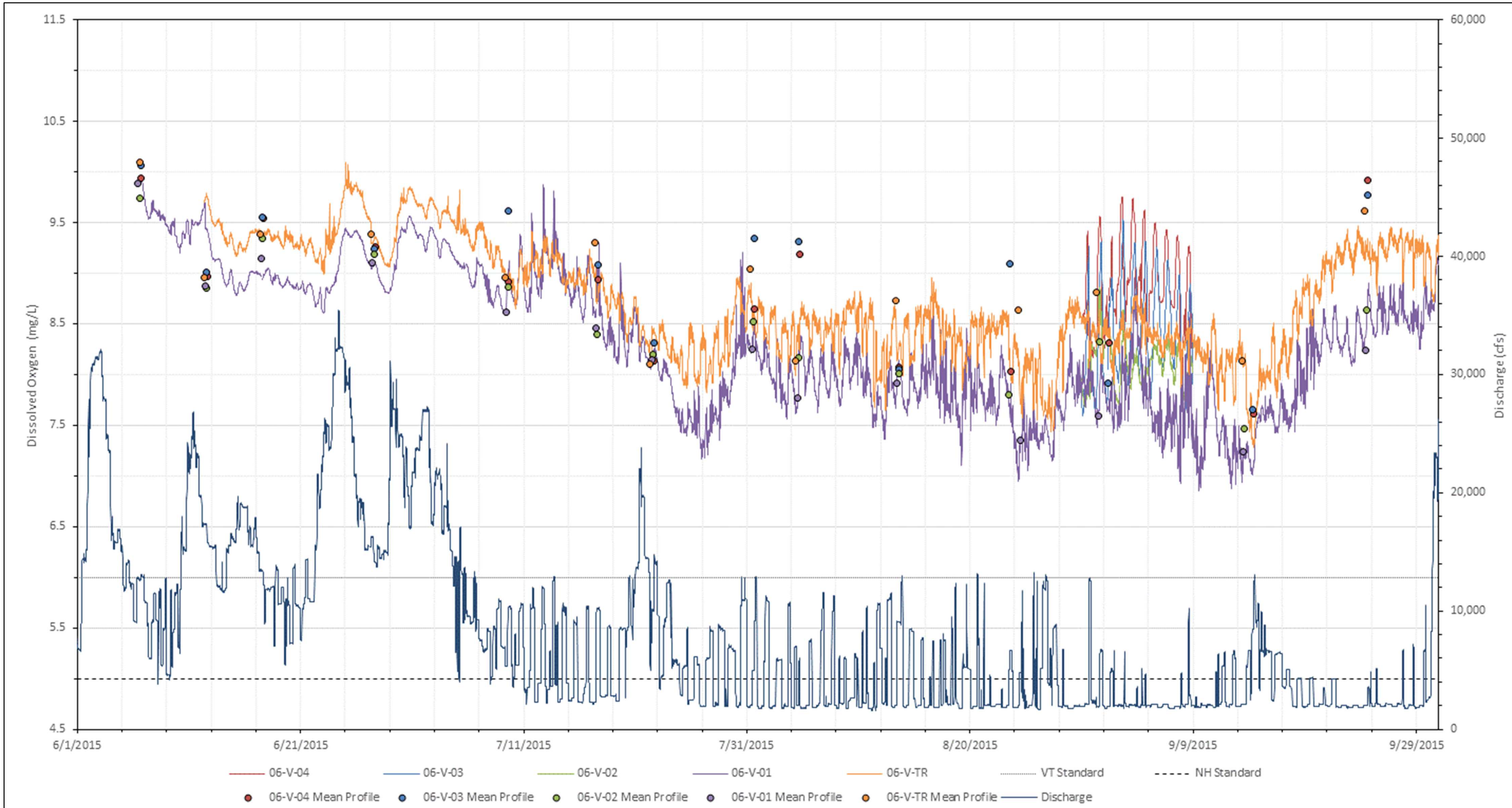

Source: ILP Study 6, *Water Quality Monitoring and Continuous Temperature Monitoring Study* (Louis Berger and Normandeau, 2016a)

Figure 3.5-37. 2015 DO saturation continuously measured in the Vernon forebay and tailrace, and at all stations during a 10-day, high-temperature low-flow period with Vernon discharge.

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Table 3.5-40. Monthly statistics of continuously monitored temperature, specific conductivity, dissolved oxygen, pH, and turbidity in the Vernon forebay in 2015.

Statistic	Jun	Jul	Aug	Sep	All
Temperature (°C)					
Maximum	20.9	25.8	27.2	26.1	27.2
Minimum	15.5	17.4	23.5	18.4	15.5
Median	18.9	23.2	24.9	22.4	23.5
Mean	18.8	22.4	24.9	22.9	22.5
Specific Conductivity (µS/cm)					
Maximum	115	151	159	170	170
Minimum	80	93	129	132	80
Median	96	129	145	152	139
Mean	96	125	145	152	131
Dissolved Oxygen (mg/L)					
Maximum	10.0	9.9	8.7	9.2	10.0
Minimum	8.6	7.2	7.0	6.9	6.9
Median	9.1	8.7	7.9	7.9	8.3
Mean	9.2	8.6	7.9	8.0	8.3
Dissolved Oxygen (% saturation)					
Maximum	104	120	105	111	120
Minimum	94	83	84	82	82
Median	98	99	95	93	96
Mean	98	99	95	93	96
Maximum daily mean	102	109	99	101	109
Minimum daily mean	96	87	89	86	86
pH (standard units)[a]					
Maximum	7.6	8.05	7.9	7.9	8.05
Minimum	7.4	7.3	7.3	7.3	7.3
Median	7.5	7.5	7.6	7.6	7.5
Mean	7.5	7.5	7.6	7.6	7.5
Turbidity (NTU)					
Maximum	32.2	13.9	3.6	22.1	32.2
Minimum	0.0	0.7	0.3	0.2	0.0
Median	1.4	1.9	1.2	1.0	1.4
Mean	3.8	2.5	1.2	1.4	2.1

Source: ILP Study 6, *Water Quality Monitoring and Continuous Temperature Monitoring Study* (Louis Berger and Normandeau, 2016a)

a. Values with two digits after the decimal point are those that exceeded state standard(s).

Table 3.5-41. Monthly statistics for continuously monitored temperature, specific conductivity, dissolved oxygen, pH, and turbidity in the Vernon tailrace in 2015.

Statistic	Jun	Jul	Aug	Sep	All
Temperature (°C)					
Maximum	20.8	25.7	26.4	25.8	26.4
Minimum	17.4	17.4	23.6	18.4	17.4
Median	19.3	23.4	25.0	22.3	23.8
Mean	19.2	22.5	25.0	22.9	22.7
Specific Conductivity (µS/cm)					
Maximum	106	153	156	170	170
Minimum	81	92	127	130	81
Median	91	129	145	153	142
Mean	91	125	144	154	134
Dissolved Oxygen (mg/L)					
Maximum	10.1	9.8	9.0	9.5	10.1
Minimum	9.0	7.8	7.4	7.3	7.3
Median	9.4	8.9	8.4	8.5	8.6
Mean	9.4	8.9	8.4	8.6	8.7
Dissolved Oxygen (% saturation)					
Maximum	110	111	108	108	111
Minimum	98	91	90	86	86
Median	102	103	102	101	102
Mean	102	102	101	100	101
Maximum daily mean	107	109	104	104	109
Minimum daily mean	99	94	94	89	89
pH (standard units)					
Maximum	7.6	7.8	7.7	7.9	7.9
Minimum	7.4	7.4	7.4	7.5	7.4
Median	7.5	7.5	7.5	7.6	7.5
Mean	7.5	7.6	7.6	7.6	7.6
Turbidity (NTU)					
Maximum	35.4	16.3	4.9	19.9	35.4
Minimum	0.0	0.9	0.4	0.1	0.0
Median	1.8	1.8	1.3	1.0	1.4
Mean	5.4	2.6	1.3	1.3	2.4

Source: ILP Study 6, *Water Quality Monitoring and Continuous Temperature Monitoring Study* (Louis Berger and Normandeau, 2016a)

Table 3.5-42. Statistics of temperature, specific conductivity, dissolved oxygen, pH, and turbidity for Vernon Project during the 10-day, high-temperature, low-flow monitoring period in 2015.

Statistic	Station			
	Upstream Riverine 06-V-04	Upper Impound. 06-V-03	Middle Impound. 06-V-02	Forebay 06-V-01
Temperature (°C)				
Maximum	25.9	26.1	25.7	26.1
Minimum	23.8	23.4	24.2	24.4
Median	24.5	24.4	24.7	24.8
Mean	24.5	24.5	24.7	24.9
Specific Conductivity (µS/cm)				
Maximum	184	163	163	152
Minimum	150	136	145	141
Median	165	150	154	146
Mean	166	150	154	146
Dissolved Oxygen (mg/L)				
Maximum	9.8	9.5	8.9	9.0
Minimum	7.9	7.4	7.7	6.9
Median	8.8	8.4	8.1	7.7
Mean	8.7	8.4	8.1	7.8
Dissolved Oxygen (% saturation)				
Maximum	118	117	108	111
Minimum	94	89	92	83
Median	104	100	99	94
Mean	105	101	98	94
Maximum daily mean	109	104	101	101
Minimum daily mean	99	95	95	91
pH (standard units)[a]				
Maximum	8.03	8.01	7.8	7.9
Minimum	7.6	7.6	7.6	7.4
Median	7.7	7.7	7.6	7.6
Mean	7.7	7.8	7.6	7.6
Turbidity (NTU)				
Maximum	7.8	1.8	1.2	2.8
Minimum	0.2	0.4	0.4	0.4
Median	1.2	0.8	0.6	0.9
Mean	1.1	0.7	0.6	0.9

Source: ILP Study 6, *Water Quality Monitoring and Continuous Temperature Monitoring Study* (Louis Berger and Normandeau, 2016a)

a. Values with two digits after the decimal point are those that exceeded state standard(s).

Table 3.5-43. Vertical profile statistics for Vernon Project in 2015.

Statistic	Upstream Riverine 06-V-04	Upper Impound. 06-V-03	Middle Impound. 06-V-02	Forebay 06-V-01	Tailrace 06-V-TR
Mean Water Depth (meters)[a]	2.4	3.3	5.6	16.2	7.4
Temperature (°C)					
Maximum	24.9	25.4	25.9	26.3	25.2
Minimum	16.0	16.1	16.3	15.4	15.9
Median	22.5	22.3	23.1	23.7	24.0
Mean	21.4	21.3	21.7	21.8	23.0
Dissolved Oxygen (mg/L)					
Maximum	10.2	10.3	10.0	9.9	10.1
Minimum	7.6	7.6	7.4	7.1	7.9
Median	8.9	9.3	8.4	8.3	8.9
Mean	8.9	9.2	8.6	8.4	8.9
Dissolved Oxygen (% saturation)					
Maximum	112	114	106	105	112
Minimum	88	88	87	85	95
Median	102	104	98	97	104
Mean	101	103	98	95	103
Specific Conductivity (µS/cm)					
Maximum	167	162	157	157	156
Minimum	86	60	95	84	83
Median	128	130	128	131	138
Mean	126	126	126	127	133
pH (standard units)[b]					
Maximum	8.06	8.0	7.7	7.7	7.8
Minimum	7.4	7.5	7.4	7.3	7.3
Median	7.6	7.6	7.5	7.5	7.6
Mean	7.7	7.6	7.5	7.5	7.6
Turbidity (NTU)					
Maximum	23.0	25.2	27.2	21.3	4.1
Minimum	0.0	0.0	0.0	0.0	0.0
Median	1.5	1.3	0.8	1.3	1.6
Mean	4.0	4.3	2.3	2.0	1.4

Source: ILP Study 6, *Water Quality Monitoring and Continuous Temperature Monitoring Study* (Louis Berger and Normandeau, 2016a)

a. Average of individual depths recorded during each station visit.

b. Values with two digits after the decimal point are those that exceeded state standard(s).

Specific Conductivity

Specific conductivity ranged from 113 to 164 μS/cm in 2012 and from 60 to 184 μS/cm in 2015 (Tables 3.5-37, 3.5-40, 3.5-41, and 3.5-42). In both study years, specific conductivity throughout the Vernon Project area was fairly consistent, although in 2015 specific conductivity levels in the forebay and tailrace generally increased over the monitoring period. In addition, specific conductivity was uniform throughout the water column in both 2012 and 2015 and increased over the deployment period in 2015 (Normandeau, 2013a; Study 6).

pH

In 2012, pH was continuously monitored in the forebay and tailrace and instantaneously during vertical profiles throughout the impoundment (Normandeau, 2013a). In the forebay, pH ranged between 6.7 and 7.9, and in the tailrace, pH ranged between 7.2 and 8.01. At the middle impoundment and upper impoundment stations, pH ranged between 7.1 and 7.6 and between 6.6 and 7.6, respectively (Table 3.5-37). Throughout the water column, pH values were consistent. Over the duration of the 2012 study, pH only exceeded the New Hampshire upper water quality standard in the tailrace for 1.5 hours (range 8.01 to 8.04) on June 21, 2012 (Normandeau, 2013a).

During 2015, pH was also continuously monitored in the forebay and tailrace, measured in vertical profiles, and continuously monitored during the 10-day, high-temperature, low-flow monitoring period throughout the Vernon Project area (Study 6). At the forebay and tailrace stations, pH levels were generally similar and ranged from 7.3 to 8.05 (Tables 3.5-40, 3.5-41, and 3.5-43). At the middle and upper impoundment and upstream stations, pH ranged from 7.4 to 8.06. As in 2012, pH values were consistent throughout the water column. The pH time-series for all stations during the 10-day, high-temperature, low-flow monitoring period showed well-defined diel fluctuations in pH levels at the upstream and upper impoundment stations, and less pronounced or no diel fluctuations in pH at the middle impoundment and forebay stations, respectively (see Study 6, Appendix J).

Turbidity

In 2015, turbidity was monitored continuously in the Vernon forebay and tailrace and at all impoundment and upstream riverine stations during the 10-day, high-temperature, low-flow monitoring period. In addition, turbidity was also measured during the collection of vertical profiles. Turbidity was generally low but increased during precipitation events (Figure 3.5-38). Turbidity ranged from 0.0 to 32 NTU in the forebay, and from 0.0 to 35 NTU in the tailrace (Tables 3.5-40, 3.5-41, and 3.5-43). Turbidity levels were uniform throughout the water column, except during or shortly after high flow and precipitation events, when turbidity varied throughout the water column. At the middle impoundment and upper impoundment stations, turbidity levels ranged between 0.0 and 27 NTU and 0.0 and 25 NTU, respectively (Table 3.5-43). At the upstream riverine station, turbidity ranged between 0.0 and 23 NTU (Table 3.5-43).

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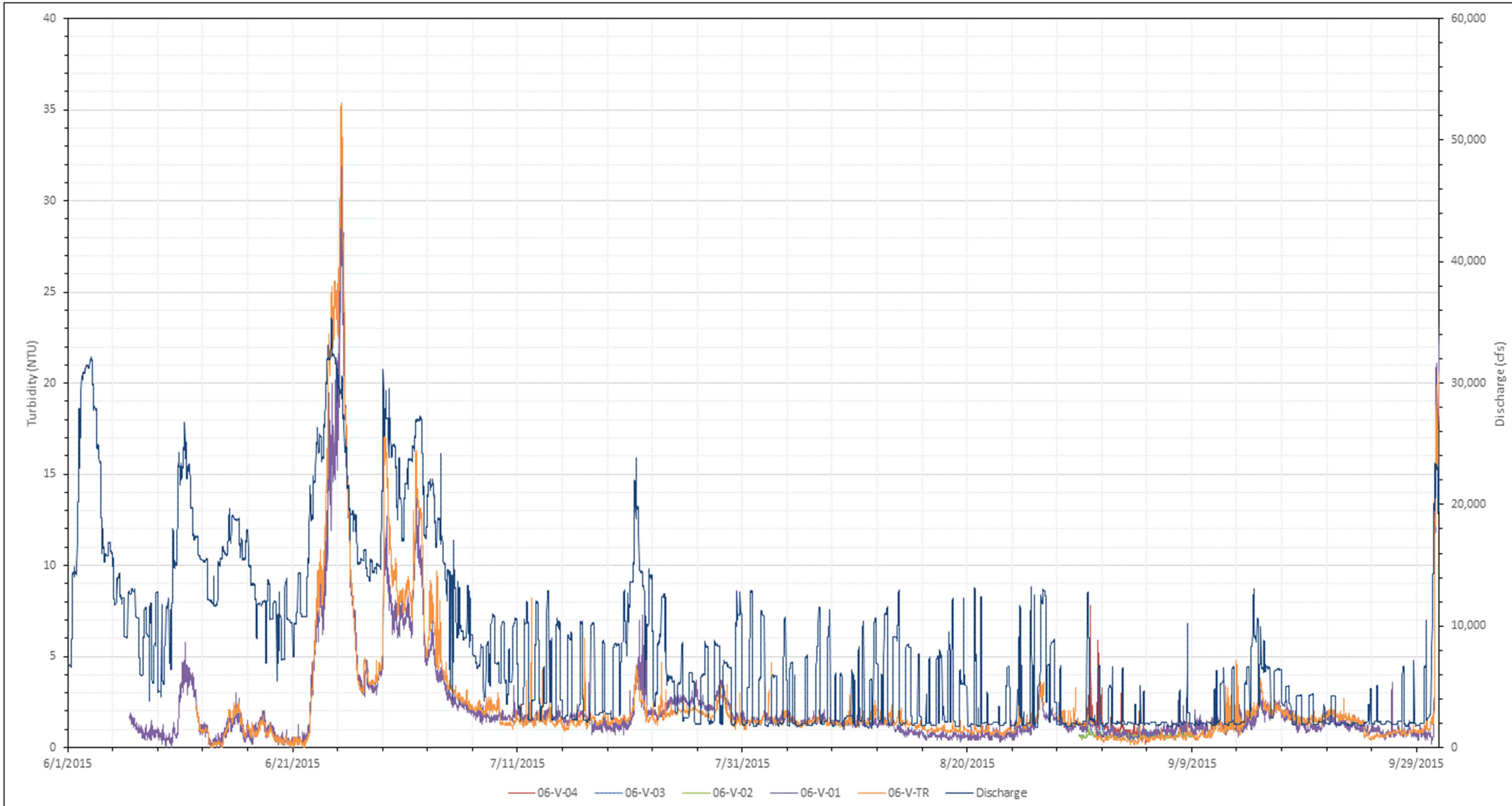

Source: ILP Study 6, *Water Quality Monitoring and Continuous Temperature Monitoring Study* (Louis Berger and Normandeau, 2016a)

Figure 3.5-38. 2015 turbidity measured in the Vernon forebay and tailrace, and at all stations during a 10-day, high-temperature, low-flow period with Vernon discharge.

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Nutrients and Chlorophyll-a

In 2012 and 2015, total nitrogen, total phosphorus, nitrate/nitrite, total Kjeldahl nitrogen, and chlorophyll-*a* concentrations were measured in a water column composite sample in the Vernon forebay. As was observed for the Wilder and Bellows Falls Projects, concentrations did not show a pronounced seasonal pattern at the Vernon Project. In 2012, mean nitrate/nitrite and total phosphorus concentrations were 0.20 and 0.020 mg/L, respectively (Table 3.5-44). Chlorophyll-*a* concentrations ranged from 2.0 to 5.9 mg/m^3 with a mean of 3.5 mg/m^3. In 2015, concentrations were similar. Mean nitrate/nitrite and total phosphorus concentrations were 0.13 and 0.019 mg/L, respectively (Table 3.5-45). Chlorophyll-*a* concentrations ranged from 0.7 to 9.0 mg/m^3 with a mean of 2.9 mg/m^3.

Table 3.5-44. Nutrient and chlorophyll-*a* concentrations in the Vernon forebay in 2012.

Date	Total Nitrogen (mg/L)	Total Phosphorus (mg/L)	Nitrate/Nitrite (mg/L)	Total Kjeldahl Nitrogen (mg/L)	Chlorophyll-*a* (mg/m^3)
7/12/2012	0.55	0.013	0.16	0.39	5.9
7/19/2012	0.75	0.058	0.20	0.55	4.2
7/26/2012	0.62	0.013	0.21	0.41	2.7
8/2/2012	0.63	0.010	0.23	0.40	2.2
8/9/2012	0.66	0.009	0.24	0.42	4.4
8/16/2012	0.69	0.038	0.18	0.51	3.8
8/24/2012	0.67	0.014	0.20	0.47	3.5
8/30/2012	0.58	0.013	0.20	0.38	3.6
9/6/2012	0.72	0.019	0.20	0.52	2.0
9/13/2012	0.68	0.013	0.21	0.47	3.1
Maximum	0.75	0.058	0.24	0.55	5.9
Minimum	0.55	0.009	0.16	0.38	2.0
Median	0.67	0.013	0.20	0.45	3.6
Mean	0.66	0.020	0.20	0.45	3.5

Source: Normandeau (2013a)

Table 3.5-45. Nutrients and chlorophyll-*a* concentrations in the Vernon forebay in 2015.

Date	Total Nitrogen (mg/L)	Total Phosphorus (mg/L)	Nitrate/ Nitrite (mg/L)	Total Kjeldahl Nitrogen (mg/L)	Chlorophyll-*a* (mg/m^3)
6/6/2015	<0.50	0.013	0.12	<0.50	0.7
6/12/2015	<0.50	0.021	0.13	<0.50	0.8
6/17/2015	<0.50	0.018	0.13	<0.50	1.1
6/27/2015	<0.50	0.019	0.09	<0.50	1.1
7/9/2015	<0.50	0.012	0.13	<0.50	1.1
7/17/2015	<0.50	0.009	0.14	<0.50	2.9
7/22/2015	1.04	0.011	0.14	0.90	1.1
7/31/2015	0.82	0.009	0.12	0.70	2.4
8/4/2015	0.72	0.009	0.12	0.60	4.6
8/13/2015	<0.50	0.023	0.14	<0.50	4.3
8/24/2015	0.88	0.009	0.18	0.70	3.2
8/31/2015	<0.50	0.010	0.14	<0.50	3.2
9/13/2015	<0.50	0.019	0.18	<0.50	4.0
9/24/2015	<0.50	0.008	0.13	<0.50	4.6
10/2/2015	0.81	0.096	0.11	0.70	9.0
Maximum	1.04	0.096	0.18	0.90	9.0
Minimum	<0.50	0.008	0.09	<0.50	0.7
Median	<0.50	0.012	0.13	<0.50	2.9
Mean[a]	0.45	0.019	0.13	0.41	2.9

Source: ILP Study 6, *Water Quality Monitoring and Continuous Temperature Monitoring Study* (Louis Berger and Normandeau, 2016a)

a. For values below the detection limit of 0.5 mg/L, a concentration of 0.25 mg/L was assumed for mean calculations for the associated analyte.

Tributaries

In 2015, water temperature was also continuously monitored in the 10 largest tributaries to the Connecticut River in the Project areas (Study 6). These tributaries were the Waits, Ompompanoosuc, White, Mascoma, Sugar, Black, Williams, Saxtons, Cold, and the West rivers. Water temperature trends were similar among the 10 tributaries; slightly cooler temperatures were observed in northern tributaries and warmer temperatures observed in southern tributaries (Table 3.5-46). The mean temperature in the two coldest tributaries—the Waits and Ompompanoosuc rivers—was 13.5 and 14.4°C, respectively. The mean temperature in the southernmost tributary, the West River, was 18.2°C.

Table 3.5-46. Monthly water temperatures in tributaries in 2015.

Temperature (°C)	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	All
Waits River (06-W-T02)									
Maximum	11.9	22.7	21.3	25.0	25.7	24.9	13.8	11.2	25.7
Minimum	0.0	5.4	9.7	12.8	15.4	11.6	2.3	2.7	0.0
Median	3.1	14.5	15.4	18.5	19.9	18.0	8.8	6.6	14.9
Mean	3.2	14.6	15.4	18.6	20.0	17.8	8.6	6.5	13.5
Ompompanoosuc River (06-W-T01)									
Maximum	9.7	23.2	21.7	25.8	26.4	24.6	14.7	11.4	26.4
Minimum	0.6	7.6	11.0	14.1	15.9	10.3	3.0	3.1	0.6
Median	4.8	14.2	16.3	19.3	20.4	17.8	9.5	7.1	15.5
Mean	4.8	14.3	16.1	19.4	20.5	17.8	9.1	7.0	14.4
White River (06-BF-T05)									
Maximum	10.2	27.4	22.6	28.6	29.2	29.4	15.4	11.2	29.4
Minimum	1.2	8.7	10.8	15.2	19.4	14.5	5.1	4.4	1.2
Median	5.4	15.3	17.2	21.7	23.5	21.2	10.6	7.7	16.9
Mean	5.3	15.5	16.9	21.4	23.5	21.2	10.4	7.8	16.1
Mascoma River (06-BF-T04)									
Maximum	9.3	25.3	24.0	28.6	28.3	27.3	17.8	12.1	28.6
Minimum	0.2	6.9	14.3	18.5	19.7	13.5	7.2	6.0	0.2
Median	3.8	15.0	19.2	22.6	23.4	21.0	12.2	8.9	17.6
Mean	3.8	15.0	19.2	22.7	23.4	20.4	12.3	9.0	16.1
Sugar River (06-BF-T03)									
Maximum	11.3	24.8	24.4	29.1	28.0	28.0	16.0	11.9	29.1
Minimum	0.5	9.0	12.6	16.9	20.7	14.3	5.0	4.4	0.5

Temperature (°C)	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	All
Median	5.8	16.9	20.3	23.0	23.7	20.1	11.3	8.2	18.0
Mean	5.5	17.3	19.6	22.9	23.8	20.2	10.7	8.1	16.9
Black River (06-BF-T02)									
Maximum	10.4	25.0	24.0	28.4	27.5	25.6	15.8	11.3	28.4
Minimum	0.3	8.7	13.3	16.7	19.7	13.6	6.3	2.9	0.3
Median	5.1	16.9	19.4	23.1	23.1	23.4	20.2	11.0	17.7
Mean	4.7	17.1	19.3	22.8	23.4	20.0	10.6	7.9	16.2
Williams River (06-BF-T01)									
Maximum	11.6	25.0	23.5	28.8	27.8	26.2	14.9	12.3	27.8
Minimum	0.2	7.5	11.2	14.6	17.4	11.7	4.7	3.8	0.2
Median	4.7	16.0	18.1	21.3	21.9	18.7	10.3	7.8	16.4
Mean	4.7	16.0	17.9	21.1	21.9	18.7	9.8	7.6	15.2
Saxtons River (06-V-T03)									
Maximum	12.5	24.9	25.3	26.9	26.3	25.2	15.1	13.2	26.9
Minimum	0.1	7.5	11.3	14.9	17.1	11.6	3.6	3.1	0.1
Median	5.0	16.2	18.5	21.2	21.7	18.8	10.2	7.8	16.3
Mean	4.9	16.2	18.3	20.9	21.7	18.6	9.8	7.7	15.0
Cold River (06-V-T02)									
Maximum	11.1	24.9	25.0	28.0	27.4	25.8	15.7	13.1	28.0
Minimum	-0.1	6.7	11.0	15.1	16.3	10.8	4.6	3.0	-0.1
Median	4.4	15.5	17.8	20.8	21.2	18.3	10.2	7.6	16.6
Mean	4.3	15.4	17.9	20.8	21.3	18.4	10.1	7.6	15.0
West River (06-V-T01)									
Maximum	12.0	27.3	27.4	31.4	30.1	29.6	16.9	12.9	31.4
Minimum	3.5	8.6	11.9	15.9	19.0	13.5	4.7	3.4	3.4
Median	7.2	18.1	20.0	23.6	24.2	20.6	10.8	8.1	19.4
Mean	7.6	18.0	19.8	23.3	24.2	21.0	10.7	8.0	18.2

Source: ILP Study 6, *Water Quality Monitoring and Continuous Temperature Monitoring Study* (Louis Berger and Normandeau, 2016a)

3.5.2 Environmental Effects

3.5.2.1 No-action Alternative

Water Quantity

Continued operation of the Wilder, Bellows Falls, and Vernon Projects will result in daily and sub-daily fluctuations in impoundment WSEs and discharge flows that have the potential to have short-term effects on water quantity in the impoundments and Project-affected riverine reaches downstream of each Project dam as defined in Section 3.1, *General Setting*. Water quantity effects (defined as flow magnitude, flow frequency, flow duration, flow timing, and rate of change in FERC's SD2) from Project operations are related to, and dependent on, current license limitations, available inflows from upstream projects, additional inflows resulting from precipitation events within the watershed, generating capacity, regional demand, and energy prices. Fluctuations in impoundment water levels, particularly in the upper extent are associated primarily with changes in daily and sub-daily inflows because the Projects have limited impoundment storage capacity. Great River Hydro is not proposing to change current operations and will continue to operate within existing license constraints and the narrower, voluntary operational parameters (see for each Project, Sections 2.1.1.5, 2.1.2.5, and 2.1.3.5, *Existing Environmental Measures*) 3.4.4.1, that collectively include normal and recreation-related impoundment water level fluctuation limits, limits on rates of impoundment level change, higher than licensed minimum flows, and supplemental flows for upstream and downstream fish passage. Therefore, existing water quantity effects will continue under the new licenses.

Water Quality

Evaluation of Project effects on water quality was based on data from deployed temperature loggers and multiparameter sondes, vertical profile measurements, and nutrient and chlorophyll-*a* analyses as a part of Study 6, as well as other relevant information as appropriate.

Temperature

New Hampshire surface water quality standards require that any increase in temperature shall not be such to appreciably interfere with the designated uses of Class B waters. Vermont surface water quality standards state the change or rate of change in temperature, either upward or downward, shall be controlled to ensure full support of aquatic biota, wildlife, and aquatic habitat uses and the total increase from ambient temperature due to all discharges and activities shall not exceed 1°F (0.56°C) from ambient temperatures, except for the assimilation of thermal waste as permitted by the Secretary (see Section 3.5.1.2, *Water Quality*, *Surface Water Quality Standards and Designated Uses*).

Continuous water temperature monitoring conducted for Study 6 demonstrated that water temperatures generally and gradually increase from the upstream riverine areas to the Project dams and tailraces. This progressive, gradual downstream warming often is observed over large spatial scales in river systems (Wetzel, 2001); however, it is unknown to what magnitude the gradual warming may be attributed to effects of the impoundments, latitude, weather, and tributary contributions. For example, river temperatures vary in relationship to air temperatures and often exhibit a strong linear relationship with some time lag (Wetzel, 2001). The continuous mainstem temperature data show that upstream riverine stations respond more quickly to changes in air temperature than lower impoundment and tailrace stations (Study 6) because the upstream riverine areas are shallower with swift currents that facilitate the addition and loss of heat energy through convection and conduction with the atmosphere, streambed, and banks, resulting in downstream impoundment and tailrace stations being either warmer or cooler relative to the respective upstream riverine area at any given time. Subsequently, the larger daily swings in water temperatures that closely follow air temperatures and weather at the shallow upstream riverine areas result in occasional exceedance of the Vermont surface water quality standard for temperature, especially over the long longitudinal distances between the upstream riverine areas and the Project dams. When air temperatures are consistent for a long period or gradually warm and cool, mainstem water temperatures throughout the Project impoundments and tailraces become similar and the Vermont surface water quality standard is attained under existing Project operations (see Study 6, Appendix P).

Within the Project impoundments in a given day, the WSE at the dams exhibited either a single maximum and minimum level, multiple maxima and minima, or relatively no change (Figure 3.5-39 through Figure 3.5-41; see also Study 6, Appendix O). The data indicate that the water temperature fluctuates over the course of each day as does the WSE, inflow and discharge; however, water temperatures in the impoundments during the study period did not correlate well with WSE fluctuations measured at the dams. Water temperatures in the impoundments consistently exhibited diurnal fluctuations regardless of WSE fluctuations or lack thereof (either single or multiple daily maxima or minima or relatively no change for a given day). This is most notable at the upstream and upper impoundment stations. At the middle impoundment and forebay stations diurnal fluctuations in water temperature were comparatively small but also did not appear to respond to changes in the WSE. When the WSE did not fluctuate, water temperatures at all stations exhibited similar patterns to periods when the WSE fluctuated. This suggests WSE fluctuations have a negligible effect on water temperature throughout the Project areas and that water temperature patterns are driven by factors other than normal Project operations, such as weather and longitudinal effects.

The continuous water temperature loggers and continuous water quality multiparameter sondes deployed in the forebays and tailraces allow for the assessment of Project effects on water temperature as water is passed through the powerhouse for generation and discharged into the tailrace. Between the Project forebays and tailraces water temperatures were generally similar (Figure 3.5-26, Figure 3.5-30, and Figure 3.5-35), and overall mean water temperatures differed by −0.07°C at Wilder, −0.31°C at Bellows Falls, and 0.10°C at Vernon (Table 3.5-19, Table 3.5-28, and 3.5-38). Any effects of Project generation on water temperature were generally indistinguishable from daily water temperature fluctuations (see Study 6, Appendix F). During the 10-day, high-temperature, low-flow monitoring period, effects of Project generation and minimum flow operations on water temperature became more apparent; water temperatures generally increased very slightly during high generation flows and decreased very slightly when only minimum flows were being passed (Figure 3.4-42).

The effect of Project operations on water temperature in the tailraces partly depends on temperatures throughout the water column in the forebay, the depth of the water column from which water is being withdrawn for generation, and whether the water column is thermally stratified. Thermal stratification occurs when surface waters are heated more rapidly than the heat is distributed by mixing, which typically occurs during warm, calm periods of several days or more. In 2015, the Wilder, Bellows Falls, and Vernon Project areas were generally well mixed with some surfacing warming and weak, brief stratification at the Bellows Falls middle impoundment station (Study 6, Appendix H). With a well-mixed water column, water temperatures in the tailraces will reflect forebay temperatures. However, in 2012, short and temporary periods of thermal stratification (over a period of 7 days in mid-July at Wilder forebay, and 1 day each in the same period at Bellows Falls, and Vernon forebays), resulted in slightly cooler temperatures in the Project tailraces (see Study 6, Appendix L; Normandeau, 2013a). Therefore, when the impoundments are thermally stratified in the vicinity of the forebays, slightly cooler temperatures are expected to be discharged into the tailraces via generation; otherwise, tailrace temperatures will reflect temperatures of the forebays.

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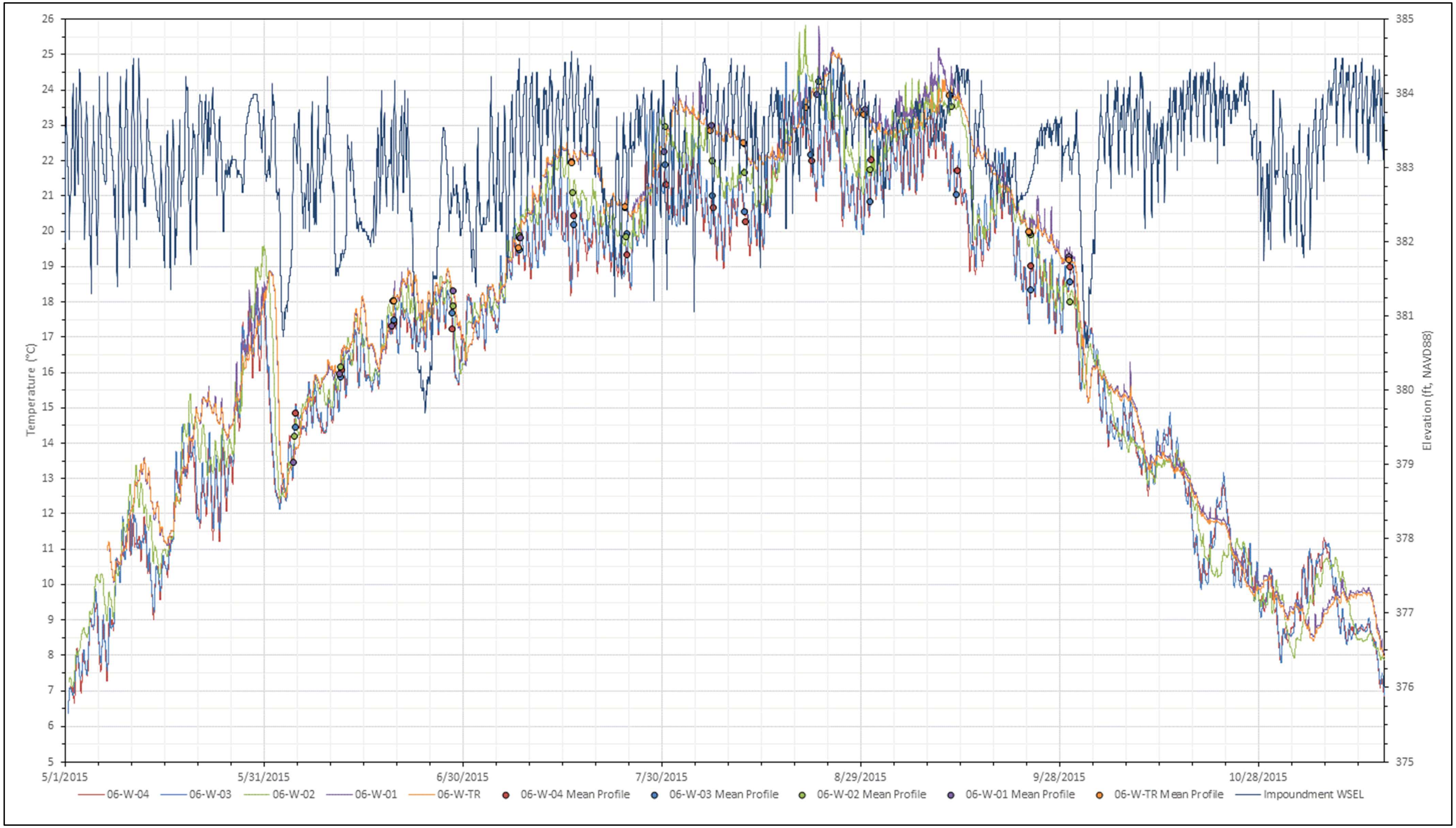

Source: ILP Study 6, *Water Quality Monitoring and Continuous Temperature Monitoring Study* (Louis Berger and Normandeau, 2016a)

Figure 3.5-39. Wilder continuous water temperatures observed during spring, summer, and fall 2015 with Wilder impoundment water surface elevations.

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Source: ILP Study 6, *Water Quality Monitoring and Continuous Temperature Monitoring Study* (Louis Berger and Normandeau, 2016a)

Figure 3.5-40. Bellows Falls continuous water temperatures observed during spring, summer, and fall 2015 with Bellows Falls impoundment water surface elevations.

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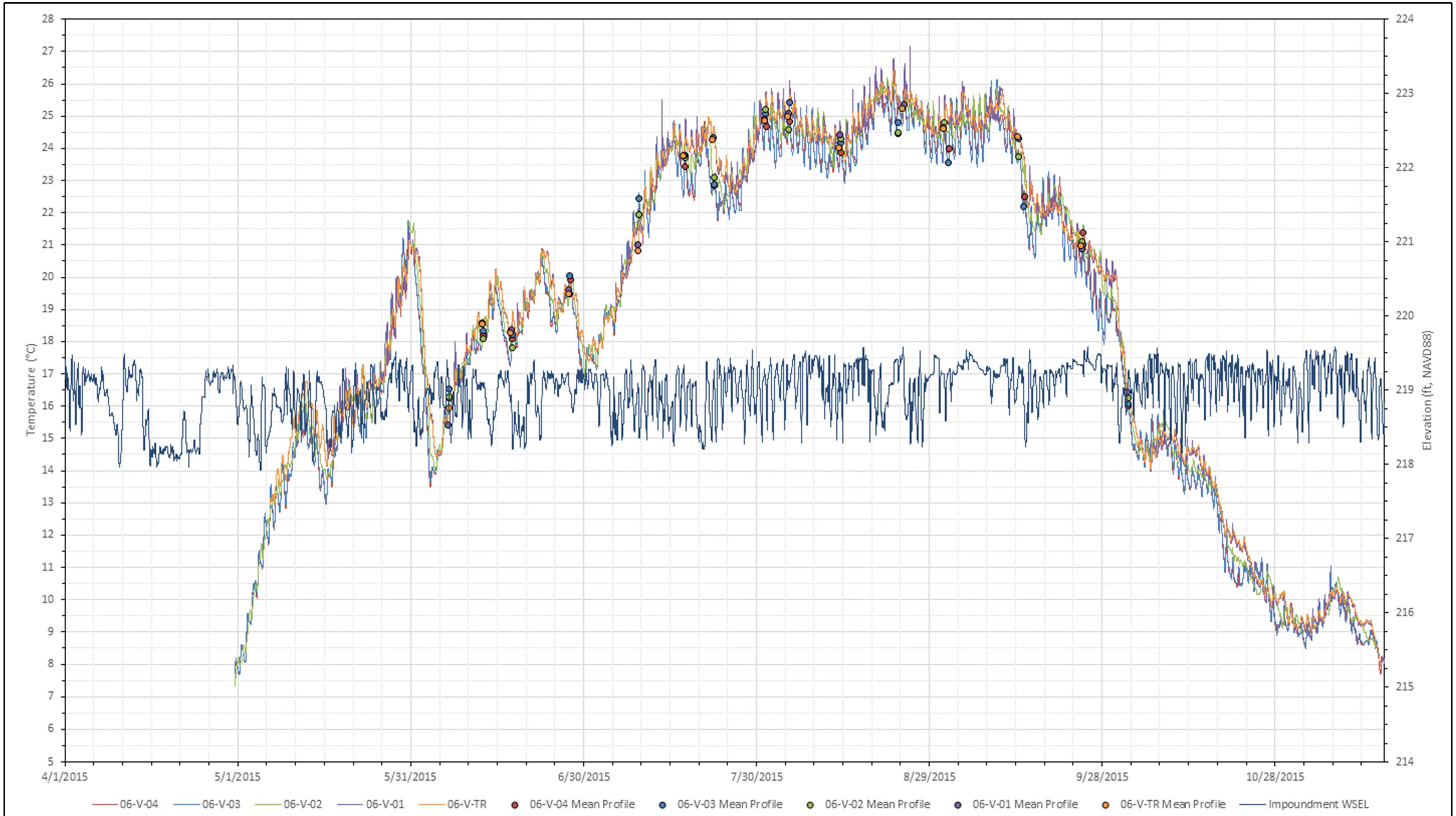

Source: ILP Study 6, *Water Quality Monitoring and Continuous Temperature Monitoring Study* (Louis Berger and Normandeau, 2016a)

Figure 3.5-41. Vernon continuous water temperatures observed during spring, summer, and fall 2015 with Vernon impoundment water surface elevations.

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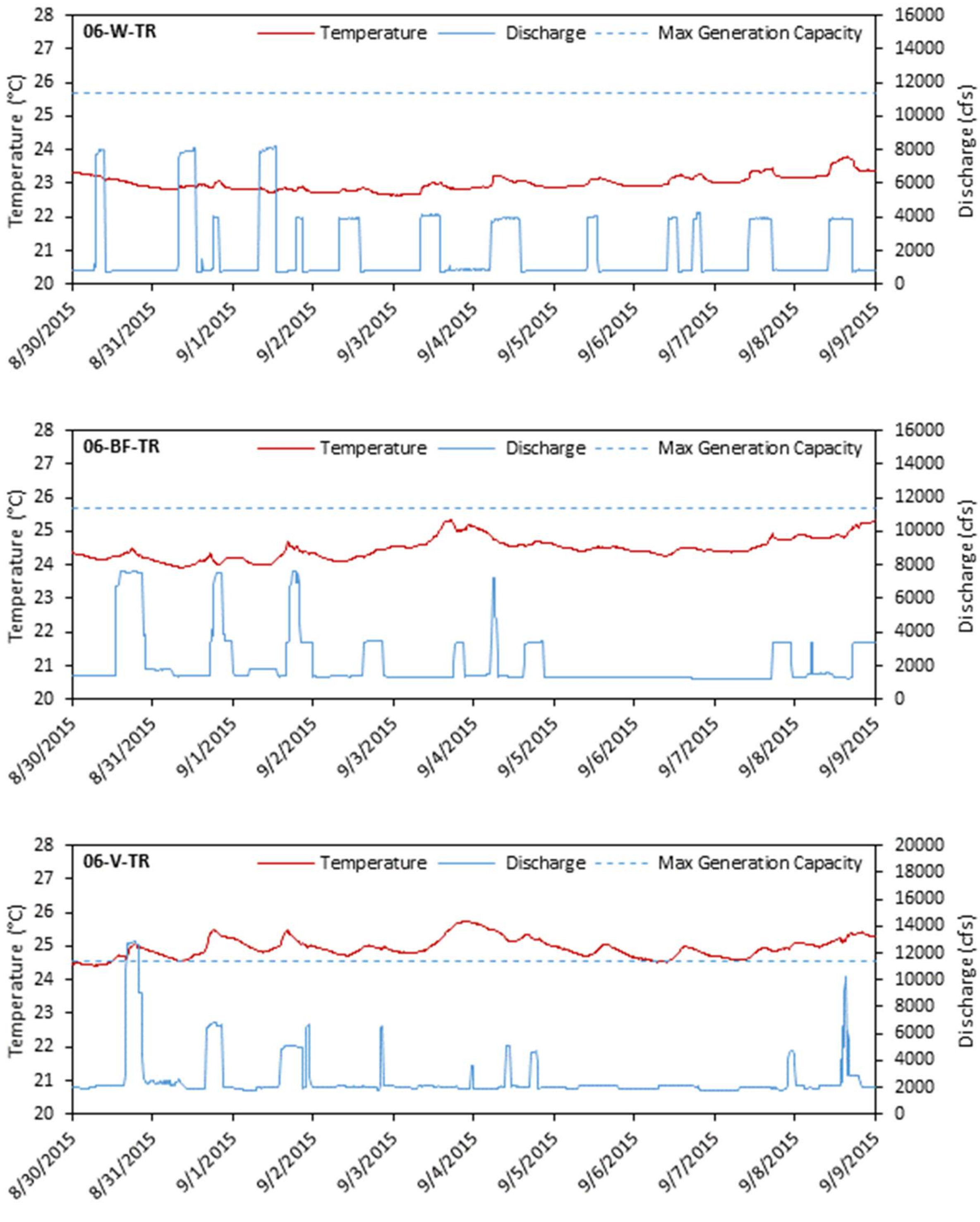


Source: ILP Study 6, *Water Quality Monitoring and Continuous Temperature Monitoring Study* (Louis Berger and Normandeau, 2016a)

Figure 3.5-42. Tailrace water temperatures and discharges at the Wilder, Bellows Falls, and Vernon Projects during the 10-day, high-temperature, low-flow period in 2015.

Overall, continued Project operations would support and maintain both states' designated uses for Class B waters as any increase in temperature from upstream riverine areas to the Project dams will be gradual over the 46-, 29-, and 30-river mile Project areas for the Wilder, Bellows Falls, and Vernon Projects, respectively. Temperature increases of more than 1 degree Fahrenheit (°F) (0.56°C) can occur when weather and climate conditions are conducive, such as those observed during 2015 (Study 6). Thermal stratification can occur in each Project forebay during an atypical warm year such as 2012, but will likely be intermittent and short in duration, and will likely result in slightly cooler temperatures in the Project tailraces from cool hypolimnetic waters.

Dissolved Oxygen

New Hampshire surface water quality standards for Class B waters require that DO concentrations do not fall below 5.0 mg/L, have a daily average of at least 75 percent saturation, and support all designated uses (Table 3.5-6). Vermont regulations specify that Class B coldwater habitat DO levels are not less than 6 mg/L and 70 percent saturation at all times and support designated uses (Table 3.5-7).

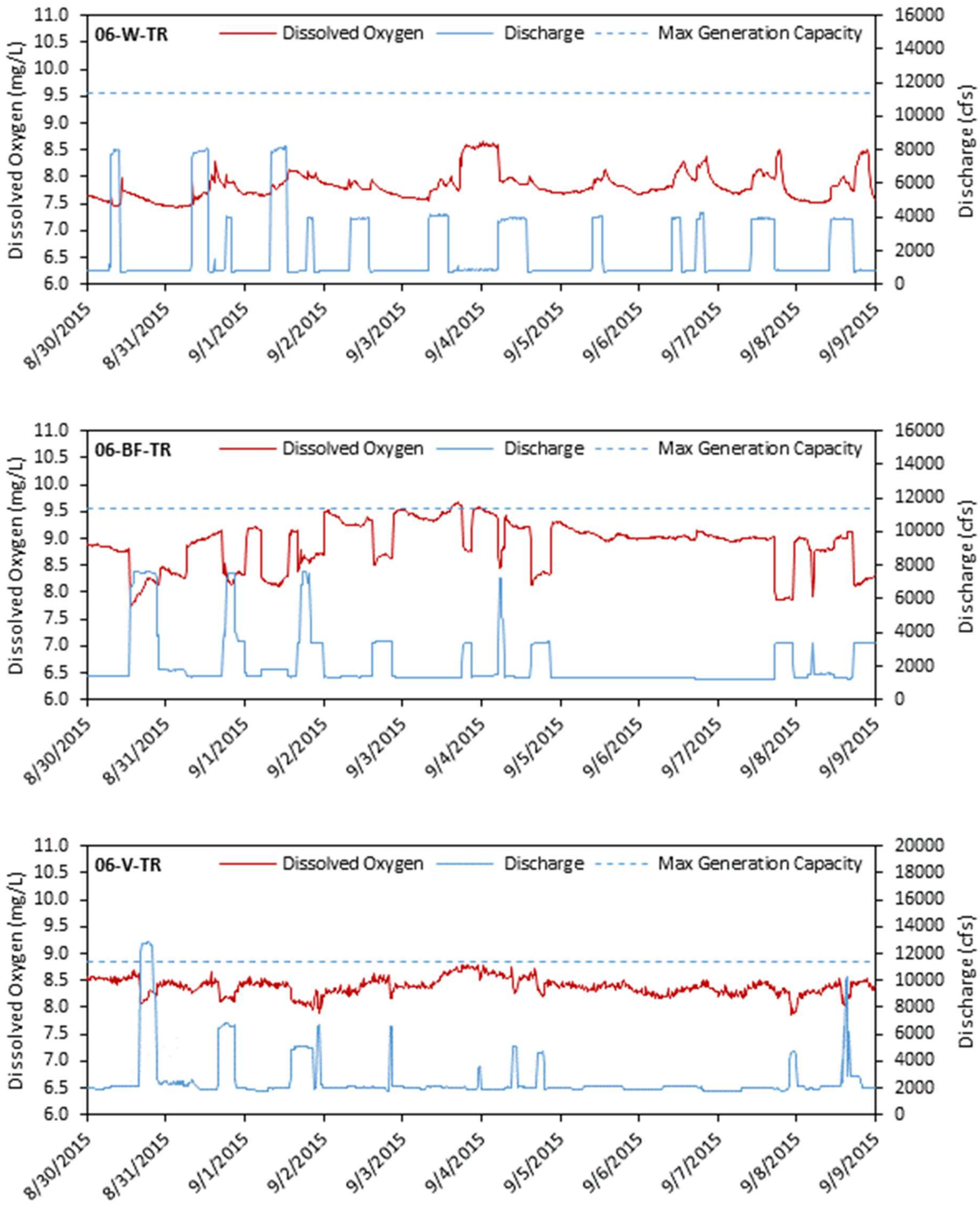
Among the three Projects, DO demonstrated seasonal trends over the 2015 study period, starting relatively high in June and decreasing through the summer because of lower oxygen solubility at higher water temperatures. DO levels reached their lowest point in mid-September prior to increasing again with decreasing water temperatures. DO levels were also observed to slightly decrease as waters flow from upstream areas through the Project impoundments. In 2015, DO levels throughout the water column and study area were above both New Hampshire and Vermont water quality standards at all times. However, in 2012, DO levels in the Wilder and Bellows Falls forebays fell below surface water quality standards (Normandeau, 2013a; Study 6). In the Wilder forebay, the minimum instantaneous DO concentration recorded was 5.7 mg/L and occurred on August 12, 2012; no other exceedances were observed. The instantaneous DO concentrations recorded in the hypolimnion of the Bellows Falls forebay that exceed state standards ranged from 3.3 to 5.9 mg/L, which occurred on a single day of July 18, 2012. Also, within the Bellows Falls forebay DO concentrations fell below state standards briefly on July 23, 2012 where a single value of 5.9 mg/L was measured.

In 2015, DO levels were slightly lower in the Bellows Falls and Vernon forebays than in the tailraces, but they were slightly higher at Wilder in the forebay than in the tailrace. The overall mean decreases in DO levels between the Wilder forebay and tailrace were 0.2 mg/L and 0.2 percent saturation at Wilder (Tables 3.5-20 and 3.5-21), 0.5 mg/L and 6.0 percent saturation at Bellows Falls (Tables 3.5-29 and 3.5-31), and 0.4 mg/L and 5.2 percent saturation at Vernon (Tables 3.5-40 and 3.5-41). In 2012 and 2015, it was generally observed that during periods of high generation flows and no spill, tailrace DO levels abruptly decreased coincident with increasing discharge, but they also abruptly increased when discharges decreased quickly (see Study 6, Appendix F). In 2015, this effect was observed in the tailraces of all three Projects but was most prominent in the Bellows Falls tailrace where DO levels generally decreased by about 1.0 mg/L when generation discharges increased, and DO levels increased quickly by about 1.0 mg/L when discharges decreased. However, DO levels within the Wilder tailrace increased as a result of increasing discharge and decreased with decreasing discharge during the 10-day high-temperature low flow monitoring period (Figure 3.5-43). In the instances in 2012 when DO levels fell below state surface water quality standards in the forebay hypolimnion at Wilder (Vermont standard only) and at Bellows Falls (New Hampshire and Vermont standards), Project discharges remained well oxygenated regardless of increasing or decreasing Project discharges (Normandeau, 2013a; Study 6). This suggests that low DO levels occurring during brief periods of stratification become re-oxygenated when passed through the powerhouses for generation and that designated uses and state surface water quality standards will be maintained downstream with continued Project operations.

Overall, under existing Project operating conditions, DO levels in Project-affected areas are generally above surface water quality standards of both New Hampshire and Vermont. The 2012 data suggest that only under atypical, low-flow, warm-weather conditions, as was observed in 2012, thermal stratification can occur resulting in potential low-DO levels below state surface water quality standards in hypolimnetic waters of the forebay. This can result in more frequent exceedances of the more stringent Vermont surface water quality standard (6 mg/L) than of the New Hampshire surface water quality standard (5 mg/L). However, as water is passed through the Project powerhouses, it becomes re-oxygenated and state surface water quality standards will be maintained in downstream reaches of the Connecticut River.

Specific Conductivity

Neither New Hampshire nor Vermont has a state surface water quality standard for specific conductivity. In the 2012 and 2015 study years, when specific conductivity was continuously recorded and measured during the collection of vertical profiles, specific conductivities throughout the Project areas ranged from 62 to 184 µS/cm. Both studies determined that specific conductivity levels did not vary in response to changes in levels of generation between the Project forebays and tailraces (Normandeau, 2013a; Study 6). Therefore, levels of specific conductivity will likely reflect existing conditions with continued Project operations.



Source: ILP Study 6, *Water Quality Monitoring and Continuous Temperature Monitoring Study*

Figure 3.5-43. Tailrace dissolved oxygen and discharges at Wilder, Bellows Falls, and Vernon Projects during the 10-day, high-temperature, low-flow period in 2015.

pH

New Hampshire surface water quality standards for Class B waters require that pH levels remain between 6.5 and 8.0 standard units, unless due to natural causes, and that pH does not affect any designated uses. Similarly, the Vermont surface water quality standard for pH in Class B waters requires pH levels to remain between 6.5 and 8.5 standard units, and the change and the rate of change in pH must be controlled so as to not affect designated uses (see Section 3.5.1.2, *Water Quality*, *Surface Water Quality Standards and Designated Uses*).

At the Wilder and Vernon forebays, pH infrequently exceeded the more stringent upper New Hampshire pH standard, and at the Bellows Falls upstream riverine and impoundment stations, pH in 2015 most frequently exceeded the New Hampshire standard in August and September but was never observed to fall below the lower pH standard of 6.5. Most of the observed exceedances occurred during the 10-day, high-temperature, low-flow monitoring period at the upstream riverine and upper impoundment areas where pH exhibited large diel fluctuations relative to lower impoundment and forebay areas (see Study 6, Appendix J). At the Bellows Falls middle impoundment station, pH barely exceeded the upper Vermont surface water quality standard of 8.5 on September 7 and September 8, 2015. Specifically, on September 7, the highest pH value was 8.56 for a few hours in late afternoon; on September 8, the highest pH value was 8.55.

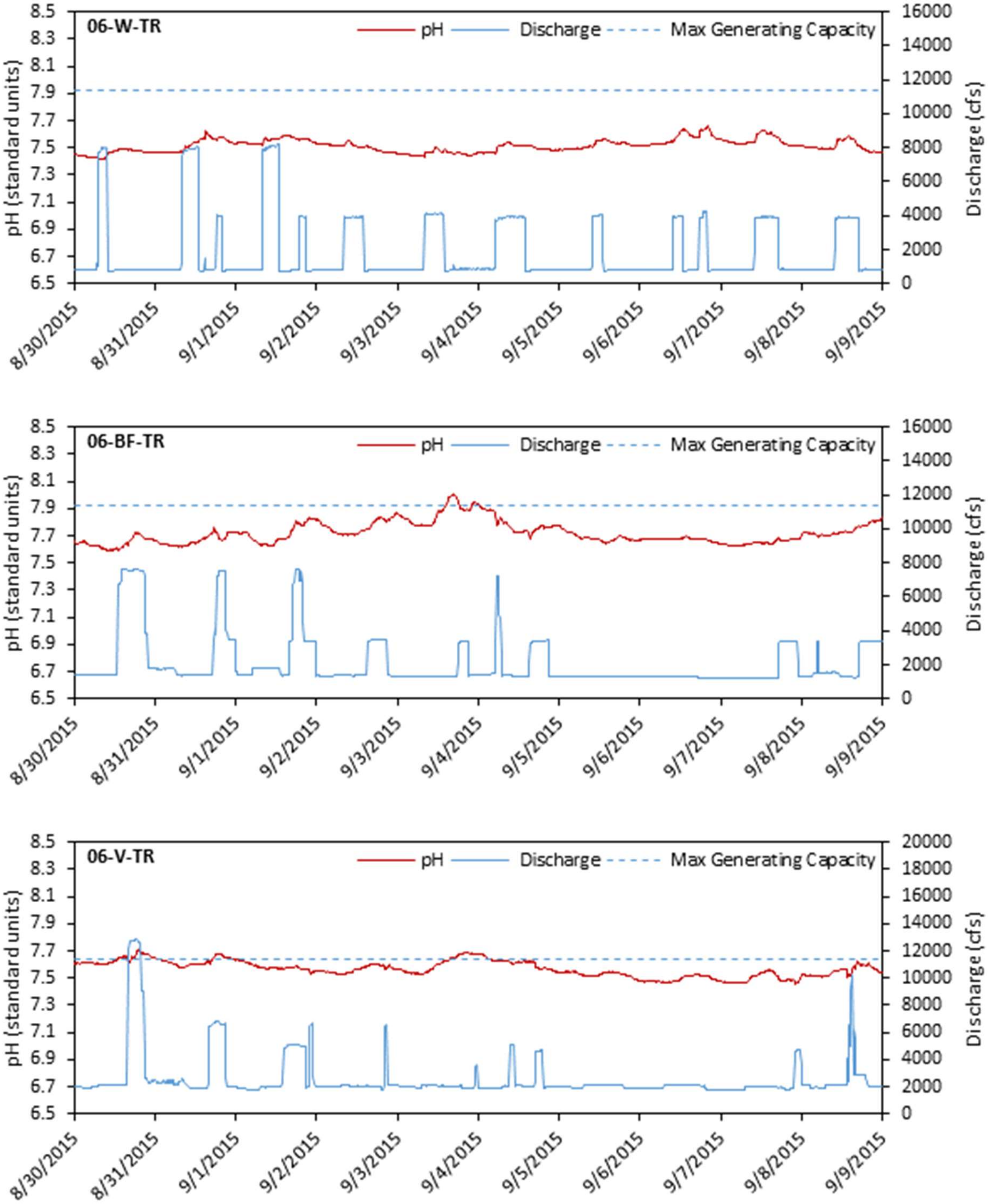
In 2012, pH values were observed to fall below both the Vermont and New Hampshire state surface water quality standards on June 26 in the Wilder upper and middle impoundment, and again on July 10 in the upper impoundment. The exceedances measured on June 26 and July 10 at the Wilder upper impoundment were measured instantaneously during the collection of a vertical profile and ranged from 5.7 to 6.1 and 5.8 to 6.0, respectively. At the Wilder middle impoundment station, only one exceedance, measuring 6.4 during the collection of a vertical profile, occurred on June 26. At the Bellows Falls upper impoundment station, pH fell below both state standards on July 11 and September 5. On July 11, pH exceedances, measured during the collection of a vertical profile, ranged from 6.1 to 6.3. However, on September 5, only one exceedance of 6.4 was measured during the collection of a vertical profile at the Bellows Falls upper impoundment station. The decrease in pH below state surface water quality standards in the Wilder and Bellows Falls impoundments was attributed to atmospheric deposition because these areas were listed as impaired for pH due to atmospheric deposition in 2012 (Normandeau, 2013a).

Also in 2012, pH was observed to exceed the more stringent upper New Hampshire surface water quality standard throughout the Bellows Falls and Vernon Project areas. Most exceedances, however, occurred in the Bellows Falls forebay and ranged from 8.01 to 8.53 (Study 6). In 2012, exceedances were observed in the forebay on July 11 and 12, August 21 through 25, and September 9 through 12. In the bypassed reach and tailrace, 2012 pH exceedances were shorter in duration and lasted from August 23 to 24 and from June 21 to 23, respectively. The high pH levels coincided with higher levels of chlorophyll-*a* and diurnal fluctuations of temperature and DO during the 10-day, high-temperature, low-flow monitoring period, suggesting that the pH exceedances are partly related to photosynthesis of algae and aquatic respiration.

The residence time of water flowing through any hydroelectric project impoundment can facilitate increased algal and vegetation growth and subsequently affect pH levels. However, because all three Projects are essentially operated as daily run-of-river projects, they typically do not store most inflow longer than 1 day,[32] and the gross storage capacity in the Wilder and Vernon impoundments is approximately 29 percent and 49 percent larger than in the Bellows Falls impoundment, respectively. Considering various flow rates, the average residence times in the Wilder impoundment are always longer than in the Bellows Falls impoundment, yet pH exceedances in the Wilder impoundment were rare in both the 2012 and 2015 study seasons, indicating that other potential causes of pH exceedances, such as nutrient loading from the watershed or atmospheric deposition, likely affect pH levels and thus compliance with state surface water quality standards. Residence times in the Vernon impoundment are more variable relative to the Bellows Falls impoundment; pH exceedances in the Vernon impoundment in 2012 and 2015 were also rare.

Over the course of Study 6, potential effects of generation on pH were generally indistinguishable from daily pH fluctuations. However, pH increased very slightly (0.05 to 0.1) in the tailraces when discharges increased, and pH decreased slightly when discharges decreased (Figure 3.5-44). Because Great River Hydro is not proposing any changes to Project operations, continued Project operations will result in pH levels that reflect existing conditions, generally comply with state water quality standards, and will likely continue to support and maintain designated uses.

[32] During typical operations, operational volumes are 7,350, 4,642, and 4,489 acre-ft in the Wilder, Bellows Falls, and Vernon impoundments, respectively. Using reported mean daily inflows measured for water years 2007 through 2016 (10-year record) at the USGS gaging stations the median values of those records are: Wells River (3,960 cfs), West Lebanon (6,085 cfs), and North Walpole (8,010 cfs), and water will be stored in the Wilder, Bellows Falls, and Vernon impoundments for 22, 9, and 7 hours, respectively. Using 7Q10 flows calculated from the same mean daily flows for the same 10-year record and using the same operational volumes, 7Q10 flows at Wells River (1,188 cfs), West Lebanon (1,560 cfs), and North Walpole (1,846 cfs), result in water storage in the Wilder, Bellows Falls, and Vernon impoundments for 3.1, 1.5, and 1.2 days, respectively.



Source: ILP Study 6, *Water Quality Monitoring and Continuous Temperature Monitoring Study*

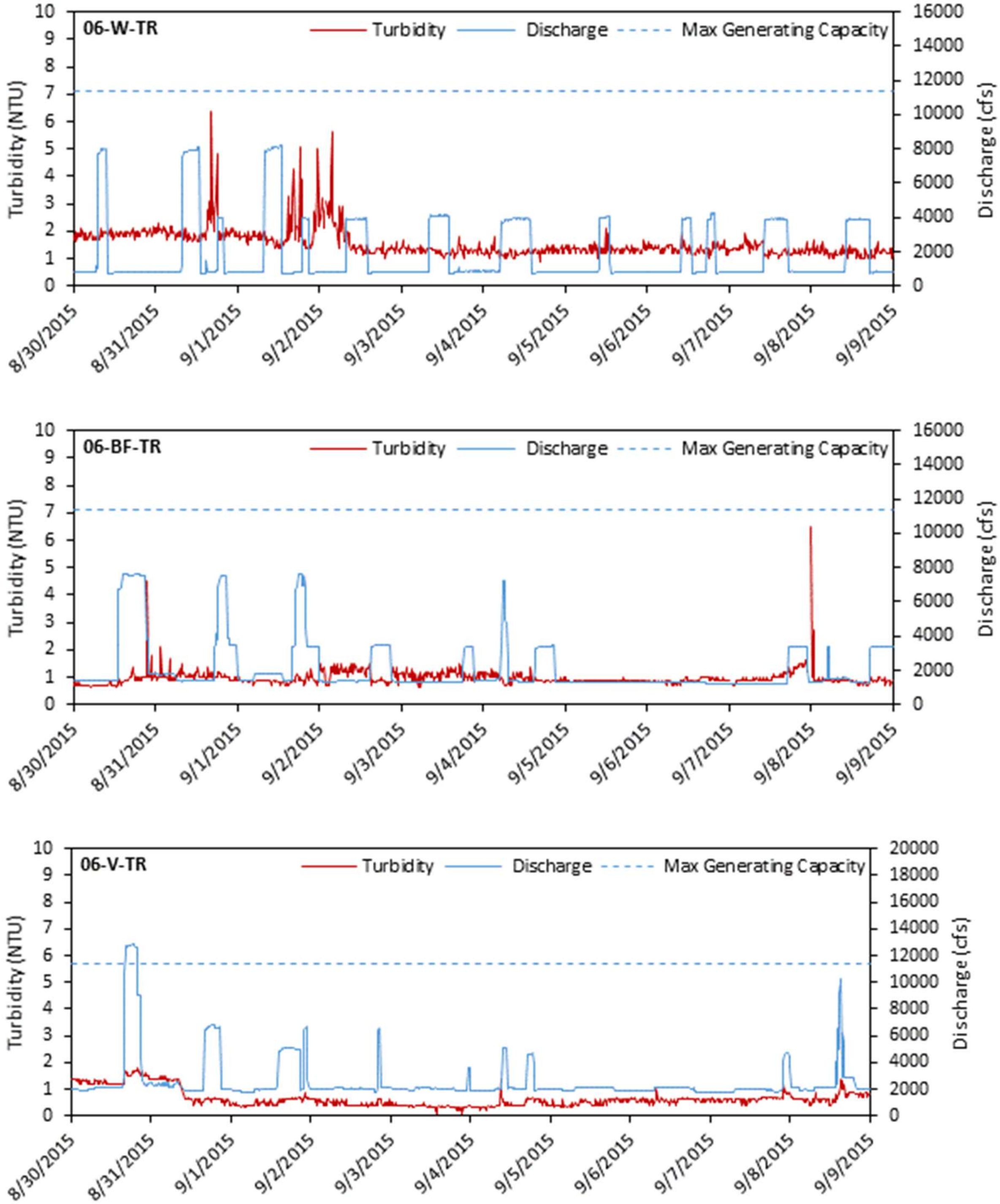
Figure 3.5-44. Tailrace pH and discharges at the Wilder, Bellows Falls, and Vernon Projects during the 10-day, high-temperature, low-flow period in 2015.

Turbidity

New Hampshire surface water quality standards for Class B waters require turbidity not to exceed 10 NTU greater than natural conditions to maintain designated uses. Similarly, the Vermont surface water quality standard for turbidity for Class B waters requires turbidity not be in such amount or concentration that prevents full support of uses, and not to exceed 10 NTU as an annual average under dry weather base-flow conditions (see Section 3.5.1.2, *Water Quality*, *Surface Water Quality Standards and Designated Uses*).

Turbidity levels recorded during the course of Study 6 were very low among all mainstem study sites (not measured at tributary sites), and mean and median turbidities were less than 5 NTU for the majority of the study period. Turbidity increased during precipitation events that often result in high flows and spill conditions (Figure 3.5-29, Figure 3.5-34, and Figure 3.5-38; also see Study 6, Appendix F). Under low-flow conditions and throughout the study period, turbidity did not exceed 10 NTU above turbidity levels measured at the upstream riverine stations; only during periods of precipitation that resulted in high flow did turbidity levels throughout the study area differ by more than 10 NTU. Mean and median turbidity value differences were negligible between the forebay and tailrace stations at all three Projects, ranging between 0.6 and 0.3 NTU (forebay) and between 0.4 and 0.3 NTU (tailrace). When the three Projects were generating above minimum flows, turbidity was low in the tailrace and did not change with increasing or decreasing discharges (Figure 3.5-45).

The continuous and vertical profile turbidity data collected at all mainstem monitoring stations indicate that turbidity on very rare occasions exceeded the New Hampshire surface water quality standard of 10 NTU beyond upstream receiving waters and that under low-flow conditions turbidity in the Project areas did not exceed the Vermont surface water quality standard. The New Hampshire turbidity standard was exceeded on June 4, 2015, in the Wilder forebay; this exceedance was attributed to sampling through a debris field. In addition, periodic turbidity spikes occurred at the continuous monitoring stations but most notably within each Project tailrace. These spikes were attributed to debris drifting in front of the turbidity sensor. Because Great River Hydro is not proposing any changes to Project operations, turbidity levels will likely reflect those observed during the course of Study 6 and will likely comply with state surface water quality standards, and support and maintain designated uses.



Source: ILP Study 6, *Water Quality Monitoring and Continuous Temperature Monitoring Study*

Figure 3.5-45. Tailrace turbidity and discharges at Wilder, Bellows Falls, and Vernon Projects during the 10-day, high-temperature, low-flow period in 2015.

*Nutrients and Chlorophyll-*a

New Hampshire surface water quality standards for nutrients in Class B waters require nitrogen to occur in no such concentrations that impair any existing or designated uses, unless naturally occurring. In addition, New Hampshire nutrient surface water quality standards require phosphorus levels to occur in no such concentrations that impair any existing or designated uses unless naturally occurring. Vermont state surface water quality standards for nutrients in Class B waters require nitrates not to exceed 5.0 mg/L (as NO_3-N) at flows exceeding low median monthly flow, and phosphorus is to be limited so that concentrations do not contribute to the acceleration of eutrophication or the stimulation of the growth of aquatic biota in a manner that prevents the full support of uses (see Section 3.5.1.2, *Water Quality*, *Surface Water Quality Standards and Designated Uses*).

Sources of nutrient loadings and enrichment in the watersheds for the three Projects include point and non-point sources, such as wastewater treatment facilities, CSOs, septic systems, and agricultural runoff. These discharges can affect attainment of surface water quality standards in the Wilder, Bellows Falls, and Vernon Project areas. Nutrient and chlorophyll-*a* analyses in 2012 and 2015 and field observations of no evidence of visual impairments (e.g., algal blooms) indicated that Project-affected waters are in compliance with state surface water quality standards and that designated uses are maintained and supported. These data and observations further indicate that Project-affected waters in the Wilder, Bellows Falls, and Vernon forebays are, on average, mesotrophic to oligotrophic under existing conditions (Tables 3.5-26, 3.5-36, and 3.5-46; Dodds et al., 1998; NHDES, 1997a; VDEC, 2000). Continued Projects will not alter these conditions.

3.5.2.2 Great River Hydro Proposal

Water Quantity

Great River Hydro's proposed operation will continue to rely upon inflow to each project to dictate operation at the dam. In contrast to normal current operation, in which limited impoundment storage at the Projects is used at Great River Hydro's discretion dispatch generation meet the generation schedule, the normal and dominant operation will not utilize storage, rather maintain impoundments at their respective Target WSE and station outflow mirroring inflow at the dam or IEO. Less frequent, discretionary Flexible Operation opportunities will rely on impoundment storage but will be limited to a varied monthly allocation of hours, as few as 10 or about 1.4 percent of hours per month (April-June) and as many as 65 or about 9 percent (December-March). Further limitation on discretionary operation and use of impoundment storage is due to Transition Operation elements of the proposed operation such as, up-ramping, down-ramping and refilling that apply when initiating Flexible Operation and returning to IEO Operation.

The proportion of time when inflow equaled outflow (within 100 cfs) under current operations was less than 6 percent of the time (Table 3.5-47). Based on simulation results of the IEO/Flexible Operation were expected to produce IEO conditions at 70 percent to 100 percent of the time in June, August, and November in both 2009 and 2015. Proportion of time at IEO in February ranged from 39 to 60 percent, due to variability in inflows and to the increased frequency of flexible operations during that month.

Table 3.5-47. Percentage of time when inflow equals outflow.

		Flow	% of Hours when Inflow=Outflow (w/in 100cfs)			
Impoundment	**Year**	**Scenario**	**Feb**	**June**	**Aug**	**Nov**
Wilder	2009	Current	1%	1%	1%	1%
		IEO/Flex	39%	89%	84%	76%
	2015	Current	0%	5%	1%	1%
		IEO/Flex	60%	97%	86%	67%
Bellows Falls	2009	Current	5%	3%	1%	2%
		IEO/Flex	57%	96%	92%	96%
	2015	Current	1%	2%	1%	1%
		IEO/Flex	44%	97%	77%	68%
Vernon	2009	Current	1%	2%	2%	2%
		IEO/Flex	59%	100%	86%	92%
	2015	Current	9%*	3%	1%	1%
		IEO/Flex	40%	96%	81%	72%

*Not representative of typical historic operation due to extreme low temperature requiring Vernon generation to operate continuously for station heating as well as numerous unit maintenance outages.

The monthly Flexible Operation limits are expected to result in a dramatic reduction in the frequency of station discharge corresponding to daily peaks in energy demand affecting riverine reaches below the dams, during spring, summer, and fall time periods, as represented by June, August, and November simulations (Table 3.5-48). Frequency of Flexible Operation events are also expected to decrease substantially during winter months (see February) in the Wilder riverine reach, although the number of operational flows in winter may not change notably in the Bellows Falls or Vernon reaches. The differences in number of operational flows in spring, summer, and fall between flow scenarios represent reductions of 58-100 percent.

Table 3.5-48. Frequency of monthly operational flow events in riverine reaches.

		Flow	Frequency of Operational Flow Events			
Project Reach	**Year**	**Scenario**	**Feb**	**June**	**Aug**	**Nov**
Wilder	2009	Current	49	34	30	33
		IEO/Flex	25	5	7	14
	2015	Current	53	19	39	47
		IEO/Flex	15	1	6	13
Bellows Falls	2009	Current	24	29	18	19
		IEO/Flex	25	2	4	4
	2015	Current	34	9	41	41
		IEO/Flex	24	1	11	17
Vernon	2009	Current	39	20	13	20
		IEO/Flex	20	0	4	5
	2015	Current	14*	10	35	40
		IEO/Flex	26	1	9	14

*Not representative of typical historic operation due to extreme low temperatures requiring Vernon generation to operate continuously for station heating as well as numerous unit maintenance outages.

The proposed operation would produce flows largely matching inflow on an instantaneous basis, higher average base flow, a subsequent decrease in the magnitude (amplitude) of Flexible Operation flows above the base [IEO] flow; less significant flow alteration due to limitations on discretionary Flexible Operation, Transitional up-ramping and down-ramping prior to and subsequent to Flexible Operation, Flexible Operation Maximum Discharge limits, and reserved downstream flow provisions during impoundment refill periods. All of these elements would provide benefits to aquatic resources through development of a more stable riverine environment.

Managing to Target WSE resulting in station discharge equal to inflow, along with the limits on Flexible Operation, Transitional Operation requirements, and Flexible Operation Maximum Discharge limits, will result in a smoother and more natural flow regime. Figure 3.5-46 shows the distribution of hourly flows in each riverine reach during August of 2015 (*note: this dataset was selected due to the known lack of unit outages in August 2015, which could otherwise mask representative flow distributions*). The difference in flow distributions between current operations, which showed a highly skewed frequency with many low flows and a low frequency but wide distribution of higher flows, versus the proposed flow regime which would result in a more central and normal distribution of flows, is clearly evident. The relative probability of occurrence shown in the exceedance plots also reveal the wide disparity of flow characteristics, with a decline in periods experiencing minimum base flow, a higher incidence of moderate flows, and a much smoother and gradual decline in probability of high flows. Although other months are not portrayed, increases in minimum flows and decreases in maximum operational flows under the proposed operations, as discussed in the following sections, indicate that this more normalized distribution of hourly flows is expected to occur in other months and years.

The proposed flow regime will directly result in higher base flows in each of the riverine reaches than is present under current operations. Under the proposed operation during non-spill conditions, the lowest flows below project dams will occur either as a result of matching low inflow or will occur during refilling of the impoundments. Refill will be conducted by releasing discharge equal to 70 percent of inflow per hour until the impoundment WSE achieves the Target WSE.

IEO management will have a cumulative downstream effect, as higher minimum flows in the Wilder reach will lead to higher inflow and minimum flows in Bellows Falls, and thence into the Vernon Project. Due to the limits on Flexible Operation and requiring Transitional Operation, discharge from an upstream Project Flexible Operation event will attenuate significantly as it routes downstream. It will not arrive at the downstream dam with similar hydrologic characteristics. The expected increases in minimum daily flows under the proposed flow regime in the Wilder riverine reach average about 100 percent in spring, summer, and fall scenarios of both years, with larger increases (200 to 300 percent) in February (Table 3.5-49). Increases in minimum flows are also expected in the Bellows Falls and Vernon riverine reaches, although the differences are less with average increases ranging from 39 to 50 percent. Figure 3.5-47 illustrates the observed and expected distributions of minimum flows in each project riverine reach during the two representative years (data combined over the four months). As noted in the previous section, these figures also illustrate the comparative lack of very low flows and the more normally distributed pattern of minimum flows under the proposed flow regime. Note that very high minimum flows shown in the figures below are mostly the result of spill conditions, not managed release flows and will not change under the proposed operation.

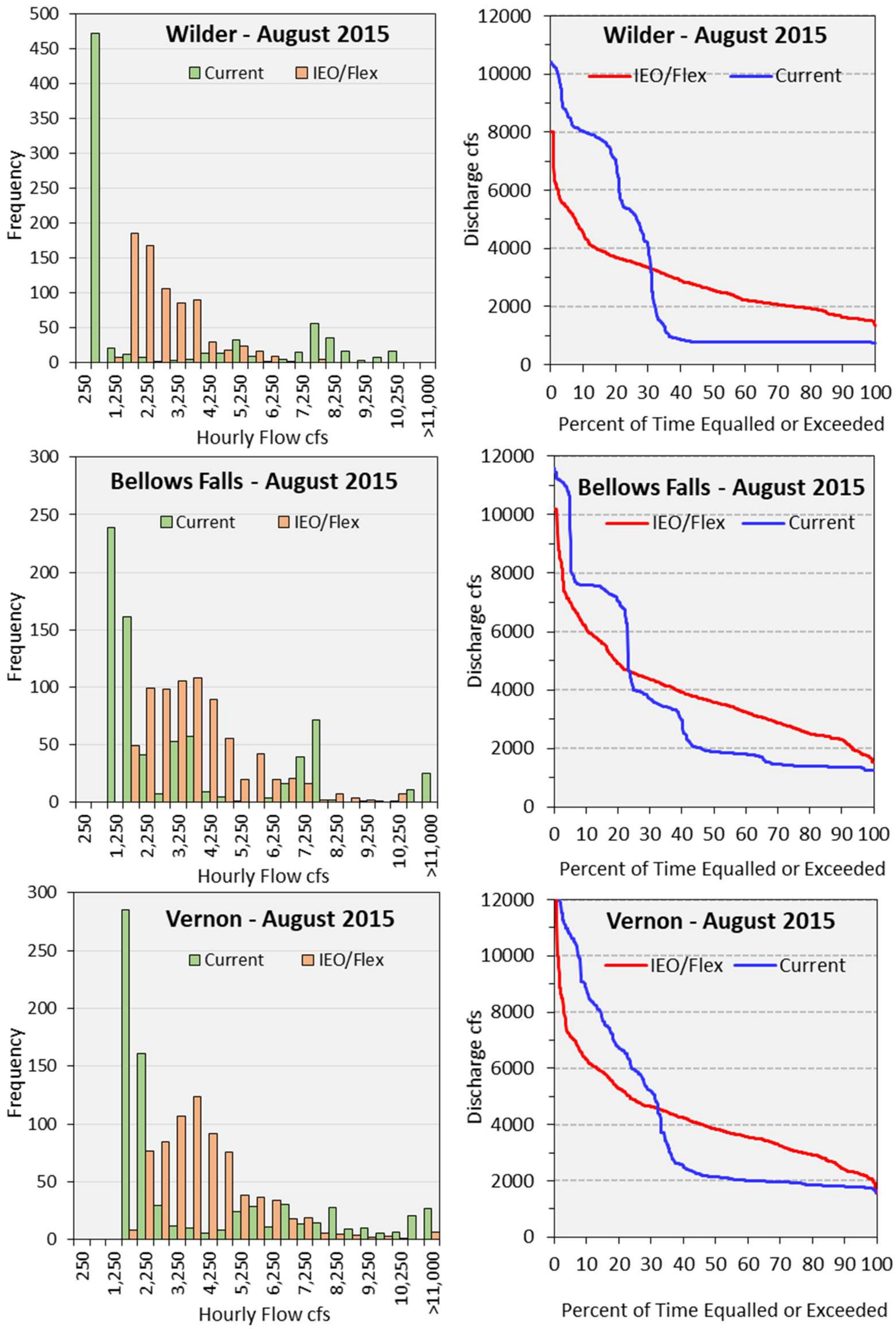


Figure 3.5-46. Frequency distribution and flow exceedance plots of hourly flows in August 2015 according to reach and flow scenario. **Note: data may include flows under spill conditions.**

Table 3.5-49. Change in mean daily minimum flows in riverine reaches.

		Flow	Mean Daily Minimum Flow (cfs)			
Project Reach	**Year**	**Scenario**	**Feb**	**June**	**Aug**	**Nov**
Wilder	2009	Current	700	1,725	1,660	1,852
		IEO/Flex	2,721	3,530	4,384	4,679
	2015	Current	724	7,866	801	1,360
		IEO/Flex	2,138	9,150	2,071	2,811
Bellows Falls	2009	Current	4,159	5,190	6,029	7,391
		IEO/Flex	4,709	7,048	8,913	10,418
	2015	Current	3,162	12,548	1,500	2,591
		IEO/Flex	3,129	14,476	2,795	4,569
Vernon	2009	Current	2,989	6,128	8,225	8,207
		IEO/Flex	5,049	8,382	10,618	10,967
	2015	Current	4,338*	13,327	1,821	2,796
		IEO/Flex	3,203	14,787	3,170	5,070

*Not representative of typical historic operation due to extreme low temperature requiring Vernon generation to operate continuously for station heating as well as numerous unit maintenance outages.

Although minimum daily or base flows are expected to increase in all riverine reaches under the proposed flow regime, maximum flows will typically be less than under current operations, due to a number of contributing factors: the Flexible Operation Maximum flow limit, the higher base flow will limit available water, Transitional Operation Requirements less than maximum flow will also utilize available water and require refilling impoundments to Target WSE. The proposed operation limits Flexible Operation Maximum Discharge to a maximum of 4,500 cfs when inflows are less than or equal to 1,800 cfs, or to the lesser of either 2½ times the inflow or Maximum Station Discharge Capacity when inflows exceed 1,800 cfs. While under proposed operation there is no reduction in the maximum station discharge capacity, and restrictions do not apply to Emergency and System Operation Requirements, the vast majority of high discharge events will be related to Flexible Operation. Therefore, the aforementioned contributing limiting factors and restrictions, together with limited Flexible Operation Hours will reduce the frequency and occurrence of flows at Maximum Station Capacity in comparison to current operations.

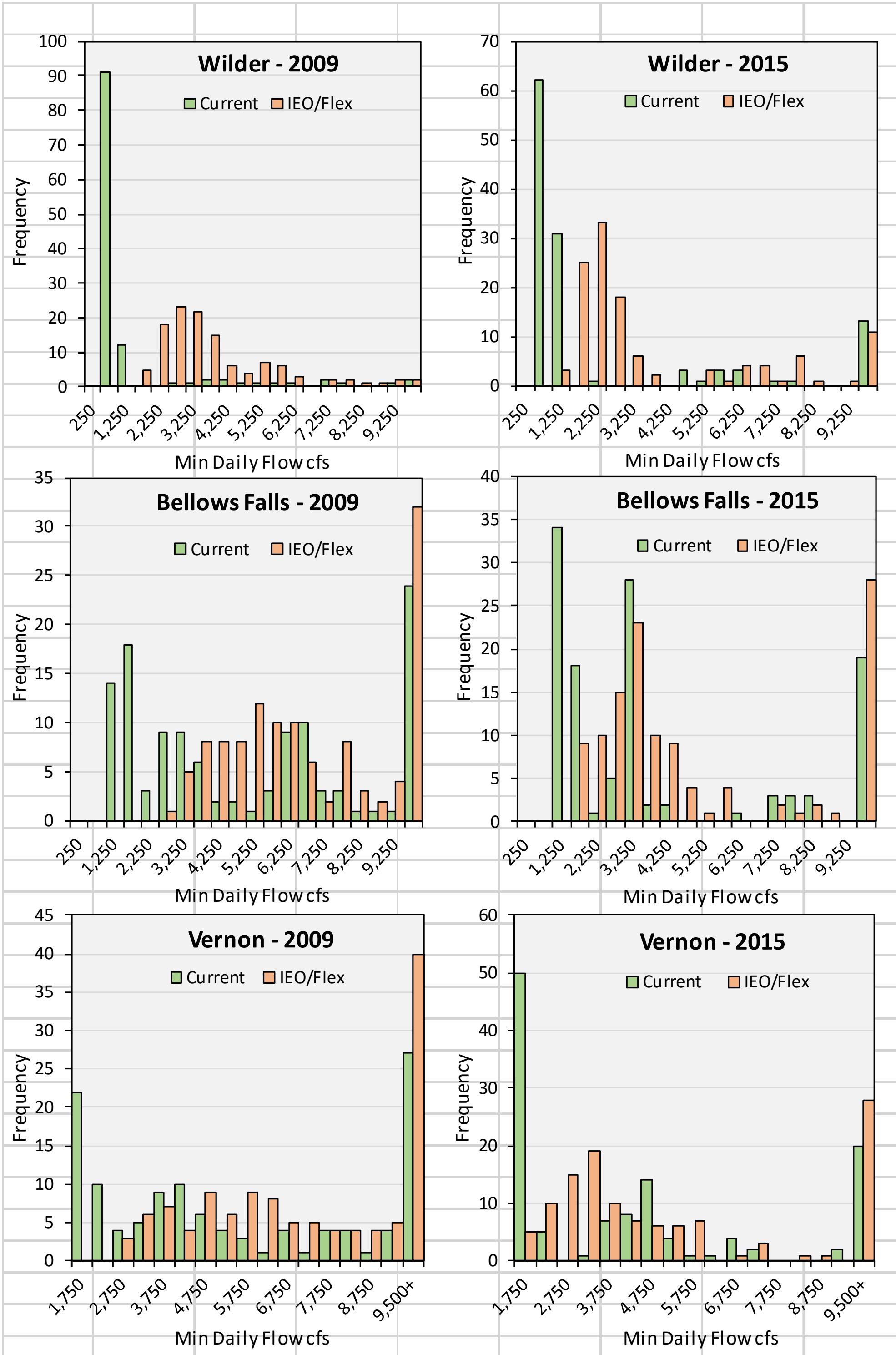


Figure 3.5-47. Minimum daily flows in riverine reaches (all 4 months combined) according to flow scenario. Note: data may include flows under spill conditions.

Decrease in Magnitude of Operations Flows

As a result of increases in the average base flow due to IEO operation and lower frequency and occurrence combined with limitations of maximum flow in Flexible Operation, the magnitude of flow fluctuations in spring, summer, and fall under the proposed flow regime are expected to be roughly 50 percent of the magnitude of flow changes under current operations based on simulation results (Table 3.5-50). As noted for previous metrics, differences between existing and proposed flow characteristics will be less during winter months than during the remainder of the year. Simulation results for February at Bellows and Vernon are overstated as they do not reflect the previously mentioned atypical operation at Vernon (station operation for heating and unit outages), or a similar situation at Bellows Falls, in February 2015. Figure 3.5-48 illustrates the difference in distribution of daily flow changes in each riverine reach in 2009 and 2015 (all 4 months combined), with a higher proportion of small-magnitude changes and a lower proportion of large-magnitude changes (excluding periods of spill) under the proposed flow scenario compared to current operations. Overall, this increase in stability in aquatic habitat, as repeatedly noted above, is expected to provide benefits to many, if not all, aquatic-dependent species.

Table 3.5-50. Mean daily magnitude of flow changes in riverine reaches.

		Flow	Mean Daily Change in Flow cfs			
Project Reach	**Year**	**Scenario**	**Feb**	**June**	**Aug**	**Nov**
Wilder	2009	Current	7,770	7,062	7,437	8,417
		IEO/Flex	4,936	3,143	2,988	3,920
	2015	Current	6,732	5,633	7,612	7,299
		IEO/Flex	3,090	3,636	2,038	2,622
Bellows Falls	2009	Current	3,670	6,014	6,798	7,429
		IEO/Flex	4,934	2,876	3,032	2,676
	2015	Current	3,505	6,448	6,496	6,492
		IEO/Flex	5,465	4,774	3,238	4,144
Vernon	2009	Current	9,061	6,782	6,626	7,492
		IEO/Flex	6,269	2,853	3,828	3,827
	2015	Current	2,312*	6,945	7,165	7,711
		IEO/Flex	7,251	5,222	3,410	5,225

*Not representative of typical historic operation due to extreme low temperature requiring Vernon generation to operate continuously for station heating as well as numerous unit maintenance outages.

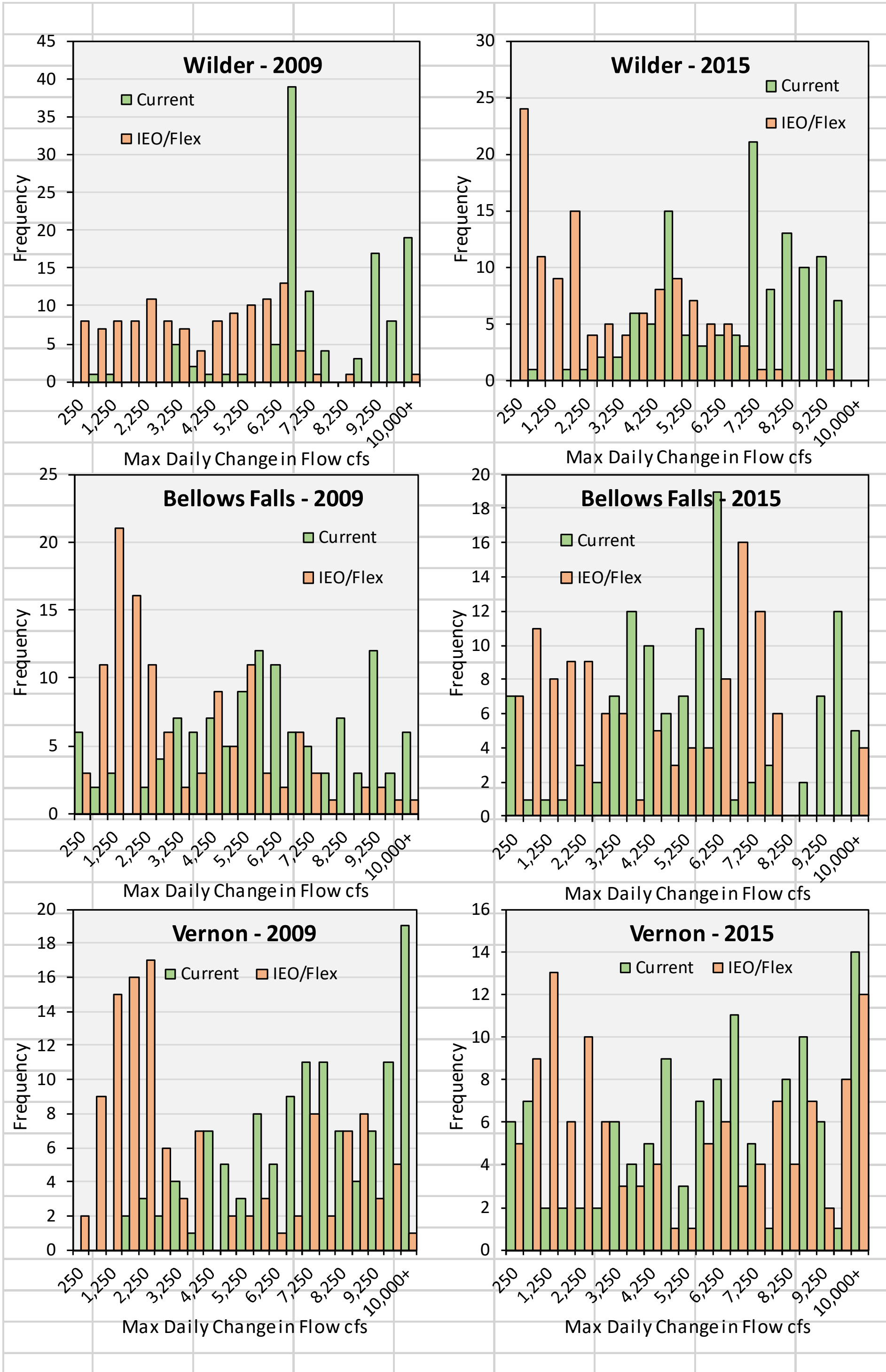


Figure 3.5-48. Mean maximum daily change in flow in each impoundment in 2009 and 2015 (all 4 months combined) according to flow scenario. **Note: many of the largest changes occur during spill events not controlled by the project.**

Transition Operation Up-ramping and down-ramping requirements associated with Flexible Operation are expected to greatly reduce the rapidity and magnitude of both increases and decreases in flow in comparison to current operations. For example, under current conditions there are no up-ramping and down-ramping requirements at the Projects. To illustrate, historic operation data at Wilder dam in 2009 indicate hourly flow changes from 7,000 cfs to over 10,000 cfs occurred in each of the four months. In contrast, under the proposed operation, simulated hourly flow changes in 2009 rarely exceeded 3,000 cfs. Ramping and refill limits applied to Flexible Operation will, in addition to attenuation reduce the magnitude of hourly flow changes in the downstream reaches.

Water Quality

As stated above, any adverse effects caused by current normal operational flows and impoundment fluctuations on water quality appear to be minimal to none in most cases. The proposed operational changes would increase the amount of time the project is operated as inflow equals outflow and at full reservoir. As described above, WSE fluctuations have negligible effect on water temperatures and water temperature patterns are driven by factors other than project operations such as weather and longitudinal effects. Therefore, any effects of Project generation on water temperatures would be indistinguishable from daily water temperature fluctuations. Similarly, the 2012 data suggest that only under atypical, low-flow, warm-weather conditions, as was observed in 2012, thermal stratification can occur resulting in potential low-DO levels in the hypolimnetic waters of the forebay. However, as water is passed through the Project powerhouses, it becomes re-oxygenated and state water quality standards would be maintained in downstream reaches of the Connecticut River. Operating under inflow equals outflow would maintain generation and a continuous passing of water through the powerhouses eliminating any low-DO conditions downstream. Data from study 6 showed that 2012 pH exceedances of state water quality standards in the impoundments was related to atmospheric deposition; while high pH levels coincided with higher levels of chlorophyll-*a* and diurnal fluctuations of temperature and DO during the 10-day, high temperature, low-flow monitoring period which suggests that pH exceedances are related to photosynthesis of algae and aquatic vegetation which would not change under this operation scenario.

3.5.3 Cumulative Effects

3.5.3.1 Water Quantity

The cumulative impacts of the three Projects' continued operations on water quantity occur within the larger context of water management in the Connecticut River System. River hydrology has been altered for more than 200 years since construction of the first canal at South Hadley, Massachusetts, in 1795. This was followed by construction of additional locks, canals, and dams on the mainstem during the early to mid-1800s from Wilder, Vermont, downstream to Windsor Locks, Connecticut (CRWC, 2013). Additional dams were built during the 1800s and

1900s on the mainstem and tributaries thoughout the watershed including several USACE flood control dams built on tributaries during the 1960s.

Hydroelectric operations on the Connecticut River are coordinated among projects and licensees and with USACE for purposes of flood control and navigation (Section 3.1.1.3, *Dams*). The Wilder, Bellows Falls, and Vernon Projects do contribute to alteration of the river's hydrology through fluctuations in impoundment water levels and discharge flows, which are highly regulated by upstream hydroelectric projects and depend on inflows from upstream and from tributaries because of limited impoundment storage capacity. Generation capacity along with licensed and voluntary operating constraints (see Section 3.5.1) further limit the Projects' effects on water quantity to localized, short-term effects that are most apparent close to the dams and in the downstream reaches occuring as a result of normal (and high flow) operations of the Projects. Because these Projects pass all inflow on a daily or near-daily basis, they do not contribute substantially to water quantity effects farther downstream and they have no effect relative to water quantity effects from the base of Moore dam to the upstream extent of the Wilder impoundment.

3.5.3.2 Water Quality

The Wilder, Bellows Falls, and Vernon Projects, as well as other hydroelectric projects and discharges from wastewater treatment facilities, operation of USACE flood control dams in the basin, irrigation and other water withdrawals, tributary contributions, and surface runoff on the Connecticut River both upstream and downstream, can cumulatively affect water quality—particularly temperature and DO. Baseline continuous and discrete water temperature data indicate that water temperatures slightly increase in the downstream direction from the upstream riverine reaches and upper impoundments toward the Project dams. This warming effect is very gradual and depends on ambient atmospheric conditions, latitude, and changes in elevation over the 122-mile Project areas because the three Projects pass all inflow on a daily or near daily basis and the impoundments have limited storage capacity. Therefore, over the large spatial extent from the base of Moore dam to Long Island, gradual warming of water temperatures is expected. Moreover, the existing thermal regime is not expected to change from existing conditions because Great River Hydro is not proposing any change in Project operations.

DO levels in the Project area follow a typical annual pattern with higher concentrations in late spring and early fall than during the summer. DO levels were observed to gradually decrease from upstream areas toward the Project dams and change in response to generation and minimum flow operations as water is passed through the powerhouses, but DO typically does not fall below either state's surface water quality standards. The exception occurred during 2012, a low water year, when DO levels were observed to briefly fall below state surface water quality standards within the hypolimnion of the Wilder (Vermont standard only) and Bellows Falls (New Hampshire and Vermont standard) Project forebays, but increased above state surface water quality standards as water was passed through the powerhouses. Therefore, DO levels can be locally affected, but because water becomes re-oxygenated as it passes through the powerhouses, the Projects will not adversely and cumulatively affect DO levels of downstream reaches. Because Great River Hydro is not proposing any change in Project operations, existing DO levels throughout the entire Project area are not expected to change.

Data collected as a part of the 2012 and 2015 baseline water quality studies indicate that pH infrequently falls outside one or both state surface water quality standards, but these exceedances were attributed primarily to atmospheric deposition and increased rates of photosynthesis, not to Project operations effects, such as impoundment residence time. Because Great River Hydro is not proposing any change in Project operations, existing pH levels throughout the Project area are not expected to change because of Project operations. Furthermore, because pH exceedances were attributed primarily to factors other than Project operations, continued operation of the Projects as proposed is not expected to cumulatively affect pH levels throughout the river.

Baseline turbidity data collected during Study 6 demonstrated that turbidity levels throughout the three Project areas were very low for the majority of the time, but increased in response to precipitation events and high flows that often resulted in spill at the Project dams. Because Great River Hydro is not proposing any changes to Project operations, turbidity levels will continue to reflect those observed throughout Study 6 and will very likely comply with state surface water quality standards. Therefore, continued operation of the Projects as proposed will not cumulatively affect turbidity levels throughout the river.

Nutrient and chlorophyll-a concentrations measured during 2012 and 2015 indicate that state surface water quality standards and designated uses are supported. Attainment of state surface water quality standards relative to nutrients will not be affected under proposed operation because the Projects do not contribute to nutrient loading in the river. Therefore, nutrients and chlorophyll-*a* levels throughout the river will not be adversely, cumulatively affected by continued Project operations.

3.5.4 Unavoidable Adverse Effects

3.5.4.1 Water Quantity

Project operations will continue to alter flows in the Connecticut River, resulting in unavoidable adverse effects on some fish and aquatic resources (see Section 3.6, *Fish and Aquatic Resources*), some terrestrial resources (see Section 3.7, *Terrestrial Resources*), and potentially cultural and historic resources (see Section 3.11, *Historic and Cultural Resources*). Several factors constrain Great River Hydro's ability to significantly alter water quantity from the existing and proposed operational regime. These factors include:

- The amount and timing of water available as a function of upstream inflow and intermediate drainage flow. A portion of this inflow is subject to regulation and can be limited or currently augmented above natural flows during low flow periods, from upstream storage reservoirs.

- Limited generation flow capacity above which spill must occur;
- Safety and flood control operations, which are required during periods of high flows;
- Normal operations, which use only a portion of the overall impoundment storage capacity; and
- Limited impoundment storage, which necessitates spilling rather than storage of available inflows that exceed Project generating capacities.

3.5.4.2 Water Quality

Unavoidable adverse effects are those that may still occur after implementation of protection and mitigation measures. The amount of warming (water temperature increases) that occurs as water flows from upstream areas to the Project dams depends primarily on natural prevailing weather conditions and latitudinal variation. At times, the amount of warming can exceed Vermont's temperature standard (>1°F), especially over the long longitudinal distance from the upstream riverine area to each Project dam and due to larger diurnal temperature changes at the upstream riverine reaches. This effect will be reduced during IEO operations as the residence time in the reservoirs will be reduced from current operations.

Stratification of the Project impoundments will occur if weather conditions are conducive, as they were in 2012. Stratification of the Project impoundment can result in depleted DO levels in the hypolimnion, particularly in the forebay, and can fall below state surface water quality standards. Depressed DO levels in the forebays of the Projects will stress aquatic life. However, waters will become oxygenated above state standards as water passes through the Project powerhouses; therefore, the effect of low DO will be confined in the forebay and not affect downstream reaches. Any unavoidable adverse effects related to lower DO in the hypolimnion will be brief, confined to forebay areas, and have limited or negligible impacts.

3.6 Fish and Aquatic Resources

3.6.1 Affected Environment

The Connecticut River within the Wilder, Bellows Falls, and Vernon Project areas provides aquatic habitat for a variety of fish, freshwater mussels, and macroinvertebrates. Aquatic species depend on suitable physical habitat for migration, reproduction, and rearing. Parameters of physical habitat used by aquatic species include large-scale features such as substrate and mesohabitat type, tributary confluences, backwater/setback habitats, islands, bedrock falls, as well as smaller scale, submerged habitat attributes such as aquatic vegetation, bottom substrate materials, and large woody debris.

3.6.1.1 Fisheries Overview

The Connecticut River within the Wilder, Bellows Falls, and Vernon Project areas provides habitat for a diverse assemblage of fishes ranging from coldwater to warmwater species, both resident and migratory (Brown, 2009). Coldwater species such as trout[33] reside or migrate seasonally, and coolwater and warmwater species, reside year-round. The makeup of the resident fish population changes as the Connecticut flows south; coldwater trout give way to coolwater Smallmouth Bass and Chain Pickerel, then warmwater species like Walleye and Largemouth Bass. Introduced species include Largemouth and Smallmouth Bass, Rainbow and Brown Trout, Walleye, and Northern Pike (CRWC, 2011).

Numerous relicensing studies were conducted to evaluate fisheries resources within the Project areas and are discussed in detail in Sections 3.6.1.2 and 3.6.1.3. Those fisheries-related studies are:

- ILP Study 10, Fish Assemblage Study;
- ILP Study 11, American Eel Survey;
- ILP Study 12, Tessellated Darter Survey;
- ILP Study 13, Tributary and Backwater Fish Access and Habitats Study;
- ILP Study 14 and ILP Study 15, Resident Fish Spawning in Impoundments and Riverine Sections Studies (reports for Studies 14 and 15 were combined into a single document: ILP Studies 14–15, Resident Fish Spawning in Impoundments and Riverine Sections Studies);
- ILP Study 16, Sea Lamprey Spawning Assessment;
- ILP Study 17, Upstream Passage of Riverine Fish Species Assessment;
- ILP Study 18, American Eel Upstream Passage Assessment;

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[33] Naming conventions for common names of fishes follow the style guidelines in Chapter 9 of the American Fisheries Society (2013).

- ILP Study 19, American Eel Downstream Passage Assessment;
- ILP Study 20, American Eel Downstream Migration Timing Assessment;
- ILP Study 21, American Shad Telemetry Study – Vernon;
- ILP Study 22, Downstream Migration of Juvenile American Shad – Vernon; and
- ILP Study 23, Fish Impingement, Entrainment, and Survival Study.

Study 22 and sampling in 2015 for Study 10 indicate that more than 40 resident and migratory fish species occur in the Project areas. According to the 2015 field sampling, the Project impoundments are dominated (50 to 60 percent by number) by 3 species (Spottail Shiner, Yellow Perch, and Fallfish), whereas 50 percent of the fish community in the Wilder and Bellows Falls riverine reaches are composed of Smallmouth Bass, Tessellated Darter, and Fallfish (Study 10 and Study 12). Diadromous species that occur in portions of the Project areas include American Eel, American Shad, Sea Lamprey, and Atlantic Salmon, which require upstream and downstream passage through portions of the Project areas to use their native ranges to complete their life cycle (see Sections 3.6.1.2, *Aquatic Habitat*, and 3.6.1.3, *Resident Fish Populations*).

Threatened and Endangered Fish Species

No fish species present in the Project areas are listed as threatened or endangered under the federal ESA. Shortnose Sturgeon, which is a federally listed endangered species, is found as far upstream in the Connecticut River as Turners Falls dam downstream of the Vernon Project. Both American Eel and Blueback Herring were the subject of ESA-listing petitions, but FWS and NMFS, respectively, determined after species status reviews in 2007 and in 2013 for eel, and in 2013 and 2019 for herring, that listing was not warranted (FWS, 2020b). The Connecticut River Blueback Herring population has declined to the point where none have been recorded passing Vernon dam since 2000 (VT WAP Team, 2015), so presently no Blueback Herring use habitats in the Project areas. However, access to those habitats is provided by fish passage facilities at the Projects, so future population restoration would presumably result in the reintroduction of the species to the Project areas.

Essential Fish Habitat

Pursuant to the Magnuson-Stevens Fishery Conservation and Management Act, amended in 1996 (Public Law 94-265), habitats essential to federally managed commercial fish species are to be identified, and measures taken to conserve and enhance that habitat. EFH is 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” (NEFMC, 1998), which includes the entire Connecticut River.

Beginning in 1967, CRASC worked to restore Atlantic Salmon to the river basin by hatchery production and stocking and other management and regulatory approaches. Upstream and downstream fish passage facilities at the Projects have provided Atlantic Salmon access through the Projects since the 1980s. However, because of low adult returns over the years, FWS discontinued culturing salmon for restoration in the Connecticut River Basin in 2012. New Hampshire, Vermont, and Massachusetts also discontinued rearing and stocking programs; however, small numbers of adult salmon have continued to return to the basin. In 2016, no adult salmon returned to the Project areas (see Section 3.6.1.3).

State-Listed Fish Species

Several sensitive fish species were found in the Project areas during field work for Study 10 conducted in 2015. These species are state-listed in New Hampshire (NHFGD, 2015) and/or Vermont (VT WAP Team, 2015) under each state's updated Wildlife Action Plan (WAP) as threatened (Bridle Shiner) or as Species of Greatest Conservation Need (SGCN) in each state's latest revision to WAPs. Table 3.6-1 summarizes the sensitive fish species found during Study 10; collectively, they constituted only 2.1 percent of the total catch in that study (see Sections 3.6.1.2 and 3.6.1.3 for detailed discussions). Additional state-listed sensitive species not found in Study 10 and not included in Table 3.6-1, but either previously documented, known to use, expected to use, or with potential to be restored to habitats within the Project areas include: Redbreast Sunfish (all three Projects), Blueback Herring (Bellows Falls and Vernon), and Rainbow Smelt (Vernon). In addition, Study 11 collected 3 American Eel in the Bellows Falls impoundment (not included in Table 3.6-1).

Table 3.6-1. Numbers of state-listed sensitive fish species found in Study 10 in the Wilder, Bellows Falls, and Vernon Project areas, 2015.

Species	NH Status[a]	VT Status[a]	Wilder		Bellows Falls			Vernon		Total
			I[b]	R[b]	I[b]	BP[b]	R[b]	I[b]	R[b]	
American Eel[c]	SC	SGCN-M	1	0	0	0	0	0	2	3
American Shad[c]	SC	SGCN-M	0	0	0	0	41	16	22	79
Blacknose Shiner		SGCN-H	50	0	0	0	0	0	0	50
Bridle Shiner	Threatened	SGCN-H	9	0	4	0	0	0	0	13
Brook Trout	SC	SGCN-M	0	7	0	0	0	5	5	17
Burbot	SC		0	0	0	0	3	0	0	3
Finescale Dace	SC		0	2	0	0	0	0	0	2
Sea Lamprey[c]	SC		0	15	8	0	13	23	3	62
Total			**60**	**24**	**12**	**0**	**57**	**44**	**32**	**229**

Source: ILP Study 10, *Fish Assemblage Study*

a. SC – species of concern, SCGN-H – high priority, SGCN-M – medium priority.
b. I – impoundment, R – downstream riverine reach, BP – Bellows Falls bypassed reach.
c. Migratory species.

Fishery Management Plans

The management of resident fishery species is addressed through state WAPs (NHFGD, 2015; VT WAP Team, 2015). The WAPs serve to identify species in greatest need of conservation, habitats that are at the greatest risk, and land uses and activities that present the greatest threats to wildlife and habitat. The Vermont 2015 WAP is currently issued as a draft document. The WAPs include characterization of habitat and non-habitat threats as well as identified research and monitoring needs for several resident species identified as SGCN by either state, and that were collected in the Project areas, including Brook Trout, Burbot, Blacknose Shiner, Bridle Shiner, and Finescale Dace. The WAPs also identified diadromous SGCN, including American Shad, American Eel, Blueback Herring, and Sea Lamprey. Fishery management plans have been published for Connecticut River diadromous species, including Atlantic Salmon, American Shad, American Eel, river herring (Blueback Herring and Alewife, not present within the Project areas), and Sea Lamprey.

American Eel

The Atlantic States Marine Fisheries Commission (ASMFC) published its fishery management plans for American Eel (ASMFC, 2008, 2006, 2000). The initial management plan presented primary objectives pertaining to an increased understanding of eel life history and population dynamics and sources of mortality through fishery dependent data collection, research, and monitoring; protection and enhancement of eels in currently used habitats; and restoration to historically used habitats where practical. The 2008 addendum was published, in part, due to evidence that the American Eel stocks had declined and are at or near low levels, and ASMFC strongly recommended that member states and FWS request special consideration for American Eel in the FERC relicensing process, including improving upstream and downstream passage and collecting data on both (ASMFC, 2008). A Benchmark Stock Assessment (ASMFC, 2012) concluded that the American Eel population in U.S. waters is depleted and at or near historically low levels because of a combination of historical overfishing, habitat loss and alteration, productivity and food web alterations, predation, turbine mortality, changing climatic and oceanic conditions, toxins and contaminants, and disease. As a result, ASMFC approved Addendum 3 (ASMFC, 2013) with the goal of reducing mortality and increasing conservation of American Eel stocks across all lifestages. The addendum focused on the establishment of new management measures for commercial and recreational eel fisheries and the implementation of fishery independent and fishery dependent monitoring. Addendum 4 (ASMFC, 2014) followed and modified management of commercial fisheries, and Addendum 5 (ASMFC, 2018) established commercial limits for Yellow Eel and new criteria for evaluating Glass Eel aquaculture proposals.

American Shad

ASMFC published its fishery management plan for American Shad and river herring (Blueback Herring and Alewife) in 1985 (ASMFC, 1985) in response to low commercial landings. Objectives of the plan included regulating fishing mortality to ensure survival and enhancement of depressed stocks; improving habitat accessibility through improved or new fish passage facilities; improving water quality; ensuring that river flow allocation decisions consider flow needs of alosine fishes; ensuring that water withdrawal effects, including turbine mortalities, do not result in stock declines; initiating and expanding stock restoration programs (larval and adult stocking); and supporting research programs relevant to development of management recommendations.

Amendment 3 to the ASMFC fishery management plan (ASMFC, 2010), specific to American Shad, was published because a 2007 stock assessment found that stocks were at all-time lows and did not appear to be recovering to acceptable levels. Amendment 3 identified the primary causes for continued declines as excessive total mortality, habitat loss and degradation, and migration and habitat access impediments. The objectives of Amendment 3 included maximizing juvenile emigration from freshwater complexes; restoring and maintaining spawning stock biomass and age structure to achieve maximum juvenile recruitment; and managing harvest so that objectives 1 and 2 will not be compromised. A strategy to achieve those objectives included ensuring that adequate monitoring techniques are implemented to measure migratory success (i.e., upstream and downstream fish passage at barriers). The plan identified issues for state and federal agencies to address. A number of these issues are specific to dams, and some may be pertinent to the Project areas, including the following (paraphrased):

- Work to identify hydropower dams that pose significant impediment to diadromous fish migration and target them for appropriate recommendations during FERC relicensing;
- Evaluate the effectiveness of upstream and downstream passage; when passage is inadequate, improve facilities;
- Where appropriate, improve upstream fish passage effectiveness through operational or structural modifications at impediments to migration;
- Guide/route fish that have ascended the passage facility to an appropriate area so that they can continue upstream migration and avoid being swept back downstream below the obstruction;
- Evaluate survival of post spawning and juvenile fish passed via each route (e.g., turbines, spillage, bypass facilities) and implement measures to pass fish via the route with the best survival rate;
- To mitigate hydrological changes from dams, consider operational changes such as turbine venting, aerating reservoirs upstream of hydroelectric plants, aerating flows downstream, and adjusting in-stream flows;
- Consider natural river discharge when altering instream flow to a river (flow regulation);
- Ensure that decisions on river flow allocation take into account American shad instream flow needs and minimize deviation from natural flow regimes; and

- Study the impacts and possible alteration of dam-related operations to enhance river habitat.

CRASC (1992) produced a management plan for American Shad in the Connecticut River basin with the overarching goal "to restore and maintain a spawning shad population to its historic range in the Connecticut River basin and to provide and maintain sport and the traditional in-river commercial fisheries for the species." The primary management objectives include achieving and sustaining an adult population of 1.5 to 2 million entering the mouth of the Connecticut River annually and achieving 40 to 60 percent passage at Holyoke dam, Massachusetts (the first barrier to upstream migration on the mainstem Connecticut River), and each successive upstream dam (Turners Falls and Vernon). In combination with a management objective of a maximum exploitation (fishing) rate of 40 percent, those objectives equate to an annual upstream passage objective of 144,000 to 432,000 American Shad at Vernon, thus making available the Project area between Bellows Falls and Vernon dams. Other pertinent management objectives include:

- Enhancing and promoting the recreational opportunities throughout the species' historical range;
- Establishing and maintaining a permanent population monitoring program on the Connecticut River; and
- Establishing an annual research program to address management programs associated with shad restoration goals and objectives.

In 2014, ASMFC approved the Connecticut Department of Energy and Environmental Protection's *American Shad Habitat Plan for the Connecticut River* (CTDEEP et al., 2014), prepared to fulfill requirements of Amendment 3 to the ASMFC Fishery Management Plan for American Shad, and supported the CRASC Management Plan for American Shad.

In 2015, CRASC prepared a species status report for Connecticut River American Shad (CRASC, 2015). It noted that while the objective of 1.5 to 2 million shad entering the Connecticut River has not been observed since the estimated 1983 and 1992 runs, using the lowest range of the population goal (1.5 million) and the lowest target passage rate (40 percent), CRASC determined that the target passage count for a restored population at the Vernon fish ladder would be >96,000 passed annually. Although achieving numeric passage targets at Vernon depends on passage at downstream dams, CRASC notes that the Vernon passage rate relative to Turners Falls passage was 53 percent, within the management plan objective, from 2012 to 2014. Between 2014 and 2019, that ratio ranged from 56.8 percent to 73.5 percent, and averaged 65.5 percent (CRASC, 2016), exceeding the management plan objective.

In 2017, an updated American Shad management plan was published (CRASC, 2017) building on the 1992 plan and incorporating additional research and monitoring data acquired during the 25-year interim. The 2017 plan includes a goal of achieving an adult shad run of 1.7 million adult fish entering the mouth of the

Connecticut River, 227,000 of which are targeted to pass upstream at Vernon dam (CRASC, 2017). Research and monitoring strategies from the 2017 plan that are designed to help achieve this population goal include:

- Increase American Shad access to spawning and nursery habitat in both the mainstem and tributaries when possible.
- Determine if fish passage measures are safe, timely, and effective for upstream migrating adult and downstream migrating adults and juveniles, at individual dam, hydropower projects, for cumulative project effects, and assess when Plan Goals and objectives are being achieved. Develop corrective action plans as needed.
- Monitor hydropower operations and facilities for any detrimental effects that may impact Plan Goals and Objectives. Develop corrective action plans as needed.
- Conduct annual pre-season, in-season, and post-season inspections of fishways, by qualified fish passage specialists (biologist and engineers), to ensure they are functioning within design criteria.
- Evaluate annually information for stock status, trends of metrics, and special study results to determine if adaptive management approaches should be developed.

The CRASC Connecticut River American Shad Management Plan Addendum—Fish Passage Performance (approved February 28, 2020) was established to support the goals and objectives of the 2017 Plan (CRASC, 2020). Using a modified version of the American Shad Passage Model (Stich et al., 2018), this Addendum sets the following fish passage performance criteria for fish passage:

- Upstream adult passage minimum efficiency rate is 75 percent, based on the number of shad that approach within 1 kilometer of a project area and/or passage barrier. Passage efficiency is [(# passed/#arrived)*100].
- Upstream adult passage time-to-pass (1-kilometer threshold) is 48 hours or less based on fish that are passed (requires achieving above objective).
- Downstream adult and juvenile passage minimum efficiency and survival rates are each 95 percent, based on the number of shad that approach within 1 kilometer of a project area and/or passage barrier and the number that are determined alive post passage (not less than 48 hours evaluation). Passage efficiency is [(# passed/# arrived)*100] and passage survival is [(# alive downstream of project/# passed)*100].
- Downstream adult and juvenile time-to-pass is 24 hours or less, for those fish entering the project area.

The performance criteria are designed to be used in conjunction with guidance set forth by the FWS Fish Passage Engineering Criteria Manual (FWS, 2017) and site-specific parameters (CRASC, 2017).

In response to comments received on the Fish Passage Performance Adendumn, CRASC acknowledged that: "We have made the decision to take a precautionary approach to restoring the shad population relative to criteria. Given the uncertainty in ocean conditions, bycatch, water quality, timing of flows, and other factors, the decision to implement high performance standards [for passage criteria] provides the highest likelihood for achieving management goals." Seemingly as recognigion of these high performance standards, CRASC states, within the Fish Passage Performance Adendumn, that the regulatory agencies charged with developing fish passage measures will determine the extent to which the performance criteria are used.

Atlantic Salmon

Atlantic Salmon management in the Connecticut River Basin is based in state and federal legislation that created CRASC. The Connecticut River distinct population segment of Atlantic Salmon was extirpated by the early 1800s with the loss of stocks indigenous to the Connecticut River (Fay et al., 2006; NMFS, 1999). Connecticut River restoration efforts have been conducted following the 1998 *Strategic Plan for the Restoration of Atlantic Salmon to the Connecticut River* (CRASC, 1998). CRASC developed a cooperative effort that included habitat protection, fisheries management, research, regulation, hatchery production and stocking. The strategic plan sought to accomplish the program mission to: "protect, conserve, restore and enhance the Atlantic salmon population in the Connecticut River Basin for the public benefit, including recreational fishing." However, during July 2012, FWS announced that it would no longer produce hatchery-reared stock for the effort to restore Atlantic Salmon to the Connecticut River Basin because of the continued costs for low numbers of returns (see Section 3.6.1.3).

Blueback Herring

Amendment 2 to the ASMFC fishery management plan (ASMFC, 2009), specific to river herring was published because stock assessments determined that many populations of river herring were in decline or depressed. The objectives of the amendment included preventing further declines in river herring abundance; improving the understanding of commercial fishery bycatch mortality; increasing understanding of fisheries, stock dynamics, and population health to evaluate management performance; retaining existing or making more conservative regulations; and promoting improvements in degraded critical habitat. Recommendations pursuant to habitat access that could be pertinent to the Project areas, assuming restoration of the migratory river herring population to the Connecticut River above Vernon dam, include (paraphrased):

- Evaluating effectiveness of existing fish passage facilities and where inadequate, improving them;

- Evaluating passage survival of post-spawn and juvenile fish passing by available routes (e.g., turbines, spillage, bypass) and optimizing passage for the route with the best survival rate;
- Preventing entrainment in hydropower intakes with behavioral barrier devices;
- Ensuring that decisions on river flow allocation consider the flow needs of alosine fishes and minimize deviation from natural flow regimes;
- Ensuring that water withdrawal effects do not affect alosine stocks by impingement/entrainment; employing intake screens or deterrent devices as needed to prevent egg and larval mortality; and altering water intake velocities, if necessary, to reduce mortality;
- To mitigate hydrological changes from dams, considering operational changes such as turbine venting, aerating reservoirs upstream of hydroelectric plants, aerating flows downstream and adjusting in-stream flows;
- When considering options for restoring alosine habitat, including study of, and possible adjustment to, dam-related altered river flows; and
- Documenting the impact of power plants and other water intakes on larval, postlarval, and juvenile mortality in spawning areas and calculating the resultant impact to adult population size.

CRASC (2004) produced an amended management plan for river herring in the Connecticut River basin with the goal to "restore and maintain a spawning river herring population within its historic range in the Connecticut River basin." The primary management objectives pertinent to achieving and sustaining annual passage of 300,000 to 500,000 adults at Holyoke include:

- Achieving annual passage of 40 to 60 percent of the spawning run at each successive upstream barrier on the Connecticut River from Holyoke to Bellows Falls [equating to an annual passage objective of 48,000 to 180,000 Blueback Herring at Vernon dam];
- Maximizing outmigrant survival for juveniles and spent adult river herring; and
- Enhancing, restoring, and maintaining river herring habitat in the Connecticut River Basin.

Sea Lamprey

Although evidence indicates Sea Lamprey have benefited from the creation of fish passage structures designed for other diadromous species, the efficiency of these structures for restoration and management remain largely unknown. In creating the first fishery management plan for Sea Lamprey, the Atlantic States Marine Fisheries Commission focused on providing information on the historic range, the amount of suitable habitat, and inaccessible habitat within the historic range of Sea Lamprey (ASMFC, 2018). This information will be used as a basis for creating future management plans focused on the restoration and recovery of Sea Lamprey. The current plan focuses on improved understanding of the current population, population monitoring for the purpose of assessing population status and trends, and identifying research needs and public outreach and education. Areas of the plan specific or pertinent to hydropower facilities include:

- Identification of impediments to migration/historic habitat
- Providing passage at barriers to allow access to historic habitat
- Operation of fishways as appropriate for Sea Lamprey including considerations for optimal passage (time of day, season, upstream and downstream passage).

3.6.1.2 Aquatic Habitat

Three relicensing studies focused on aquatic habitat:

- ILP Study 7, Aquatic Habitat Mapping Study;
- ILP Study 8, Channel Morphology and Benthic Habitat Study; and
- ILP Study 9, Instream Flow Study.

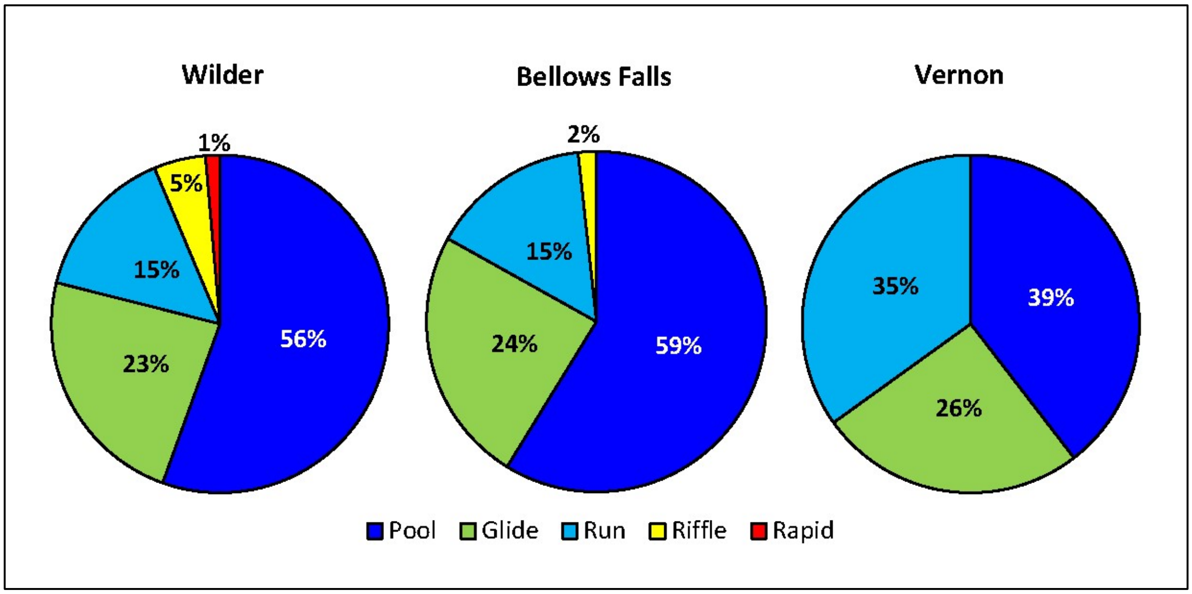
Several wildlife and botanical studies were also conducted that included evaluation of aquatic habitats relevant to those studies (see Section 3.7 and Section 3.8).

Habitat Types

The Project impoundments are generally classified as lentic (lake-like) habitat, although the upper portions of each impoundment possess more lotic (riverine) characteristics and the lower portions can also be more lotic at higher river flows. Overall, shallower depths, higher water velocities, and greater proportions of coarse substrate types (gravels, cobbles, and boulders) are present in the upper several miles of each impoundment (see below for substrate descriptions). The majority of aquatic habitat in each impoundment is placid and deep with steeply sloped banks and largely composed of fine substrate materials (e.g., silt, sand). Because of this basic homogeneity of habitat in the impoundments, the habitat in these reaches was predominantly classified according to dominant substrate composition (see Substrate Types below).

In contrast to the impoundment reaches, the three riverine reaches, located downstream of each Project's dam, possess alternating lengths of different mesohabitat types. In particular, WSE in the short, 1.5-mile reach below Vernon dam is also affected by several feet of fluctuation by Turners Falls and the Northfield Mountain Pumped Storage projects so exhibits less riverine flow-dependent characteristics at times. Mapping of riverine mesohabitat types, conducted as part of Study 7, used a classification system largely based on the attributes of depth and velocity, with the associated mixture of substrate types. Individual mesohabitat units were defined as pools, glides, runs, riffles, or rapids, and all split or side-channels were mapped separately. Study 7 includes a description of all mapping methodologies and mesohabitat type definitions.

The relative percentages of mesohabitat types were very similar in the Wilder and Bellows Falls riverine reaches; pool habitats dominate each reach at 56 to 59 percent by length, 23 to 24 percent glide habitats, 15 percent run habitats, and 2 to 5 percent riffle habitats (Figure 3.6-1). The Wilder reach also had a single rapid habitat at Sumner Falls (discussed below). Mesohabitat type proportions in the Vernon riverine reach were more evenly split at 39, 26, and 35 percent of pool, glide, and run habitats, respectively. Note that the Vernon riverine reach is only 1.5 miles long, so the total number of mesohabitat units (10) is far fewer than in the 17.7-mile Wilder and the approximate 6-mile Bellows Falls riverine reaches, which contained 101 and 28 mesohabitat units, respectively.



Source: ILP Study 7, *Aquatic Habitat Mapping Study*

Figure 3.6-1. Percentage by length of mesohabitat types in the riverine reaches.

The riverine mesohabitat mapping was conducted mostly at low release levels, e.g., 900 cfs in the Wilder riverine reach and 2,000 to 3,000 cfs in the Bellows Falls riverine reach, under which flows the character of individual mesohabitat units are more distinct and easier to identify. In contrast, the short riverine reach below Vernon dam was mapped at flows 3,500 cfs just prior to mapping, increasing to approximately 9,600 cfs during the time mapping occurred and at a median tailrace elevation.

The Bellows Falls bypassed reach, a 0.7-mile channel immediately below Bellows Falls dam, was mapped as part of Study 7 and under conditions at that time; approximately 400 cfs was being discharged from the dam. This flow is somewhat higher than the typical leakage flow of approximately 125 cfs. The reach is a rock-dominated channel consisting of these mapped mesohabitats: pool (73 percent), run (16 percent), riffle (8 percent), and rapid/cascade (3 percent).

Tributaries

Tributaries are an important component of aquatic habitat associated with both the impoundment and riverine reaches. More than 150 named and unnamed tributaries enter Project waters. Most are small (first or second order streams) with steeper gradients that result in relatively minor interaction with the mainstem reaches in comparison to medium (third and fourth order streams) or large (fifth or higher order) tributaries, some of which are influenced by Project operations for several miles upstream of their mouths. Tributaries contribute flow, cool water temperatures, coarse sediments, woody debris, and other important habitat attributes to the mainstem reaches. Medium and large tributaries also provide additional rearing and spawning habitat for many fish species, including Walleye, White Sucker, Sea Lamprey, and Fallfish. Smallmouth Bass were noted to spawn in the lower reaches of larger tributaries, and the gravel-dominated deltas formed by small and medium tributaries at their confluence with impoundment reaches were found to support substantial spawning activity by both Smallmouth Bass and Fallfish (Studies 14-15). Colder tributaries likely provide a source of recruitment of salmonid species that are sought after by some anglers. Tributaries of all sizes can also serve as temporary refuge habitats for small and large fish species during times when the main channels are experiencing flood flows. Table 3.6-2 lists the medium and larger tributaries in the Project areas and the reaches into which they drain.

Table 3.6-2. List of medium and large (≥third order) tributaries in the Project areas.

Project Area	Tributary Name (listed from upstream to downstream)	Stream Order
Wilder Impoundment	Clark Brook	3
	Oliverian Brook	4
	Halls Brook	4
	Waits River	5
	Eastman Brook	3
	Indian Pond Brook	3
	Jacobs Brook	3
	NA	3
	Clay Brook	3
	NA	3
	Grant Brook	3
	Hewes Brook	3
	Ompompanoosuc River	5
	Bloody Brook	3
	Mink Brook	4
	Dothan Brook	3
Wilder Riverine	White River	7
	Mascoma River	5
	Kilburn Brook	3
	Bloods Brook	4
	Ottauquechee River	5
	Lulls Brook	3
	Blow-me-down Brook	3
	Hubbard Brook	3
	Mill Brook VT	4
	Mill Brook NH	4
Bellows Falls Impoundment	Sugar River	6
	Mill Brook	3
	Barkmill Brook	3
	Meadow Brook	3
	NA	3
	Ox Brook	3
	Little Sugar River	4
	Beaver Brook	4
	Spencer Brook	4
	Black River	5
	Clay Brook	4
	Commissary Brook	3
	Williams River	5

Project Area	Tributary Name (listed from upstream to downstream)	Stream Order
	Jabes Hackett Brook	4
	NA	3
Bellows Falls Riverine	Saxtons River	5
	Cold River	5
	Cobb Brook	3
	Blanchard Brook	3
	NA	3
Vernon Impoundment	NA	3
	Great Brook	3
	Houghton Brook	3
	Aldrick Brook	3
	Mill Brook	4
	East Putney Brook	4
	Partridge Brook	4
	Ox Brook	3
	Sacketts Brook	4
	Canoe Brook	3
	Salmon Brook	3
	Catsbane Brook	3
	NA	3
	West River	6
	Whetstone Brook	4
	Broad Brook	4
	Ash Swamp Brook	3
Vernon Riverine	NA	3

Source: USGS (2016b)

Backwater/Setback Habitats

Like the tributaries discussed above, backwater or setback habitats provide unique opportunities for spawning and rearing by many aquatic species. Forty-one backwaters are identified in the Project areas based on the National Hydrography Dataset (USGS, 2016b). The species that use backwaters are typically different than tributary-associated species. Yellow Perch, Northern Pike, Chain Pickerel, Largemouth Bass, Bluegill, Pumpkinseed, Black Crappie, and Golden Shiner frequent the shallow, vegetated habitats that are characteristic of many backwater habitats (Studies 14–15). With the exception of backwaters connected by a narrow channel (e.g., culverts under a railroad track), changes in WSEs in most backwaters closely mirror changes in the adjacent main stem. The shallow waters typical of smaller backwater habitats also tend to warm up more quickly in the spring and produce wider fluctuations in diel water temperatures with higher daily maxima during both spring and summer in comparison to mainstem temperatures. Exceptions to these rules were evident for backwaters associated with medium or larger tributaries (e.g., the backwater at the mouth of the Williams River in the Bellows Falls impoundment), which were influenced by cooler inflows.

Island Habitats

Eighteen permanent islands occur in the Project areas—8 in impoundment reaches and 10 in riverine reaches. Island habitats were targeted for sampling in the Studies 14–15 riverine and impoundment spawning studies because of the added complexity of habitat produced by the deposition zones associated with islands. Project segments containing islands have double the amount of margin-related habitat per length of channel, which includes shallow shoal habitat and large woody debris. Islands in riverine reaches provide additional eddy habitat that is heavily used for spawning by Smallmouth Bass, and gravel/cobble bars present at the heads of islands were frequently selected for spawning by Sea Lamprey and Fallfish. Chase Island near the lower boundary of the Wilder riverine reach was one of few known locations in the Project areas to harbor the endangered DWM, discussed in Section 3.8, *Threatened and Endangered Species*.

Bedrock Falls

Prominent bedrock-formed rapids and falls are rare in the Project areas; consequently, the rapids at Sumner Falls in the Wilder riverine reach represents a unique habitat unit that was assessed independently from the other more common mesohabitat types in Study 9. The rapids themselves offer relatively little habitat for fish on the Vermont side, which is composed of smooth bedrock bottom affording little protection from currents during high flows and a deep, bedrock slot possessing rapid velocities at all flows. The New Hampshire side contains more diversity of bedrock ridges, small slots, and some relatively large eddy areas at all but the highest project flows. A deep but moderately flowing slot occurs along a portion of the New Hampshire bank. Although habitat for aquatic species is limited within the rapids themselves, the habitat immediately downstream of the falls outlet is a very popular angling location that appears to produce high catch rates of gamefish, including Walleye, Smallmouth Bass, and Northern Pike.

The Bellows Falls bypassed reach also contains a bedrock-dominated channel with riffle and rapid habitat, although the upper, lower gradient portion of the 0.7-mile reach is not accessible to upstream migrating fish because of a fish barrier dam that is located 0.3 mile upstream from the bypass outlet.

Large Woody Debris

The presence and relative abundance of woody debris were assessed in the impoundment reaches using side-scanning sonar and visual surface observations. Although the overall percentage of woody debris was small in each reach, ranging from 1 percent by area in the Bellows Falls impoundment to a maximum of 3 percent in both the Wilder and Vernon impoundments, woody debris provides an important source of instream cover for both spawning and rearing for many fish species, particularly the piscivorous (i.e., fish eating), cover-oriented ambush predators such as Black Crappie, Largemouth and Smallmouth Bass, Northern Pike, and Chain Pickerel. Woody branches, whether dead or alive, were also heavily used by spawning Yellow Perch, which seemed to prefer draping their egg masses over branches rather than dropping them to the substrate (Figure 3.6-2, left). Woody debris was also uncommon in the riverine reaches, but where it did occur, it was frequently used by spawning Smallmouth Bass, which used the logs and branches as current breaks to protect the eggs and fry from excessive velocities and potential displacement from the nest (Figure 3.6-2, right).

Source: ILP Studies 14–15, *Resident Fish Spawning in Impoundments* and R*iverine Sections Study*

Figure 3.6-2. Use of woody vegetation and debris for spawning by Yellow Perch (left) and Smallmouth Bass (right).

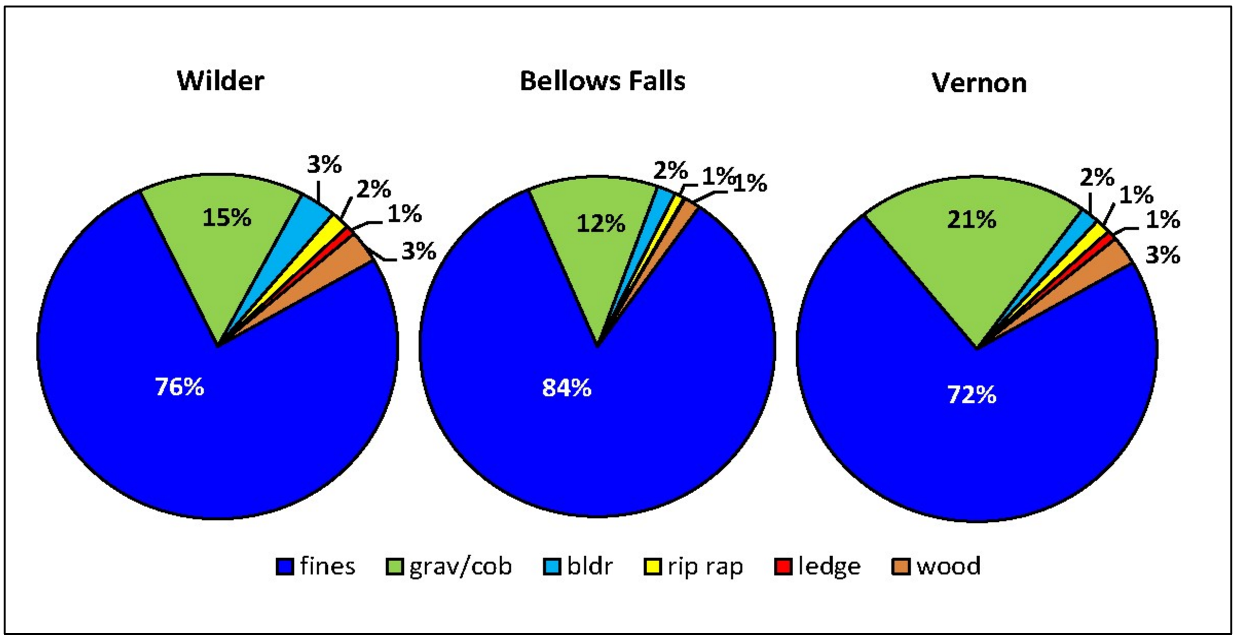
Substrate Types

Substrate composition in lakes and rivers has a significant influence on the suitability of habitat for fish spawning, feeding, and rearing (especially for benthic fish); mussel colonization; invertebrate productivity; vegetation establishment; and the like. Many of the fish species assessed in Studies 14-15 and 16 have specific substrate requirements for spawning, such as aquatic vegetation for Northern Pike and Chain Pickerel spawning, clean (free of fine sediments) gravel and cobble particles for Sea Lamprey and Fallfish nest construction, and clean rock substrate for sucker and Walleye egg development. Although Smallmouth Bass can sweep thin layers of fine sediments to expose suitable substrate for egg incubation, heavy deposition of fines also will limit spawning success for this species.

Side-scan sonar and surficial observations were used to broadly characterize substrate composition within 3,000 acres of habitat in each of the impoundment reaches (Study 7). Surficial observations were used to assess dominant substrate composition in the riverine reaches, and a combination of surficial and underwater video was used throughout both two-dimensional (2D) hydraulic modeling study locations for assessing flow/habitat relationships (Study 9). Substrate composition was also an important component of Study 8.

Impoundments

The side-scan sonar data collected for Study 7 within the Project impoundments classified substrate into six categories: (1) sand/silt/clay, (2) gravel/cobble, (3) boulder, (4) riprap, (5) ledge, and (6) woody debris. Substrate patches down to 100 square ft (and often smaller) were delineated in GIS to produce a separate layer for further assessment. As noted above, fines (sand, silt, and clay) dominated the substrate in each impoundment, representing from 72 percent of habitat in the Vernon impoundment to 84 percent in the Bellows Falls impoundment (Figure 3.6-3). Gravel/cobble substrate was the only other type that occurred in abundance in the Project impoundments, representing 15, 12, and 21 percent of the total substrate in the Wilder, Bellows Falls, and Vernon impoundments, respectively. Boulder, riprap, bedrock ledge, and woody debris composed between 1 and 3 percent of habitat in each reach. Overall, the Bellows Falls impoundment contained the most homogeneous habitat within the main channel, although all three impoundments contained rocky substrates in their upper reaches as well as along most major channel bends and at tributary mouths.



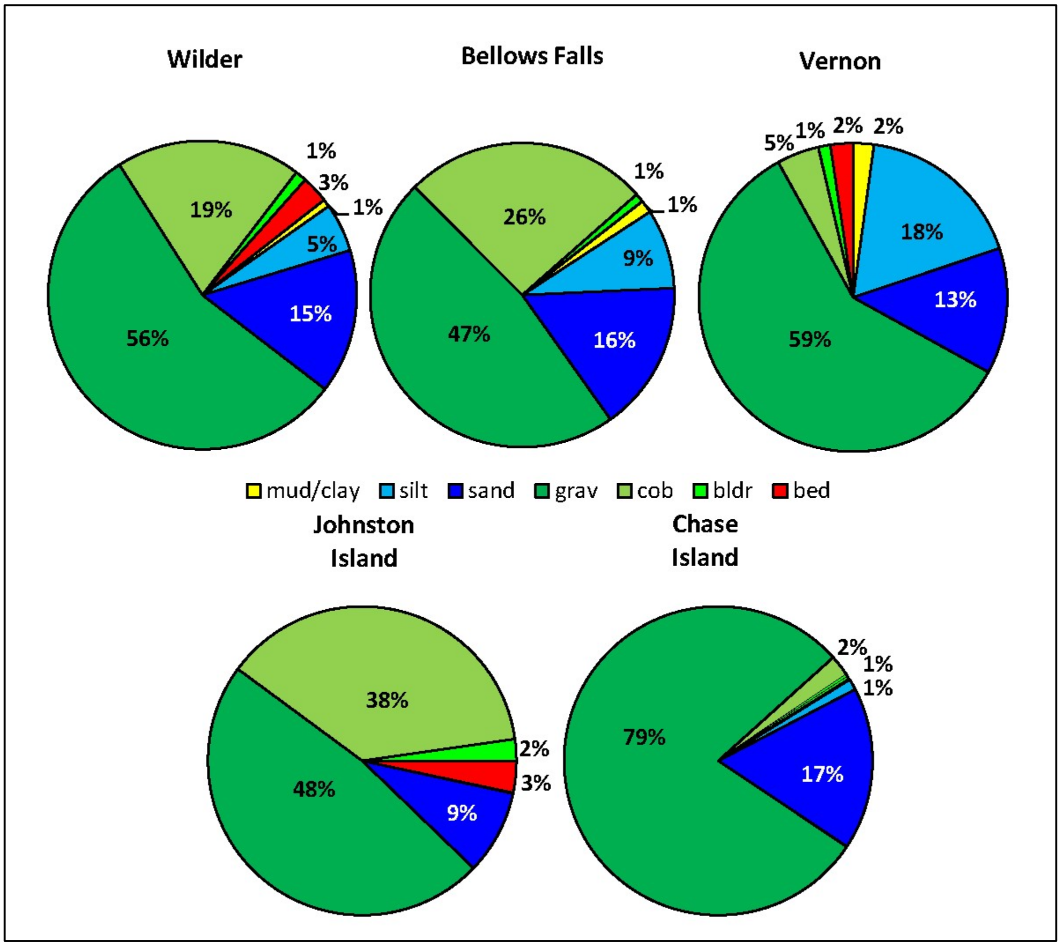
Source: ILP Study 7, *Aquatic Habitat Mapping Study*

Figure 3.6-3. Percentage by area of substrate types in the impoundment reaches.

Riverine Reaches

As expected, the proportion of larger, rocky substrate types was higher in the riverine reaches than in the impoundment reaches. Combined together, gravel, cobble, and boulder made up 65 to 76 percent of dominant substrate along the 1D transects in the three riverine reaches (Figure 3.6-4). The proportion of fines (mud/clay, silt, and sand) ranged from 21 percent in the Wilder reach to 33 percent in the Vernon reach; the principal difference between reaches was the lower percentage of cobble and the higher percentage of silt in the Vernon riverine reach, possibly reflecting the dul nature of this reach, resembling more impounded characteristics when WSE in the Turners Falls impoundment is high.

As noted above, the island habitats were frequently associated with large expanses of shallow bar and riffle habitats. Both the island-based 2D study sites contained 80 to 90 percent rocky substrate with gravel dominating at the Chase Island study site versus a gravel/cobble mixture at the Johnston Island study site (Figure 3.6-4). Fines were relatively uncommon at Johnston Island, whereas the longer Chase Island study site (which extended well upstream of the actual island) contained 17 percent sandy substrate.



Source: ILP Study 7, *Aquatic Habitat Mapping Study*

Figure 3.6-4. Percentage by length of dominant substrate types along 1D transects in the riverine reaches, and by area in the 2D study sites (Johnson and Chase Islands) in the Wilder riverine reach.

3.6.1.3 Resident Fish Populations

Abundance and Distribution

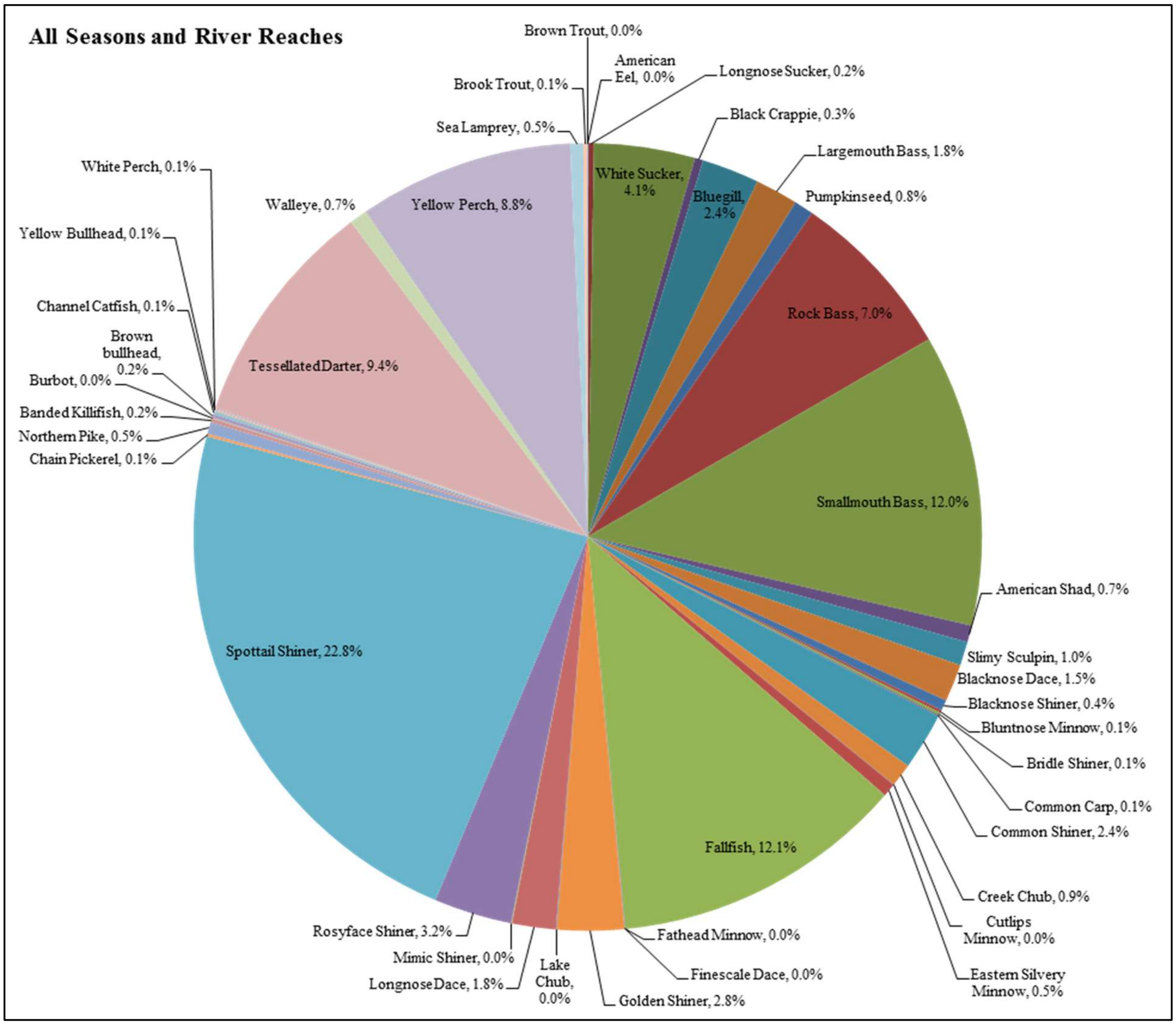
All Projects

The Connecticut River within the Wilder, Bellows Falls, and Vernon Project areas contains a diversity of habitats supporting a variety of resident fish species. Both intentional and accidental introductions have altered native fish communities within the basin (FWS, 2013a). The states of New Hampshire and Vermont annually stock Brook Trout, Brown Trout, and Rainbow Trout into the mainstem Connecticut River (New Hampshire) and in numerous tributaries upstream of, or within the Project areas, and formerly stocked Atlantic Salmon until 2013 (see Section 3.6.1.4). In 2016, the states collectively stocked approximately 33,000 Brook Trout, 28,000 Brown Trout, and 43,000 Rainbow Trout (NHFGD, 2016b; VFWD, 2016). Results from both historical surveys and sampling in 2015 (Study 10) indicate that more than 40 resident and migratory fish species occur in the Project areas.

Study 10 was conducted to characterize the occurrence, distribution, and relative abundance of both resident and migratory fish species present in the Project areas. Sixty-nine sites including impounded regions, riverine and bypassed reaches, tributaries, and backwaters within the Project-affected area were randomly selected during three seasonal periods (spring, summer, and fall) for sampling. Impoundment sites were sampled by 1,640-ft (500-meter) boat electrofishing transects as well as 2-hour experimental gillnet sets, while riverine and bypassed reaches, tributaries and backwater sites were sampled by up to 1,640-ft (500-meter) portable electrofishing transects and either a 100-ft beach seine sample (riverine sites) or 24-hour trapnet set (backwater sites).

A total of 11,551 fish representing 43 species and 14 families was collected over the Project areas (Figure 3.6-5 and Table 3.6-3)—40 resident species representing 11 families and 3 diadromous species representing 3 families (see Section 3.6.1.4, *Migratory Species*). Overall, Spottail Shiner, Fallfish, and Smallmouth Bass were the most abundant species collected across all river reaches and seasons combined. In addition to those 3 species, Tessellated Darter, Yellow Perch, and Rock Bass were the only other species to account for more than 5 percent each of the total number of individuals collected. The catch by specific gear type, season, and study reach is presented in Study 10.

Six species of the Centrarchidae family were collected during Study 10—Largemouth Bass, Smallmouth Bass, Pumpkinseed, Bluegill, Rock Bass and Black Crappie. Centrachids are typically found in habitats with protective cover for feeding and nesting, generally in the littoral zone (along the shoreline to a depth of about 6 to 20 ft), in backwaters and other off-channel habitats. Spawning occurs from spring, when water temperatures are near 60˚F, into summer and early fall. Males typically construct nests in shallow water by sweeping a depression into sand or gravel, usually around brush, rocks, and logs.



Source: ILP Study 10, *Fish Assemblage Study*

Figure 3.6-5. Percent composition by species for all seasons, sampling gears, in all Project areas, 2015.

Table 3.6-3. Total catch (N) and percent composition for fish species collected in 2015 in the Project areas.

Family / Common Name	REACH														ALL	
	Wilder Impoundment		Wilder Riverine		Bellows Falls Impoundment		Bellows Falls Bypassed Reach		Bellows Falls Riverine		Vernon Impoundment		Vernon Riverine			
	N	%	N	%	N	%	N	%	N	%	N	%	N	%	N	%
Anguillidae																
American Eel	1	<0.1	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	2	0.6	3	<0.1
Catostomidae																
Longnose Sucker	0	0.0	26	1.1	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	26	0.2
White Sucker	88	4.1	163	6.9	74	2.8	8	3.9	52	3.0	62	3.0	31	8.7	478	4.1
Centrarchidae																
Black Crappie	0	0.0	0	0.0	16	0.6	1	0.5	0	0.0	20	1.0	2	0.6	39	0.3
Bluegill	20	0.9	5	0.2	25	0.9	0	0.0	19	1.1	154	7.4	49	13.7	272	2.4
Largemouth Bass	50	2.3	3	0.1	37	1.4	1	0.5	24	1.4	87	4.2	1	0.3	203	1.8
Pumpkinseed	10	0.5	0	0.0	40	1.5	0	0.0	3	0.2	38	1.8	1	0.3	92	0.8
Rock Bass	261	12.2	186	7.8	154	5.8	3	1.5	99	5.7	80	3.8	26	7.3	809	7.0
Smallmouth Bass	145	6.8	395	16.6	238	9.0	43	21.0	379	21.9	79	3.8	107	30.0	1386	12.0
Clupeidae																
American Shad	0	0.0	0	0.0	0	0.0	0	0.0	41	2.4	16	0.8	22	6.2	79	0.7
Cottidae																
Slimy Sculpin	7	0.3	73	3.1	1	<0.1	0	0.0	1	0.1	13	0.6	18	5.0	113	1.0
Cyprinidae																
Blacknose Dace	2	0.1	25	1.1	118	4.4	0	0.0	32	1.8	1	<0.1	0	0.0	178	1.5
Blacknose Shiner	50	2.3	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	50	0.4
Bluntnose Minnow	9	0.4	3	0.1	0	0.0	0	0.0	1	0.1	0	0.0	0	0.0	13	0.1
Bridle Shiner	9	0.4	0	0.0	4	0.2	0	0.0	0	0.0	0	0.0	0	0.0	13	0.1
Common Carp	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	4	0.2	2	0.6	6	0.1
Common Shiner	5	0.2	131	5.5	1	<0.1	1	0.5	134	7.7	0	0.0	0	0.0	272	2.4

Family / Common Name	REACH														ALL	
	Wilder Impoundment		Wilder Riverine		Bellows Falls Impoundment		Bellows Falls Bypassed Reach		Bellows Falls Riverine		Vernon Impoundment		Vernon Riverine			
	N	%	N	%	N	%	N	%	N	%	N	%	N	%	N	%
Creek Chub	21	1.0	31	1.3	33	1.2	0	0.0	19	1.1	5	0.2	0	0.0	109	0.9
Cutlips Minnow	0	0.0	1	<0.1	1	<0.1	0	0.0	0	0.0	0	0.0	0	0.0	2	<0.1
Eastern Silvery Minnow	3	0.1	0	0.0	0	0.0	1	0.5	25	1.4	34	1.6	0	0.0	63	0.5
Fallfish	358	16.7	375	15.8	200	7.5	2	1.0	254	14.7	192	9.2	12	3.4	1393	12.1
Fathead Minnow	0	0.0	2	0.1	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	2	<0.1
Finescale Dace	0	0.0	2	0.1	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	2	<0.1
Golden Shiner	95	4.4	2	0.1	102	3.8	0	0.0	22	1.3	96	4.6	1	0.3	318	2.8
Lake Chub	0	0.0	1	<0.1	0	0.0	0	0.0	3	0.2	0	0.0	0	0.0	4	<0.1
Longnose Dace	2	0.1	32	1.3	16	0.6	127	62.0	30	1.7	0	0.0	0	0.0	207	1.8
Mimic Shiner	0	0.0	0	0.0	0	0.0	0	0.0	4	0.2	0	0.0	0	0.0	4	<0.1
Rosyface Shiner	0	0.0	313	13.2	20	0.9	0	0.0	34	2.0	1	<0.1	1	0.3	369	3.2
Spottail Shiner	302	14.1	174	7.3	1163	43.8	0	0.0	216	12.5	755	36.3	22	6.2	2632	22.8
Esocidae																
Chain Pickerel	6	0.3	0	0.0	5	0.2	0	0.0	1	0.1	1	<0.1	0	0.0	13	0.1
Northern Pike	28	1.3	0	0.0	12	0.5	0	0.0	1	0.1	12	0.6	3	0.8	56	0.5
Fundulidae																
Banded Killifish	3	0.1	1	<0.1	0	0.0	1	0.5	7	0.4	1	<0.1	6	1.7	19	0.2
Gadidae																
Burbot	0	0.0	0	0.0	0	0.0	0	0.0	3	0.2	0	0.0	0	0.0	3	<0.1
Ictaluridae																
Brown bullhead	1	<0.1	0	0.0	11	0.4	2	1.0	3	0.2	2	0.1	0	0.0	19	0.2
Channel Catfish	0	0.0	0	0.0	1	<0.1	0	0.0	2	0.1	2	0.1	9	2.5	14	0.1
Yellow Bullhead	0	0.0	0	0.0	1	<0.1	0	0.0	6	0.3	0	0.0	0	0.0	7	0.1
Moronidae																
White Perch	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	7	0.3	0	0.0	7	0.1

Family / Common Name	**REACH**														**ALL**	
	Wilder Impoundment		**Wilder Riverine**		**Bellows Falls Impoundment**		**Bellows Falls Bypassed Reach**		**Bellows Falls Riverine**		**Vernon Impoundment**		**Vernon Riverine**			
	N	**%**	**N**	**%**	**N**	**%**	**N**	**%**	**N**	**%**	**N**	**%**	**N**	**%**	**N**	**%**
Percidae																
Tessellated Darter	231	10.8	397	16.7	50	1.9	15	7.3	282	16.3	114	5.5	2	0.6	1091	9.4
Walleye	68	3.2	0	0.0	10	0.4	0	0.0	0	0.0	4	0.2	3	0.8	85	0.7
Yellow Perch	371	17.3	8	0.3	316	11.9	0	0.0	20	1.2	273	13.1	29	8.1	1017	8.8
Petromyzontidae																
Sea Lamprey	0	0.0	15	0.6	8	0.3	0	0.0	13	0.8	23	1.1	3	0.8	62	0.5
Salmonidae																
Brook Trout	0	0.0	7	0.3	0	0.0	0	0.0	0	0.0	5	0.2	5	1.4	17	0.1
Brown Trout	0	0.0	2	0.1	1	<0.1	0	0.0	1	0.1	0	0.0	0	0.0	4	<0.1
Total Individuals	**2146**		**2373**		**2658**		**205**		**1731**		**2081**		**357**		**11551**	
Total Families	**9**		**8**		**9**		**6**		**12**		**12**		**12**		**14**	
Taxa Richness	**26**		**26**		**28**		**12**		**31**		**28**		**23**		**43**	

Source: ILP Study 10, *Fish Assemblage Study*

Three species collected during Study 10 belong to the family Percidae, including two that fall within the subfamily Percinae (Walleye and Yellow Perch) and one within the subfamily Etheostomatinae (Tessellated Darter). Walleye and Yellow Perch commonly occur in lakes and rivers, occupying a variety of habitats and depths, while Tessellated Darter can be found in habitats ranging from small streams to large rivers and lakes, typically over mud or sand bottom in areas of little to no current (Langdon et al., 2006). Spawning for Yellow Perch and Walleye occurs at night during early spring after ice out. Tessellated Darter spawn in late April to May when water temperatures are between 50°F and 59°F, creating nests under rocks (Langdon et al., 2006).

Two species of the family Esocidae—Northern Pike and Chain Pickerel—were collected during Study 10. Not native to the Connecticut River, Northern Pike were introduced and are now naturalized within the Project impoundments. Esocid species prefer warm to cool lakes and rivers with slow current and large amount of aquatic vegetation. Spawning occurs during spring just after ice out, typically when waters reach 40°F in the Connecticut River. Esocids move into the shallow water of marshes and backwaters where adhesive eggs are broadcast onto vegetation (Langdon et al., 2006).

White Sucker and Longnose Sucker, representing the family Catostomidae, were collected during Study 10. White Sucker are found in a variety of habitats and environmental conditions including lakes and large rivers as well as small ponds and streams. It can be found in high and low gradient habitats and is generally tolerant of degraded environmental conditions including pollutants and siltation (Langdon et al., 2006). Longnose Sucker are commonly found in colder waters than White Sucker, which are often associated with gravel bottomed streams, rivers, and lakes (Scarola, 1973). Spawning occurs when water temperatures reach 40°F for Longnose Sucker and 50°F for White Sucker, typically between late April and June in the upper Connecticut River (Langdon et al., 2006). Adults migrate up tributaries to higher gradient riverine sections or even along windswept regions of lakes where they use rocky, shallow areas with moderate current (Langdon et al., 2006). No nests are prepared, and no parental care is provided for the eggs, which are scattered along the bottom of these spawning areas.

Eighteen species from the family Cyprinidae were collected during Study 10 including Blacknose Dace, Blacknose Shiner, Bluntnose Minnow, Bridle Shiner, Common Carp, Common Shiner, Creek Chub, Cutlips Minnow, Eastern Silvery Minnow, Fallfish, Fathead Minnow, Finescale Dace, Golden Shiner, Lake Chub, Longnose Dace, Mimic Shiner, Rosyface Shiner, and Spottail Shiner. Cyprinids favor a variety of habitats, depths, temperatures, and water quality conditions, and at least one representative of this family can most likely be found within almost any reach of the Project areas. Three of the most commonly found species are Fallfish, Golden Shiner, and Spottail Shiner. While all three species inhabit lakes and large rivers, their habitat preferences distinguish them. Fallfish prefer clear water lakes and rivers with gravel bottoms, while Golden Shiner and Spottail Shiner are associated more with slower currents and modest to high concentrations of aquatic vegetation. Spawning periods for the three most common cyprinids range from spring through mid-summer with Fallfish initiating spawning the earliest (late April to May) followed by Golden Shiner and Spottail Shiner (May to August). Fallfish spawn over piles of stones or gravel bottoms in flowing water, which then are covered by mounds of additional stones (Scott and Crossman, 1973). Golden Shiner broadcast spawn over beds of vegetation, while Spottail Shiner are reported to aggregate for spawning at tributary mouths where they broadcast spawn over gravel bottoms (Becker, 1983).

Brown Bullhead, Yellow Bullhead and Channel Catfish are species of the family Ictaluridae collected during Study 10. Bullheads prefer warm water and usually inhabit regions near or on the bottom in shallow ponds, lakes, and slow-moving rivers with abundant aquatic vegetation and soft bottoms. Channel Catfish also inhabit lakes and rivers but prefer clearer water associated with gravel (Scott and Crossman, 1973). Spawning for bullheads and Channel Catfish typically occurs from late spring to late summer when water temperatures range between 69^{o}F and 85^{o}F in nests with newly hatched young guarded by adult males (Becker 1983; Scott and Crossman, 1973).

Brook Trout and Brown Trout represent the members of the family Salmonidae collected during Study 10 (no Rainbow Trout were collected). Brook Trout, native to the region, can be found in a variety of habitats from deep lakes and large rivers to small headwater streams provided that a steady supply of cold, well-oxygenated water is present year-round. Brown Trout, introduced from Europe, are more tolerant of warmer temperatures than Brook Trout but tend to thrive under similar cold, well-oxygenated conditions. Spawning occurs in autumn over redds created by females for both species (Scarola, 1973; Scott and Crossman, 1973).

Banded Killifish, Burbot, Slimy Sculpin and White Perch are the sole species collected during Study 10 that represent the families Fundulidae, Gadidae, Cottidae, and Moronidae, respectively. Banded Killifish are a hardy species found in shallow reaches of lakes and streams throughout the eastern coastal plain of North America. Burbot are most often found in cold, deep lakes across northern North America but also can be found in streams and rivers. These fish migrate to shallow reaches of lakes or up rivers and streams to spawn under the ice in December through March. Slimy Sculpin occur widely throughout northern North America, typically in small gravel and cobble streams, although they have been found in larger lakes and rivers (Scarola, 1973). White Perch are not native to the upper Connecticut River but has been successfully introduced to many inland waters in New Hampshire and Vermont. These fish prefer shallow, warmer waters in lakes and rivers, spawning in shallow coves and tributaries in the spring (Scarola, 1973).

Wilder Project

A total of 2,146 fish was captured in the Wilder impoundment, of which Yellow Perch, Fallfish, and Spottail Shiner made up 48.1 percent of the total catch. The Wilder riverine reach (2,146 total fish captured) was dominated by Smallmouth Bass, Fallfish and Tessellated Darter (49.1 percent of the total catch) (Table 3.6-3).

Bellows Falls Project

In the Bellows Falls impoundment (2,658 total fish captured), Spottail Shiner accounted for 43.8 percent of the total catch followed by Yellow Perch (11.9 percent) and Smallmouth Bass (9.0 percent). The Bellows Falls bypassed reach catch included only 205 fish captured of which 62.0 percent were Longnose Dace, making this the only reach where this species accounted for greater than 2.0 percent of the total species composition. The Bellows Falls riverine reach (1,731 total fish captured) was similar to the Wilder riverine reach in that Smallmouth Bass, Fallfish, and Tessellated Darter were the dominant species, accounting for 52.9 percent of the total catch (Table 3.6-3).

Vernon Project

The Vernon impoundment (2,081 total fish captured), similar to the Bellows Falls impoundment, was dominated by Spottail Shiner (36.3 percent) as well as Yellow Perch (13.1 percent). The Vernon riverine reach (357 fish captured) was dominated by Smallmouth Bass, Bluegill and White Sucker, that together accounted for 52.4 percent of the total catch (Table 3.6-3).

Tessellated Darter Study

Study 12 was conducted in 2015 to characterize the distribution and relative abundance of this species through habitat-based field surveys. As one of three known hosts for the glochidia stage of federally endangered DWM, (discussed in detail in Section 3.8, *Threatened and Endangered Species*), the Tessellated Darter is important to the life cycle of that species. Sampling in September 2015 was conducted at 45 randomly selected 1,640-ft (500-meter) map units within the Project areas, and within each map unit, three cross-river transects were randomly placed. A 3-meter radius ring count circle was then placed at five count locations along each transect at which darters were quantified. From 675 count circles, 263 darters were observed (Table 3.6-4), 80 percent of which were determined to be juveniles based on estimated body length of less than 2.5 inches.

Table 3.6-4. Summary statistics for Tessellated Darter observations by river reach, 2015.

Description	Total Count of Darters	Mean Number of Darters/ 25 square meters (m^2)	Standard Deviation	Min Number of Darters / 25 m^2	Max Number of Darters / 25 m^2
Wilder impoundment	208	1	4.4	0	40
Wilder riverine	9	0.1	0.3	0	1
Bellows Falls impoundment	37	0.3	1.1	0	9
Bellows Falls riverine	6	0.1	0.4	0	3
Vernon impoundment	2	<0.1	0.1	0	1
Vernon riverine	1	<0.1	0.2	0	1
Total	**263**	**0.4**	**2.5**	**0**	**40**

Source: ILP Study 12, *Tessellated Darter Survey*

The majority of darters were observed in the Wilder impoundment followed by the Bellows Falls impoundment, while the fewest observations occurred in the southern-most reaches (Vernon impoundment and Vernon riverine reach). Across all sample sites, the majority of darters were identified in depths of less than 8 feet, in locations where water velocities did not exceed 0.6 feet/second, with a substrate preference of sand/silt/clay. These findings are in-line with accepted life history data form local sources (Langdon et al., 2006; Scarola, 1987). Results from Study 10 demonstrated a similar geographic distribution with the greatest number of Tessellated Darters encountered in Wilder followed by Bellows Falls and Vernon. Further breaking out Tessellated Darter presence in the project affected areas by riverine and impounded reaches shows the highest darter counts in Study 10 were from Wilder Riverine (N = 397) and Bellows Falls Riverine (N = 282) where, proportionately, far fewer darters were identified in Study 12. Tessellated Darter were one of the five most commonly encountered species from the fish assemblage study (Study 10; 9.4 percent of the total catch) and their diverse capture locations (Figure 3.6-6) in Study 10 indicate a presence in habitats and water velocities that are different than those which they are commonly associated with from the literature (Scarola, 1987; Landon et al., 2006) and in Study 12. Taken together, it is likely Tessellated Darter is more widely distributed throughout Project affected areas than determined by individual study results.

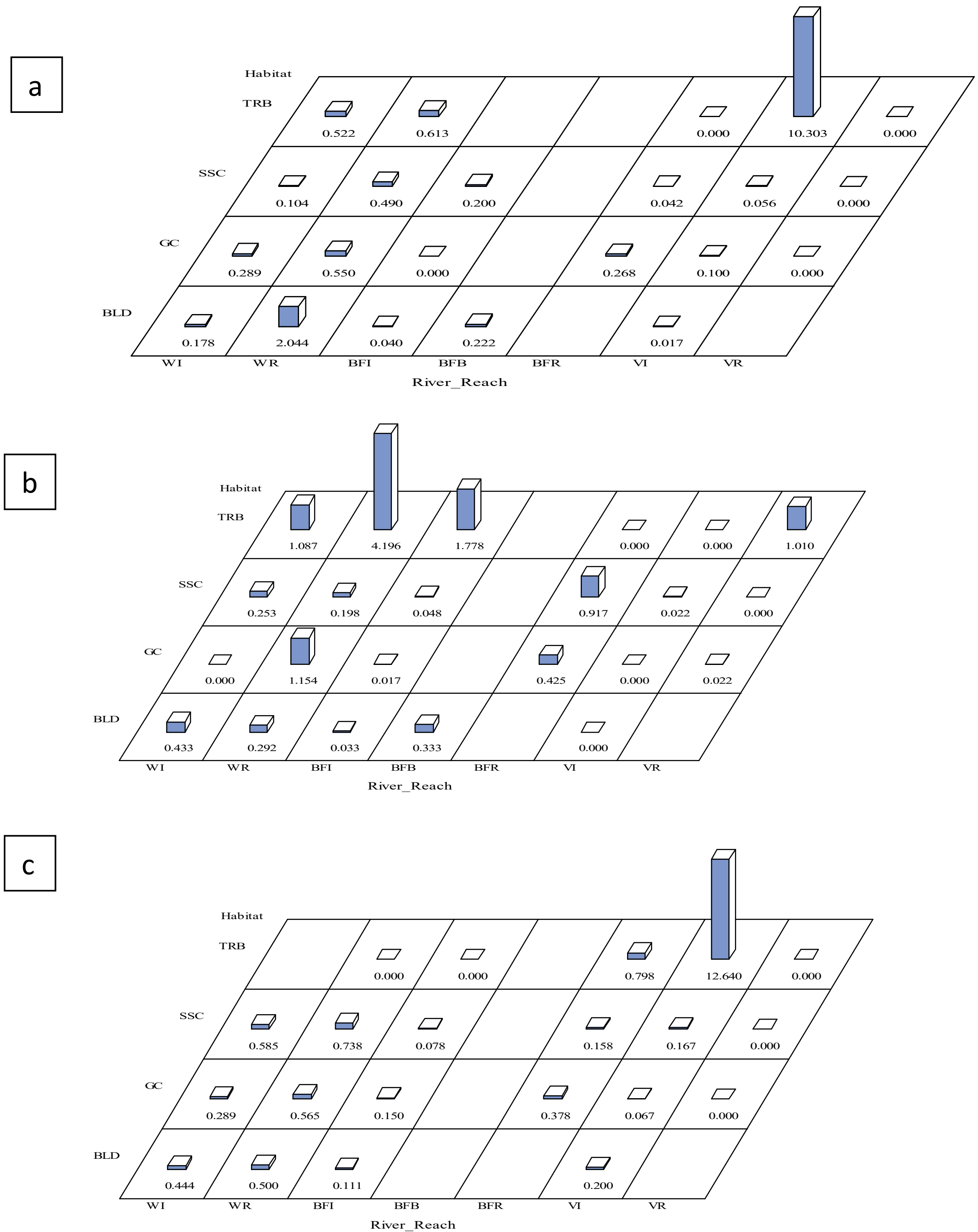


Figure 3.6-6. Mean CPUA values (# individuals/100 m^2) for Tessellated Darter captured during Study 10 by river reach and substrate/habitat type for the (a) Spring, (b) Summer, and (c) Fall sampling seasons.

No DWM were identified among the five species of freshwater mussels found during Study 12 sampling. However, Tessellated Darters found during Study 12 and Study 10 were distributed within the mussel survey reaches and were found nearby or in the general vicinity (within 1 to 2 miles up or downstream) of most locations where DWM were found during Study 24. Darters were also present near some mussel survey sites where no DWM were found (e.g., near Sumner Falls).

Upstream Passage

Study 17 was conducted in 2015 to evaluate fish ladder use by resident species at the three Projects. The study used digital video fish passage monitoring systems consisting of a closed-circuit video camera; a laptop computer capable of running Salmonsoft's FishCap/FishRev, version 2.6.3.0[34] software; an uninterruptable power source battery backup; and accessories as recommended by the Vermont Agency of Natural Resources (VANR). Movements of 15 species/genera past the viewing areas at each Project fish ladder were tabulated by the direction of movement (upstream or downstream) and net passage counts were calculated (upstream counts – downstream counts) on an hourly basis.

The Projects' fish ladders are normally operated on an as-needed seasonal basis for migratory species based on passage counts at downstream projects (see Sections 2.1.1.5, 2.1.2.5, and 2.1.3.5, *Existing Environmental Measures*, for each Project). For purposes of this study of resident species fish passage, video recording was conducted from as early as possible in spring 2015 until ice-in during early January 2016.

High numbers of upstream and downstream movements relative to the net upstream passage counts suggests milling of fish in the fish ladder counting windows, resulting in multiple recordings of the same fish. That conclusion is supported by anecdotal observations made by fisheries technicians of fish resting and/or moving in and out of the field of view, indicating a pattern of occupancy rather than passage (Study 17). Alternatively, the occurrence of multiple counts of individuals could result from fallback and unsuccessful upstream passage. In either case, the number of both upstream and downstream movements likely highly overestimates the actual number of individuals using the fish ladders. Therefore, net passage is the best metric for estimating actual passage, particularly in the context of monitoring for upstream passage, which was the purpose of Study 17.

Wilder Project

The fish ladder operated from April 17, 2015, to January 7, 2016. Resident species were recorded to have low fish ladder usage and minimal net passage. Five of the 11 target resident species/genera were recorded with only net downstream passage recorded for sunfish (Table 3.6-5). The majority of net passage for all species except trout, and for all species combined, occurred during the fish ladder's normal

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Table 3.6-5. Wilder fish ladder total recorded movements and net passage of target resident species by operating period, 2015.

Species/ Genera	Ladder Opening–July 15				July 16–January 7, 2016				80% Net Passage Date	Total Net No. Passed[a]
	First Date	Last Date	Obser-vations	Net No. Passed[a]	First Date	Last Date	Obser-vations	Net No. Passed[a]		
Bass	May 21	July 8	548	28	July 20	Dec 21	321	11	July 22	39
White Sucker	May 12	June 8	19	1	NA	NA	0	0	May 12	1
Walleye	May 12	July 15	111	13	July 22	Oct 16	210	8	Aug 2	21
Trout	May 16	July 15	267	37	July 16	Jan 7	1,887	37	Jul 30	74
Sunfish	May 21	July 5	3	-1	July 24	Sep 15	48	-4	Aug 25	-5
Bullhead	No observations									
Crappie	No observations									
Pike/Pickerel	No observations									
Yellow Perch	No observations									
Carp	No observations									
Other	No observations									

Source: ILP Study 17, *Upstream Passage of Riverine Fish Species Assessment*

a. Negative net passage value indicates overall net downstream movement.

operating season (from opening in spring through July 15, but note that the Wilder fish ladder is only operated if there has been passage of adult Atlantic Salmon at Bellows Falls). Cumulative net passage reached 80 percent for bass on July 22, for Walleye on August 2, and for sunfish on August 25. The single net passage for White Sucker occurred on June 8.

Trout were recorded most frequently in the ladder and throughout the extended 2015 study season, with only 50 percent cumulative net passage by July 15, yet 80 percent of trout cumulative net passage had occurred by July 30. Bass were also recorded frequently throughout the extended season, but net passage was low.

Bellows Falls Project

The fish ladder operated from April 15, 2015, to January 6, 2016. Overall fish ladder usage was very low. Five of 11 target resident species/genera were recorded with bass being the most common species recorded (Table 3.6-6).

The majority of net passage for all species but sunfish and for all species combined occurred during the fish ladder's normal operating season (from opening in spring through July 15, but note that the Bellows Falls fish ladder is only operated if there has been passage of adult salmon or sufficient numbers of Sea Lamprey at the Vernon Project). Cumulative net passage reached 80 percent for bass on May 25, for White Sucker on May 5, for Walleye on May 14, and for trout on July 8. For sunfish, 80 percent net passage occurred on September 3. Bass were recorded most frequently in the ladder and from May 12 to November 3. However, no net upstream passage occurred after May 21 (80 percent of cumulative net downstream passage occurred by May 25).

Table 3.6-6. Bellows Falls fish ladder total recorded movements and net passage of target resident species by operating period, 2015.

Species/ Genera	Ladder Opening–July 15				July 16–January 6, 2016				80% Net Passage Date	Total Net No. Passed[a]
	First Date	Last Date	Obser-vations	Net No. Passed[a]	First Date	Last Date	Obser-vations	Net No. Passed[a]		
Bass	May 12	July 15	787	-47	July 16	Nov 3	474	0	May 25	-47
White Sucker	May 3	May 26	91	7	NA	NA	0	0	May 5	7
Walleye	May 10	June 22	36	2	July 21	Oct 15	22	0	May 14	2
Trout	May 20	July 15	87	15	July 16	Sep 21	193	-7	July 8	8
Sunfish	May 29	July 15	15	1	Aug 7	Sep 18	38	6	Sep 3	7
Bullhead	No observations									
Crappie	No observations									
Pike/Pickerel	No observations									
Yellow Perch	No observations									
Carp	No observations									
Other	No observations									

Source: ILP Study 17, *Upstream Passage of Riverine Fish Species Assessment*

a. Negative net passage value indicates overall net downstream movement.

Vernon Project

The fish ladder operated from May 5, 2015, to January 6, 2016. Opening was delayed in the spring from the planned mid-April date due to high water and late snow melt delaying internal and external (FWS) pre-season inspections and subsequent maintenance. Overall, 10 of the 11 target resident species/genera were recorded. Of the target species/genera, only Yellow Perch was not recorded; the category of "other" included primarily Channel Catfish (Table 3.6-7). Note that long-standing operating procedures dictate that attraction flow (i.e., the volume supplied via the attraction water pumps of 200 cfs) is shut down overnight and operates generally from 7:00 a.m. to 7:00 p.m. during the normal passage season, although other supplemental flows (flow in the fish ladder itself, downstream fishway flows) operate at night.

The majority of net passage for all species but sunfish, and for all species combined, occurred during the fish ladder's normal operating season (from opening in spring through July 15). Cumulative net passage of 80 percent was reached for White Sucker on May 7, for Walleye on June 10, for trout on July 12, for bullhead on June 21, for crappie on May 30, and for pike and pickerel on July 11 (see Section 3.6.2.6, *Resident Fish Passage – Vernon Project* for additional information on 2016 passage of Walleye and White Sucker). Common Carp and "other" species both reached 80 percent cumulative net passage on July 20.

Bass were the most common species recorded in the ladder followed by sunfish. All species, except Common Carp, were recorded during the extended season after July 15, but only in very small numbers with the exception of sunfish and bass, which were recorded more frequently during that period. For bass, cumulative net passage reached 69 percent of net passage by July 15 and 80 percent by August 20. For sunfish, cumulative net passage reached only 17 percent by July 15, 50 percent by August 26, and 80 percent by September 6 (Study 17).

Table 3.6-7. Vernon fish ladder total recorded movements and net passage of target resident species by operating period, 2015.

Species/ Genera	Ladder Opening–July 15				July 16–January 6, 2016				80% Net Passage Date	Total Net No. Passed[a]
	First Date	Last Date	Obser-vations	Net No. Passed[a]	First Date	Last Date	Obser-vations	Net No. Passed[a]		
Bass	May 5	July 15	8,954	522	July 16	Nov 6	925	239	Aug 20	761
White Sucker	May 5	June 27	4,381	325	July 23	Oct 31	5	-3	May 7	322
Walleye	May 5	July 1	187	49	July 22	Nov 6	17	9	June 10	58
Trout	May 12	July 12	138	24	July 31	Dec 22	12	6	July 12	30
Sunfish	May 7	July 15	2,244	204	July 16	Oct 22	5,794	984	Sep 6	1188
Bullhead	May 10	July 15	11	3	July 20	Aug 13	3	-1	June 21	2
Crappie	May 16	June 11	14	14	NA	NA	0	0	May 30	14
Pike/Pickerel	May 6	July 11	3	-1	NA	NA	0	0	July 11	-1
Yellow Perch	No observations									
Common Carp	May 25	July 15	160	6	July 20	July 23	8	2	July 20	8
Other	May 10	July 13	233	9	July 20	Dec 10	27	3	July 20	12

Source: ILP Study 17, *Upstream Passage of Riverine Fish Species Assessment*

a. Negative net passage value indicates overall net downstream movement.

3.6.1.4 Migratory Species

The Connecticut River in the vicinity of the Vernon, Bellows Falls, and Wilder Projects supports a variety of migratory species. They include the catadromous American Eel and anadromous species including Atlantic Salmon, American Shad, and Sea Lamprey. Before reaching Vernon and the upstream Projects, upstream migratory fish must first successfully pass the hydroelectric facilities at Holyoke (RM 87) and Turners Falls (RM 122). Annual passage numbers at all dams on the Connecticut River have varied over time depending on a number of factors including annual adult population (run) size in the river, numbers passing Holyoke and Turners Falls dams, the timing of passage at Holyoke and Turners Falls dams relative to spawning state, condition of fish that have passed Turners Falls, river flow conditions, and fish ladder effectiveness. While Atlantic Salmon have occurred historically in the Project areas, current management and stocking efforts have been curtailed because of poor returns. Similarly, Blueback Herring made limited historical use of the Project areas based on reported collections or observations in recent decades, but none have been observed since 2000. The historical upstream extent of the range of both Blueback Herring and American Shad in the Connecticut River is understood to be Bellows Falls due to the natural gradient of the river (VT WAP Team, 2015).

Table 3.6-8 provides historical upstream passage counts for migratory species that are currently present at the three Great River Hydro Projects, American Eel is excluded since returns were not tabulated historically. Historical passage counts at downstream projects are discussed in Section 3.6.3, *Cumulative Effects*. For all species, video recording of fish movements in fish ladders and fishways cannot distinguish individual fish that may mill in front of the window, so the total number of video detections is likely to include multiple detections of the same individuals, inflating estimates of the actual number of fish using the fish ladders. Therefore, only net passage values provide a reasonably valid estimate of ladder usage (see Sections 3.6.2.6, *Resident Fish Passage,* and 3.6.2.7, *Upstream Passage of Migratory Fish,* for more detailed discussion).

Upstream fish passage facilities are operated in spring and fall based on an annual schedule provided by CRASC and depend on passage counts at downstream hydroelectric projects (see Section 2.1, *No-action Alternative*). Fish ladders would be operated from May 15 through July 15 at Wilder for Atlantic Salmon if Atlantic Salmon pass Bellows Falls; at Bellows Falls for Atlantic Salmon if Atlantic Salmon pass Vernon, and for Sea Lamprey if 100 individuals are counted passing Vernon; and from April 15 through July 15 at Vernon for Atlantic Salmon and American Shad (and for Blueback Herring, but none have passed Vernon since 2000). The spring operational start date for Vernon depends on passage counts at Turners Falls and Holyoke. In fall, if required for Atlantic Salmon only, fish ladders would operate from September 15 to November 15.

Table 3.6-8. Annual upstream passage counts for the Vernon, Bellows Falls, and Wilder fish ladders.

Year	Vernon			Bellows Falls			Wilder		
	American Shad	Atlantic Salmon	Sea Lamprey	American Shad	Atlantic Salmon	Sea Lamprey	American Shad	Atlantic Salmon	Sea Lamprey
1981	97	8	306						
1982	9	0	5						
1983	2,597	0	379						
1984	335	0	195	1	0	0			
1985	833	4	1,257	0	2	10			
1986	982	4	573	0	2	11			
1987	3,459	10	667	39	8	35	0	3	0
1988	1,370	5	281	24	3	0	0	2	0
1989	2,953	0	205	[c]	[c]	[c]	[c]	[c]	[c]
1990	10,894	9	387	0	5	47	0	1	0
1991	37,197	6	750	65	3	34	0	1	0
1992	31,155	13	749	103	4	89	0	0	0
1993	3,652	7	627	2	0	17	[c]	[c]	[c]
1994	2,681	8	767	3	3	34	0	1	0
1995	15,771	5	509	147	1	44	[c]	[c]	[c]
1996	18,844	9	853	1	3	180	0	0	0
1997	7,384	4	1,506	46	0	40	[c]	[c]	[c]
1998	7,289	12	16,438	55	3	198	[d]	[d]	[d]
1999	5,097	8	836	110	2	195	[d]	1	[d]
2000	1,548	5	855	9	2	102	[d]	2	[d]
2001	1,744	1	3,212	[d]	1	[d]	[d]	[d]	[d]
2002	356	3	2,210	[d]	[d]	[d]	[d]	[d]	[d]
2003	268	0	8,119	[c]	[c]	[c]	[c]	[c]	[c]
2004	653	1	3,668	[d]	1	[d]	[d]	1	[d]

Year	Vernon			Bellows Falls			Wilder		
	American Shad	Atlantic Salmon	Sea Lamprey	American Shad	Atlantic Salmon	Sea Lamprey	American Shad	Atlantic Salmon	Sea Lamprey
2005	167	4	3,669	3	3	229	[d]	2	[d]
2006	133	4	2,895	0	0	261	[c]	[c]	[c]
2007	65	5	17,049	0	3	709	0	0	0
2008	271	8	22,434	0	8	2,233	0	4	2
2009	16	7	1,532	0	4	100	0	1	0
2010	290	8	3,179	0	4	392	0	2	0
2011	46	9	329	1	6	74	0	3	0
2012	10,715	4	696	0	2	99	0	2	0
2013	18,220	e	1,008	0	e	213	0	e	0
2014	27,706	11	399	0	2	212	0	0	0
2015[a]	39,196	6	2,440	44	1[b]	970	0	1	2
2016	35,732	0	5,539	1,973	0	1,619	c	c	c
2017	28,682	2	2,612	0	1	1,261	c	c	c
2018	31,725	1	3,124	733	1	162	c	c	c
2019	12,872	0	2,330	3	0	148	c	c	c

Sources: CRASC (2016); FWS (2016c, 2015, 2014a, 2013a); Normandeau (2011); VFWD (2010); ILP Study 17, *Upstream Passage of Riverine Fish Species Assessment*

a. Net upstream passage counts from ILP Study 17.

b. One salmon assumed to pass Bellows Falls since one was recorded at Wilder.

c. Fish ladder was not operated.

d. Fish ladder was operated but not monitored; Atlantic Salmon counts from radio telemetry.

e. No salmon were released above Holyoke.

American Eel

The American eel is a catadromous fish species, typically spending the majority of its life cycle in freshwater and returning to the sea to spawn. Various developmental stages of the species occur in freshwater, coastal waters and the open ocean as far north as Labrador and Greenland along the North American east coast, to as far south as the Gulf of Mexico and northern South America (Facey and Van Den Avyle, 1987). Following spawning in the Sargasso Sea (south of Bermuda, east of the Bahamas), larvae, called leptocephali, are transported from spawning areas to the eastern seaboard by ocean currents (Facey and Van Den Avyle, 1987). While drifting, leptocephali metamorphose, becoming a transparent but miniature post-larval version of an eel called a glass eel. American Eels migrate toward freshwater from the ocean in the form of glass eels. As they enter coastal areas, the body begins to pigment and the eels are then known as elvers (Facey and Van Den Avyle, 1987). The majority of glass eels and elvers reach the coastal rivers of New England during the spring (March–June). As elvers enter the juvenile growth phase, they become known as yellow eels and remain in that phase until they begin to metamorphose into the sexually mature silver-phase and prepare to emigrate to the ocean for spawning. When in freshwater, American Eels tend to be bottom dwellers, increasing their activity levels at night (Scott and Crossman, 1973). They prefer to hide in burrows, plant masses, or other natural substrate shelters (Facey and Van Den Avyle, 1987).

Sexual differentiation does not occur until eels are about 8 to 10 inches (20 to 25 centimeters [cm]) long. American Eels may spend between 5 and 24 years in freshwater and sexual maturing takes place in the later summer or fall (ASMFC, 2014; Smith and Tighe, 2002). Upon initiation of maturity, eels stop feeding, develop a sharply bicolored body pattern (gray to black dorsal side and white ventral side, known as silver eels), eyes and pectoral fins enlarge, and the individual begins to move downstream. Emigrating silver eels primarily move at night and are also stimulated by pulses in flow associated with rain events. The minimum size of silver eels is approximately 11.5 inches (29 cm) for males and 18 inches (45 cm) for females. Female American Eels grow much larger than males and average 24 to 39 inches (60 to 100 cm). American Eels are among the most highly fecund fish species with egg production estimates reported to reach up to 10 million eggs.

During Study 10, only three eels were collected despite the extended sampling effort (spring, summer, and fall). All three were collected during the fall (September and October) sampling. Two of the three eels were identified as silver eels based on morphometric parameters. One was collected in the Wilder impoundment and one in the Vernon riverine reach. The third eel was also collected in the Vernon riverine reach and identified as a juvenile (yellow eel).

Study 11 was conducted in 2015 to evaluate the presence of eels throughout the approximate 122-mile extent of the Project areas. A total of 102 mainstem and 24 tributary locations was sampled by electrofishing, and a 24-hour, baited eel trap set was conducted at each of the 126 sites selected. Three types of bait were tried during sets but no eels were collected in the traps. Only three eels, all greater than

18 inches in length, were collected at two sampling locations in the Bellows Falls impoundment. One eel was determined to be a silver eel based on morphometric parameters, and the other two were determined to be immature yellow eels. The dominant substrate where these eels were captured was sand/silt/clay and this was also the dominant substrate throughout most of the study area. No characteristics of those two sites differentiated them from other stations sampled that resulted in no eel collections.

The low catch of eels recorded in Study 11 have been observed in other Connecticut River studies. Yoder et al. (2009) conducted a fish assemblage and habitat assessment of the Upper Connecticut River from Lake Francis (RM 325.6) to Turners Falls (RM 122). Electrofish sampling over the 203.6 miles covered by Yoder et al. (2009) collected only two American Eels—one was captured in the Vernon impoundment below VY and the other was captured upstream of Turners Falls, outside the Study 11 study area. Similarly, annual electrofishing at VY within the lower Vernon impoundment recorded 27 American Eels over 25 years of sampling (1991–2014; Normandeau, 2015b). Greater numbers of eels were identified in Study 17 and in Study 18 than in Studies 10 and 11 although the focus of those studies was specific to monitoring fish ladder usage and identifying areas where eels might congregate at the dams in an attempt to migrate upstream.

Net positive counts of American Eels recorded at the fish ladders in 2015 for Study 17 indicated the fewest numbers present in the ladders at Wilder (52), slightly greater numbers at Bellows Falls (60), and substantially higher passage at Vernon (1,545). While eel counts provide an index of eel migratory activity, video recording of eel passage is considered to be inaccurate because of significant negative counts observed, thereby casting doubt on any reasonable accuracy of the actual numbers of eels attempting to migrate. The fish ladder structures that guide fish to counting windows are not necessarily effective for guiding eels past the window, and bottom-oriented eels moving at night may not trigger the video recording motion sensing component.

In 2015, Study 18 identified no American Eels below Wilder dam, 3 eels below Bellows Falls dam, and 80 eels below Vernon dam during approximately 5 months of weekly nighttime observations and eel pot sampling. Eel count numbers within the Vernon fish ladder outweighed collections elsewhere at the dam and indicate it as a potential preferred route for upstream passage although subsequent investigations have indicated repetitive attempts by eel to navigate the ladder to the exit (see Section 3.6.2.7, *Upstream Passage of Migratory Fish*, for further discussion).

Study 18 was conducted again at Vernon in 2016, 2017 and 2018; in 2019 a tagging study tracked juvenile eels as they moved through the Vernon fish ladder. Section 3.6.2.7, *Upstream Passage of Migratory Fish*, describes these studies in detail, a summary is provided here.

In 2016, Study 18 included weekly nighttime observations from late July through mid-October, and fabrication and operation of an eel ramp trap near the fish ladder entrance for upstream migrating eels beginning in early September. Seventy eels were identified in nighttime observations and only one eel was collected from the ramp trap (Study 18, 2016 report supplement); however, the survey began relatively late in the season. Though no aggregations of upstream migrating eels were identified, sites where most eels were observed included the fish ladder entrance area and approach (n = 11), stanchion bay leakage and the associated bedrock outcrop (n = 25), and the tainter gate areas (primarily deep gates set below the tainter gates, n = 34).

Study 18 eel surveys were continued within the reach downstream of Vernon during 2017 and 2018. During 2017, nighttime visual surveys occurred along the spillway, sluice gate, and at the fish ladder during and after normal fish ladder operations. Over a 23-week period (June 1 through November 6) a total of 148 eels were observed, 55.4 percent of which were observed at the fish ladder viewing window (n = 82). In addition to visual surveys, the interim ramp trap was operational during the survey period and recorded 123 eels captured between July 4 and September 19 with peak collections in August. VANR upstream fish passage counts identified a net upstream passage of 581 juvenile eels in 2017 and 120 were counted in the fish ladder during dewatering at the end of the fish passage season.

The 2018 surveys were conducted using the same general methodology as used during previous years and occurred over a 22-week period from June 7 through November 1, 2018. A total of 221 eels were observed with the majority (61.1 percent) of the observations occurring at the fish ladder. During the 2018 evaluation, the use of the interim ramp trap was discontinued, and modifications were made to the fish ladder with the intent of improving the accuracy of eels counts documented by the video monitoring system. Observations of juvenile eels from the counting room window indicated they usually appeared to be traveling upstream at the bottom of the water column and "falling back" or traveling downstream through the mid-water portion of the water column, resulting in negative net counts reported by VANR. Despite modifications made to the ladder, the 2018 fish passage counts recorded a net negative upstream passage of over 6,000 eels.

To provide a better understanding of juvenile eel movements within the fish ladder and to help inform on improved future counts and overall passage effectiveness, Great River Hydro conducted a passive integrated transponder (PIT) study during 2019.

Seven PIT detection locations were distributed from the lower leg of the Vernon fishway to the fishway exit weir and a total of 161 juvenile eels, sourced from the Vernon fish ladder and Holyoke dam, Holyoke, MA were PIT tagged and released over four dates spanning July 29 through September 5. One hundred and twenty-six PIT tagged eels demonstrated upstream movement within the fish ladder. Approximately 73 percent of all ascent attempts reached the lower end of the regulating pool midway up the ladder where it transitions from the downstream ice harbor section to the upstream vertical slot section (Figure 3.6-14 and Figure 3.6-15) and 47 percent reached the upper end of the regulating pool. The majority of ascent events terminated with a final detection at these locations. It is suspected that a high proportion of ascent attempts ended with departure from the ladder via the regulating pool overflow weir. A total of seven tagged eels reached the uppermost PIT detection location at the fish ladder exit structure.

Study 20 reviewed the scientific literature on environmental cues associated with downstream migration of silver American Eel in the Connecticut River basin and the Northeast. The cues that trigger adult eel migration are generally, though not necessarily specifically, understood. Primary cues include water temperature and increased river flow. Other factors that have been hypothesized to act as cues, either singly or in combination include precipitation, changes in atmospheric pressure (associated with precipitation), and increased turbidity or other chemical factors (associated with precipitation and increased flow).

In New England and mid-Atlantic rivers, spawning emigrations begin in the late summer and seem to be concentrated in the fall, specifically in October (Haro, 2003; Winn et al., 1975), although winter emigrations have been noted (Euston et al., 1997; Facey and Helfman, 1985). The timing of maturation and subsequent emigration is associated with water temperature, which establishes bounds of the emigration period as well as potentially triggering movements. In the Connecticut River, downstream passage has been documented as occurring when water temperature is from 45.5 to 68.0°F (7.5 to 20°C). It has been hypothesized that a migratory response to a drop in water temperature synchronizes emigrating silver eels, increasing their chances of reaching the Sargasso Sea simultaneously (CESAR, 2010; FWS, 2007a). Silver eel migration in the Connecticut River appears to occur primarily at night with peak activity within several hours after sunset. Lunar illumination may influence migration with intervals of low light proximal to the new moon promoting migratory behavior. However, any effect of lunar illumination has been found to be less important than environmental cues, such as water temperature and flow (Study 20).

American Shad

American Shad are an anadromous, highly migratory, coastal pelagic, schooling species that spend the majority of their life at sea (Munroe, 2002; Stier and Crance, 1985). American Shad are found along the Atlantic coast from northern Labrador to the St. Johns River, Florida. They are the largest member of the herring family (Clupeidae) and females are larger than males at all ages. Mature male shad range from 12.0 to 17.5 inches (30.5 to 44.7 cm) and mature females range from 15 to 19 inches (38.3 to 48.5 cm) (Stier and Crance, 1985). The historical upstream extent of the range of American Shad in the Connecticut River is understood to be Bellows Falls because of the natural steep falls at this location (VT WAP Team, 2015). In some years, small numbers of American shad have passed upstream of Bellows Falls dam (Table 3.6-8). However, access to habitat upstream of the dam may be artificial due to the provision of fish passage upstream of the natural migration limit.

Shad form large schools during their time at sea, ranging vertically from surface waters to a depth of 772 ft (220 meters, Munroe, 2002). Adult shad return to coastal rivers to spawn during the spring when water temperatures are 61.7 to 66.2°F (16.5 to 19.0°C). In New England waters, males typically reach sexual maturity between ages 3 and 5 and females between ages 4 and 6. American Shad are prolific spawners, and large females can produce up to 600,000 eggs. Reproductive rates are highest in the southern portion of the species range and in older and larger females. Male shad arrive at spawning areas ahead of females. Although shad spawn only in freshwater, there does not appear to be any required distance upstream of brackish water (Stier and Crance, 1985). Shad runs typically reach far upriver and often to the headwaters. Spawning occurs in river areas characterized by broad flats with relatively shallow water (3.3 to 19.7 ft, 1 to 6 meters) and moderate current (0.98 to 3.3 ft/s [0.3 to 1.0 meter/s]). Viable eggs have been recorded over bottom types ranging from fine sand to coarse rock and ledge but never over silt or mud bottom (Munroe, 2002). Northern populations of American Shad exhibit high post-spawning survival and are considered iteroparous (repeat spawners). Fertilized eggs slowly sink to the bottom where they water-harden. Hatching takes place during a 6- to 15-day period (depending on water temperature), and the majority of larvae emerge during June. Larvae may remain in fresh water or drift into brackish water and grow rapidly, transforming into juveniles approximately 4 to 5 weeks after hatching (Stier and Crance, 1985). Juvenile shad form schools and gradually move downriver prior to departing for the ocean during late fall of the same year that they were hatched.

In Study 10, 79 American Shad were captured across all sampling locations, seasons and gear types (Figure 3.6-5 and Table 3.6-3), totaling 0.7 percent of the catch in that study. During spring sampling, 3 adult shad were captured in the Vernon riverine reach below Vernon dam, amounting to 2.8 percent of all fish captured during spring sampling in the Vernon riverine reach, and 0.1 percent of the total spring catch when considering all gear types and sampling locations. Summer sampling captured a total of 33 young-of-year American Shad. The majority of shad captured in the summer were from the Bellows Falls riverine reach (n = 31), with an additional 2 captured in the Vernon riverine reach. Shad contributed a small percentage to the overall species composition in the summer when considering all gear types and sampling locations (0.9 percent) and had a slightly greater contribution when considering only the reach where they were captured (Bellows Falls riverine = 6.3 percent, Vernon riverine = 1.9 percent). Forty-three young-of-year shad were captured during fall sampling—10 from the Bellows Falls riverine reach, 16 from the Vernon impoundment, and 17 from the Vernon riverine reach. These fish accounted for 1.1 percent of the total catch across all gears and location during fall sampling, and ranged from 1.3 percent of the fish captured in the Bellows Falls riverine reach to 12.1 percent of the fish from the Vernon riverine reach.

In Study 17, net upstream passage of adult American Shad was assessed at the Vernon and Bellows Falls fish ladders. No passage occurred or was expected at Wilder. At Vernon, adult shad were recorded in the fish ladder from May 10, 2015, through August 22, 2015, during which a total net upstream passage of 39,196 individuals was recorded, and at Bellows Falls, net upstream passage of 44 shad occurred between May 26, 2015, and June 20, 2015 (Table 3.6-3).

In 2016, CRASC reported net upstream passage of shad at Vernon of 35,732 and 1,973 at Bellows Falls (Table 3.6-8) during the regular springtime fish ladder operational season. The proportional net passage of shad at Vernon relative to Turners Falls has ranged from 57 percent to 73 percent between 2014 and 2019 (CRASC, 2016), meeting or exceeding CRASC's 1992 Management Plan goals of 40 to 60 percent in all years from 2012 through 2019. Lower passge was observed in 2020 with 34 percent of shad that passed Turners Falls passing Vernon. While data have not been fully processed, the lower passage numbers may be a condition of the unually low water year that presented both low flow and high water temperatures during the latter part of the run at the time shad generally arrive at Vernon.

Study 21 included an assessment of 65 radio-tagged adult shad and their migratory movements in the river from the Vernon riverine reach upstream to Bellows Falls dam. Fifty-four shad were tagged and released into the Vernon impoundment and 11 had been released downstream of Vernon and successfully passed upstream through the fish ladder (another shad passed the fish ladder as detected by its PIT tag but lost its radio tag and was unavailable for tracking upstream of the fish ladder). Approximately 28 percent of those shad continued upstream and were detected in the Bellows Falls tailrace. No tracking was conducted upstream of Bellows Falls dam, so it is not known if any of these shad were included in the 44 counted passing Bellows Falls in Study 17. It is likely that the remaining 72 percent not tracked to Bellows Falls found suitable spawning habitat in the approximate 31-mile reach between Vernon dam and Bellows Falls, because radio-tagged fish were tracked, and eggs and/or larvae were collected throughout this reach.

Results of Study 21 related to upstream passage, downstream passage route selection, and turbine survival at Vernon are discussed in Section 3.6.2.6*, Effects on Resident Fish Passage*, and Section 3.6.2.10, *Effects on Turbine Survival*. Study 22 included an assessment of the timing of the shad outmigration at Vernon, downstream passage route selection, and turbine survival and is also discussed in Section 3.6.2.6*, Effects on Resident Fish Passage*, and Section 3.6.2.10*, Effects on Turbine Survival*.

Sea Lamprey

The Sea Lamprey is an elongate, eel-like anadromous species found along the Atlantic coast from Labrador to Florida (Flescher and Martini, 2002; Smith, 1985). Adult Sea Lamprey reach an average length of 28 inches (72 cm) at the start of spawning with a maximum recorded length of 35 inches (90 cm; Flescher and Martini, 2002). Sexually mature adults are characterized by strong sexual dimorphism with male lamprey developing a pronounced dorsal ridge and female lamprey developing a prominent ventral fold.

While at sea, adult lamprey parasitize a range of fish species by attaching to them, using 11 to 12 rows of horny, hooked teeth located in an oral hood. Sea lamprey typically attach to the side of their prey and rasp at the flesh until they can feed on blood. Adult lamprey return to coastal streams during the spring, peaking during May and June in Gulf of Maine rivers. Sea Lamprey seek out river or stream reaches that contain suitable habitat in terms of substrate and current, typically using gravel substrate and swift current velocities. Eggs are deposited in a shallow nest depression constructed on the bottom. The majority of spawning adults are 8 years of age (Beamish and Medland, 1988), and an average female contains 200,000 eggs. Deposited eggs develop during a 10- to 13-day period after which the larvae (called ammocoetes) develop gill clefts, an oral hood and body pigmentation (Flescher and Martini, 2002). Ammocoetes travel downstream to low velocity areas with muddy or sand bottom where they construct a shallow burrow. Ammocoetes are filter feeders and diatoms make up the majority of their diet. The larval period generally lasts for 5 years (Beamish and Medland, 1988) after which ammocoetes transform into juveniles during a 4- to 6-month period. During the transformation, eyes and related musculature, teeth, a new oral hood, salivary glands, new kidneys and pigmentation develop (Flescher and Martini, 2002). Juvenile lamprey move away from the river bottom and downstream where they are capable of entering seawater and adopting a parasitic life style.

FWS lists the current upstream extent of Sea Lamprey range as Bellows Falls dam, noting, however, reproduction has been documented as far north as the White River, Vermont (FWS, 1999). Others have documented Sea Lamprey upstream and downstream of Bellows Falls dam including Yoder et al. (2009). In certain years, hundreds to more than 2,000 lamprey have been recorded passing the Bellows Falls fish ladder, although numbers are typically low and inconsistent from year to year (Table 3.6-8). Thirty-three individuals were collected during the 2008 electrofishing survey (Yoder et al., 2009), which sampled approximately 4.3 river miles of habitat in the Bellows Falls impoundment and 0.6 river miles downstream of the Bellows Falls dam. Abundance relative to total catch at the four sites where lamprey were present in the impoundment ranged from 0.59 to 1.49 percent. At the single station sampled below the dam, 5 individuals were collected representing 2.28 percent of the total catch (Yoder et al., 2009). In the 2008 surveys, Yoder et al. (2009) also documented Sea Lamprey just downstream of Wilder dam to the confluence of the White River with the Connecticut River, where 9 individuals were collected in approximately 3.1 river miles of habitat. In Study 10, Sea Lamprey were collected in all river reaches downstream of Bellows Falls and represented 0.5 percent (n = 62) of the total species composition. Sea Lamprey ammocoetes were identified in samples throughout the Project areas below Wilder dam but were absent from the Bellows Falls bypassed reach. During spring sampling, 38 ammocoetes (contributing 1.0 percent of the total spring species catch) were collected. Similarly, 15 ammocoetes were collected in summer sampling and contributed 0.4 percent of the total species catch for that season. During fall, 9 ammocoetes were captured contributing 0.2 percent of the total species catch for that sampling season, with the most upstream capture location in the Bellows Falls impoundment and the most downstream occurrence in the Vernon riverine reach.

In Study 17, 2015 net upstream passage of Sea Lamprey at the Vernon fish ladder was 2,440 or 29 percent of Turners Falls passage and (CRASC, 2016) and net upstream passage at Bellows Falls was 971 individuals, or 40 percent of that recorded at Vernon. Two Sea Lamprey were also recorded passing Wilder dam. In 2016, Vernon passed 5,521 lamprey and Bellows Falls passed 1,619 (CRASC, 2016).

In Study 16, 23 study sites were distributed among five reaches from the Wilder riverine reach to the Vernon riverine reach and were pre-selected based on habitat suitability criteria. In the Bellows Falls and Vernon impoundments, site selection focused on the mouths of large- and medium-sized tributaries (second to sixth order streams) and island bars. Radio telemetry tracking of tagged adult Sea Lamprey was used to further inform and adjust the selection of sites. Telemetry relocations in areas of suitable habitat were considered to be verification of pre-selected sites for spawning habitat assessment, and in a few cases, was the rationale for adjusting site selection. Many telemetry locations occurred in water that was too deep and/or turbid to visually verify spawning behavior, conditions likely exacerbated by generally high flows during the spawning season. As a result, sites that could not be adequately surveyed for evidence of spawning, and that had not been characterized as having insufficient suitable habitat, were revisited in August or September 2015 during low-flow conditions when the maximum amount of habitat was exposed or accessible to survey. That supplementary habitat assessment included the recording of nest elevations for use in analyses of potential Project effects. Of the 23 sites surveyed, 4 sites were determined to have unsuitable habitat (e.g., fine substrate dominance, excessive embeddedness of coarse substrates, and lack of swift flows; or insufficient habitat [e.g., some characteristics of suitable habitat were observed, but others were lacking, within the Project-influenced area of the study site]). Of the remaining 19 sites, 16 (84 percent) were classified as active spawning areas and 3 (16 percent) were classified as having suitable habitat, but with no evidence of spawning (see Section 3.6.2.1, *Aquatic Habitat*).

Atlantic Salmon

Atlantic Salmon is a highly migratory, anadromous fish species that was indigenous to suitable riverine habitat from northeastern Labrador south to the Housatonic River which flows into Long Island Sound in Connecticut (Kocik and Friedland, 2002). Numerous reviews detail the life history of Atlantic Salmon (e.g., NMFS, 2009; Fay et al., 2006; Kocik and Friedland, 2002). Adult Atlantic Salmon begin to return to natal freshwater rivers during the spring and continue into October, often producing a spring and a fall upstream run. The majority of salmon returning to rivers in New England have been at sea for 2 years. A lesser component of the run consists of 1- or 3-sea-winter salmon and repeat spawners. Nests, or redds, are constructed by female salmon and eggs are deposited and immediately fertilized by male salmon during the late fall, generally in riffle habitat with coarse gravel substrate. Following fall spawning, approximately 20 percent of spent adult salmon (called kelts) move downstream to the ocean but the majority return to the ocean the following spring (Baum, 1997).

Eggs remain in the gravel until hatching during the early spring. Following a 3- to 6-week period, the young salmon emerge as fry and begin to actively seek food. As fry begin to feed, they develop cryptic vertical stripes and are then known as parr. Atlantic Salmon in the Gulf of Maine region typically remain in the parr stage for 1 to 3 years and remain resident to the freshwater river. Following that period, parr undergo a series of physiological and morphological changes known as smoltification during which they lose their parr markings and develop a streamlined, silvery body and a pronounced forked tail. In this smolt stage salmon migrate downstream to the ocean. This downstream migration takes place during spring (April to June). Outmigrating smolts must adapt to changes in water temperature, pH, DO, salinity, pollution levels, predation, and other factors as they move downstream.

Atlantic Salmon fry and smolts were stocked in tributaries throughout the Connecticut River Basin from 1968 to 2013, with an annual stocking goal of 10 million fry per year, as part of efforts to restore Atlantic Salmon to the Connecticut River basin. Atlantic Salmon smolts migrating downstream from tributaries upstream of the Project areas passed downstream through the Projects. However, in July 2012, FWS announced that it would no longer produce hatchery-reared stock for the restoration efforts because of the continued high costs for the program with very low numbers of resulting adult returns. New Hampshire, Vermont, and Massachusetts followed suit and discontinued their stocking programs after 2013, when approximately 580,700 fry were stocked in the watershed upstream of the Projects (FWS, 2013a). The State of Connecticut subsequently developed and operates the "Salmon Legacy Program" which continues to stock salmon in some Connecticut River tributaries in the State (FWS, 2014a).

No Atlantic Salmon were collected in Study 10, and very few Atlantic Salmon were counted passing upstream at the three Projects during Study 17 in 2015. One was counted at Wilder, one at Bellows Falls, and six at Vernon. No salmon were counted in 2016 at any locations upstream of Holyoke where only three were counted (CRASC, 2016). Access to habitat is provided at all mainstem dams, so any future Atlantic Salmon population increases would presumably result in the reintroduction of the species to the Project areas.

3.6.1.5 Freshwater Mussels

Freshwater Mussels

Various surveys of freshwater mussels were conducted in support of Project relicensing with results detailed in the following study reports:

- ILP Study 24, Dwarf Wedgemussel and Co-Occurring Mussel Study – Phase 1 Report;
- ILP Study 24, Dwarf Wedgemussel and Co-Occurring Mussel Study – Phase 2 Report;
- ILP Study 24, Dwarf Wedgemussel and Co-Occurring Mussel Study – Development of Delphi Habitat Suitability Criteria Report; and

- ILP Study 24, Dwarf Wedgemussel and Co-Occurring Mussel Study – Development of Habitat Suitability Criteria for Co-Occurring Mussels.

The Connecticut River watershed in New Hampshire and Vermont supports nine species of freshwater mussels, seven of which are found within the mainstem of the Connecticut River and near the mouth of mainstem tributaries, including the federally endangered DWM (see Section 3.8, *Threatened and Endangered Species*), which is also listed as endangered in New Hampshire and Vermont.

Species Descriptions[35]

Eastern elliptio is the most common freshwater mussel species in New Hampshire. It is a medium-sized mussel up to 5 inches in length, and can be highly variable in coloration, size, and shape. The species is found in all major watersheds in lakes, ponds, streams, and rivers in all substrate types. It is not likely to occur in high gradient streams where no other mussels occur. It uses a large number of host fish including perch, bass, sunfish, and pickerel.

Eastern lampmussel is a common medium sized to large mussel reaching 5 inches in length. The thick shell varies in coloration from yellowish-green to brownish-black often with numerous green rays on the shell. The inner shell is white or bluish-white. The species is found in coastal watersheds, as well as the Connecticut and Merrimack River watersheds in sandy and gravely substrates of rivers, streams, lakes, and ponds, mainly in coolwater or warmwater habitats. It uses a variety of host fish including bass, perch, sunfish, and crappie.

Eastern floater is a common medium sized to large, elongate mussel up to 7 inches in length. The shell is very thin and colored greenish-yellow or brownish. The inner shell is silvery-white or metallic-bluish. The species is found in the coastal, Connecticut, Merrimack, and Androscoggin River watersheds in small rivers and streams as well as ponds and lakes, and some wetlands, not usually in fast moving currents. It prefers sandy, muddy, or silt substrates. It uses a wide variety of fish species as host fish such as Yellow Perch, Bluegill, and White Sucker.

Triangle floater is a common, medium sized mussel up to 3 inches in length. Shell color is generally a mix of greenish-brown or yellow. The inner shell is pinkish or bluish-white. The species is found in all major watersheds in New Hampshire most commonly in rivers and streams with sand or gravel substrates. It can tolerate a range of flows and substrates and seems to prefer low-gradient rivers with low to moderate velocities. It uses a variety of host fish including the Common Shiner, White Sucker, and Largemouth Bass (NHFGD, 2015).

Alewife floater is identified as a SGCN in both New Hampshire and Vermont. It is a large, elongate and thin mussel reaching 6-7 inches in length. Shells are usually yellowish-brown or blackish and have prominent growth lines. The inside shell is usually a white or pinkish color. The species is found in parts of the Connecticut River downstream of Bellows Falls including in most major tributaries, and in the Merrimack River, and coastal watersheds of New Hampshire in rivers, streams,

[35] If not otherwise cited, species descriptions are from NHFGD (undated).

ponds, and lakes. It seems to tolerate a range of flows and substrate types, including sand, sand and gravel, and silt. Host fish include the anadromous Alewife, Blueback Herring, and American Shad (NHFGD, 2015; VT WAP Team, 2015).

Creeper is identified as a SGCN in New Hampshire. It is medium sized, growing up to 3 inches. The shell is greenish-brown or yellowish-brown with a rough appearance from prominent growth lines. It is uncommonly found in most major watersheds in New Hampshire, including the lower Connecticut River, generally in small streams and rivers with sand, cobble, or gravel substrates. It seems to prefer low to moderate flow velocities. Host fish include Largemouth Bass, Yellow Perch, Fathead Minnow, Fallfish, Golden Shiner, and Bluegill. Creepers may also use amphibians as hosts, such as the Northern two-lined salamander (NHFGD, 2015).

The DWM is a small, wedge-shaped mussel measuring 1-1.5 inches in length. Shell color varies from yellowish-brown to blackish-brown, and the inner shell is bluish-white. It is found in the Connecticut River mainstem and some tributaries (NHFGD, 2015; VT WAP Team, 2015). It is a generalist in terms of preference for stream size, substrate, and flow conditions (Nedeau, 2008; Nedeau, 2006; McLain and Ross, 2005; Michaelson and Neves, 1995; Strayer and Ralley, 1993). It inhabits small streams less than 5 meters wide to large rivers more than 100 meters wide in a variety of substrate types including clay, sand, gravel, and pebble, and often in areas of rivers with large amounts of silt (e.g., depositional areas and near banks). The DWM inhabits very shallow water along streambanks and can move laterally or horizontally in the substrate as water levels fluctuate (Nedeau, 2006), but they have also been found at depths of 25 ft in the Connecticut River (Nedeau, 2006). Fish hosts include the Tessellated Darter, Slimy Sculpin, Banded Killifish, and Atlantic Salmon, as well as Mottled Sculpin and Striped Bass (Nedeau, 2008) (see Section 3.8, *Threatened and Endangered Species*, for detailed discussion).

Survey Results

Mussel surveys were conducted in 2011 and 2013 at 210 sites within the Project areas. A total of 147 sites was located in impoundments, and 24 sites were located immediately downstream of dams (8 sites below each dam). Surveys were carried out between May and October in both years, and included semi-quantitative mussel sampling (i.e., timed searches) and documentation of habitat conditions. Surveys were typically conducted by SCUBA diving in deep (>5 ft) water and snorkeling in shallow areas. Table 3.6-9 summarizes mussel species found within the Project areas during field surveys conducted in 2011 and 2013.

Table 3.6-9. Freshwater mussel species found in the Wilder, Bellows Falls, and Vernon Project areas, 2011 and 2013.

Species (status)	Wilder Imp.	Wilder Riverine	Bellows Falls Imp.	Bellows Falls Riverine	Vernon Imp.	Vernon Riverine
Eastern Elliptio	X	X	X	X	X	X
Eastern Lampmussel	X	X	X	X	X	X
Eastern Floater			X	X	X	X
Alewife Floater (NH SGCN, VT SGCN)			X	X	X	X
Triangle Floater (NH SGCN)	X	X	X	X	X	
Creeper (NH SGCN)	X		X		X	
Dwarf Wedgemussel (endangered, federally and in NH and VT)	X		X			

Source: ILP Study 24, *Dwarf Wedgemussel and Co-Occurring Mussel Survey – Phase 1 Report*

Sixty-nine DWM were counted in the Wilder and Bellows Falls impoundments; none were found in the Vernon impoundment or in the downstream riverine reaches (see Section 3.8, *Threatened and Endangered Species*). Six other species of freshwater mussels were found during the surveys: eastern elliptio, eastern lampmussel, Alewife floater, triangle floater, creeper, and eastern floater. The mussel communities were dominated by eastern elliptio and eastern lampmussel, which were found at 95.2 and 87.6 percent of survey sites, respectively. Together, these two species comprised more than 99 percent of the mussels observed at most survey sites. Alewife floaters were the third most common species overall, occurring at 12.6 percent of all survey sites, and at 66.7 percent of all survey sites located downstream of the Bellows Falls dam. A total of 460 Alewife floaters was counted, including 2 upstream from the Bellows Falls dam, 217 below the Bellows Falls dam, 166 in the Vernon impoundment, and 75 below the Vernon dam.

The other three species were far less common. Creepers were found at 22 survey sites (10.5 percent) and usually only present at very low numbers. Creepers were found at 2 sites (2 animals) in the Wilder impoundment, 2 sites (2 animals) in the Wilder riverine reach, 14 sites (44 animals) in the Bellows Falls impoundment (mostly in the lower Black River), and 4 sites (6 animals) in the Vernon impoundment. No creepers were found immediately downstream of any of the dams. Triangle floaters were found at 31 survey sites (14.8 percent) and usually at very low numbers, including at 10 sites (19 animals) in the Wilder impoundment, and 4 sites (6 animals) in the riverine reach, 9 sites (18 animals) in the Bellows

Falls impoundment, and 2 sites (2 animals) in the Vernon impoundment. Triangle floaters were also found downstream of Wilder dam (3 live animals) and Bellows Falls dam (5 live animals). Eastern floaters occurred primarily in two locations: in the lower Black River in the Bellows Falls impoundment and within the downstream half of the Vernon impoundment.

The three fluvial (i.e., not found in lake environments) mussel species—DWM, triangle floater, and creeper—were rare and patchily distributed. DWM were not found in the Wilder riverine reach where the species was historically known to occur (e.g., near Sumner Falls and the Cornish Covered Bridge), and densities of other fluvial species (triangle floater and creeper) were also very low in the Wilder riverine reach, which contained the lowest species richness and mussel density (all species) among the areas surveyed, and had the poorest quality mussel habitat. Important areas for the rare fluvial species in the Wilder impoundment were primarily confined to a 14-mile reach in the upper third of the impoundment. Important areas for the three fluvial species in the Bellows Falls impoundment appeared to include Wethersfield Bow, the Connecticut River near the Black River confluence, and the lower Black River. Eastern elliptio and eastern lampmussel are the only two species with robust populations throughout all of the mussel study area, although alewife floater populations may also be stable in areas of the Connecticut River downstream of Bellows Falls dam.

3.6.2 Environmental Effects

Continued operations of the Wilder, Bellows Falls, and Vernon Projects will maintain the current modest daily and sub-daily fluctuations in impoundment water levels, variations in discharge flows, and instream flow alterations in the downstream riverine reaches that can affect aquatic habitat, spawning and reproduction, and migration. The presence and operations of turbines can affect rates of impingement, entrainment, survival and/or migration timing. Because Great River Hydro does not propose to change Project operations, the environmental effects identified in this section are expected to remain the same under new licenses.

3.6.2.1 Aquatic Habitat

No-action Alternative

Current Project operations include cyclical discharges, largely corresponding to upstream inflows, ranging from minimum flows to full generating capacity during normal (non-spill) Project operations, and discharges greater than Project generating capacities during high flow (spill) conditions. Normal Project operations have the effect of changing WSEs and associated water depths, wetted area, and availability of riparian cover in both the impoundment reaches upstream of each dam and in the downstream riverine reaches. Although changes in impoundment WSEs generally exert little to no influence on mainstem wetted areas and water velocities in the uppermost reaches of the impoundments, both normal and high flow operations can have effects that increase water velocities and affect wetted area in the shallow, low-sloped habitat types in downstream riverine reaches. For example, higher flow and discharge levels can alter the character of riverine reach mesohabitat units, especially riffles which tend to “flood-out” and appear more like run habitats. Glide habitats can also take on a more run-like appearance at higher flows, and runs tend to get deeper and faster but still retain the characteristics of a run habitat. In contrast to riffle habitats, pool habitats change the least in response to flow changes.

The magnitude and rate of change in WSEs varies spatially within and between impoundments and downstream reaches, as well as temporally according to inflows, and changes in Project outflows. Typically, impoundment WSEs during periods of normal Project operations fluctuate approximately 2.5 ft at Wilder dam, 1.8 ft at Bellows Falls dam, and 1.8 ft at Vernon dam on a daily or sub-daily basis, but can differ at points upstream of the dam dependent upon upstream inflow (see Sections 2.1.1.4, 2.1.2.4, and 2.1.3.4, *Existing Project Facilities*). Fluctuations in water levels can alternately expose and inundate shallow margin habitats in a similarly variable degree dependent upon inflow and location within the Projects or Project affected reaches. Project-related water level fluctuations can potentially affect resources dependent upon these habitats such as fish eggs or nests; small, newly emerged fish fry; and water-dependent lifestages of terrestrial species (see Section 3.7, *Terrestrial Resources*).

DWM and co-occurring mussel species are relatively sedentary, year-round residents of the Connecticut River and require instream habitat and host fish for all aspects of their life cycle. Habitat suitability criteria for freshwater mussel species (including DWM, see Section 3.8, *Threatened and Endangered Species*) were developed as part of Study 24 as well as other modeling and fish and aquatics studies, such as Studies 4, 5, 10, and 12, providing comprehensive information on DWM populations, co-occurring species, and the presence of potential host fish species. Using these data along with existing source material, preliminary evaluation as would be done in a biological assessment was developed to assess potential impacts on DWM from project operations. Based upon a thorough review of all of the data, two separate effect determinations are apparent. The preliminary assessment concludes that direct effects are unlikely to occur on the DWM populations as a result of current dam operations. A rapid and significant drop in water level is the most significant threat to these populations; however, most individuals are located in water at depths greater than 6 ft, which is well below the limit of current normal operations for these projects. Indirect adverse effects are likely to impact mussels in shallow water (areas potentially exposed during normal operations or areas above maximum pool elevation) due to water level drawdowns in the impoundments. As such, this preliminary assessment concludes that normal operation under the no-action alternative for these three facilities is likely to affect but is not likely to adversely affect the continued existence of the DWM in this area.

As noted in Studies 14-15, effects on spawning by some species can occur even when nests are not completely dewatered, as adult members of the Centrarchid family (e.g., bass and sunfish) will guard the nest from potential predation until eggs have hatched and fry dispersed, and thus require minimum depths to remain at the nest until their guardian role is fulfilled. Environmental effects on fish spawning and rearing are addressed in more detail in the following sections.

The greater magnitude of fluctuation in WSEs in the riverine reaches downstream of each Project combined with the typically shallower nature of riverine habitats results in greater potential for WSE-related effects on aquatic resources in the flowing reaches. In general, daily fluctuations in WSE in the three riverine reaches can be up to 5 to 6 ft in the vicinity of the dams during normal Project operations, though fluctuations are typically attenuated to 3 to 4 ft or less in the lower portions of riverine reaches (Study 5). Pool habitats, which represent 40 to 60 percent (by length) of aquatic habitat in the three riverine reaches (Figure 3.6-1), are less subject to streambed exposure during periods of minimum flow releases, due to their steeper streambanks and deeper habitat, than are shallower mesohabitat types such as glides and riffles. Riverine areas with expansive bar or shoal habitats, such as the vicinity of Chase Island in the Wilder riverine reach or Stebbins Island in the Vernon riverine reach are subject to wide variations in wetted habitat area during normal Project operations. These areas are also heavily used for spawning by several species of fish (as reported in Studies 14-15, Study 16, and Study 21, and discussed in the species-specific sections below).

In the Project impoundments, the majority of margin habitat along the mainstem channels is steeply sloped, and mid-channel habitats are far deeper than the fluctuations in WSEs; consequently, relatively little change in wetted width occurs during normal Project operations. Exceptions may occur in shallow, low-slope habitats such as those in the margins of backwaters, mid-channel island complexes, and at deltas formed at the mouths of tributaries.

The change in acreage of wetted habitat from normal high elevation to normal low elevation was estimated for the 12 of 41 backwaters in the Project areas that were assessed for spawning in Studies 14-15. The estimates were made with conservative operational WSE fluctuations (rounded to the nearest foot of WSE) in order to calculate backwater acreages based on 1-ft bathymetry contours.

Percent reductions in habitat area at the 12 spawning assessment backwater locations were based on differences in WSE at transect locations base upon steady-state, HEC-RAS modeled WSEs at the Wilder, Bellows Falls and Vernon dams of 3 ft, 2 ft and 1 ft respectively. The reductions in backwater habitat ranged from a low of 4 percent in Vernon backwater 14-VB-045 to almost 90 percent in Wilder backwater 14-WB-016 (Table 3.6-10), with a mean change of 36 percent among the 12 backwaters. The larger magnitude of WSE fluctuations in the Wilder impoundment (assessed with a 3-ft change, rounded up from the normal 2.5-ft range to fit HEC-RAS computational units) is largely responsible for the conservative, high estimates of dewatered backwater habitat in that reach, averaging 44.9 percent by total acreage within the 3-ft WSE fluctuation range.[36] In comparison, the approximate 2-ft fluctuations in the Bellows Falls backwaters and the approximate 1-ft fluctuations in the Vernon backwaters produced estimated acreage reductions of 24.5 percent and 16 percent, respectively. At Vernon, these values were also calculated using a 2-ft fluctuation range, which results in an overall backwater acreage reduction of 29 percent by total acreage. Another factor

[36] The PLP reported the average of all backwater percent reductions rather than the average of total acreage reductions.

is the relative location of backwater habitats in each impoundment. Four of the six sampled backwaters in the Wilder impoundment were located in the upper, shallower half of the impoundment where WSE are s influenced by upstream and tributary inflows than by WSE fluctuations at Wilder dam further contributing to the conservative, if not over-stated, effect (see Section 3.5.1.1, *Affected Environment, Water Quantity, High Flow Operations*). In contrast, all 13 available (and all six sampled) backwaters in both the Bellows Falls and the Vernon impoundments are located in the lower halves of each impoundment, and consequently have higher proportions of deeper water which is somewhat less subject to dewatering and three of those backwaters are associated with major tributaries (Black, Williams, and West Rivers). In these cases, the estimates of backwater acreage reductions do not account for any tributary contributions to backwater WSE.

Table 3.6-10. Change in backwater acreage under normal Project operations WSE fluctuations.

Impoundment (WSE in NAVD88)	Studies 14-15 Backwater Site ID	Acres @ High WSE	Acres @ Low WSE	% Reduction in Acres
Wilder High WSE: 384.0 ft Low WSE: 381.0 ft Difference: 3 ft	14-WB-012	34.3	25.3	26.2
	14-WB-016	6.3	0.7	89.4
	14-WB-028	33.3	13.3	60.1
	14-WB-032	34.1	20.3	40.4
	14-WB-051	5.1	1.1	79.1
	14-WB-060	22.4	14.0	37.3
	Total	**135.4**	**74.6**	**44.9**
Bellows Falls High WSE: 291.0 ft Low WSE: 289.0 ft Difference: 2 ft	14-BB-019	29.6	25.7	13.2
	14-BB-030	170.7	121.2	29.0
	14-BB-033	76.4	62.0	18.9
	Total	**276.7**	**208.9**	**24.5**
Vernon High WSE: 219.0 ft Low WSE: 218.0 ft Difference: 1 ft	14-VB-039	133.7	107.4	19.7
	14-VB-045	75.3	72.2	4.1
	14-VB-050	256.7	211.5	17.6
	Total	**465.7**	**391.0**	**16.0**

Source: ILP Studies 14-15, *Resident Fish Spawning in Impoundments and Riverine Sections Studies* as modified by Great River Hydro

Because of the shallower nature and greater magnitude of WSE fluctuations in riverine reaches than in impoundment reaches, the associated changes in wetted area are also greater. The percent change in wetted widths in each of the three riverine reaches during normal Project operations was estimated as part of the 1D instream flow study conducted in ILP Study 9, *Instream Flow Study*. Mean percent change in wetted widths varied by mesohabitat type, with the least change for riffles in the Bellows Falls riverine reach, and the largest changes for runs in the Bellows Falls and Wilder reaches, and riffles in the Wilder reach, respectively (Table 3.6-11). Margin or shoal habitats that are regularly dewatered are not likely to support aquatic resources, except for transitory rearing by mobile species (e.g., fish). Rearing or spawning by species such as mussels or nest-guarding fish are not likely to inhabit such areas due to the cyclical regularity of dewatering, although extended periods of high flows outside Project control as a result of annually occurring spring runoff or commonly occurring storm events can lead to egg deposition or nest building in areas that may be dewatered later when Project operations return to normal.

Table 3.6-11. Percentage change in riverine wetted width under normal Project operations.

Reach	Habitat Type	No. of Habitats	% Change in Wetted Width Under Normal Project Operations		
			Min.	Max.	Mean
Wilder riverine	Pool	13	5	38	16
	Glide	9	4	24	14
	Run	11	12	72	41
	Riffle	4	6	53	30
Bellows Falls riverine	Pool	6	5	21	11
	Glide	7	5	49	23
	Run	4	27	72	47
	Riffle	2	4	9	7
Vernon riverine	Pool	4	2	18	12
	Glide	3	3	37	15
	Run	6	9	61	27
	Riffle	0	-	-	-

Source: ILP Study 9, *Instream Flow Study*

Study 8 was conducted in 2014 to assess the movement of coarse sediment (gravel and cobble) in the downstream riverine reaches and tributary mouths in the three Project areas as it relates to the availability and stability of coarse-grained benthic habitats. The study evaluated 18 representative sites, and coarse-grained substrates were quantified using pebble counts at each site over two sampling rounds. Availability of habitat for coarse-grain-substrate dependent biota was also evaluated based on embeddedness condition using established methods (Barbour et al., 1999). Study 8 identified embeddedness conditions that indicate habitat for coarse-grain-substrate dependent biota is available along the Connecticut River in the Project areas. Additional analysis using modeled data from Study 4 included development of (1) peak-flow statistics, and (2) critical shear stress criteria for coarse-grained substrate.

Study results indicate that at most study sites, the evaluated coarse-grained substrates are stable at flows up to and including the applicable Project's maximum station discharge, and that flows greater than that are the dominant factors that contribute to the availability and stability of coarse-grained benthic habitat. Based on the presence and stability of coarse-grained substrates, habitat is persistent for coarse-grain-substrate dependent fauna, including different life-history stages of anadromous and riverine fish, and aquatic invertebrates. Studies 2-3 evaluated sediment removal and transport of fine-grained materials. Measured flow velocities at a subset of Studies 2-3 study sites were compared to published guidelines on threshold flow velocities needed to entrain fine sediments and remove them from the riverbanks. Results of that analysis indicate that under normal Project operations, flow velocities in the impoundments are much lower than threshold velocities. In the riverine reaches, threshold velocities can occur at flows close to or slightly above maximum generation flows (see Section 3.4, *Geologic and Soil Resources)*. Supplemental modeling and sediment sampling at all of the 21 erosion study sites yielded similar results. Flows occurring under Project operations may be capable of sediment entrainment in isolated incidents, butoperations cannot be responsible for widespread bank sediment entrainment or bank erosion (Field and Normandeau, 2017b). Therefore, normal Project operations do not significantly affect aquatic habitats related to sediment transport.

Great River Hydro Proposal

Comparison of effects on aquatic habitat due to current operations with effects due to proposed operations relies in part on summary statistics of discharge flows and impoundment WSEs under proposed operation versus current operations (Section 3.3). From the 12 simulations provided to compare proposed operations with current operations (four water years x three Project reaches), summary statistics were developed for the Wilder, Bellows Falls, and Vernon reaches under two water years representing comparatively high flow (2009) and low flow (2015) conditions.

Impoundment Reaches

Section 3.3.1 describes the changes that are expected to occur in impoundment WSEs with proposed operation. Under the proposed operation, WSEs in all three Project impoundments will exhibit much greater stability and remain at or near each impoundment's Target WSE for 60 percent to over 90 percent of the time in most months and both yearly scenarios (Table 3.3-1, Figure 3.3-1). In contrast, WSEs under current operations are much more variable and display stable WSE elevations less than 10 percent of the time in most months. The proposed operation will also reduce the frequency of WSE fluctuations by 58 to 100 percent (average 79 percent) (Table 3.3-4), and the magnitude of WSE changes during Flexible Operations flows is expected to be less than 0.4 ft in most month and year scenarios (average 0.23 ft), whereas average monthly WSE fluctuations under current operations ranged from 0.45 ft to 1.67 ft with an overall average change of 1.03 ft (Table 3.3-2, Figure 3.3-2).

WSEs at the upper portions of impoundments would be less stable than at the dams where Target WSE is maintained under the proposed operation. The comparative effects of inflow versus reservoir management on WSEs in the upper impoundments would be most notable in the Wilder impoundment, which is almost twice as long at 46 miles as the 26-mile Bellows Falls and Vernon impoundments. WSE changes at the Wilder Impoundment headwaters are largely outside of Project control.

Although WSEs in the upper portions of the impoundment would continue to be influenced in part by inflow, the increased stability of impoundment WSEs under the proposed operations would also benefit less mobile species, including DWM and co-occurring mussel species. Most DWM found in the Project impoundments were located in water at depths greater than 6 feet, which is well below the lower range of current and proposed WSEs.

Impoundment backwater habitats are typically shallow and low-sloped and consequently can be susceptible to dewatering due to chages in WSE within the backwater areas. Backwater areas do not have as drastic a change in WSE in comparison to the main river channel. Nonetheless, under proposed operations, these reductions in backwater habitat area would be reduced. Although natural high flow events beyond Project control will continue to affect water levels and the habitat affected, early spring spawners, such as Yellow Perch and Northern Pike or Pickerel, the proposed operation will significantly improve spawning and rearing environments by reducing in the frequency and magnitude of WSE fluctuations in Project impoundments under non-spill conditions. This will hold true for not only the species listed above as well as Smallmouth and Largemouth Bass, sunfish (Bluegill and Pumpkinseed), Fallfish, and other spring and summer spawners.

Riverine Reaches

Similar improvements to aquatic habitat are expected to occur in riverine reaches under the proposed operation. Section 3.3.2 details expected changes in many riverine habitat characteristics, including the reduction in frequency of significant increases in discharge, as mentioned above and listed in Table 3.3-4. The proposed IEO and Flexible operations outlined in the proposal will also reduce the magnitude of changes between base flow and higher discretionary generation flow by maintaining IEO for the vast majority of time (Table 3.3-6 and Table 3.3-3). Figure 3.3-4 illustrates the increase in minimum flows in all three riverine reaches, which will also result in a more normative flow distribution throughout year, as shown for August 2015 in Figure 3.3-3.

The increases in base flow levels and the reduction in frequency, occurrence, and amount of change in flow, particularly during critical seasonal periods under the proposed operation will reduce the frequency and magnitude of gravel and cobble-bar wetting and dewatering, and will provide a more stable environment for riverine species. In particular, the proposed flow regime is expected to increase success of spawners utilizing shallow shoal habitats, including Smallmouth Bass, Fallfish, and Sea Lamprey. The higher base flow and Transitional Operation of up-ramping and down-ramping preceding and following Flexible Operation will also provide more consistency for mussel recruitment and less likelihood of stranding of mussels or other less mobile species, including small fish fry. Similarly, reduction in frequency, occurrence and amount of change in flow, particularly during critical seasonal periods will reduce nest scour or abandonment due to high velocities, reduce displacement of newly emerged fry of many species, and should provide extended periods of more stable flow for nest construction by fallfish and sea lamprey.

Other beneficial effects of the proposed flow regime on riverine habitat conditions described in Section 3.3.2 include a reduction in the duration of operational flow events, and a decrease in the rate of flow increases and decreases during each up-ramping and down-ramping event. The proposed flow regime is anticipated to achieve IEO conditions, which is a major goal of the new proposal, between 67 and

100 percent of the time in spring, summer, and fall months, and in 39 to 60 percent of the time during winter (Table 3.3-3). In contrast, under current conditions station discharge matching inflow occurs less than 10 percent of the time.

3.6.2.2 Flow—Habitat Relationships

No-action Alternative

Study 9 was conducted to evaluate the relationships between aquatic habitats and river flows in the reaches downstream of each Project dam. The study was based primarily on Physical Habitat Simulation (PHABSIM) as one aspect of the Instream Flow Incremental Methodology process for the evaluation of instream flow needs for aquatic habitats. PHABSIM uses measurements of depth, velocity and substrate in conjunction with habitat suitability criteria (HSC) to produce an index as a primary measure of aquatic habitat over a range of flows. Eighty-five 1D transects, inclusive of split and side channels, were established: 43 in the Wilder riverine reach, 19 in the Bellows Falls riverine reach, 7 in the Bellows Falls bypassed reach, and 16 in the Vernon riverine reach. Two 2D sites were chosen to represent island complexes in the Wilder riverine reach, one site Chase Island, specifically selected for modeling DWM habitat. Sumner Falls, a unique bedrock feature downstream of Wilder dam, was evaluated using a combination of a qualitative demonstration flow assessment and quantitative depth and wetted width measurements.

Literature-based habitat preferences were used to develop HSC for 8 fish species/23 lifestages and macroinvertebrates. HSC for DWM were developed using professional judgement by a Delphi panel of experts with reference to field data collected in other locations, while co-occurring mussel HSC was developed using site-specific data collected on Eastern Elliptio (*Elliptio complanata*) from Study 24 field surveys. Original Sea Lamprey spawning curves were modified for depth based on site-specific data collected during field surveys for Study 16. Habitat index values relating flow to aquatic habitat, area weighted suitability (AWS) and Weighted Usable Area (WUA), were calculated over a range of flows from current minimum to 25,000 cfs, inclusive of operation constraints for each project. Seasonal occurrence of species and lifestages evaluated for flow-habitat relationships by project are shown in Table 3.6-12.

Wilder Project

Maximum AWS for most species/lifestages occur at a flow of 2,000 cfs or less (Table 3.6-13). The only exceptions are Walleye and Sea Lamprey spawning, activities which take place in the spring often under uncontrolled flows, and macroinvertebrates. Though maximum AWS is frequently used as an indicator of the “best” flow level there are other aspects of flow-habitat relationships that are as important. For instance, Longnose Dace fry show the highest AWS at 2,000 cfs, although AWS at 700 cfs is 98 percent of the peak value, thus representing a relative broad range of high quality habitat across differing flows. Other species/lifestages display similar results including Fallfish juvenile, adult and spawning, and Smallmouth Bass adult. Even Walleye and Sea Lamprey spawning habitat is maintained at a high level over a range of flows outside the maximum

AWS. Similar results were obtained for the two 2D sites and can be found in the Study 9 report.

Flows from Wilder dam are not consistent throughout the riverine reach due to accretion from multiple sources, the largest being the White River which separates Wilder reach 1 and reach 2 and the Ottauquechee River which separates reach 2 and reach 3 (Table 3.6-14). In the summer in reach 2 an additional 621 cfs on average, above project flows, will occur while in the spring an additional 2,544 cfs on average is predicted based on Study 5 inflow dataset that includes historic gage and back-routed dam discharge minus change in upstream storage (Operations Model). As a result, over the 17.7-mile Wilder riverine reach, the majority (16.2 miles) maintains flows within or above the maximum AWS range of most species/lifestages at minimum flow releases from the dam.

Table 3.6-12. Seasonal occurrence of aquatic species and lifestages evaluated for flow-habitat relationships in project riverine reaches.

Species	Lifestage	Project	Fall			Winter			Spring			Summer		
			Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept
American Shad	juvenile	BF,V												
American Shad	adult	BF,V												
Walleye	juvenile	W,BF,V												
Walleye	adult	W,BF,V												
Fallfish	juvenile	W,BF,V												
Fallfish	adult	W,BF,V												
White Sucker	juvenile/adult	W,BF,V												
Longnose Dace	juvenile	W,BF,V												
Longnose Dace	adult	W,BF,V												
Tessellated Darter	adult	W,BF,V												
Smallmouth Bass	juvenile	W,BF,V												
Smallmouth Bass	adult	W,BF,V												
Walleye	fry	W,BF,V												
Fallfish	fry	W,BF,V												
White Sucker	fry	W,BF,V												
Longnose Dace	fry	W,BF,V												
Smallmouth Bass	fry	W,BF,V												
American Shad	spawning	BF,V												
Walleye	spawning	W,BF,V												
Fallfish	spawning	W,BF,V												
White Sucker	spawning	W,BF,V												
Smallmouth Bass	spawning	W,BF,V												
Sea Lamprey	spawning	W,BF,V												
Macroinvertebrates	na	W,BF,V												
DWM	adult	W,BF												
Co-occurring Mussels	adult	W,BF,V												

Project: W=Wilder, BF=Bellows Falls, V=Vernon

Table 3.6-13. Flow and AWS values for aquatic species and lifestages evaluated for flow-habitat relationships in the Wilder Project riverine reach (maximum AWS bold/shaded).

Species/Life Stage	Flow (cfs)												
	700	**1000**	**2000**	**3000**	**4000**	**5000**	**6000**	**7000**	**8000**	**9000**	**10000**	**11000**	**12000**
Fry													
Walleye	**14.2**	10.9	7.3	6.3	6.3	6.6	6.5	6.2	6.0	5.7	5.4	4.9	4.4
Fallfish	**92.3**	88.4	74.7	58.1	44.8	35.5	28.3	22.4	18.1	14.9	12.3	11.0	10.4
White Sucker	**217.9**	188.5	118.4	84.0	65.6	55.5	50.7	47.7	45.3	43.4	42.1	41.2	40.3
Longnose Dace	48.8	49.0	**49.7**	42.5	33.1	22.5	16.9	12.8	9.8	7.8	6.4	5.7	5.5
Smallmouth Bass	**52.3**	43.2	28.9	21.5	16.0	12.3	10.2	8.7	7.7	6.7	5.9	5.3	4.8
Adult and Juvenile													
Walleye juvenile	**19.3**	17.4	13.1	10.8	9.5	8.7	8.3	8.0	7.7	7.5	7.3	7.1	6.9
Walleye adult	**62.8**	51.7	37.7	35.6	34.3	33.2	31.9	30.2	28.8	27.7	26.5	25.2	24.1
Fallfish juvenile	116.1	**118.4**	114.5	104.4	90.3	74.4	59.4	48.3	39.6	32.2	26.4	22.4	19.3
Fallfish adult	231.8	**239.3**	227.6	201.7	176.3	154.4	135.7	119.8	106.6	95.9	87.6	81.2	76.1
White Sucker adult/juvenile	**146.3**	133.5	88.7	62.9	48.5	39.6	34.1	31.1	29.2	27.7	26.4	25.4	24.7
Longnose Dace juvenile	19.0	20.2	**26.6**	24.1	18.2	11.6	7.7	5.6	4.1	3.1	2.2	2.0	2.1
Longnose Dace adult	32.7	34.1	**43.2**	41.6	35.6	27.7	19.4	13.4	9.7	7.3	5.6	4.6	4.4
Tessellated Darter adult	30.6	32.2	**39.5**	38.7	32.2	24.5	18.1	13.3	9.9	7.5	5.7	4.7	4.4
Smallmouth Bass juvenile	106.2	114.4	**120.9**	115.5	104.5	92.0	79.6	68.5	59.3	51.9	45.9	41.1	37.1
Smallmouth Bass adult	90.1	**93.4**	83.4	72.0	62.7	54.5	47.7	42.1	37.4	33.8	30.9	28.5	26.5
Spawning													
Walleye	18.5	22.8	36.6	52.0	62.7	69.0	**72.6**	72.1	69.0	65.2	60.7	55.3	48.7
Fallfish	50.6	**51.1**	49.7	45.4	38.6	31.5	23.7	17.3	12.3	8.7	6.3	4.8	4.0
White Sucker	10.3	11.2	**16.3**	15.5	13.2	9.1	6.1	4.4	3.3	2.6	2.1	1.9	2.1
Smallmouth Bass	**66.3**	55.4	33.1	24.4	19.3	16.2	13.7	11.6	10.0	8.9	7.9	7.2	6.5
Sea Lamprey	56.0	67.5	84.9	**89.1**	86.1	80.6	74.5	67.6	60.0	52.4	45.3	38.9	33.1
Benthic													
Macroinvertebrates	23.3	35.0	64.3	79.4	86.8	**88.9**	87.2	83.9	79.7	75.1	69.8	64.7	59.6
DWM	94.8	**98.8**	81.4	56.1	38.1	27.0	19.7	15.6	13.0	11.2	9.9	9.1	8.3
Co-occurring mussels	145.8	153.8	**166.4**	166.2	157.0	141.7	123.3	105.4	89.3	75.5	64.3	55.2	48.0

Table 3.6-14. Average seasonal accretion estimates (cfs) for Wilder reach 2 and 3 based on operations model (Study 5).

	Season			
Reach	**Winter (Jan-Mar)**	**Spring (Apr-Jun)**	**Summer (Jul-Sep)**	**Fall (Oct-Dec)**
Wilder 2	1,396	2,544	621	1,353
Wilder 3	1,806	3,319	779	1,737

Sumner Falls

Sumner Falls is a unique bedrock feature in the Wilder riverine reach downstream of the Ottauquechee River. Stakeholders expressed an interest in evaluating the effects of flow on potential dewatering and/or isolation of pools within the falls area. The site was evaluated using a combination of qualitative observation and quantitative depth and wetted width measurements under a range of flow releases between 700 and 3,500 cfs from Wilder dam (Table 3.6-15).

Water surface elevation and depths were measured based on temporary gage readings at 5 cross section locations. Resulting changes in depth and wetted width were estimated for depth ranges of ≥0.5 ft, ≥0.7 ft and >1.0 ft. Depths greater than 1.0 ft were predominantly due to deep channels that run through the study area and account for over 50 percent of wetted width at most locations at lowest flow. The greatest change in total wetted width for all depth categories was for flow releases between 1,500 and 2,500 cfs. Little change in wetted width for all depth categories occurred between flow releases of 2,500 and 3,500 cfs.

Table 3.6-15. Flow releases from Wilder dam and observed (measured) flows at Sumner Falls.

Observation Time	Flow from Wilder	Observation Flow at Sumner Falls
NA	700	1,300
1300	1,500	2,078
1600	2,500	3,121
1800	3,500	3,942

Utilization of Sumner Falls by species and lifestages modeled for the instream flow study is unknown. Although it is likely individuals of some species use the area, it is questionable whether the site is essential to their life history.

Bellows Falls Project

Similar to the Wilder project, maximum AWS values for most species and lifestages evaluated in the Bellows Falls riverine reach are at flows of 2,000 cfs or less (Table 3.6-16). The only significant deviation is for American Shad, which were not modeled for the Wilder project (both impoundment and the riverine section below the project) and the Bellows Falls impoundment, due to the absence of an historical population. Even though American Shad adult and spawning peak AWS occurs at 10,000 cfs and 9,000 cfs respectively, habitat equivalent to 90 percent of the maximum is observed over a flow range of 5,000 cfs to 16,000 cfs. Spawning and adult presence in the reach only occurs in the spring during frequent spill when this range of flows is common.

Bellows Falls Bypassed Reach

The Bellows Falls bypassed reach is a bedrock dominated feature approximately 1,300 feet in length. Currently there is no minimum flow release for the bypassed reach, though leakage through the dam and gates is estimated to range between 200 cfs and 300 cfs. Potential aquatic habitat was modeled based on 7 transects representing predominant mesohabitats, primarily runs and riffles for flows between leakage and 2,500 cfs.

At the request of the aquatics working group all species and life stages identified in the Bellows Falls riverine reach were also assessed in the bypassed reach. AWS results were variable depending on the species and life stage though many showed a decline in habitat as flows increased while others displayed a bimodal response with peak AWS at leakage flow and another around 1,500 cfs. The bimodal habitat curve is a function of the channel geometry, at seepage flows most water remains within a central bypass channel which provides habitat for many species. As flows increase the central channel becomes too fast and/or deep for some species or life stages (e.g., small species or fry of larger fish), but as flows increase further it inundates the wide cobble/boulder lateral and point bars which increases suitable habitat for species preferring shallow and/or slower water. For some species these intermediate flows provide more habitat than the central channel at seepage flows; however at high flows the bars also become too deep and/or swift for many species, resulting in a reduction in suitable habitat when flows exceed the primary central bypass channel and inundate the boulder/bedrock dominated floodplain. The present leakage flow is generally contained within the central channel whereas the broader floodplain channel sees flow only during spring runoff or due to storm or precipitation related highwater spill.

However, results from the fish assemblage study (Study 10) indicated only significant numbers of juvenile and adult Longnose Dace (n=127) and juvenile and young-of-year (YOY) Smallmouth Bass (n=43) in the reach. Other species of interest included Tessellated Darter adult and juvenile (n=15), White Sucker YOY (n=8), and Fallfish YOY (n=2). Due to lack of suitable spawning habitat for White Sucker, Smallmouth Bass, and Fallfish it is presumed that presence of YOY is due to recruitment of fish through the seepage channels or during high flow spill events as immigration from downstream is prohibited by a steep bedrock falls and weir. It is also likely that high spring flows in the steep and confined bypassed reach would prohibit permanent residence of larger species, such as Smallmouth Bass, White Suckers, or Fallfish.

Table 3.6-16. Flow and AWS values for aquatic species and lifestages evaluated for flow-habitat relationships in the Bellows Falls reach (maximum AWS bold/shaded).

Species/Life Stage	Flow (cfs)												
	1300	2000	3000	4000	5000	6000	7000	8000	9000	10000	11000	12000	13000
Fry													
Walleye	**28.3**	23.3	14.8	12.1	11.9	10.8	8.9	7.4	5.9	4.7	3.9	3.9	3.8
Fallfish	**115.7**	96.4	75.2	56.1	41.5	31.1	26.7	21.0	17.9	15.6	13.3	11.2	9.9
White Sucker	**245.5**	199.2	153.5	123.2	105.1	93.8	86.8	81.2	77.1	73.0	69.6	66.5	64.1
Longnose Dace	**70.0**	62.7	48.1	35.4	26.4	19.2	15.4	13.1	11.0	10.6	9.1	7.9	6.6
Smallmouth Bass	**44.5**	34.7	25.7	16.2	10.8	8.3	6.8	5.9	5.3	4.7	4.2	3.7	3.3
Adult and Juvenile													
American Shad juvenile	320.1	340.8	**349.0**	344.0	334.5	322.6	309.8	296.5	283.0	270.4	257.9	245.5	233.3
American Shad adult	239.4	276.0	315.3	344.9	367.0	382.9	392.6	398.3	401.3	**402.1**	400.7	397.4	391.9
Walleye juvenile	**32.0**	30.0	28.1	25.2	22.3	20.3	19.1	18.0	16.8	15.6	14.5	13.5	12.7
Walleye adult	**95.5**	80.4	76.0	76.7	73.4	69.6	66.8	64.4	62.7	60.6	58.4	55.6	52.8
Fallfish juvenile	153.1	**153.4**	134.6	108.1	88.6	76.3	63.0	52.1	43.8	37.1	32.9	28.5	24.8
Fallfish adult	289.4	**295.5**	285.4	266.7	245.8	226.3	208.9	194.0	180.7	169.2	159.0	149.8	141.9
White Sucker adult/juvenile	**162.6**	146.2	117.2	95.3	78.6	66.2	58.0	52.1	47.4	43.6	40.4	37.7	35.4
Longnose Dace juvenile	**30.3**	29.1	20.6	13.2	11.4	10.8	9.1	7.5	5.7	5.6	4.9	3.8	2.6
Longnose Dace adult	**52.4**	48.6	40.2	27.3	19.9	18.0	16.8	15.0	11.8	10.7	10.0	8.4	7.0
Tessellated Darter adult	**49.5**	47.8	39.8	30.0	22.9	18.6	15.7	13.7	11.2	10.0	9.1	7.8	6.3
Smallmouth Bass juvenile	125.5	**131.4**	130.5	123.9	114.1	104.4	95.1	86.6	78.7	71.8	65.9	60.8	56.4
Smallmouth Bass adult	93.6	**94.2**	89.6	82.0	74.0	66.9	60.7	55.4	50.7	46.7	43.3	40.5	38.0
Spawning													
American Shad	197.6	243.0	288.0	318.1	337.2	349.2	356.4	360.1	**361.0**	360.5	358.9	356.3	353.1
Walleye	33.1	45.8	56.9	66.9	73.1	**74.8**	73.4	70.2	65.2	57.9	49.9	43.7	38.7
Fallfish	**63.9**	63.9	54.2	42.8	33.0	26.8	20.6	16.5	12.3	9.5	8.3	6.7	5.7
White Sucker	13.9	**14.0**	11.9	7.9	7.7	7.9	7.6	6.4	4.7	4.8	4.4	3.3	2.3
Smallmouth Bass	**58.1**	44.8	35.9	25.6	19.8	16.2	13.0	10.5	8.6	7.3	6.2	5.4	4.9
Sea Lamprey	82.1	96.7	**105.2**	102.7	95.6	86.1	76.2	67.1	58.8	51.6	45.2	39.3	33.8
Benthic													
Macroinvertebrates	52.2	72.2	90.2	97.5	**100.0**	99.5	96.0	90.3	83.7	78.9	74.6	70.3	65.7
DWM	**118.2**	110.6	90.9	75.6	59.2	45.7	37.6	32.4	28.7	26.0	23.8	21.7	20.4
Co-occurring mussels	186.3	**192.3**	190.6	182.4	171.8	160.6	148.5	135.4	122.6	110.9	100.3	90.9	82.3

Vernon Project

Maximum AWS in the Vernon riverine reach occur at flows of 3,000 cfs or less for most species and life stages modeled based on a stable WSE of 181.6 (NAVD88) at the Turners Falls dam (Table 3.6-17). Exceptions are similar to those observed for the Wilder and Bellows Falls projects, primarily spring spawning species American Shad, Walleye and Sea Lamprey which show affinity for much higher flows.

However, the Vernon riverine reach is complex in that both Vernon discharge and WSE at Turners Falls dam and Northfield Mountain Pumped Storage project affect water levels within the reach. Water levels within the reach directly affect AWS (Table 3.6-18). Actual historic operation data comparing station discharge and tailwater elevation indicates the range of tailwater elevation due to Turners Falls or Northfield Mountain pumped storage project operation (Figure 3.6-7). To account for all possible WSEs that may occur AWS was modeled at one-foot intervals over a range of potential WSE between 175.6 and 186.6 (NAVD88).

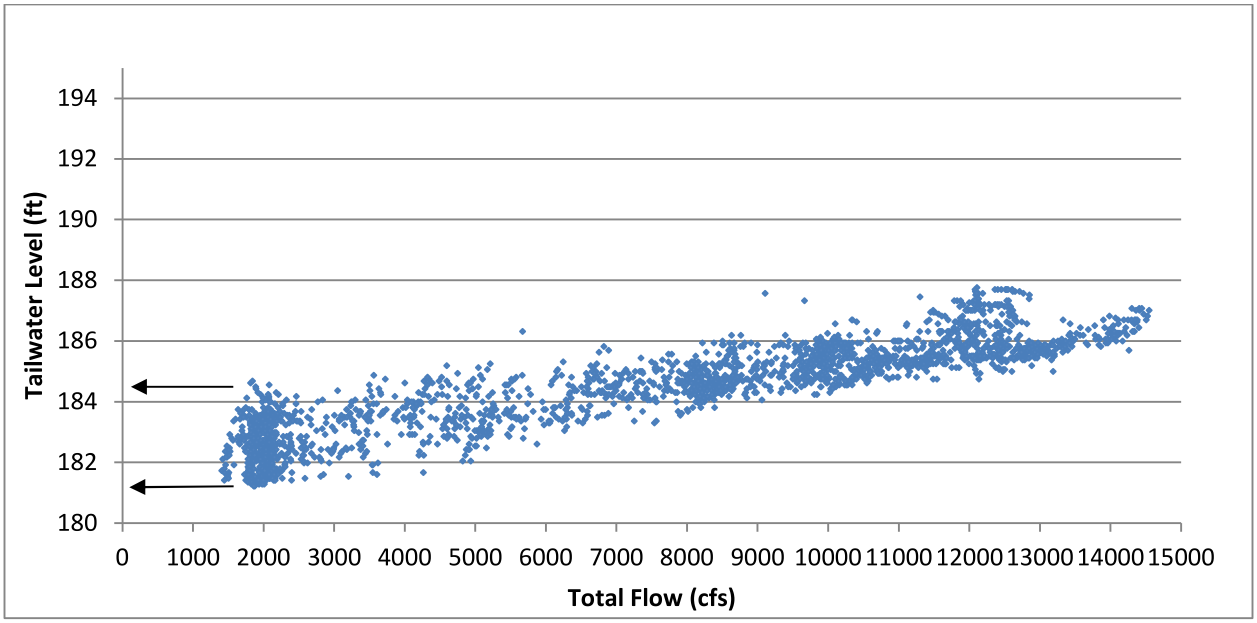


Figure 3.6-7. Vernon Project hourly discharge (absent spill) plus fish passage discharge compared with tailwater elevation (NGVD29) for January 1 to July 1, 2018. Tailwater elevation range of 3-4 feet indicates changes in tailwater elevation unrelated to discharge.

Table 3.6-17. Flow and AWS values for aquatic species and lifestages evaluated for flow-habitat relationships in the Vernon reach at 181.6 (NAVD88) (maximum AWS bold/shaded).

Species/Life Stage	Flow (cfs)												
	1200	2000	3000	4000	5000	6000	7000	8000	9000	10000	11000	12000	13000
Fry													
Walleye	**24.9**	21.2	20.0	20.1	19.7	18.8	17.2	14.7	12.6	10.9	9.1	7.6	6.5
Fallfish	**106.9**	103.0	86.6	73.8	65.9	58.3	53.3	47.4	41.5	35.4	30.0	25.6	20.9
White Sucker	**422.0**	328.3	232.6	174.8	140.0	117.6	103.5	94.7	88.3	83.0	78.4	74.5	71.6
Longnose Dace	68.1	**73.2**	68.5	54.6	43.2	35.8	30.3	25.7	21.8	18.9	15.8	13.0	10.4
Smallmouth Bass	**47.6**	38.5	26.8	21.0	17.2	15.0	14.1	13.3	12.0	11.0	10.1	9.1	8.2
Adult and Juvenile													
American Shad juvenile	254.0	268.1	**272.5**	268.8	262.6	255.9	251.2	246.0	240.2	234.2	228.1	222.1	216.6
American Shad adult	209.5	226.9	239.8	252.1	263.7	274.6	284.6	293.9	302.3	309.5	315.5	320.7	**324.8**
Walleye juvenile	**45.5**	35.4	29.2	25.6	24.0	23.1	22.6	22.3	21.9	21.3	20.6	19.7	18.8
Walleye adult	**136.1**	92.1	70.6	60.6	56.2	53.2	51.3	49.8	49.2	49.5	50.3	50.8	50.8
Fallfish juvenile	114.7	123.1	**124.7**	118.7	105.8	93.4	85.6	78.6	70.7	62.1	53.7	45.3	39.1
Fallfish adult	370.1	**373.3**	356.2	327.7	301.0	275.9	256.3	239.4	224.0	210.2	198.1	187.8	179.2
White Sucker adult/juv	**226.7**	208.4	161.0	122.2	97.4	81.1	71.5	65.0	59.7	56.3	54.3	52.4	50.7
Longnose Dace juvenile	20.5	**26.8**	24.4	20.0	14.9	11.9	10.4	9.3	8.0	6.5	4.9	3.2	1.9
Longnose Dace adult	32.4	47.3	**49.1**	42.9	33.6	24.0	18.2	15.6	13.6	12.0	9.9	7.6	5.5
Tessellated Darter adult	30.4	44.3	**47.4**	42.3	35.4	28.9	23.8	19.8	16.8	14.5	12.2	9.8	7.8
Smallmouth Bass juvenile	93.3	103.4	**105.3**	101.7	96.0	88.3	80.9	74.6	69.2	64.7	61.2	58.0	55.3
Smallmouth Bass adult	83.2	**85.8**	77.0	67.7	61.0	55.7	51.3	47.8	44.4	41.6	39.5	37.7	36.4
Spawning													
American Shad	122.4	157.8	191.0	211.2	223.3	232.8	241.0	248.4	255.1	260.6	264.9	268.2	**270.4**
Walleye	11.6	15.0	21.8	31.5	40.7	49.7	56.6	61.5	**63.7**	63.4	61.3	57.6	53.2
Fallfish	72.4	77.7	**79.2**	74.9	66.0	55.9	47.6	40.0	33.9	28.8	23.7	18.8	14.4
White Sucker	9.9	14.3	**15.3**	11.9	9.4	8.0	7.1	6.5	5.6	4.6	3.3	2.1	1.3
Smallmouth Bass	**81.7**	60.7	42.1	34.5	30.4	26.5	23.6	21.4	19.4	18.1	17.3	16.5	15.9
Sea Lamprey	43.2	65.7	83.1	92.1	96.1	**96.7**	94.1	90.5	85.8	80.3	74.0	67.6	60.6
Benthic													
Macroinvertebrates	4.4	20.7	43.5	62.3	73.3	79.4	82.5	**83.4**	82.6	80.3	77.0	72.8	68.5
Co-occurring mussels	185.9	**196.9**	196.3	195.6	184.0	172.3	163.6	154.9	146.4	137.8	130.0	122.2	115.5

Table 3.6-18. Example of different AWS values calculated for a range of flows and WSE pairs for a typical generation cycle within the length of Vernon reach.

Date:Hour Ending	Flow (cfs)	WSE (ft NAVD88)	Walleye Juvenile AWS (ft^2/ft)	Fallfish Adult AWS (ft^2/ft)
07-04-1990:04	2,150	181.8	32.93	355.81
07-04-1990:05	2,150	181.2	28.91	317.57
07-04-1990:06	2,150	180.6	26.23	286.97
07-04-1990:07	2,150	180.0	24.24	260.97
07-04-1990:08	6,293	179.6	17.16	190.54
07-04-1990:09	8,956	179.7	17.38	171.85
07-04-1990:10	8,854	179.2	16.93	166.07
07-04-1990:11	9,563	179.1	16.96	160.83
07-04-1990:12	14,127	179.4	15.85	145.35
07-04-1990:13	14,405	179.8	15.89	146.99
07-04-1990:14	15,416	180.4	15.50	146.42
07-04-1990:15	15,673	180.9	15.66	149.64
07-04-1990:16	15,627	181.5	16.14	156.24
07-04-1990:17	15,577	182.1	16.67	163.42
07-04-1990:18	15,524	182.6	17.21	170.35
07-04-1990:19	14,295	183.0	18.75	184.18
07-04-1990:20	14,139	183.1	19.06	187.79
07-04-1990:21	14,191	183.2	19.14	189.48
07-04-1990:22	14,429	183.3	18.93	188.06
07-04-1990:23	2,150	183.4	48.37	441.70
07-04-1990:24	2,150	183.4	48.53	442.16
07-05-1990:01	2,160	183.1	44.70	431.08
07-05-1990:02	2,150	182.6	39.75	404.85
07-05-1990:03	2,150	182.1	34.98	373.80
07-05-1990:04	2,150	181.5	30.84	335.91

The primary tools used for the instream flow study to examine project effects on aquatic habitat in riverine reaches below the dams are time series and dual flow analysis. Habitat index versus flow relationships were used to develop a habitat duration time series to represent the magnitude and duration of available habitat seasonally, over critical periods, and/or in critical locations or habitat types under five inflow hydrologies developed from the operations model (Study 5). In general, habitat suitability for most fish species and their lifestages was highest for flows nearer current minimum flows and lowest for flows exceeding current Project generating capacity for all reaches. No definitive conclusion can be drawn from an instream flow study time series and habitat duration analysis alone, except to infer that one operational alternative scenario may produce more or less habitat than another across the period of time under evaluation. From Study 9, lower flows tend to provide the highest AWS values for a majority of species and life stages.

Habitat duration results demonstrate that during summer (July to September) the highest habitat suitability for most species and lifestages is maintained for a longer period versus other seasons, a function of water availability which limits higher generating operations. In contrast, in the spring (April to June) lower seasonal habitat suitability for many species and lifestages occurs over longer periods due to high flows. There is a significant difference between operational flow control and the capability to control or manage flow during the spring spawning period (April, May, and June) versus summer fry rearing (July-September). In both periods natural flow conditions play a major role, notable when sustained flows are often high and exceed station capacity, or when inflow is low due to sustained dry conditions.

Dual-flow analyses were completed for multiple paired flows within the Projects' generating capacities. A dual-flow analysis provides static information on changes in habitat in terms of area of weighted usable area (WUA) between one flow and another. At each flow, the amount of usable habitat is the amount of habitat that overlaps in space of suitable locations that were available at the base flow. This is most often identified as persistent habitat. Similarly, persistent habitat represented in a dual-flow analysis neither reflects the dynamic shift is spatial habitat that occurs over time as flows change or the capability of a species and life stage to move to available adjacent (not persistent) suitable habitat as flows change. As a result, the appropriate application of dual flow analysis should focus on target lifestages that are is generally immobile or have limited mobility as flows change (e.g., fish eggs and nests, mussels, and some fry). Detailed results from the dual-flow and persistent habitat analysis are provided in the final Study 9 report filed May 2019.

The degree of habitat persistence varies greatly depending on the species and life stage being evaluated. In most cases the greatest change, typically loss of persistent habitat, occurs when flows increase from minimum flow to maximum normal Project operational flows. As would be expected, the narrower the range of project operational flows the more attenuated the change in habitat becomes. In general, species and lifestages with broad suitability ranges, particularly for depth, show the least decline in quality habitat and persistent habitat versus total habitat (e.g., American Shad spawning, macroinvertebrates, Walleye spawning, White Sucker fry, DWM, co-occurring mussels). In contrast, those with narrow ranges of suitability for depth and/or velocity show the greatest decline in persistent habitat versus total habitat (e.g., most fry lifestages, Fallfish spawning, Smallmouth Bass spawning, White Sucker spawning, Sea Lamprey spawning).

Spawning behavior for different species ranges from nest building to broadcast spawning, rarely resulting in similar flow requirements. Lifestages with narrow depth and low velocity criteria will always respond negatively to changes from low to high flows based on AWS. Trade-offs between what are perceived to be ideal flows for some species or lifestages must be balanced with the effect of alternative stream flows on project operations and on other resources. Seasonal flow requirements can be provided or limited by natural variability more so than Project operations.

Great River Hydro Proposal

By maintaining IEO for the vast majority of time, changes in downstream flows under the proposed operation will have a beneficial effect on aquatic resources through a reduction in the frequency, occurrence, and magnitude of changes between base flow and higher discretionary generation flow. Based on the allocation of Flexible Operation hours, the reduction in number of flow change events (IEO operation to Flexible Operation) compared to existing operation (minimum flow to higher generation) flows is expected to be between 70-100 percent during April to September; less reduction between November in March by design (Table 3.3-4). Although the increase in base flow under the proposed operation may result in less suitable habitat for some species at any given time (ILP Study 9, *Instream Flow Study*), the concurrent reduction in frequency, occurrence, duration, and degree of significant changes at the level observed under current operation is expected to result in increased suitable habitat for most species.

In addition to reduced frequency, occurrence, and degree of significant change, Transition Operation up-ramping, down-ramping, and refill requirements will reduce the likelihood of stranding of small fish or less mobile species, such as mussels.

3.6.2.3 Tributary and Backwater Access

No-action Alternative

The buildup or shifting of coarse sediments at the mouths of many small to medium tributaries can also lead to shallow, high gradient confluences during periods of low water levels, and can potentially influence the ability of fish to access those tributaries for spawning or rearing. Observations during Study 8 site visits indicated that tributaries are a primary source of coarse-grained substrates to the Connecticut River, where large accumulations of coarse-grained substrate were observed adjacent to the confluences of tributaries such as the Saxtons and Cold rivers located downstream of Bellows Falls. Similar observations were made during Study 13, which was conducted to assess whether water level fluctuations from Project operations impede fish movement into and out of tributaries and backwater areas within the Project areas, and whether normal Project operations affect access to potential available fish habitat and water quality in those tributaries and backwater areas. Thirty-six study sites were randomly selected from the set of all smaller tributaries (first through third order streams) that enter the Project areas, including seven backwaters associated with the Project areas, and the Cold River (fifth order stream) that was included at the request of New Hampshire Fish and Game Department (NHFGD). Field work was conducted from the period between late-July and mid-November 2014 during which time each site was visited multiple times. Water level loggers were installed within the tributaries and backwaters along with a comparison water level logger installed in the Connecticut River mainstem near the confluence with the tributary/backwater. Bed profiles were measured, and the extent of the Project-affected reach was estimated for each study site. Water quality data were collected, and photographs were taken during each site visit.

Analysis of Project effects was based on summer/fall 2014 field observations and water level logger data as well as on hydraulic and operations model data (Studies 4 and 5) for the springtime spawning period (April 1 to June 30). Analysis included only effects from water depths at the confluence with the mainstem. Neither the springtime analysis nor the 2014 field-based analysis considered effects associated with low tributary inflows or tributary flow-related water depths. The majority of study sites (27 or 73 percent) had summer/fall 2014 water depths of 0.5 ft or greater (the study criterion for minimum accessible water depth) at the confluence cross section at least 75 percent of the time, based on each site's water level logger data period of record. Twenty-one sites (57 percent) had depths greater than 0.5 ft for greater than 97 percent of the time, including all backwater sites.

Analysis of springtime access restrictions focused on the range of WSEs during normal Project operations only and used very conservative criteria to categorize predicted access restrictions. Access restrictions were defined as "negligible" if they occurred on fewer than 10 percent of springtime days (approximately 1 day per week) in up to three modeled inflow hydrologies, and "infrequent" in four or all five modeled inflow hydrologies. "Occasional" access restrictions were defined as occurring for 10 percent or more of springtime days in up to three modeled inflow hydrologies, and "frequent" access restrictions were those that occurred for 10 percent or more of springtime days in four or all five modeled inflow hydrologies. Table 3.6-19 summarizes the number of study sites affected based on these criteria for two broader categories of restriction of a "50 percent criterion" where at least 50 percent of all hours under normal Project operations in each day provided 0.5 ft or more of water depth at the confluence, and a "100 percent criterion" where all hours under normal Project operations in each day provided 0.5 ft or more of water depth at the confluence. Both criteria are presented; however, the 100 percent criterion is considered too conservative a criterion on which to base analysis of Project effects, because it is reasonable to assume that access for up to half of each day is sufficient for fish desiring to enter a tributary or backwater on that day.

Table 3.6-19. Summary of modeled spring access restrictions to study sites under normal (non-spill) Project operations for 50% and 100%-of-day criteria.

50% Daily Access (April 1–June 30)					
Reach	**None**	**Negligible**	**Infrequent**	**Occasional**	**Frequent**
Wilder impoundment	8	3	1	2	0
Wilder riverine	0	0	0	2	3
Bellows Falls impoundment	5	1	0	0	0
Bellows Falls riverine	0	1	0	3	0
Vernon impoundment	4	0	0	1	1
Vernon riverine	0	1	0	1	0
All reaches	**17**	**6**	**1**	**9**	**4**

100% Daily Access (April 1–June 30)					
Reach	**None**	**Negligible**	**Infrequent**	**Occasional**	**Frequent**
Wilder impoundment	7	1	1	3	2
Wilder riverine	0	0	0	0	5
Bellows Falls impoundment	4	0	0	2	0
Bellows Falls riverine	0	0	0	0	4
Vernon impoundment	2	1	1	0	2
Vernon riverine	0	0	0	0	2
All reaches	**13**	**2**	**2**	**5**	**15**

Source: ILP Study13, *Tributary and Backwater Fish Access and Habitats Study*

Four sites (10.8 percent) were predicted to have "frequent" access restrictions under the 50 percent-of-day criterion under normal Project operations. These sites (all first or second order streams) were also restricted from 24 percent to 100 percent of occurrences in the 2014 field surveys. Three of these sites are located in the Wilder riverine reach and one is located in the Vernon impoundment. Based on field observations, access at these sites is largely affected and determined by the amount of flow in the tributaries themselves rather than mainstem WSEs. These four sites also have short Project-influenced reaches (less than 100 ft), culverts, and/or natural or human-made blockages that restrict access within the tributaries themselves.

Another nine sites (24 percent) were predicted to have "occasional" access restrictions and of those, four were below the 25 percent of occurrence threshold in summer/fall 2014; three had 2014 access restrictions between 40.5 and 58.6 percent of occurrences. The remaining two sites were undetermined in 2014 due to a lack of mainstem water level logger data, and one of these (the Cold River, a fifth order stream tributary) generally has sufficient inflow and depth even in the summer/fall to maintain access. Access at these sites is also largely affected and determined by the amount of flow in the tributaries themselves rather than mainstem WSEs. Five of the "occasionally" restricted sites also have non-Project-related physical limitations including short Project-influenced reaches (less than 300 ft), culverts, variable thalweg profiles, and/or natural blockages that restrict access. Furthermore, while low order streams represent a greater number of tributaries entering the Project areas than high order streams, low order streams are shorter and typically have more non-Project–related access restrictions including variable thalwegs, culverts and other blockages that restrict access particularly under low tributary flows. Therefore, low order streams are likely to constitute a small fraction of all available fish habitat in tributaries and backwaters within the Project areas, and Study 13 focused on the smallest tributaries (first, second, and third order streams), which would be most likely to have limited stream flow on their own. It is very likely that adequate access exists at the many other larger tributaries (fourth order stream or higher) and in backwaters throughout the Project areas. Of the seven backwaters included in the study, five had no access restrictions under the

2014 summer/fall conditions and under both the 50 percent and 100 percent criterion. The remaining two backwaters had less than 1 percent occurrence of access restriction in the summer/fall and "negligible" and "occasional" restrictions, under the 50 percent and 100 percent criterion, respectively.

Therefore, normal Project operations under new licenses will have little effect on the ability of fish to access small tributaries on most days and will continue to provide access to backwaters and to larger tributaries throughout the Project areas. Because seasonal variability in flows and physical barriers within the tributary streams themselves would continue irrespective of Project operations, these factors outside normal Project operations will continue to limit access into some small tributaries under some conditions. Project operations also do not appear to alter water quality in tributaries and backwaters based on water quality data collected in 2014, which generally met state water quality standards. Results of the 2012 and 2015 water quality studies (Normandeau, 2013a; Study 6) also indicate that water quality in the mainstem is supportive of fish productivity.

Great River Hydro Proposal

Impoundment WSE will be significantly stabilized around specific Target WSE under the proposed operation (Table 3.3-1). Flexible Operation will lower impoundment WSE, but within the context of largely maintaining IEO, limited hours of Flexible Operation and given impoundment refill requirements, the duration and extent of generation driven impoundment WSE drawdown will be significantly less than current operation; particularly in the April-September period. For those tributaries that displayed shallow deltas at their confluence with the mainstem reaches, access restrictions low WSEs or impoundment drawdown should have higher average depths or short-term restrictions. In upper portions of the Bellows Falls and Vernon impoundments, the additional benefit from higher average base flows will further improve access that may be restricted for short periods due to current project operations and station discharge.

Higher base flow is expected as a result of the predominant IEO Operations, Flexible Operation and during Transition operation. Low flows can still occur, but only under extremely dry conditions dictate such and require IEO to have to pass that same low flow. Other than extreme low flow periods, tributary access from riverine portions below the three projects, affected by discharge from the three projects should improve with higher base flows. Restrictions to tributary access caused as a result of low tributary flow may improve in cases where the shallow water barrier will experience deeper water due to higher base flow in the mainstem, but otherwise low tributary flow is expected to continue to remain a factor in small stream access just above the confluence with the mainstem. Larger streams that deposit significant sediment load following a major storm or runoff event that is responsible for the shallow water at the confluence may see greater depths but will continue to be a factor, but more stable riverine WSE due to higher base flow and IEO operations will largely eliminate the barriers that exist under current operation when only minimum flow is discharged. As noted in Section 5, a number of tributary or backwater sites contained access restrictions due to non-Project-related factors, such as culverts, and site observations further suggested that many restrictions were due to tributary streamflows, not mainstem WSEs. For those tributaries that displayed shallow deltas at their confluence with the mainstem reaches, low WSEs due to impoundment drawdown or reduced discharge below the dams could result in short, high-gradient and/or shallow (<0.5 ft) entrance channels (Table 3.6-19). However, note that WSEs in the upper reaches of each impoundment will be highly influenced by IEO management, with increasing effects of dam operations in the lower reaches of each impoundment.

3.6.2.4 Resident Fish Spawning and Reproduction

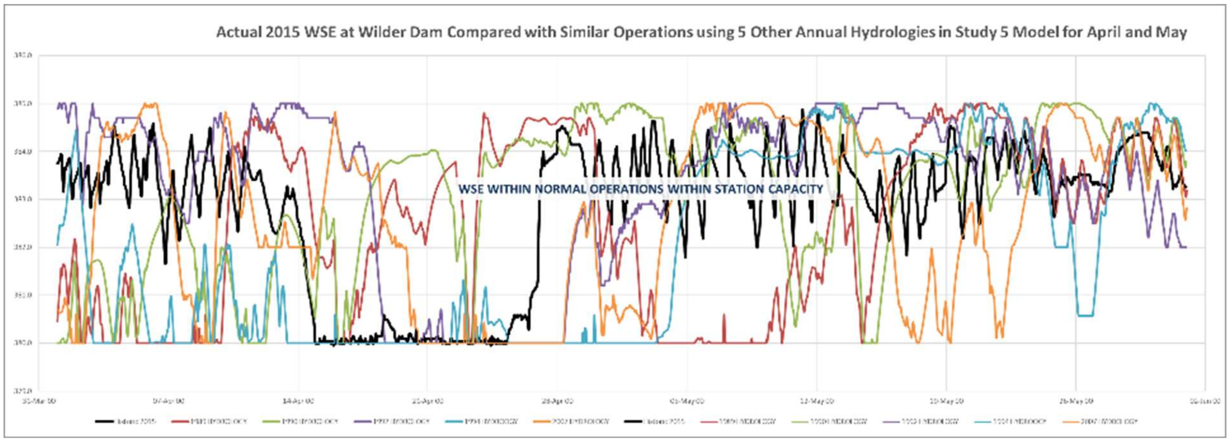
No-action Alternative

As indicated in the discussion of Study 10 in Section 3.6.1.3, *Resident Fish Populations*, 40 species of resident fish rear and spawn within the Project areas and are thus subject to potential effects from Project operations. The spawning lifestages of species that build nests are particularly susceptible because, unlike the rearing lifestage, nests are immobile and cannot move in response to changes in flow and associated WSEs.

The effects of Project operations on spawning by resident fish species in impoundments and riverine reaches were assessed by Studies 14-15. The assessment generally followed two stages: (1) comparison of 2015 spawning observations with WSEs measured at each site during the April-July 2015 spawning period; and (2) comparison of 2015 spawning observations with modeled WSEs at each site using five historic inflow datasets (1989, 1990, 1992, 1994, and 2007; Study 5 operations model). In the second stage, modeled WSEs were used to estimate the proportion of days within a species spawning period when WSEs dropped below specified elevation criteria.

The number of spawning observations made for each of these species during the 2015 field season is listed in Table 3.6-20. Overall, 1,057 observations were made at individual egg masses or nests of resident species, including abundant observations for Yellow Perch egg masses, sunfish (Bluegill and Pumpkinseed) nests, Smallmouth Bass nests, and Fallfish nests. In contrast, few spawning observations were made for many species known to be relatively abundant in the Project areas, likely due to restricted spawning locations not encompassed by the randomized sampling design (Northern Pike, Chain Pickerel, Black Crappie), difficulty in detecting actual spawning locations for small species (Golden and Spottail Shiner), or spawning outside Project-affected areas, such as in tributaries upstream of Project influence (White Sucker, Walleye), or deeper water habitats not affected by normal Project operations (Walleye, other species).

The potential effects of normal Project operations on resident fish spawning are summarized in Table 3.6-21 and for each species below. It should be noted that observations, or lack thereof due to depths and visibility, made under Studies 14 and 15 reflected river and flow conditions specific to April-July 2015, which featured a significant high water period in April. Those conditions are distinctly different than the water surface elevation, flow and depth results from the operations modeling. Water surface elevations at Wilder dam in April-July 2015 are compared with modeled results in Source: ILP Study 5 and Great River Hydro. Figure 3.6-8. As a result, the project effects cannot be viewed as fully representative unless the project operations reflect the hydrology and water conditions specific to the year in which spawning occurs. Details on sampling designs, field protocols, and site-specific spawning results are included in the Studies 14–15 revised final study report.



Source: ILP Study 5 and Great River Hydro.

Figure 3.6-8. Comparison of 2015 actual and Study 5 modeled water surface elevations at Wilder dam.

Yellow Perch

Yellow Perch is a common species distributed throughout the Project areas. Newly laid egg masses were observed in 2015 in backwater habitats over a 6- to 14-day period following initiation of backwater surveys. Spawning was observed from April 20–May 15 at Wilder sites, and from April 15–May 10 at Bellows Falls and Vernon sites. More than 800 egg masses were collected in April and May 2015 (Table 3.6-20). Yellow Perch deposited egg masses on the bare substrate and draped over aquatic vegetation, woody debris, and inundated riparian vegetation. Elevations of observed Yellow Perch egg masses were measured on the substrate adjacent to the egg mass, unless the egg mass was suspended out of water, in which case elevations were measured at the top elevation of the egg mass. Many egg masses deposited on suspended surfaces were subsequently dewatered when backwater water levels decreased as a result of decreasing inflows after high flows and impoundment WSEs returned to normal Project fluctuations. Although limited springtime water visibilities prevented assessment of spawning activities that likely occurred in deeper, protected waters, overall up to 71 percent of measured Yellow Perch eggs deposited in 2015 in shallow backwater habitats were estimated to be exposed to air during lower WSEs, based on 2015 water level logger data.

Comparison of observed median egg mass elevations collected in 2015 with the periodicity of backwater elevations from five modeled inflow hydrologies (Study 5) suggested that WSEs typically do not drop below the 2015 median egg mass elevations in the Bellows Falls and Vernon impoundments (0 to 5 percent of days in the Yellow Perch spawning period) but may drop below the median elevation in Wilder backwaters on 33 to 62 percent of days (Table 3.6-21). That analysis compared elevations of visible egg masses collected in 2015 with WSEs under a suite of different modeled inflow hydrologies and does not account for the fishes' ability and high probability of choosing different spawning elevations under different hydrologic conditions. Despite this potential effect in Wilder backwaters, Yellow Perch remained the first or second most abundant fish species captured in all three Project impoundments (Study 10).

Sunfish (Bluegill and Pumpkinseed)

The two targeted sunfish species were regularly observed in most backwater habitats in the spring and summer of 2015. Survey measurements were taken on 120 sunfish nests, which were similarly distributed between the Bellows Falls and Vernon impoundments (Table 3.6-20). Although sunfish and older silted nests were regularly observed in the Wilder impoundment, few active nests were found prior to cessation of sampling in early July. Also, very few active sunfish nests containing eggs or fry were observed, likely because of the very short duration of egg incubation and fry dispersion (less than 1 week). Despite these limitations, data collected on the active nests indicated that some percentage of sunfish nests was either dewatered or, more likely, abandoned because of insufficient depths. Male adult sunfish will remain and guard the developing eggs from predation until hatching; consequently, this analysis assumed that a minimum depth of 0.5 ft was necessary to ensure nest success.

Overall, an overall average of 23 percent of sunfish nests monitored in 2015 were either dewatered or maintained depths less than 0.5 ft in Project impoundments. Comparing median nest elevations (with the added 0.5-ft buffer) observed in 2015 with projected WSEs during five modeled inflow hydrologies (Study 5) suggested that WSEs drop below this criteria for an average of 33 to 64 percent of days in the Wilder impoundment backwaters, 2 to 23 percent of days in the Bellows Falls impoundment backwaters, and 1 to 5 percent of days during the sunfish spawning period in the Vernon impoundment (Table 3.6-21). These percentages represent conservative estimates because, as noted above, the entire duration of sunfish egg deposition, hatching, and fry dispersion is expected to be completed in 3 to 5 days, whereas the analysis above is based on the full 40-day duration of the spawning season (observed from May 20–June 30 at Wilder sites, and from May 15–June 20 at Bellows Falls and Vernon sites). In other words, many nests could progress successfully in-between individual dewatering events. Also, like all species, it is likely that sunfish would spawn at different elevations in years with different WSE characteristics (Studies 14–15).

Fallfish

Twenty-six new Fallfish nests were assessed in all three riverine reaches and in tributaries to the Bellows Falls impoundment in 2015 (Table 3.6-20). Although Fallfish adults do not guard their nests after egg deposition, this analysis assumed that a minimum depth of 0.5 ft was necessary to ensure successful egg incubation and fry dispersion. None of the Fallfish nests observed in the impoundment-influenced reaches of Bellows Falls tributaries were susceptible to dewatering in 2015; however, 5 of the 7 nests observed in Wilder and Vernon riverine reaches were either dewatered or else subject to depths <0.5 ft during the assumed 15-day incubation period (spawning observed from May 15–June 5 at Wilder sites, May 10–May 30 at Bellows Falls and Vernon sites). Comparison of the 2015 median nest elevations (plus 0.5 ft) to predicted WSEs during five modeled inflow hydrologies (Study 5) suggested that, like for the species described above, potential dewatering of median nest elevations was more likely in the Wilder riverine reach (average of 32 to 61 percent in riverine habitats) than in the Bellows Falls (0 percent of days) or the Vernon (0 to 14 percent of days) riverine reaches (Table 3.6-21).

Smallmouth Bass

Smallmouth Bass, a large component of the fisheries community in the Project impoundments, was the first or second most frequently captured species in the three riverine reaches (Study 10). Spawning surveys located and assessed 75 active Smallmouth Bass nests, 31 nests in the three impoundments (in lower tributaries or associated deltas), and 44 nests at island habitats in the three riverine reaches (Table 3.6-20). Of the Smallmouth Bass nests in the impoundments, 1 nest was dewatered, and 4 nests were subject to depths less than 1 ft, the assumed minimum depth criteria for continued residence of male adult Smallmouth Bass. Smallmouth Bass nests were more vulnerable to dewatering or insufficient depths in the riverine reaches, where 15 of the 44 riverine nests (34 percent) were either dewatered (4 nests) or subject to depths <1.0 ft (11 nests).

The predicted WSEs over five modeled inflow hydrologies (Study 5) suggests that 50 percent of Smallmouth Bass nests (using the median nest elevations) measured in 2015 could be dewatered in 39 to 54 percent of days over the Smallmouth Bass spawning period in the Wilder riverine reach. Spawning was observed in 2015 from May 20–June 20 in all study reaches. As seen for the species described above, the percentage of potential dewatering events is lower in the downstream riverine reaches, at 1 to 34 percent of days in the Bellows Falls riverine reach and 9 to 34 percent of days in the Vernon riverine reach (Table 3.6-21). Although the duration of a Smallmouth Bass spawning event (from egg deposition to fry dispersion) is relatively long (up to 30 days or more), this species appears somewhat more adaptable during spawning than sunfish or Fallfish, which in 2015 appeared to construct nests near nests from prior years. In some locations, new, cleaned Smallmouth Bass nests were observed in shallow water but neither adults, eggs, nor fry were observed on them, suggesting that these nests were abandoned prior to egg deposition. The relatively high abundance of Smallmouth Bass in the riverine reaches suggests this species is somewhat immune to the observed effects on spawning from Project operations, particularly in the more dynamic riverine reaches.

Largemouth Bass

Largemouth Bass were regularly observed roaming along margin habitats during spring backwater surveys, but as spawning progressed only five confirmed Largemouth Bass nests were located (Table 3.6-20), an insufficient number with which to assess Project effects. The relative lack of nest observations for this species may be due to the depth of spawning or the frequency of rain events and turbid conditions that occurred during June 2015. In addition, Largemouth Bass nests are more indistinct in nature than the distinctively cleaned appearance of Smallmouth Bass and sunfish nests that were regularly observed.

White Sucker

Spawning by White Suckers was assessed by deploying 242 egg blocks at 16 impoundment tributaries and 12 riverine riffle habitats for a total sampling time of 4,168 block/days. Despite this level of effort, only 62 confirmed White Sucker eggs were collected on 11 blocks deployed in 2 tributaries to the Wilder impoundment (Table 3.6-20). All blocks containing eggs were subsequently found to be located upstream of the Projects full-pool elevation. Based on these data and the observation of staging schools of suckers at other sampling locations, most spawning by suckers in tributaries occurs upstream of Project influence. Furthermore, the lack of collected eggs on blocks deployed in shallow mainstem riffles of riverine reaches also suggests that mainstem spawning likely occurs in deeper habitats not subject to dewatering at low flows (Studies 14-15).

Walleye

Sampling effort for Walleye spawning was conducted using the same egg blocks deployed for White Suckers, yet only a single Walleye egg was collected on a block deployed in the lower reaches of the Cold River in the Bellows Falls riverine reach (Table 3.6-20). Fish passage data from Study 17 showed that egg blocks were deployed during the period of upstream migration by both White Suckers and Walleyes, and frequent observations of fishermen targeting Walleyes in the immediate vicinity of egg block locations also indicated that blocks were deployed near fish aggregations during the period of spawning migration (from April 15 to May 10 observed in 2015). The lack of Walleye egg collections suggests that spawning either occurred in tributaries upstream of Project influence or in mainstem riffles deeper than the deployed egg blocks and were thus not subject to dewatering (Studies 14–15).

Northern Pike and Chain Pickerel

Spawning surveys by wading and boat to target shallow water spawning by Northern Pike and Chain Pickerel were conducted in 12 backwater habitats in the three Project impoundments between April 28 and July 2, 2015. More than 180 surveys, most of which extended greater than a mile in length, failed to locate active spawning by either species (Table 3.6-20), although adult fish were observed in shallow, vegetated habitats in most backwaters. Backwater surveys were initiated several weeks following ice-out and water temperatures during surveys were well within the published range of temperatures known to illicit spawning activities by both species. Any spawning that may have occurred prior to initiation of backwater surveys would have occurred during a period of high, uncontrolled flow that likely resulted in WSEs well above levels manageable by the Project facilities. The lack of spawning observations may thus be associated with a highly restricted distribution of selected spawning locations; spawning occurring in deeper water limiting detection of spawning activities and thus not subject to dewatering; or other unknown factors (Studies 14–15).

Black Crappie

Black Crappie are reportedly a common fish species in angler catches in some backwater habitats; however, they were a relatively uncommon component of the fish assemblage catches (Study 10), and no Black Crappie nests were detected during Studies 14–15 in 2015 (Table 3.6-20).

Golden and Spottail Shiners

Gravid individuals of both shiner species were captured in June 2015; however, actual spawning behavior or specific egg deposition locations were not found (Table 3.6-20), although a field crew did observe and photograph a spawning aggregation of Rosyface Shiners (not a target species in Studies 14–15) spawning over an active Fallfish nest (Figure 3.6-9).

Source: ILP Studies 14–15, *Resident Fish Spawning in Impoundments and Riverine Sections Studies*

Figure 3.6-9. Photo of Rosyface shiner spawning aggregation with captured male shiner (inset).

Table 3.6-20. Resident species spawning observations[a] in 2015 according to habitat type, reach, and species.[b]

Habitat Type	Impoundment Backwaters			Impoundment Tributaries			Riverine Riffles			Riverine Islands			All Reaches
Reach	Wilder	Bellows Falls	Vernon	Wilder	Bellows Falls	Vernon	Wilder	Bellows Falls	Vernon	Wilder	Bellows Falls	Vernon	
Yellow Perch	216	561	42	NA	NA	NA	NA	NA	NA	NA	NA	NA	**819**
Bluegill and Pumpkinseed	2	53	65	NA	NA	NA	NA	NA	NA	NA	NA	NA	**120**
Fallfish	NA	NA	NA	0	12	0	NA	NA	NA	5	7	2	**26**
Smallmouth Bass	NA	NA	NA	14	13	4	NA	NA	NA	21	15	8	**75**
Largemouth Bass	3	2	0	NA	NA	NA	NA	NA	NA	NA	NA	NA	**5**
White Sucker	NA	NA	NA	11	0	0	0	0	0	NA	NA	NA	**11**
Walleye	NA	NA	NA	0	0	0	0	1	0	NA	NA	NA	**1**
Northern Pike	0	0	0	NA	NA	NA	NA	NA	NA	NA	NA	NA	**0**
Chain Pickerel	0	0	0	NA	NA	NA	NA	NA	NA	NA	NA	NA	**0**
Black Crappie	0	0	0	NA	NA	NA	NA	NA	NA	NA	NA	NA	**0**
Golden Shiner	0	0	0	NA	NA	NA	NA	NA	NA	NA	NA	NA	**0**
Spottail Shiner	0	0	0	0	0	0	NA	NA	NA	0	0	0	**0**

Source: ILP Studies 14-15, *Resident Fish Spawning in Impoundments and Riverine Sections Studies*

a. Observations include the number of nests, egg masses, and egg blocks with eggs.

b. NA indicates species was not a target in that habitat type.

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Table 3.6-21. Average proportion of days, modeled under inflow hydrologies other than 2015, when WSEs drop below specified spawning elevation criteria according to species spawning periodicity, reach/habitat type, based on field observations of spawning under 2015 actual flow conditions.

Species	Reach/Habitat Type	DRIER <						OPERATIONS UNDER NORMAL CONDITIONS (from ILP Study 5, *Operations Modeling Study*)						> WETTER		
		1992			1989			1994			2007			1990		
		% Days Below Min.	% Days Below Median	% Days Below Max.	% Days Below Min.	% Days Below Median	% Days Below Max.	% Days Below Min.	% Days Below Median	% Days Below Max.	% Days Below Min.	% Days Below Median	% Days Below Max.	% Days Below Min.	% Days Below Median	% Days Below Max.
Yellow Perch	Wilder BWs	10	45	77	8	33	69	21	53	83	21	42	65	27	62	90
	Bellows BWs	0	0	4	0	4	13	0	5	15	0	3	8	0	0	0
	Vernon BWs	0	0	3	0	0	0	0	5	10	0	0	8	0	1	21
Sunfish	Wilder BWs	62	64	70	42	50	61	26	33	45	26	43	49	32	37	42
	Bellows BWs	10	22	47	8	17	35	0	2	12	0	23	42	6	14	31
	Vernon BWs	0	1	25	0	5	27	0	1	14	0	4	19	0	5	23
Fallfish	Wilder islands	61	61	61	33	34	34	40	40	42	35	35	36	31	32	32
	Bellows tribs.	0	0	5	0	0	0	0	0	2	0	0	3	0	0	0
	Bellows islands	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Vernon islands	10	14	38	0	0	0	0	5	10	0	5	5	0	0	5
Smallmouth Bass	Wilder tribs.	6	41	46	0	22	35	2	11	31	2	20	31	0	19	31
	Bellows tribs.	4	7	36	3	6	25	0	0	11	0	6	29	2	5	20
	Vernon tribs.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Wilder islands	48	54	79	44	50	74	38	39	64	38	48	70	40	45	69
	Bellows islands	5	34	46	4	22	29	0	1	6	0	29	34	4	15	25
	Vernon islands	6	34	78	0	16	47	0	9	28	0	22	59	6	13	47

Source: ILP Studies 14–15, *Resident Fish Spawning in Impoundments and Riverine Sections Studies*

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Great River Hydro Proposal

As noted in previous sections, stabilization of impoundment WSEs and the reduced frequency, occurrence, duration, and magnitude change between IEO and Flexible Operation flows below Project dams will have beneficial effects on fish spawning habitat and spawning success. In Project impoundments, high storm-related flows or spring runoff exceeding station capacity will continue to require lowering the WSE at the dams under required high water profile procedures, reducing the impoundment WSEs to a lesser extent upstream of the dams. These conditions will continue to result in some loss of eggs deposited by early spring spawners, such as Yellow Perch and Northern Pike or Pickerel; however, these impacts are outside of Project control. Similarly, high water conditions above station capacity will continue to cause elevated stream flows and WSE in riverine portions below the dams during early summer may support nest building by bass, Fallfish, or sunfish that will ultimately be dewatered or will lead to nest abandonment. However, these impacts are not related to normal Project operations.

Impoundment Reaches

The dramatic decrease in the occurrence and extent of impoundment drawdowns under proposed operations will provide significant benefits to all spring and summer spawners. When flows are within station capacity, managing Project operations to maintain a Target WSE will reduce the incidence of perch egg dewatering and will provide more stable backwater and vegetated marsh habitats used by early spring Northern Pike and Pickerel spawners. Detailed results described in Study 14/15 (*Resident Fish Spawning in Impoundments and Riverine Sections Studies*) and summarized in Section 3.6.1 showed a large number of Yellow Perch eggs dewatered in many backwaters, particularly in Wilder impoundment. Although many of these egg masses were clearly deposited during high, uncontrolled flows, others were identified during non-spill conditions. Changes in WSEs during these periods frequently exceeded 1 foot, and it is clear that many egg masses would not have been dewatered under a very limited number of Flexible Operation hours per month with drawdowns averaging less than 0.5 ft (Table 3.3-2).

The reduced drawdowns will also decrease the incidence of nest dewatering or abandonment by Smallmouth Bass, Fallfish, and sunfish. In 2015, relatively few sunfish nests (28 of 120 nests) were assumed to have been abandoned by adults as impoundment drawdowns were largely less than 0.5 ft, the criteria set for adult abandonment. Of the 28 potentially impacted nests, only 4 to 5 nests would likely have been impacted given the 0.1 ft to 0.3 ft average drawdown expected to occur in June and August under the proposed flow scenario, but this assumes the nest themselves would exist at the same elevation under a more stable impoundment management situation.

Because most main channel habitats in impoundment reaches possessed relatively steep banks, drops in WSEs typically produce minor changes in wetted area or extent of dewatered habitat under current operations, and changes will be further minimized under proposed operations. Main channel habitats most susceptible to exposure during current operations included island-related shoals and tributary deltas. Smallmouth Bass and Fallfish were observed to use the gravel-dominated deltas formed at the mouth of impoundment tributaries for spawning in 2015. Only one smallmouth bass nest located in impoundment reaches was assumed to have been impacted by low WSEs leading to nest abandonment by the adult male guardian due to depths less than 1 ft; 3 other nests were impacted due to high flow operations outside of Project control. That nest would have retained more than 1 ft of water given the proposed operations.

In addition to the clear benefits to impoundment spawners such as Yellow Perch, Northern Pike and Pickerel, sunfish, and Smallmouth Bass, more stable WSEs in impoundments such as those with the proposed operation will provide more consistent opportunities for adult White Suckers and Walleyes to immigrate into tributary habitats for spawning.

Riverine Reaches

The anticipated benefits of the proposed operation to fish spawning in the impoundment reaches will be even more evident for fish spawning in the riverine reaches, which are subject to greater levels of WSE drawdowns due to flow changes under current operations. As noted above, the proposed dominant IEO and limited Flexible Operation during the spring spawning and summer/fall rearing seasons will result in elevated base flows through station discharge matching inflow and reduced frequency, occurrence, and magnitude of changes above and below inflow, which will significantly reduce rapid and pronounced reductions in WSE fluctuations in riverine reaches (Table 3.3-6).

Of the 14 Fallfish nests located in Project riverine reaches in 2015, 5 were projected to be impacted by WSE drawdowns that resulted in dewatering or insufficient depths (<0.5 ft). Several of these nests would likely have retained sufficient depths under the proposed operations, as some nests may not have been built at the given elevations if a higher base flows and lower peak flows had been maintained.

Similarly, 15 of 44 Smallmouth Bass nests identified in riverine reaches were believed to have been impacted by flow reduction and dropping water levels resulting in nest dewatering or abandonment. Of the 15 nests, approximately 7 were estimated to retain slightly less than 1 ft of water over the nests (the minimum criteria for bass occupancy); however, these 7 nests would likely have remained viable under the proposed operations given the reduced magnitude of flexible operation flows.

Among other species spawning in riverine reaches, the proposed operation will reduce the likelihood that White Sucker or Walleye eggs will be dewatered along mainstem bars. Also, IEO operations and reduction in magnitude of changes between base flow and higher discretionary Flexible Operation are expected to decrease the potential for stranding of small, newly emerged fry of many resident and migratory species. Although not specifically documented in ILP Study 14-15, *Resident Fish Spawning in Impoundments and Riverine Sections Studies,* it is likely that large flow fluctuations may have caused delay in nest construction by Fallfish and Sea Lamprey. IEO and limited Flexible Operation would be expected to lessen interruptions in nest construction by these species.

3.6.2.5 Migratory Fish Spawning and Reproduction

No-action Alternative

Sea Lamprey

Project effects analyses on spawning Sea Lamprey included calculations of the incidence of nest exposure using water level logger data and Operations Model (Study 5) output applied to nest observations and elevations under 2015 flow and WSE conditions. Water level logger data were specific to 2015 field conditions, whereas modeling was done for the five modeled inflow hydrologies selected for Study 5, representing a range of river flow conditions and simulated Project operations in terms of flows, impoundment elevations, and energy production. For the analyses, the Sea Lamprey spawning season was conservatively defined as May 15 to July 15, 2015, based on upstream passage records at Vernon dam, water temperature, and the general gestation period for lamprey eggs.

Water level loggers were deployed in 2015 for Studies 14–15, and/or Study 16. For each study site, except those characterized as having insufficient spawning habitat, water level logger data were used to calculate the observed range and mean WSE, and rate of change in WSE. For each identified nest with a recorded elevation, the range and mean occurrence, and range and mean duration of exposures were also calculated. Then, the same calculations were made using WSE output from the operations model.

Of the 16 active spawning sites, three (19 percent) had "no Project effects," meaning that no nest elevations at these sites were exposed in any portion of the 2-month modeling analysis. One site was in riverine habitat, and two were in impoundment habitats, though those were both in tributaries rather than the mainstem. Nine sites (56 percent) were found to have "moderate Project effects" meaning that some nests at each site were exposed (at any point in the analysis), but at least one nest elevation at each site was continuously inundated in all modeled inflow hydrologies. Two sites with "'moderate Project effects" were located downstream of Vernon dam in the reach affected by Turners Falls and Northfield Mountain Pumped Storage Project operations. The remaining four sites (25 percent) experienced "Project effects," meaning all nests at each site were exposed at some point during the 2-month modeling analysis, regardless of frequency or duration.

In 2015, the frequency and duration of nest exposure were greatest at Wilder riverine reach sites, particularly those closest to the dam where WSE fluctuations were the greatest. However, for nests that experienced exposure, the average period of exposure at each site was no more than 11 hours based on 2015 level logger data and, except one specific nest elevation at one site, less than 24 hours for all model years (Table 3.6-22).

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Table 3.6-22. Number and mean duration of Sea Lamprey nest exposure events[a] during periods of normal Project operations for 2 months (May 15–July 15)[b] by site and nest elevation (in increasing order / decreasing depth) for operations model output for five model years.

Site[c]	Nest[d]	← Drier						Wetter →			
		Model Year 1992		Model Year 1994		Model Year 2007		Model Year 1989		Model Year 1990	
		N Events	Mean Duration (hour)	N Events	Mean Duration (hour)	N Events	Mean Duration (hour)	N Events	Mean Duration (hour)	N Events	Mean Duration (hour)
16-WL-001	1	0	.	0	.	0	.	0	.	0	.
16-WL-001	2	85	11.6	64	9.4	69	11	59	9.5	71	7.1
16-WL-001	3	80	12.9	67	9.7	77	10.8	64	9.6	72	7.9
16-WL-002	1	0	.	0	.	0	.	0	.	0	.
16-WL-002	2	84	11.5	66	9	68	11.1	54	10.1	69	7.2
16-WL-002	3	84	11.5	66	9	68	11.1	54	10.1	69	7.2
16-WL-002	4	84	11.5	65	9.2	68	11.2	54	10.1	70	7.1
16-WL-002	5	85	11.9	64	9.5	72	10.9	59	9.7	71	7.2
16-WL-003	0	Insufficient habitat									
16-WL-004	0	No nests observed									
16-WL-005	1	45	14.8	41	10.3	32	15.9	30	11.2	30	7.7
16-WL-005	2	55	14.2	47	10.5	42	14.5	41	10.5	40	8.6
16-WL-005	3	62	16.8	60	11	60	13.8	51	11.4	58	9.1
16-WL-006	1	0	.	0	.	0	.	0	.	0	.
16-WL-006	2	16	9.4	17	5	6	11.5	0	.	3	7.7
16-WL-006	3	30	13.3	26	8	20	13.3	8	8.9	10	7
16-WL-007	1	0	.	0	.	0	.	0	.	0	.
16-WL-007	2	27	10.5	22	6.1	11	13	0	.	8	6.1
16-WL-007	3	29	15	27	9.3	21	16.3	13	12.3	17	6.7
16-WL-007	4	46	14.6	41	10.3	34	15.1	30	11.1	33	7.6
16-BT-004	1	47	13.9	44	9.2	35	14.5	28	11.4	31	6.6
16-BT-003	1	77	35	19	12	60	26	40	15	5	5

Site[c]	Nest[d]	← Drier					Wetter →				
		Model Year 1992		Model Year 1994		Model Year 2007		Model Year 1989		Model Year 1990	
		N Events	Mean Duration (hour)	N Events	Mean Duration (hour)	N Events	Mean Duration (hour)	N Events	Mean Duration (hour)	N Events	Mean Duration (hour)
16-BT-006	0	No nests observed									
16-BT-013	1	0	.	0	.	0	.	0	.	0	.
16-BT-013	2	43	11	37	11	35	13.2	30	9.6	31	9.7
16-BT-018	1–10	Tributary site; no model data									
16-BT-031	0	Insufficient habitat									
16-BL-001	1	0	.	0	.	0	.	0	.	0	.
16-BL-001	2	0	.	0	.	0	.	0	.	0	.
16-BL-001	3	0	.	0	.	0	.	0	.	0	.
16-BL-001	4	6	1.3	0	.	0	.	0	.	0	.
16-BL-001	5	36	5.3	22	1.8	28	4	19	2.9	0	.
16-BL-001	6	65	12.3	48	9.5	42	13	35	9.7	0	.
16-BL-002	1	5	11.6	1	4	4	5.3	1	3	0	.
16-BL-002	2	13	7.9	1	6	9	7.7	3	5.3	0	.
16-BL-002	3	13	7.9	1	6	9	7.7	3	5.3	0	.
16-BL-003	1	0	.	0	.	0	.	0	.	0	.
16-BL-003	2	0	.	0	.	0	.	0	.	0	.
16-BL-003	3	0	.	0	.	0	.	0	.	0	.
16-BL-003	4	0	.	0	.	0	.	0	.	0	.
16-VT-014	0	No nests observed									
16-VT-016	1	0	.	0	.	0	.	0	.	0	.
16-VT-016	2	45	18.4	62	9.4	42	15.9	34	12.2	72	5
16-VT-016	3	45	18.4	62	9.4	42	15.9	34	12.2	72	5
16-VT-016	4	45	18.4	62	9.4	42	15.9	34	12.2	72	5
16-VT-018	1–4	Tributary site, no model data									
16-VT-040	0	Insufficient habitat									

Site[c]	Nest[d]	← Drier						Wetter		→	
		Model Year 1992		Model Year 1994		Model Year 2007		Model Year 1989		Model Year 1990	
		N Events	Mean Duration (hour)	N Events	Mean Duration (hour)	N Events	Mean Duration (hour)	N Events	Mean Duration (hour)	N Events	Mean Duration (hour)
16-VT-046	0	Insufficient habitat									
16-VL-01	1	0	.	0	.	0	.	0	.	0	.
16-VL-01	2	0	.	0	.	0	.	0	.	0	.
16-VL-01	3	0	.	0	.	0	.	0	.	0	.
16-VL-01	4	51	5.5	40	3.6	39	4.9	27	4.4	28	2.8
16-VL-01	5	51	5.5	40	3.6	39	4.9	27	4.4	28	2.7
16-VL-01	6	120	5.3	94	4	87	5	58	4.7	79	3.4
16-VL-02	1	0	.	0	.	0	.	0	.	0	.
16-VL-02	2	0	.	0	.	0	.	0	.	0	.
16-VL-02	3	0	.	0	.	0	.	0	.	0	.
16-VL-02	4	0	.	0	.	0	.	0	.	0	.
16-VL-02	5	0	.	0	.	0	.	0	.	0	.
16-VL-02	6	0	.	0	.	0	.	0	.	0	.
16-VL-02	7	0	.	0	.	0	.	0	.	0	.
16-VL-02	8	9	4.2	8	3.6	7	6.3	4	4.3	3	4
16-VL-02	9	21	6.7	11	4	18	5.4	9	4.3	4	3.5
16-VL-02	10	30	6.1	22	4.2	25	5.7	12	4.8	7	3.4
16-VL-02	17	43	5.9	32	4	34	5.1	23	4.8	20	3.5

Source: ILP Study 16, Sea Lamprey Spawning Assessment

a. An exposure event is defined as an uninterrupted period that observed (2015) or modeled (1992, 1994, 1989, 2007, 1990) water surface elevation was less than nest elevation. Exposure events are based on nest elevations observed in 2015, which may not be representative of nest elevations in different years.

b. A 2-month period was selected to encompass the entire spawning and gestation season, but is a highly conservative period for analysis of project effects.

c. Sites WL – Wilder riverine reach, BT – Bellows Falls impoundment, BL – Bellows Falls riverine reach, VT – Vernon impoundment, VL – Vernon riverine reach.

d. Not all identified nests were included in the analysis because elevations were redundant. For example, at least 28 individual nests were identified at site 16-VL-02, but only 11 nest elevations are included for analysis.

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It is probable that the selection of a nest location by Sea Lamprey, is somewhat dependent on the particular water year as lamprey will build nests at locations where water levels are suitable at that time. To better characterize actual Project operations in 2015, Great River Hydro used the hydraulic model (Study 4) to simulate actual Project operations and WSEs during the spawning season. The results of this effort indicate that 2 additional sites in riverine reaches (5 of the 16 sites) or 31 percent of sites had "no project effects" in 2015 compared to the Operations Model prediction of 19 percent of sites. The number of sites classified with "moderate Project effects" decreased from 9 to 8 sites (from 56 percent to 50 percent), and the number of sites classified with "Project effects" decreased from 4 to 3 sites (from 25 percent to 19 percent).

At many sites classified with "moderate" or "Project effects," the 2015 hydraulic model simulation predicted an improvement in the number and duration of exposure events compared to the operations model output. Twenty-six nests at 10 sites (of 56 nests at 14 active non-tributary sites) had fewer exposure periods, and 20 nests at 9 sites had shorter average durations of exposure. Only 1 nest at a Vernon riverine site (VL-001) was predicted to have a longer mean duration of exposure (6.7 hours versus 3.4–5.3 hours in the operations model), but that nest would experience fewer exposure events.

In addition, the average hourly rate of change in WSE (ramping) was often lower in the hydraulic model 2015 simulation compared to the operations model output, particularly for the most vulnerable Wilder and Vernon riverine sites. The up-ramping rate (rate of WSE change when increasing flows, in ft/hour) was reduced at 7 of 14 sites (50 percent), and the down-ramping rate was reduced at 8 of 14 site (57 percent), based on the hydraulic model 2015 simulation. For example, the operations model ramping rate for site 16-WL-001 ranged from 1.4–2.2 ft/hour for both rising and falling WSE, while the hydraulic model 2015 simulation WSE rose at a rate of 0.5–0.8 ft/hour and fell at 0.4–0.6 ft/hour (Table 3.6-23).

Sea Lamprey nest structure condition was evaluated by comparing nest characterization criteria for those nests that had repeated visits. Limited data, however, are available because many specific sites could not be located during high flow (including high operational discharge into riverine reaches), were located only once, or were not located until after the spawning season. The most frequently revisited nests were those that received nest caps;[37] however, it was determined that the nest caps protected nest structures from the forces of water velocity, and

[37] Nest caps consisted of a 5-ft-long x 3.25-ft-wide x 0.8-ft-high frame of steel reinforcement bar welded in a teardrop shape and funneling down to a PVC cod-end. The frame was covered with 1.5 mm mesh landscaper's heavy shade cloth, positioned over the nest with the cod-end oriented downstream, staked to the river bottom with reinforcement bar. The cod-end was terminated with a section of perforated aluminum plate to allow water flow through the nest cap from end to end. A skirt of shade cloth that extended approximately 0.5 ft beyond the frame was buried in the substrate to prevent escapement

altered deposition of fine substrates in the nest, so those sites were disregarded in this evaluation. For non-capped nests, condition was observed and classified in terms of overall structure. Substrate embeddedness inside the nest and the amount that coarse substrates (gravel–boulder) were embedded in fine substrates (mud–sand) was classified. A decreased embeddedness classification value was interpreted as scour, while an increased value was interpreted as deposition.

Table 3.6-23. Comparison of ramping effects on Sea Lamprey nest sites based on the Operations Model output for five annual hydrologies versus simulated 2015 modeled WSEs.

Site Id	Reach	Up-ramping (ft/hour)		Down-ramping (ft/hour)	
		Ops Model	2015 Model	Ops Model	2015 Model
16-WL-001	Wilder Riverine	1.4–2.2	0.5–0.8	1.4–2.2	0.4–0.6
16-WL-002		1.4–2.1	0.8	1.4–2.2	0.6
16-WL-005		0.4–0.7	0.5	0.6–0.7	0.4
16-WL-006		0.4	0.4	0.4	0.3
16-WL-007		0.4	0.3	0.4	0.3
16-BT-004	Bellows Falls Impoundment	0.4	0.3	0.3–0.4	0.3
16-BT-003		0.2	0.2	0.2	0.2
16-BT-013		0.1	0.1	0.1	0.1
16-BL-001	Bellows Falls Riverine	0.5–0.6	0.4	0.7 - 0.9	0.4
16-BL-002		0.3 - 0.4	0.3	0.3 - 0.4	0.3
16-BL-003		0.2 - 0.3	0.2	0.2 - 0.3	0.2
16-VT-016	Vernon Impoundment	0.1 - 0.2	0.1	0.1	0.1
16-VL-01	Vernon Riverine	0.5 - 0.8	0.3	0.7 - 0.9	0.3
16-VL-02		0.4 - 0.7	0.2 - 0.3	0.6 - 0.8	0.2 - 0.3

Source: ILP Study 16, *Sea Lamprey Spawning Assessment* modified by Great River Hydro

Observed changes in nest structure and embeddedness were subject to the number and timing of visits, site location, and nest meso-habitat. For example, site visits that occurred before a rain event that resulted in high river discharges would potentially yield different observations than immediately after such an event. Site location was important because sites located above tributary mouths were subject to changes in nest condition as a result of the effects of tributary flows such as increased WSE, velocity, and suspended sediments. Spawning habitat in those sites tended to occur toward the upper extent of the Project-influenced reaches where stream gradient began to increase, and Project impoundment effects were negligible. Meso-habitat changes were important because evident nest degradation, scour, and sediment deposition could vary within a site.

Of 13 nests evaluated, structure degradation was noted for 8 (62 percent) nests, and 5 of those nests were attributed to tributary effects;[38] nest scour was noted for 5 of 13 nests (38 percent) and was attributed to tributary effects at 4 of those; and sediment deposition was noted in 7 of 13 nests (54 percent) and was attributed to tributary effects at 4 of those.

American Shad

American Shad spawn in river reaches dominated by broad flats with relatively shallow water (3 to 19 ft) and moderate currents (1.0 to 3.2 ft/s) (Munroe, 2002). Fertilized eggs are semi-buoyant and non-adhesive. Shad are broadcast spawners and eggs are swept downstream and lodge in the substrate. Shad develop quickly from egg to larval stage and it appears that spring river flows and water temperature are determining factors for survival (Savoy et al., 2004). Larvae drift downstream into areas of reduced velocity along shorelines and backwaters. Following fertilization eggs sink toward the bottom where they increase in diameter due to water-hardening, which may cause them to lodge into the bottom substrate. Most shad eggs travel between 1 and 4 miles (1.6 and 6.4 km) downstream of their spawning location prior to hatch (Marcy, 1976).

Study 21 included an assessment of American Shad spawning in the Project areas from Bellows Falls dam downstream to the Vernon riverine reach. Spawning surveys were conducted on 30 nights between May 26 and July 2, 2015. Sampling locations were selected based on the presence of radio-tagged shad that had been released into the Vernon impoundment or had been released downstream of Vernon and successfully passed upstream through the Project. Tagged shad were tracked throughout the Vernon impoundment and up to Bellows Falls dam to potential spawning locations. A total of 120 ichthyoplankton net samples at 60 trawling locations was collected. Approximately 38 percent (46 of the 120) of the ichthyoplankton net samples contained American Shad eggs or larvae. Overall, 794 eggs and larvae were collected at just over half (31 of 60) of the sampling locations. The majority of eggs and larvae were contained in samples collected in the Vernon riverine reach (46.3 percent of total) and the Bellows Falls riverine reach (48.6 percent of total).

Collected eggs were examined and a developmental stage was assigned. The majority of eggs collected (78 percent) were determined to be stage 1 (blastodisk stage, occurs within 0.5 hour of spawning). Eggs classified as older (stages 2 through 9) were also collected but in lower abundance. American Shad yolk-sac and post yolk-sac larvae were also observed in low numbers with each lifestage representing 1 percent of the total catch. For all stage 1 eggs, a back-calculated spawning location was determined using the estimated time between spawning and

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[38] Tributary effects include tributary inflows that increased WSE, velocity, and/or suspended sediments. Spawning habitat in those sites tended to occur toward the upper extent of the Project-influenced reaches where stream gradients began to increase, and Project impoundment effects were negligible.

egg collection, along with water velocity at the point of collection to determine the approximate distance upstream of the collection point where the egg was likely spawned. Back-calculated spawning locations were not calculated for eggs older than stage 1 because the water velocity information collected at the time of measurement was less likely to be representative over longer periods and potentially consisted of varied river flows.

Based on back calculations, six general spawning areas were identified: Bellows Falls tailrace and the downstream reach to Saxtons River; the Vernon tailrace and Stebbins Island reach; in the vicinity of the confluences of the Cold River, Mad Brook, and Mill Brook in the Bellows Falls riverine reach; and upstream of the Route 119 Bridge in the lower Vernon impoundment (with less evidence and based on a single stage 1 egg collected downstream of that area). When standardized to the number of individuals per hour of net sampling, the average catch per unit of effort rate for stage 1 shad eggs was highest for the Bellows Falls tailrace downstream to the Saxtons River confluence, followed by the Vernon tailrace to Stebbins Island spawning areas (although the two areas were not substantially different).

Project operations during the 2015 sampling period ranged from approximate minimum flows, which are uncommon in the spring, to sustained periods of high flow. Monthly flow exceedance curves (from 1979–2019, see figures 3.3-6 through 3.3-9 and Exhibit B2.3 *Project Flows and Flow Exceedence Curves*) indicate that minimum flows at Bellows Falls and Vernon occur less than 1 percent of the time during May and June. Flows equal to mid-range generating flows at Bellows Falls (approximately 5,000 cfs) occur only 5 percent of the time in May and 25 percent in June. Flows equal to mid-range generating flows at Vernon (8,000 cfs) occur about 16 percent of the time in May and 46 percent in June. Flows are typically higher than 5,000 to 8,000 cfs in May and June.

Shad eggs and larvae were found throughout the study area in a variety of substrates, conditions, and flows, indicating that the entire study reach is likely suitable for spawning, particularly in the riverine reaches where most eggs and larvae were collected. Collections were more concentrated in the Bellows Falls and Vernon riverine reaches where telemetered shad were mainly concentrated during sampling events. Overall, during 20 of the 30 sampling dates, samples with eggs were collected in locations proximate to samples with no eggs collected during the same time periods (and hence during the same operational periods). No ichthyoplankton were caught downstream of Bellows Falls dam during early June 2015 when flows were high and temperatures cool (<15°C). In general, American Shad will enter rivers at temperatures between 13-16°C and spawning activity can slow or cease if water temperatures dip below that range (Munroe, 2002). However, eggs and larvae were collected later in June during a sustained period of high flow and warm temperatures. Downstream of Vernon, ichthyoplankton were collected in early June when flows were high and water temperatures less than 15°C; no ichthyoplankton were collected after June 19. However, no sampling was conducted in that reach between June 20 and June 26 due to sustained high flows throughout that period that prevented safe sampling.

The potential effects of Project operations on shad spawning in each of the six general spawning areas were evaluated using the modeled effects of Project operations on three parameters (mean channel velocity, channel width, and thalweg depth) at the upper and lower model cross sections bounding each general spawning area. A range of discharges, from minimum flow to spill flows (including flows at which back-calculated spawning occurred) were evaluated for each general spawning location. For the riverine reaches, estimates of AWS for American Shad spawning were evaluated over the target range of discharges from minimum flows to full generating flows and higher flows when spawning occurred in 2015. As would be expected, mean channel velocity, channel width, and thalweg depth all increased with increases in river flow. Each of the six general spawning areas contained areas with adequate depth and velocity to support shad spawning at all flows modeled. In no case did the modeled thalweg depth drop below the literature reported range of water depths for shad spawning activity (i.e., 3-19 ft), even under minimum flow conditions. While the difference in modeled wetted channel width between the discharges when spawning was observed decreased from 1 to 39 percent between those flows and minimum flow conditions, minimum flows at both projects typically occur less than 1 percent of the time during May and June so the minimum wetted channel width estimate and potential Project effects related to channel width is considered to be very conservative. This modeling indicated that Project operations would have minimal effect on shad spawning.

Great River Hydro Proposal

The proposed changes in WSE management in Project impoundments and the reduction in changes in downstream flows under the proposed operation is expected to benefit spawning success for migratory fish species, particularly Sea Lamprey which construct nests in relatively shallow shoal habitats. Comparison of Sea Lamprey nest elevations measured in 2015 with WSEs the same year (ILP Study 16, *Sea Lamprey Spawning Assessment*) showed that 24 of 70 lamprey nests may have been dewatered, if only for a brief time. Under the proposed operations, IEO Operation will be the dominant mode of operation during much of the Sea Lamprey nesting period with only 1.4 percent of hours per month available for Flexible operation in April, May, and June, as well as a similar number of hours in the first half of July. This is expected to reduce that number of impacted nests by up to 50 percent. For example, the mean daily magnitude of flow changes along Stebbins Island below Vernon dam, where numerous Sea Lampreys nests were observed in 2015, is expected to decrease by 1,700 cfs to 2,900 cfs in June (Table 3.3-6). In addition to the reduced level of fluctuation, the more gradual up-ramp and down-ramp and the shorter duration of flexible operations (Section 3.3.2) is also expected to reduce the incidence of lamprey nest stranding.

Higher base flows under the proposed operation will support a higher amount of suitable American Shad habitat for both adult and spawning lifestages (ILP Study 9, *Instream Flow Study*). In addition, the higher base flows and reduced magnitude of changes between base flow and higher discretionary Flexible Operation flow may increase the likelihood that shad eggs would settle in suitable habitat and increase the likelihood of successful hatching. As noted previously, the reduction in magnitude of operational flows is expected to decrease the potential for stranding of small, newly emerged fry of many resident and migratory species.

3.6.2.6 Resident Fish Passage

No-action Alternative

The primary issue related to resident fish passage is whether passage should be provided for resident species outside of the normal operating season for migratory species (see Sections 2.1.1.5, 2.1.2.5, and 2.1.3.5, *Existing Environmental Measures*, for each Project). Note that the number of "observations" in the tables below does not indicate the total number of individuals actually using the fish ladders for passage, because milling was commonly observed (i.e., the back and forth transit movement of the same fish past the counting window). For all species, video recording cannot distinguish individual fish, so the total number of video detections is likely to inflate estimates of the actual number of fish using the fish ladders. Therefore, only net passage values provide a reasonably accurate estimate of ladder usage.

Wilder Project

The majority of net passage for all resident species except trout occurred during the fish ladder's normal operating season (from opening in spring through July 15). For trout 80 percent net passage occurred by July 30, but observations continued until ladder closing including. Most species exhibited passage during the spring over a range of river flows, while a concentrated period of passage of bass and Walleye occurred in the fall which appeared to be associated with a brief spike in total river discharge that resulted in spill conditions.

Table 3.6-24 summarizes total recorded movements and percent of net passage during the normal fish ladder operating season, the 2015 extended season from July 16, 2015 to January 7, 2016, and over the entire 2015 study season. For the four resident species with net upstream passage, the percentage of net passage to total movements ranged from 5.1 to 13.9 percent during the normal operating season. For the three species with net upstream passage after July 15, net passage ranged from 2.0 to 3.8 percent of total movements. For the entire 2015 study season, net upstream passage ranged from 3.4 to 6.5 percent of total movements. For all resident species combined, the total net passage was 8.2 percent through July 15, 2.1 percent after that date, and 3.8 percent overall. While more total movements were recorded after July 15, the total net upstream passage (n = 52) was low during that period and low overall (n = 130). Therefore, while resident species may take up residence in the ladder after the normal operating season (after July 15), there is little upstream passage of those species in the extended season, indicating there would be little benefit to extended operation of the ladder for resident species.

Table 3.6-24. Wilder fish ladder net passage of target resident species by operating period, 2015.

Species/ Genera	Ladder Opening–July 15			July 16–January 7, 2016			Total 2015 Study Period		
	Observations	Net No. Passed[a]	% Net No. Passed	Observations	Net No. Passed[a]	% Net No. Passed	Observations	Net No. Passed[a]	% Net No. Passed
Bass	548	28	5.1	321	11	3.4	869	39	4.5
White Sucker	19	1	5.3	0	0	NA	19	1	5.3
Walleye	111	13	11.7	210	8	3.8	321	21	6.5
Trout	267	37	13.9	1,887	37	2.0	2,154	74	3.4
Sunfish	3	-1	-33.3	48	-4	-8.3	51	-5	-9.8
Bullhead	No observations								
Crappie	No observations								
Pike/Pickerel	No observations								
Yellow Perch	No observations								
Carp	No observations								
Other	No observations								
Total	948	78	8.2	2,466	52	2.1	3,414	130	3.8

Source: ILP Study 17, *Upstream Passage of Riverine Fish Species Assessment*

a. Negative values indicate net downstream passage.

Bellows Falls Project

Limited fish ladder usage occurred overall. The majority of net passage for all resident species except sunfish occurred during the fish ladder's normal operating season (from opening in spring through July 15). Bass passage was distributed over a range of flows including spill during spring and summer. White Sucker passage occurred only during the period in spring when freshet flows were receding. Walleye, trout, and sunfish passage was sporadic and distributed over a variety of flow scenarios from spring until early fall (see Study 17).

Table 3.6-25 summarizes total recorded movements and percent of net passage during the normal fish ladder operating season, the 2015 extended season from July 16, 2015, to January 6, 2016, and over the entire 2015 study season. For the four resident species with net upstream passage, the percentage of net passage to total movements ranged from 5.6 to 17.2 percent during the normal operating season. For sunfish, which was the only species with net upstream passage after July 15, net passage was 15.8 percent of total movements. For the entire 2015 study season, net upstream passage ranged from 2.9 to 13.2 percent. For all resident species combined, total net passage was -2.2 percent through July 15, -0.1 percent after that date, and -1.38 percent overall (i.e., net overall downstream movement, influenced primarily by the greater proportion of bass movements). Given the low fish ladder usage, net downstream passage, and minimal upstream passage of only one species, there would be little benefit to extended operation of the ladder for resident species.

Table 3.6-25. Bellows Falls fish ladder net passage of target resident species by operating period, 2015.

Species/ Genera	Ladder Opening–July 15			July 16– January 6, 2016			Total 2015 Study Period		
	Observations	Net No. Passed[a]	% Net No. Passed	Observations	Net No. Passed[a]	% Net No. Passed	Observations	Net No. Passed[a]	% Net No. Passed
Bass	787	-47	-6.0	474	0	0.0	1,261	-47	-3.7
White Sucker	91	7	7.7	0	0	NA	91	7	7.7
Walleye	36	2	5.6	22	0	0.0	58	2	3.4
Trout	87	15	17.2	193	-7	-3.6	280	8	2.9
Sunfish	15	1	6.7	38	6	15.8	53	7	13.2
Bullhead	No observations								
Crappie	No observations								
Pike/Pickerel	No observations								
Yellow Perch	No observations								
Carp	No observations								
Other	No observations								
Total	1,016	-22	-2.2	727	-1	-0.1	1,743	-23	-1.3

Source: ILP Study 17, *Upstream Passage of Riverine Fish Species Assessment*

a. Negative values indicate net downstream passage.

Vernon Project

The majority of net passage for all resident species except sunfish occurred during the fish ladder's normal operating season (from opening in spring through July 15). Bass passage was distributed over a range of flows including spill during spring and summer. White Sucker passage occurred only during the period in spring when freshet flows were receding. Walleye, trout, and sunfish passage was sporadic and distributed over a variety of flow scenarios from spring until early fall (Study 17). Because of the long-standing operating procedure of shutting off the attraction flow pump discharge overnight (see Section 3.6.1.3, *Resident Fish Populations*), diel periodicity of fish activity is likely affected both by species behavior and by fish ladder operations.

Table 3.6-26 summarizes total recorded movements and percent of net passage during the normal fish ladder operating season, the 2015 extended season from July 16, 2015, to January 6, 2016, and over the entire 2015 study season. For the nine resident species with net upstream passage, the percentage of net passage to total movements ranged from 3.86 to 27.3 percent (and 100 percent for crappie) during the normal operating season. For the six resident species with net upstream passage after July 15, the percentage of net passage to total movements ranged from 11.1 to 52.9 percent.

For the entire 2015 study season and the nine species with net upstream passage, the percent of net passage ranged from 4.69 to 28.4 percent (100 percent for crappie) of total movements. For all resident species combined, total net passage was 7.1 percent through July 15, 18.2 percent after that date, and 10.4 percent overall. The Vernon fish ladder usage had more resident species and substantially more total movements and net upstream passage than did the Wilder and Bellows Falls fish ladders. However, net upstream passage for resident species was negative, zero, or less than 10 individuals after July 15 for all species, except bass and sunfish. Sunfish had higher net passage after July 15 (n = 984) than earlier in the season (n = 204). Cumulative net passage for sunfish reached only 17 percent by July 15, but had reached 50 percent by August 26, and 80 percent by September 6. Approximately 31 percent of all bass recorded in 2015 (239 of 761) had net passage after July 15, but cumulative passage on that date was 69 percent, and had reached 80 percent by August 20 (Study 17).

White Sucker and Walleye were present upon opening of the Vernon fish ladder on May 5, 2015, and according to FWS in its study comments, White Sucker and Walleye runs may have been missed due to the late opening. Because of this, VANR requested that Salmonsoft recordings made by the agency in the 2016 upstream passage season be reviewed to determine presence and ladder usage of these species earlier in the season. Video was reviewed for the April 15 through May 31, 2016, period at Vernon.

Results of the 2016 evaluation showed net upstream passage through May 31 of 7 Walleye and 148 White Sucker, compared to 2015 results through May 31 of 46 Walleye and 326 White Sucker with a later fish ladder opening that year. The first net passage in 2016 occurred on April 17 for Walleye and on April 16 for White Sucker and 100 percent net passage occurred on May 17 and May 23, respectively. In 2015, both species were recorded with net upstream passage upon fish ladder opening on May 5, 2015. By May 31, 2015, cumulative net passage was 79 percent for Walleye and 100 percent for White Sucker (100 percent cumulative passage had occurred on May 14). Overall, more net passage was recorded for both species during the shorter 2015 period from May 5 through May 31 than during the longer period from April 15 through May 31, 2016. Conditions (e.g., flows, temperature) and the number of fish observed in fish ladders will vary from year to year, making comparisons between the numbers of fish observed during specific time frames in different years potentially problematic. Water temperature at the beginning of the 2016 passage season on April 15 was lower than the later starting date on May 5, 2015 (7.0°C vs. 11.9°C), but temperature was similar by May 31 in both years (15.1°C vs. 15.0°C). In both years, the range of flows during the passage period from ladder opening through May 31 were comparable and ranged from 1,850 to 19,300 cfs in 2015, and from 2,595 to 20,649 cfs in 2016.

Overall, resident fish activity and passage was greater in the Vernon fish ladder than at Bellows Falls and Wilder, although most of that activity and passage occurred during the normal operating season (through July 15). Minimal net passage of only five species occurred after July 15, and most of that passage was limited to two species. Therefore, there would be little benefit to extended operation of the ladder for resident species.

Table 3.6-26. Vernon fish ladder net passage of target resident species by operating period, 2015.

Species/ Genera	Ladder Opening - July 15			July 16 - January 6, 2016			Total 2015 Study Period		
	Observations	Net No. Passed[a]	% Net No. Passed	Observations	Net No. Passed[a]	% Net No. Passed	Observations	Net No. Passed[a]	% Net No. Passed
Bass	8,954	522	5.8	925	239	25.8	9,879	761	7.7
White Sucker	4,381	325	7.4	5	-3	-60.0	4,386	322	7.3
Walleye	187	49	26.2	17	9	52.9	204	58	28.4
Trout	138	24	17.4	12	6	50.0	150	30	20.0
Sunfish	2,244	204	9.1	5,794	984	17.0	8,038	1,188	14.8
Bullhead	11	3	27.3	3	-1	-33.3	14	2	14.3
Crappie	14	14	100.0	0	0	NA	14	14	100.0
Pike/Pickerel	3	-1	-33.3	0	0	NA	3	-1	-33.3
Yellow Perch	No observations								
Carp	160	6	3.8	8	2	25.0	168	8	4.8
Other	233	9	3.9	27	3	11.1	260	12	4.6
Total	16,325	1,155	7.1	6,791	1,239	18.2	23,116	2,394	10.4

Source: ILP Study 17, *Upstream Passage of Riverine Fish Species Assessment*

a. Negative values indicate net downstream passage.

Great River Hydro Proposal

Resident fish passage was documented in Study 17, Upstream Passage of Riverine Fish Species Assessment, from April 2015 through early January 2016 at Wilder, Bellows Falls, and Vernon. Overall, passage for resident species was limited with the majority of movement occurring during the migratory fish passage season (April through mid-July).

Proposed operations will largely reduce significant flow fluctuation in riverine reaches immediately downstream of stations (Section 3.3). IEO and Flexible Operation limited to 10 hours per month in April, May, June, and the first half of July will create a more natural flow regime for fish seeking passage (Section 3.3.2). Stabilizing flow downstream of dams will present less chance of stranding for species using the riverine margins. Reduced magnitude and frequency of maximum flows (Section 3.3.2 will decrease the potential of creating velocity barriers for smaller individuals and weaker swimming species (e.g., Lepomis spp) attempting to approach and locate fish passage entrances.

Upstream and downstream fish passage structures are operated in accordance with the Licensee's written policies and procedures. The proposed flow operations will not impact the ability to operate the fish passage structures at Vernon, Bellows Falls, or Wilder dams. These facilities were designed to operate under the overall current operating range of each Project and therefore will continue to be capable of operating under proposed operations .

Great River Hydro and resource agencies with prescriptive authority under Section 18 of the Federal Power Act and state fish and wildlife agencies have initiated discussion of upstream and downstream fish passage at the Projects and will continue those discussions after these amended FLAs are filed in an effort to reach agreement on fish passage requirements, plans, and schedules to be included in the FWS recommendation for terms and conditions to be filed within 60 days of the Notice of REA. White Sucker and Walleye, resident species that move up-river to spawn in early spring, were observed in each of the three Project fish ladders when Study 17 was conducted in 2015 and supplemented in 2016. Although relatively small numbers of each species were observed, individuals entered the ladders the day of, or within days of, opening, suggesting an earlier opening might benefit these species. Therefore, and at resource agencies' request, Great River Hydro proposes operating the three fish ladders for these two species from April 1 to May 15.

3.6.2.7 Upstream Passage of Migratory Fish

No-action Alternative

The Wilder, Bellows Falls, and Vernon Projects have successfully passed migratory fish upstream (see Table 3.6-8) since construction of passage facilities in the early 1980s. Wilder and Bellows Falls upstream fish ladders were designed to pass Atlantic Salmon, and the Vernon fish ladder was designed to pass both Atlantic

Salmon and American Shad. Based on species' migratory ranges and current status, upstream passage is relevant at all three Projects for juvenile American Eel, and for adult Sea Lamprey and adult American Shad at Bellows Falls and Vernon.

Atlantic Salmon restoration efforts have been suspended by federal and state resource agencies due to poor returns and, therefore, this species was not included in this environmental analysis although salmon passage records are included herein for completeness. See Table 3.6-8 in Section 3.6.1.4, *Migratory Species,* for historical upstream passage counts through 2016. Should salmon populations rebound or be restored in the future, the continued operation of the project fish passage facilities and the close interaction of Great River Hydro with the resource agencies would ensure that upstream salmon migrations are maintained. Because Blueback Herring are not present in the Project areas, that species is also excluded from further discussion.

Table 3.6-27, Table 3.6-28, and Table 3.6-29 summarize fish ladder use by migratory species at each Project as recorded in 2015 for Study 17. Results are delineated between the normal fish ladder operating season ending date of July 15, and the extended 2015 operating season used to conduct Study 17, into January 2016.

Table 3.6-27. Wilder fish ladder migratory fish passage by operating period, 2015.

Species	Ladder Opening–July 15				July 16–January 7, 2016				80% Net Passage Date	Total Net No. Passed
	First	Last	Obser-vations	Net No. Passed	First	Last	Obser-vations	Net No. Passed		
American Eel	June 2	July 13	66	28	July 20	Nov 9	288	24	Sep 30	52
Sea Lamprey	May 30	June 2	6	2	NA	NA	0	0	June 2	2
Atlantic Salmon	NA	NA	0	0	Oct 5	Oct 5	1	1	NA	1
American Shad	No observations									
Total			72	30			289	25		55

Source: ILP Study 17, *Upstream Passage of Riverine Fish Species Assessment*

Table 3.6-28. Bellows Falls fish ladder migratory fish passage by operating period, 2015.

Species	Ladder Opening–July 15				July 16–January 6, 2016				80% Net Passage Date	Total Net No. Passed
	First	Last	Obser-vations	Net No. Passed	First	Last	Obser-vations	Net No. Passed		
American Eel	June 21	July 15	91	-17[a]	July 16	Nov 1	339	77	Sep 13	60
Sea Lamprey	May 19	July 7	3,712	970	NA	NA	0	0	June 1	970
American Shad	May 26	June 20	130	44	NA	NA	0	0	May 30	44
Atlantic Salmon	June 8	June 8	2	1[b]	NA	NA	0	0	NA	1[b]
Total			3,935	998			339	77		1,075

Source: ILP Study 17, *Upstream Passage of Riverine Fish Species Assessment*

a Negative values indicate net downstream passage.

b One salmon was assumed to have passed because one salmon was observed at Wilder.

Table 3.6-29. Vernon fish ladder migratory fish passage by operating period, 2015.

Species	Ladder Opening–July 15				July 16–January 6, 2016				80% Net Passage Date	Total Net No. Passed
	First	Last	Obser-vations	Net No. Passed	First	Last	Obser-vations	Net No. Passed		
American Eel	May 21	July 15	4,180	1,088	July 16	Dec 16	4,109	457	July 21	1,545
Sea Lamprey	May 13	July 14	12,959	2,439	July 18	July 18	1	1	May 31	2,440
American Shad	May 10	July15	71,541	39,203	July 17	Nov 9	37	-7[a]	May 30	39,196
Atlantic Salmon	May 20	July 12	6	6	NA	NA	0	0	June 17	6
Total			88,686	42,736			4,147	451		43,184

Source: ILP Study 17, *Upstream Passage of Riverine Fish Species Assessment*

a Negative values indicate net downstream passage

Wilder Project

American Eel

In Study 17, American Eels were recorded from June 2 through November 9 with a total net passage of 52. The most concentrated activity (53.8 percent of total net passage) occurred from early June through July 15 (Table 3.6-27), the end of the normal fish ladder operating season. Peak net passage occurred on June 27 and July 9 with net passage of 4 eels on each occasion. Activity was distributed around-the-clock, likely owing to milling (i.e., the back and forth movement of the same eel past the counting window), but with a strong preponderance toward nighttime hours. A second period of concentrated activity occurred from late September through mid-October that resulted in 23 percent of the total net passage for the year. A 1-day peak occurred on October 17 with net passage of 4 eels. More total movements were recorded after July 15 than before that date, but net passage during this period was 46 percent of total net passage for the year. Therefore, even though the Wilder fish ladder was not designed for American Eel, the low but overall net upstream passage value from Study 17 suggests that eels can successfully navigate the fish ladder. Only small numbers of eels reach the Wilder Project (see Study 18), but for those eels that reach the project, the Project fish ladder can provide an upstream passage route and no additional measures are required at this time.

Sea Lamprey

Study 17 recorded only two Sea Lamprey passing upstream of the Wilder Project. Passage occurred on May 30 and June 2 during the normal fish ladder operating season (Table 3.6-27). Because of this low number and rare historical occurrences (two individuals in a single year prior to 2015, see Table 3.6-8 in Section 3.6.1.4, *Migratory Species*), the Project has minimal effect on upstream passage of this species and no additional measures are required.

Bellows Falls Project

American Eel

American Eels were recorded in the Bellows Falls fish ladder from June 21 through November 1, with a total net passage of 60 (Table 3.6-28). The most concentrated activity occurred from early July through mid-September. All passage was net downstream from the opening of the fish ladder through July 15 (n = -17). Peak upstream passage occurred on 12 days later in the summer, and cumulatively, 80 percent of total net passage occurred by September 13. American Eel activity was recorded around-the-clock, but with a strong preponderance toward the nighttime. More total movements were recorded after July 15 than before that date and all net upstream passage occurred during this period.

During Study 18, only 3 eels were observed migrating upstream at Bellows Falls, so no migratory aggregations were identified. These observations occurred during the summer, on July 8, July 21, and August 25. Two observations were made in the tailrace near the fish ladder entrance, and one observation was made in the upper portion of the bypassed reach. These data indicate that only small numbers of eels reach the Bellows Falls Project (see Study 18), but for those eels that reach the Project, the fish ladder can provide an upstream passage route and no additional measures are required at this time.

Sea Lamprey

For Study 17, Sea Lamprey were recorded in the Bellows Falls fish ladder from May 19 through July 7 with a total net passage of 970, all during the normal fish ladder operating season ending July 15 (Table 3.6-28). Peak upstream passage occurred from May 29 through June 1, and cumulatively, 80 percent of net passage occurred by June 1. Sea Lamprey were recorded around-the-clock with a preponderance toward daytime. Net passage at Bellows Falls was 40 percent of net passage at Vernon. Wide fluctuations in historical passage have occurred at both Vernon and Bellows Falls (see Table 3.6-8 in Section 3.6.1.4, *Migratory Species*), and the proportion of lamprey passing Vernon that also pass Bellows Falls has also varied widely. Passage at Bellows Falls in 2015 and 2016 was higher than in most previous years, except 2008, which had the peak recorded passage at Bellows Falls of 2,233 since records began in 1984 (Table 3.6-8). It is unknown at this time if recent increases in passage are anomalous or suggest an overall increasing trend. Despite the fact that the Bellows Falls fish ladder was not designed specifically to pass Sea Lamprey, it is apparent that this species is able to access and use the ladder. Therefore, the Project has minimal effects on upstream passage of this species and no additional measures are required.

American Shad

American Shad use the Bellows Falls fish ladder even though Bellows Falls is considered the historical upstream migratory limit for the species in the Connecticut River. Study 17 recorded a net passage of 44 shad in 2015 (Table 3.6-28). Shad were recorded from May 26 through June 20; peak passage occurred from May 28 through May 30, and 80 percent cumulative passage occurred on May 30. Shad were recorded during both day and night, but with a strong preponderance toward daytime (between 8:00 a.m. to 7:00 p.m.). Passage activity was mostly concentrated during a period of relatively low river discharge following the spring freshet. Net passage of American Shad at Bellows Falls in 2015 was 0.1 percent of passage at Vernon. In 2016, passage at Bellows Falls was 1,973 (a historical record) and 5.5 percent of Vernon passage, yet Vernon passage in 2016 was only 91 percent of 2015 passage. Between 2005 and 2014, the only shad recorded passing Bellows Falls were in 2005 (n = 3) and 2011 (n = 1), although prior records from 1984 to 2000 show limited passage in most years (maximum = 147, mean = 38) (Table 3.6-8). The Bellows Falls fish ladder was not designed specifically to pass American Shad, but its design has been used to pass shad at other Projects and it is apparent that shad are able to access and use the ladder; therefore, the Bellows Falls ladder should be adequate to pass any shad that approach the Project with the desire to move upstream and additional measures are not required.

Vernon Project

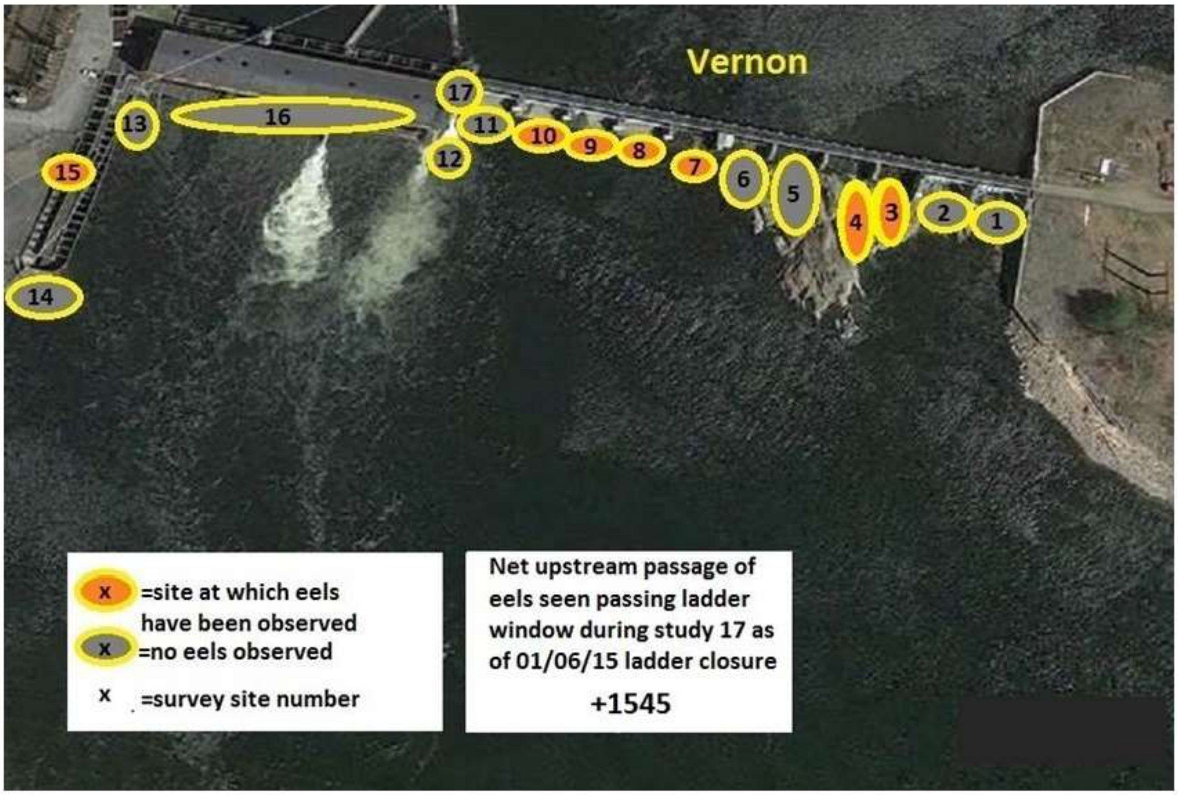
American Eel

American Eels were recorded at the ladder counting window from May 21 through December 16, 2015, in Study 17 (see Table 3.6-29). Net upstream count was 1,545 with about 70 percent of cumulative net upstream counts occurring during the normal fish ladder operating season (through July 15), and 80 percent cumulative net upstream counts occurred by July 21. The most concentrated activity occurred from late May through July. Peak upstream counts occurred on 3 days in spring and 1 day in summer. CRASC (2016) reported only net downstream counts of 920 eels in 2016.

Eighty eels were recorded in Study 18 in 2015 over 24 weeks of surveys conducted from May 7 to October 13 downstream of the Project, including the fish ladder. All observations occurred between June 17 and September 28. Most were observed in summer with 41.3 percent of the total observed during the normal fish ladder operating season. Eels were observed at four discernible sites: the fish ladder window and surrounding area viewed from the catwalk surrounding the ladder (Site No. 15), an area in the vicinity of the submerged flood gates below four tainter gates (Site No. 10) just east of the powerhouse, a submerged flood gate below one of the hydraulic panels (Site No. 7), and an area of emergent rocks below the stanchion bays (Site Nos. 3 and 4) (Figure 3.6-10).

While no large aggregations of eels were observed at any surveyed location, the fish ladder was the site where eels were most frequently observed with 39 individuals (49 percent of the total), likely as a result of extended fish ladder operations conducted for Study 17. The submerged flood gate sites collectively yielded 36 eel observations (45 percent of the total) (Table 3.6-30).

All of the eels observed at the fish ladder in 2015 were seen swimming by the window and thus appeared to use the fish ladder to move upstream. Behavioral notes of the eels observed at the Vernon flood gate sites indicated that many individuals did not seem to be attempting to migrate upstream at the time of observation and appeared to be taking cover under the overhead lip of these submerged structures. Most eels (66 percent) were estimated to be in the 12 to 18-inch (30-45 cm) size class and another 30 percent were estimated to be in the 6 to 12-inch (15–30 cm) size class. Very few eels were in the estimated 18-inch (>45 cm) or larger size class (Table 3.6-30).



Source: ILP Study 18, *American Eel Upstream Passage Assessment*

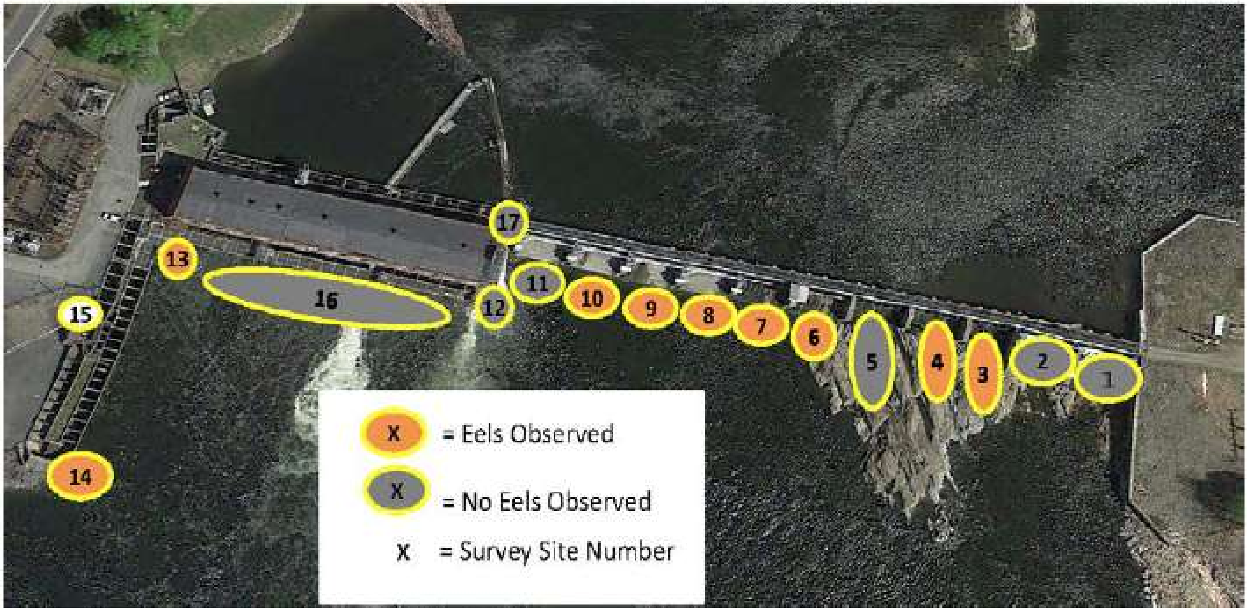
Figure 3.6-10. American Eel systematic survey locations at Vernon, 2015.

Table 3.6-30. Distribution of eel size classes observed by site and major location type at Vernon, 2015.

		Site Type							**Total**
		Fish Ladder	**Flood Gates below Tainter Gates**			**Flood Gate below Hydraulic Panel**	**Rocks below Stanchion Bays**		
Site Number:		**15**	**10**	**9**	**8**	**7**	**4**	**3**	
Size class	6-12 in.	12	2	2	4	1	3	0	24
	12-18 in.	24	3	3	17	4	1	1	53
	>18 in.	3	0	0	0	0	0	0	3
Total		39	5	5	21	5	4	1	80

Source: ILP Study 18, *American Eel Upstream Passage Assessment*

Supplemental surveys in support of Study 18 were conducted in 2016 at Vernon to evaluate eel presence below the dam in the absence of normal fish ladder operations (i.e., after July 18, 2016). Surveys were conducted from July 28 to October 20 using the same general methodology used in 2015. During weekly visits over 13 weeks, 70 eels were observed (Figure 3.6-11 and Table 3.6-31).



Source: ILP Study 18, *American Eel Upstream Passage Assessment Report Supplement*

Figure 3.6-11. American Eel systematic survey locations at Vernon, 2016.

These results may represent an overestimate because eels were not marked as they were in 2015 for studies at all three Projects to determine whether eels observed at one Project migrated upstream to the next Project), thus some eels could have been counted more than once during 2016. Length of eels was estimated by visual observation. Most eels (66 percent) were estimated as greater than 8 inches (20 cm) in length and another 33 percent were estimated to be in the 4 to 8-inch (10–20 cm) size class (Table 3.6-31). A majority of all eel observations occurred in two weekly surveys on August 18 and August 25 (51.4 percent of the total) and cumulative observations reached 90 percent by September 9. Overall, Site Nos. 3 and 10 had the most frequent observations, 27 percent and 24 percent, respectively, and had more observations than the area near the fish ladder entrance and in the vicinity of the fish ladder at Site Nos. 13 and 14 (15.7 percent) (Figure 3.6-11 and Table 3.6-31). The fish ladder itself (Site No. 15) was dewatered on July 18, 2016 after the shad specific fish passage season.

Table 3.6-31. Distribution of eel size classes observed by site and major location type at Vernon, 2016.

		Site Type								Total
		Fish Ladder Entrance and Vicinity	Flood Gates below Tainter Gates					Rocks Below Stanchion Bays		
Site number:		13, 14	12	11	10	9	8	4	3	
Size class	<10 cm (<4 in.)	0	0	0	0	0	0	0	1	1[a]
	10–20 cm (4–8 in.)	1	1	0	7	1	1	2	10	23
	>20 cm (8 in.)	10	3	8	10	4	1	2	8	46
Total		11	4	8	17	5	2	4	19	70

Source: ILP Study 18, *American Eel Upstream Passage Assessment, Report Supplement*

a. Due to flowing water and water depth, eel size may have been misjudged and is possible eel belongs in 10–20 cm size class.

The 2016 study also included fabrication and installation of a temporary eel ramp and trap near the fish ladder entrance. The system was designed in consultation with the aquatics working group, which visited the site to determine ramp location, angle of incline, and needed water flows. The ramp and collection tank are shown in Figure 3.6-16. The ramp began operation on September 6 and a single eel, which was 10.9 inches (27.6 cm) in length, was collected on September 23.

Eel surveys were continued at Vernon in 2017 to further evaluate eel presence below the dam both during and after fish ladder operations. In 2017 the fish ladder was operated from May 1 through August 7. Eel surveys were conducted from June 1 to November 6 using the same general methodology used in 2015 and 2016. During weekly visits over 23 weeks, 148 eels were observed (Figure 3.6-12 and Table 3.6-32).

Source: ILP Study 18 – American Eel Upstream Passage Assessment Supplement #2 to Study Report.

Figure 3.6-12. Vernon nighttime visual survey sites, 2017.

While the majority of eels observed during surveys were in the 6 to 12-inch class (15-30 cm), in the fish ladder (Site No. 15), the majority (54.9 percent) were identified as 12 – 18 inches (30-45 cm; Table 3.6-32). Peak eel observations occurred between mid-June and mid-July (71 percent of the total) with the greatest number of eels observed in a single survey on June 28 (n=22). Eels were observed at 11 of the 15 survey sites with the greatest number of eels counted at Site No. 15 (55.4 percent), Site No. 8 (14 percent) and Site No. 9 (8.1 percent) (Table 3.6-32).

Table 3.6-32. Length classified counts of eels observed by survey site in nighttime visual surveys, 2017.

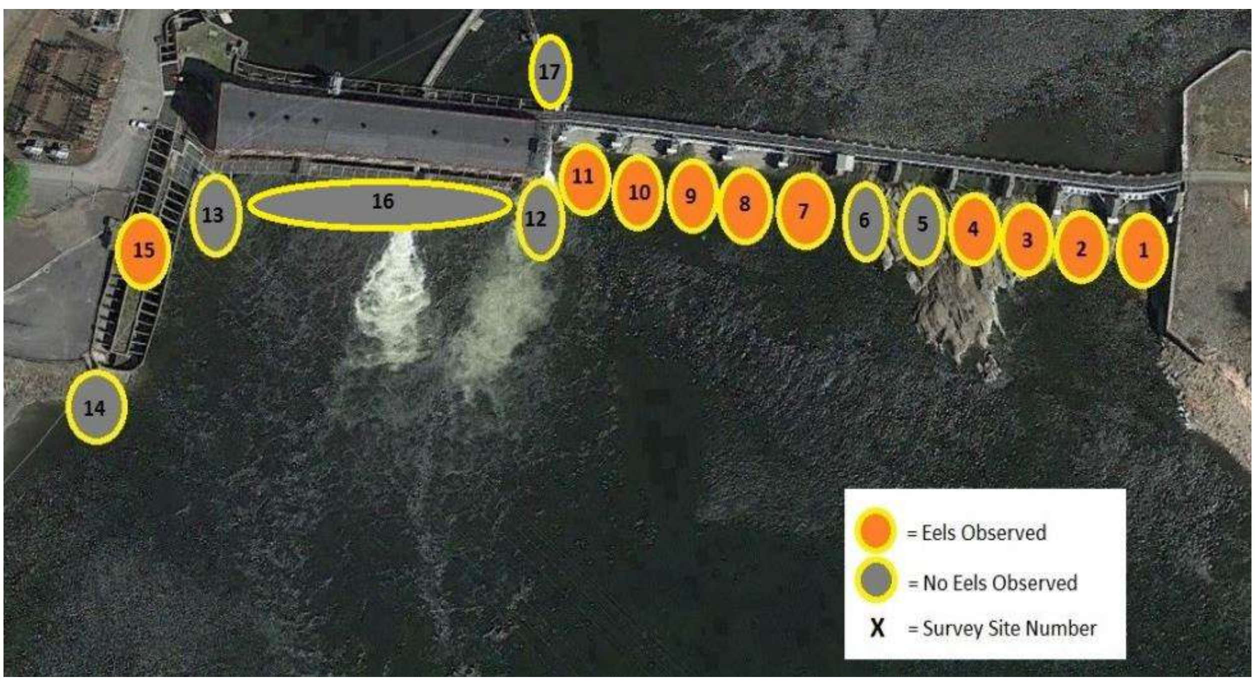
Site number:		**Fishway**	**Flood Gates Below Tainter Gates & Hydraulic Panels**					**Rocks BelowTainter Gates & Stanchion Bays**				**Total**
		15	**11**	**10**	**9**	**8**	**7**	**4**	**3**	**2**	**1**	
Size Class (in.)	< 6	0	0	0	0	0	0	0	0	0	1	1
	6 - 12	33	2	8	10	19	3	7	3	5	1	91
	12 - 18	45	0	1	2	2	0	0	2	0	0	52
	> 18	4	0	0	0	0	0	0	0	0	0	4
Total		**82**	**47**					**19**				**148**

Source: ILP Study 18 – American Eel Upstream Passage Assessment Supplement #2 to Study Report.

The interim eel trap was operated continuously from June 1 to November 8, 2017, with 123 eels collected between July 5 and September 19. Peak collections occurred over a 3-day period (August 21-23) where 60 percent of the annual total was captured. This period corresponds with the peak observation period in the 2015 study. Eels collected from the ramp trap ranged from 6.5 to 14.2 inches (17-36 cm) and averaged 9.6 inches (24 cm).

During the 2017 upstream shad passage fish ladder operating period, 581 eels were counted using the Vernon fishway through VANR's Vernon fish passage monitoring. The fishway was dewatered on August 7, 2017. Observations made during the dewatering identified about 120 eels using or residing in the facility that then passed downstream during dewatering. The Vernon temporary eel ramp trap, operated during late spring, summer, and fall, collected 123 eels. Most of those were collected a couple of weeks after dewatering of the fishway, and it is possible that eels that abandoned the fishway when it was dewatered increased the abundance of eels available to collection by the ramp trap.

Eel surveys at Vernon in 2018 were conducted from June 7 to November 1 using the same general methodology as used in previous years except that the fish ladder was operated through October 15, the interim trap was not operated, and additional survey locations were added to search for eels in the tailrace (Site No. 16) and upstream of the upper trash sluice gate (Site No. 17) (Figure 3.6-13).



Source: ILP Study 18 – American Eel Upstream Passage Assessment Supplement #3 to Study Report.

Figure 3.6-13. Vernon nighttime visual survey sites, 2018.

During weekly visits over 22 weeks, 221 eels were observed (Figure 3.6-13 and Table 3.6-33).Eels classified in the 6-12 inch and 12-18 inch size group were the most abundant during the 2018 visual nighttime surveys, representing 48 percent and 46 percent of the total number observed, respectively (Table 3.6-33). The majority of all eel observations occurred in June and July (79 percent of the total) with the greatest number of eels observed in a single survey (n = 42) on June 13. Eels were observed at 11 of the 17 survey sites. Overall, the greatest number of eels were observed at Site No. 15 within the ladder (61.1 percent of total), Site No. 2 (7.2 percent of total), Site No. 3 (7.2 percent of total), and Site No. 8 (6.8 percent of total) (Table 3.6-33).

Table 3.6-33. Length classified counts of eels observed by survey site during nighttime visual surveys, 2018.

		Fishway	Flood Gates Below Tainter Gates & Hydraulic Panels					Rocks Below Taintor & Stanchion Bays				Total
Site number:		**15**	**11**	**10**	**9**	**8**	**7**	**4**	**3**	**2**	**1**	
Size Class (in.)	< 6	2	0	0	1	0	0	0	0	2	3	8
	6 - 12	57	0	2	5	6	2	4	15	14	1	106
	12 -18	71	1	6	5	9	9	0	1	0	0	102
	> 18	5	0	0	0	0	0	0	0	0	0	5
Total		**135**	**46**					**40**				**221**

Source: ILP Study 18 – American Eel Upstream Passage Assessment Supplement #3 to Study Report.

As observed during the 2015-2017 visual eel surveys, the fishway appeared to be the dominant aggregation point during 2018 (61 percent of all observations). In-ladder observations during 2018 were primarily from the visitor's viewing window, located at a large turn-pool in the lower section of the fish ladder, or the counting room window located just downstream from where the fishway transitions to a vertical slot configuration. Observations of juvenile eels from the counting room window indicated they usually appeared to be traveling upstream at the bottom of the water column and "falling back" or traveling downstream through the mid-water portion of the water column. This behavioral observation coupled with the negative net count of juvenile eels reported for the Vernon fishway by VANR for 2018 suggests that the SalmonSoft monitoring equipment is not accurately enumerating both upstream and downstream passage.

Several modifications to the upstream fish ladder at Vernon were made both prior to and during the 2018 American Eel upstream passage season with the goals of improving the accuracy of counting eels via the fish passage video monitoring system and improving the potential for eels to ascend the upper fish ladder to exit upstream (Figure 3.6-14). These modifications were made to the downstream entrance of the Regulation Pool, the floor grates at the counting window, the upstream entrance to the Regulation Pool, the Diffuser, and the Exit Weir (Figure

3.6-14). On October 15, when the fishway was dewatered, a negative net count of 6,251 eels was estimated using the Vernon fishway by the VANR[39].

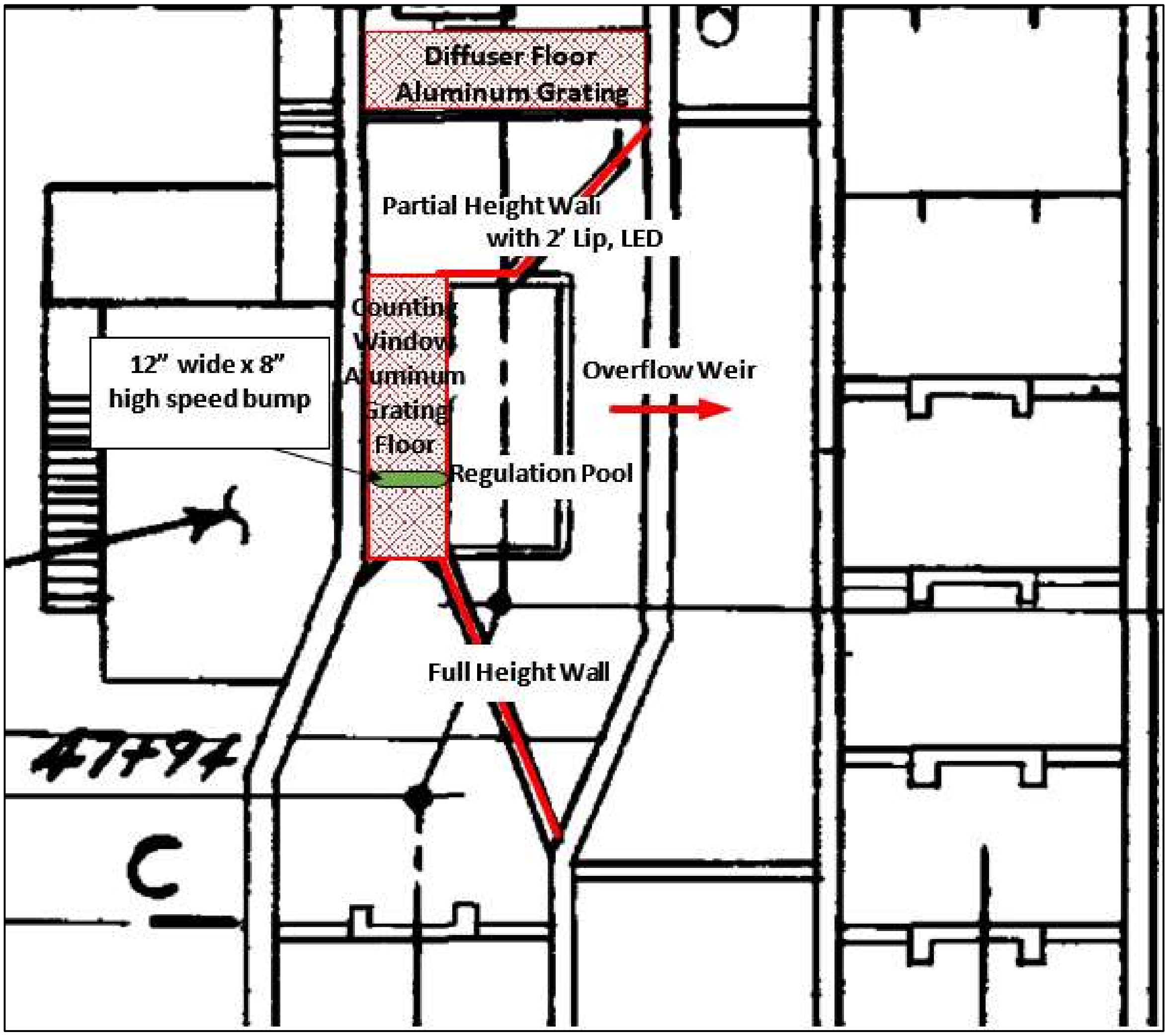


Figure 3.6-14. Overview of modifications made to fish ladder in the area of the counting window.

The results of Study 18 and supplemental surveys from 2015 through 2018 as well as other Connecticut River studies (Yoder et al., 2009) indicate that a small number of eels may attempt to migrate upstream past Vernon. In the absence of the release in 2015 of nearly 6,000 collected eels upstream of Turners Falls dam (Kleinschmidt and Gomez and Sullivan, 2016b), substantial numbers of eels do not appear to use the Vernon fish ladder; however, it can provide an upstream passage route.

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[39] Source: Personal communication – Lael Will (Vermont Agency of Natural Resources). Email dated December 17, 2018.

In 2019, an evaluation of upstream passage of juvenile eels through the Vernon fishway was conducted under normal shad passage flows (64 cfs). A series of seven PIT detection locations were distributed from the lower leg of the Vernon fishway to the fishway exit weir (Figure 3.6-15). One hundred and sixty-one eels had PIT tags injected into the body cavity and were released in four events between July 29 and September 5. The objectives of the 2019 PIT evaluation were as follows:

- Evaluation of the rate and upstream magnitude of travel through the fishway;
- Inform on the number of attempts for an individual eel to pass through the fishway; and
- Identify any particular areas or reaches within the fishway which may provide conditions problematic to continued upstream movement.

One hundred and twenty-six PIT tagged eels demonstrated upstream movement within the fish ladder. These individuals made a total of 188 unique ascent events within all or a portion of the fish ladder during the 2019 study period. A total of seven tagged eels reached the uppermost PIT detection location (Station G). The time of travel from the release location to the upper most reader for those seven individuals ranged from 33 to 1,176 hours with a median ascension rate of around 605 hours (Table 3.6-34).

Table 3.6-34. Minimum, maximum, 25th, 50th, and 75th percentiles of occurrence for movement rate (feet per hour) of PIT tagged juvenile eels from the release location to upstream detection locations within the Vernon fishway (by release and for all eels).

Eel Origin	Parameter (hours)						
	Upstream Location	Min	Max	P25	Median	P75	n
Holyoke and Vernon	Station B	0.1	547.5	0.3	0.5	1.1	107
	Station C	0.5	1131.5	2.2	4.4	23.7	79
	Station D	1.3	1133.1	7.6	23.0	57.4	82
	Station E	4.2	1128.6	24.2	45.5	138.8	70
	Station F	32.8	1184.5	116.7	145.0	1134.1	9
	Station G	33.4	1184.8	116.3	604.5	1175.7	7

The average number of ascent events was 1.5 per individual and ranged from 1 up to a total of 12 events. The majority of ascent events terminated with a final detection just downstream of the counting window (i.e., Station D) or just upstream of the counting window (i.e., Station E). Prior to the study it was assumed that ascent events which did not result in successful upstream passage would be characterized by a series of detections at PIT stations in descending order as an individual eel exited the fishway structure (e.g., Station D, Station C, Station B and finally Station A). However, based on observations of flow patterns within and out of the fishway as well as review of the time-stamped series of stationary reader detections for the full set of PIT tagged eels released within the fishway, it is suspected that a high proportion of ascent attempts ended with departure from the ladder via the regulating pool overflow weir. These ascent attempts included a final detection at either Station D or Station E prior to either no additional detections for the duration of the study (including during dewatering and manual search at completion of the monitoring period) or subsequent detections at the downstream extent of the array (i.e., Station A, B) following a period of time. This study identified outflow from the resting pool overflow weir and reduced passage through the vertical slot section of the fishway as potential issues associated with juvenile eel passage through the Vernon fishway under the operating conditions run during the upstream shad passage season.

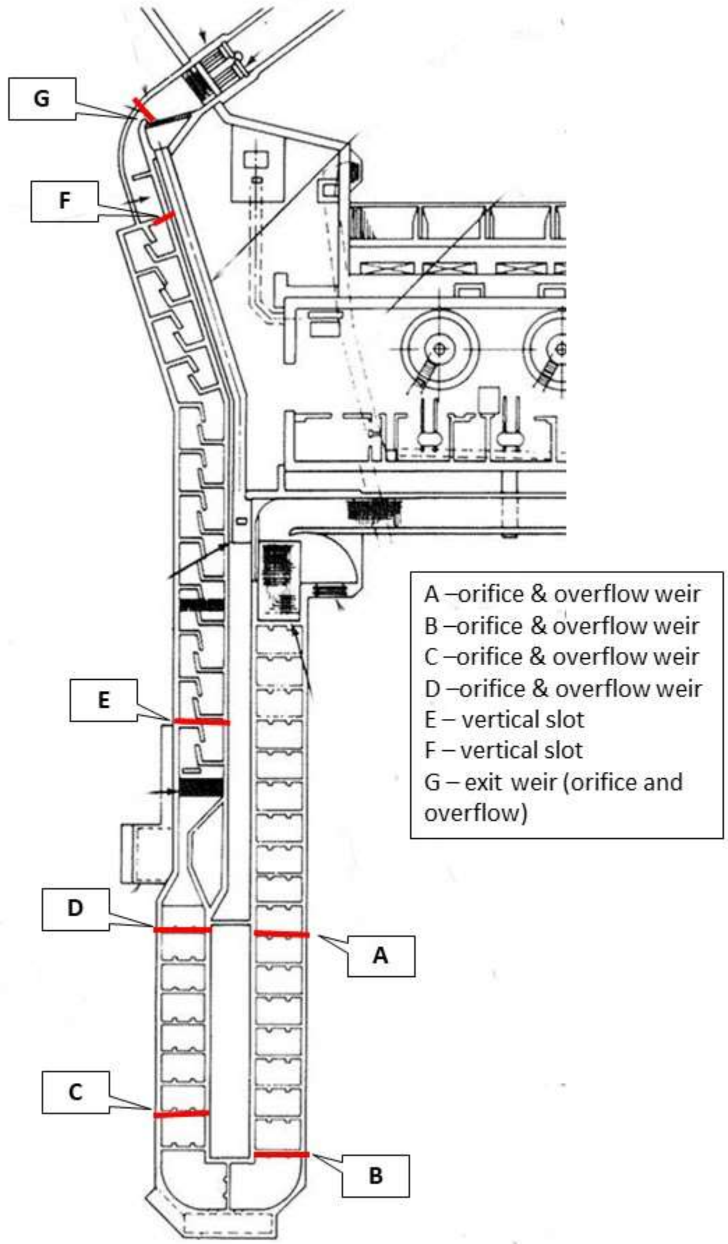
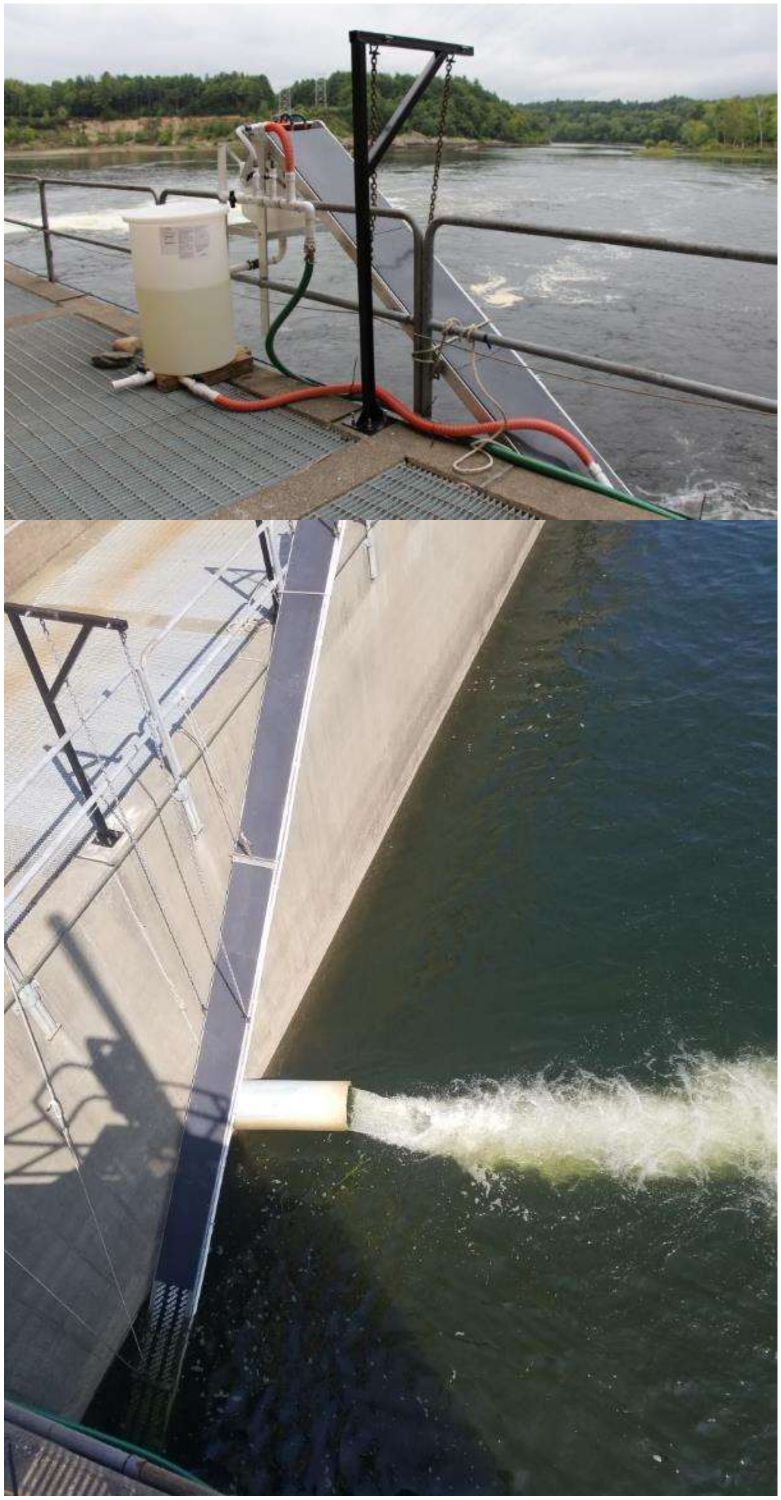


Figure 3.6-15. PIT antenna locations for the evaluation of upstream passage effectiveness of juvenile American eels in the Vernon fishway, 2019.



Source: ILP Study 18, *American Eel Upstream Passage Assessment, Report Supplement*

Figure 3.6-16. Temporary eel trap and ramp, Vernon, 2016.

Sea Lamprey

In Study 17, Sea Lamprey were recorded from May 13 through July 18, 2015 (see Table 3.6-29 above) with a total net passage of 2,440, which peaked on May 28 and June 1. Cumulatively, 80 percent of the total net passage count was recorded on May 31. Sea Lamprey passage was most concentrated during a period of relatively low total river discharge following the spring freshet. However, a reduced rate of passage also occurred during a variety of subsequent discharge scenarios including spill.

In 2016 and similar to passage results at Bellows Falls, Sea Lamprey passage at Vernon was higher than in 2015 (5,539, see Table 3.6-8 above). It is unknown if recent increases in passage are anomalous or suggest an overall increasing trend. Despite the fact that the Vernon fish ladder was not designed specifically to pass Sea Lamprey, it is apparent that this species is able to access and use the ladder. Therefore, the Project has minimal effects on upstream passage of this species and no additional measures are required.

American Shad

American Shad were the dominant migratory species counted for Study 17 in the Vernon fish ladder with an historical record of net passage (n = 39,196) from May 10 through August 22, 2015 (see Table 3.6-29). After June 20, net passage counts showed mostly downstream movements and after July 15, all net passage was downstream, indicating downstream movement of post-spawning adults. Peak upstream passage occurred on May 18 when 10 percent of the total net passage occurred. The 80 percent cumulative passage occurred on May 30. Net passage was 67 percent of FirstLight's Turners Falls Gatehouse fish ladder passage (FWS, 2015), which exceeds the CRASC management goal of 40 to 60 percent (see Section 3.6.1.1, *Fisheries Overview*). Activity was most concentrated during a period of relatively low river discharge following the spring freshet, and while activity within the ladder was recorded during day and night hours (indicating that lack of the attraction pump flow at night does not completely disallow passage), the preponderance of fish movement occurred during the daytime hours (between 8:00 a.m. and 7:00 p.m.).

Study 21 included evaluation of upstream passage of adult American Shad at Vernon. The study included assessment of approach, tailrace residency, attraction to the fish ladder, movement within the fish ladder, and subsequent passage upstream for shad tagged with both radio and PIT tags (dual-tagged) and for PIT-tagged shad (to evaluate movement within the fish ladder). One hundred shad were tagged with PIT tags and 52 of those also received radio tags. Shad were released in Northfield, Massachusetts approximately 9.5 river miles downstream of Vernon dam. An additional 793 PIT or dual-tagged shad were released farther downstream in the Turners Falls impoundment or downstream of Turners Falls dam in a similar study conducted by FirstLight (Kleinschmidt and Gomez and Sullivan, 2016a). The Vernon study area for PIT-tagged shad included only the fishway from the entrance to the exit. In the case of dual-tagged shad, the Vernon study area included the reach from Stebbins Island to the tailrace, the tailrace, fishway, and forebay. Fifty-eight dual-tagged shad were detected in the Vernon Project area and 71 PIT-tagged shad[40] were detected at PIT-monitoring stations at the entrance or within the fish ladder, thus 129 individuals (36 released for Study 21 and 93 released by FirstLight) were considered "available" for the upstream passage study.

The median downstream residence time for dual-tagged shad was just under two days. There was no statistically significant difference between the mean tailrace residence time observed for dual-tagged shad that successfully passed upstream of Vernon versus those that eventually fell back downstream without passage. Numbers of dual-tagged shad in the Vernon tailrace peaked during the second half of May, coinciding with controlled river conditions and an absence of spill. The majority of dual-tagged shad used for calculating duration of residence downstream of Vernon were not present during spill conditions.

Three metrics were calculated to evaluate the performance of the Vernon fish ladder for upstream passage of American Shad: nearfield attraction, entrance efficiency, and internal efficiency. These upstream performance metrics were based on the subset of tagged shad considered "available" determined by movement into the Vernon study area.

The attraction effectiveness of the fish ladder is the proportion of dual-tagged shad detected within the immediate vicinity of the fish ladder. Thirty-four of the 58 available dual-tagged shad (58.6 percent) [41] were detected within 30 ft of the entrance to the fish ladder. This value is independent of whether or not an individual entered the fish ladder and is within the broad range of attraction effectiveness values (11–73 percent) observed at other facilities where similar studies were conducted (e.g., Normandeau, 2008; Normandeau and Gomez and Sullivan, 2012).

Twenty-five dual-tagged shad and 71 PIT-tagged shad were determined to have moved through the fish ladder entrance. Entrance efficiency (the proportion of dual-tagged shad detected within the immediate vicinity of the fish ladder that subsequently entered the ladder) was 73.5 percent. Following initial detection at the fish ladder entrance, tagged shad may turn and depart in a downstream direction, or are recorded at upstream points within the fish ladder prior to either successful passage or termination of the attempt and movement back downstream and out of the fish ladder. Therefore, a single foray could represent a fish that had entered the ladder but then exited the ladder at either the downstream entrance or the upstream exit (i.e., successfully passed into the impoundment). More than one

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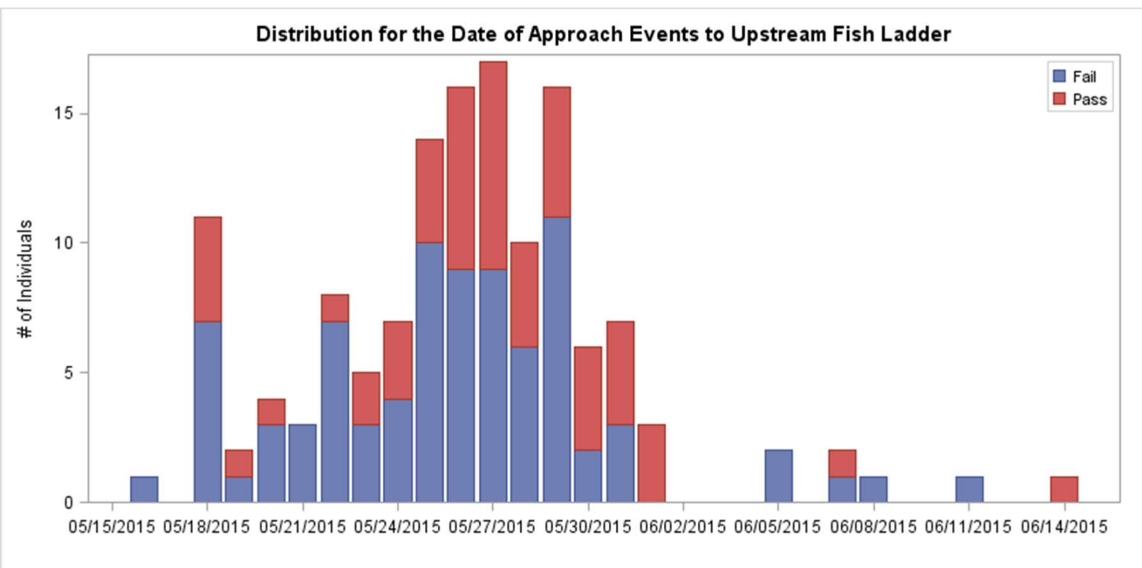
[40] This total includes three individuals originally dual-tagged that had shed their radio-transmitter prior to arrival at Vernon. Information from those fish was used in metrics where PIT-tagged data were used.

[41] The Study 21 final report correctly reports this value in Section 5.3, but incorrectly reports 56.3 percent in the Executive Summary and in Section 6.1, *Discussion and Conclusions*.

foray for a single individual would indicate that the fish exited the ladder at the downstream entrance at least one time prior to exiting the ladder at the downstream entrance or the upstream exit for the final time.

A total of 137 individual forays, by the 96 dual- and PIT-tagged shad detected inside the fish ladder entrance, was identified and the total number of forays for each tagged individual ranged from a high of 10 to a low of 1 (mean = 1.6; median = 1). The average number of forays ending in failure (i.e., fish that did not ascend the fish ladder and enter the impoundment) was 1.8 (range = 1 to 10), and was 1.3 (range = 1 to 3) for forays ending in successful upstream passage. The average duration of foray events for tagged shad that failed to successfully pass upstream was longer than for individuals that successfully passed upstream.

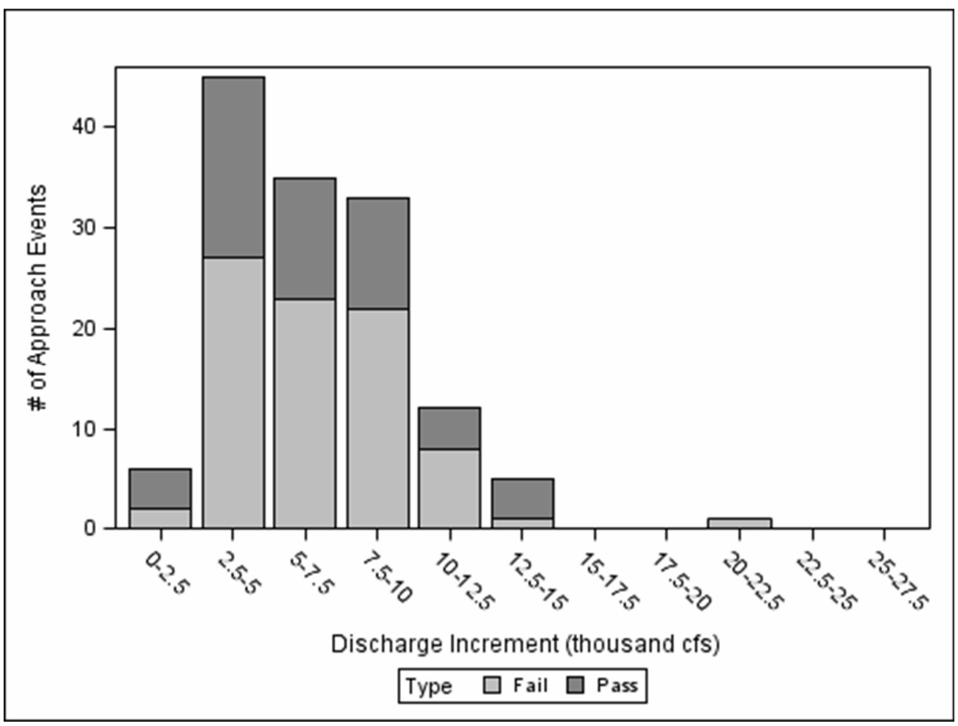
Approach events (and corresponding upstream forays within the fish ladder) were initiated over a range of dates from May 16 to June 14 with over half of those occurring between the dates of May 25 and May 29. The temporal distribution for approach events resulting in successful and unsuccessful foray attempts did not differ greatly from one another. Successful passage events occurred between May 18 and June 14 and unsuccessful passage events occurred between May 16 and June 11. The peak in occurrence for both successful and unsuccessful events occurred during the same May 25-29 time period (Figure 3.6-17). Forays that resulted in eventual passage success were generally initiated when the fish ladder attraction water flow was cycled on during daytime hours to supplement fish ladder flow (94 percent of successful passage events).



Source: ILP Study 21, *American Shad Telemetry Study - Vernon*

Figure 3.6-17. Distribution of the observed initiation dates for fish ladder approach events resulting in successful and unsuccessful American Shad upstream forays at Vernon, 2015.

Overall, the majority of approach events and corresponding fish ladder forays occurred during flow conditions between 2,500-12,500 cfs (Figure 3.6-18). Total discharge ranged from 2,002 to 14,990 cfs (mean = 5,373 cfs) during approach events that resulted in successful upstream forays, and from 2,123 to 22,227 cfs (mean = 6,780 cfs) during approach events that resulted in unsuccessful upstream forays. Average total discharge at the time of approach did not show a significant difference for events resulting in successful or unsuccessful upstream forays. From April 15–July 15 (during normal seasonal upstream passage operations) operating preference is generally given first to Unit No. 10, followed by Unit Nos. 8 or 7, then Unit No. 9, Unit Nos. 5 or 6, and lastly, Unit Nos. 1–4. Operations during 2015 followed these guidelines and discharge from Unit Nos. 1–4 (farthest away from the fish ladder entrance) was lowest during May, which coincided with the lower flow portion of the 2015 study period, as well as the majority of approach events and corresponding upstream forays within the fish ladder. The majority of approach events resulting in successful forays were initiated when units closest to the fish ladder entrance were operating and those farther away (i.e., Unit Nos. 1–4) were offline. When all 10 units were in operation, the percentage of approach events resulting in successful fish ladder foray events was low (two of six events, or 33 percent). When unit operations for the full duration of the study period are considered, all 10 units were in operation for nearly 50 percent of the time.



Source: ILP Study 21, *American Shad Telemetry Study - Vernon*

Figure 3.6-18. Frequency distribution of total Project discharge (cfs) and fish ladder approach events with successful and unsuccessful upstream American Shad forays at Vernon, 2015.

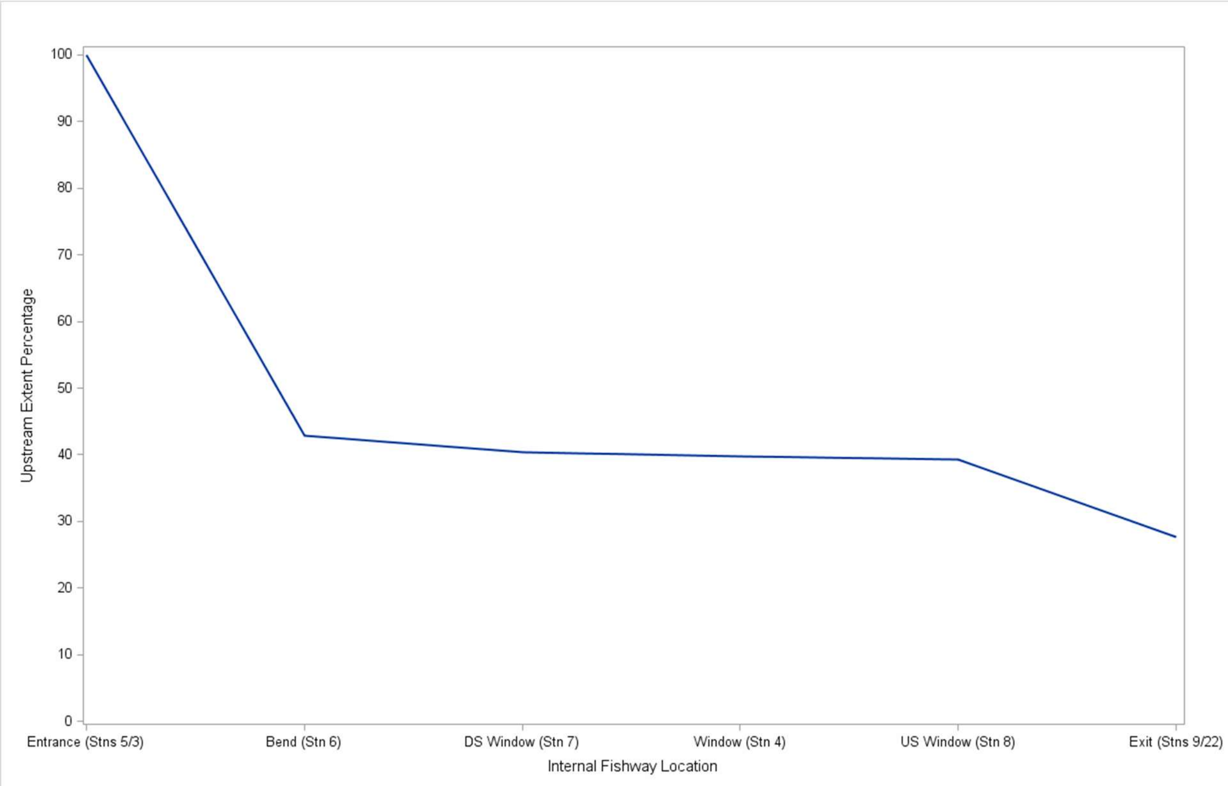
For all forays into the fish ladder, both successful and unsuccessful, residency within the fish ladder from entry to exit (whether upstream to the impoundment or back downstream) ranged in duration from less than 1 minute to 6.4 days. The mean duration of within-fish ladder forays differed significantly for successful passage versus downstream fall back (Wilcoxon; $z = 2.8834$; $p = 0.0039$). The mean duration of unsuccessful forays was longer than for successful forays. (Table 3.6-35).

Table 3.6-35. Within-fish ladder foray duration for dual-tagged shad from time of entry to time of upstream passage or downstream exit from the Vernon fish ladder, 2015.

Foray Type	Sample Size (No. of Forays)	Hours			
		Min	Max	Median	Mean
Successful	53	0.9	99.6	3.4	8.8
Unsuccessful	84	<0.1	152.9	1.1	10.2
All	137	<0.1	152.9	2.4	9.6

Source: ILP Study 21, *American Shad Telemetry Study - Vernon*

Internal efficiency of the fish ladder based on the number of both dual-tagged and PIT-tagged shad that entered the fish ladder and subsequently exited the upstream end and remained upstream of Vernon dam for greater than 48 hours, was 55.2 percent. The fish ladder counting station consists of a regulating pool provided with a constant water flow at a constant water surface elevation. Fish are guided by flow and crowder screens through a narrow opening past the counting window. The counting station is the transition point between the downstream, longer Ice Harbor section of 26 overflow weirs with 12-inch drop between pools, and the upstream, shorter vertical slot section consisting of 25 pools with 6-inch drop between pools. The median time of passage was comparable in the Ice Harbor and vertical slot sections of the fish ladder (approximately 1.1 hours and 1.4 hours, respectively). Figure 3.6-19 presents the percentage of shad ascending the Vernon fish ladder as recorded by stationary monitoring equipment. The majority of unsuccessful forays terminated at points either between the fish ladder entrance and the first bend, or between the counting window and the exit.



Source: ILP Study 21, *American Shad Telemetry Study - Vernon*

Figure 3.6-19. Upstream extent of foray events within the Vernon fish ladder, 2015.

Based on the upstream passage results of Studies 17 and 21, it is apparent that adult American Shad are able to successfully locate and navigate in a reasonably timely manner through the Vernon fish ladder in large numbers and at rates within the range of passage goals set in the CRASC management plan. However, during annual inspections, resource agencies identified potential unfavorable hydraulics for shad passage within the 180 degree turn of the ice harbor section of the ladder. At the request of resource agencies, Great River Hydro constructed suggested fish ladder modifications from resource agency designs to address those concerns. Prior to the 2019 passage season, a partition wall was installed that reduced the area for fish passage to the outer portion of the turn as shown in Figure 3.6-20 and Figure 3.6-21. An evaluation of flow velocities planned for 2020 was necessarily curtailed, to be rescheduled for 2021.

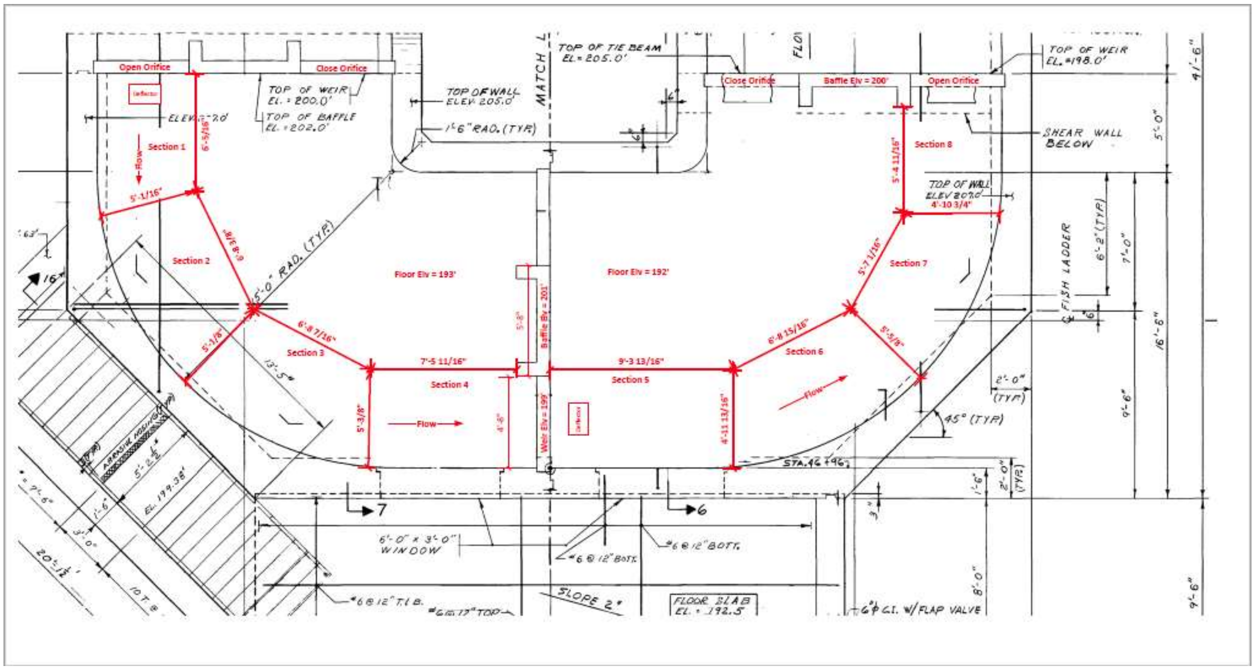


Figure 3.6-20. Design drawing of partition wall installed at the Vernon fish ladder, 2019.

Figure 3.6-21 Partition wall installed at the Vernon fish ladder prior to the 2019 fish passage season.

Great River Hydro Proposal

With the suspension of the Atlantic Salmon restoration efforts, the primary focus on upstream passage at Vernon is for juvenile American Eel, adult American Shad, and adult Sea Lamprey. At Bellows Falls and Wilder, juvenile American Eel and adult Sea Lamprey are the primary focus for upstream passage. Under the current operating conditions, Vernon operates from April 15 (actual date dependent on passage at Holyoke and Turners Falls) to July 15 for American Shad, Sea Lamprey, and Blueback Herring. Bellows Falls operates from May 15 through July 15 for Sea Lamprey while Wilder, designed to operate for Atlantic Salmon May 15 through July 15 and September 15 through November 15, did not run in 2019 and 2020. American Eel passage at Vernon was recently evaluated through an interim eel ramp (2016-2017) and currently through the use of the Vernon dam fish ladder (2018-2019) during the summer and fall.

The effects of the proposed action will have impacts on upstream passage approach at all Project stations for migratory species. By altering operations to increase IEO goals and reducing the frequency and magnitude of discharge fluctuations, the riverine reach downstream of the dams will be more representative of a natural flow regime for migratory species (Section 3.3.2). Species using the margins for protection or to avoid higher velocity flows (e.g., juvenile American Eel) will be less likely to be stranded along low-sloped river margins by fluctuating water levels. The reduction in frequency and magnitude of maximum flows could benefit smaller species and individuals (river herring, juvenile American eel) that might otherwise have difficulty overcoming higher flow velocities, avoiding depletion of energy reserves and potential migratory delays. Higher base flows could create the potential for more competing flows, attracting individuals away from the entrance of passage structures. Operations will also still be subject to seasonal events (low discharge from drought, flooding/spill from extreme storm events) that will impact inflow and generation independent of the proposed action.

Each Project station has an upstream passage structure that operates based on site-specific concerns (e.g., species, fish ladder design, attraction water source). Effects of the proposed action on each Project station’s upstream passage are discussed by station below.

Wilder

Juvenile American Eel and adult Sea Lamprey were both observed using the Wilder fish ladder during Study 17. A total of two Sea Lamprey passed upstream during the designated fish passage season, while juvenile eels passed upstream through the spring, summer and fall, peaking in late June and early July. There is no indication that WSE or discharge from current operations impacted passage. The Wilder fish ladder is required to commence operation with the passage of an adult Atlantic Salmon at Bellows Falls. With the discontinuation of the Atlantic Salmon restoration project on the Connecticut River, the Wilder dam fish ladder did not operate during 2019 or 2020.

As discussed in Section 3.6.2.6, Great River Hydro proposes to operate the Wilder fish ladder from April 1, or as soon as practicable thereafter considering weather and fish ladder maintenance, to May 15 to pass White Sucker and Walleye. In addition, the fish ladder would be operated from May 15 to July 15 to pass Sea Lamprey.

Wilder fish ladder has adjustable weir gates that allow the provision of a constant 20 cfs through the ladder during current operating conditions. Attraction water is added proportionate to generation flows ranging from a minimum of 60 cfs to a high of 320 cfs. When the Wilder fishway is required to operate, proposed operations reducing magnitude and frequency of WSE and discharge fluctuations (Section 3.3.1.1, 3.3.2) will not impact the ability to maintain required operating conditions.

Bellows Falls

Similar to Wilder, adult Sea Lamprey and juvenile American Eel are the primary diadromous species usign the Bellows Falls fish ladder. Sea Lamprey pass during the spring fish passage season (April through mid-July); a total of 970 were observed passing the dam during Study 17. American Eel passage occurred throughout the spring, summer, and fall at low levels. Although Bellows Falls was determined to be the historical upstream migratory limit for American Shad, passage of 44 shad in 2015 was recorded in Study 17. The passage activity for shad was associated with periods of low discharge following the spring freshet. For upstream fish passage at Bellows Falls, the proposed operations should not have any additional adverse impacts.

When the Connecticut River Atlantic Salmon restoration program was discontinued, upstream passage at Bellows Falls focused on Sea Lamprey, with the ladder opening when 100 Sea Lamprey passed Vernon. As discussed in Section 3.6.2.6, Great River Hydro proposes to operate the Bellows Falls fish ladder from April 1, or as soon as practicable thereafter considering weather and fish ladder maintenance, to May 15 to pass White Sucker and Walleye. In addition, the fish ladder would be operated from May 15 to July 15 to pass Sea Lamprey.

The fish ladder at Bellows Falls operates with a through-ladder flow of 25 cfs supplied by adjustable weir gates that can be raised and lowered with forbay elevation changes. An attraction water flow of 80 cfs is supplied through an ice/debris sluice. Proposed operations will reduce the magnitude and frequency of WSE fluctuations in the impoundment (Section 3.3.1.1), and generally reduce the magnitude and variation in downstream discharges (Sections 3.3.2). These changes will not impact the ability to maintain the required operating conditions at the Bellows Falls fish ladder.

Vernon

Upstream passage for adult American Shad, juvenile American Eel, and adult Sea Lamprey are the focus during the fish passage season while passage for juvenile

American Eel continued through the summer and fall. Upstream adult American Shad passage occurred almost entirely within the fish passage season (April through July 15) during study 17, Upstream Passage of Riverine Fish Species Assessment. It was determined in Study 21, American Shad Telemetry Study, that passage at Vernon is associated with low discharge following the spring freshet. Despite this, while average total discharge at the time of approach did not significantly impact shad passage success or failure, discharge associated with units closest to the fishway entrance was more important. Adult Sea Lamprey passage, similar to shad, occurred almost entirely within the designated fish passage season and was associated with low discharge following the spring freshet. Juvenile American Eel were observed using the Vernon fish ladder from May through December during Study 17 with peaks occurring during summer. Under the proposed operating conditions by Great River Hydro, reduced frequency and magnitude of WSE changes and discharge fluctuations are not likely to have additional adverse impacts on fish passage for upstream migratory species.

As discussed in Section 3.6.2.6, Great River Hydro proposes to operate the Vernon fish ladder from April 1, or as soon as practicable thereafter considering weather and fish ladder maintenance, to May 15 to pass White Sucker and Walleye. In addition, the fish ladder would be operated from May 15 to July 15 to pass American Shad and Sea Lamprey. Resource agencies have requested that the ladder remain open through November 15 for upstream migrating American eel. As discussed in Section 3.6.2.7, Great River Hydro has been working towards more efficient passage of American Eel at the Vernon ladder; however, continuing to operate for an additional four months will add little value to the resource until passage efficiency and counting methods have improved. At this time, Great River Hydro does not support expanding the ladder operation through November 15, but intends to discuss this within the overall discussions on developing requirements, any additional passage study needs, designs, and implementation plans and schedules for upstream passage improvements for American Eel. Great River Hydro would amend its proposal on fish leader operating season for American Eel if appropriate after completion of those discussions.

The fish ladder at Vernon operates with a through-ladder flow of 64 cfs maintained at a constant level when headwater elevations are low by an additional 'make up water' supplied by the 30-inch pipe located at the attraction water intake. Attraction water to the entrance of the fish ladder (up to 254 cfs) is supplied to provide the required 260 cfs for the fishway. Proposed changes, including the reduction in magnitude and frequency of WSE and discharge fluctuations (Sections 3.3.1.1, 3.3.2) will not impact the ability to maintain the required operating conditions at the Vernon fish ladder.

Great River Hydro, state and federal fishery agencies held consultation meetings throughout 2021 and part of 2022 with the goal of reaching agreement on fish passage enhancements at Vernon, Bellows Falls and Wilder under respective new licenses. On August 2, 2022, an executed Settlement Agreement on Fish Passage between these parties was filed with the Commission. The Settlement Agreement resolves all issues related to the appropriate prescriptions for fish passage at the Projects under the new licenses pursuant to Section 18 of the Federal Power Act ("FPA")1 and the Parties' recommended terms and conditions related to fish passage under Sections 10(a) and 10(j) of the FPA. It specifies a schedule for implementation of passage measures and enhancements as well as pre-construction design and consultation tasks and post-construction effectiveness evaluations. In the August 2, 2022 filing, updated Exhibit D Table D-1's were submitted that reflect the measures and schedule. Section 18 prescriptions as well as reommendations under Sections (10(a) and 10(j) are expected to correspond with those provided in the Settlement Agreement but will not be submitted until the Applications are Ready for Environmental Analysis.

3.6.2.8 Downstream Passage of Migratory Fish

No-action Alternative

The Wilder, Bellows Falls, and Vernon Projects have successfully passed migratory fish downstream since construction of passage facilities in the early 1990s (see Sections 2.1.1.5, 2.1.2.5, and 2.1.3.5, *Existing Environmental Measures*, for each Project). Safe and timely downstream passage through one or more of the Projects is important for adult American Eel and for juvenile and adult American Shad. Three relicensing studies evaluated downstream passage at the Wilder, Bellows Falls, and Vernon Projects for migratory fish species as described below.

Wilder Project—American Eel

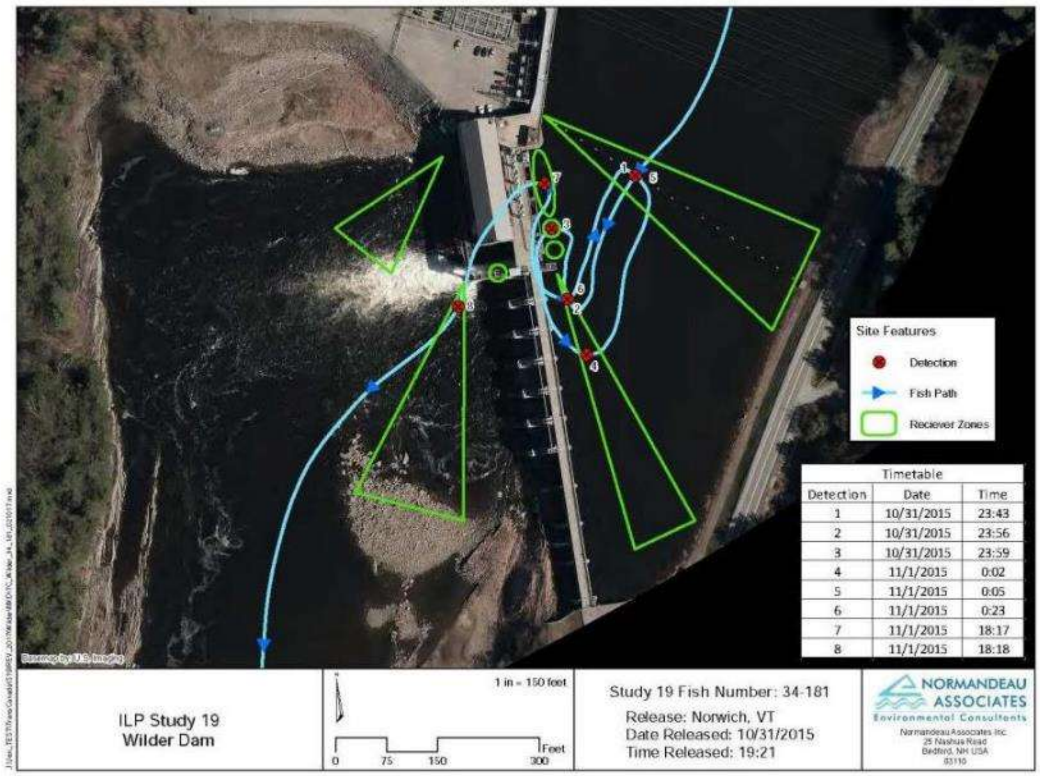
Study 19 was conducted to evaluate movement rates, timing, and proportions of silver American Eels passing downstream via available passage routes at the Project. Eels for the study were imported from Newfoundland, Canada, due to the large number of eels needed to conduct Study 19, and simultaneous American Eel downstream passage studies conducted by FirstLight and Holyoke Gas and Electric Department at the downstream projects, and the inadequate number of silver eels available within the Connecticut River Basin. Imported eels were subjected to pathological testing and quarantine, and all required permits were secured, prior to importation and release into the Project area. Fifty eels were radio-tagged and released approximately 3 miles upstream of the Project in separate groups of 10 between October 27 and November 5, 2015. Radio receivers were installed to detect eels in the forebay and at all available downstream passage routes (spillway, turbine units, trash/ice sluice).

Travel and Residence Time

Forty-eight of the 50 released eels (96 percent) moved downstream from the release point and were detected in the Wilder forebay. Approach duration from the time of release to first detection ranged from approximately 1.7 hours to 8.1 days with a median duration of 25.1 hours. Approximately 38 percent of individuals were detected in the forebay within 8 hours following release, and another 27 percent were detected the following evening, approximately 24 hours after release. Forebay residency time ranged from less than 6 minutes to 16.7 days, with a median of about 12 minutes. Forebay residency times for the 47 eels that subsequently entered a passage route (including 2 eels that entered Unit No. 3 but did not ultimately pass) ranged from less than 6 minutes to 1.6 days, with the majority (79 percent) passing in 4 or fewer hours after initial detection. There were no statistically significant differences among mean forebay residency times for different passage routes.

Specific criteria to define a forebay residency time that may suggest impacts from the Project on continued downstream success are not available for eels. NMFS has identified a residence time of 24 hours upstream of a hydroelectric project to be detrimental for federally endangered Atlantic Salmon smolts in critical habitat in Maine rivers (NMFS, 2012), although this may not be directly applicable to American Eel. In this study, it was assumed that residence times greater than 8 hours and 24 hours were indications of potential Project impacts associated with wandering or potential searching behavior.

Based on analysis of telemetry data and detections at radio receivers, 2 eels that subsequently passed the Project were present in the forebay for more than 24 hours prior to passage, and both were detected multiple times between the forebay entrance and potential downstream routes. Another 6 eels were present in the forebay area for between 8 and 24 hours prior to passage, and most were detected at multiple potential downstream routes (example shown in Figure 3.6-22). The remaining 37 eels (82.2 percent) that passed the Project did so in less than 8 hours, and 34 of those (75.6 percent of all passed eels) passed in less than 1 hour, regardless of demonstrating potential searching behavior.



Source: ILP Study 19, *American Eel Downstream Passage Assessment*

Figure 3.6-22. Example of eel wandering pattern prior to passage at Wilder, 2015.

Route Selection

A total of 45 eels passed the Project starting on the date after the first release (October 28, 2015); the latest downstream passage event occurred on November 14, 2015. Of the 47 eels that entered a passage route, 45 subsequently passed downstream of the Project. The majority of eels passed during the evening and early night hours of 5:00 p.m. to 10:00 p.m. The remainder of passage events occurred during the early morning.

The majority of eels (33 eels, 73.3 percent) passed via Unit Nos. 1 and 2. Seven individuals (14.9 percent) entered Unit No. 3, and 5 of those (11.1 percent of the 45 passing eels) were later detected in the tailrace. Two individuals (4.4 percent) passed via the trash/ice sluice. Five (11.1 percent) passed via an unknown route (Table 3.6-36). The trash/ice sluice was opened seasonally on November 3, and one of the two eels that passed via that route did so when it was operating. There may have been enough leakage flow (not registered in flow monitoring data) through the trash/ice sluice to allow passage for the other individual.

Table 3.6-36. Eel passage routes at Wilder, 2015.

Passage Route	No.	Percent of All Passed	Percent of All Released
Turbine Units 1 and 2	33	73.3	66.0
Turbine Unit 3	5[a]	11.1	10.0
Trash/ice sluice	2	4.4	4.0
Unknown	5	11.1	10.0
Total passed	**45**	**100.0**	**90.0**
Did not pass	3[a]		6.0
Did not approach	2		4.0
Total released	**50**		**100.0**

Source: ILP Study 19, *American Eel Downstream Passage Assessment*

a. Two eels that entered Unit 3 were not later detected in the tailrace.

Discharge through the units at the time of passage ranged from non-reported to 9,018 cfs (mean = 7,024 cfs) at Unit Nos. 1 and 2 and from 703 to 743 cfs (mean = 718) at Unit No. 3. The average proportion of total Project flow passing via the determined downstream passage route was 81.5 percent for Unit Nos. 1 and 2, 39.6 percent for Unit No. 3, and 20.9 percent for the trash/ice sluice. Individuals did not necessarily pass downstream via the route with the greatest proportion of total Project discharge at that time. However, passage via the downstream route with the greatest proportion of flow at the time of passage occurred 78.6 percent of the time. The trash/ice sluice, a surface oriented flow conduit historically operated to facilitate downstream passage of Atlantic Salmon, was opened briefly on October 27 and then for the rest of the study duration on the afternoon of November 3. During that period, 27 eels (57.4 percent of the 47) entered the forebay, and 2 eels were last detected in the forebay prior to passage near the trash/ice sluice. Both subsequently passed the Project, 1 via the trash/ice sluice and 1 via an unknown route. While the trash/ice sluice was not available as a passage route for more than half of all passage events, 1 eel passed via that route once it was open and there may have been enough leakage flow (not registered in flow monitoring data) through the trash/ice sluice to allow passage for the other individual.

Downstream Detection after Passage

Total Project residence duration for the 45 eels detected passing the Project ranged from 6 minutes to just over 10 days (median = 1.7 hours), and approximately 75 percent of eels arrived and departed the Wilder study area in less than 24 hours. Of the 50 eels released upstream of Wilder, 29 (58 percent) subsequently reached Bellows Falls. Of those, detection information was available for 27 individuals to evaluate transit time between the Wilder tailrace and the monitoring station immediately upstream of the Bellows Falls bypassed reach/power canal area, a distance of approximately 44 river miles. Transit through that reach ranged from 26 hours to 7.1 days (median = 53.5 hours).

Because residence time within the forebay prior to downstream passage was short, most eels did not exhibit potential searching behavior, and 93.8 percent of eels that approached the Project passed; therefore, American Eel are able to locate downstream routes of passage through the Wilder Project, and thus the Project does not hinder the timing of current adult eel emigration. If the Connecticut River American Eel population increase in the futures, the Project would similarly not adversely affect future adult eel emigration.

Total Project Survival Estimate

The final fate of eels that did not approach the Project or that were not later detected downstream of the Project is unknown and cannot be gleaned from any data collected in Study 19. It is possible that undetected eels moved into tributaries and did not migrate; their tags became dislodged; they died either before or after passage and settled on the river bottom; or they were preyed upon by other fish or birds.

As a result, total Project survival based on telemetry data was conservatively estimated at 59.6 percent in Study 23 (report supplement), based on the radio telemetry passage route proportional distribution and estimated route survival rates based on subsequent telemetry detection at Bellows Falls (Table 3.6-37). Applying both the HI-Z tag direct turbine survival estimate and Franke turbine survival estimates (see Section 3.6.2.10, *Effects on Turbine Survival*, below) to the proportion of eels passing via turbines, along with the telemetry-based estimates for non-turbine routes, total Project survival through all passage routes ranges from 44.1 percent to 76.4 percent, with the radio telemetry-based total Project estimate (59.6 percent) being slightly higher than the HI-Z total Project estimate of 56.3 percent, and in the middle of the broader calculated range of the Franke-based total Project estimate (44.1–76.4 percent).

Table 3.6-37. Passage route distribution and associated route-specific survival estimates for adult American Eel at Wilder.

Passage Route	No.	Proportion	Estimated and Predicted Survival Rates (%)		
			HI-Z (48-hour)	Conservative Radio Telemetry, Estimate	Franke Formula (30-inch Fish)[a]
Units 1 and 2	33	.702	62.0	66.7	44.6–90.6
Unit 3	7[b]	.149	NA	28.6	0.0–46.9
Trash/ice sluice	2	.043	NA	50.0	NA
Unknown	5	.106	NA	60.0	NA
Total	**47**	**1.0**		**59.6**	

Source: ILP Study 23, *Fish Impingement, Entrainment, and Survival Study Report Supplement*

a. Calculated at typical full load for Units 1 and 2, and at minimum flow for Unit 3.
b. Includes two eels detected entering Unit No. 3 but not later detected and presumed mortalities.

Bellows Falls Project—American Eel

During Study 19, 50 eels were radio-tagged and released approximately 3 miles upstream of the dam in separate groups of 10 between October 27 and November 5, 2015. An additional 20 eels were released in 2 groups of 10 eels each into the Bellows Falls power canal on October 29 and October 31, to avoid unintentional passage over the dam during periods of spill. Radio receivers were installed to detect eels in the forebay and at all available downstream passage routes through the powerhouse (turbine units, trash/ice sluice), and at the Bellows Falls power canal entrance, dam, and downstream end of the Bellows Falls bypassed reach.

Travel and Residence Time

Forty-nine of the 50 eels released into the Bellows Falls impoundment (98 percent) moved downstream from the release point and were detected in the study area, as well as all 20 eels released into the power canal. In addition, 29 of the 50 eels originally released into the Wilder impoundment (100 percent of those that passed Wilder) were detected within the Bellows Falls study area. Of these 98 individuals in the study area, 96 (98 percent) subsequently passed the Project.

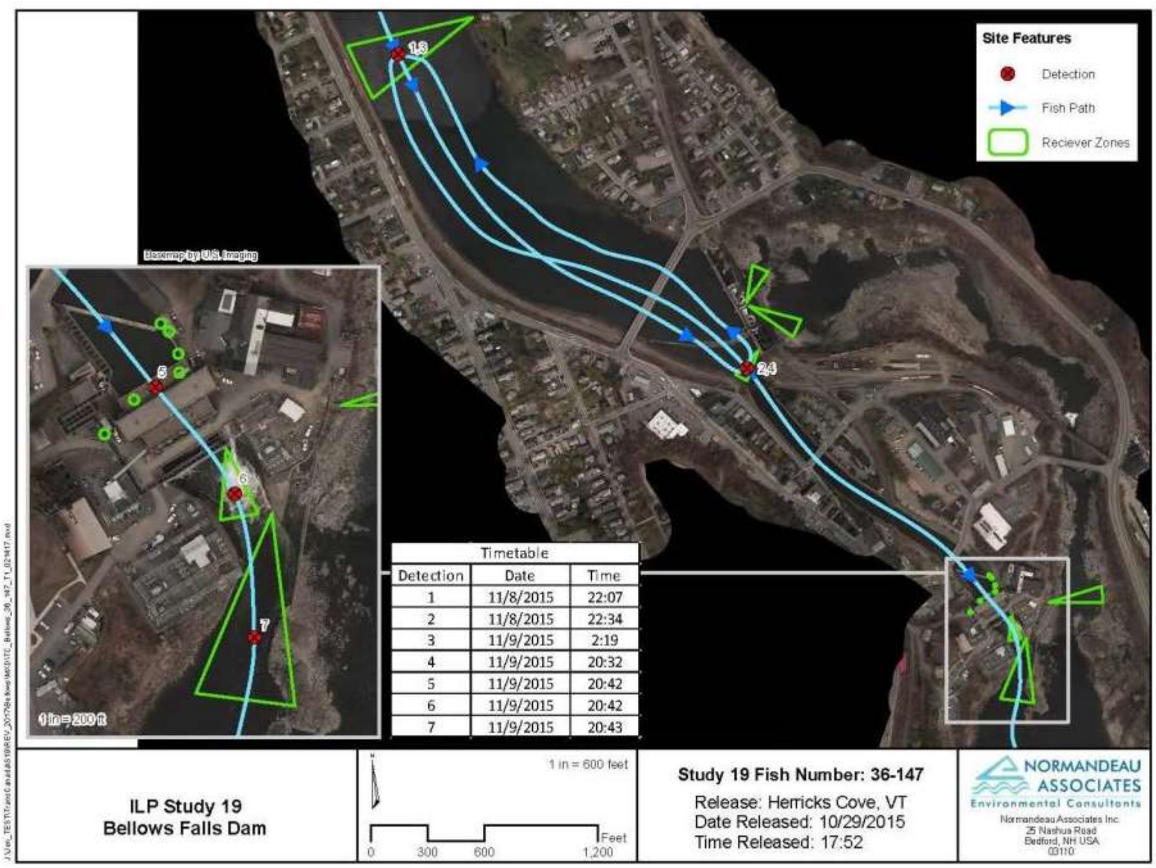
Approach duration for eels released into the Bellows Falls impoundment from the time of release to initial detection at the Pine Street boat launch (located about 0.3-mile upstream of the entrance to the power canal and spill sections on dam) ranged from approximately 36 minutes to 36.1 days with an overall median duration of 16.0 hours. Approximately 50 percent of eels released in the impoundment were present within the study area within 8 hours following release.

For eels that entered the power canal, power canal residency time ranged from 6 minutes to 12.8 days with an overall median of 12 minutes. For the majority of these eels that passed the Project and had a known power canal residency duration (84 percent), the duration of residency in the power canal was less than 3 hours. There was no statistically significant difference between the mean power canal residency time for eels passing via the turbine units or via the trash/ice sluice.

Six eels released into either the Wilder or Bellows Falls impoundments passed via the spillway into the bypassed reach. The duration of time those individuals were present within the bypassed reach following initial detection at the upstream end of the reach ranged from 13.1 hours to 69.7 days with an overall median duration of 50.7 hours. The one individual with residency duration of more than 69 days was still present in the reach at the conclusion of the study and was likely a mortality, and excluding that individual results in a median bypassed reach residency of 46.8 hours.

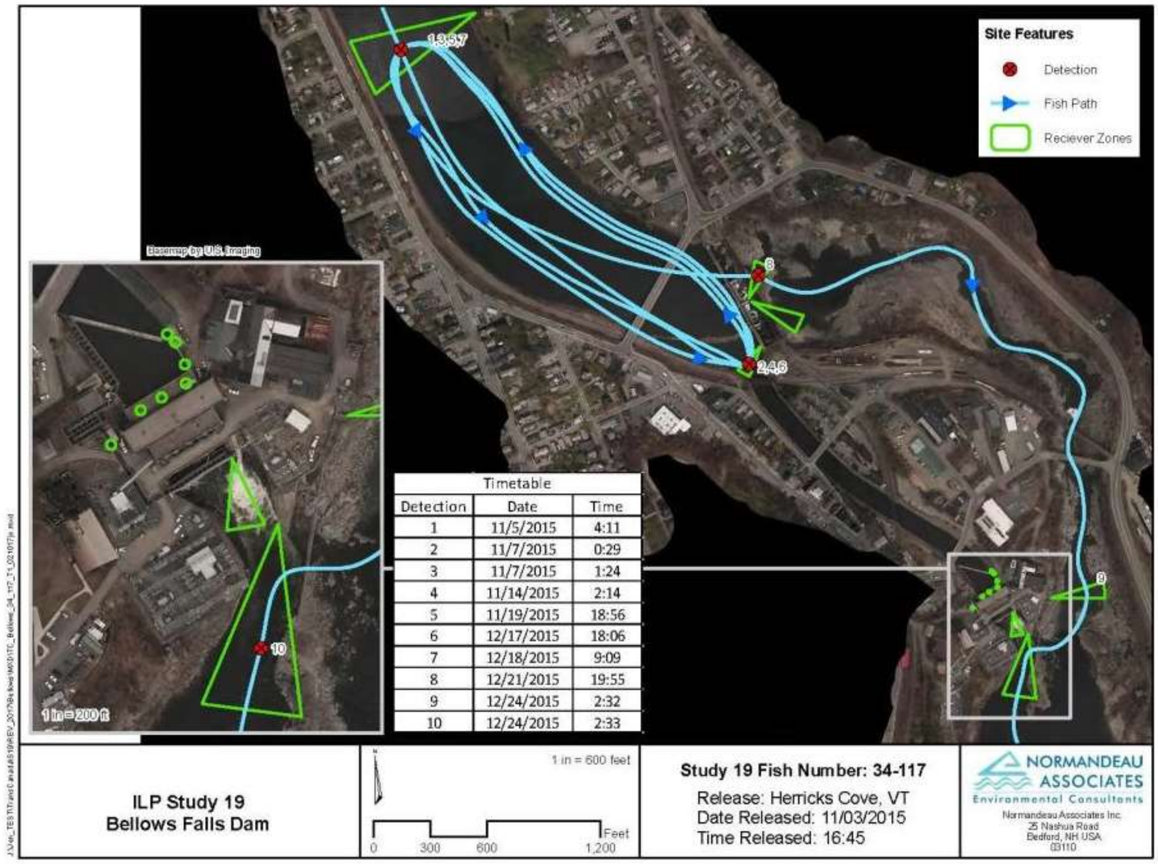
As described above for Wilder, specific criteria to define a forebay residency time that may suggest impacts from the Project on continued downstream success are not available for eels. In this study, it was assumed that residence times greater than 8 hours and 24 hours were indications of potential Project impacts associated with wandering or potential searching behavior.

Based on analysis of telemetry data and detections at radio receivers, 9 eels that subsequently passed via the power canal and powerhouse were present in the forebay for more than 24 hours prior to passage and detected multiple times between the forebay entrance and potential downstream routes. Another 3 eels were present in the forebay area for between 8 and 24 hours prior to passage, and most were detected at multiple potential downstream routes (example shown in Figure 3.6-23). The remaining 78 eels (86.7 percent) of the 90 that passed via the powerhouse did so in less than 8 hours, and 67 of those (74.4 percent of all eels that passed via the powerhouse) passed in less than 1 hour regardless of demonstrating potential searching behavior. Of the 6 eels that passed via the spillway, only 1 (16.7 percent) exhibited potential searching behavior (Figure 3.6-24).



Source: ILP Study 19, *American Eel Downstream Passage Assessment*

Figure 3.6-23. Example of eel wandering pattern prior to passage at Bellows Falls, 2015.



Source: ILP Study 19, *American Eel Downstream Passage Assessment*

Figure 3.6-24. Example of eel wandering pattern prior to passage via the spillway at Bellows Falls, 2015.

Route Selection

A total of 96 eels passed the Project. The majority (79 percent) of eels released into the Bellows Falls impoundment passed the Project within 1 day after the final release (November 5, 2015), with the latest documented passage event occurring on December 21, 2015. Nineteen of the 20 eels released directly into the power canal (95 percent) passed downstream between the initial release date on October 29, 2015 and November 5, 2015. Eels released into the Wilder impoundment passed Bellows Falls between October 30 and November 15, 2015, and downstream passage for those individuals peaked on November 2–3. The majority of eels passed during the evening and early morning hours from 5:00 p.m. to 4:00 a.m. Downstream passage events during the daylight hours were limited in frequency.

The majority of eels (77 eels, 80.2 percent) passed via the turbine units, 13 individuals (13.5) percent passed via the trash/ice sluice and 6 eels (6.3 percent) passed via the spillway into the bypassed reach (Table 3.6-38). The trash/ice sluice was opened seasonally on November 2, and 11 of the 13 eels that passed via that route did so when it was operating. There may have been enough leakage flow (not registered in flow monitoring data) through the trash/ice sluice to allow passage for the 2 eels that passed on other dates. Five of the 6 eels that used the dam spillway did not pass during a spill event and it is suspected that leakage at the dam may be sufficient for emigrating eels to navigate.

Table 3.6-38. Passage routes for all eels approaching the Bellows Falls Project (from Wilder and Bellows Falls release groups), 2015.

Passage Route	No.	Percent of all Passed	Percent of all Released
Turbine Units 1–3	77	80.2	64.2
Trash/ice sluice	13	13.5	10.8
Dam spillway	6	6.3	5.0
Total passed	**96**	**100.0**	**80.0**
Did not pass	2		1.7
Did not approach	22[a]		18.3
Total released	**120**		**100.0**

Source: ILP Study 19, *American Eel Downstream Passage Assessment*

a. 21 eels that passed Wilder, and 1 that passed Bellows Falls did not approach.

Discharge through the turbine units at the time of downstream passage ranged from 1,380 to 11,186 cfs (mean = 8,867 cfs) for all units combined. The average proportion of total Project flow for eels passing was 97.9 percent for Unit Nos. 1-3, 4.3 percent for the dam spillway and 1.4 percent for the trash/ice sluice. Individuals did not necessarily pass downstream via the route with the greatest proportion of total Project discharge at that time. However, passage via the route with the greatest proportion of flow at the time of passage occurred 80.2 percent of the time. The trash/ice sluice, a surface oriented flow conduit historically operated to facilitate downstream passage of Atlantic Salmon, was opened on November 2 for the remainder of the study. Prior to opening, final pre-passage forebay detections (as opposed to final pre-passed detections at the dam) occurred for 42 (45.7 percent) of the 90 eels that passed via the canal and powerhouse. Eleven of the 13 eels that passed via the trash/ice sluice did so when it was operating. While the trash/ice sluice was not available as a passage route for nearly half of all passage events, there may have been enough leakage flow (not registered in flow monitoring data) through the trash/ice sluice to allow passage for the two eels that passed prior to its opening. In total, 7 of the 13 eels (53.8 percent) that passed via the trash/ice sluice did so when monitored trash/ice sluice flows were very low, between zero and 12 cfs.

Downstream Detection after Passage

Valid detection information was available to calculate total Project residency duration for 71 of the 76 eels released into either the Wilder or Bellows Falls impoundment and determined to have passed downstream of Bellows Falls. Total Project residence duration from initial upstream approach detection until final detection at the downstream tailrace or lower bypassed reach receivers ranged from 24 minutes to over 76 days (median = 1.6 hours). Of the eels released into the two Project impoundments, approximately 80 percent arrived and departed the Bellows Falls study area in less than 24 hours. When only eels released directly into the power canal are considered, total Project duration ranged from six minutes to nearly 82 days (median = 3.5 hours). The majority of eels (70 percent) released into the power canal had a total Project residency duration of less than 24 hours.

Of the 96 eels (representing individuals released into Wilder and Bellows Falls impoundments and Bellows Falls power canal) that passed Bellows Falls, 69 (72 percent) subsequently reached the Vernon Project. Of those, detection information was available for 62 individuals to evaluate transit time between the Bellows Falls tailrace and the monitoring station immediately upstream of Vernon (a distance of approximately 31 river miles). Transit through that reach ranged from 16.2 hours to 18.2 days (median = 62.4 hours).

Because residence time within the forebay prior to downstream passage was short, most eels did not exhibit potential searching behavior, and 98 percent of eels that approached the Project passed; therefore, American Eel are able to locate downstream routes of passage through the Bellows Falls Project, and the Project does not hinder the timing of current adult eel emigration. If the Connecticut River American eel population increases in the future, the Project would similarly not adversely affect future adult eel emigration.

Total Project Survival Estimate

The final fate of eels that did not approach the Project or that were not later detected downstream of the Project is unknown and cannot be gleaned from any data collected in Study 19. It is possible that undetected eels moved into tributaries and did not migrate; their tags became dislodged; they died either before or after passage and settled on the river bottom; or they were preyed upon by other fish or birds.

As a result, total Project survival based on telemetry data was conservatively estimated at 75.0 percent in Study 23 (report supplement) based on the radio telemetry passage route proportional distribution and estimated route survival rates based on subsequent telemetry detection at Vernon (Table 3.6-39). Applying both the HI-Z tag direct turbine survival estimate and Franke turbine survival estimates (see Section 3.6.2.10, *Turbine Survival*, below) to the proportion of eels passing via turbines, along with the telemetry-based estimates for non-turbine routes, total Project survival through all passage routes ranges from 57.8 percent to 93.2 percent, with the radio telemetry estimate (75 percent) lower than the HI-Z total Project estimate of 93.2 percent and at the high end of the broader calculated range of the Franke-based total Project estimate (57.8–76.3 percent).

Table 3.6-39. Passage route distribution and associated route-specific survival estimates for adult American Eel at Bellows Falls.

Passage Route	No.	Proportion	Estimated and Predicted Survival Rates (%)		
			HI-Z (48-hour)	Conservative Radio Telemetry, Estimate	Franke Formula (30-inch Fish)[a]
Units 1–3	77	0.802	98.0	75.3	53.9–77.0
Trash/ice sluice	13	0.135	NA	76.9	NA
Spillway	6	0.063	NA	66.7	NA
Unknown	0	0	NA	NA	NA
Total	96	1.0		**75.0**	

Source: ILP Study 23, *Fish Impingement, Entrainment, and Survival Study Report Supplement*

a. Calculated at typical full load for Units 1–3.

Vernon Project—American Eel

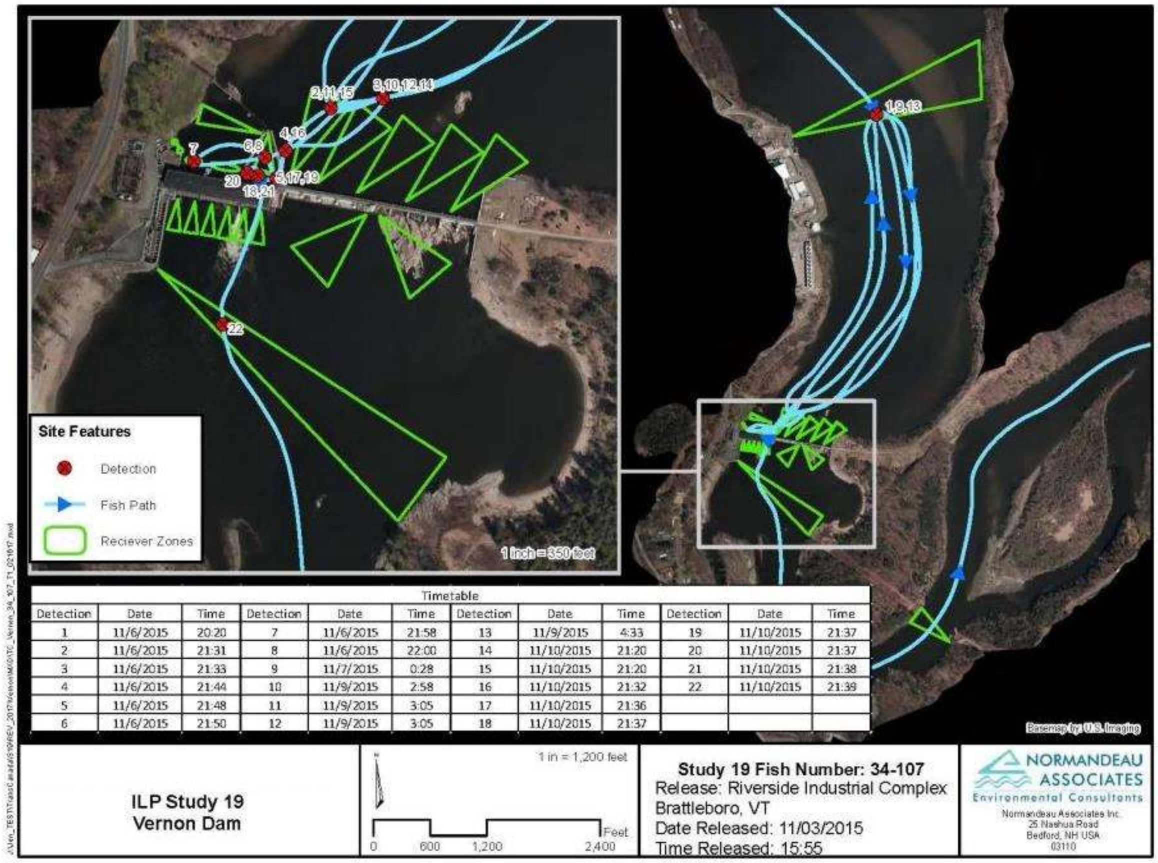
In Study 19 fifty eels were radio-tagged and released approximately 3 miles upstream of the dam in separate groups of 10 between October 27 and November 5, 2015. Radio receivers were installed to detect eels in the forebay and at all available downstream passage routes through the powerhouse (turbine units, trash/ice sluice, fish pipe, fish tube, and fish ladder).

Travel and Residence Time

Forty-four of the 50 eels released into the Vernon impoundment (88 percent) moved downstream from the release point and were detected in the study area. In addition, 45 of the 67 eels released at Bellows Falls that passed Bellows Falls (including all 20 released into the Bellows Falls power canal), and 25 of the 29 eels released at Wilder that passed Bellows Falls were detected in the study area. Of the 114 eels in the Vernon study area, 112 (98 percent) subsequently passed the Project.

Approach duration for American Eels released in the Vernon impoundment from the time of release to initial detection in the forebay ranged from approximately 4.3 hours to 22.2 days, with a median duration of 49.5 hours. Approach from the Vernon impoundment release site to the forebay was slower than observed at the upstream Wilder and Bellows Falls Projects. Approximately 36 percent of eels released in the Vernon impoundment were present within the Vernon study area within 24 hours following release. Forebay residency time ranged from less than 6 minutes to 34.8 days, with a median of 12 minutes. For the majority of eels (89 percent; 102 of the 114 in the study area) that subsequently passed the Project, forebay residency duration was less than 4 hours. When examined among individuals with known passage routes and an adequate sample size (i.e., greater than five individuals) there were no statistically significant differences among the mean forebay residency times for different passage routes.

As described for Wilder, specific criteria to define a forebay residency time that may suggest impacts from the Project on continued downstream success are not available for eels. In this study, it was assumed that residence times greater than 8 hours and 24 hours were indications of potential Project impacts associated with wandering or potential searching behavior. Based on analysis of telemetry data and detections at radio receivers, 5 of the 112 eels that subsequently passed the Project (4.5 percent) were in the forebay for more than 24 hours prior to passage and were detected multiple times between the forebay entrance and potential downstream routes (Figure 3.6-25). Another 7 eels (6.3 percent) were present in the forebay area for between 8 and 24 hours prior to passage, and all but one were detected at multiple potential downstream routes. The remaining 100 eels (89.3 percent) passing the Project did so in less than 8 hours, and 67 of those (74.4 percent of all eels that passed) passed in less than 1 hour, regardless of demonstrating potential searching behavior.



Source: ILP Study 19, *American Eel Downstream Passage Assessment*

Figure 3.6-25. Example of eel wandering pattern prior to passage at Vernon, 2015.

Route Selection

A total of 112 eels passed the Project. The majority (70 percent) of eels released into the Vernon impoundment passed the Project within 1 day after the final release on November 5, 2015, with the latest documented passage event occurring on November 20, 2015. Eels approaching from the Bellows Falls impoundment and power canal release sites passed Vernon between October 29 and December 28, 2015, with most passing during the first half of November. Eels approaching from the Wilder impoundment release site passed Vernon between November 1 and November 21, 2015. The majority of all eels that passed the Project did so during the evening and early morning hours from 5:00 p.m. to 7:00 a.m. Downstream passage events during the daylight hours were limited in frequency.

Analysis of overall eel passage through the Project indicates that 93 (83 percent) of eels passed via the turbine units. Four eels used the fish pipe, 2 used the trash/ice sluice, and 1 each used the fish tube and fish ladder. Eleven eels (9.8 percent) passed via unknown routes. Table 3.6-40 summarizes passage routes for the full set of radio-tagged eels within the Vernon study area.

Table 3.6-40. Eel passage routes at Vernon for all eels released into the Wilder, Bellows Falls or Vernon impoundments, and Bellows Falls power canal, fall 2015.

Passage Route	No.	Percent of all Passed	Percent of all Released
Combined Wilder, Bellows Falls, and Vernon Released Fish			
Turbine intake 5–8	53	47.3	31.2
Turbine intake 9–10	26	23.2	15.3
Turbine intake 1–4	14	12.5	8.2
Fish pipe	4	3.6	2.4
Trash/ice sluice	2	1.8	1.2
Fish tube	1	0.9	0.6
Fish ladder	1	0.9	0.6
Unknown	11	9.8	6.5
Total passed	**112**	**100.0**	**65.9**
Did not pass	2		1.2
Did not approach	56		32.9
Total released	**170**		**100.0**

Source: ILP Study 19, *American Eel Downstream Passage Assessment*

Discharge through the turbine units at the time of passage ranged from non-reported to 4,028 cfs (mean = 1,102 cfs) for Unit Nos. 1-4; 748 to 7,042 cfs (mean = 6,065) for Unit Nos. 5-8; and from 1,280 to 3,261 cfs (mean = 1,871) for Unit Nos. 9-10. The average proportion of total Project flow at the determined downstream passage routes was 59.9 percent for Unit Nos. 5-8; 40.1 percent for Unit Nos. 9-10; 8.7 percent for Unit Nos. 1-4; 7.6 percent for the fish pipe, and less than 5 percent for all other routes. Individuals did not necessarily pass downstream via the route with the greatest proportion of total Project discharge at the time of passage. However, passage via the downstream route with the greatest proportion of flow at the time of passage occurred 61.4 percent of the time. Project operations at the determined time of passage for eels using the trash/ice sluice did not coincide with significant discharge there. It is suspected that there may have been enough leakage flow (not registered in flow monitoring data) to allow passage at those times.

Downstream Detection after Passage

Valid detection information was available to calculate total Project residency duration for all 112 eels determined to have passed the Project. Total Project residence duration from initial forebay detection until final detection at the downstream tailrace receivers ranged from 6 minutes to 81.8 days (median = 1.2 hours). Of eels that passed, approximately 76 percent arrived and departed the Vernon study area in less than 24 hours.

Of the 112 eels (representing individuals released from all upstream release sites) that were determined to have passed downstream of Vernon, detection information was available for 102 individuals to evaluate transit time between the Vernon tailrace and the Stebbins Island monitoring station (a distance of 0.75 river miles). Transit through that reach ranged from less than 6 minutes to 27.4 days. Evaluation of detections farther downstream could not be conducted due to the potential for detection overlap as a result of some redundant radio tag codes used for American Eels released in Study 19 and juvenile American Shad released in FirstLight's juvenile shad downstream passage study, and required exclusion of data from that study (Kleinschmidt et al., 2016) and and from FirstLight's adult eel downstream passage study (Kleinschmidt and Gomez and Sullivan, 2017). Exclusion of those data likely underestimates the number of eels that passed Vernon and subsequently arrived at Turners Falls.

Because residence time within the forebay prior to downstream passage was short, most eels did not exhibits potential searching behavior, and 98.2 percent of eels that approached the Project passed; therefore, American Eel are able to locate downstream routes of passage through the Vernon Project, and the Project does not hinder the timing of current adult eel emigration. If the Connecticut River American eel population increases in the future, the Project would similarly not adversely affect future adult eel emigration.

Total Project Survival Estimate

The final fate of eels that did not approach the Project or that were not later detected downstream of the Project is unknown and cannot be gleaned from any data collected in Study 19. It is possible that undetected eels moved into tributaries and did not migrate; their tags became dislodged; they died either before or after passage and settled on the river bottom; or they were preyed upon by other fish or birds.

As a result, total Project survival based on telemetry data was conservatively estimated at 89.3 percent in Study 23 (report supplement) based on the radio telemetry passage route proportional distribution and estimated route survival rates based on subsequent telemetry detection at Stebbins Island (Table 3.6-41). Applying both the HI-Z tag direct turbine survival estimate and Franke turbine survival estimates (see Section 3.6.2.10, *Turbine Survival*, below) to the proportion of eels passing via turbines, along with the telemetry-based estimates for non-turbine routes, total Project survival through all passage routes ranges from 39.8 percent to 89.3 percent with the radio telemetry estimate higher than the HI-Z total Project estimate of 88.7 percent and higher than the broader calculated range of the Franke-based total Project estimate of 39.8–81.1 percent.

Table 3.6-41. Passage route distribution and associated route-specific survival estimates for adult American Eel at Vernon.

Passage Route	No.	Proportion	Estimated and Predicted Survival Rates (%)		
			HI-Z (48-hour)	Conservative Radio Telemetry, Estimate	Franke Formula (30-inch Fish)[a]
Units 1–4	14	.125	93.5	92.9	24.4–65.1
Units 5–8	53	.473	80.8	84.9	17.4–82.4
Units 9–10	26	.232	97.9	92.3	53.8–76.9
Fish pipe	4	.036	NA	100.0	NA
Fish tube	1	.009	NA	100.0	NA
Trash/ice sluice	2	.018	NA	100.0	NA
Fish ladder	1	.009	NA	100.0	NA
Unknown	11	.098	NA	90.9	NA
Total	**43**	**1.0**		**89.3**	

Source: ILP Study 23, *Fish Impingement, Entrainment, and Survival Study Report Supplement*

a. Calculated at peak efficiency for Units 1-4 and Units 5-8, and at minimum flow for Units 9–10.

Vernon Project—Adult American Shad

Study 21 included evaluation of downstream passage of tagged adult American Shad through the Vernon Project. Sixty-five individuals were potentially available for monitoring, including 54 that were collected at the Vernon fish ladder trapping facility, radio-tagged, and purposely released upstream of Vernon dam on May 17, 24, and 30, 2015. The other 11 shad were fish that had volitionally passed upstream through the fish ladder between May 18 to June 14, and that had retained their radio tags, allowing them to be tracked above Vernon and then later detected during downstream migration at Vernon.

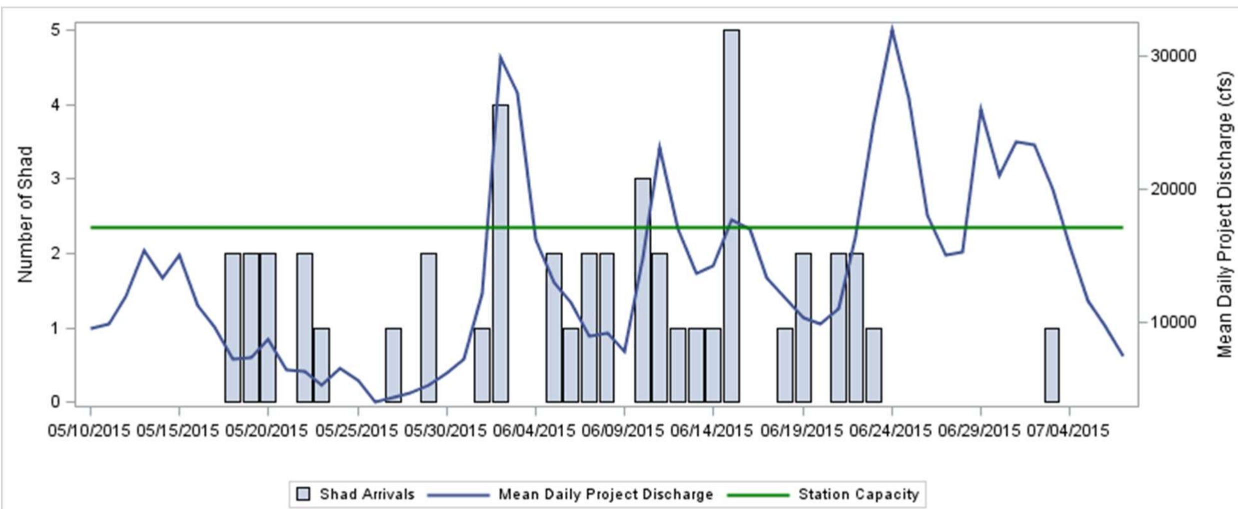
Travel and Residence Time

The duration of time from release or upstream passage to the subsequent "return" detection in the Vernon forebay ranged from 20.9 hours to 39.5 days, with a median time of 12.3 days. Of the 65 tagged shad above Vernon, 59 (91 percent) returned to the Vernon forebay following a period of time upstream of the dam (i.e., in the Vernon impoundment or the Bellows Falls riverine reach). Nine were determined to be mortalities that were removed from the trash racks, and 1 was excluded from the analysis due to conflicting detection data between telemetry data collected by FirstLight and in Study 21. Of the remaining 49 shad, forebay residency time could be determined for 39 individuals.[42] Forebay residency was

[42] Detection information for 3 of the 49 shad was not collected at forebay or spillway monitors, but they were detected on the downstream side of the Project. An additional 7 shad approached Vernon did not successfully pass. They had a known release upstream

defined as the duration of time from initial detection in the forebay following a period of upstream residence until the last detection, indicating downstream passage. Radio-tagged shad returned to the forebay area between May 18 and July 3, 2015. The majority of return events occurred during June with minor peaks in the daily number of downstream migrants coinciding with peaks in the mean daily discharge (Figure 3.6-26).

Forebay residency ranged from several minutes to greater than 21 days with a median of 12 hours. Shad with relatively short forebay residence times (i.e., ≤12 hrs) were generally associated with periods when discharge exceeded maximum station generating capacity (i.e., during spill). When examined by passage route for the 28 shad with a known passage route (see *Route Selection and Passage Efficiency* below), the median forebay residency time was shortest for those passing via the fish pipe and higher for those passing via Unit Nos. 5-8 and Unit Nos. 9-10. River and operational conditions varied over the full duration of forebay residence time for an individual shad.



Source: ILP Study 21, *American Shad Telemetry Study - Vernon*

Figure 3.6-26. Distribution of forebay entry dates for radio-tagged adult American Shad approaching the Vernon dam during their downstream migration relative to mean daily project discharge (cfs), 2015.

Route Selection

Of the 59 radio-tagged shad subsequently located in the Vernon forebay following upstream migration, 7 shad approached the dam but did not pass. As noted above, 9 were found dead on the trash racks, and 1 was excluded from analysis due to data conflicts. The remaining 42 (71.2 percent) passed downstream. A definitive

and one or more detections only on receivers from the upstream forebay area, but no downstream detections in the Vernon or FirstLight study areas.

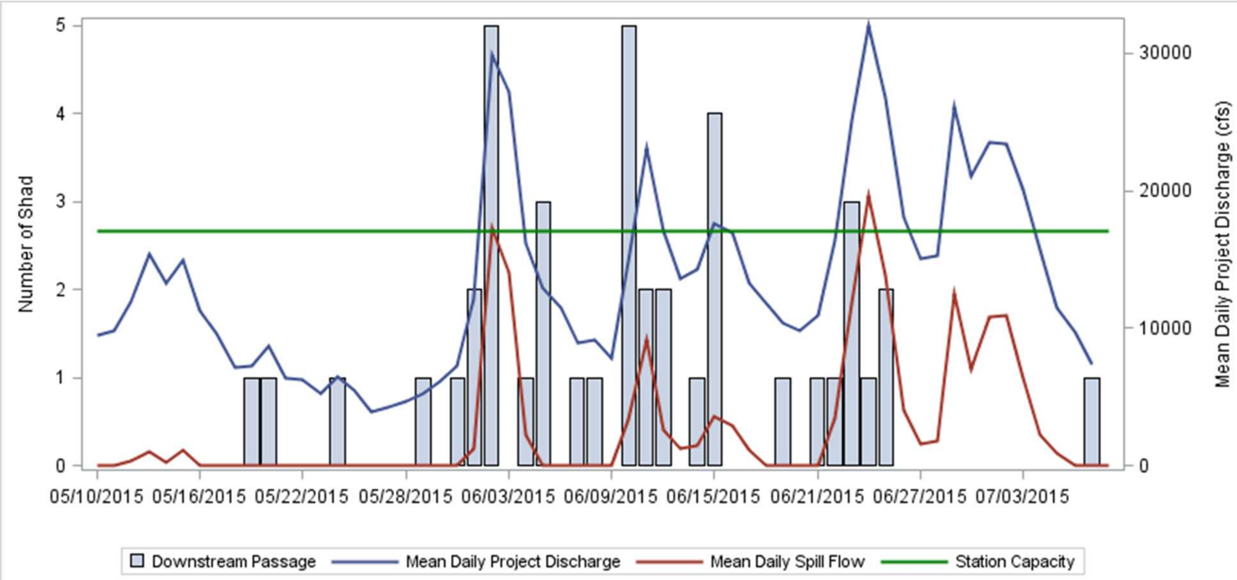
passage route could not be determined for 14 individuals (33 percent) based on telemetry detections. For those with known routes, the majority passed via the spillway (36 percent) and through the fish pipe (19 percent); the remainder used turbine Unit Nos. 5–10. No shad passed via Unit Nos. 1–4, or via the smaller fish tube located along the western shoreline, adjacent to Unit No. 10 (Table 3.6-42).

Table 3.6-42. Final disposition and downstream passage routes of dual-tagged adult American Shad at Vernon dam, 2015.

Final Disposition	Downstream Passage Route	Number	Percent of Number Passed
Did not return from upstream	---	6	---
Approached but did not pass	---	7	---
Mortality on trash racks	---	9	---
Excluded due to data conflicts	---	1	---
Passed downstream of Vernon	Turbine Units 1–4	0	0.0
	Turbine Units 5–8	3	7.1
	Turbine Units 9–10	2	4.8
	Fish tube	0	0.0
	Fish pipe	8	19.0
	Spillway	15	35.7
	Unknown	14	33.3
Subtotal (approaching Vernon)		**59**	**-**
Subtotal (passing Vernon)		**42**	**-**
Total		**65**	**-**

Source: ILP Study 21, *American Shad Telemetry Study - Vernon*

The majority of downstream passage events occurred when all 10 turbine units were in operation which occurred during approximately 48 percent of the study period. The temporal pattern of downstream passage events relative to total discharge and spill discharge is presented in Figure 3.6-27. Peaks in downstream passage events generally coincided with peaks in both total discharge and spill flows. The timing of downstream passage events appeared to be fairly uniform in distribution, with no strong pattern in diel timing when examined by route selection. This is likely a function of a relatively small sample size. Note that 1 of the 15 shad that passed via the spillway did so when spill gates were not open; as did 4 of the 8 shad that passed via the fish pipe, 2 of the 3 shad that passed via Unit Nos. 5–8, both shad that passed via Unit Nos. 9–10, and 5 of the 14 that passed via unknown routes.



Source: ILP Study 21, *American Shad Telemetry Study - Vernon*

Figure 3.6-27. Distribution of downstream passage dates for radio-tagged adult American Shad at Vernon dam relative to mean daily project discharge (cfs) and project spill (cfs), 2015.

Five individuals carrying only PIT tags were also detected passing downstream via the fish pipe during the same period as radio-tagged shad. The total period of travel and residence in the Connecticut River upstream of Vernon (potentially including the forebay, Vernon impoundment, and Bellows Falls riverine reach) ranged between 9 and 34 days for these individuals. PIT-tagged shad were not included in the evaluation of downstream route selection, due to the inability to detect PIT-tagged shad as they returned to the forebay, and the inability to calculate residence within the forebay. With regard to route selection, only the fish pipe had PIT tag coverage. As a result, inclusion of PIT-tagged individuals in the assessment of route selection along with the radio-tagged individuals would bias the overall route distribution, because detection efficiency for PIT- tagged shad at all routes other than the fish pipe was equal to zero (due to lack of coverage).

Downstream Detection after Passage

The route selection component of Study 21 was not intended to evaluate downstream passage survival. The final fate of adult shad that did not approach the Project or that were not later detected downstream of the Project is unknown and cannot be gleaned from any data collected in Study 21. Determination of the degree of downstream progress for adult shad following passage at Vernon is potentially influenced by factors, including injury and mortality associated with dam passage, natural mortality (i.e., predation, post-spawning effects, and body condition), and incidental tag loss.

However, based on data that are available (Study 21 and FirstLight's monitoring associated with a concurrent downstream study [Kleinschmidt and Gomez and Sullivan, 2016a, 2016b]), the downstream progress for 42 adult shad following passage at Vernon is shown by passage route in Table 3.6-43. Stationary telemetry data detections were compiled at Stebbins Island located 0.75 mile downstream of Vernon dam, Northfield Mountain located about 15 miles downstream of Vernon, and at Turners Falls dam located about 22 miles downstream of Vernon. Although comparisons among known passage routes are limited by sample size, individuals passing Vernon via Unit Nos. 9-10 and via the fish pipe showed a higher degree of downstream progress as indicated by detection at Turners Falls, (100 percent, and 75 percent, respectively) than individuals passing via spill (60 percent), or Unit Nos. 5-8 (33.3 percent). Farther downstream from Vernon, detections declined overall (but not for shad that passed via turbine units). Uncertainty about potential Project-related survival increases with distance from Vernon because of potential tag loss and non-project related mortality (i.e., predation, natural post-spawning mortality).

Table 3.6-43. Number of adult American Shad detected by radio telemetry monitoring at Stebbins Island, Northfield Mountain, and Turners Falls following downstream passage at Vernon dam (by passage route), 2015.

Passage Route	No. Passing Vernon	Stebbins Island		Northfield Mountain		Turners Falls	
		No.	Percent Detected	No.	Percent Detected	No.	Percent Detected
Units 5-8	3	1	33.3	1	33.3	1	33.3
Units 9-10	2	2	100.0	2	100.0	2	100.0
Fish Pipe	8	7	87.5	6	75.0	6	75.0
Spill	15	14	93.3	10	66.7	9	60.0
Unknown	14	9	64.3	6	42.9	5	35.7
Total	**42**	**33**	**78.6**	**25**	**59.5**	**23**	**54.8**

Source: ILP Study 21, *American Shad Telemetry Study - Vernon*

Total Project Survival Estimate

Applying the Franke turbine survival estimate ranges (see Section 3.6.2.10, *Turbine Survival*, below) to the proportion of adult shad passing via turbines, along with the telemetry-based estimates for non-turbine routes, total Project survival through all passage routes ranges from 79.3 to 82.2 percent at Stebbins Island, 60.2 to 63.1 percent at Northfield Mountain, and 55.5 to 58.3 percent at Turners Falls, all slightly higher than the corresponding telemetry based estimates which are based on small sample sizes (Table 3.6-44).

Table 3.6-44. Passage route distribution, detections, and survival estimates for adult American Shad at Vernon based on radio telemetry detections at Stebbins Island, Northfield Mountain, and Turners Falls.

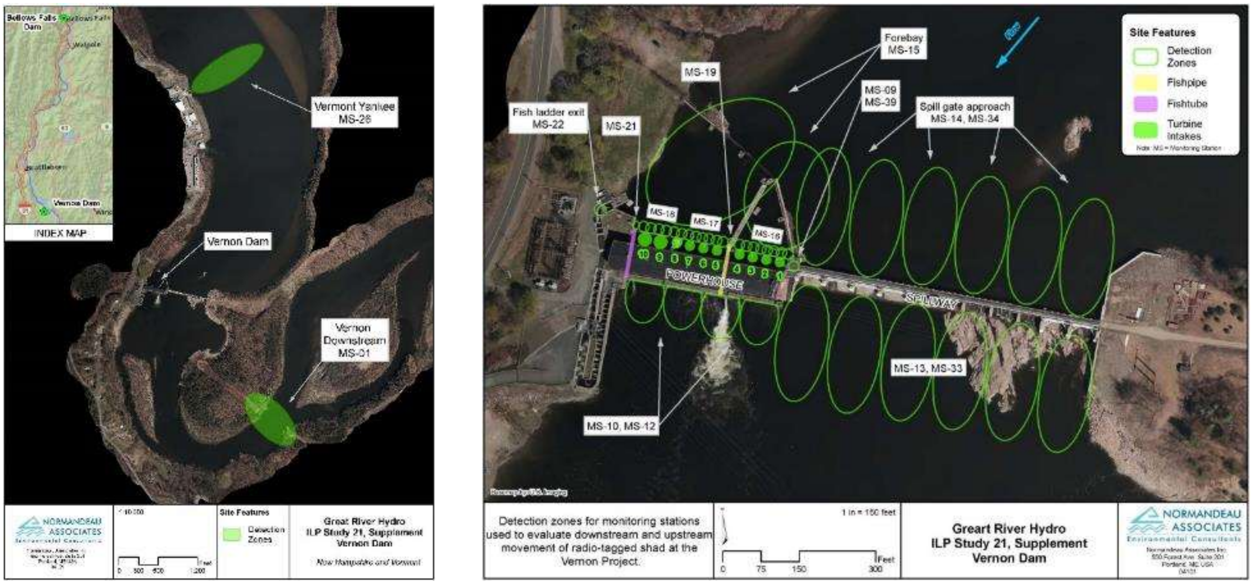
Passage Route	No.	Proportion	Estimated and Predicted Survival Rates						
			Franke Formula (15-inch Fish)[a]	Stebbins Island		Northfield Mountain		Turners Falls	
				No.	Survival Rate (%)	No.	Survival Rate (%)	No.	Survival Rate (%)
Units 1–4	0	0	62.2–82.6	0	NA	0	NA	0	NA
Units 5–8	3	0.071	58.7-91.2	1	33.3	1	33.3	1	33.3
Units 9–10	2	0.048	76.9-88.5	2	100	2	100.0	2	100.0
Fish pipe	8	0.190	NA	7	87.5	6	75.0	6	75.0
Spill	15	0.357	NA	14	93.3	10	66.7	9	60.0
Unknown	14	0.333	NA	9	64.3	6	42.9	5	35.7
Total	**42**	**1.0**	**NA**	**33**	**78.6**	**25**	**59.5**	**23**	**54.8**

Source: ILP Study 23, *Fish Impingement, Entrainment, and Survival Study Report Supplement*

a. Calculated at peak efficiency for Units 1-4 and 5-8, and at minimum flow for Units 9–10.

Because residence time within the Vernon forebay prior to downstream passage was relatively short (median <12 hours), adult American shad are able to locate downstream routes of passage through the Vernon Project, and thus the Project does not adversely affect the timing of the adult shad emigration. However, because the number of tagged shad available to determine a passage route was low in 2015, an additional downstream passage assessment of radio-tagged adult American Shad was conducted in 2017.

The additional downstream passage assessment of radio-tagged adult shad conducted during 2017 (Normandeau 2018b) included a larger study group (N = 99) released above Vernon dam and a larger detection array upstream of the dam to more accurately determine downstream passage routes. The radio-telemetry monitoring array generally reproduced the array used in the 2015 study but was enhanced in an effort to reduce the number of unknown route of passage determinations (Figure 3.6-28). Antenna coverage of the intake bays for turbine units 1-4 and 5-8 was increased from one to two underwater antennas for each ~20-foot (6.1 m) wide intake bay; coverage of the east fish pipe was enhanced by combining a series of four underwater antennas that trailed into the pipe; and coverage of both the impoundment approach to the spill gates (above dam) and spillway (below dam) was increased to two receivers coupled with three aerial antennas each.



Source: ILP Study 21, *American Shad Telemetry Study – Vernon; Supplement to Final Study Report*

Figure 3.6-28. Enhanced downstream passage route coverage for out-migrating adult American Shad at Vernon dam during 2017

Fish used for this study were collected from the Vernon fish ladder. Ninety-nine fish were tagged with a radio transmitter and released at the Old Ferry boat launch in Brattleboro, Vermont, approximately 11.3 miles upstream of Vernon dam. Releases were scheduled to occur during the early, mid, and late portions of the spawning run (Table 3.6-45). Sixty-one of the 99 radio-tagged fish returned to Vernon, and downstream passage was documented for 48 of those. Of the remaining 13, 6 fish returned to points upstream, and did not subsequently return to Vernon, 5 fish became stationary in the Vernon forebay, and 2 fish were last detected in the forebay, but their ultimate fate was unknown.

Table 3.6-45. Release date, number, sex and water temperature for release groups of American Shad used in the addendum to study 21 during the spring and summer, 2017.

Release Group	Shad Run Segment	Collection Location	Release Dates	Number Released	Sex and No. of Tagged Shad		Release Water Temp. °C
1	Early	Vernon Fish Trap	30-May	25	M	19	14.7
					F	6	
2	Mid	Vernon Fish Trap	11-Jun	30	M	21	17.7
					F	9	
3	Late	Vernon Fish Trap	13-Jun	44	M	31	20.2, 20.7
					F	13	
				Total = 99	**M**	**71**	
					F	**28**	

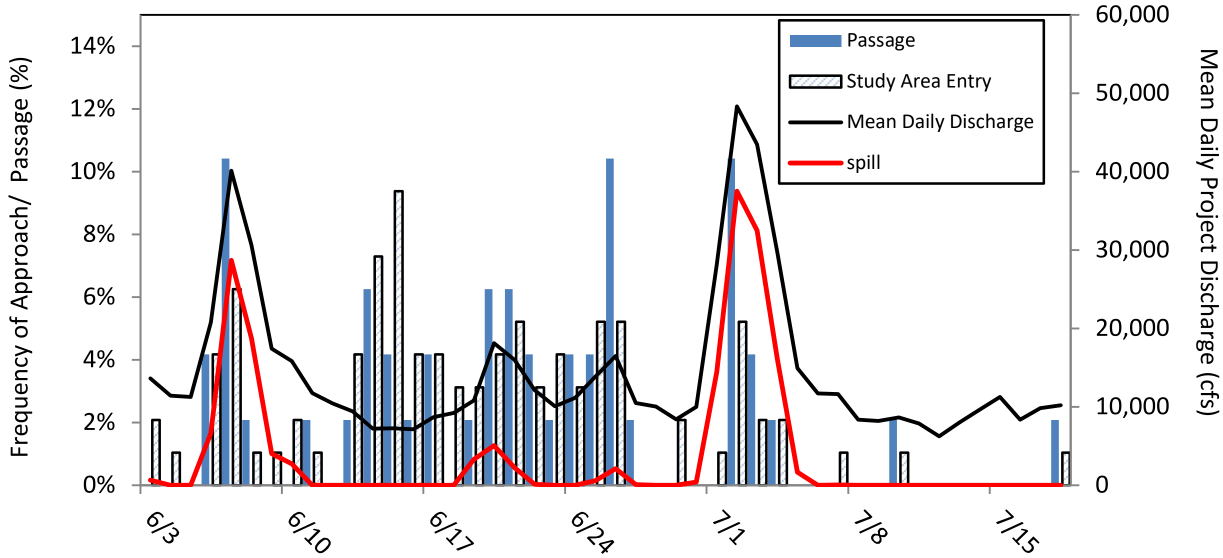
Source: ILP Study 21, *American Shad Telemetry Study – Vernon; Supplement to Final Study Report*

Travel time and residency

The duration of time from release upstream of Vernon to the first detection in the study area ranged from 0.96 days to 37.22 days with a median of 7.80 days. Tagged shad arrived in the study area from June 3 through July 18, 2017, with the majority (86 percent) of return events occurring during June (Figure 3.6-29).

For 48 individuals determined to have passed, forebay residency, defined as the duration from initial detection in the study area until the time of passage, ranged from 0.01 hours to 426.30 hours and had a median of 11.69 hours. However, many fish made more than one approach, as defined by series of detections on the MS-26 receiver following a series of detections in the study area, so residency times are biased. Therefore, adjusted residency times, defined as the sum of durations when a fish was present in the study area, were also calculated. The duration of each residency segment included the time from first detection in the study area to the first subsequent detection upstream at MS-26. A second residency segment began with the first detection in the study area following a sequence of detections upstream and ended at the time of passage or return upstream to MS-26. Adjusted residency durations ranged from 0.01 to 247.27 hours and had a median value of 4.72 hours.

When examined by passage route, the median adjusted residency time was shortest for those passing via spill, units 9-10, and the east fish pipe and longer for those passing via the sluice, units 5-8 and units 1-4. Residency attributed to fish passed by the debris sluice may have been biased, however. Two fish, (58:153 and 58:180) had relatively long detection periods in the station forebay that suggested they may have been dead and retained in a debris pile that tended to aggregate on the debris boom, particularly between periods when the sluice was used to clear it.



Source: ILP Study 21, *American Shad Telemetry Study – Vernon; Supplement to Final Study Report*

Figure 3.6-29. Temporal distribution of study area entry and downstream passage events of radio-tagged American Shad at Vernon with mean daily project discharge (cfs) and spilling flows (cfs), 2017.

Route Selection

Of the 99 radio-tagged shad, 13 were determined not to have passed downstream of the project. Six of the 13 shad returned upstream and did not re-enter the study area. Five became stationary in the forebay while two were last detected in the forebay. This supplementary route of passage assessment was therefore based on the downstream passage of 48 fish (i.e., 78.7 percent of individuals identified as having returned to the study area).

Passage route selection by radio-tagged shad are presented in Table 3.6-46. A definitive passage route could not be determined for one individual (2.1 percent). The largest proportional route of passage was via the east fish pipe (N = 16, 33.3 percent). Thirteen (27.1 percent) passed via the spillway, 3 (6.3 percent) passed via the sluice gate, 5 (10.4 percent) passed via units 5-8, 5 (10.4 percent) passed via units 9-10, 2 (4.2 percent) passed via units 1-4, and 3 (6.3 percent) passed via the fish ladder. No out-migrating shad were determined to have passed via the west fish tube, and none were determined to have been entrained through the former construction bypass.

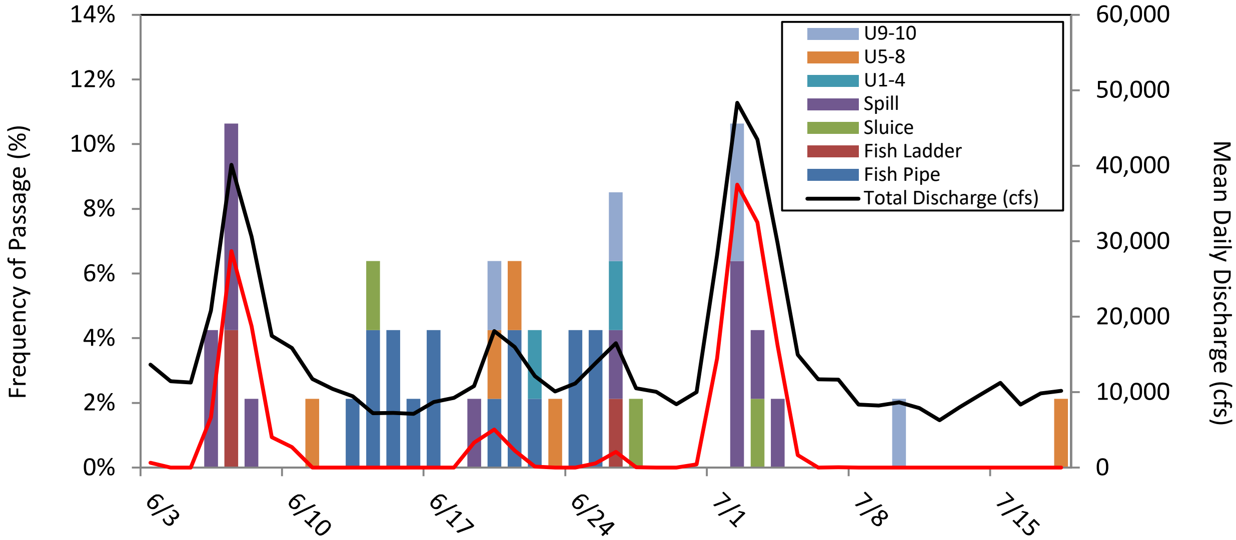
Table 3.6-46. Summary of adult shad tagging and releases, Vernon 2017.

Final Disposition	Downstream Passage Route	Number	% of Number Passed
Did not return from upstream	-	38	-
Approached but did not pass	-	13	-
Returned upstream	-	7	-
Unknown		1	
Stationary in Forebay	-	5	-
Passed downstream of Vernon	Turbine Units 1-4	2	4.2
	Turbine Units 5-8	5	10.4
	Turbine Units 9-10	5	10.4
	Fish tube	0	0.0
	Fish ladder	3	6.3
	Fish pipe	16	33.3
	Sluice gate [a]	3	6.3
	Deep gate	0	0.0
	Spillway	13	27.1
	Former construction bypass	0	0.0
	Unknown	1	2.1
Subtotal (approaching Vernon)		**61**	-
Subtotal (passing Vernon)		**48**	-
Total		**99**	-

Source: ILP Study 21, *American Shad Telemetry Study – Vernon; Supplement to Final Study Report*

a. Two fish, 58:153 and 58:180, may have been dead at time of passage

Twenty three of 48 downstream passage events occurred when all 10 units were in operation and 21 events occurred when at least one spill gate was open. Temporally, downstream passage events indicate passage generally tended to increase with total discharge and spill conditions suggesting elevated flows facilitated passage (Figure 3.6-30). While movements occurred throughout the day, 89 percent occurred during daylight hours.



Source: ILP Study 21, *American Shad Telemetry Study – Vernon; Supplement to Final Study Report*

Figure 3.6-30. Temporal distribution of downstream passage of radio-tagged American Shad at Vernon by route of passage with mean daily project discharge (cfs) and spilling flows (cfs), 2017.

Tagged shad tended to move through the study area and pass downstream quickly, with an overall adjusted median residency of 4.72 hours. Shad that passed via the east fish pipe passed with a median adjusted residency of 2.03 hours. Passage via hydroelectric units 1-4 and 5-8 occurred with slightly longer residence times (median adjusted residency = 13.63 hours and 14.43 hours, respectively), but through units 9-10 with a median adjusted residency of only 0.94 hours.

During the 2017 study period, two substantial, and three lesser (in magnitude and duration) spill events occurred, accounting for 21.0 percent of the study period. The average proportion of forebay residency that occurred during spill conditions was 47.9 percent. In comparison, the average proportion in 2015 was 51.5 percent. The relatively high proportional period of spill during residency is informative. It suggests that high flows facilitate outmigration, and as a result, when spill conditions, particularly of high magnitude, occur during the outmigration period, a relatively large proportion of passage may be expected to occur via the spill gates.

Vernon Project—Juvenile American Shad

Study 22 evaluated proportional route selection and forebay residency time for juvenile shad by radio-tagging and systematically monitoring movement and passage tagged shad through the Vernon Project. A total of 310 juvenile shad was radio-tagged and released upstream of Vernon dam on 15 occasions during a 6-week period between September 25 and October 30, 2015. Fish were tagged and released in groups of 13–20 and released in three general areas (east, west and mid-river) along a perpendicular transect across the river, which originated near the VY cooling water intake located approximately 0.75 mile upstream of Vernon dam. Remote telemetry monitoring occurred at the Vernon forebay, log boom and diversion boom, fish pipe, fish tube, turbines, tailrace, and spillway.

Movement and Behavior of Radio-Tagged Juvenile Shad

Of the 310 released shad, 270 (87.1 percent) approached Vernon and 40 (12.9 percent) did not approach the Project. When examined among the 15 release groups, the percentage of juvenile shad failing to approach Vernon was greatest during the earlier releases. Four individuals failing to approach Vernon were located during manual tracking efforts upstream of the project and the rest went undetected following release. The final fate of those individuals is unknown. It is possible their tags became dislodged, they died and settled on the bottom, or they were -preyed upon. Regardless, as these individuals failed to approach Vernon, they were excluded from all subsequent analyses.

Valid detection information was available for all 270 shad that entered the forebay area to determine the approach duration, which ranged from approximately 0.1 hours to 70.8 hours (2.4 days) with a median duration of 1.9 hours. The majority of individuals (68 percent) were present within the Vernon forebay within four hours following release.

Forebay Residency

Valid detection information was available to determine the forebay residency duration for 265 of the 270 radio-tagged juvenile shad known to have entered the forebay area. For those fish, forebay residency time ranged from less than 6 minutes to 237.7 hours (9.9 days) with a median duration of 44 minutes. When examined by release group, the highest median forebay residency time of 39.5 hours was associated with release 1, conducted on September 25.[43] The extended residency time indicates that fish spent a greater amount of time milling around in the forebay area than was observed for subsequent releases conducted later in the season. Of the eighteen individuals from release group 1 that approached Vernon, 38 percent (7 of the 18) did not pass the Project. When individuals from all 15 release groups are considered, the forebay residency time was significantly longer for individuals that did not pass than for those that did pass (Mann-Whitney test; $z = 6.5048$ $p = <0.0001$). Approximately 87 percent of the shad that passed Vernon did so in 12 hours or less after detection at the Project (median residency for all passed shad = 0.6 hours, mean = 4.2 hours). By passage route, the passed fish with a median forebay residency greater than 1 hour were the two individuals that passed via the fish ladder (median = 15.4 hour).

[43] Section 4.1.3 of the final study report incorrectly reported the date of release 1 as October 3. Table 4.1.2.1 in the final report correctly reports the date as September 25.

Route Selection

Of the 270 juvenile shad detected in the forebay, 226 individuals (83.7 percent) passed downstream of the dam. The remaining 44 individuals (16.3 percent of those detected in the forebay), although located in the forebay, did not have confirmed passage. Of the individuals with confirmed passage, a definitive passage route was determined for 75.2 percent (170 out of the 226). The remaining 24.8 percent (56 of the 226) were determined to have passed Vernon based on downstream detection information, but a definitive passage route could not be determined (Table 3.6-47).

Table 3.6-47. Summary of juvenile American Shad emigration at Vernon, fall 2015.

Downstream Passage Status	No.	Percent of Number Released
Total released	310	100.0
Total detected in forebay	270	87.1
Total failing to exit forebay	44	14.2
Total passing Vernon	226	72.9
Total Passing Vernon via known passage route	170	54.8
Total passing Vernon via unknown route	56	18.1
Total detected at Stebbins Island	159	51.3

Source: ILP Study 22, *Downstream Migration of Juvenile American Shad Study - Vernon*

The majority of confirmed passed shad (86.5 percent; 147 of 170) passed through the turbine units, and the remaining 13.5 percent (23 of 170) passed via non-turbine routes (trash/ice sluice, fish pipe, fish tube, fish ladder). The frequency of downstream passage routes used ranged from 39.8 percent at turbine Unit Nos. 5-8 to 0.4 percent through the fish tube and open spill gates (Table 3.6-48).

Downstream passage route could not be determined for all individuals known to have passed Vernon based on initial detections in the forebay followed by detections in the downstream tailrace area or at the Stebbins Island receiver. Of the 226 individuals known to have passed, 56 (24.8 percent) did so by an unknown route. In all instances, multiple routes of exit from the forebay were available (based on flow) at the time of downstream passage for each of the 56 individuals classified with unknown routes. The majority of Project discharge was through Unit Nos. 5-8 during 80 percent of the downstream passage events classified as unknown, and through Unit Nos. 9-10 during the remaining 20 percent of events classified as unknown. Those two routes were also the most frequently used by shad with determined passage routes (Table 3.6-48).

Table 3.6-48. Summary of passage routes taken by juvenile American Shad though Vernon, fall 2015.

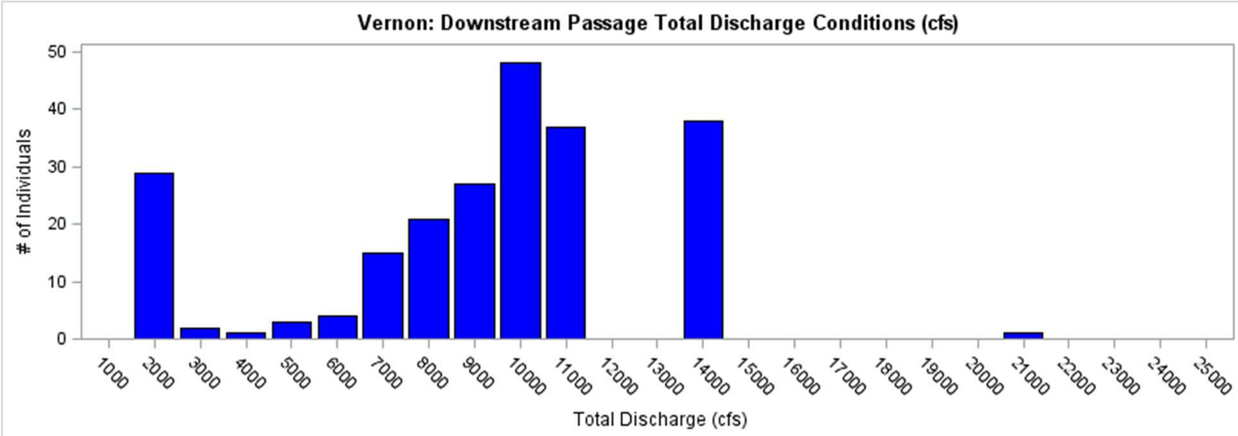
Passage Route	No.	Percent of Total	Percent of Those with Known Passage Route
Units 5–8	90	39.8	52.9
Units 9–10	35	15.5	20.6
Units 1–4	22	9.7	12.9
Fish Pipe	17	7.5	10.0
Fish Ladder	2	0.9	1.2
Trash/Ice Sluice	2	0.9	1.2
Fish Tube	1	0.4	0.6
Spill	1	0.4	0.6
Unknown	56	24.8	NA
Total	**226**	**100.0**	**100.0**

Source: ILP Study 22, *Downstream Migration of Juvenile American Shad Study - Vernon*

When all radio-tagged juvenile shad passing Vernon were considered, the majority (85 percent) of downstream passage events occurred during the late evening hours (approximately 5:00 p.m. to 10:00 p.m.). This observation is consistent with previous studies (O'Leary and Kynard, 1986).

Downstream passage was also examined as a function of total flow for the 163 individuals with known passage times. Whereas one shad passed Vernon during spill (i.e., river flow greater than maximum station generating capacity), 29 shad (12.8 percent) passed from minimum flow to approximately 2,000 cfs, and a majority (n = 133) passed at flows between approximately 8,000 and 11,000 cfs (Figure 3.6-31). Project operations at the time of last forebay detection were evaluated for the 44 shad that did not pass Vernon. Half of non-passing shad (n = 22) were last detected at times of approximate minimum flow; 25 percent (n = 11) were last detected at flows from minimum flow to 7,000 cfs; 20.5 percent (n = 9) were last detected at flows between 7,000 and 14,000 cfs; and 2 shad (4.5 percent) were last detected when the Project was spilling at flows greater than 20,000 cfs.

Individuals did not necessarily pass downstream via the route with the greatest proportion of total Project discharge at that time. Passage via the downstream route with the greatest proportion of flow at the time of passage occurred only 53.5 percent of the time. Two shad passed via the trash-ice sluice when flow monitors did not register any flow through the trash/ice sluice during the time of passage, although there was likely to be sufficient leakage flow to allow passage at those times.



Source: ILP Study 22, *Downstream Migration of Juvenile American Shad Study - Vernon*

Figure 3.6-31. Passage of juvenile American Shad by discharge at Vernon, fall 2015.

Downstream Detection after Passage

The route selection component of Study 22 was not intended to evaluate downstream passage survival which was evaluated using an appropriate methodology for turbine passage survival (see Section 3.6.2.10, *Turbine Surviva*l). Because there are no available estimates of background mortality on emigrating juvenile American Shad in the Project area, the impact of predation on the downstream detection of radio-tagge d juveniles cannot be quantified. In addition, the retention rate of externally attached radio tags for juvenile shad passing via any turbulent passage route (e.g., turbines, fish pipe, spill, etc.) is unknown. The pilot study evaluating juvenile shad tag retention (Normandeau, 2014) was conducted in a tank environment and was intended to be representative of retention of tags by juvenile shad moving through the forebay area in the period of time immediately prior to downstream passage. Interpretation of downstream detection information for externally tagged juvenile American Shad as "Project survival" is likely negatively biased by lowered tag retention associated with turbulent downstream passage. While considering these factors, available data on the downstream progress for radio-tagged juvenile shad following passage at Vernon are shown by passage route in Table 3.6-49. Overall, 70.4 percent of juvenile shad that passed Vernon were detected at Stebbins Island.

Evaluation of detections farther downstream could not be conducted due to the potential for detection overlap as a result of some redundant radio tag codes used for American Eels released in Study 19, and juvenile American Shad released in FirstLight's juvenile shad downstream passage study, requiring exclusion of those data from that study (Kleinschmidt et al., 2016b) and from FirstLight's adult eel downstream passage study (Kleinschmidt and Gomez and Sullivan, 2017). Exclusion of those data likely underestimates the number of juvenile shad that passed Vernon and subsequently arrived at Turners Falls; therefore, the data are not presented.

Table 3.6-49. Number and percentage of radio-tagged juvenile American Shad that passed downstream of Vernon and were detected at Stebbins Island (by downstream passage route), fall 2015.

Passage Route	No. Passing Vernon	No. Detected at Stebbins	Percent Detected at Stebbins Island
Units 1–4	22	13	59.1
Units 5–8	90	68	75.6
Units 9–10	35	23	65.7
Fish pipe	17	14	82.4
Fish tube	1	1	100.0
Trash/ice sluice	2	0	0.0
Fish ladder	2	0	0.0
Spill	1	1	100.0
Unknown	56	39	69.6
Total	**226**	**159**	**70.4**

Source: ILP Study 22, *Downstream Migration of Juvenile American Shad Study - Vernon*

Total Project Survival Estimate

Applying both the HI-Z tag direct turbine survival estimate and Franke turbine survival estimates (see Section 3.6.2.10, *Turbine Survival*, below) to the proportion of eels passing via turbines, along with the telemetry-based estimates for non-turbine routes, total Project survival through all passage routes ranges from 83.1 percent to 87.5 percent, with the radio telemetry estimate (70.4 percent) lower than both the HI-Z total Project estimate of 85.8 percent and the broader calculated range of the Franke-based total Project estimate (83.1–87.5 percent) (Table 3.6-50).

Table 3.6-50. Passage route distribution and associated route-specific survival estimates for juvenile American Shad at Vernon.

Passage Route	No.	Proportion	Estimated and Predicted Survival Rates (%)		
			HI-Z (1-hour)	Conservative Radio Telemetry, Estimate	Franke Formula (4-inch Fish)[a]
Units 1–4	22	0.097	91.7	59.1	89.9–95.4
Units 5–8	90	0.398	95.2	75.6	89.0–97.7
Units 9–10	35	0.155	94.7	65.7	93.8–96.9
Fish pipe	17	0.075	NA	82.4	NA
Fish tube	1	0.004	NA	100	NA
Trash/ice sluice	2	0.009	NA	0	NA
Fish ladder	2	0.009	NA	0	NA
Spill	1	0.004	NA	100	NA
Unknown	56	0.248	NA	69.6	NA
Total	**226**	**1.000**		**70.4**	

Source: ILP Study 23, *Fish Impingement, Entrainment, and Survival Study Report Supplement*

a. Calculated at peak efficiency for Units 1-4 and Units 5-8, and at minimum flow for Units 9–10.

Movement and Behavior of Untagged Juvenile Shad

Study 22 also included evaluation of the timing of the 2015 juvenile shad emigration in the vicinity of the entrance to the downstream fish pipe (the primary existing downstream passage route) in the forebay, by continuous hydroacoustic sampling (i.e., sonar). The time series of the acoustic index of abundance was used to determine the onset, departure, timing, and duration of peak abundance, diel periodicity, and depth distribution of juvenile shad. Temporal trends were verified by three independent complementary sampling methods: (1) discrete cast net samples in the forebay, (2) visual observations of fish near the surface in the forebay, and (3) electrofishing samples immediately upstream of the forebay.

Results of the hydroacoustic evaluation showed that schooling fish first appeared in the Vernon forebay on August 17 and last appeared on October 30 (74 days); however, they were not consistently present until the beginning of September. Fish density increased through September to the highest density on October 3, decreased on subsequent days, and then peaked moderately on two isolated late occasions (October 23 to 24 and 30) before declining to zero by November. The major peak started with a steady increase in fish density from September 25 to the highest peak on October 3 and then steadily declined to October 8 (a duration of 13 days) before density increased again over several days of fluctuation. The second highest daily mean fish density occurred on October 24 during a 2-day peak on October 23 and 24. A single-day peak with the fifth highest daily mean fish density occurred on October 30. These temporal trends are consistent with a single major outmigration run followed by two pulses of late migrants. Timing of the emigration observed in this study was in reasonable agreement with observations made by others in other locations in the Connecticut River in the past (e.g., Normandeau, 2015b; O'Leary and Kynard, 1986). As observed in other studies (O'Donnell and Letcher, 2008; O'Leary and Kynard, 1986; Leggett and Whitney, 1972), fish school echoes were most abundant following a sharp decrease in water temperature and were absent once water temperatures remained below 50°F (10°C). Results of this study indicate some correlation between density in the forebay and river flow, in addition to peak densities triggered by decreasing water temperature.

Fish density was highest during the afternoon and dusk, periods when juvenile shad are known to move at other locations in the Connecticut River (O'Leary and Kynard, 1986). Schools concentrated in the mid-water column generally in an approximate 20- to 33-ft (6- to 10-meter) range during the day and then migrated toward the surface before and during dusk. There was a central tendency of school echoes found closer to the surface and within the depth layer of the fish pipe opening later in the season during October.

Based on hydroacoustic evaluation and the complementary sampling, juvenile shad were determined to have passed Vernon because fish density representative of juvenile shad within the forebay quickly decreased from observed peak densities, with some peak densities lasting only 1 or 2 days, and tracked echoes of juvenile-shad-sized fish primarily moved through the beam in the west-southwesterly direction toward the fish diversion boom and the powerhouse. No evidence is available to indicate that juvenile shad accumulated in the forebay over the emigration season.

Because of the results of the telemetry and hydroacoustic evaluations, the Vernon Project and its operations do not appear to limit the ability of juvenile shad to quickly locate downstream routes through the Project.

Great River Hydro Proposal

Under the current operating conditions, the Project operates downstream fish passage facilities at all three of the Project stations. Depending on the species considered, operations occur between April and December 31. With the suspension of the Atlantic Salmon restoration efforts, the primary focus on downstream passage at Vernon is for silver- phase (adult) American Eel, juvenile American Shad, and adult American Shad. At Bellows Falls and Wilder only downstream passage for silver-phase American Eel is considered relevant. Currently, there are no provisions required for passage of juvenile Sea Lamprey at any of the Project stations. River conditions can impact downstream migration and passage route selection. Results from Study 19, American eel Downstream Passage Assessment, and Study 22, Downstream Migration of Juvenile American Shad at Vernon, indicate out-migrating species often select passage routes through which the majority of inflow is allocated. The proposed operational regime should result in a reduction in the magnitude and frequency of WSE fluctuations (Section 3.3.1.1, 3.3.1.2) and a reduction in the discharge fluctuations (higher base flows, lower maximum flows, fewer events; Sections 3.3.2). This should result in more stable conditions and a more natural flow regime for out-migrating species although extreme events (e.g., storms, droughts) will influence changes in WSE and discharge outside of Project control.

Great River Hydro and resource agencies with prescriptive authority under Section 18 of the Federal Power Act have initiated discussion of upstream and downstream fish passage at the Projects and will continue those discussions after these amended FLAs are filed in an effort to reach agreement on fish passage requirements, plans, and schedules to be included in the FWS recommendation for terms and conditions to be filed within 60 days of the Notice of REA. In those discussions, Great River Hydro will work with resource agencies and FWS fishway engineers to assess potential structural and operational improvements for safe and efficient downstream passage of migratory fish species at each of the Projects.

Each Project station has a specific structure(s) designated for providing downstream passage requiring unique maintenance and operation. Effects of the proposed action on each Project station’s downstream passage follow.

Wilder

Downstream passage for diadromous species at Wilder was designed to pass out-migrating Atlantic Salmon kelts. The passage structure at Wilder, designed to operate from October 15 through December 31, is not currently required to operate until 50 adult salmon are counted passing upstream of the facility. Current downstream passage concerns focus on adult American Eel. Water inflow was an important variable for silver eels in Study 19, *American Eel Downstream Passage Assessment*, with 78.5 percent of radio-tagged eels selecting routes where the greatest proportion of flow was allocated. Stabilization of impoundment WSE and a greater proportion of time at IEO will establish a more natural flow regime through the Project although these changes will not likely alter where the majority of flow is allocated at the Project under normal conditions. Similar to upstream passage, seasonal events such as drought and large storms will continue to exert influence on flow allocation (e.g., large storms result in spill events) outside of the control of Project operations.

The Wilder downstream passage provision is an existing log sluice located between Unit 3 and the fish ladder entrance. A flow of 512 cfs is designed during the downstream passage season. Proposed operational changes will not impact Great River Hydro’s ability to maintain downstream passage facilities at Wilder if it is required to run.

As juvenile American Eel upstream passage facilities improve at downstream dams and eventually, based on the success of those facilties, lead to upstream passage improvements at Wilder, Great River Hydro will pivot attention to effective downstream passage of adults when evidence of a significant number of downstream migrating eels is determined or alternatively after a period of years following upstream passage of a significant population of juvenile eels. Great River Hydro will discuss these concepts, metrics, and triggers with resource agencies in the aforementioned discussions.

Bellows Falls

Similar to Wilder, downstream passage at Bellows Falls was designed for adult Atlantic Salmon. The operation period, triggered when 50 or more individuals were counted passing upstream of the facility, runs from October 15 through December 31. Downstream passage at Bellows Falls currently focuses on adult American Eel. A majority (80.2 percent) of eel radio-tagged in Study 19 selected passage routes where the greatest proportion of flow was being allocated. Changes under the proposed flow regime will result in more consistent flow through the Project. However, these reductions in magnitude and frequency of WSE fluctuations and the greater proportion of time where inflow equals outflow (Sections 3.3.1, 3.3.2) from operational changes will not likely impact where the majority of flow is allocated under normal operating conditions. Similar to upstream passage, seasonal events such as drought and large storms will continue to exert influence on flow allocation (e.g., large storms result in spill events) outside of the control of Project operations.

Downstream passage facilities at Bellows Falls consist of a forebay sluiceway/skimmer gate and a solid, partial depth diversion boom. The gate is designed for Atlantic Salmon smolt, and adult downstream passage and is not required to be operated when fish are not present. The proposed operations will not impact the ability to operate the downstream passage facility at Bellows Falls.

As juvenile American eel upstream passage facilities improve under the upstream passage proposal, the focus for Great River Hydro will pivot to effective downstream passage of adults when evidence of a significant number of downstream migrating eels is determined or alternatively after a period of years following upstream passage of a significant population of juvenile eels. Great River Hydro will discuss these concepts, metrics, and triggers with resource agencies in the aforementioned discussions.

Vernon

Downstream migration of diadromous fish at Vernon is considered for juvenile and adult American Shad and adult American Eel. Similar to Wilder and Bellows Falls, a plurality of radio-tagged American Eel in Study 19, American Eel Downstream Passage Assessment, (61.4 percent) selected passage routes where the greatest proportion of flow was allocated. Juvenile American Shad displayed a similar trend in Study 22, Downstream Migration of Juvenile American Shad at Vernon, with just over half (53.5 percent) selecting passage routes where the greatest proportion of flow was allocated. Adult shad downstream passage (Study 21) appears to be more influenced by high water events with the shortest Project residency and increased passage generally associated with high total discharge and spill. Overall, the reductions in magnitude and frequency of WSE fluctuations, proportion of time at IEO, and discharge from operational changes will not likely impact where the majority of flow is allocated under normal operating conditions. For adult out-migrating American Shad passage, which tends to increase with high total discharge and spill events, seasonal storm events that influence river inflow and spill will continue impact the Project in a similar way under the proposed operation regime.

Downstream passage facilities at Vernon consist of a fish pipe that passes through the powerhouse, a fish bypass at the Vermont end of the powerhouse, and a 15 foot deep louver with 3-inch panel spacing to guide fish into the fish pipe. The fish bypass discharges 350 cfs and the bypass 40 cfs. Both downstream passage facilities are required to operate from April 7 through November 15 to accommodate the migration period for all diadromous species present. Proposed changes to operations will not impact the ability to maintain the required operating conditions at the Vernon downstream passage facilities.

Great River Hydro proposes to operate the Vernon downstream passage facilities from the day the upstream fish ladder is opened to December 1. Operartion of the facilities from early spring to July 31 provides passage for adult American Shad, operation from August 1 thorugh November 15 provides passage for juvenile American Shand, and operation from September 1 thorugh December 1 provides passage for adult American Eel. In addition, Great River Hydro proposes to further discuss downstream passage for adult American Eel at Vernon in the aforementioned discussions.

3.6.2.9 Impingement and Entrainment

No-action Alternative

Study 23 was a literature-based evaluation of impingement and entrainment susceptibility and effects of a representative group of fish species based on the overall fish assemblage for the Projects. These target species were primarily identified based on a combination of life history strategies, relative abundance in the impoundment community, and trophic guild. Additional species were added when a major family or trophic guild was not included based on those criteria.

For individuals susceptible to entrainment and impingement, avoidance of the intakes is related to fish size and swimming performance (Castro-Santos and Haro, 2005). A literature review of swim speed information was conducted for the 15 target fish species that inhabit the Wilder, Bellows Falls, or Vernon impoundments to compare available swim performance data for these species to measured water velocity proximal to the Project intakes. Intake or approach velocities were calculated for the various turbine unit types at the Projects (Table 3.6-51).

Table 3.6-51. Calculated intake velocities at Wilder, Bellows Falls, and Vernon.

Project and Unit	Maximum Potential Turbine Discharge (cfs)[a]	Calculated Intake Velocity at the Intake Racks (ft/s)
Wilder Units 1–2	5650	2.2
Wilder Unit 3	825	1.4
Bellows Falls Units 1–3	3850	2.2
Vernon Units 1–4	1100	1.4
Vernon Units 5–8	1860	2.5
Vernon Units 9-10	2060	2.1

Source: ILP Study 23, *Fish Impingement, Entrainment, and Survival Study*

a. Maximum turbine discharge capacity values are based on unit-specific power and efficiency curves developed in Study 5, not on the unit maximum hydraulic capacity values reported in Exhibit B.

Impingement

Fish impingement is a function of trashrack spacing. Fish body widths for representative species and lengths were taken from the scientific literature or derived via calculation from body width proportions (Smith, 1985) to determine the tendency of fish to be impinged at Project trashracks (Table 3.6-52). The rate of impingement for species/body lengths is also a function of their ability to escape the flow field associated with the intake structures.

Wilder Project

For the 14 target species at Wilder and their representative lengths, no calculated body widths were wider than the trashrack clear spacing on Unit Nos. 1 and 2 (5.0 inches); therefore, impingement is unlikely. Unit No. 3 has a narrower clear spacing (1.625 inches). As a result, most of the target species that can reach 15 inches or more in total length (Table 3.6-52) have a calculated body width that may leave them vulnerable to impingement on the Unit No. 3 trashracks.

Bellows Falls Project

Bellows Falls Unit Nos. 1–3 are all shielded by trashracks with 4.0-inch clear spacing. Of the 14 target species, only Northern Pike and Walleye with a body length greater than 30 inches (Table 3.6-52) reached calculated body widths wider than the trashrack clear spacing that could make them vulnerable to impingement.

Vernon Project

Vernon Unit Nos. 1–8 have clear spacing of 1.75 inches, and as a result, most of the target species that can reach 15 inches or more in total length (Table 3.6-52) have a calculated body width that may leave them vulnerable to impingement. Unit

Nos. 9 and 10 have a 3.625-inch clear spacing, and similar to Bellows Falls, only Northern Pike and Walleye with a body length greater than 30 inches reached calculated body widths wider than the Unit Nos. 9 and 10 trashrack clear spacing that could make them vulnerable to impingement.

Table 3.6-52. Fish body widths for representative lengths of target fish at the Wilder, Bellows Falls, and Vernon Projects.

Target Species	Max. Adult Length[a]	Body Width (BW) for Given Total Length (TL) (in.)						BW as % of TL
		TL=5	TL=10	TL=15	TL=20	TL=30	TL=40	
American Eel	45	0.2	0.4	0.6	0.8	1.1	1.5	3.8
White Sucker	25	0.9	1.8	2.7	3.6			17.8
Bluegill	10	0.8	1.7					16.8
Largemouth Bass	20+	0.8	1.7	2.5	3.3			16.5
Smallmouth Bass	20	0.8	1.6	2.4	3.2			15.8
American Shad[b]	18	0.8	1.6	2.5	3.3			16.4
Fallfish	20	0.8	1.6	2.4	3.2			16.1
Golden Shiner	12	0.7	1.3	2				13
Spottail Shiner	6	0.9						18
Northern Pike	40+	0.8	1.6	2.4	3.2	4.8	6.4	16
Brown Bullhead	12	1	2.1	3.1				20.6
Yellow Perch	15	0.7	1.4	2.1				14.1
Walleye	34	0.8	1.5	2.3	3	4.5		15
Tessellated Darter	4.5	0.8						16.9
Sea Lamprey	36	0.4	0.8	1.2	1.6	2.3		7.8[c]

Source: ILP Study 23, *Fish Impingement, Entrainment, and Survival Study*

a. As indicated in Langdon et al. (2006).

b. American Shad included as a target species at Vernon only.

c. Body depth was used instead of body width because body width information was not available, and Lamprey are more or less cylindrical in cross section.

Entrainment

Assessing entrainment potential included an examination of the characteristics of each Project relative to life history and behavioral traits of the target species, including swim speed. Juvenile individuals of littoral fish species (i.e., Bluegill, Largemouth Bass, and Smallmouth Bass) are likely more susceptible to entrainment than adults of those species due to their lesser swimming abilities. However, these species are more prevalent in shallower, shoreline habitat and would likely have a lower entrainment potential at units positioned near the center of the channel. Likewise, the preference for more nearshore habitat of forage species such as Golden and Spottail Shiner may help to offset their relatively weak swimming ability and lower their entrainment potential. Entrainment potential for pelagic, predatory species such as Walleye and Yellow Perch may be increased while following prey species into the intake areas (i.e., during the fall out migration of juvenile American Shad at Vernon). Adults of those species are strong swimmers and should be capable of avoiding intake velocities at all three Projects. However, the ability to react to intake velocities may be reduced for injured fish or those that become lethargic due to loss or reduction of swimming ability, which can occur in coldwater conditions. Members of the target fish community most susceptible to entrainment are those whose life history strategies include downriver movement, and small bodied (i.e., juvenile) fish. As reported in Winchell et al. (2000), there is little difference in fish size distributions for the wide range of bar rack clear spacing represented in the reviewed studies. Across all rack spacings, 94 percent of entrained fish were less than 8 inches long. Comprehensive reviews of entrainment data (EPRI, 1997; FERC, 1995) suggest that several factors can influence the potential for entrainment at any given hydroelectric project as summarized in Table 3.6-53 and described for each Project below.

Table 3.6-53. Comparison of factors that may influence entrainment of target fish species at the Wilder, Bellows Falls, and Vernon Projects.

Influencing Factors	Wilder	Bellows Falls	Vernon
Intake adjacent to shoreline	Yes	No	Yes
Intake location in littoral zone	No	No	Yes
Abundant littoral zone species	Yes	Yes	Yes
Abundant clupeids	No	No	Yes
Obligatory migrants	Few	Some	Yes
Intake depth (ft) at max./min. impoundment elevation	~30	surface	~5
Approach velocity (ft/s)	1.4–2.2	2.2	1.4–2.5
Maximum station capacity (cfs)	10,700[a]	11,400	17,100[b]
Seasonal impoundment drawdown	No	No	No
Water quality	No	No	No

Source: ILP Study 23, *Fish Impingement, Entrainment, and Survival Study*

a. Value represents the maximum discharge value 98% of the time, not the maximum capacity based on the sum of individual unit capacities reported in Exhibit A.

b. Value represents the sum of individual unit capacities reported in Exhibit A, actual maximum discharge is approximately 15,500 cfs.

Wilder Project

Factors reducing entrainment potential at Wilder are the lack of clupeids, low numbers of obligatory migrants, relatively deep intakes (upper intake elevations are approximately 30 ft below the maximum operating impoundment level), and the lack of a seasonal impoundment drawdown. Approach velocities at the trashracks were estimated to be relatively low (1.4 to 2.2 ft/s), which also helps reduce the likelihood of entrainment. Primary factors increasing entrainment potential may include the location of the intakes relative to the shoreline (within approximately 200 ft).

Bellows Falls Project

Primary factors reducing entrainment potential at Bellows Falls may include the lack of clupeids, low numbers of obligatory migrants, lack of a seasonal impoundment drawdown, and the absence of a natural shoreline (i.e., suitable littoral habitat) adjacent to the intake structure due to the presence of the elongated power canal. Approach velocities at the trashracks were estimated to be relatively low (2.2 ft/s), which will also help reduce the likelihood of entrainment because many fish can swim faster than this. Primary factors increasing entrainment potential include the shallow depth of the upper intake elevations (surface level) in relation to the maximum operating impoundment level.

Vernon Project

The primary factors reducing entrainment potential are slightly reduced intake depths (upper intake elevations are approximately 5 ft below the maximum operating impoundment level) and the lack of a seasonal impoundment drawdown. Approach velocities at the trashracks were estimated to be relatively low (1.4 to 2.5 ft/s), which will also help reduce the likelihood of entrainment. Primary factors increasing entrainment potential at Vernon may include the location of the intakes relative to the shoreline (within approximately 300 ft) as well as the large number of obligatory migrants (juvenile American Shad) upstream of the Project.

Overall Entrainment Potential

The resulting qualitative assessment of entrainment potential used Project-specific factors along with data previously described from the literature (i.e., habitat and life history, swim speeds, and comparable hydroelectric locations as summarized in EPRI, 1997) to evaluate the potential entrainment of target fishes at each of the Projects. The qualitative assessment used a multi-step rank from high (H) to medium (M) to low (L). An overall entrainment potential was assigned to each target species and lifestage at each Project (Table 3.6-54), which indicates the potential for adverse Project effects on some species and lifestages. Note that the likelihood of entrainment for a particular species or lifestage in the vicinity of the intakes may be low due to low abundance in the impoundment (see Section 3.6.1.3, *Resident Fish Populations*, and Section 3.6.1.4, *Migratory Species*), but if present in the Project forebays, these species and lifestages would be expected to have the same overall potential for entrainment as estimated in Table 3.6-54.

Table 3.6-54. Overall qualitative assessment of the entrainment potential of target fish species for the Wilder, Bellows Falls, and Vernon Projects.

Species and Lifestage	Wilder	Bellows Falls	Vernon
American Shad			
Juvenile	NA[a]	NA[a]	H
Adult	NA[a]	NA[a]	H-M
American Eel			
Juvenile	M-L	M-L	L
Adult	H-M	H-M	H-M
Bluegill			
Juvenile	H-M	H-M	H-M
Adult	M-L	M-L	M-L
Brown Bullhead			
Juvenile	M-L	M-L	M-L
Adult	L	L	L
Fallfish			
Juvenile	L	L	L

Species and Lifestage	Wilder	Bellows Falls	Vernon
Adult	L	L	L
Golden Shiner			
Juvenile	H-M	H-M	H-M
Adult	M-L	M-L	M-L
Largemouth Bass			
Juvenile	M	M	H-M
Adult	M-L	M-L	M
Northern Pike			
Juvenile	L	L	M-L
Adult	L	L	L
Sea Lamprey			
Juvenile	M-L	M-L	M
Adult	L	L	L
Smallmouth Bass			
Juvenile	M	M	H-M
Adult	M-L	M-L	M-L
Spottail Shiner			
Juvenile	H-M	H-M	H-M
Adult	H-M	H-M	H-M
Tessellated Darter			
Juvenile	M-L	M-L	L
Adult	M-L	M-L	L
Walleye			
Juvenile	M	M	H-M
Adult	M-L	M-L	M-L
White Sucker			
Juvenile	M	M	M
Adult	M-L	M-L	M-L
Yellow Perch			
Juvenile	H-M	H-M	H-M
Adult	M-L	M-L	M-L

Source: ILP Study 23, *Fish Impingement, Entrainment, and Survival Study*

a. NA indicates the species does not occur at the Project.

Great River Hydro Proposal

No additional impacts on impingement and entrainment are expected to be associated with the proposed operations. Impingement and entrainment at the Project are related to species life-history characteristics and habitat preferences as well as the ability to avoid intake velocities in the vicinity of the trashracks. Proposed changes in operations will not have substantial impacts to the habitat or species composition currently existing within the Project-influenced reaches or result in an increase in intake velocities.

3.6.2.10 Turbine Survival

No-action Alternative

Study 19 included direct turbine survival studies of tagged silver-phase American Eels emigrating through the Wilder, Bellows Falls, and Vernon Projects during typical operating conditions. Study 22 included turbine survival studies of tagged juvenile American Shad emigrating through Vernon during typical operating conditions. Study 23 used a desktop approach to estimate turbine survival rates for target species of both resident and migratory fish at the Projects.

Desktop Analysis of Turbine Survival

Franke et al. (1997) defines the three primary risks to emigrating fish passing through the turbine environment as: (1) mechanical mechanisms; (2) fluid mechanisms; and (3) pressure mechanisms. Mechanical mechanisms are primarily defined as forces on a fish’s body resulting from direct contact with turbine structural components (e.g., rotating runner blades, wicket gates, stay vanes, discharge ring, draft tube, passage through gaps between the blades and hub, or at the distal end of blades or other structures placed into the water passageway). The probability of that contact depends on the distance between blades, number of blades, and fish body length. Additional sources of mechanical injury may include gap grinding, abrasion, wall strike, and mechanical chop. Fluid mechanisms are defined as shear-turbulence (the effect on fish of encountering hydraulic forces due to rapidly changing water velocities) and cavitation (injury resulting from forces on fish body due to vapor pockets imploding near fish tissue). Impacts from pressure result from fish inability to adjust from regions of high pressure immediately upstream of turbines to regions of low pressure immediately downstream of turbines. Results from most studies indicate that mechanical related injuries are the dominant source of mortality for fish in the turbine environment at low head (less than 100 ft) projects (Franke et al., 1997). Blade strike is considered the primary mechanism of mortality when fish pass through turbines (Cada, 2001; Eicher Associates Inc., 1987), and pressure related injuries appear to be of minor secondary importance when working at low head hydroelectric projects.

Study 23 included calculation of blade strike potential and estimated survival at applicable turbine settings for each of the turbine types at each Project (e.g., at maximum unit discharge (based on unit-specific power and efficiency curves developed in Study 5), peak unit efficiency, and minimum flow) as discussed below.

Wilder Project

Blade strike potential and estimated survival rates were calculated for the two adjustable-blade Kaplan turbines (Unit Nos. 1 and 2) and the vertical Francis turbine (Unit No. 3). Under typical full load (higher than the discharge at peak unit efficiency) for Unit Nos. 1 and 2, survival estimates ranged from 95 to 99 percent for small (4- to 8-inch) fish, from 86 to 95 percent for 15-inch fish, and from 45 to 91 percent for 30-inch fish. At Unit No. 3 under minimum flow only (because that is typical operation for the unit), survival estimates ranged from 72 to 93 percent for small (4- to 8-inch) fish, from 47 to 73 percent for 15-inch fish, and from 0 to 47 percent for 30-inch fish.

Bellows Falls Project

Blade strike potential and estimated survival rates were calculated for the three vertical Francis units at maximum unit discharge, at peak unit efficiency, and at minimum flow. Under all scenarios, survival estimates ranged from 87 to 97 percent for small (4- to 8-inch) fish and from 52 to 88 percent for larger (15- and 30-inch) fish.

Vernon Project

Blade strike potential and estimated survival rates were calculated for the four vertical Kaplan units (Nos. 5–8) and the six vertical Francis units (Nos. 1–4 and Nos. 9 and 10) at maximum unit discharge, at peak unit efficiency, and at minimum flow (Unit Nos. 5–8 and No. 10 only because those are the units used for minimum flow). Under all scenarios for the Kaplan turbines, survival estimates ranged from 78 to 98 percent for small (4- to 8-inch) fish, from 59 to 83 percent for 15-inch fish, and from 18 to 86 percent for 30-inch fish. Survival estimates for the Francis units ranged from 80 to 96 percent for small (4- to 8-inch) fish under all scenarios, and for larger fish, survival estimates ranged from 62 to 85 percent for 15-inch fish and from 24 to 71 percent for 30-inch fish.

American Eel

The turbine survival portion of Study 19 was conducted in late October and early November 2015 at the Wilder, Bellows Falls, and Vernon Projects. Adult American Eels (imported, see Section 3.6.2.8*, Downstream Passage of Migratory Fish*) were tagged using the HI-Z Turb'N (HI-Z) tag (Heisey et al., 1992) recapture technique and associated statistical methods to estimate immediate (1-hour) and delayed (48-hour) survival. For comparison purposes, control eels were tagged and released at each Project but were not subjected to passage through turbines. Tagged "treatment" eels were released into the intakes of designated turbine units at each Project. After passage, live and dead eels were captured and the condition of each was examined. At the end of the 48-hour holding period, tags were removed, and all alive and uninjured eels were released to the river. Survival and malady-free rates were estimated for each passage location with the exception of Wilder Unit No. 3 where the study was suspended because of low recapture rates (see below). Descriptions of the observed injuries were recorded to help assess the probable causal mechanisms for injury/mortality. Fish free of visible injuries, having less than 20 percent scale loss per side and free of loss of equilibrium were designated with a malady-free status. Study results are discussed below for each Project and summarized in Table 3.6-55.

Wilder Project

For Study 19, 10 eels were released through Francis Unit No. 3 (the minimum flow unit); however, testing at that unit was curtailed after the release when it was determined that most of the discharge from this unit was directed to the upstream fish ladder for attraction flow required for the simultaneous and extended-season upstream passage operations required for Study 17, and the features within the fish ladder prevented the recapture of 7 of those 10 eels. Fifty eels were released through Kaplan Unit No. 2, and 40 eels (80 percent) were recaptured alive, while 7 (14 percent) were retrieved dead. Only dislodged inflated HI-Z tags were retrieved on 3 (6 percent) treatment eels. The eels with only the HI-Z tags recaptured were assigned a dead status. Ten control eels were also released.

The direct survival estimate of 62.2 percent for eels passing through Kaplan Unit No. 2 was lower at this unit than any of the other units tested at Bellows Falls and Vernon. The injury rate (42.6 percent) for the recaptured eels was also the highest observed, and 36.2 percent of the injuries were classified as major. These injuries were primarily bruised or severed bodies. Similar survival and injury results would be expected for the untested, but similar, Kaplan Unit No. 1. This direct survival estimate falls in the middle of the range of predicted survival estimated in Study 23 of 45 to 91 percent at discharge flows similar to flows during testing (Table 3.6-55).

Although the Francis Unit No. 3 was not able to be tested because of the configuration of the discharge, its characteristics are similar to the Francis turbine tested at Vernon Unit No. 4 (see below). The small Francis turbine at Wilder has 14 buckets, a runner speed of 212 revolutions per minute (rpm), and a runner diameter of 72 inches. The turbine at Vernon Unit No. 4 has 13 buckets, a runner speed of 133.3 rpm, and a runner diameter of 62.5 inches. The 48-hour survival of eels passed through this turbine was 93.5 percent. Based on these results, adult eels passing through Wilder Unit No. 3 could have a similar survival rate; however, Study 23 results predict much lower survival values for Unit No. 3 (0 to 50 percent), depending on the Franke et al. (1997) correlation factors and fish entry point in the turbine (e.g., blade tip, mid-blade, and near hub).

Bellows Falls Project

Fifty eels were released in Study 19 through the Francis Unit No. 2 along with 10 control eels. Both treatment and control eels had a recapture rate of 100 percent, but the recapture rate of 97.4 percent for the combined controls from all of the Projects was used in the analysis. The estimated immediate (1-hour) survival was 100 percent. The 48-hour direct survival rate of 98 percent for eels passing Unit No. 2 was the highest obtained at any of the turbines tested at the Projects. The injury rate of 14 percent was the second lowest observed, and only 6 percent of the examined eels had injuries considered major. Injuries were primarily bruises to the body. Because all the Bellows Falls units are similar, eels should incur little mortality and injury passing the Bellows Falls turbines. This direct survival estimate is higher than the range of predicted survival estimated in Study

23 (54 to 77 percent) at discharge flows similar to flows during testing (Table 3.6-55).

Vernon Project

For Study 19, eels were released on 4 days at Vernon—48 eels through the Francis Unit No. 4; 48 eels through the Kaplan Unit No. 8 discharging 1,000 cfs; 50 eels through Unit No. 8 discharging 1,700 cfs; and 48 eels through the Francis Unit No. 9. Control eels were released on two dates during the study (10 and 9 eels). Recapture rates were high at 93.8 percent at Unit No. 4; 95.8 percent at Unit No. 8 at 1,000 cfs; 88.0 percent at Unit No. 8 at 1,700 cfs; and 95.8 percent at Unit No. 9. The recapture rate of 97.4 percent for the combined controls from all of the Projects was used in the subsequent analysis. Inflated, dislodged HI-Z tags were retrieved on 1 at Unit No. 4; 2 at Unit No. 8 at 1,000 cfs; and 4 at Unit No. 8 at 1,700 cfs. The eels with only the HI-Z tags recaptured were assigned a dead status.

The 48-hour direct survival was highest (97.9 percent) for eels passed through the larger Francis turbine Unit No. 9 at Vernon. This unit also had the lowest injury rate (8.7 percent) of any of the turbines tested. Additionally, none of the injuries (bruises on head and body and fin damage) were classified as major. This survival estimate is higher than the range of predicted survival estimated in Study 23 (57 to 79 percent) at discharge flows similar to flows during testing (Table 3.6-55).

The smaller Francis Unit No. 4 also had a relatively high, 48-hour survival of 93.5 percent; however, 36.5 percent were injured, primarily bruises to head and body, and 20 percent of the eels had major injuries. This survival estimate is much higher than the range of predicted survival estimated in Study 23 (24 to 62 percent) at discharge flows similar to flows during testing (Table 3.6-55).

The Kaplan Unit No. 8 had a higher 48-hour survival (87.5 percent) at the lower discharge tested (1,000 cfs) than at the higher discharge (1,700 cfs) for which the survival was 74 percent. Injury rates were similar, 28.3 and 27.3 percent, respectively, for the two discharge rates. Although injury rates were similar, the lower discharge inflicted fewer major injuries (8.7 percent) than the higher discharge (22.7 percent). Additionally, more fish were severed at the higher discharge. This survival estimate is slightly higher than the range of predicted survival estimated in Study 23 (17 to 82 percent) at discharge flows similar to flows during testing (Table 3.6-55).

Table 3.6-55. Comparison of direct survival and injury, and predicted survival of adult eels passed through Wilder, Bellows Falls, and Vernon turbines, 2015.

Project	**Wilder**	**Bellows Falls**	**Vernon**			
Turbine Type	**Kaplan**	**Francis**	**Francis**	**Kaplan**	**Kaplan**	**Francis**
Unit Tested	**No. 2**	**No. 2**	**No. 4**	**No. 8**	**No. 8**	**No. 9**
Average Unit Discharge During Testing	4,748	3,229	992	1,236	1,681	1,308
Runner Speed (rpm)	112.5	85.7	133.3	144	144	75
Runner Diameter (inches)	180	174	62.5	122	122	110
48-hour Survival (%)	62.0	98.0	93.5	87.5	74.0	97.9
Visibly Injured (%)	42.6	14.0	35.6	28.3	27.3	8.7
Major Injuries (%)	36.2	6.0	20.0	8.7	22.7	0.0
Dominant Injury	Severed or bruised body	Bruises on body/head	Bruises on body/head	Bruises on body/head	Severed body	Bruises on body/head
Predicted Survival at Approximate Tested Discharge (%)[a]	45–91	54–77	24–62	17–82	18–85	57–79

Source: ILP Study 19, *American Eel Downstream Passage Assessment*; ILP Study 23, *Fish Impingement, Entrainment, and Survival Study*

a. Data are from Study 23. Predicted survival ranges are based on Franke et al. (1997) correlation factors and different fish entry points (e.g., blade tip, mid-blade, and near hub).

Juvenile American Shad

Vernon Project

Direct turbine survival studies for juvenile American Shad were conducted at Vernon as part of Study 22 during the fall of 2015. Approximately 500 juvenile shad for this study were transported from the North Attleboro National Fish Hatchery in Massachusetts to Vernon. Because of high mortality rates within a day or two after being placed in the holding tank, a decision was made to use wild in-river fish even though they were much smaller. High mortality of hatchery fish was also observed in the 2014 tagging experiments conducted on wild and hatchery juvenile shad (Normandeau, 2014). As a result, 600 wild fish were collected upstream of Vernon dam. Each fish of sufficient size for tagging was fitted with a miniature radio transmitter and a HI-Z tag using standard procedures (Heisey et al., 1992) and associated statistical methods to estimate immediate (1-hour) and delayed (48-hour) survival. For comparison purposes, control shad were tagged and released but were not subjected to passage through turbines. Tagged fish were introduced individually into the penstocks of Unit Nos. 4 and 8 (151 and 150, respectively) by an induction apparatus, and 150 control fish were released directly into the tailrace. While Unit Nos. 9 and 10 were not evaluated in the relicensing study, Unit No. 10 had been tested previously (Normandeau, 1995) and results of that study are included here for completeness. Testing occurred at Unit No. 8 on October 7, 8, and 10 and at Unit No. 4 on October 10 and 11, 2015.

Fish showing erratic behavior or external injuries and/or fungal infections were rejected and not used in the analysis. After release of both treatment and control fish, the fish were tracked downstream of the powerhouse and retrieved once they were buoyed to the surface by the inflated HI-Z tag. Because of the high mortality of control fish (30.3 percent) at 48 hours, only the 1-hour direct survival estimates could be made reliably. Estimated survival was 91.7 percent for Francis Unit No. 4 and 95.2 percent for Kaplan Unit No. 8, these survival rates are near the median and mean direct survival estimates attained at numerous similar direct survival studies conducted on juvenile clupeids at other projects (referenced in Study 22) and at Vernon's Francis Unit No. 10 in 1995 (Normandeau, 1995).

The estimated survival rates for the Francis turbines (Unit Nos. 4 and 10) and the Kaplan turbine (Unit No. 8) tested at Vernon followed the trends observed for the relationship between survival and runner diameter and number of blades. Unit No. 4 has the smallest diameter (62.5 inches) and the lowest survival (91.7 percent) while survival rates were higher (94.7 percent) for the larger Francis Unit No. 10 (156 inches), and 95.2 percent for the Kaplan Unit No. 8 (122 inches). The effect of the number of blades on survival was most evident when comparing the results for the 5-bladed Unit No. 8 to those for the 13-bladed Unit No. 4. The relative high survival (94.7 percent) for the 15-bladed Unit No. 10 was primarily due to its larger diameter and slower runner speed (74 rpm). Unit No. 4 runner speed is 133 rpm, nearly twice that of Unit 10. Operational head was not a factor because all three Vernon units have a similar operating head.

In Study 23, the ranges of estimated survival rates for 4-inch fish at each unit type and at flows similar to those tested in Study 22 encompass the direct survival results and thus results from both studies are in agreement. Study 23 results indicate survival of 90 to 95 percent at Unit Nos. 1–4, 89 to 98 percent at Unit Nos. 5–8, and 93 to 97 percent at Unit Nos. 9 and 10 (Table 3.6-56).

Table 3.6-56. Comparison of direct and estimated survival rates for juvenile American Shad at Vernon.

Unit No.	Test Date	Flow (cfs)	Study 22	Study 23	
			1-Hour Survival (%)	Flow Type	Calculated Survival (%)
4	Oct 10	1,298	91.7	Peak efficiency / maximum discharge	90–95
4	Oct 11	1,370	91.7	Peak efficiency / maximum discharge	90–95
8	Oct 7	1,234	95.2	Peak efficiency	89–98
8	Oct 8	1,233	95.2	Peak efficiency	89–98
8	Oct 10	1,157	95.2	Peak efficiency	89–98
10	NA	NA	94.7	All flows	93–97

Source: ILP Study 22, *Downstream Migration of Juvenile American Shad – Vernon*; ILP Study 23, *Fish Impingement, Entrainment, and Survival Study*

Based on turbine characteristics, estimated direct juvenile American Shad survival for the three turbine types tested, and a previous direct survival study on juvenile Atlantic Salmon at Vernon (Normandeau, 1996), juvenile shad should fare best passing through Kaplan Unit Nos. 5–8, followed by Francis Unit Nos. 9 and 10. The smaller Francis Unit Nos. 1–4 would likely be least fish friendly.

Great River Hydro Proposal

Turbine survival was estimated for species using a desktop approach in Study 23 and through direct turbine injection in Study 19 (juvenile American Shad) and 22 (silver phase American Eel). The three primary risks for fish passing through turbines established by Franke et al. (1997) include mechanical, fluid, and pressure mechanisms. Under proposed operations, reductions in magnitude of WSE fluctuations (Section 3.3.1) and the magnitude and frequency of discharge fluctuations (Section 3.3.2) should have no negative impact on the primary risk factors associated with turbine survival rates.

3.6.3 Cumulative Effects

3.6.3.1 Migratory Fish Passage

Because hydroelectric dams influence both upstream and downstream fish migration within river systems, FERC (in SD2) identified the geographical extent of potential cumulative effects on anadromous, catadromous, and diadromous fish species to include the Connecticut River from Long Island Sound upstream to each species' historical habitat range.

Upstream Passage

Before reaching the Vernon fish ladder, migratory fish that return to the Connecticut River from marine environments and do not find spawning and rearing habitat downstream of one or more projects must first successfully pass upstream through the hydroelectric facilities at Holyoke (RM 87) and at Turners Falls (RM 122), and successfully navigate the obstacles that may be present due to Northfield Mountain (RM 127). The cumulative effects analysis for the three Projects is necessarily limited to the contribution of proposed actions for the Wilder, Bellows Falls, and Vernon projects (continuance of existing operations under new licenses) to the cumulatively affected resource. Because Great River Hydro's proposed actions have no effect on the ability of fish to successfully pass the downstream projects before arriving at Vernon, such an analysis of the contribution to the cumulative effects of the downstream projects is not applicable. This analysis should be included in FERC's combined EIS for the Great River Hydro and FirstLight projects.

American Shad

CRASC (2016) reports historic counts of adult shad passage at Holyoke and Turners Falls (Table 3.6-57). Between 1981 and 2016, passage at Holyoke ranged from 116,511 to 721,764 (mean = 317,314). After peaking in 1992, passage at Holyoke declined until 2005 and has been increasing since that time resulting in increased passage at the upstream projects. Passage at Turners Falls from 1981 to 2016 ranged from 11 to 60,089 (mean = 15,864) and passage at Vernon ranged from 9 to 39,771 (mean = 7,911).

Proportional net passage from 1981 to 2016 at Turners Falls relative to passage at Holyoke ranged from 0 percent to 14 percent (mean = 5 percent), and proportional net passage at Vernon relative to passage at the Turners Falls Gatehouse ranged from less than 1 percent to 86 percent[44] (mean = 49 percent). Recently returns have increased at Holyoke to levels not seen since the early 1990s resulting in increased returns at the upstream projects. From 2012 to 2016, Turners Falls and Vernon had mean passage ratios of 11 percent and 59 percent, respectively, with passage at Vernon relative to Turners Falls meeting CRASC's overall proportional passage goal of 40 to 60 percent over those 5 years and exceeding that goal in 2014, 2015, and 2016 (Table 3.6-57).

Results of the FirstLight study of upstream migration of tagged adult shad (Kleinschmidt and Gomez and Sullivan, 2016a), reported fish ladder efficiency rates (combined entrance and internal efficiencies) of 10.2 percent at the Cabot ladder,

[44] Excluding data for 1996 and 2001 when reported returns exceeded 100 percent of Turners Falls passed shad passing Vernon.

32.7 percent at the Spillway ladder, and 76.9 percent at Gatehouse ladder, the most upstream ladder that provides ultimate passage into the Turners Falls impoundment (Kleinschmidt and Gomez and Sullivan, 2016a). As discussed in Section 3.6.2.7, *Upstream Passage of Migratory Fish*, Vernon fish ladder entrance efficiency was 73.5 percent and internal ladder efficiency was 55.2 percent, for an overall passage efficiency of 41.1 percent.

Table 3.6-57. American Shad fish ladder counts, 1981-2019.

Year	Passed Holyoke	Passed Turners Falls	Percent of Holyoke passed shad that passed Turners Falls	Passed Vernon	Percent of Turners Falls passed shad that passed Vernon
1981	377,124	200	0.1	97	48.5
1982	294,842	11	0.0	9	81.8
1983	528,185	12,705	2.4	2,597	20.4
1984	496,884	4,333	0.9	335	7.7
1985	487,158	3,855	0.8	833	21.6
1986	352,122	17,858	5.1	982	5.5
1987	276,835	18,959	6.8	3,459	18.2
1988	294,158	15,787	5.4	1,370	8.7
1989	354,180	9,511	2.7	2,953	31.0
1990	363,725	27,908	7.7	10,894	39.0
1991	523,153	54,656	10.4	37,197	68.1
1992	721,764	60,089	8.3	31,155	51.8
1993	340,431	10,221	3.0	3,652	35.7
1994	181,038	3,729	2.1	2,681	71.9
1995	190,295	18,369	9.7	15,771	85.9
1996	276,289	16,192	5.9	18,844	116.4
1997	299,448	9,216	3.1	7,384	80.1
1998	315,810	10,527	3.3	7,289	69.2
1999	193,780	6,751	3.5	5,097	75.5
2000	225,042	2,590	1.2	1,548	59.8
2001	273,206	1,540	0.6	1,744	113.2
2002	374,534	2,870	0.8	356	12.4
2003	286,814	268	0.1	76	28.4
2004	191,555	2,192	1.1	653	29.8
2005	116,511	1,581	1.4	167	10.6
2006	154,745	1,810	1.2	133	7.3
2007	158,807	2,248	1.4	65	2.9
2008	153,109	4,000	2.6	271	6.8
2009	160,649	3,813	2.4	16	0.4
2010	164,439	16,422	10.0	290	1.8
2011	244,177	16,798	6.9	46	0.3
2012	490,431	26,727	5.4	10,386	38.9
2013	392,967	35,293	9.0	18,220	51.6
2014	370,506	39,914	10.8	27,706	69.4
2015	412,656	58,079	14.1	39,771	68.5

Year	Passed Holyoke	Passed Turners Falls	Percent of Holyoke passed shad that passed Turners Falls	Passed Vernon	Percent of Turners Falls passed shad that passed Vernon
2016	385,930	54,069	14.0	35,513	65.7
2017	536,670	48,727	9.1	28,682	58.9
2018	275,232	43,146	15.7	31,725	73.5
2019	314,361	22,649	7.2	12,872	56.8
2020	362,418	41,252	11.4	12,835	31.1
Mean	**322,800**	**18,172**	**5.2**	**9,392**	**39.4[a]**
Min	**116,511**	**11**	**0.0**	**9**	**0.3[a]**
Max	**721,764**	**60,089**	**14.1**	**39,771**	**85.9[a]**

Source: CRASC (2020) as modified by Great River Hydro

a. Data for 1996 and 2001 excluded from mean, minimum, and maximum calculations.

Sea Lamprey

Table 3.6-58 summarizes the historical counts of Sea Lamprey upstream passage at Connecticut River mainstem dams as reported by various sources (CRASC, 2016; FirstLight Power Resources, 2016b; TransCanada, 2012a; FWS, 2013a, 2014a, 2015, 2016c). Between 1981 and 2016, passage at Holyoke ranged from 14,089 to 97,277 (mean = 33,100). After peaking in 1998, passage at Holyoke declined until 2012 and has recently started increasing again resulting in increased passage at the upstream projects. Passage at Turners Falls from 1981 to 2016 ranged from 210 to 32,035 (mean = 4,952). At Vernon passage ranged from 5 to 22,434 (mean = 2,574) and at Bellows Falls from 0 to 2,233 (mean = 291). The only reported counts at Wilder (2 lamprey each) occurred in 2008 and 2015.

Proportional net passage from 1981 to 2016 at Turners Falls relative to passage at Holyoke ranged from less than 1 percent to 56 percent (mean = 15 percent); proportional net passage at Vernon relative to passage at the Turners Falls Gatehouse ranged from less than 2 percent to 96 percent45 (mean = 37 percent); and proportional net passage at Bellows Falls relative to passage at Vernon ranged from 0 percent to 53 percent (mean = 13 percent).

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[45] Excluding data for 1998, 2001, and 2007 when reported returns exceeded 100 percent of Turners Falls passed shad passing Vernon.

Table 3.6-58. Sea Lamprey fish ladder counts, 1981-2016.

Year	Passed Holyoke	Passed Turners Falls	Percent of Holyoke passed lamprey that passed Turners Falls	Passed Vernon	Percent of Turners Falls passed lamprey that passed Vernon	Passed Bellows Falls	Percent of Vernon passed lamprey that passed Bellows Falls
1981	53,105	935	1.8	306	32.7		
1982	25,684	210	0.8	5	2.4		
1983	29,263	703	2.4	379	53.9		
1984	21,619	683	3.2	195	28.6	0	
1985	40,301	1,809	4.5	1,257	69.5	10	0.8
1986	20,000	1,961	9.8	573	29.2	11	1.9
1987	22,553	2,590	11.5	667	25.8	35	5.2
1988	15,911	1,175	7.4	281	23.9	0	0.0
1989	15,343	868	5.7	205	23.6	---	---
1990	22,421	1,301	5.8	387	29.7	47	12.1
1991	40,904	4,090	10.0	750	18.3	34	4.5
1992	27,567	2,710	9.8	749	27.6	89	11.9
1993	22,786	1,637	7.2	627	38.3	17	2.7
1994	29,958	1,702	5.7	767	45.1	34	4.4
1995	15,095	1,813	12.0	509	28.1	44	8.6
1996	44,917	4,556	10.1	853	18.7	180	21.1
1997	32,377	2,265	7.0	1,506	66.5	40	2.7
1998	97,277	7,579	7.8	16438	216.9	198	--
1999	20,217	916	4.5	836	91.3	195	23.3
2000	21,036	1,350	6.4	855	63.3	102	11.9
2001	49,306	2,144	4.3	3,212	149.8	---	---
2002	74,979	10,160	13.6	2,210	21.8	---	---
2003	53,030	---	---	8,119	---	---	---

Year	Passed Holyoke	Passed Turners Falls	Percent of Holyoke passed lamprey that passed Turners Falls	Passed Vernon	Percent of Turners Falls passed lamprey that passed Vernon	Passed Bellows Falls	Percent of Vernon passed lamprey that passed Bellows Falls
2004	59,461	8,418	14.2	3,668	43.6	---	---
2005	28,134	---	---	3,669	---	229	6.2
2006	17,636	3,005	17.0	2,895	96.3	261	9.0
2007	39,933	15,438	38.7	17,049	110.4	709	4.2
2008	57,049	32,035	56.2	22,434	70.0	2233	10.0
2009	18,996	8,296	43.7	1,532	18.5	100	6.5
2010	39,782	6,352	16.0	3,179	50.0	392	12.3
2011	19,136	2032	10.6	329	16.2	74	22.5
2012	14,089	4503	32.0	696	15.5	99	14.2
2013	22,092	6016	27.2	1,008	16.8	213	21.1
2014	22,136	5553	25.1	399	7.2	212	53.1
2015	22,245	8423	37.9	2,440	29.0	971	39.8
2016	35,249	15128	42.9	5,539	36.6	1619	29.2
2017	21,526	9,257	43.0	2,612	28.2	1,261	48.3
2018	10,238	4,010	39.2	3,124	77.9	162	5.2
2019	18,347	3,700	20.2	2,330	63.0	148	6.4
2020	33,739	17,525	51.9	7,292	41.6	2,142	29.4
Mean	**31,886**	**5,338**	**17.6**	**3,047**	**38.5[a]**	**370.8**	**14.6[a]**
Min	**14,089**	**210**	**0.8**	**5**	**2.4[a]**	**0**	**0.0[a]**
Max	**97,277**	**32,035**	**56.2**	**22,434**	**96.3[a]**	**2,233**	**53.1[a]**

Sources: CRASC (2020), FirstLight (2016b), TransCanada (2012a), FWS (2013a), FWS (2014a), FWS (2015), FWS (2016c) as modified by Great River Hydro

Note: --- = Data not reported, fish ladder not monitored, or fish ladder not operated.

a. Data for 1998, 2001, and 2007 excluded from mean, minimum, and maximum calculations.

American Eel

CRASC has not historically reported fish ladder counts for eel; however, active upstream eel passage efforts conducted at Holyoke since 2003 have resulted in collections and passage ranging from approximately 100 to a peak of 50,319 in 2014. In 2015 and 2016, respectively, 20,038 and 38,449 eels were actively passed upstream (Normandeau, 2017g).

At Turners Falls, visual surveys were conducted in 2014 to identify staging points for upstream migrating eels and to assess the feasibility of active upstream eel passage. An estimated 6,263 eels were observed, with 94 percent occurring in the Turners Falls Spillway Fishway (Kleinschmidt and Gomez and Sullivan, 2015). In 2015, FirstLight installed temporary eel ramp traps and passive traps resulting in the collection and passage of 5,972 eels (Kleinschmidt and Gomez and Sullivan, 2016c), approximately 30 percent of the Holyoke passage count for the same year.

At Vernon, visual surveys and passive trapping methods were used in Study 18 in 2015, 2016, 2017 and 2018 to investigate potential aggregation points. In 2015 only 80 eels were observed in the visual surveys, but 1,545 eels were also enumerated as passing upstream via the Vernon fish ladder in Study 17. That count reflected passage of approximately 26 percent of the Turners Falls passage and 8 percent of the Holyoke passage in the same year. Note, however, that the comparison of eels passing upstream by the Vernon fish ladder with passage as the result of active eel trap collections may not be appropriate. Video monitoring of fish ladder passage is likely inaccurate for recording eel passage, and the Turners Falls and Holyoke counts are specific to active eel passage efforts and do not incorporate any fishway passage. In 2016, visual surveys were again conducted at Vernon in Study 18, and a temporary eel ramp trap was installed. Seventy eels were visually observed, but CRASC (2016) reported only net downstream passage of eels at Vernon fish ladder. Only one eel was collected from the ramp trap which was operated only in late summer and fall. Visual surveys were continued in 2017 and 2018 with observations of 148 and 221 eels, respectively, mostly from locations within the fish ladder. The eel trap collected 123 fish in 2017 but was not installed in 2018. In that year, modifications were made to the ladder to restrict eels from entering non-passage areas and retarding their upstream movement. A telemetry study conducted in 2019 found that while some of the modifications were effective, most of the tagged eels passed into the fish ladder regulating pool rather than continuing though the upper section of the ladder. From the regulating pool eels circulated back to the fish ladder entrance. This recirculating pattern affects acurate video counting of eels in the ladder. These studies show that eels are finding the ladder for upstream passage but, for the most part, are not able to successfully navigate the length of the ladder.

Atlantic Salmon

For Atlantic Salmon, electrofishing studies conducted by VY from 1991 to 2011 yielded a total of one salmon upstream of Vernon dam and one salmon downstream of Vernon (in two different years) over the 21 years of surveys (Normandeau, 2012). As discussed in Section 3.6.1.4, *Migratory Species*, no Atlantic Salmon were collected in Study 10, and very few Atlantic Salmon were counted passing upstream in 2015 during Study 17 (one at Wilder, one at Bellows Falls, and six at Vernon). No salmon were counted in 2016 at any locations upstream of Holyoke where only three were counted (CRASC, 2016). Given the discontinuation of the salmon restoration program in the Connecticut River, there is no reason to consider cumulative effects. Further, Project fish ladders provide upstream passage and access to habitat so any future salmon population increases would presumably result in the reintroduction of the species to the Project areas.

Downstream Passage

American Eel

Cumulative effects may accrue for American Eels, some of which must pass multiple Projects on the Connecticut River during emigration, including Wilder, Bellows Falls, and/or Vernon as well as the downstream projects (Turners Falls and Holyoke). The Northfield Mountain intakes also pose a risk of impingement or entrainment to downstream migrating fish. As noted in Section 3.6.2.8, *Downstream Passage of Migratory Fish*, of the 170 eels released at all Projects in Study 19, 9 did not approach their intended Project (2 at Wilder, 1 at Bellows Falls, and 6 at Vernon). Cumulatively, of all available eels upstream of each Project, 22 did not approach Bellows Falls and 56 did not approach Vernon. The final fate of these eels is unknown and cannot be gleaned from any data collected in Study 19. It is possible that they moved into tributaries and did not migrate; their tags became dislodged; they died either before or after passage through one or more of the Projects and settled on the river bottom; or they were preyed upon by other fish or birds. Overall, 112 (65.9 percent) of the 170 eels released in Study 19 passed the Vernon Project.

Evaluation of cumulative effects of downstream projects on American Eel could not be conducted in full since the concurrent FirstLight study (Kleinschmidt and Gomez and Sullivan, 2017) excluded detection data for some tagged eels at Turners Falls which likely underestimates the number of eels that arrived at Turners Falls (see Section 3.6.2.8, *Downstream Passage of Migratory Fish, Vernon Project – American Eel*). Considering exclusion of some data, of the valid eel detections in the Turners Falls impoundment, 43 percent of eels were later detected in the Cabot Station tailrace (Kleinschmidt and Gomez and Sullivan, 2017). Eel downstream migration has also been investigated at Holyoke. In a study conducted in 2006, 84 percent of a small sample of tagged adult eels that reached the Holyoke study area passed the Holyoke project (Normandeau, 2007).

In 2015, Holyoke Gas & Electric Department constructed new downstream passage protection measures and a post-construction downstream eel telemetry study was conducted in 2017 to evaluate those facilities (Normandeau, 2018c). A total of 101 radio-tagged eels were monitored to determine passage route, timing, and estimated survival. Residence times (from entering the study area to Project passage) was short (<1 hour) regardless of route selection. The probability of passing via Hadley Falls Station/Holyoke dam was 73 percent and 27 percent for the Holyoke Canal System. Of the eels passing via the Hadley Falls Station/Holyoke dam, there was a 56 percent probability of turbine passage and 44 percent probability of bypass guidance. For eels within the canal system, the probability of downstream passage through the bypass was 71 percent as opposed to only 29 percent through the canal louver. The overall probability of post-passage survival through the Holyoke Project was 89-94 percent with higher probabilities for survival for bypass use (85-100 percent) than for turbine (86-89 percent) and eel passing the canal louver (86 percent).

Adult American Shad

Cumulative effects may accrue for downstream migrating adult American Shad after passing Vernon since they must also pass Turners Falls and Holyoke on their emigration. As noted in Section 3.6.2.8, *Downstream Passage of Migratory Fish, Vernon Project – Adult American Shad*, determination of the degree of downstream progress for adult shad following passage at Vernon is potentially influenced by factors including: injury and mortality associated with dam passage, natural mortality (i.e., predation, post-spawn effects, and body condition), and incidental tag loss. Given these limitations, 54.8 percent of adult shad that passed Vernon were later detected at Turners Falls. The concurrent FirstLight study reported that 82 percent of adult shad that entered the Turners Falls canal subsequently passed that project, and no tagged adult shad were entrained at the Northfield Mountain intakes (Kleinschmidt and Gomez and Sullivan, 2016a).

In 2016, Holyoke Gas & Electric Department conducted a downstream passage adult shad telemetry study to evaluate the newly constructed downstream passage protection facilities; however, results are not available at this time. Results from the Holyoke study will be included in an amended FLA if appropriate.

Juvenile American Shad

Cumulative effects may accrue for juvenile American Shad, some of which, after passing Vernon must pass multiple downstream projects on the Connecticut River (Turners Falls and Holyoke). As noted in Section 3.6.2.8, *Downstream Passage of Migratory Fish, Vernon Project – Juvenile American Shad*, the impact of predation on the downstream detection of radio-tagged juveniles cannot be quantified. In addition, the retention rate of externally attached radio tags for juvenile shad passing via any turbulent passage route (e.g., turbines, fish pipe, spill, etc.) is unknown.

Evaluation of cumulative effects of downstream projects on juvenile American Shad could not be conducted since the concurrent FirstLight study (Kleinschmidt et al., 2016) excluded detection data for some tagged juvenile shad at Turners Falls which likely underestimates the number of juvenile shad that passed Vernon and subsequently arrived at Turners Falls (see Section 3.6.2.8, *Downstream Passage of Migratory Fish, Vernon Project – Juvenile Shad*). In addition, FirstLight reported significant mortality, tag loss, and irregular swimming behavior in a control group of juvenile shad tagged in their concurrent study, rendering study results unreliable (Kleinschmidt et al., 2016). FirstLight plans to conduct additional downstream passage study for juvenile shad in 2017, and results from that study will be included in an amended FLA if appropriate.

In 2016, Holyoke Gas & Electric Department conducted a downstream passage juvenile shad telemetry study to evaluate the newly constructed downstream passage protection facilities; however, results are not available at this time. Results from the Holyoke study will be included in an amended FLA if appropriate.

3.6.3.2 Resident Fish, Mussels, Sediment Movement

In SD2, FERC identified the geographical extent of cumulative effects on resident fish species, freshwater mussels, and sediment movement to include the upper extent of the Wilder impoundment downstream to the Route 116 Bridge in Sunderland,[46] Massachusetts. FERC chose this geographic area because "the operation of the five Projects (the TransCanada [now Great River Hydro] and FirstLight Projects) could be a contributing factor to sediment movement within the river and cumulative effects on resident fisheries and freshwater mussel habitat in this area."

Based on the results of Studies 2–3 (see Section 3.4, *Geologic and Soil Resources*) and Study 6 (see Section 3.5.2.2, *Environmental Effects, Water Quality*), negligible effects will occur from normal Project operations on sediment movement or on levels of turbidity that might indicate sediment movement large enough to affect fish and aquatic species or their habitats downstream. Therefore, no cumulative effects on resident fish and mussels due to sediment movement from the Wilder, Bellows Falls, or Vernon Projects are likely.

3.6.4 Unavoidable Adverse Effects

Unavoidable adverse effects are those that may still occur after implementation of protection and mitigation measures. As discussed above, some adverse effects from normal Project operations will continue to occur under new licenses, including dewatering of some fish eggs or nests during the spawning season for some resident species and for migratory species, such as the Sea Lamprey. The level of adverse effects varies depending on the water year as suggested by Study 5 modeling output, but overall these effects are likely to be small for most fish and aquatic species and aquatic habitats. Some injury or mortality to downstream migrating American Eels and American Shad will continue to occur through impingement, entrainment, or turbine mortality.

46 From FERC SD2: The Route 116 Bridge is located at the approximate upstream extent of the Holyoke Project (FERC No. 2004) impoundment.

3.7 Terrestrial Resources

3.7.1 Affected Environment

The Connecticut River corridor within the Wilder, Bellows Falls, and Vernon Projects provides terrestrial habitat for a variety of terrestrial species. The "terrestrial study area" is defined as lands with flowage easements retained by Great River Hydro, lands owned in fee by Great River Hydro, the Project-affected riverine reaches downstream of each dam, plus a 200-foot buffer (Figure 3.7-1). The terrestrial study area extends from the upper extent of the Wilder impoundment to about 1.5 miles below Vernon dam and encompasses approximately 9,200 acres.

As part of the relicensing process, several studies were conducted to gather information necessary to understand the potential effects of the Wilder, Bellows Falls, and Vernon Projects and associated WSE fluctuations on terrestrial resources. These studies included:

- Jesup's Milk Vetch Hydrologic Study (Normandeau, 2013b);
- Rare, Threatened, and Endangered Plant and Exemplary Natural Community Assessment (Normandeau, 2013c);
- ILP Study 25, Dragonfly and Damselfly Inventory and Assessment;
- ILP Study 26, Cobblestone and Puritan Tiger Beetle Survey;
- ILP Study 27, Floodplain, Wetland, Riparian, and Littoral Vegetation Habitats;
- ILP Study 28, Fowler's Toad Survey; and
- ILP Study 29, Northeastern Bulrush Survey.

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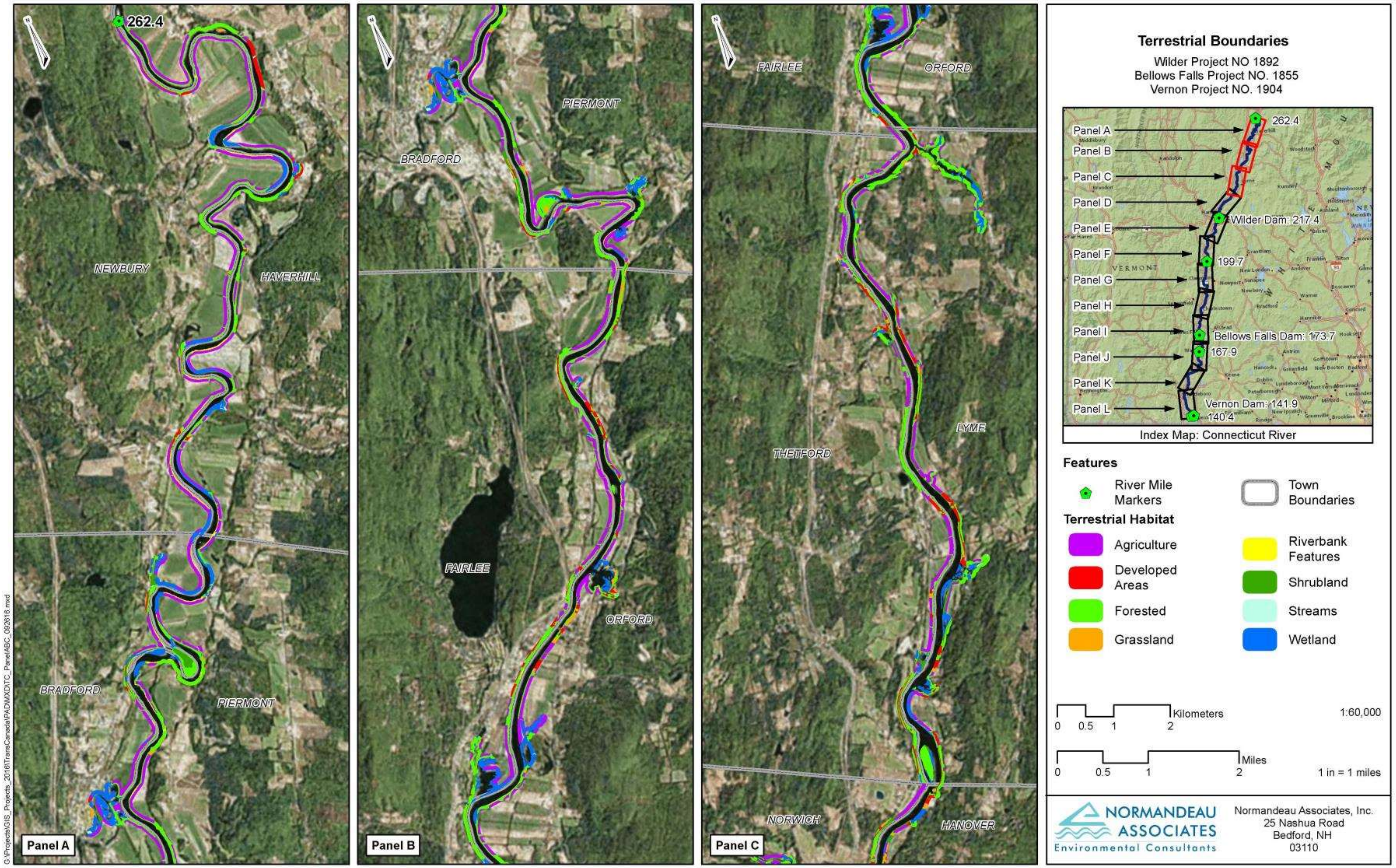

Source: ILP Study 27, *Floodplain, Wetland, Riparian, and Littoral Vegetation Habitats Study*

Figure 3.7-1. Terrestrial study area.

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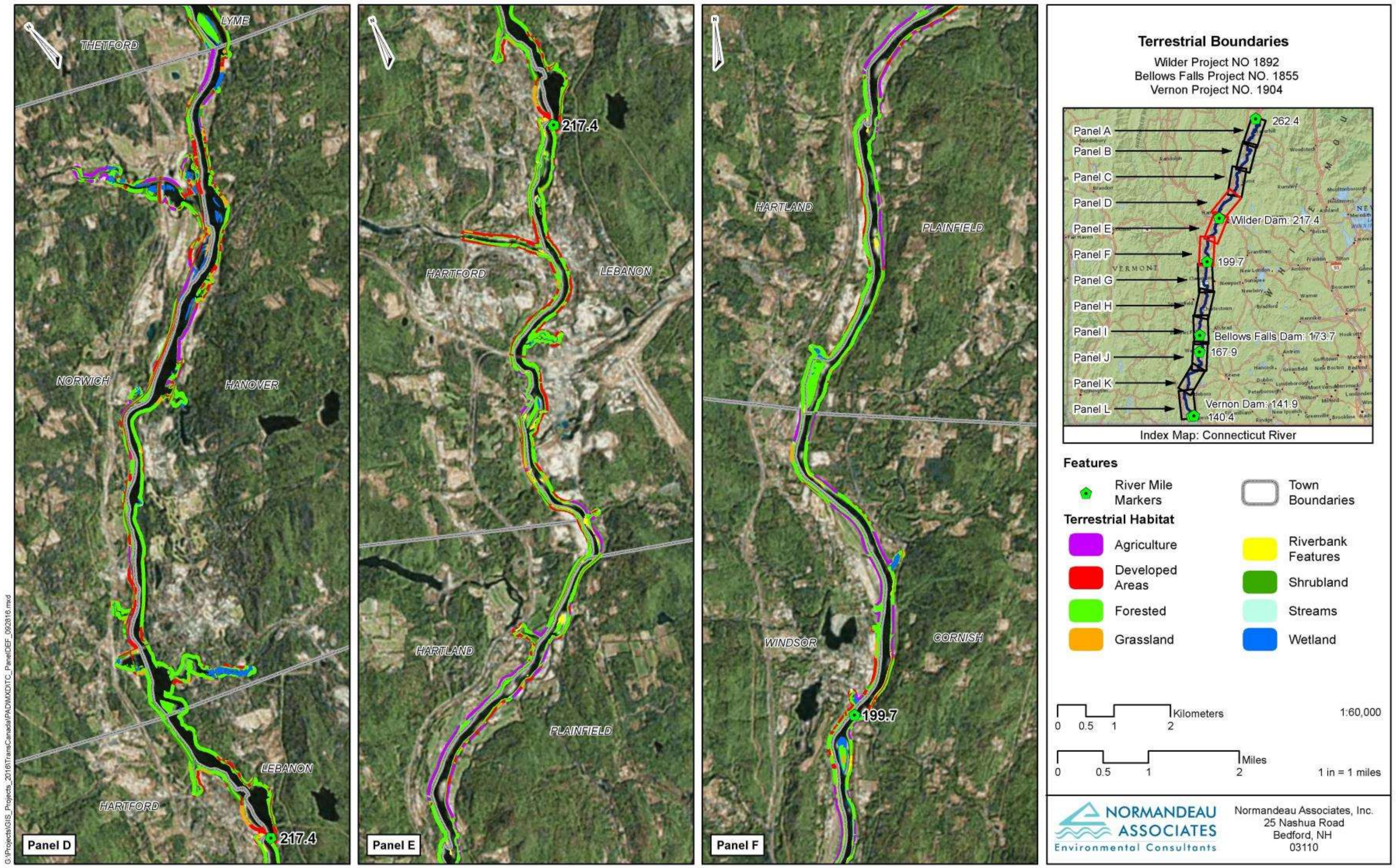

Source: ILP Study 27, *Floodplain, Wetland, Riparian, and Littoral Vegetation Habitats Study*

Figure 3.7-1. Terrestrial study area (continued).

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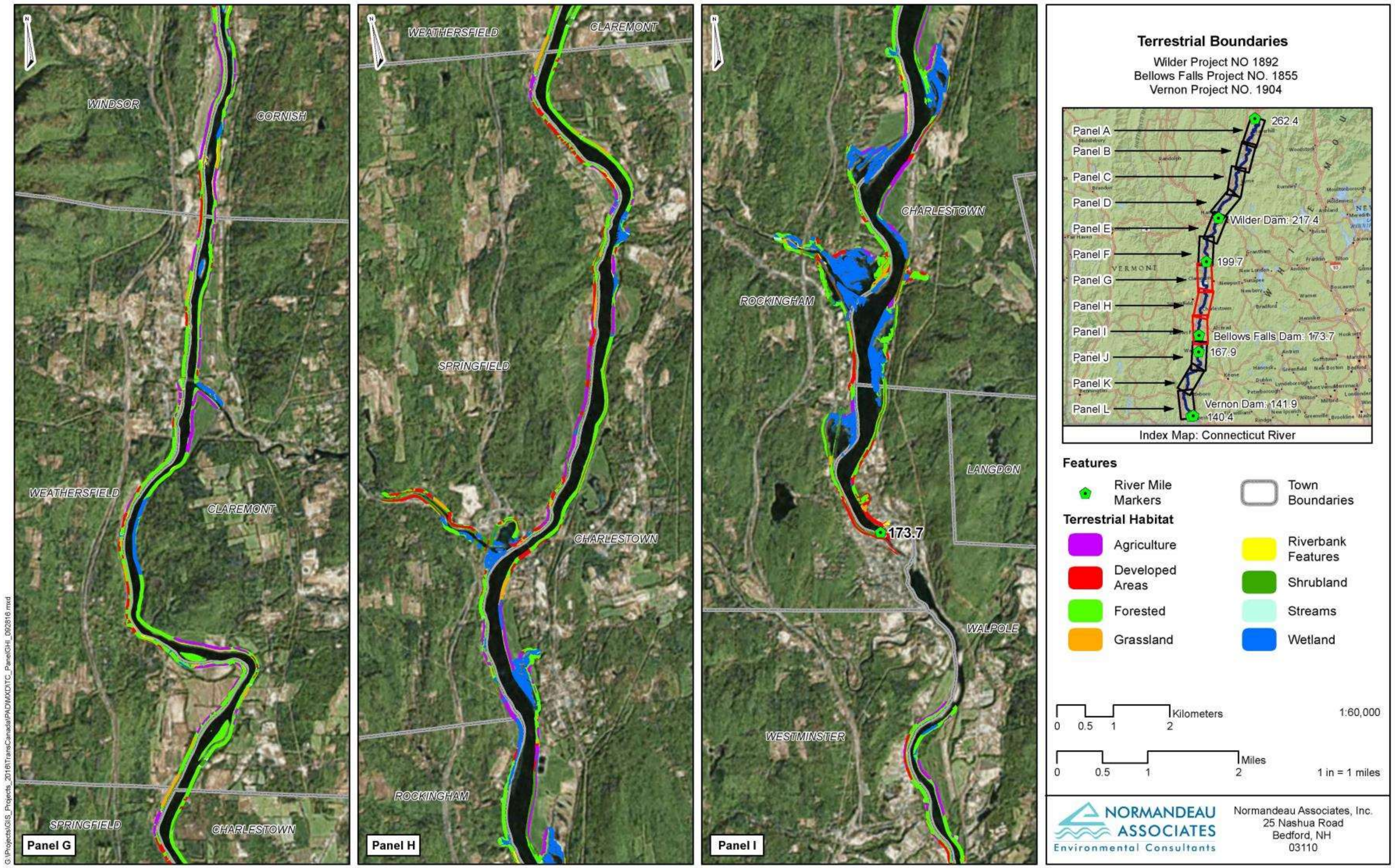

Source: ILP Study 27, *Floodplain, Wetland, Riparian, and Littoral Vegetation Habitats Study*

Figure 3.7-1. Terrestrial study area (continued).

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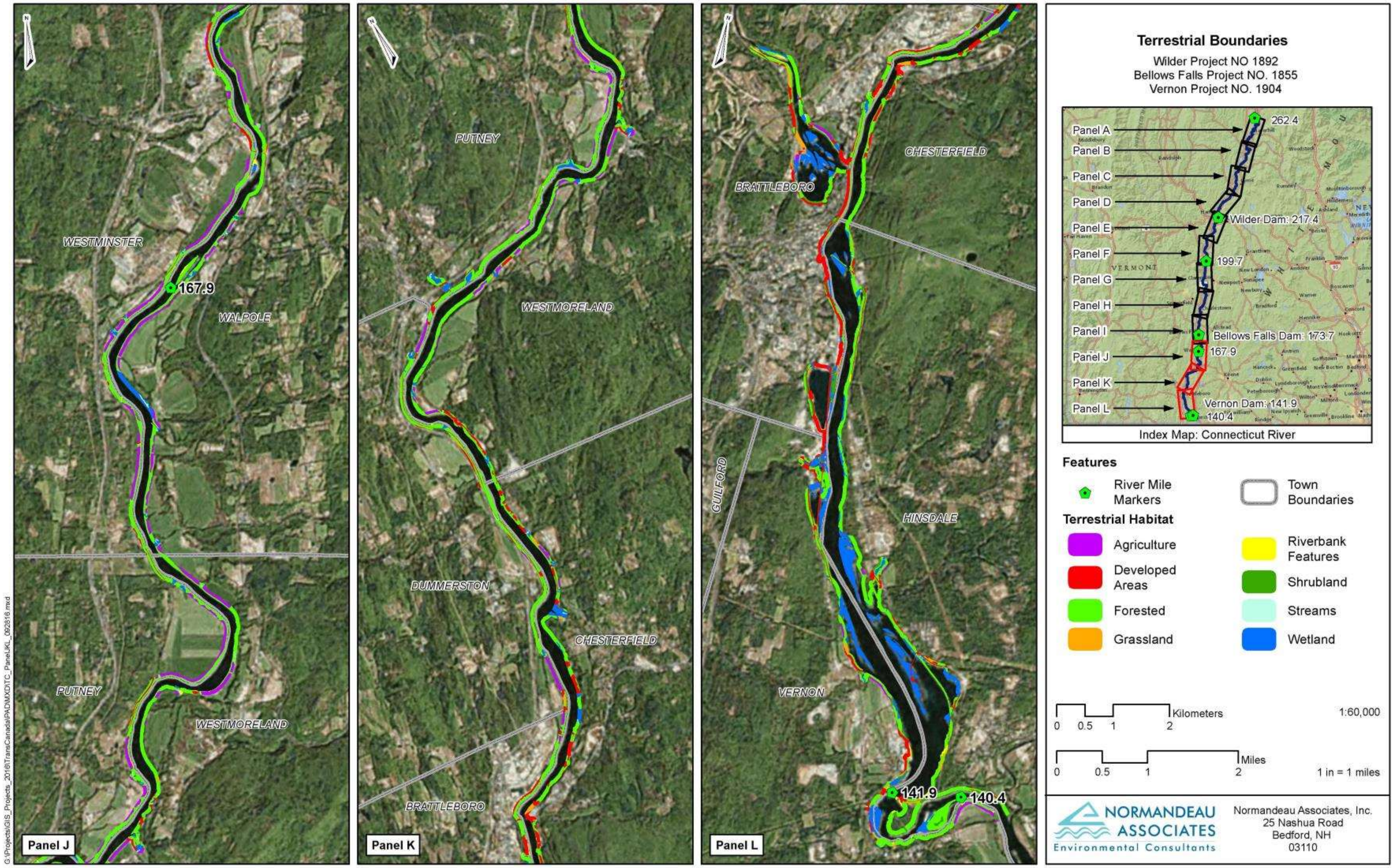

Source: ILP Study 27, *Floodplain, Wetland, Riparian, and Littoral Vegetation Habitats Study*

Figure 3.7-1. Terrestrial study area (continued).

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3.7.1.1 Botanical Resources

The terrestrial study area supports a variety of vegetative cover types and a diversity of land uses. To quantify and properly describe the available habitat within the terrestrial study area, land use and vegetative cover types were mapped as part of Study 27. Vegetation cover type boundaries were digitized from aerial photos using stereo imaging software. Because aquatic vegetation was not visible at the time of the imagery flight, aquatic beds were mapped from true-color orthophotographs (U.S. Department of Agriculture, 2009) and refined during field work. During photointerpretation, other resources were referenced for supporting information, including hydric soil maps, National Wetlands Inventory (NWI) maps, hydrology maps, topographic maps, and additional publicly available aerial photographs, as needed, to confirm features.

Upland vegetation cover is predominantly forest (64 percent of the upland cover) followed by agricultural land (29 percent of the upland cover) (Table 3.7-1). Agricultural use, primarily cropland and pasture/hayfield, is the predominant cover type over much of the more level terrain adjacent to the river, especially along the Wilder impoundment. Wetlands are widely distributed across the terrestrial study area with the majority consisting of aquatic vegetation (43 percent of the wetland cover), emergent (25 percent of the wetland cover), deciduous forested (22 percent of the wetland cover), and scrub-shrub (10 percent of the wetland cover) cover types.

Upland Forest

Upland and Riparian Hardwood

The upland hardwood canopy component includes a relatively homogenous group of trees dominated by sugar maple, northern red oak, American beech, and basswood. Shrubs are generally sparse except for the invasive species glossy buckthorn and bush honeysuckle at a few sites. However, the herbaceous component of the forests is diverse and includes wild-lily-of–the-valley, wild sarsaparilla, white wood aster, rough horsetail, hog peanut, and a variety of fern species.

Riparian hardwood forest differs from upland hardwood forest primarily with respect to plant species and the potential for flooding. Typical dominant canopy species for this cover type include silver maple, eastern cottonwood, slippery elm, green ash, and boxelder. Bush honeysuckle and glossy buckthorn are common in the understory, and cinnamon fern, Japanese knotweed, ostrich fern, and rough horsetail are abundant in the herbaceous layer. These forests are likely to flood on a seasonal or annual basis. As evidence of the river's influence on these communities, fine litter is replaced by alluvial sediment deposits in areas subject to periodic flooding. Coarse litter is abundant in the form of trees, limbs, and other debris washed in during high water events.

The results of Study 27 indicate that the majority of the upland hardwood forests in the terrestrial study area are at a mid-successional stage. They are dominated by trees at an intermediate age and height but include a few large trees and a limited shrub and sapling layer. The canopy reaches heights of 60 to 90 feet, and canopy closures range from 60 to 90 percent. Most of the upland hardwood forest is relatively high in elevation and shows little evidence of flood scour or deposition.

Upland hardwood forest is the predominant cover type in the terrestrial study area covering 24 percent of the entire terrestrial study area, and it is most abundant within the Vernon impoundment (812 acres, 33 percent of the combined Vernon impoundment and short riverine reach; see Table 3.7-1).

Mixed Hardwood/Softwood Forest

The upland mixed forest canopy includes both hardwood and softwood components. White pine and eastern hemlock make up the softwood component of the canopy, and the hardwoods are predominantly northern red oak and sugar maple. The understory is generally lacking in shrubs with the exception of glossy buckthorn and witch hazel, and the herbaceous layer is diverse but sometimes sparse or patchy. Frequently occurring herbaceous species include poison ivy and a variety of fern species.

Results of Study 27 indicate that most of the mixed forests are at a mid-successional stage. They are dominated by trees at an intermediate age and height but include a few large trees and a limited shrub and sapling layer. Canopy species reach heights of 80 to 100 feet, and canopy closures range from 60 to 90 percent. Fine litter includes up to several inches of leaves, and coarse litter ranges from a few to many deadfalls and downed limbs. Nearly all of this cover type is located on higher elevation terraces and slopes with little evidence of flood scour or deposition.

Upland mixed forest is common throughout the area covering 10 percent of the terrestrial study area. However, it is most abundant in the reach encompassing the Wilder impoundment and the free flowing section of the river downstream of Wilder dam (see Table 3.7-1).

Softwood Forest

Softwood forest is dominated by eastern hemlock and white pine, but often includes a variety of common hardwood species, such as northern red oak, red maple, and sugar maple. Because of the dense canopy cover, the understory and herbaceous layers remain very sparse. In the terrestrial study area, most softwood forests are at a medium successional stage with most trees at an intermediate age and height, a few large trees, and a limited shrub and sapling layer. Canopy species reach heights of 60 to 100 feet, and canopy closures are 80 percent or higher. Fine litter is composed of several inches of leaves, and coarse litter ranges from a few to many deadfalls and downed limbs.

The results of Study 27 indicate that most softwood forests in the area occur on steep slopes and terraces with little evidence of flood scour or deposition. Softwood forest is very abundant along the periphery of the Wilder impoundment (328 acres, 10 percent of that area; see Table 3.7-1). The largest expanse of this cover type is along the eastern side of the impoundment between the dam and Hanover, New Hampshire (see Figure 3.7-1).

Grassland and Agricultural Lands

Agricultural uses, which are primarily cropland and pasture/hayfield, are the predominant cover type over the level terrain adjacent to the river, especially along the Wilder impoundment. When combined, the cover types pasture/hayfield, crop, maintained grassland, and old field make up 20 percent (1,821 acres) of the upland cover in the terrestrial study area (see Table 3.7-1).

Wetlands

Palustrine wetlands include all non-tidal freshwater wetlands dominated by trees, shrubs, persistent emergent vegetation, emergent mosses, or lichens (Cowardin et al., 1979). They offer a variety of habitat types for wildlife from vegetated beaver ponds to open marshes to vernal pools. Wetland habitats cover 1,211 acres or 23 percent of the terrestrial study area (see Table 3.7-1). Palustrine cover types occurring in these areas are divided into four basic sub-categories: aquatic vegetation, emergent wetland, scrub-shrub wetland, and forested wetland.

Aquatic Vegetation

The aquatic vegetation cover type is the most abundant wetland cover type, covering 903 acres (see Table 3.7-1). Aquatic beds are typically composed of floating and submerged aquatic vegetation and grow abundantly in shallow water zones in the lower ends of all three impoundments, as well as in the mouths of the larger tributaries. Aquatic bed vegetation also occurs in the upper reaches of the impoundments in small patches and narrow discontinuous bands in shallow water along the edges of the river, many of which were too small to map. Most species are found in all three impoundments, and many of the same species predominate in the three impoundments including white water lily, Eurasian water-milfoil, water celery, waterweed, and water stargrass.

Aquatic vegetation is typically found in silty-sandy substrates, and vegetative cover varies from dense floating and mid-column cover with 100 percent canopy closure to relatively sparse cover with little or no floating-leaved canopy. Species composition varies between areas and is influenced by factors such as water depth and water current. For example, during Study 27, white water lily was usually found in more protected areas with slower currents and shallow depths, whereas water celery grew abundantly in areas with faster currents and to observed water depths of up to 8 feet.

Emergent Wetlands

Emergent wetlands are characterized by the presence of herbaceous hydrophytes for most of the growing season. These wetlands are often referred to as marshes, meadows, or fens. In the terrestrial study area, the largest emergent wetland stands are vegetated by dense stands of broad-leaved cattail and softstem bulrush. Other dominant emergent species include rice cutgrass, woolgrass, American bur-reed, water-horsetail, narrow-leaf cattail, pickerel weed, duck potato, and numerous sedges. Invasive non-native wetland species, such as reed canary grass, purple loosestrife, and Phragmites, are also abundant (see Section 3.7.1.2, *Invasive Plant Species*).

Emergent wetlands in the area are typically located within 1 foot of estimated high water levels and are typically saturated or subject to frequent flooding. Water stains on the stems indicate that these marshes are periodically inundated from 6 to 18 inches. Emergent marshes are the most abundant wetland cover type in the terrestrial study area (PEM and PEM5 coverages combined make up 43 percent of the combined Projects' wetland habitat; see Table 3.7-1). They are located in coves, protected shorelines, old river channels, and deltas at the mouths of tributaries. Emergent wetlands in the Wilder impoundment are located primarily in the upstream reach from the vicinity of Fairlee, Vermont, to Bradford, Vermont (see Figure 3.7-1). At Bellows Falls, which accounts for nearly 50 percent of the terrestrial study area total for this cover type (see Table 3.7-1), large expanses of emergent wetlands are present in the lower third of the impoundment (see Figure 3.6-1). In the Vernon impoundment, emergent wetlands are found primarily in the broad delta at the mouth of the West River and downstream of Brattleboro (see Figure 3.7-1).

Scrub-Shrub Wetlands

Scrub-shrub wetlands are dominated by woody vegetation less than 20 feet tall. In the terrestrial study area, the scrub-shrub cover is dominated by the invasive non-native glossy buckthorn. However, speckled alder, black willow, and silky dogwood are also common. Canopy height ranges from 6 to 20 feet, and canopy cover ranges widely from 20 to 100 percent. The overall herbaceous component is relatively diverse and consists of species such as wrinkled goldenrod, jewelweed, false nettle, cleavers, common horsetail, meadow horsetail, climbing nightshade, giant goldenrod, sensitive fern, and ostrich fern. Structural diversity and patchiness are low in areas of dense shrub cover but moderate to high in the vegetative communities with more open cover enabling robust herbaceous growth.

Scrub-shrub wetlands in the terrestrial study area are frequently located slightly higher in elevation than emergent marshes, but they still experience frequent inundation as exhibited by multiple debris lines and water stains on lower trunks and leaves. In larger coves, the scrub-shrub cover type often forms a band between emergent marshes and the upland or forested wetland.

Scrub-shrub wetlands make up 14 percent of wetland habitat in the terrestrial study area (170 acres; combined PSS and PSS/PEM cover types in Table 3.7-1). The distribution of scrub-shrub wetlands is similar across all three impoundments and occurs in backwaters, along shorelines, on islands and peninsulas, and in the lower reaches of tributaries. Scrub-shrub wetlands are found throughout the Wilder impoundment but primarily in the lower half of the Bellows Falls and Vernon impoundments (see Figure 3.7-1).

Forested Wetlands

Forested wetlands are dominated by deciduous woody vegetation greater than 20 feet tall throughout the terrestrial study area. Eastern cottonwood, silver maple, boxelder, green ash, and slippery elm are prominent in the overstory and understory. Ostrich fern, sensitive fern, jewelweed, rough horsetail, and Canada nettle are abundant in the herbaceous layer. In addition, non-native invasive plants such as glossy buckthorn, stilt grass, and Japanese knotweed were noted at some locations during terrestrial habitat mapping and field work for Study 27.

Deciduous forested wetlands in the terrestrial study area are at an early to mid-successional stage. Canopy species reach heights of 60 to 80 feet, and canopy closure ranges widely from 30 to 80 percent. Structural diversity is generally moderate, patchiness is low, and fine litter consists of leaves and herbaceous plant debris. Coarse litter is common and includes deadfalls and downed limbs as well as woody debris and herbaceous material deposited as debris. Although some deciduous forested wetlands appear to experience periodic inundation, many are located at high elevations and flood less frequently.

Deciduous forested wetlands are the second-most abundant wetland cover type in the terrestrial study area (415.3 acres, 4.54 percent of combined areas; see Table 3.7-1). These wetlands are evenly distributed across the three impoundments and are generally found in medium to large tracts in backwaters, along point bars, and in the lower reaches of tributaries. Deciduous forested wetlands are found in the upper reaches of the Wilder impoundment, largely in the lower part of the Bellows Falls impoundment, and throughout the Vernon impoundment (see Figure 3.7-1).

Table 3.7-1. Acreages of cover types within the 200-foot terrestrial study area.

Cover Code	Cover type	Wilder	Wilder Riverine	Bellows Falls	Bellows Falls Riverine	Vernon[a]	Total Acres	Percent of Terrestrial Study Area
Upland								
H	Hardwood	486.3	379.2	469.8	59.1	812.1	2206.4	24.1
H/S	Hardwood/softwood	364.3	134.9	193.9	5.7	235.3	934.2	10.2
S	Softwood	328.2	61.7	69.1	1.2	48.1	508.2	5.6
SHR	Shrub	126.6	12.2	84.3	6.6	40.9	270.6	3.0
H/SHR	Hardwood/shrub	3.1	5.2	0.4	0.6	6.1	15.3	0.2
SHR/G	Shrub/grassland	0	0	0	0	0	0	0.0
OLD FIELD	Old field	21.2	3.5	15.3	0	2.9	42.9	0.5
GRASS	Maintained grassland	62.0	19.9	43.5	1.2	34.2	160.8	1.8
CROP	Crop	597.3	146.2	188.9	17.6	215.9	1166.0	12.7
PASTURE	Pasture/hayfield	307.8	15.3	74.6		53.4	451.2	4.9
	Total	**2296.8**	**778.1**	**1139.8**	**92.0**	**1448.9**	**5755.6**	**62.9**
Wetland								
PFO1	Deciduous forested	141.3	7.7	142.2		124.1	415.3	4.5
PFO4	Coniferous forested	0.7	0	0	0	0	0.7	< 0.1
PFO1/4	Mixed forested	5.3	0	0.4	0	3.6	9.3	0.1
PFO1/PSS	Deciduous forested/shrub	1.7	0	26.8	0	7.6	36.0	0. 4
PFO1/PEM	Deciduous forested/ emergent	0	0	1.0	0	0.7	1.7	< 0.1
PSS	Scrub-shrub	48.3	1.8	35.3	0	33.9	119.3	1.3
PSS/PEM	Scrub-shrub/emergent	25.6	0.6	16.1	0	7.9	50.3	0. 6
PEM	Emergent	133.1	4.7	241.0	0	108.2	486.9	5.3
PEM5	Phragmites	7.3	0	4.7	0	22.8	34.8	0.4
PERENN	Perennial stream	7.1	1.9	4.6	0.7	10.9	25.2	0.3
INTERMIT	Intermittent stream	1.2	0.4	1.9	0	2.1	5.6	0.1
PUB	Pond	11.6	0	3.7	0	7.1	22.4	0.3
PVP	Possible vernal pool	0.5	0.3	1.3	0	1.5	3.6	< 0.1

Cover Code	Cover type	Wilder	Wilder Riverine	Bellows Falls	Bellows Falls Riverine	Vernon[a]	Total Acres	Percent of Terrestrial Study Area
PAB/RAB	Submerged aquatic vegetation	318.0	0	258.3	0	326.9	903.2	9.9
	Total	**701.7**	**17.4**	**737.3**	**0.7**	**657.3**	**2114.3**	**23.1**
Developed								
Comm	Commercial	47.5	47.4	31.3	24.1	73.4	223.7	2.4
Res	Residential	135.5	36.6	108.9	1.0	81.7	363.6	4.0
Sub	Suburban	0	0	9.3	0	19.2	28.5	0.3
Mineral/dams	Dams	1.4	25.8	3.4	0	2.1	32.8	0.36
Infra	Infrastructure	154.6	70.9	89.6	17.0	129.1	461.3	5.04
	Total	**339.0**	**180.7**	**242.5**	**42.1**	**305.5**	**1109.9**	**12.1**
Riverine Features								
Ledge	Bedrock ledge	0.2	4.1	0.5	20.1	2.1	26.9	0.29
Rocky	Rocks and boulders	0.4	3.1	0.2	0	1.9	5.6	0.06
Gravel	Gravel	0.3	19.0	1.9	6.8	3.5	31.6	0.34
Sand-mud	Sand-mud	0.9	27.3	2.7	0	10.3	41.1	0.45
Riverbank	Riverbank	9.2	4.5	18.9	0	5.7	38.3	0.42
Eroding bank	Eroding bank	20.9	0	7.2	0	1.4	29.5	0.32
Riprap	Riprap	0.3	0.2	0	0	0.3	0.9	0.01
	Total	**32.2**	**58.2**	**31.4**	**26.9**	**25.2**	**173.9**	**1.9**
	Grand Total	**3369.4**	**1034.5**	**2150.9**	**161.8**	**2437.0**	**9153.6**	**100.0**
	Percent of Total	**36.8**	**11.3**	**23.5**	**1.8**	**26.6**	**100.0**	

Source: ILP Study 27, *Floodplain, Wetland, Riparian, and Littoral Vegetation Habitats Study, Report Supplement*

a. Includes Vernon impoundment and 1.5 miles below Vernon dam.

3.7.1.2 Invasive Plant Species

Invasive plant species are very prevalent throughout the Connecticut River Valley, as indicated by the Invasive Species Atlas (IPANE, 2016), and have been observed in abundance along the banks and in most vegetation communities within the terrestrial study area. Twenty-seven plant species designated as invasive, non-native species and one additional plant considered potentially invasive were documented in the terrestrial study area during Study 27 habitat mapping and during the 2012 rare species and exemplary community survey (Normandeau, 2013c). More than 163 acres of discrete stands of invasive plants were mapped as part of Study 27. The majority of species occur along more than one impoundment (Table 3.7-2).

Table 3.7-2. Invasive plant species observed in the terrestrial study area.

Common Name	Location	Growth Form	Special Status NH/ VT [b,c,d]
Climbing nightshade *Solanum dulcamara*	Vernon, Wilder	Herb	
Black locust *Robinia pseudoacacia*	Vernon	Tree	Restricted
Brittle naiad *Najas minor*	Bellows, Wilder	Submerged Aquatic	None / Class B
Bush honeysuckles *Lonicera sp.*	All impoundments	Shrub	Prohibited / Class B
Canada bluegrass[a] *Poa compressa*	Entire study area	Forb	
Coltsfoot *Tussilago farfara*	Bellows	Herb	
Common buckthorn *Rhamnus cathartica*	Vernon, Wilder	Tree	Prohibited / Class B
Phragmites *Phragmites australis*	All impoundments	Forb	None / Class B
Crown-vetch[a] *Securigera varia*	Wilder	Herb	Restricted
Dame's rocket *Hesperis matronalis*	Wilder riverine	Herb	Prohibited
Eurasian water-milfoil *Myriophyllum spicatum*	All impoundments	Submerged Aquatic	Class B
Forget-me-not *Myosotis sp.*	All impoundments	Herb	

Common Name	Location	Growth Form	Special Status NH/ VT [b,c,d]
Garden loosestrife[a] *Lysimachia vulgaris*	Entire study area	Herb	
Glossy buckthorn *Rhamnus frangula (Frangula alnus)*	All impoundments	Shrub	Prohibited / Class B
Japanese barberry *Berberis thunbergii*	All impoundments	Shrub	Prohibited / Class B
Japanese knotweed *Polygonum cuspidatum (Fallopia japonica)*	All impoundments	Herb	Prohibited / Class B
Japanese stilt grass *Microstegium vimineum*	Wilder riverine	Forb	Prohibited
Mile-a-minute vine *Polygonum perfoliatum*	All impoundments	Vine	Prohibited
Moneywort *Lysimachia nummularia*	Vernon, Bellows	Herb	Restricted
Multiflora rose *Rosa multiflora*	All impoundments	Shrub	Prohibited
Oriental bittersweet *Celastrus orbiculatus*	All impoundments	Vine	Prohibited / Class B
Purple loosestrife *Lythrum salicaria*	All impoundments	Herb	None / Class B
Reed canary grass *Phalaris arundinacea*	All impoundments	Forb	Restricted
Russian olive *Elaeagnus angustifolia*	Wilder	Shrub	Restricted
Spotted knapweed *Centaurea biebersteinii*	Vernon	Herb	Prohibited
Swallow-wort[a] *Cynanchum sp.*	Entire study area	Vine	Prohibited / Class A (pale); Class B (black)
Winged euonymus (Burning bush) *Euonymus alatus*	Vernon	Shrub	Prohibited / Class B
Yellow flag iris *Iris pseudacorus*	All impoundments	Herb	Prohibited / Class B

Source: IPANE (2016), ILP Study 27, *Floodplain, Wetland, Riparian, and Littoral Vegetation Habitats*

a. Observed in the study area during the 2012 rare, threatened, and endangered plant and exemplary natural community field surveys (Normandeau, 2013c).
b. New Hampshire Department of Agriculture "Watch List" (NHDA, 2015).
c. New Hampshire Department of Agriculture List of Prohibited Species (NHDA, 2012).
d. Vermont Agency of Agriculture, Food & Markets (VAAFM, 2012).

Japanese knotweed is the most widespread invasive species. Dense stands were mapped along the shoreline and on islands and in a variety of habitats, and 79 acres were verified in the field in the terrestrial study area (Table 3.7-3). It is common along the edges of agricultural fields bordering the river, on riverbanks, and disturbed slopes. It also occurs as discrete smaller patches within larger, typically forested plant communities.

Approximately 35 acres of Phragmites-dominated scrub-shrub and emergent wetland cover were mapped in the terrestrial study area (Table 3.7-3). This species forms clonal stands in herbaceous wetlands, frequently forming dense monocultures to the exclusion of native species. These larger stands are most prevalent in the extensive emergent wetlands found in the lower reaches of the Vernon impoundment. Approximately two-thirds of the Phragmites found in the terrestrial study area occur at Vernon (22.8 acres) with lesser amounts and smaller stands in the Wilder (7.3 acres) and Bellows Falls (4.7 acres) portions of the terrestrial study area. Smaller stands are common in the middle reaches of Bellows Falls and Vernon impoundments. This species is relatively uncommon on riverine reaches.

A well-defined stand of Japanese barberry (1.8 acres) was mapped on Stebbins Island below Vernon dam. Otherwise this species was common but diffuse in the understory in many forested areas. Other species such as glossy buckthorn, oriental bittersweet, non-native honeysuckles and purple loosestrife composed the remaining 49 acres in Table 3.7-3. These species typically occurred in varying combination with each other and native species; therefore, they were grouped together in the table as "other." Frequent combinations included oriental bittersweet, bush honeysuckles and multiflora rose on riverbanks; glossy buckthorn, honeysuckles and purple loosestrife in scrub-shrub wetlands; and purple loosestrife and reed canary grass in emergent wetlands. Similar to Japanese barberry, these species also were found in low densities (not quantified) in many habitats in the Project area. Acreages of aquatic invasives were not defined because they were usually intermixed with native species and could not be reliably separated.

Table 3.7-3. Distribution and extent (acres) of mapped invasive species by Project.

Study Area	Japanese Knotweed	Phragmites	Other	Total
Wilder impoundment	25.6	7.3	32.4	65.3
Wilder riverine	12.0	0	0	12.0
Bellows Falls impoundment	19.4	4.7	11.6	35.7
Bellows Falls riverine	19.0	0	1	20.0
Vernon impoundment	3.0	22.8	2.4	28.2
Below Vernon	0	0	1.8	1.8
Total	79	34.8	49.2	163

Source: ILP Study 27, *Floodplain, Wetland, Riparian, and Littoral Vegetation Habitats*

3.7.1.3 Wildlife Resources

During the relicensing studies listed in the beginning of this section, a total of 87 species of wildlife was recorded as incidental observations in Study 27 and occasionally during species-specific surveys in other terrestrial studies. Table 3.7-4 provides a complete list of wildlife species observed; **bolded** species in the table are typically associated with wetlands or open waters in the Northeast.

Table 3.7-4. Wildlife species observed during ILP studies, 2012–2015.

Common Name	Scientific Name
Amphibians/Reptiles	
American bullfrog	***Lithobates catesbeianus***
American toad	***Anaxyrus americanus***
Common snapping turtle	***Chelydra serpentina***
Fowler's toad	***Bufo fowleri***
Gray tree frog	***Hyla versicolor***
Green frog	***Lithobates clamitans melanota***
Spring peeper	***Pseudacris crucifer***
Wood frog	***Lithobates sylvaticus***
Mammals	
American beaver	***Castor canadensis***
Eastern gray squirrel	*Scirius carolinensis*

Common Name	Scientific Name
Mink	***Mustela vison***
Muskrat	***Ondatra zibethicus***
Opossum	*Didelphis virginiana*
Red fox	*Vulpes*
Red squirrel	*Sciurus vulgaris*
White-tailed deer	*Odocoileus virginianus*
Birds	
American crow	*Corvus brachyrhynchos*
American goldfinch	*Spinus tristis*
American kestrel	*Falco sparvarious*
American redstart	*Setophaga ruticilla*
American robin	*Turdus migratorius*
American woodcock	*Scolopax minor*
Bald eagle	***Haliaeetus leucocephalus***
Bank swallow	***Riparia***
Barn swallow	*Hirundo rustica*
Belted kingfisher	***Megaceryle alcyon***
Black-and-white warbler	*Mniotilta varia*
Blackburnian warbler	*Setophaga fusca*
Black-capped chickadee	*Poecile atricapillus*
Black-throated blue warbler	*Setophaga caerulescens*
Black-throated green warbler	*Setophaga virens*
Blue jay	*Cyanocitta cristata*
Blue-headed vireo	*Vireo solitarius*
Bobolink	*Dolichonyx oryzivorus*
Broad-winged hawk	*Buteo platypterus*
Brown creeper	*Certhia americana*
Brown-headed cowbird	*Molothrus ater*
Canada goose	***Branta canadensis***
Cedar waxwing	*Bombycilla cedrorum*
Chestnut-sided warbler	*Setophaga pensylvanica*
Common merganser	***Mergus merganser***

Common Name	Scientific Name
Common nighthawk	***Chordeiles minor***
Common raven	*Corvus corax*
Common yellowthroat	*Geothlypis trichas*
Double-crested cormorant	***Phalacrocorax auritus***
Downy woodpecker	*Picoides pubescens*
Eastern kingbird	*Tyrannus*
Eastern phoebe	*Sayornis phoebe*
Eastern wood-pewee	*Contopus virens*
European starling	*Sturnus vulgaris*
Fish crow	*Corvus ossifragus*
Gray catbird	*Dumetella carolinensis*
Great blue heron	***Ardea herodias***
Great crested flycatcher	*Myiarchus crinitus*
Great egret	***Ardea alba***
Green heron	***Butorides virescens***
Hairy woodpecker	*Picoides villosus*
Hermit thrush	*Catharus guttatus*
House wren	*Troglodytes aedon*
Killdeer	*Charadrius vociferus*
Mallard	***Anas platyrhynchos***
Mourning dove	*Zenaida macroura*
Northern cardinal	*Cardinalis*
Northern flicker	*Colaptes auratus*
Northern waterthrush	*Parkesia noveboracensis*
Osprey	***Pandion haliaetus***
Ovenbird	*Seiurus aurocapilla*
Peregrine falcon	*Falco peregrinus*
Pileated woodpecker	*Dryocopus pileatus*
Red-bellied woodpecker	*Melanerpes carolinus*
Red-eyed vireo	*Vireo olivaceus*
Red-tailed hawk	*Buteo jamaicensis*
Red-winged blackbird	***Agelaius phoeniceus***

Common Name	Scientific Name
Rock dove	*Columba livia*
Rose-breasted grosbeak	*Pheucticus ludovicianus*
Rough-legged hawk	*Buteo lagopus*
Ruby-throated hummingbird	*Archilochus colubris*
Scarlet tanager	*Piranga olivacea*
Song sparrow	*Melospiza melodia*
Spotted sandpiper	***Actitis macularius***
Tree swallow	*Tachycineta bicolor*
Turkey vulture	*Cathartes aura*
Veery	*Catharus fuscescens*
Wild turkey	*Meleagris gallopavo*
Winter wren	*Troglodytes hiemalis*
Wood duck	***Aix sponsa***
Wood thrush	*Hylocichla mustelina*
Yellow-bellied flycatcher	*Empidonax flaviventris*

Sources: ILP Study 25, *Dragonfly and Damselfly Inventory and Assessment*; ILP Study 26, *Cobblestone and Puritan Tiger Beetle Survey*; ILP Study 27, *Floodplain, Wetland, Riparian, and Littoral Vegetation Habitats Study*; and ILP Study 28, *Fowler's Toad Survey*

Reptiles and Amphibians

American toads, spring peepers, green frogs, and bullfrogs were observed or heard in most of the quieter waters with emergent wetlands and aquatic beds. These regular incidental observations were made during field work for ILP Studies 25, 26, and 27. In addition, the field work for Study 28 included both standard call surveys and acoustic monitoring targeting Fowler’s toad (state-listed in New Hampshire and Vermont; see Section 3.7.1.4), and survey scientists recorded all observations of other amphibian species.

One Fowler's toad was detected using acoustic monitoring during Study 28, but none were detected during the standard call surveys. Other amphibians were heard calling at all survey locations from the riverine reach downstream of Wilder dam in Lebanon, New Hampshire, to Stebbins Island downstream of Vernon dam. All other amphibian species potentially present in the survey area based on their known distribution, and that are expected to call during the month of June, were detected (e.g., American toad, spring peeper, green frog, bull frog, and gray treefrog). American toad was the species most commonly heard, both in terms of number of times detected and geographic distribution throughout the Study 28 study area.

Insects

Large, riverine systems such as the Connecticut River provide habitat for scores of insects that rely on aquatic habitat. Unique terrestrial habitats for insects within the terrestrial study area include riparian forest; riparian agriculture/grassland; and riverine edge features including banks, riprap, cliffs, and rocky shore. In addition, riverine islands and tributary confluences often create bars of sand, cobble, and gravel where insects are found.

Because hundreds of insect species spend their larval stage in rivers and emerge as adults, the shoreline interface between these aquatic and terrestrial environments is extremely important. For example, dragonfly and damselfly nymphs crawl from the river and emerge as adults on the banks of the river. Study 25 included a baseline inventory of dragonflies and damselflies (odonates) emerging along the shoreline throughout the terrestrial study area, during which 19 species of dragonfly and damselfly were identified. The three sites with the fewest odonate observations were in the riverine reaches. The two sites in the Wilder riverine reach had the fewest observations, with each site recording nine individual odonates of 5 species each, on study transects. The site in the Bellows Falls riverine reach had 30 odonate observations of 7 species. The site in the Vernon riverine reach had 159 odonate observations of 9 species, more than any other site.

The most frequently observed odonate species, which were recorded at least once at each Study 25 survey site, were zebra clubtail, riverine clubtail, rusty snaketail, cobra clubtail, rapids clubtail, and spinecrowned clubtail. In addition, prince baskettail and black-shouldered spinyleg were each observed more than 50 times during the study. Many state-listed species were observed during this study and are discussed further in Section 3.7.1.4, *Sensitive Terrestrial Species*.

Tiger beetles are among the many insect species using the cobble and sand habitat found on riverine island edges and at tributary confluences. In Study 26, the common shore tiger beetle was observed most frequently throughout the terrestrial study area, using sun-exposed cobble, gravel, and sand for foraging and mating. Adjacent sandy and loose substrates support burrows where larval stages develop for one to two summers before emerging as mating adults (Leonard and Bell, 1999). Study 26 obtained baseline distributional and abundance data for cobblestone tiger beetle (state-listed in both New Hampshire and Vermont, see Section 3.7.1.4) and Puritan tiger beetle, although that species was not observed (federally listed as threatened; see Section 3.8, *Threatened and Endangered Species*). However, common shore tiger beetles were observed at least once at each of the 14 study sites, and scientists discovered active common shore tiger beetle burrows directly adjacent to two study sites. Study sites were selected from a variety of locations throughout the terrestrial study area (except at the Wilder impoundment, where no suitable habitat could be identified), but appropriate habitat was most common in the Wilder riverine reach and the Bellows Falls impoundment.

Mammals

Although a variety of mammalian species use the terrestrial study area habitat, no targeted relicensing studies focused on mammal inventory or habitat assessment. However, many incidental observations were recorded during Studies 25, 26, 27 and 28. Study scientists observed beaver lodges and dams in backwaters and evidence of bank dens on the mainstem, mostly in the three impoundments. Muskrat were observed in the larger emergent marshes, primarily in the lower Vernon impoundment. A white-tailed deer fawn observed on Chase Island indicates the value of such locations for nursery habitat. Finally, tracks of raccoon, deer, mink, opossum, and mice were frequently observed along the river shorelines.

Birds

Although various bird species use the terrestrial study area habitat, no targeted relicensing studies focused on avian inventory, and habitat assessment was limited to bald eagle nesting and roosting habitat. Bird activity was incidentally observed throughout the field surveys conducted for Studies 25, 26, 27, 28, and 29 in 2014 and 2015. Twelve species of wading birds and waterfowl were observed, including common mergansers observed throughout the terrestrial study area and a brood of six young that were observed in the Vernon impoundment. Wood ducks were observed in multiple backwater and floodplain areas throughout the Bellows Falls impoundment, and mallards were noted in both Wilder and Vernon impoundments. Other waterfowl species including Canada geese and double-crested cormorants were also abundant. Shoreline-dependent species were noted throughout the terrestrial study area. Spotted sandpipers were frequently seen along the water's edge on both protected and exposed shoreline and gravel bars throughout the river. Bank swallow colonies were relatively common throughout the Wilder and Vernon impoundments on bare banks. Belted kingfisher, great blue heron, and green heron were common throughout the terrestrial study area. These species were usually noted perching on trees and, when disturbed, would leave the roost tree and fly up or downstream from the observer's location. Great egrets were observed only once in the lower reaches of the Vernon impoundment near Vernon dam.

Juvenile and adult bald eagles were observed at multiple locations throughout the terrestrial study area, as were numerous other species of raptors including turkey vulture, osprey, red-tailed hawk, broad-winged hawk, American kestrel, and a peregrine falcon (at the Vernon impoundment). The importance of the Connecticut River corridor for bird migration (see discussion below at *Significant Wildlife*

Habitats) was evident when flocks and individual passerines were observed, including mixed warbler flocks in May and June and common nighthawk in August.

Significant Wildlife Habitats

Riparian Zone

The term "riparian" refers to anything connected or immediately adjacent to the shoreline or bank of a river. The riparian zone can include floodplain, wetland (forested, scrub-shrub, or emergent), upland forest, or grassland. The riparian zone serves as the primary interface between riverine and upland habitats, influencing both the primary productivity and food resources within the river. Primary wildlife resources associated with riparian habitats include early spring plant growth in lowland riparian habitats, which provide food sources for migrating birds, black bear, white-tailed deer, and otter. In addition, bank swallows and belted kingfishers dig nesting sites in sandy riparian areas adjacent to rivers (Sperduto and Kimball, 2011), and aquatic, larval dragonflies use undercut riverbanks to leave their larval exuviae behind and emerge as flying adults (see Section 3.7.1.4).

Amphibian Breeding

River backwaters and associated riparian flowage can create vernal pools or temporary spring-filling basins. When vernal pools become inundated with water in the spring, certain amphibians lay eggs in the pools (e.g., spotted salamander, wood frog, blue-spotted salamander, Jefferson salamander, and Fowler's toad; Coburn, 2004). A complex and unique cycle of predation and reproduction occurs each year among larval amphibians, breeding invertebrates, and external predators, driven by the length of time that passes before the pool dries up in the summer.

River channels also frequently spread into vast, emergent wetland features such as Upper Meadows in Rockingham, Vermont, and Lower Meadows in Charlestown, New Hampshire. These permanent waterbodies offer habitat for green frog, bullfrog, and red-spotted newt breeding. American toads can also breed in emergent wetlands, as well as river shallows, vernal pools, or even water-filled ditches found in the terrestrial study area (Kenney and Burne, 2000).

Bald Eagle Breeding/Wintering

Bald eagles breed and overwinter in the vicinity of the Connecticut River in the terrestrial study area. Eagles generally nest in mature softwoods with easy access to fishing and limited disturbance. They establish winter roosts in mature pine stands close to features that maintain open water during sub-freezing winter temperatures (e.g., dams, fast-flowing stretches, outfalls). Ideal winter roosts also face southeast to catch early morning sun. Bald eagles are federally protected under the Bald and Golden Eagle Protection Act (16 U.S.C. § 668–668c) and are state-listed as threatened in New Hampshire and endangered in Vermont. For a full species account, see Section 3.7.1.4.

Migratory Songbird Stopovers

The Connecticut River serves as a migratory pathway for birds. Habitat between Charlestown, New Hampshire, and the Massachusetts border, which includes the Bellows Falls impoundment, Bellows Falls riverine reach, and the Vernon impoundment, has been designated as an Important Bird Area, a program implemented by the National Audubon Society, the U.S. partner for Birdlife International (National Audubon Society, 2016). The program is an effort to identify and conserve areas that are vital to birds and other biodiversity. Important Bird Areas must meet at least one of the following four criteria:

- Species of conservation concern;
- Species that are vulnerable because their populations are concentrated in one general habitat or biome type, also termed "responsibility species";
- An outstanding example of a representative or rare habitat type; or
- Species, or groups of similar species, that are vulnerable because they occur at high densities due to their congregatory behavior.

As a north-south running feature, the Connecticut River provides an important orientation tool for bird species during their migration. Between 1996 and 1998, during 6 days of surveys, an average of 3,782 migratory birds was observed annually near the White River confluence with the Connecticut River just below Wilder dam (Litwin et al., 2006). The number of birds observed per survey correlated strongly with proximity to the river and even more strongly at lower Connecticut River survey sites in Massachusetts (Litwin et al., 2006).

Locations within and adjacent to the Project areas providing stopover habitat include the Wantastiquet Mountain Natural Area adjacent to the Vernon impoundment in Chesterfield, New Hampshire, which has diverse acidic talus/rocky summit forests and provides stopover habitat for warblers during spring migration (Visit New Hampshire, 2012).

3.7.1.4 Sensitive Species

Sensitive terrestrial species include state-listed species or species considered imperiled. Large numbers of rare plant species are concentrated along the Connecticut River’s banks and floodplains. These riverine and riparian habitats also support state listed wildlife species. During the 2012 and 2014 field seasons, study staff worked with the New Hampshire Natural Heritage Bureau (NHNHB) and Vermont Natural Heritage Inventory (VTNHI) to develop a database of known records of state-listed species. This consultation resulted in the identification of 79 listed species that occur within 1,000 feet of the river’s edge from the upstream extent of the Wilder impoundment to 1.5 miles downstream of Vernon dam (i.e., including those records outside the 200-foot terrestrial study area) (Table 3.7-5). All federally listed terrestrial and aquatic wildlife and botanical species that are known to occur or that may occur within the Project areas are discussed in Section 3.8, *Threatened and Endangered Species*.

Table 3.7-5. State-listed terrestrial species that occur or may occur within 1,000 feet of the Connecticut River within the Project areas.

Scientific Name	Common Name	VT Status[a]	NH Status[a]	Federal Status[a]	Habitat
Invertebrate Animals (excluding freshwater mussels, see Section 3.6, *Fish and Aquatic Resources*)					
Cicindela marginipennis	Cobblestone tiger beetle	T	E	---	Sandy beaches on river's edge (Leonard and Bell, 1998)
Cicindela puritana	Puritan tiger beetle	T	T	T	Sandy beaches on river's edge (Leonard and Bell, 1998)
Gomphus ventricosus	Skillet clubtail	---	SC	---	Medium to large rivers with mud bottom (Nikula et al., 2003)
Stylurus amnicola	Riverine clubtail	---	SC	---	Medium to large rivers with sand, gravel, or mud bottom (Nikula et al., 2003)
Vertebrate Animals[b]					
Rana pipiens	Northern leopard frog	---	SC	---	Wet open meadows, wet fields, river floodplains
Glyptemys insculpta	Wood turtle	---	SC	---	Meandering streams with sandy bottoms
Myotis septentrionalis	Northern long-eared bat	E	T	T	Upland forests, caves (Lacki et al., 2009; Sasse and Perkins, 1996)
Dendroica cerulea	Cerulean warbler	---	SC	---	Mature, deciduous, floodplain forests
Haliaeetus leucocephalus[c]	Bald eagle[c]	E	T	P[c]	Large lakes and rivers; large, riparian trees for nesting, roosting
Podilymbus podiceps	Pied-billed grebe	---	T	---	Freshwater ponds with large areas of emergent vegetation, marshy edges of rivers/lakes

Scientific Name	Common Name	VT Status[a]	NH Status[a]	Federal Status[a]	Habitat
Plants[d]					
Acer nigrum	Black maple	---	T	---	Rich, mesic forests, riparian forests
Adlumia fungosa	Allegheny-vine	---	E	---	Rocky forests, cliff bases, gardens
Allium schoenoprasum	Wild chives	---	E	---	Riverbanks, shoreline outcrops, meadows, fields, roadside, and vacant lots
Arabis pycnocarpa	Hairy eared-rockcress	---	E	---	Ledges, rock outcrops, rocky woodands
Arisaema dracontium	Green dragon	T	E	---	Floodplain forest (NHNHB; VTNHI); rich mesic forests, riparian forests
Asclepias quadrifolia	Four-leaved milkweed	---	E	---	Forests and woodlands, associated with rich soils and/or circumneutral bedrock
Asclepias tuberosa	Butterfly milkweed	T	E	---	Dry fields, sand plains, roadsides, disturbed areas
Astragalus robbinsii var. jesupii	Jesup's milk vetch	E	E	E	River shore beaches and ledges, cliffs, and talus
Bromus kalmii	Kalm's brome	---	E	---	Dry, mesic soils of outcrops, open forests and woodlands, less frequently in wet mesic meadows and riparian forests
Calystegia spithamaea	Upright false bindweed	T	E	---	Sandy fields, roadsides, clearings, railroads, woodlands, and sad plain grasslands
Cardamine concatenata	Cut-leaved toothwort	---	E	---	Rich, moist woods and talus (NHNHB; VTNHI)
Cardamine maxima	Large toothwort	---	T	---	Rich, mesic, upland and riparian forests
Carex aurea	Golden-fruited sedge	---	T	---	Rich fens and seeps; rich wet meadows; calcareous riverside seeps (NHNHB; VTNHI); Cobble pavement and seepy outcrop river shorelines, wet ledges, and borrow pits

Scientific Name	Common Name	VT Status[a]	NH Status[a]	Federal Status[a]	Habitat
Carex baileyi	Bailey's sedge	---	T	---	Rich fens and seeps; rich swamps; rich wet meadows (NHNHB; VTNHI); lake shores, stream edges, ditches, meadows, and other low wet ground
Carex foenea	Bronze sedge	E	---	---	Woodlands, cliffs, sandy fields, and open, disturbed soil
Carex garberi	Elk sedge	T	T	---	Calcareous riverside seeps (NHNHB; VTNHI); river shores in high pH bedrock, usually seepy outcrops or cobble pavement
Carex granularis	Limestone-meadow sedge	---	E	---	Rich fens and seeps; rich wet meadows (NHNHB; VTNHI) shorelines, disturbed soils, meadows, high pH bedrock
Carex retroflexa	Reflexed sedge	--	E	---	Mesic to dry-mesic, deciduous forests, woodlands, clearings and open areas
Carex trichocarpa	Hairy-fruited sedge	---	E	---	Rich swamps (NHNHB; VTNHI) wet meadows, ditches, lake shores, riverside margins
Crassula aquatica	Pygmy-weed	---	E	---	Aquatic bed; brackish marshes, mudflats, and margins of freshwater pools and rivers (NHNHB; VTNHI); open, often muddy shorelines, brackish tidal rivers and non-tidal rivers
Crocanthemum bicknellii	Plains frostweed	T	---	---	Open, sandy soils of woodlands, roadsides, clearings, dry fields, and sandplains
Crotalaria sagittalis	Rattlebox	T	E	---	Sandy soil of fields, roadsides, borrow pits, and pond shores
Cynoglossum virginianum ssp. boreale	Wild hound's-tongue	T	E	---	Deciduous and mixed evergreen-deciduous forests, trails, old logging roads
Cyperus diandrus	Low cyperus	E	---	---	Moist to wet, usually sandy or peaty, shorelines
Cyperus houghtonii	Houghton's umbrella sedge	T	E	---	Dry, sandplain openings (NHNHB; VTNHI); Dry mesic to xeric \sands and edges, roadsides, lake shores, sandplains, and woodlands

Scientific Name	Common Name	VT Status[a]	NH Status[a]	Federal Status[a]	Habitat
Cyperus squarrosus	Incurved umbrella sedge	---	E	---	River and lake shores, usually in sand
Cypripedium arietinum	Ram's-head lady's-slipper	T	E	---	Deciduous and mixed evergreen-deciduous forests, often on enriched soils due to bedrock influence or colluvial deposits, swamps
Diplazium pycnocarpon	Narrow-leaved glade fern	---	E	---	Rich, mesic woods
Equisetum palustre	Marsh horsetail	T	E	---	Lake and stream shores, marshes, river shore seeps, and pools
Eupatorium sessilifolium	Upland thoroughwort	E	E	---	Rocky forests and woodlands, edges of rock balds
Galearis spectabilis	Showy orchid	---	T	---	Rich, usually deciduous forests, areas influenced by high pH bedrock or colluvial deposits
Gentianella quinquefolia	Stiff dwarf-gentian	---	E	---	Fields, pastures, roadsides, banks, pond shores, commonly in regions of high-pH bedrock
Geum fragarioides	Appalachian barren-strawberry	---	T	---	Forests, woodlands, riparian terraces, riverbanks, fields, clearing, logging roads
Glyceria acutiflora	Sharp manna-grass	E	E	---	Shallow water of pools, lakes, and streams
Hackelia virginiana	Virginia stickseed	---	E	---	Mesic, deciduous forests, talus, cliff bases, high pH bedrock
Helianthus strumosus	Harsh sunflower	T	---	---	Deciduous forest, riverbanks, fields, roadsides, open rights-of-way
Heteranthera dubia	Grass-leaved mud-plantain	---	T	---	Aquatic beds, southern riverbanks (NHNHB; VTNHI); shallow, still or slow-moving, circumneutral to basic water of lakes and rivers
Hydrophyllum virginianum	Eastern waterleaf	---	T	---	Mesic, often rich, deciduous forests, riparian forests
Hypericum ascyron	Great St. John's-wort	T	E	---	Calcareous riverside seeps (NHNHB; VTNHI); riparian forests, riverbanks, low fields

Scientific Name	Common Name	VT Status[a]	NH Status[a]	Federal Status[a]	Habitat
Isoetes engelmannii	Engelmann's quillwort	T	E	---	Shallow waters of lakes and rivers, sometimes emergent
Isoetes riparia var. canadensis	Canada shore quillwort	---	E	---	Sandy and muddy margins of streams and lakes, including tidal shorelines
Lechea mucronata	Hairy pinweed	E	---	---	Fields, roadsides, waste areas, woodlands, clearings
Lespedeza hirta	Hairy bush-clover	T	---	---	Woodlands, forest clearings, dry openings
Liparis loeselii	Loesel's wide-lipped orchid	---	T	---	Rich fens and seeps; northern rich swamps; rich wet meadows; calcareous riverside seeps (NHNHB; VTNHI); Mesic to hydric, open soils of meadows, fens, shorelines, and, disturbed places such as abandoned borrow pits and cleared rights-of-way
Lobelia kalmii	Brook lobelia	---	T	---	Calcareous riverside seeps; rich, wet meadows (NHNHB; VTNHI); Fens, stream shores, seepy river shore outcrops, and disturbed soil in regions with high pH-bedrock
Mimulus moschatus	Musky monkey-flower	---	E	---	River and stream shores, seeps, stream-side meadows, low roadsides, ditches
Nabalus serpentarius	Lion's-foot rattlesnake-root	---	E	---	Woodlands, rocky slopes, cliffs roadsides, powerline rights-of-way, sandplains, clearings
Nuphar microphylla	Small-leaved pond-lily	---	E	---	Ponds
Packera paupercula	Balsam groundsel	---	T	---	Rich fens and seeps; calcareous riverside seeps (NHNHB; VTNHI); rivershore outcrops and gravels, woodlands, ridges
Panax quinquefolius	American ginseng	---	T	---	Rich, mesic forests, often on rocky slopes near cliff bases, rarely in wet-mesic forests that are influenced by high-pH bedrock

Scientific Name	Common Name	VT Status[a]	NH Status[a]	Federal Status[a]	Habitat
Parnassia glauca	Fen grass-of-parnassus	---	T	---	Fends, river-shore seeps, wet meadows, rarely also found in wet lawns and in ditches, usually in high-pH bedrock regions
Physostegia virginiana	Obedient plant	T	---	---	Fields, roadsides, gardens, river shores, lake shores
Potamogeton alpinus	Reddish pondweed	---	E	---	Shallow, still or slow moving, circumneutral to basic lakes and rivers
Potamogeton nodosus	Long-leaved pondweed	---	T	---	Aquatic beds (NHNHB; VTNHI); Shallow, still or slow moving, circumneutral to basic lakes and rivers
Potamogeton vaseyi	Vasey's pondweed	---	E	---	Aquatic beds (NHNHB; VTNHI); Shallow, still or slow moving, slightly acidic to basic water of lakes and rivers
Potamogeton zosteriformis	Flat-stem pondweed	---	E	---	Aquatic beds (NHNHB; VTNHI); Shallow, still or slow moving, circumneutral to basic lakes and rivers
Pterospora andromedea	Pine-drops	E	E	---	Deciduous to mixed evergreen-deciduous forests
Pycnanthemum virginianum	Virginia mountain-mint	---	E	---	Fields, banks, roadsides, clearings
Quercus macrocarpa	Mossy-cup oak	---	E	---	Swamps, riparian and lacustrine forests, dry mesic to mesic soil of forests in regions of high pH bedrock
Sagittaria cuneata	Northern arrowhead	---	E	---	Circumneutral to slightly basic waters of lakes, slow-moving streams, and pools
Sagittaria rigida	Sessile-fruited arrowhead	---	E	---	Aquatic beds; sandy pond shores /sand plain basin marshes (NHNHB; VTNHI); lakes, river shores, backwaters, pools including fresh to brackish tidal rivers

Scientific Name	Common Name	VT Status[a]	NH Status[a]	Federal Status[a]	Habitat
Salix exigua ssp. interior	Sandbar Willow	---	E	---	Sand, gravel, and cobble shorelines of major rivers, less frequently lake shores, rarely in borrow pits
Sanicula odorata	Clustered sanicle	---	E	---	Rich mesic forests, including uplands and riparian types
Sanicula trifoliata	Large-fruited sanicle	---	T	---	including uplands and riparian types
Scirpus ancistrochaetus	Northeastern bulrush	E	E	E	Wet fields, lake borders, graminoid marshes, temporary pools
Senna hebecarpa	Northern wild senna	T	E	---	Fields, roadsides, forest borders, riparian corridors
Solidago speciosa	Showy goldenrod	---	E	---	Fields, roadsides, clearings
Spiranthes lucida	Shining ladies'-tresses	---	E	---	River and lake shores, most prevalent in areas influenced by high-pH bedrock, also in seeps and meadows
Staphylea trifolia	American bladdernut	---	T	---	Forest borders and fragments, woodlands, rocky, slopes, roadsides
Stuckenia pectinata	Sago false pondweed	---	E	---	Aquatic beds, salt marshes, mudflats, and borders (NHNHB; VTNHI); shallow, still, or slow moving, neutral to basic waters of lakes and rivers
Triantha glutinosa	Sticky false asphodel	T	E	---	Rich fens and seeps, calcareous riverside seeps (NHNHB; VTNHI); Fens, meadows, Rivershore seeps in regions of high-pH bedrock or till

Source: 2014 and 2013 data-sharing agreements with NHNHB and VTNHI, and sources as listed in the table and notes b and d.

a. SC – Special Concern; T – Threatened; E – Endangered; "---" – not listed.

b. Vertebrate habitat associations are from DeGraaf and Yamasaki (2001) unless otherwise noted.

c. The bald eagle is federally protected under the Bald and Golden Eagle Protection Act (16 U.S.C. § 668-668c).

d. Plant habitat associations are from Haines (2011) or Magee and Ahles (1999) unless otherwise noted.

Invertebrates

Cobblestone Tiger Beetle

The cobblestone tiger beetle is listed as threatened in both New Hampshire and Vermont. It has an extremely restricted habitat and is found on cobble and gravel beaches on river edges and the upstream side of riverine islands where the river deposits small- to medium-sized cobble in times of high flow (Leonard and Bell, 1999). Before Study 26, individuals of this species were found in the vicinity of the Wilder, Bellows Falls, and Vernon Project areas with existing records spanning from Johnston Island (Lebanon, New Hampshire, in the Wilder riverine reach) to Walpole Island (Walpole, New Hampshire, in the Bellows Falls riverine reach). A previous record also existed as far south as the West River (Brattleboro, Vermont, in the Vernon impoundment), but that record was just outside the defined influence of Vernon Project operations.

Study 26 commenced with a desktop analysis to review sites of previous records and identify potentially suitable new habitat available to cobblestone tiger beetles in the study area. Sources of data included maps of cobblestone tiger beetle observations and existing aerial photographs. Survey sites were subsequently chosen from these habitat areas based on accessibility and field checks to verify the habitat suitability. The 13 selected sites were each visited 3 times during the summer of 2014 in warm, humid conditions (ideal foraging/breeding conditions for adults).

During Study 26, the cobblestone tiger beetle was found to be widely distributed throughout the study area. Adult cobblestone tiger beetles were positively identified at 7 of the 13 survey sites. Survey scientists found them at least once at each of the 5 previously recorded sites, and at 2 survey sites, Hart Island (Wilder riverine reach) and Walpole Island (Bellows Falls riverine reach); cobblestone tiger beetles were observed during all 3 survey visits between July and August 2014. One new site, a mainstem riverbank cobble bed in Ascutney, Vermont, was identified for the species.

In an assessment of habitat features of occupied sites, Study 26 results indicate that adult cobblestone tiger beetles have specific habitat preferences related to the size and variability of cobble substrate. The mean cobble size ranged from about 2 to 3 inches in all high-quality habitats, and the target species was absent at most sites with cobble averaging either smaller or larger than this range. In addition, the cobble diameter variability (measured as standard deviation of the a-axis) of high-quality survey sites fell within an approximate range of 0.75 to 1.5 inches. Among the study sites, the majority of appropriate habitat was available in the Wilder riverine reach with one high-quality site in the Bellows Falls riverine reach.

Dragonflies and Damselflies

Seven of Vermont's dragonflies and damselflies (odonates) that occur in the terrestrial study area have been designated as a Species of Greatest Conservation

Need (SGCN)—spine-crowned clubtail, rapids clubtail, skillet clubtail, cobra clubtail, rusty snaketail, riverine clubtail, and zebra clubtail. An eighth species, common sanddragon, which had not been recorded in Vermont prior to the commencement of Study 25, may be rare. Two of the species listed above—rapids clubtail and skillet clubtail—are also state-listed as special concern in New Hampshire, but none of these species have federal conservation status.

Although dragonflies are most frequently observed as adults, they spend most of their life cycle as aquatic larvae. After growing for a year or more, larvae crawl from the water and metamorphose to adults. Eclosure occurs when the adult form exits the larval exoskeleton. After eclosure, the individual dries and hardens before taking flight. During eclosion, odonates are unable to move until the process is complete, making it a particularly vulnerable part of their life cycle (Paulson, 2011; Silsby, 2001).

Because the distribution of habitat of the above-listed focal species has not been well understood, Study 25 was designed to inventory the large river-dependent odonate assemblages in the terrestrial study area, including life history, ecology, and behavior information for each species. Six surveys were conducted between June 1 and July 30, 2015, where survey scientists systematically searched 11 survey sites for eclosing odonates and collected data about available riverbank habitat. The following information was collected for each of the six focal species found during Study 25:

- Spine-crowned clubtail was found at three sites in the Vernon study area and at a single site in the Bellows Falls impoundment. This species was previously only known to occur in the Vernon study area, so this represents an extension of the species' known range. Although it was found at four different sites, spine-crowned clubtail was only observed 10 times. Nine of the 10 observations came from sites in impoundments, and 7 of those were in sites immediately upstream of the dams, suggesting that the species may be more likely to occur in impounded areas of the river.

- Rapids clubtail was only located at a single site in the Wilder impoundment, where a single exuvium was found during transect surveys. This represents a range extension over previous surveys, in which this species had been recorded only in the Vernon study area and in extremely low densities (Hunt, 2012; Hunt et al., 2010). Failure to detect the species in the Vernon, and possibly Bellows Falls, study sites is likely a result of low densities, rather than extirpation.

- Cobra clubtail was detected at nine study sites and was the most frequently found species during transect surveys. However, it was not found at study sites immediately upstream or downstream of Wilder dam. This species was also not found in the vicinity of these sites during 2005–2006 field work (Hunt et al., 2010).

- Rusty snaketail was only recorded in riverine reaches. No site had high numbers of this species, although 7 of the 10 exuvia were collected from the same site near Stebbins Island. This species has been previously found in the Bellows Falls and Vernon impoundments as well as the Bellows Falls riverine reach; it likely still occurs in these areas but at low densities. Notably, this species was found at both study sites in the Wilder riverine reach, despite those sites having the lowest odonate abundances.

- Riverine clubtail was recorded at eight sites. It was absent from the Wilder riverine reach but was found in the remaining impoundments and riverine reaches, although it was also not found at the site just above Wilder dam in the Wilder impoundment. This finding is consistent with previous surveys (Hunt, 2012; Hunt et al., 2010) in which the species was not found in this stretch of river. Of special note was a teneral (adult odonate not yet capable of sustained flight) observed on July 29, 2015, in Lyme, New Hampshire. This species had not previously been recorded as an adult after July 1 in New Hampshire and is only previously known in Vermont from exuviae. This observation contributes to an understanding of the flight season of this rarely observed species.

- Zebra clubtail was observed in the Bellows Falls and Wilder study areas and was widespread within them. This species was not observed at the sites immediately above either dam.

Vertebrates

Bald Eagle

Several sections of the terrestrial study area provide both breeding and winter roosting habitat for bald eagles. The bald eagle is federally protected under the Bald and Golden Eagle Protection Act (16 U.S.C. § 668–668c) and the Migratory Bird Treaty Act, and it is currently state-listed as threatened in New Hampshire and endangered in Vermont, although New Hampshire is currently considering de-listing the species.[47] Because bald eagles are not federally listed as threatened or endangered, information about their use of the lands within the Wilder, Bellows Falls and Vernon Project areas was not available from FWS. However, because the bald eagle is federally protected under the Bald and Golden Eagle Protection Act, it is covered in this section as a federally protected species. The species is also protected as part of the Migratory Bird Treaty Act (listed in 50 C.F.R. § 10.13).

Study staff obtained information about bald eagle nesting and wintering from NHNHB, VNHI, and New Hampshire Audubon (NHA). During the 2016 mid-winter eagle survey on January 9, 2016, a volunteer survey effort coordinated by NHA, 21 bald eagles were observed along the Connecticut River, including 14 adults and 7 immatures. According to VNHI and NHNHB, bald eagles roost in 2 locations in the

[47] http://www.wildlife.state.nh.us/legislative/documents/fis-1000-species-ip.pdf.

Project areas during the winter: near Vernon dam in Vernon, Vermont, and in the north end of Westmoreland, New Hampshire. As part of Study 27, aerial photo interpretation followed by field verification identified 12 additional softwood stands that appear to offer suitable winter roosting conditions: 6 in Vermont and 6 in New Hampshire. They are all located essentially on the Connecticut Riverbank, with 2 located on tributary inlets (Mink Brook and Clay Brook) and 2 located on islands (Gilman Island and an unnamed island in Lyme, New Hampshire). These potentially suitable winter roosting sites are relatively evenly distributed throughout the terrestrial study area, and although the distribution is not extensive in comparison to the entire size of the terrestrial study area, winter roosting habitat is unlikely to be a limiting resource. Bald eagles are highly mobile using multiple roosts in the course of a winter, and communal roosting behavior is common (Buehler, 2000).

The locations and conditions of existing bald eagle nests in the terrestrial study area were summarized from data provided by NHA's ongoing Connecticut River Bald Eagle Restoration and Habitat Protection Project, which TransCanada supported with a three-year grant of nearly a quarter of a million dollars (NHA, 2014, 2013, 2012). In the 2014 breeding season, NHA documented 9 nests within the study area, 8 of which were active (NHA, 2014). Maps of the locations are considered privileged information and are being filed separately as such in Appendix C to Exhibit E. 2014 represented an increase from 6 nests (5 active) in 2012, when NHA began tracking nests along the Connecticut River, and 7 nests (6 active) observed in 2013. Productivity of the nests was 0.8, 0.7, and 0.6 fledged young per nest in 2012, 2013, and 2014, respectively. While the overall productivity of these nests is lower than for nests throughout the entire watershed (NHA, 2014, 2013, 2012), low nest success in 2014 was also observed across the watershed. Cold weather and heavy snow in March likely depressed hatching rates throughout Vermont and New Hampshire in 2014. The current active nests are in Piermont, Plainfield, and Hinsdale (two nests), New Hampshire; and in Newbury, Hartford, Rockingham, and Dummerston, Vermont (Table 3.7-6). All the known locations of nests are within approximately 200 feet of the Connecticut River shoreline.

Table 3.7-6. Bald eagle nest tree locations and conditions within the terrestrial study area.

Town	Distance to River	Ownership / Type	Setting	Cover Type	Tree Species	Tree Condition	Diameter at Breast Height	Predator Guard?	Years Active
Newbury, VT	~ 200 ft	Private	Tributary bank	NA[a]	White Pine	Live	Unknown	No	2012, 2013, 2014
Piermont, NH	Unknown[b]	Private	Riverbank	Upland Forest	Unknown[b]	Unknown[b]	Unknown	No	2014
Hartford, VT	>25 ft	Private	Riverbank	Upland Forest	White Pine	Live	Unknown	No	2012, 2013, 2014
Plainfield, NH	~ 25 ft	Private	Riverbank	Upland Forest	White Pine	Live	Unknown	No	2012, 2013, 2014
Claremont, NH	>25 ft	Flowage Easement	Riverbank	Wetland Forest	White Pine	Live	Unknown	No	none
Rockingham, VT	>125 ft	Fee Owned	Upland	Wetland Forest	Cottonwood	Live	Unknown	Yes	2012, 2013, 2014
Dummerston, VT	>25 ft	Fee Owned	Riverbank	Upland Forest	White Pine	Dead	Unknown	No	2014
Hinsdale, NH	>100 ft	Fee Owned	Small island	Wetland Scrub-shrub	White Pine	Live	Unknown	No	2014
Hinsdale, NH	~125 ft	Fee Owned	Upland	Upland Forest	White Pine	Live	25 inches	Yes	2012, 2013, 2014

Source: NHA (2014, 2013, 2012) as modified by Great River Hydro

a. Not mapped —outside the terrestrial study area

b. Exact location of nest was not described

Cerulean Warbler

The cerulean warbler is a species of special concern in New Hampshire; three small populations are known to exist in the state. The species has not been observed at its most reliable breeding site in the state, Pawtuckaway State Park, since 2012 (NHFGD, 2015). The cerulean warbler is known to occupy mature floodplain forest (NHFGD, 2015; DeGraaf and Yamasaki, 2001), but in New Hampshire has been recorded mostly in upland hardwood forests (NHFGD, 2015). The only location with multiple records in the vicinity of the combined Wilder, Bellows Falls, and Vernon Projects is Mount Wantastiquet in Hinsdale, New Hampshire. Because of the significant elevation difference between the Vernon Project area and the known element occurrences (EOs; i.e., plants and exemplary natural communities) on Mount Wantastiquet, it is unlikely that Project operations have any effect on the cerulean warbler. No targeted relicensing studies were requested or performed for this species, and the species was not incidentally observed during any field studies.

Fowler's Toad

Fowler's toad is considered a high priority SGCN in Vermont and is listed as an S1 "Very Rare" species in Vermont's wildlife action plan (VT WAP Team, 2015). This species was listed as endangered by Vermont in 2015 and is considered a Species of Special Concern in New Hampshire. It has no federal status. Verified reports of the Fowler's toad span from White River Junction, Vermont, where it was first reported and photographed in 1983, to Vernon, Vermont, where a population was well documented from 1994 through 2007. Although the Vernon record is the sole record from the Connecticut River itself, the other records are primarily from towns adjacent to the river and therefore define the possible range of Fowler's toad in the vicinity of the Connecticut River.

Study 28 was conducted in the summer of 2014 and commenced with a desktop analysis to identify potentially suitable habitat available to Fowler's toads in the terrestrial study area within the geographic range of previous observations. Sources of data included relevant reports and maps created from concurrent studies as well as existing maps and aerial photos. Survey sites were subsequently chosen from these habitat areas based on accessibility at night, private landowner permission, and field checks to verify the habitat suitability. Both standard nocturnal call surveys and acoustic surveys were performed, and one population of Fowler's toad was confirmed in a breeding pool on Stebbins Island, just below Vernon dam.

Suitable habitat for Fowler's toad requires pools with reasonably stable hydrology for breeding, and bare, sandy soils suitable for estivation and hibernation in proximity. This combination of conditions in proximity to each other appears to be inherently rare on the Connecticut River. In general, persistent, shallow pools tend to be concentrated in and around large wetland features associated with bays and old oxbows (e.g., Herricks Cove in Rockingham, Vermont). However, the most extensive areas of bare, sandy soils in the study area are associated directly with the banks of the river and some of the islands. Locations with both potential breeding pools and bare soils appear to be most abundant in the Wilder riverine reach and the Bellows Falls impoundment where potential breeding pools form on sand bars and behind scour deposits and where sandy soils area also available. However, Fowler's toad was absent from these sites during Study 28.

Plants

In the 2012 growing season, a field survey was conducted to identify state-listed rare, threatened, or endangered (RTE) plants and communities within the immediate environs of the Connecticut River. The survey area extended from the upper end of the Wilder impoundment to Vernon dam (Normandeau, 2013c). The survey assessed the current status of individual populations of all plant species listed by New Hampshire and Vermont that are potentially influenced by Project operations. A total of 185 EOs was identified for potential survey in the study, 66 in Vermont and 119 in New Hampshire. Of these, surveys were performed for 175 EOs (95 percent), and surveys were not attempted for the remaining 10 EOs (5 percent) due to access or logistical difficulties. Ninety-two EOs were located in 2012 (53 percent) and 43 new EOs were documented, bringing the total number of documented extant EOs in the terrestrial study area to 135 in the 2012 survey.

Individual occurrences of rare species and exemplary natural communities proximal to normal Project operational flows correspond to one of three broad groups: (1) aquatic floating leaved and submerged species that remain inundated during daily operational flows; (2) aquatic to emergent species that are partially or entirely within the range of normal daily operational flows; and (3) species that are restricted entirely or in large part to areas on the riverbank above normal daily operational flows (inundated by flows exceeding maximum station discharge). No RTE species occur both above and below the normal operational range of flows or impoundment water levels, and no species were confined entirely to the operational flows or impoundment water level ranges. Populations of species that occurred partially within the normal operational range were usually centered or concentrated either above or below operational flows; however, some individual patches or subpopulations occurred entirely within the normal operational range (e.g., pygmy-weed, obedient plant, and common silverweed). Additional examples of each species groups were documented during the 2012 study.

One-hundred-sixty-three state-listed plant species and exemplary communities were to be incidentally investigated in 2014 during Study 27, if the EOs were located on public or Project-owned or leased land. Of those 163 EOs, 88 had been located since 1990 and 75 had not been observed since that date, and the 2014 survey focused on the 88 more recent observations. Seven EOs were confirmed during the 2014 field verification, including five silver maple-wood nettle-ostrich fern floodplain communities, and two rare species, black maple and obedient plant.

3.7.2 Environmental Effects

3.7.2.1 Botanical Resources

Vegetation communities, particularly along large river systems, are hydrologically and physically influenced by the river in several ways:

- Flooding by cyclical and periodic high waters resulting from snowmelt and precipitation;
- Scour by ice, water, and debris;
- Erosion, deposition, tributary coarse sediment outflow;
- Short-term, water level and flow fluctuations; and
- Low flow conditions.

On a regulated system such as the Connecticut River, large water inputs exceeding the generating capacity of the Wilder, Bellows Falls, and Vernon Projects during snowmelt and large precipitation events determine flood levels and scour events, while impoundment WSE changes and discharge from current Project operations affect day-to-day water level fluctuations. Vegetation communities respond to high water events and current Project operations in different ways. Lower elevation communities (marshes and scrub-shrub wetlands) are largely controlled by current Project operations, and the higher elevation communities (forested wetlands) are controlled by high water events resulting in flooding and scour. This analysis focuses primarily on water levels that coincide with current Project operations (excluding periods of high water and spill).

No-action Alternative

The vascular vegetation communities bordering the river in the terrestrial study area can be described according to their positions relative to water level fluctuation zones. The wide diversity of vegetative communities along the Connecticut River reflects varying hydrologic conditions throughout the terrestrial study area and adjacent aquatic areas. Submerged aquatic vegetation occurs almost exclusively below the lower limit of daily and sub-daily water level fluctuations associated with cyclical inflow and normal Project operations. Emergent and scrub-shrub wetlands are also most commonly found within the zone influenced by normal Project operations. Wetlands higher in the hydrologic gradient, primarily forested wetlands, are typically located above normal Project operational WSEs, as are other riparian vegetation communities bordering the river. By virtue of location, the vegetation in the riparian zone must be able to tolerate occasional flooding, and in the case of floodplains, this vegetation is specifically adapted to periodic flood events and other high flows beyond the range of normal Project operations.

The various vegetation communities and their positions relative to current WSEs under normal Project operations, and thus the potential for Project-related effects, are described in more detail in the following sections.

Project maintenance activities, including recreation area maintenance, occur from time to time along the riverbanks. These activities are generally localized and minor in nature. Such activities are conducted in accordance with state and federal wetlands regulations and related stormwater pollution prevention measures and best management practices to avoid compromising riverbank integrity or creating shoreline erosion that might otherwise lead to localized sediment transport or adverse effects on riparian and wetland vegetation. Because no new maintenance activities are proposed, no new effects on riparian and wetland vegetation are anticipated.

Aquatic Vegetation

Because aquatic vegetation is susceptible to desiccation and scour, it proliferates in areas that are protected from strong currents and are not exposed at low flow water levels. The most well-developed aquatic communities occur in backwaters and the mouths of large tributaries to the Connecticut River, where they are both protected from scour and high currents but are situated in sufficient water depth to remain covered at low water levels. Riverine aquatic beds are also prevalent in the upper reaches of the three impoundments. Submerged aquatic vegetation is much less common, and no beds were large enough to map on the truly riverine sections below the dams, where naturally occurring high flow scour and velocities are too strong for most aquatic species to persist.

Emergent and Scrub-shrub Wetlands

Emergent and scrub-shrub wetlands tend to be tolerant of short- and long-term inundation, but are vulnerable to scour by currents and ice, as reflected by their prevalence in protected locations. Deep-marsh emergent vegetation such as pickerel weed, cattail, and soft-stem bulrush dominate in the lower elevations of the emergent marsh zones, anecdotally appearing to seldom be exposed at low water levels. Low scrub-shrub vegetation was often observed at slightly higher elevations and was observed to experience frequent inundation and water level fluctuation. Tall scrub-shrub wetlands are higher in elevation and were observed to be only periodically inundated or saturated.

Emergent and scrub-shrub wetlands are generally absent from terrestrial study area sections that experience strong river currents. This is evident along sections of the mainstem riverbanks and on the leading tips of islands where vegetation was generally sparse or absent. Some species such as sand willows, dogbane, obedient plant, and cardinal flower were found with low sparse cover across areas observed to experience frequent inundation and scour. These species have adapted to tolerate active flow conditions to some extent, although they can be periodically destroyed during flood events (e.g., above normal Project operational flows). Such early successional communities are maintained by such events and forces and are less able to compete as more heavily vegetated succession occurs.

Forested Wetlands

Forested wetlands in the Northeast are not adapted to tolerate prolonged or frequent inundation. This was observed in the terrestrial study area where forested wetlands occur either on terraces or tributary mouths above the zone of normal Project operational WSEs. These forested wetlands are typically small in size and seldom occur along the riverbank. They are more frequently found adjacent to beaver impoundments or backwaters at elevations that are several feet higher than the emergent marsh and presumably inundated only during high water events. They also are found at tributary mouths where signs of flooding were limited to larger debris and sediment deposits typically associated with high water events.

Floodplain Forests

Most floodplain forests occur on terraces that are higher in elevation than the zone of normal Project operations and therefore above the influence of Project-related water level fluctuations. An exception is silver maple floodplain forest, some of which occur on several islands and low terraces adjacent to the Connecticut River. Several low-lying forested floodplains, such as Ash Swamp Brook (in the lower Vernon impoundment just upstream of the dam), showed evidence of periodic inundation or saturation near the zone of normal Project operations. Most other silver maple floodplain forests appear to be well above the zone of normal Project operations and demonstrate classic annual or seasonal flood evidence based on scour marks, sediment deposition in the soils, and large flood debris trapped in trees or bushes.

Upland and Riparian Habitats

The upland and riparian habitats bordering the Connecticut River are above elevations affected by normal Project operations. These include upland riverbanks, riparian habitats, and agricultural fields. Although the vegetation in these habitats is not adapted to frequent inundation or scour, it can generally tolerate periodic flooding and infrequent scour. These communities provide important substrate stabilization when such events occur.

Vegetation Management

The primary purposes of Great River Hydro's vegetation management program are: (1) maintain conditions conducive to visual inspections of water impounding structures including earthen and stone rip-rap embankments, and rights-of-way; (2) maintain public recreation areas to provide habitat for desirable plant communities including grasses, ferns and wildflowers; (3) control of invasive species for public safety (e.g., poison ivy). At the three Projects, vegetation control is assessed on an annual basis and managed as needed (primarily on annual or three-year cycles). All applicable state permits are obtained for chemical treatment which is the primary control method. FERC Project recreation picnic areas are mowed weekly during the recreation season (Memorial Day through Columbus Day). Hazard tree removal is performed as needed.

The Vernon Neck area of the Vernon Project has a site-specific vegetation management plan due to its unique configuration as a natural dam between the Vernon impoundment and the riverine section downstream of Vernon dam. The managed area is about 9 acres and managed with the goal of increasing the ability to perform visual inspections while maintaining the appropriate amount of vegetative cover to control erosion of the slope and deter tree reseeding from adjacent wooded areas. A 3-year rotation treatment plan includes selective hand cutting followed by selective herbicide applications to control sprouts from the roots, and application of selective herbicides that have little or no impact on grasses but control broad leaf plants along the toe of the downstream slope to create predominately grass vegetation cover and allow for easy foot access and increased visibility of the slope structure. A Special Permit issued by the New Hampshire Division of Pesticide Control is obtained before application of herbicides at this spot.

In cases where maintenance activities could adversely affect terrestrial species or their habitats, Great River Hydro works in consultation with the NHNHB and VTNHI to prevent or mitigate those effects (see, for example, discussion of sensitive plants in Section 3.7.2.4, *Sensitive Species*). For example, routine dredging of the Pine Street boat launch in the Bellows Falls impoundment was conducted in 2015 under state and federal wetlands permits. Since sensitive submerged aquatic plants had been recorded at that site, it was mapped, and sensitive species were relocated pursuant to a plan approved by NHNHB. In 2016 transplants were monitored and a report submitted to NHNHB. Monitoring will continue in 2017.

Great River Hydro Proposal

Proposed changes in Project operations may affect vegetation communities near the river's edge, primarily emergent marshes and aquatic vegetation. The more stable water levels at the dam will likely result in an expansion of deep and shallow marsh species and SAV in coves and other protected areas. This effect will diminish with distance upstream from the dam, as the water levels and flows are more affected by riverine conditions. The sparse aquatic vegetation in the main channels is expected to persist as IEO Operations will limit the development of additional SAV.

3.7.2.2 Wildlife Resources

No-action Alternative

In the terrestrial study area, low elevation vegetative communities (marshes and scrub-shrub wetlands) are largely controlled by cyclical inflow and normal Project operations and can be affected by daily water level fluctuations. These communities have established themselves to adapt to the daily hydrology of the river, and the wetland-dependent wildlife species have followed. Amphibians such as American toads, spring peepers, green frogs, and bullfrogs breed in Project-affected emergent and scrub-shrub wetlands.

Notches and overhangs in banks that characterize the initial stages in the cycle of erosion may occur as a result of several factors including WSE fluctuations, waves, groundwater seepage, and high flows (see Section 3.4, *Geologic and Soil Resources*). Certain wildlife species that rely on shallow, benthic infauna (e.g., migratory shorebirds) use these areas. Spotted sandpiper were frequently seen along the water's edge on both protected and exposed shoreline and gravel bars throughout the river, but no targeted study was requested or performed to assess shorebird habitat use or availability. More significant bank erosion caused by larger precipitation events benefits some wildlife, including bank-nesting species (belted kingfisher and bank swallows) and mink and otter that use undercut riverbanks for travel and cover. Also, dragonfly and damselfly larvae emerge from the water and use undercut and eroded banks for eclosure (see Section 3.7.2.4).

Project maintenance activities, including road and facility maintenance, and recreation activities occur at the Projects. Maintenance activities are generally localized and minor in nature and recreation occurs at already developed recreational facilities. Because no changes in such activities are proposed, no new effects on wildlife resources are anticipated.

Great River Hydro Proposal

The proposed changes in Project operations are not anticipated to substantially alter bank and shoreline habitat on the riverine reaches where associated species are unlikely to be affected. In the impoundments, the percent of unvegetated shallows will likely be reduced, therefore those species (e.g., migratory shorebirds) that feed on exposed substrates will have less habitat, while waders and ducks will most likely see an increase in habitat as deep marsh and SAV increase under the more stable water level operations.

3.7.2.3 Invasive Species

No-action Alternative

Invasive plant species, which are prevalent throughout the Connecticut River Valley, as indicated by the Invasive Species Atlas (IPANE, 2016), were observed in abundance along the shores and in most vegetation communities along the study corridor. Invasives typically thrive along large river corridors such as the Connecticut River, in part due to their ability to aggressively colonize areas of disturbance created by periodic scour and erosion during high water events. With the exception of the large marshes behind the dams where Phragmites and purple loosestrife were probably transported by drift and waterfowl, few invasives occurred in the zone affected by daily water level fluctuations; therefore, it is unlikely that normal Project operations directly causes or aggravates colonization and persistence of invasive plant species.

Great River Hydro Proposal

Under Great River Hydro's proposal, the more stable WSE at the dams will likely result in an expansion of deep and shallow marsh species and SAV. Because many invasives have the ability to respond rapidly, the transition to more stable water levels may allow invasives to expand, including some of those listed in Table 3.7-2, such as Phragmites, purple loosestrife, brittle naiad, Eurasion water-milfoil, and others.

3.7.2.4 Sensitive Species

No-action Alternative

Fowler's Toad

The effect of changes in WSE at any potential Fowler's toad breeding site is mediated by the relative arrangement of potential breeding habitat (pools), its connection to the river (direct, indirect, upstream, downstream), and any features (banks, sandbars, wetlands, human-made structures) that could slow water fluctuations and buffer their magnitude. Periodic (every 5 to 15 years) high-energy, high-water events are needed to maintain suitable estivation and hibernation habitat for Fowler's toads along the Connecticut River. In the absence of major flood events, smaller cyclical flow and WSE fluctuations can also create conditions that float away litter and/or discourage vegetation from growing. However, these daily WSE fluctuations can also make otherwise physically suitable breeding pools unsuitable because toad eggs and tadpoles can be easily washed into the river by WSE fluctuations, if accompanied by sufficient flow velocity in un-protected locations, where they will not survive. Study 28 examined the magnitude and frequency of water level fluctuations under normal Project operations and their potential effects on Fowler's toad breeding habitat.

Four study sites with suitable habitat in the Wilder riverine reach are estimated to have Project effects (as defined in Study 28 where modeled WSEs are predicted to be greater than 3 feet more than 90 percent of the time during the breeding season), which is not surprising given that water level fluctuations are typically higher in the riverine reaches than in the impoundments. At the Stebbins Island site in the Vernon riverine reach, the only site where Fowler's toad is known to occur, the modeled WSEs indicated moderate Project effects. While water level fluctuations of more than 3 feet occurred more than 90 percent of days during the breeding season, the site's topography and orientation tends to protect it from scour during non-flooding conditions, and it does not appear to entirely dewater except at low water levels and low flows.

The best Fowler's toad habitat along the Connecticut River is created in locations that are affected by large water fluctuations and high velocities from flood flows, but where, during the breeding season, the adverse effects of scour and dewatering are buffered by the topography of the site. This type of WSE fluctuation regime is uncommon along the Connecticut River as a whole, but occurs at Stebbins Island, where Fowler's toad was confirmed present and, based on historical records, where the population has persisted. Boat-accessed camping occurs at the Stebbins Island canoe rest area as part of the Connecticut River Paddlers' Trail, which is owned and managed by Great River Hydro as a non-Project primitive campsite (see Section 3.9.1.1, *Recreation Resources*). The camping area is typically accessed in the vicinity of Fowler's toad habitat but the campsite itself is located in the middle of the island amidst understory vegetation (Study 30, *Recreation Facility Inventory and Use & Needs Assessment*). Therefore, it is unlikely that recreational activities at the site will adversely affect the species or its habitat.

Cobblestone Tiger Beetle

Adults

Adult tiger beetles are winged and can avoid most direct mortality from habitat inundation. However, indirect energetic costs from daily water fluctuations are possible if they occupy areas affected by such. Adult cobblestone tiger beetles are most active on the riverbanks, and upstream ends and edges of riverine islands during the hottest part of humid summer days (Leonard and Bell, 1999; Study 26), historically corresponding with times of peak hydroelectric power generation. Recently, hourly hydropower operations in the summer have more commonly corresponded with later, end-of-day periods when solar energy production wanes and electrical demand continues to be strong. In general Wilder, Bellows Falls and Vernon operate in more of a cyclical generation pattern largely driven by timing and amount of inflow from upstream projects.

In Study 26, operations modeling data (from Study 5) were used to determine the frequency with which the cobblestone tiger beetle habitat at each study site became completely inundated as a result of normal Project operations. The study sites currently occupied by adults become fully inundated during the adult daily active period no more than 20 percent of the days during the summer, based on modeled data. Therefore, while normal Project operations may have some effect, overall these operations are unlikely to negatively affect current cobblestone tiger beetle populations. But rather this occasional flooding condition may help to sustain the critical habitat conditions sought by the species. Recreational use occurs in the vicinity of several Study 26 sites, but that use is apparently limited and not at FERC Project recreation areas and therefore not affected by the Projects.

Larvae

Cobblestone tiger beetle larvae are currently undescribed, but if other sympatric tiger beetle species are a valid indicator, cobblestone tiger beetle larvae are adapted to tolerate some inundation while within burrows (Brust et al., 2005). Seasonal averages based on Study 5 data show that, during most of the year, typical Project operations do not create constant inundation in presumed burrow locations at the sites known to support adult cobblestone tiger beetles. During the spring freshet, when 8 of the 12 study sites have modeled mean WSEs above presumed burrowing elevations, cobblestone tiger beetles likely occur exclusively in their burrows, and can tolerate the inundation. Although larval habitat and behavior have yet to be described, the presence of adults at 7 of the 13 study sites indicates at least moderate larval success; therefore, continued Project operations are not likely to affect this species in the larval stage.

Dragonflies and Damselflies

Normal Project operations may cause direct, adverse effects on odonate populations. There are two potential types of adverse effects: (1) loss of habitat when the entire bank height becomes inundated and (2) direct mortality from rising water levels at the time of eclosion if the water rises enough to submerge the individual. Study 25 evaluated the time, rate and distance travelled by emerging odonates, the bank habitat utilized, and water levels at the site.

Appropriate habitat for odonates consists of fine aquatic substrates (sand and silt) for larvae with nearby steep, sparsely vegetated banks for eclosion. Habitat needed during the critical emergence period may be unavailable when the entire bank height becomes inundated. To assess Project effects on habitat, during Study 25, hourly WSE data from the hydraulic and operations models (Studies 4 and 5) were analyzed during the critical period for emergence from May 15 to August 31, between 04:00 and 21:00 (Hunt, 2012; Paulson, 2011). Hydraulic rating curves near each study site were analyzed to determine whether the range of measured habitat elevations fell within the modeled range of normal Project operational WSEs. At all study sites, the maximum habitat elevation was never inundated under normal Project operations leaving at least some portion of the suitable habitat range available for larvae to emerge and initiate eclosion.

The most sensitive stage for odonate emergence is the eclosion period, when odonates have started to shed their exoskeleton but are not yet capable of climbing or flight. As described in Study 25, pre-eclosion larvae were quite mobile and several were observed falling in the water and returning to the bank to resume egress. Post-eclosion tenerals were observed to begin climbing soon after eclosion, or in several cases, swimming or climbing out again if they fell into the water. Both horizontal and vertical distances from the water were measured for larval individuals observed leaving the water through eclosion. Horizontal distance travelled by larvae before eclosing varied from 0 inches to 120 inches and appeared related to bank topography—a steeper bank meant less horizontal distance travelled. Although the vertical distance travelled before eclosure varied by species, the conservative benchmark of 8 inches from the water surface was selected for assessing direct mortality risk. Horizontal distance was not found to be a good predictor of vertical distance travelled, so there is no reason to expect low water levels alone to result in a shorter horizontal or vertical distance travelled.

The entire eclosion process took about 20 to 45 minutes for the 5 species observed eclosing (average about 30 minutes). Water level logger data, recorded every 15 minutes at each study site, were used to evaluate rates of water level change. During normal Project operations, the rate of water level rise typically was considerably less than 8 inches in 30 minutes. However, 8-inch rises in water elevation per half-hour were recorded with a less than 2 percent frequency at 5 of the 11 study sites, including at all four sites in the riverine reaches below the three Project dams. No statistically significant difference in 8-inch water level increases occurred during periods of normal Project operations or storm events. Therefore, normal Project operations are unlikely to cause substantial mortality of sensitive dragonfly species in the Project areas. Effects of Project maintenance, agricultural leases, or recreation activities were not evaluated in Study 25, but it is unlikely that these activities adversely affect the species or its habitat.

Bald Eagles

For nesting, bald eagles require mature softwood stands with easy access to riverine food resources. Once a territory is established and a suitable nesting tree is identified, eagle pairs return to established nests each year. Both floodplain forests and terrestrial forests within the terrestrial study area are generally higher in elevation than the zone of normal Project operations and, therefore, above the influence of normal Project-related water level fluctuations. However, nesting trees immediately adjacent to the river are more susceptible to downing during high flow events that scour or undercut banks.

For roosting habitat, bald eagles also prefer mature softwoods with an emphasis on softwood stands rather than individual trees. Availability of food resources during winter is also a critical component of roosting habitat, and open, unfrozen water provides eagles with the ability to fish and hunt waterfowl. Normal Project operations are unlikely to affect conifer stands, which are generally above the influence of daily water fluctuations. In addition, when a suitable conifer stand is available, dam operations can improve or create wintering habitat. The known winter roosting area mapped by NHNHB is located directly below Vernon dam, where dam operations maintain open water across a range of winter temperature and weather conditions.

Project maintenance activities, including road and facility maintenance, and recreation activities occur at the Projects. Maintenance activities are generally localized and minor in nature, and recreation occurs at already developed recreational facilities. Because Great River Hydro does not propose to change these activities, no new effects on bald eagles and their habitat are anticipated, other than the occasional need to remove hazard trees that might provide nesting or roosting habitat.

Plants

Many rare plant species populations have adapted to, tolerate, or rely on the existing flow regime associated with the particular zone in which they occur. Because normal Project operational flows have been in place nearly 70 years under the existing licenses, rare species intolerant of daily inundation probably did not occur in lower riverbank zones historically (i.e., prior to dam construction) or have since been relegated to areas either above or below the normal Project operational range, where habitat conditions remain suitable for the particular individual species.

Some species (or individual populations) apparently tolerate or benefit from the daily inundation associated with normal operational flows. Two newly discovered populations of the New Hampshire-listed as endangered pygmy-weed (Normandeau, 2013c) occurred entirely within normal operational ranges: one along the Vernon impoundment and one in the tailrace vicinity of Bellows Falls. The only other New Hampshire pygmy-weed population found in the terrestrial study area was a previously documented population occurring below the normal operational range in shallow water of a stream inlet of the Bellows Falls impoundment. The locations of the newly discovered populations are consistent with the ecology of this primarily fresh-tidal species and may indicate a positive response to the daily fluctuations of normal Project operations.

Obvious active or imminent erosion threatening individual sensitive species populations was infrequent according to the 2012 RTE survey (Normandeau, 2013c). Only a few populations were on riverbanks with obviously unstable, unconsolidated sediments or deeply undercut banks. Two examples are hairy-eared rockcress and fescue sedge, both of which are also documented from eroding, sandy banks above operational ranges (one location each).

In cases where maintenance activities could adversely affect sensitive species or their habitats, Great River Hydro works in consultation with the NHNHB and VTNHI to prevent or mitigate those effects. For example, routine dredging of the Pine Street boat launch in the Bellows Falls impoundment was conducted in 2015 under state and federal wetlands permits. Because sensitive submerged aquatic plants had been recorded at that site, sensitive species were mapped and relocated pursuant to a plan approved by NHNHB. In 2016 transplants were monitored and a report submitted to NHNHB. Monitoring will continue in 2017.

Great River Hydro Proposal

Fowler's Toad

Under Great River Hydro's proposed Project operation, the hydrologic conditions at the Fowler's toad breeding area below the Vernon dam are not likely to change substantially. This is in part because water levels are controlled by both Vernon and Turner Falls, and in part because its topography and orientation are influenced by high flows from Vernon and less by Project operations.

Cobblestone Tiger Beetle

Under Great River Hydro's proposed Project operation, the more stable water levels at the dam are expected to result in less water level fluctuation at the cobblestone tiger beetle sites within the influence of the Bellows Falls impoundment (Chase, Ascutney). The remaining sites on the riverine sections of Wilder and Bellows Falls (Johnston, Burnaps, Sumner Falls, Hart and Walpole), which currently experience greater water level fluctuation than the impoundment sites, are expected to see a reduction in daily water surface fluctuation under Great River Hydro's proposed Project operation. The effect will be mostly at the lower water surface elevations but will reduce operational flow events (Flexible Operations) by as much as 0.5 feet and will reduce the frequency of those events by as much as 90 percent in June (Table 3.3-4). The combination of reduced frequency and magnitude of high water surface elevations will result in less inundation of cobblestone tiger beetle habitat.

For adults, a more stable water regime is expected to have little direct effect, but may affect the amount and type of vegetation within the existing habitat. The decrease in range of water level fluctuation in the riverine and upper impoundment sections will result in less inundation of larval habitat. The effect will be more pronounced on the impoundment sites, with continued but lesser fluctuation on the riverine sites. The reduction in fluctuation and associated decrease in flooding of larval burrows could potentially increase the success of cobblestone tiger beetle larvae. The effect on habitat is more difficult to anticipate; less cyclical flooding could allow more perennial plant species to establish, which could benefit cobblestone tiger beetles if the density is low and/or the plant form is sparse. Conversely, dense vegetation growth would potentially reduce the availability of larval habitat. High flows associated with floods will be unaffected by the proposed change in project operations and are expected to continue being the dominant influence controlling most vegetation and substrates in these locations.

Dragonflies and Damselflies

While current Project operations do not appear to adversely affect odonate eclosure, proposed Project operation will further reduce any risk to odonates from rapid rises in water levels. The amplitude of the water level change will reduce by between approximately 40-80 percent at the dams (see Table 3.3-2), and the up-ramping rate will be slowed (see Section 2.2.1). The combined effects of less fluctuation occurring at a slower rate will only be beneficial to eclosing odonates.

Bald Eagles

Mature softwood stands preferred by bald eagles are generally higher in elevation than the zone of Project-related water surface elevation for both normal Project operations and Great River Hydro's proposed operations. Proposed operations are not expected to alter the bald eagle winter roosting area directly below Vernon dam. The extent of open water in winter, where bald eagles frequently feed, is also not expected to change under the proposed project operations.

Plants

The effect of proposed Project operation will be minimal on the vast majority of rare species in the Project area. Most plants occupy habitats that are either above or below the project operating ranges (see Section 2.2.1, however a few have the potential to be affected. Hairy-eared rock cress and fescue sedge were documented on open eroding sandy banks, but well above the operational range for the project. At these sites, these two upland plants likely depend on scour and flooding during storm flows to maintain open habitat on the riverbank and are not affected by Project operations. Pygmy-weed lies within Project operating ranges and could be affected by the proposed change in operation. Pygmy-weed is typically a fresh tidal species and most likely occurs in the Project area because current daily water level fluctuations simulate a tidal regime. The existing populations may be well enough established to persist, but the proposed reductions in frequency and extent of fluctuating water levels during the growing season have the potential to adversely affect the species. Incurved umbrella sedge co-occurs with pygmy-weed below Bellows Falls dam and similarly has the potential to be affected by the proposed change in Project operations. Several other protected species, including obedient plant, sandbar willow and black-seeded clearweed, also occur at the water's edge but in a wider range of habitats. These species could also be affected by the proposed change in Project operations in some locations. See also Jesup's milkvetch in Section 3.8.2.4.

3.7.3 Cumulative Effects

As described in Section 3.2.2, FERC identified the geographic scope of cumulative effects on terrestrial and floodplain communities to include the 100-year floodplain (as defined by the Federal Emergency Management Agency) adjacent to the Project-affected areas from the upstream extent of the Wilder impoundment downstream beyond the Vernon Project to the Route 116 Bridge in Sunderland, Massachusetts. FERC chose this geographic area because the operations of the Wilder, Bellows Falls, and Vernon Projects and the downstream FirstLight Projects, "in combination with other land uses in the Connecticut River Basin, may cumulatively affect floodplain communities adjacent to Project reservoirs and downstream riverine reaches in this area."

Since the commencement of water regulation on the Connecticut River, cumulative changes have likely occurred within the riparian and terrestrial habitats within the 100-year floodplain of the river. Vegetative communities, including populations of sensitive plant species and non-native invasive species, have adjusted their extent and elevation according to their individual inundation tolerances and soil requirements, and wildlife have, in turn, adjusted their habitat use.

Future cumulative changes in the 100-year floodplain from current operations of the Wilder, Bellows Falls, and Vernon Projects would not be expected.

Future cumulative changes under proposed operations are expected to be minimal as described above. The most likely sources of cumulative impacts predicted for the 100-year floodplain will result from indirect impacts from continuing residential and commercial development and expansion of human infrastructure.

3.7.4 Unavoidable Adverse Effects

Unavoidable adverse effects are those that may still occur after implementation of protection and mitigation measures. Normal Project operations have few adverse effects on terrestrial wildlife and botanical resources in the Project areas. However, Studies 25, 26, 27, 28, and 29 have identified some minor effects and/or inconclusive results (Section 3.7.2, *Terrestrial Resources, Environmental Effects*). Similarly, few unavoidable adverse effects are anticipated under Great River Hydro's proposed operations, as discussed in Section 3.7.2. Normal recreation area maintenance or construction maintenance activities could potentially affect some terrestrial species or their habitats on a limited and/or localized basis.

3.8 Threatened and Endangered Species

3.8.1 Affected Environment

Listings of all federally threatened and endangered species were obtained from map and database information provided by FWS. Within the Wilder, Bellows Falls, and Vernon Project areas, five federally protected species either occur or have historically occurred (Table 3.8-1). These species, their habitat requirements, and their current status in the Project areas are detailed in the following sections. Targeted relicensing studies were conducted to search the Project areas for the federally endangered Jesup's milk vetch in 2012 (Normandeau, 2013b) and northeastern bulrush in 2014 (Study 29). In 2014, the Project areas were also searched for suitable Puritan tiger beetle habitat as part of Study 26, and in 2011, 2013, and 2014, surveys were conducted to search for the DWM (Study 24).

3.8.1.1 Puritan Tiger Beetle

FWS lists the Puritan tiger beetle as threatened (55 FR 32088–32094). FWS has not designated critical habitat for this species. It has greenish-bronze outer wing plates with extensive white patterning and a distinct angle on each side as the plate approaches the ventral apex. Larval density of Puritan tiger beetle is highest along big rivers in sparsely vegetated patches of fine to medium sand (particles predominantly 0.125 to 0.5 millimeters [Omland, 2002]). In some instances, suitable habitat may be embedded in wide beaches (e.g., at Northampton, Massachusetts), but in other instances, the beach may be quite narrow (e.g., 13 to 20 feet wide in Cromwell, Connecticut). Although the Puritan tiger beetle is associated with clay banks in Maryland, this may not be relevant to habitat preferences in New England (Vogler et al., 1993).

According to the Recovery Plan for the Puritan tiger beetle (FWS, 1993a), the species has been historically documented in the vicinity of the Project areas. The historical distribution in New England included locations on the Connecticut River that extended from Claremont, New Hampshire, to Cromwell, Connecticut. Puritan tiger beetle was considered extirpated from nine of these sites by the early 1900s, with the latest collection records in the 1930s (Knisley, 1987, cited in Hill and Knisley, 1993). In New Hampshire, the Puritan tiger beetle is only known historically in the Bellows Falls Project area from one site in Claremont, New Hampshire, and one site in Charlestown, New Hampshire (Hill and Knisley, 1993). An additional single Vermont siting was historically documented along the Connecticut River in the town of Hartland, Vermont. However, despite intense searching by tiger beetle experts, no occurrences have been found upstream of Hadley, Massachusetts, in the past 25 years (Hill and Knisley, 1993).

Table 3.8-1. Federally listed species within the Project areas.

Scientific Name	Common Name	VT Status[a]	NH Status[a]	Federal Status[a]	Habitat
Invertebrate Animals					
Cicindela puritana	Puritan tiger beetle[b]	T	T	T	Sandy beaches on river's edge
Alasmidonta heterodon	Dwarf wedgemussel	E	E	E	Variable-sized rivers with stable flow and substrate
Vertebrate Animals					
Myotis septentrionalis	Northern long-eared bat	E	T	T	Upland forests, caves
Plants					
Astragalus robbinsii var. jesupii	Jesup's milk vetch	E	E	E	Upper scour zone on calcareous ledges along river
Scirpus ancistrochaetus	Northeastern bulrush	E	E	E	Emergent wetland with intermittently exposed substrate

Source: FWS (2020b)

a. T – Threatened, E – Endangered

b. Species likely extirpated. The last individual was observed the Bellows Falls Project area in 1932. The nearest known extant population is located at Rainbow Beach in Northampton, Massachusetts, downstream of the Projects and in the Holyoke impoundment.

As part of Study 26, the Wilder, Bellows Falls and Vernon Project areas were researched for potential Puritan tiger beetle habitat. To select areas of interest, aerial photography and data from preliminary aquatic and terrestrial habitat mapping (from Studies 7 and 27) were examined for patches of potentially suitable habitat. Areas of interest contained fine to medium sand and sparse vegetation, but no new suitable habitat was found in the Project areas. As a result, Study 26 site selection focused on cobblestone tiger beetle habitat because of the higher probability of locating this species, but scientists still thoroughly searched for Puritan tiger beetles within the chosen survey sites. The species was not observed during Study 26, so all Puritan tiger beetle records in the Project area remain historical.

3.8.1.2 Northern Long-eared Bat

FWS listed northern long-eared bat as threatened in 2015 (81 FR 1900–1922) based on severe population declines due to the fungal disease called white-nose syndrome. Until the onset of this disease, the non-migratory northern long-eared bat was widespread throughout the Northeast. In summer, this species uses a wide variety of upland forest types. FWS has not designated critical habitat for this species, but issued regulations in 2016 under Section 4(d) of the ESA (50 C.F.R. § 17.40(o)). Those regulations prohibit incidental take of the species within the zone where white-nose syndrome occurs and related actions that could result in incidental take, such as tree removal (except for removal of hazard trees) within 0.25 mile of a known hibernaculum, or that cuts or destroys known occupied maternity roost trees, or any other trees within a 150-foot radius from the maternity roost tree, during the pup season (June 1 through July 31). Purposeful removal from human structures is also not prohibited.

Unlike most other species of bat in the Northeast that prefer to forage along forest edges and watercourses, northern long-eared bats forage primarily under the canopy using a combination of hawking and gleaning (e.g., catching flying insects in the air, or plucking them from surfaces) behaviors to capture prey (Brack and Whitaker, 2001). In summer, this species typically roosts under the exfoliating bark or in cracks and crevices of trees greater than 3 inches in diameter at breast height (Lacki et al., 2009; Sasse and Perkins, 1996). It overwinters in hibernacula (typically caves) that offer steady temperatures just above freezing and adequate humidity (Van Zyll de Jong, 1985). Northern long-eared bat was state and federally listed after the development and implementation of the Project study plans, and there were no requests from stakeholders to evaluate this species; therefore, the species was not evaluated within the Project areas.

3.8.1.3 Northeastern Bulrush

Northeastern bulrush is a federally listed endangered perennial species in the sedge family. This species looks similar to several common species, but the most reliable diagnostic feature is the presence and length of bristles with recurved barbs on the fruit. Habitat requirements for northeastern bulrush are variable and can range from inundated pond margins to emergent wetlands with a subsurface water table. The common characteristics of northeastern bulrush habitat in the northern part of its range are an open canopy and an intermittently variable water table. It is hypothesized that receding water caused by seasonal variation or the removal of an impoundment (beaver dam or structure) exposes bare substrate that the northeastern bulrush requires for flowering and germination. Without intermittently exposed substrate, the bulrush appears to be outcompeted by other species adapted to more consistent water levels. Drastic changes in hydrology, such as prolonged inundation or drought, have also been shown to adversely affect the species (FWS, 2008, 1993c; Royte and Lortie, 2000).

The northeastern bulrush was classified as federally endangered in 1991 (56 FR 21091–21096) with 9 known occurrences in New Hampshire and 22 in Vermont, one of which is on the Connecticut River in the Bellows Falls Project area. FWS has not designated critical habitat for this species. FWS issued a Recovery Plan for the northeastern bulrush in 1993 (FWS, 1993c).

As part of Study 29, scientists searched for the known population of northeastern bulrush and attempted to locate undocumented populations within the Wilder, Bellows Falls, and Vernon Project areas. Four sites contained high potential northeastern bulrush habitat in at least portions of the site, but no individuals of the species were observed. This includes negative findings from the previously documented Bellows Falls site, at which northeastern bulrush had been last observed in 1999.

3.8.1.4 Jesup’s Milk Vetch

FWS listed the Jesup’s milk vetch is as endangered in 1987 (52 FR 21481–21484). FWS has not designated critical habitat for this species. Jesup’s milk vetch grows in rock crevices within calcareous ledge along the upper reaches of the scour zone of the river (FWS, 2010). This perennial plant uses a taproot for stability and to hold nutrients. It is flood-tolerant, which allows it to outcompete many other species, but non-native species such as black swallowwort and Morrow’s honeysuckle (*Lonicera morrowii*) are becoming a threat as they encroach on the rocky shoreline habitat on the Connecticut River (FWS, 2010).

Jesup’s milk vetch occurs naturally at only three known sites in the world, all along the Connecticut River downstream of Wilder dam: Sumner Falls (Plainfield, New Hampshire); Jarvis Hill (Claremont, New Hampshire); and Hartland Ledges (Hartland, Vermont). The Jarvis Hill site lies within the Wilder riverine reach and at the most upstream extent of the Bellows Falls impoundment. Another site that lies above the RTE project area, Cornish Ledges in Cornish, New Hampshire, is an introduction site where Jesup’s milk vetch establishment is being attempted.

FWS prepared a Recovery Plan for the species in 1989 (FWS, 1989) and included actions to:

- Protect known populations;

- Seek protection of essential habitats; and
- Ensure continuation of pre-1989 dynamics of the portion of the Connecticut River ecosystem directly affecting known populations.

The three natural Jesup's milk vetch populations and the introduction site have been the subject of long-term monitoring by NHNHB and VTNHI based on the requirements of the initial Recovery Plan (FWS, 1989). In 2012, a hydrologic study was conducted (Normandeau, 2013b) to facilitate the states' long-term monitoring of the species and to provide additional information in support of the Project PADs. The study developed stage-discharge rating curves for the four sites relative to flows at the USGS West Lebanon gage with the goal of determining at what flows certain features may become inundated, such as at established reference bolts and plant locations. The results of this study are discussed in Section 3.7.2.4.

3.8.1.5 Dwarf Wedgemussel

FWS listed the DWM as endangered (55 FR 9447–9451) in 1990 (for a review of its listing history, see FWS, 2019, 2013b, 2007b, 1993b). It is the only federally listed endangered mussel in New England, and it is listed as endangered by every northeastern state where it occurs (Connecticut, Massachusetts, Vermont, New Hampshire, New York, New Jersey, Pennsylvania, and Maryland), as well as states in the southern end of its range. It is considered to be extirpated in Canada (Committee on the Status of Endangered Wildlife in Canada, 2009). FWS has not established critical habitat for DWM, and no habitat conservation plans have been published for the species. FWS issued a Recovery Plan for this species with the main goals of protecting and enhancing habitat of current DWM populations and establishing or expanding populations within rivers or river corridors historically supporting the species (FWS, 1993b). The latest 5-year review (FWS, 2019) concluded that dwarf DWM should continue to remain listed as endangered because criteria specified in the Recovery Plan to delist the species or down-list it to threatened have not been (and may never be) met. An updated 5-year review was initiated in 2018 (83 FR 39113-39115).

DWM have a lower fecundity than most other mussel species (McLain and Ross, 2005; Michaelson and Neves, 1995). Larvae, called glochidia, are released between March and May following spawning the prior summer and becoming gravid the prior fall (Michaelson and Neves, 1995). To complete larval development and metamorphose into juveniles, glochidia typically attach to the fins or gills of a fish for several weeks. Mussels have species-specific preferences for host fish. The Tessellated Darter is considered the primary host for DWM in the Connecticut River watershed, and its range is most congruent with that of the DWM (Nedeau, 2008). Several other fish have been identified as potential hosts, including Slimy Sculpin, Mottled Sculpin, Atlantic Salmon, Striped Bass, and Banded Killifish (Nedeau, 2008). In Study 12, Tessellated Darter were found nearby or in the general vicinity (within 1 to 2 miles up or downstream) of most locations were DWM were found. Darters were also present near some mussel survey sites where no DWM were found (e.g., near Sumner Falls). In Study 10, Tessellated Darter, Slimy Sculpin, and Banded Killifish were collected in all river reaches and accounted for 9.4 percent, 1 percent, and 0.2 percent, respectively, of the total catch of all collected species.

The parasitic phase of a mussel's life cycle is one of the few opportunities for long-distance dispersal. Tessellated Darters have limited mobility—they may move less than 100 meters during their short lives—thus the dispersal ability of DWM is low and the rate at which they might recolonize former habitat is slow (McLain and Ross, 2005). The life span of a DWM is considered less than 12 years (Michaelson and Neves, 1995), which is short compared with many other freshwater mussel species in the Northeast. Short life spans, low fecundity, high degree of host specificity, limited dispersal ability of its host species (except for the Atlantic salmon and striped bass), and low population densities likely all contribute to the endangered status of the DWM.

The historical range of the DWM included 70 locations in 15 major Atlantic coastal watersheds from North Carolina to eastern New Brunswick. By the early 1990s, its range was thought to have shrunk to about 20 locations in 8 watersheds (FWS, 1993b). In the last 25 years, biologists rediscovered populations that were considered extirpated and discovered entirely new populations (FWS, 2019; Nedeau, 2008; Strayer et al., 1996). It is currently known from at least 70 locations in 15 major watersheds, with the largest populations in the Connecticut River watershed and in the Neversink River in New York. It currently occurs in 14 rivers in the Connecticut River watershed, including 4 in Connecticut, 4 in Massachusetts, 3 in Vermont (Black River, Ottauquechee River, and Connecticut River), and 4 in New Hampshire (Ashuelot River, South Branch Ashuelot River, Johns River, and Connecticut River). The upper Connecticut River mainstem is thought to support the largest populations remaining in the world (Nedeau, 2008), although field data collected from 2011 to 2014 in parts of the Middle and Southern Macrosites of the Connecticut River suggest potential declines and highlighted uncertainty about population size (Study 24; see also Section 3.6.1.5).

In Study 24, DWM were found consistently along a 14-mile reach of the Wilder impoundment, from 27 to 41 miles upstream from the dam. This range generally corresponds to the 16-mile range documented in 2006 (Nedeau, 2006), the main difference being that animals were found slightly farther downstream in 2006 than in 2011 or 2013. DWM were not found immediately downstream from Wilder dam. The mussel community in the riverine reach farther downstream of Wilder dam exhibited low species richness and low abundance compared to the other survey areas. DWM were only found near Chase Island and were not found at two of the historical monitoring sites near Cornish Covered Bridge or Sumner Falls, or at other sites between Wilder dam and Cornish Covered Bridge.

DWM were found over a 17-mile distance in the Bellows Falls impoundment, but always at low densities. The same was generally true for the co-occurring triangle floater and creeper, two species that have similar habitat preferences and usually co-occur with DWM (see Section 3.6.1.5). The Bellows Falls impoundment contains a tributary population of DWM, in the lower Black River. DWM were not found immediately downstream from Bellows Falls dam.

DWM were not found in the Vernon impoundment or below Vernon dam; this finding corroborates results of the few recent surveys conducted in the impoundment (Nedeau, 2005). However, DWM were found in the impoundment near Brattleboro, Vermont, 30 years ago (VT WAP Team, 2015).

3.8.2 Environmental Effects

3.8.2.1 Puritan Tiger Beetle

No-action Alternative

The Puritan tiger beetle is presumed extirpated from the Wilder, Bellows Falls, and Vernon Project areas by FWS. The desktop analysis and field verification conducted for Study 26 confirmed that no suitable habitat is currently available in the Project areas. Therefore, continuing Project operations will not affect this species.

Great River Hydro Proposal

Neither the Puritan tiger beetle nor its preferred habitat exist in the Project area, therefore, proposed Project operations will have no adverse impacts to the species or habitat.

3.8.2.2 Northern Long-Eared Bat

No-action Alternative

Although no study for northern long-eared bat was conducted in the Project areas, their preference for foraging and roosting under the forest canopy suggests that continuing Project operations and maintenance are not likely to adversely affect this species because the existing forest canopy is not likely to be disturbed other than for hazard tree removal or for other incidental tree removal conducted for purposes of routine facility maintenance. Such activities will be conducted in accordance with 50 C.F.R. § 17.40(o) (see Section 3.8.1.2).

Great River Hydro Proposal

The proposed Project operations will not affect the forest canopy and therefore will have no adverse effect on Northern long-eared bat.

3.8.2.3 Northeastern Bulrush

No-action Alternative

Northeastern bulrush does not normally occur in large riverine habitats. All four sites within the Project areas with suitable habitat for northeastern bulrush are occupied by beavers and their dams that control water levels in the wetlands behind those dams. Beavers are extremely unlikely to build dams in locations or at heights that are inundated on a continual or frequent (e.g., daily/weekly) basis as a result of normal Project operations, particularly during the growing season. In addition, the water level behind the beaver dams at all four sites may produce prolonged high water levels within the sites, resulting in temporary or permanent suppression, reduction, or elimination of the species from the sites that is unrelated to Project operations.

Non-flow-related Project effects, such as from recreation areas or leasing of fee-owned Project land for agricultural activity, could also affect populations if located in proximity to those activities. Two of the four sites with suitable habitat identified in Study 29 are located adjacent to agricultural operations in the applicable Project's boundary. Direct agricultural impacts (e.g., runoff) may occur but are unrelated to Project operations. One site with suitable habitat is located within the applicable Project's boundary near a road and non-FERC Project car top boat launch. Road runoff could have an adverse effect on habitat, but it is unlikely that boating or the occasional camping that may occur there (Study 30) would cause adverse effects on northeastern bulrush habitat. The fourth site, while within the applicable Project's boundary, did not appear to have such associated activities. Existing Project operations would not adversely affect northeastern bulrush.

Great River Hydro Proposal

For the same reasons discussed previously under current operations, proposed Project operations will not adversely affect the northeastern bulrush.

3.8.2.4 Jesup's Milk Vetch

No-action Alternative

The 2012 Jesup's milk vetch study (Normandeau, 2013b) found no evidence to suggest that normal Project operational flow ranges affect Jesup's milk vetch individuals or populations. The lowest elevations at which Jesup's milk vetch plants grew were equated to discharges of 29,000 cfs at the Jarvis Hill site and 38,000 cfs at the Sumner Falls site, which is much greater than the normal operational flows from Wilder (700 to 10,500 cfs). It is likely that scour from high flows (well above normal Project operations) may be an important influence in the establishment or maintenance of Jesup's milk vetch plants. No routine maintenance or recreation activities occur at Jesup's milk vetch sites. Although whitewater boating at Sumner Falls occurs in the general vicinity of the Jesup's milk vetch site (see Section 3.9.1.1), Great River Hydro has no FERC Project recreation area at this location, and access to the falls for boating is owned and management by the town of Hartland, Vermont, and does not directly impact the site. Therefore, continued Project operations will not adversely affect Jesup's milk vetch.

Another factor influencing Jesup's milk vetch growth is the presence of invasive species, such as black swallowwort which thrives in conditions similar to those preferred by Jesup's milk vetch. NHNHB and VTNHI are employing active vegetation management techniques including the use of approved herbicides and removal of black swallowwort during the growing season on a periodic basis.

Great River Hydro Proposal

Great River Hydro's proposed Project operations are unlikely to affect Jesup's milk vetch for the same reasons current Project operations do not affect the species.

3.8.2.5 Dwarf Wedgemussel

FWS issued the Recovery Plan for the DWM in 1993 (FWS, 1993b); in the 24 years since it was published, there have been three 5-year reviews (2007, 2013, and 2018). The 2018 review determined that the common threats identified in the original listing remain the same and there was no recommended change in the classification based on the low potential of recovery in the southern portions of the species range (FWS, 2019). Further, it was recommended that the recovery plan be revised to reflect new information on biology and individual populations using the Species Status Assessment (SSA) framework. This framework will identify recovery actions based on the specific needs of this species at a regional or individual population level. The recommendations for specific recovery actions prioritized in the 2018 review are:

- Priority 1 - Resolve the question of whether or not northern and southern populations are genetically distinct.
- Priority 1 - Develop habitat protection strategies for high priority populations.
- Priority 2 - Complete statewide population surveys in NY, NJ, MA, NC, and VA, and assess population status in these states.
- Priority 2 - Resurvey the Neversink River (NY), Delaware River (NY/NJ), and Flat Brook (NJ) to assess impacts from severe flooding in 2012 and establish new baselines for future comparison.
- Priority 2 - Revisit established survey sites on the Connecticut River that have not been resurveyed within the last 10 years to verify that the subpopulations still persist, as well as to determine the long-term viability of the macrosites.
- Priority 2 - Support and assess ongoing methods for captive propagation efforts and subsequent augmentation/reintroduction efforts.
- Priority 3 - Develop new rangewide database and maps with partners. Use maps to update IPaC and assist with targeted project reviews and surveys.
- Priority 3 - Develop persistence probability models to help determine when a population is healthy and when it may need intervention. To create these models and to ensure that they are realistic and reliable, more data are required. Additional studies that address age structure, sex ratio, age specific growth rate and death rate, and age specific reproduction and survival rates of DWM populations are needed to fill data gaps.

- Priority 3 - Develop standardized survey protocols to be used across the range.

Operation of the Wilder, Bellows Falls, and Vernon Projects relates broadly and indirectly to recovery actions. The Project areas include nearly all Southern and Middle Macrosites for DWM, which are regarded as two of the largest populations remaining in the species' range. The presence and operations of the Projects have helped to shape DWM population distribution, size, and habitat in these areas, although the direction and magnitude of such effects remains unknown. The DWM studies conducted in the Project areas from 2011 to 2014 as part of Study 24, as well as other modeling and fish and aquatics studies, such as Studies 4, 5, 9, 10, and 12, provide comprehensive information on DWM populations, co-occurring species, presence of potential host fish species, and habitat in the Project areas, as well as potential effects of Project operations (e.g., water level fluctuations) on the species. Tesselated darter, a confirmed host species, was identified during study 10 in all pools across diverse habitat types, including those regions with confirmed DWM.

No-action Alternative

An assessment of potential impacts from Project-related effects was developed for DWM. Direct effects to DWM are unlikely to occur as a result of current or proposed project operations unless water level drops rapidly enough to expose and strand shallow individuals. In the Project impoundments, the majority of margin habitat along the mainstem channels are steeply sloped and mid-channel habitats are far deeper than the fluctuations in WSEs; consequently, relatively little change in wetted width occurs during normal Project operations. The majority of DWMs observed in Project reaches were at water depths deeper than six feet and well below the lower limit of normal WSEs under current operations. It is unlikely that DWMs located at these depths will be exposed, injured or adversely affected by current operations. Potential for direct effects to DWM through normal operations are considered to be low. Although direct impacts to DWM are not expected to occur under current operations, indirect effects to DWM are likely to occur in areas located along the shallow river margin. While the majority of the observed populations in Wilder and Bellows Falls are deeper than the lower limits of current operations under normal conditions, a smaller portion of this population (approximately 19 percent) exists in the shallow river margins above the lower operating limit. DWM located in the shallower areas may be exposed to increased predation or other indirect effects. The following indirect effects were considered:

- Increased predation
- Increased water temperatures in shallows
- Increased energy expenditure for burrowing or lateral movement
- Loss of habitat through water fluctuation

- Reduced gamete transfer
- Reduced host fish access

For the purposes of the assessment, indirect effects were considered for reaches where DWMs were identified. Neither the lower sections of project impoundments nor riverine sections below project dams were considered appropriate habitat to support DWM, and therefore, were not considered. Historic sites were known in the Vernon reach from the Brattleboro area and existing populations are known from the Ashuelot River, a tributary immediately downstream of Vernon dam. However, no DWMs were observed in the Vernon project area during the targeted surveys. It is unlikely that substantial portions of the known DWM population will be indirectly affected in the Vernon project area. This area was considered in the context of the species recovery plan and potential effects but was not considered for direct or indirect effects to individuals or occupied habitat.

Aside from direct stranding or sudden exposure of known shallow populations, which is not expected to occur, estimation of the number of individuals that can be attributed to effects created by Project operation versus another adverse effect would be nearly impossible. Portions of each Project area contain slower impounded sections, flow protected areas of the upper impoundments, and riverine reaches. The effects determination indicate that current Project operations may affect DWM and its habitat, but that current Project operations are unlikely to adversely affect the species, resulting in direct mortality. No critical habitat has been designated for DWM by FWS; therefore, the proposed current operations will not result in any adverse modification of critical habitat.

Great River Hydro Proposal

The simulated changes in impoundment WSEs and downstream flows occurring as a result of the IEO/Flexible Operations proposal is expected to minimize potential direct and indirect impacts to existing DWMs in the Project reaches. As noted in Section 3.3, the average changes in WSEs under current operations range from 1.03 ft to 1.67 ft in the Wilder Impoundment, and 0.59 ft to 1.21 ft in the Bellows Falls Impoundment (Table 3.3-2). In contrast, the proposed operations are expected to maintain Target WSEs for 50 percent to 96 percent of the time (Table 3.3-1), with average fluctuations of only 0.05 ft to 0.40 ft.

Known locations of DWMs in the Project area are largely limited to the upper portions of the Wilder and Bellows Falls impoundments, with few located in the lower Bellows Falls impoundment (within 12 miles of the dam). WSEs at the upper portions of the impoundments will be significantly affected by inflow which will dictate proposed IEO Operations. IEO operating conditions are expected to be met during spring, summer, and fall months for 67 percent to 97 percent of the time in the Wilder Impoundment, and for 68 percent to 97 percent of the time in the Bellows Falls Impoundment (Table 3.3-3).

The influence of IEO Operations on WSEs in the vicinity of DWM locations is illustrated in Figure 3.8-1. Although bed elevation data was not recorded at most locations where DWM were observed during field sampling, approximate bed elevations can be derived from transect counts conducted in the Wilder Impoundment in 2014 (ILP Study 24). Bed elevations at the locations of 6 DWM were estimated using the GIS bathymetry layer, along with maximum elevations within 2 meters of each DWM location to account for uncertainty (Table 3.8-2). Nodal WSE data in proximity to the DWM locations in 2009 (a wetter year) and 2015 (a drier year) under IEO only or IEO with Flexible operations were nearly identical, with WSEs rarely dropping below 385.0 ft. The nodal WSEs were compared to the estimated DWM elevations, which showed that all 6 DWM elevations were at least 3 ft below the minimum WSE, and only one DWM location (with 2 mussels) showed potential for dewatering with a maximum elevation just below 385 ft. In contrast, the other 4 DWM elevations were all at least 5 ft below the minimum WSE, and more likely 7 or more ft below the minimum WSE.

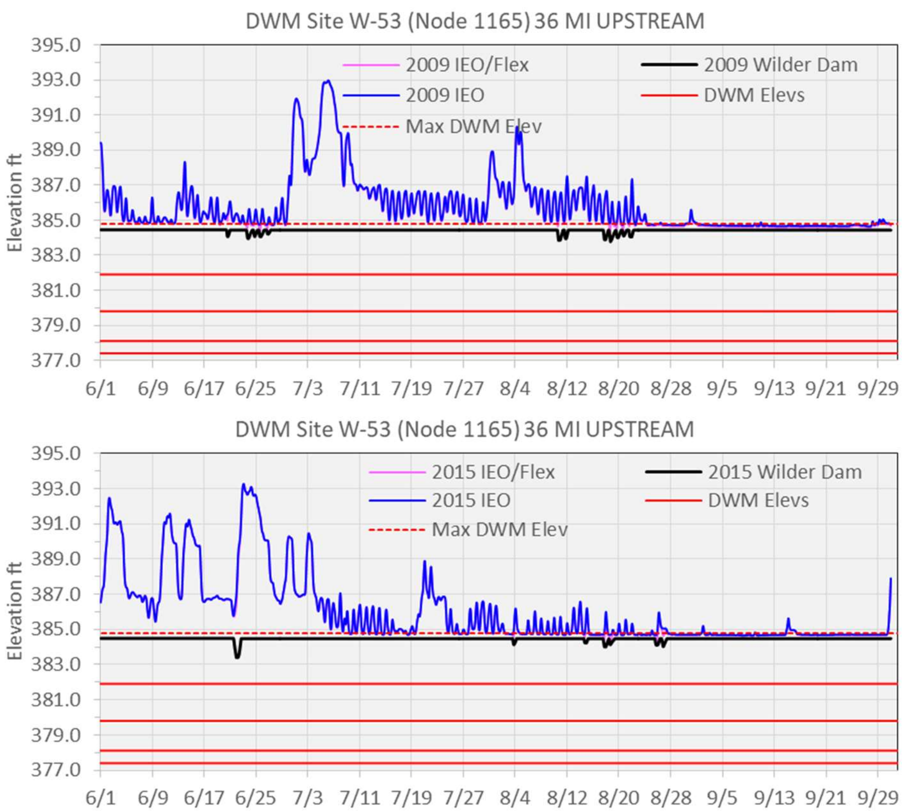


Figure 3.8-1. Estimated bed elevations at 4 locations with 6 DWMs in Wilder Impoundment from 2014 survyes, along with 2009 (upper graph) and 2015 (lower graph) WSEs at a nearby modeling node.

The maximum estimated elevation of all DWM is also shown (note the IEO WSE line overlaps and largely hides the IEO/Flex WSE line).

Table 3.8-2. Estimated bed elevations at 4 locations with 6 DWMs in the Wilder Impoundment from 2014 surveys, along with maximum elevations within 2 m of each DWM location.

Impoundment	WSE Node	DWM ID	DWM Elev	Max Elev w/in 2m
Wilder	1165	DWM 10-6	381.9	384.8
Wilder	1165	DWM 10-7	381.9	384.6
Wilder	1165	DWM 8-4	378.1	380.3
Wilder	1165	DWM 8-5 (2)	377.4	379.7
Wilder	1165	DWM 9-6	379.8	382.9

The proposed operation will restrict the Bellows Falls Flexible Operating Impoundment Range to 1.0 ft from June through September to further protect DWMs located in the lower Bellows Falls impoundment where WSE's are affected by changes at the dam rather than changes in inflow. The increased stability in WSEs will result in multiple time periods of 3 or more consecutive days when IEO conditions are met, and the restricted operating range at the Bellows Falls dam will provide an additional buffer against dewatering. These measures are expected to reduce lateral movements of DWM and improve feeding, growth, and reproductive success.

In addition, the Wilder and Bellows Falls impoundments will initiate pre-winter habitat operations to reduce the likelihood of dewatering or freezing DWM during their winter hibernation. This will be accomplished by maintaining WSEs near the lower limit of the proposed operational range for a period of time when water temperatures are dropping from 15°C to 10°C, a period when DWM are expected to be seeking overwintering habitat. Once water temperatures are consistently below 10°C, the Project will return to normal operations and will not drop WSEs below the pre-winter elevation during the remainder of the winter period (unless required to by flood profile operation) to ensure hibernating DWM remain submerged. The DWM pre-winter habitat operations are further detailed in Section 2.2.1.

As noted above, DWM habitat in the upper ends of Project impoundments will be largely influenced by IEO Operations, with some effects of Flexible Operations evident in the uppermost reaches, such as at Chase Island, a known DWM location at the Wilder riverine/Bellows Falls impoundment transition zone. The potential effects of Flexible Operations on DWM habitat in the transition zones will be moderated by several factors, including attenuation of flow changes from the Project dams down through the Wilder and Bellows Falls riverine reaches, and changes to the discharge regimes under the proposed operations. As a result of the IEO//Flexible operations proposal, minimum flows will be increased and maximum flows will be decreased in spring, summer, and fall months in the Wilder and Bellows Falls riverine reaches. These changes will result in a reduced the frequency and magnitude of flow fluctuations in comparison to current operations (Table 3.3-5 and Table 3.3-6). The more consistent flow regime under the proposed IEO operations, as well as the reduced duration and decreased rate of change under the

Flexible Operations (Section 3.3), will lessen the likelihood of direct and indirect impacts to DWM, including stranding or dewatering.

3.8.3 Cumulative Effects

No cumulative effects related to federally listed threatened or endangered species have been identified, so no cumulative effects on these species were evaluated as part of this environmental analysis.

3.8.4 Unavoidable Adverse Effects

Unavoidable adverse effects are those that may still occur after implementation of protection and mitigation measures. Normal Project operations have no identified adverse effects on current federally threatened or endangered terrestrial species that are located in the Wilder, Bellows Falls, and Vernon Project areas and were evaluated in this environmental analysis. DWM is the only federally listed aquatic species known to be present within the Project areas. An assessment of direct and indirect effects of current project operations indicate no direct effect on the population but possible indirect effects. As discussed above, Great River Hydro's proposed operations will have no direct effect on existing DWM populations and will mitigate the potential indirect effects assessed under current operations.

3.9 Recreation Resources and Land Use

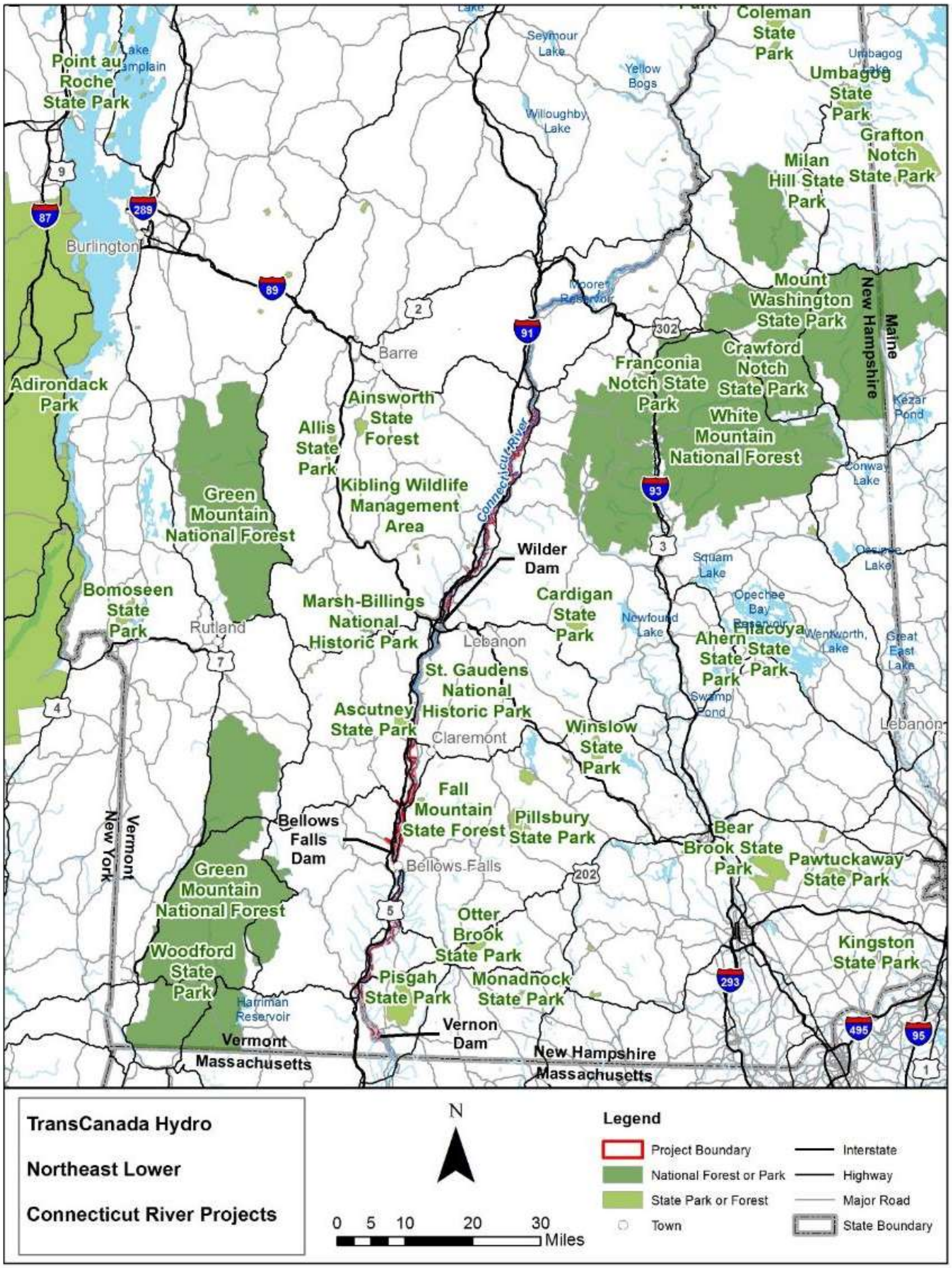
Great River Hydro developed and conducted ILP Study 30, *Recreation Facility Inventory and Use & Needs Assessment*, to assess existing recreational facilities and uses at the Projects and ILP Study 31, *Whitewater Boating Study*, to assess whitewater resources potentially affected by the Wilder and Bellows Falls Project operations. The methodologies for the Study 30 included facility inventories and condition assessments, spot counts, trail and traffic counters, aerial photography review, visitor surveys and interviews (i.e., exit interviews and mail surveys), and recreation site use records. Methodologies for Study 31 included multiple flow assessments with various skilled paddlers in different types of crafts. Unless otherwise stated, all of the following information has been sourced from Study 30, Study 31, and Project PADs (TransCanada, 2012a, 2012b, 2012c).

3.9.1 Affected Environment

3.9.1.1 Recreation Resources

Regional Recreation Resources

Numerous regional public recreation resources surround the three Project impoundments including access for boating (flatwater and whitewater), fishing, hiking, camping, picnicking, swimming, wildlife viewing, and educational programming, as shown in Figure 3.9-1. Recreation sites in proximity to the Projects provide river boating access, hiking and nature observation opportunities, while numerous state lands provide opportunities for hiking, hunting, and enjoyment of the outdoors. Some of the nearby regional recreation resources on federal lands include White Mountain National Forest (approximately 30 miles northeast of Wilder dam), Marsh-Billings National Historic Park (approximately 12 miles southwest of Wilder dam), and Green Mountain National Forest (approximately 35 miles northwest of Wilder dam and 30 miles west of Bellows Falls and Vernon dams). Numerous state, county, and local governments also provide recreational opportunities and facilities in the region and along the Connecticut River. State Parks, listed from north to south, include: Cardigan State Park (approximately 18 miles east of Wilder dam), Ascutney State Park (approximately 17 miles south of Wilder dam), Winslow State Park (approximately 34 miles northeast of Bellows Falls dam), Pillsbury State Park (approximately 18 miles northeast of Bellows Falls dam), Otter Brook State Park (approximately 19 miles northeast of Vernon dam), and Pisgah State Park (approximately 6 miles northeast of Vernon dam). Fall Mountain State Forest is located in Charlestown and Langdon, New Hampshire, adjacent to the Bellows Falls impoundment.



Source: TransCanada (2012a, 2012b, and 2012c)

Figure 3.9-1. Regional recreation resources in proximity to the Projects.

The Connecticut River Paddlers' Trail is a regional resource for multi-day canoe/kayak trips along the Connecticut River. It extends along the length of the

Connecticut River in Vermont and New Hampshire and offers visitors a series of access points and primitive campsites. The trail is managed by a group of partner organizations who collaborate on trail development and stewardship (Connecticut River Paddlers' Trail, 2016).

Numerous other FERC licensed hydropower projects along the Connecticut River also provide recreation opportunities in the region, including the FMF Project (comprising the Moore, Comerford, and McIndoe's developments); and a portage trail and primitive campsite at the Dodge Falls Project, located upstream of the Wilder Project; and the Northfield Mountain and Turners Falls Projects located downstream of Vernon Project. The Deerfield River, which flows into the Connecticut River at Greenfield, Massachusetts, has 9 dams that also provide recreational opportunities including whitewater boating, within approximately 20 miles of Vernon. In addition, USACE operates several flood control projects in the region that provide water and land based recreation opportunities.

Project-related Recreation Resources

People from the towns and communities throughout the Connecticut River Valley, including Vermont, New Hampshire, and Massachusetts, enjoy visiting recreation facilities and engaging in recreation opportunities in the Project areas. Interstate Route 91 and U.S. Route 5 run along the Vermont side of the valley, while New Hampshire Route 10 and Route 12 run along the New Hampshire side, providing highway access throughout the Connecticut River Valley. The Boston and Maine Railroads run along the Vermont side nearly paralleling U.S. Route 5. These railroad tracks make recreation access difficult to many areas along the three Project impoundments. Various managing entities including state, municipal, non-governmental organizations, private landowners, and Great River Hydro provide access to Project lands and waters for the various recreation facilities. The existing recreation setting is discussed by Project and river reach from upstream to downstream, followed by a description of the amount of recreation use at Project-related sites.

Wilder Project Recreation Resources

The Wilder Project is located between Hartford, Vermont, and Lebanon, New Hampshire, at RM 217.4 on the Connecticut River. The Project impoundment extends upstream about 45 miles to a point several miles downstream of both the Wells River and Ammonoousuc River confluences, located in the villages of Wells River, Vermont, and Woodsville, New Hampshire. The Wilder impoundment has a maximum WSE of 385 ft, resulting in about 105 miles of shoreline at full pond, which is predominantly surrounded by railroad corridors, low-lying wetlands, and agricultural fields. Private landowners or local municipalities own the majority of land surrounding the impoundment (Table 3.9-1). Table 3.9-2 summarizes Great River Hydro's Wilder Project recreation facilities.

Developed recreation sites near to the Wilder Project provide opportunities for camping, fishing, hiking, boating (motorized and canoe/kayaking), swimming, hunting, and winter sports such as ice fishing, snowmobiling, cross-country skiing, and ice skating. Great River Hydro holds fee ownership of 123 acres of land in the Wilder Project boundary, 59 acres of which is set aside for public outdoor recreation use. Developed recreation facilities adjacent to the Project include boat ramps and boat launches, canoe launches, campsites, picnic areas, day use areas, athletic fields, shoreline docks, and a portage trail.

The most popular recreation activities at the Wilder impoundment are canoeing/kayaking, boating and boat-based fishing; however, waterfowl hunting and hiking are also prevalent near the Project. New Hampshire and Vermont residents can obtain a permit for hunting along the Connecticut River Birding Trail.[48] Bird hunting season in New Hampshire is open in August and March, depending on the species type (NHFGD, 2016c). In Vermont, bird hunting permits are issued for the calendar year, but the waterfowl season generally occurs between September and December (VFWD, 2015). Hiking opportunities in proximity to the Project are available on the Appalachian Trail, Montshire Science Museum Riverwalk Trail, Bald Mountain Trail, and Kilowatt Park North and South Trails. Public recreation facilities and opportunities adjacent to and crossing the Wilder Project boundary are shown on Figure 3.9-2.

Table 3.9-1. Public recreation areas at the Wilder Project.

Site Name	River Mile	Town	Manager
Connecticut River Paddlers' Trail campsite: Harkdale Farm	259.5	Newbury, VT	Upper Valley Land Trust
Newbury-Haverhill Bridge access	257.5	Haverhill, VT	VDFG
Bedell Bridge State Park	255	Haverhill, NH	NH Parks and Recreation
Connecticut River Paddlers' Trail campsite: Vaughn Meadows	254	South Newbury, VT	Upper Valley Land Trust
Bugbee Landing access point	248	Bradford, VT	VDFG
Connecticut River Paddlers' Trail campsite: Bugbee Landing	248	Bradford, VT	Bradford Elementary School
Connecticut River Paddlers' Trail campsite: Underhill Camp	245	Piermont, NH	Piermont, NH, Conservation Commission
Orford boat landing	239	Orford, NH	Town of Orford, NH
Connecticut River Paddlers' Trail campsite: Pastures Campground	239	Orford, NH	Private Landowner
Connecticut River Paddlers' Trail campsite: Birch Meadow	236.5	Fairlee, VT	Hulbert Outdoor Center; Upper Valley land Trust

[48] The Connecticut River Birding Trail is not a linked *trail* with connecting paths but a joint conservation, education and tourism venture that identifies 128 prime places for birding in the Connecticut River watershed.

Site Name	River Mile	Town	Manager
Connecticut River Paddlers' Trail campsite: Roaring Brook	234	Thetford, VT	Upper Valley Land Trust
North Thetford Landing	232.5	Thetford, VT	State of VT
Hewes Brook boat launch	228	Lyme, NH	Lyme, NH, Conservation Commission
Ompompanoosuc launch	225	Pompanoosuc, VT	State of VT
Connecticut River Paddlers' Trail campsite: Patchen's Point	224	Norwich, VT	Friends of Patchen Miller
Norwich Landing	216	Norwich, VT	Town of Norwich, VT
Wilson's (Fullington) Landing	221	Hanover, NH	Town of Hanover, NH
Ledyard Canoe Club	218.5	Hanover, NH	Dartmouth College
East Wilder boat launch	216	West Lebanon, NH	City of Lebanon, NH
Hartford (Wilder) picnic area at Kilowatt Park (North)	219.3	Hartford, VT	Great River Hydro, leased to Town of Hartford, VT
Gilman Island Titcomb Cabin managed through Dartmouth Outing Club	217.5	Hanover, NH	Island leased to Dartmouth College (the Outing Club manages Titcomb Cabin)
Connecticut River Paddlers' Trail campsite			Primitive campsite maintained by Great River Hydro
Wilder dam (Olcott Falls) boat launch at Kilowatt Park (South)	216	Hartford, VT	Great River Hydro, leased to Town of Hartford, VT
Wilder dam fish ladder and angler parking	215	Hartford, VT	Great River Hydro
Lebanon (Wilder dam) picnic area, vista, and hiking trails	215	West Lebanon, NH	Great River Hydro
Wilder dam portage and downstream natural areas	215.5	West Lebanon, NH	Great River Hydro
Downstream of Wilder Project Boundary			
Lyman Point Park launch	217	Hartford Township, VT	Hartford, VT, Township
Two Rivers Park and Lebanon public boat launch	215	Lebanon, NH	City of Lebanon, NH
Blood's Brook launch (True's Brook Landing)	213	Lebanon, NH	NHFGD

Site Name	River Mile	Town	Manager
Ottaquechee boat launch	212	N. Hartland, VT	Town of Hartland, VT
Connecticut River Paddlers' Trail campsite: Burnaps Island Campsite	212	Plainfield, NH	Upper Valley Land Trust
Sumner Falls (Hartland Rapid)	209	Hartland, VT	Town of Hartland, VT
Connecticut River Paddlers' Trail Campsite: Burnham Meadow Campsite	205	Windsor, VT	Upper Valley Land Trust
Cornish boat landing	202	Cornish, VT	NHFGD

Source: ILP Study 30, *Recreation Facility Inventory and Use & Needs Assessment*

Note: **Bold type face** – Great River Hydro-owned Project recreation site

Table 3.9-2. Wilder Project recreation sites and facilities.

Recreation Site Name	Recreation Facilities
Hartford (Wilder) picnic area at Kilowatt Park (North)	Kilowatt Park North River Trail to Kilowatt Park (South) (wildlife viewing area; courtesy dock/hand-launch area; picnic area with 7 tables, 3 grills, 3 benches; paved parking with capacity for approximately 10 vehicles; 2 grass parking areas; dog waste disposal station; port-a-potty
Gilman Island and Titcomb Cabin	Primitive campsite and rental cabin. Gilman Island provides campers with a primitive campsite for 15 to 30 tents, a picnic table, a fire pit with grilling grate, various hiking trails, and a privy. Titcomb Cabin provides lodging for 10 people.
Wilder dam (Olcott Falls) boat launch at Kilowatt Park (South)	Single-lane, concrete boat ramp; dock; Kilowatt Park South River Trail to Kilowatt Park (North) 3 picnic tables; 2 benches; 2 athletic fields; dog waste disposal station; 3 gravel parking areas with capacity for a total of 30 vehicles; port-a-potty
Wilder dam portage and picnic area	Portage trail; put-in downstream of Wilder dam; take-out; unmarked, gravel parking area
Lebanon (Wilder dam) picnic area vista and hiking trails	3 picnic tables; walking trails; 2 unmarked, gravel parking lots
Wilder dam fish ladder and angler parking	1 picnic table; gazebo; fish ladder viewing window; unmarked, gravel parking area

Source: ILP Study 30, *Recreation Facility Inventory and Use & Needs Assessment*

Wilder Project Recreation Sites

Great River Hydro owns and manages 6 formal Project recreation sites at the Wilder Project, Kilowatt Park (North and South) operated and maintained by Town of

Hartford (agreement), Wilder dam portage and picnic area, Lebanon (Wilder dam) picnic area vista and hiking trails, Wilder dam fish ladder and angler parking, and Gilman Island, operated and maintained by Dartmouth College (lease) and Great River Hydro. Table 3.9-2 summarizes Wilder Project recreation facilities as described below.

Great River Hydro owns and manages the Hartford (Wilder) picnic area at Kilowatt Park (North) through a cooperative use agreement with the Town of Hartford, Vermont. The site is located on Gillette Street on the west side of the river in Hartford (see Figure 3.9-2). Facilities include a picnic area with 7 picnic tables, 3 grills, and 3 benches; an open area for viewing wildlife; a hand-launch area for car-top boat launching with a dock; and walking trails of varying lengths that connect to Kilowatt Park (South). The park also provides paved parking for about 10 vehicles with grass overflow parking and port-a-potty. Because dog walking is popular at this site, Great River Hydro provides a dog waste disposal station. The facility inventory condition assessment reported the site condition and visible condition scores for this site as *excellent*.

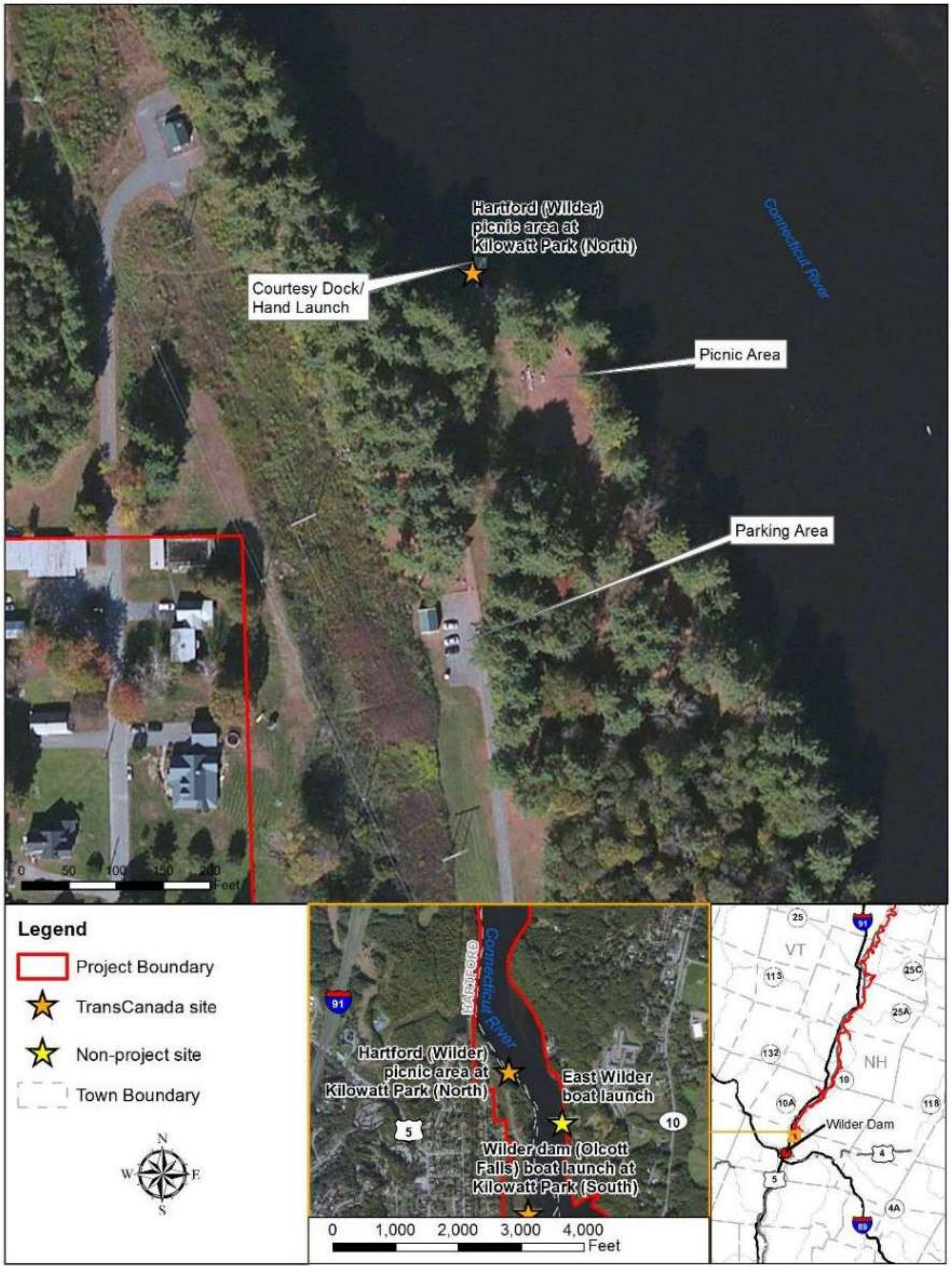
Great River Hydro also owns and manages the Wilder dam (Olcott Falls) boat launch at Kilowatt Park (South) through a cooperative use agreement with the Town of Hartford. The site lies directly above Wilder dam on Wilder Dam Road on the west side of the river in Hartford, Vermont (Figure 3.9-3). Project recreation facilities include a single-lane, concrete boat ramp with an L-shaped dock, a picnic area with 3 picnic tables and 2 benches, 2 athletic fields with bleachers, and walking trails of varying lengths that connect to Kilowatt Park (North). Other amenities include 3 gravel parking areas with capacity for 30 vehicles, port-a-potties, and dog waste disposal stations. Popular activities include walking/hiking, boat launching, and using the athletic field. The facility inventory condition assessment reported site condition and visible condition scores for this site as *excellent*.

The Wilder dam portage and picnic area provides portage around the east side of Wilder dam on the New Hampshire side of the river (Figure 3.9-4). The take-out is located just downstream from the overhead transmission lines at the upstream boat barrier about 1,000 ft upstream of the dam and includes stairs leading up the riverbank. The portage trail follows a grassy path that runs along the bank, parallel to Highway 10, and then crosses a parking area and follows a gravel road to a gravel foot path with granite stairs to a sand/gravel beach. The trail's total length is about 0.2 mile with an elevation gain of 33 ft and an elevation loss of 90 ft. The average uphill slope is 4.7 percent, and the average downhill slope is −8.2 percent. The parking area between the dam and New Hampshire Route 10 can accommodate about 5 vehicles. This site is mostly used by shoreline fishermen and car-top access boaters. The facility inventory condition assessment reported a site condition score of *good* and a visible condition score for this site as *excellent.*

Lebanon (Wilder dam) picnic area vista and hiking trails, shown in Figure 3.9-5, are directly adjacent to Wilder dam on the east side of the river in West Lebanon, New

Hampshire, and the Wilder dam fish ladder and angler parking is directly adjacent to and downstream of Wilder dam on the west side of the river in Hartford, Vermont (Figure 3.9-6). The picnic area vista and hiking trails overlook the dam and impoundment, and the site serves as a trailhead to hiking opportunities to Boston Lot Lake. Project recreation facilities at the fish ladder include a picnic area with 1 table and a gazebo and a fish ladder viewing window, located at the east end of the powerhouse and accessed using a gated stairway. The site is open seasonally and is popular in the spring with anglers fishing the tailrace. The facility inventory condition assessment reported site and visible condition scores here as *excellent*.

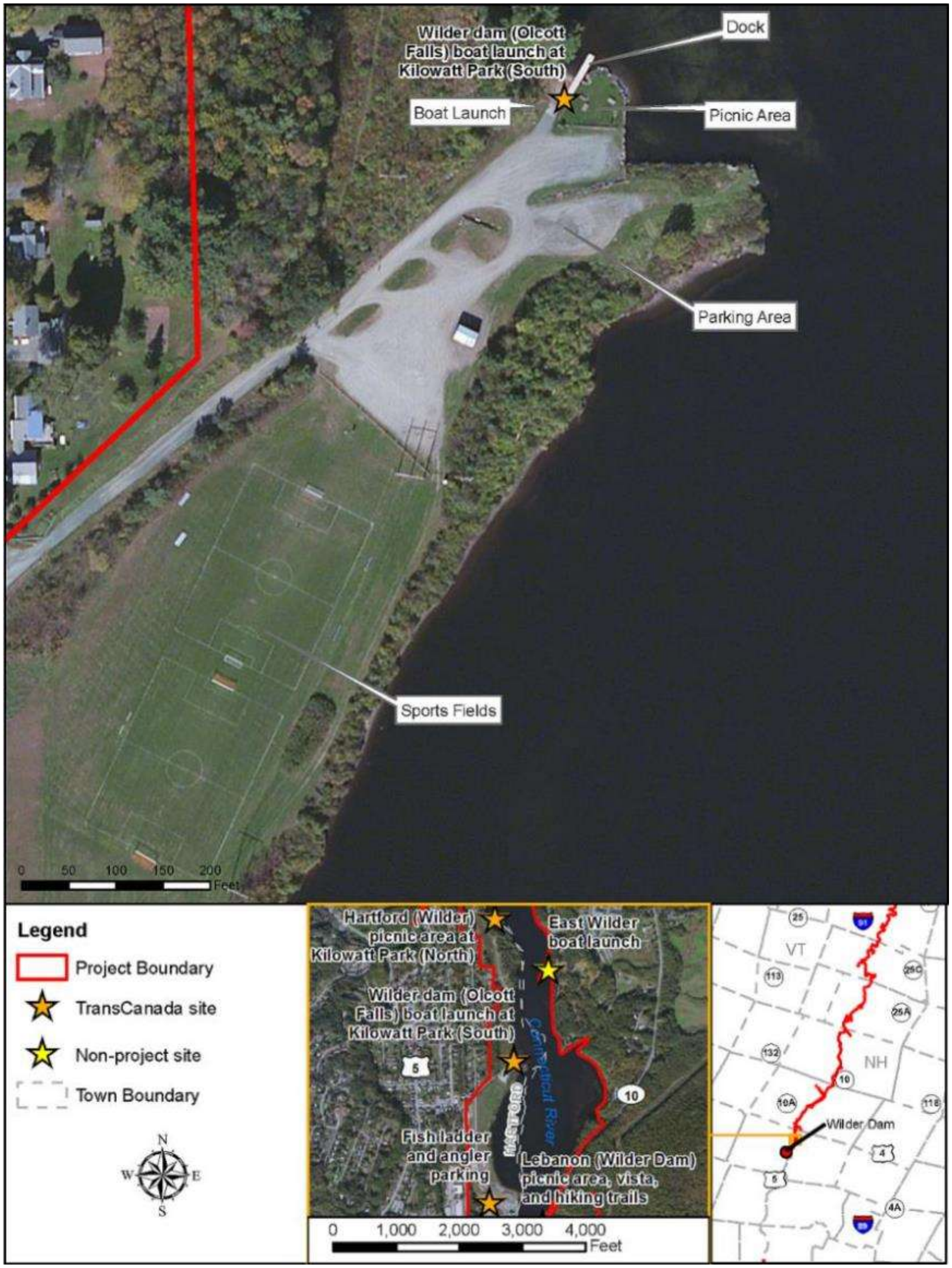
Great River Hydro owns and manages Gilman Island through a lease with Dartmouth College. The Dartmouth College Outing Club maintains and operates Titcomb Cabin for overnight accommodations and functions. Also located on the island is a primitive canoe campsite maintained by Great River Hydro in cooperation with the Connecticut River Paddlers' Trail. The island is boat-in only and available to the public as part of the Connecticut River Paddlers' Trail (Figure 3.9-7). Gilman Island provides campers with a primitive campsite for 15 to 30 tents, a picnic table, a fire pit with grilling grate, various hiking trails, and a privy. Titcomb Cabin provides lodging for 10 people. The cabin is available for rent between May 1 and November 30. The facility inventory condition assessment reported the site condition and visible condition scores for this site as *excellent*.



Source: ESRI (2016), as modified by Louis Berger (2015) and Great River Hydro (2017a)

Note: This figure shows the Project boundary finalized after issuance of the PLP and study report for ILP Study 30, *Recreation Facility Inventory and Use & Needs Assessment*.

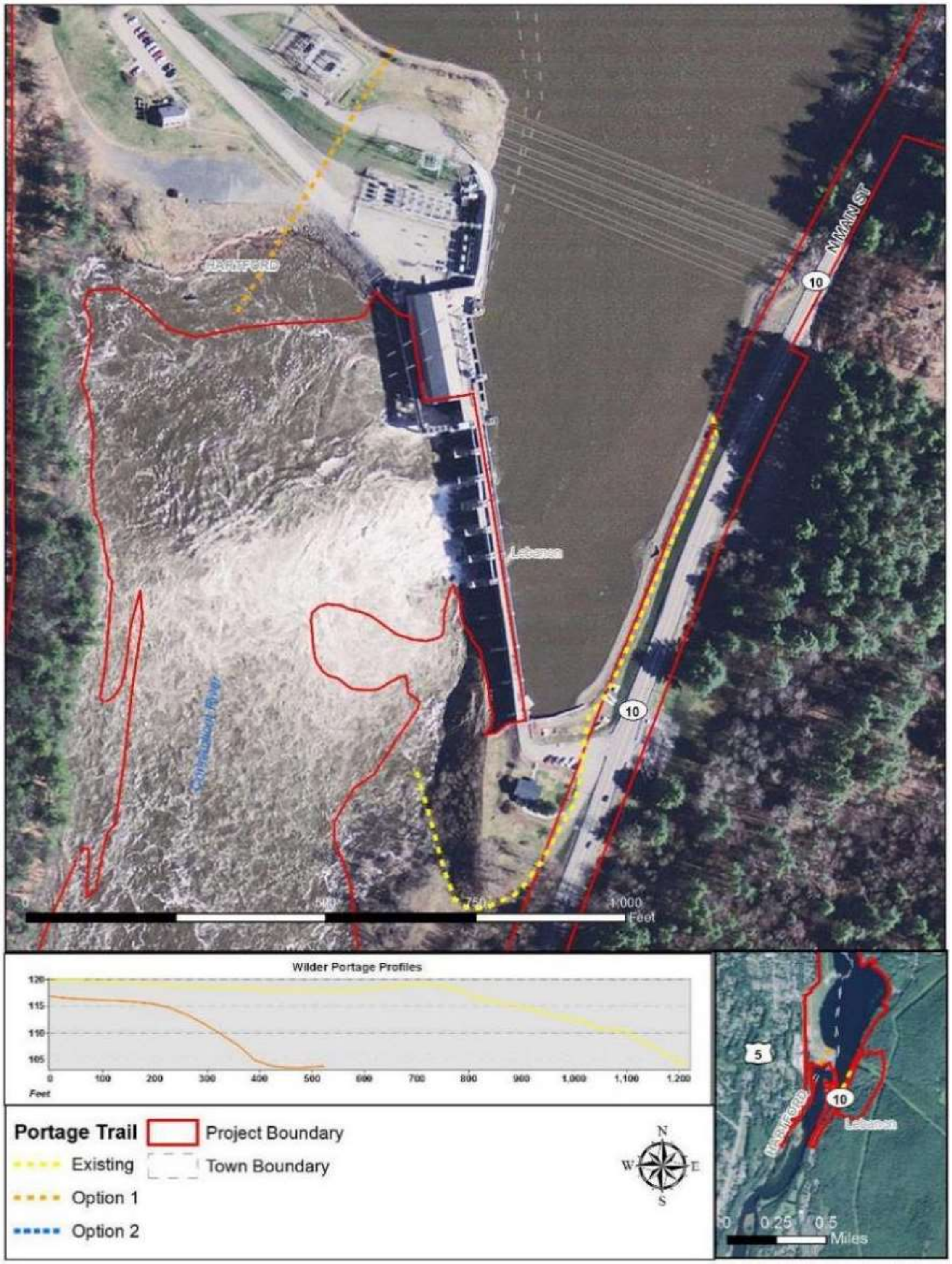
Figure 3.9-2. Hartford (Wilder) picnic area at Kilowatt Park (North).



Source: ESRI (2016), as modified by Louis Berger (2015) and Great River Hydro (2017a)

Note: This figure shows the Project boundary finalized after issuance of the PLP and study report for ILP Study 30, *Recreation Facility Inventory and Use & Needs Assessment*.

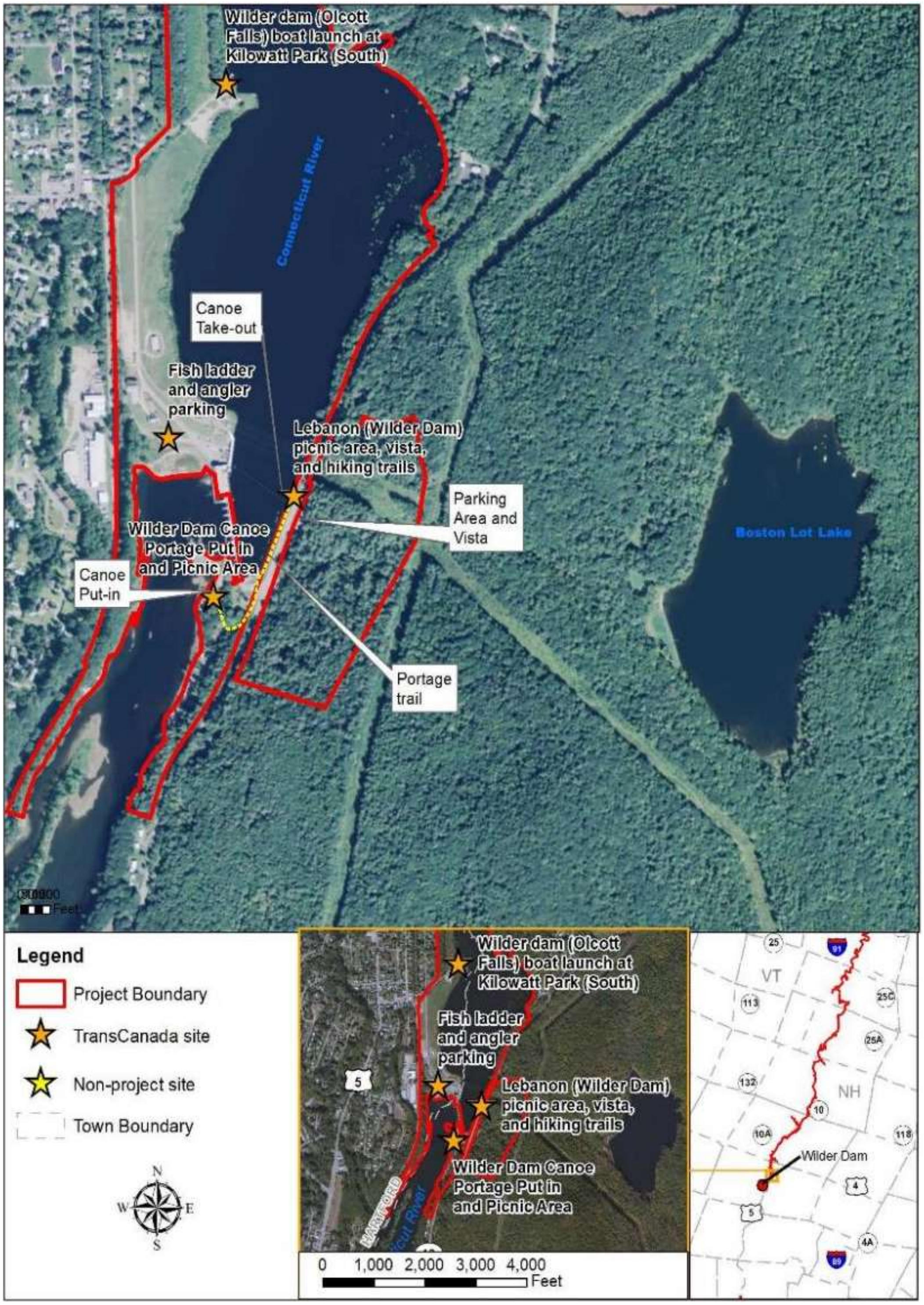
Figure 3.9-3. Wilder dam (Olcott Falls) boat launch at Kilowatt Park (South).



Source: ESRI (2016), as modified by Louis Berger (2015) and Great River Hydro (2017a)

Note: This figure shows the Project boundary finalized after issuance of the PLP and study report for ILP Study 30, *Recreation Facility Inventory and Use & Needs Assessment*.

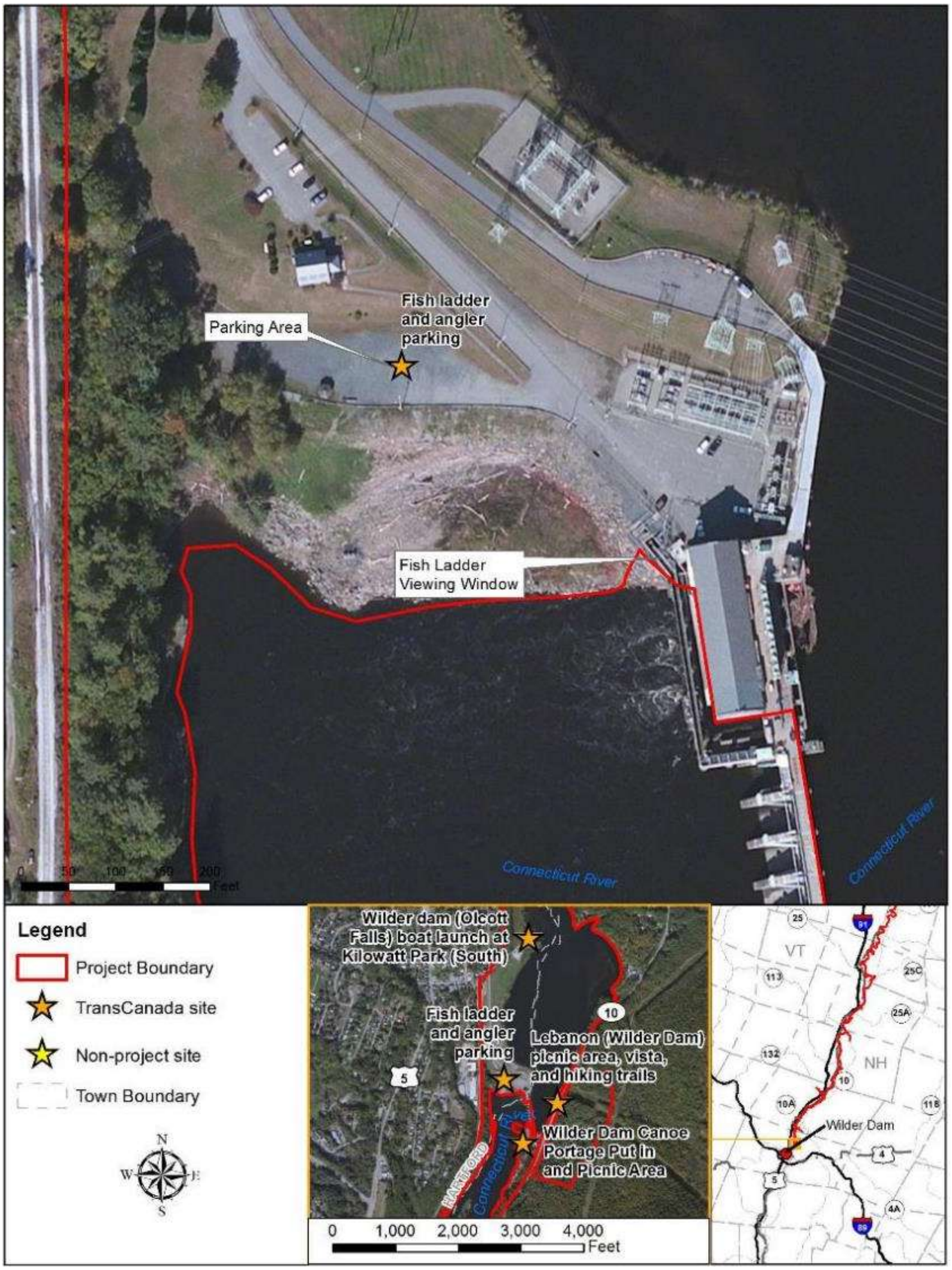
Figure 3.9-4. Wilder dam portage and picnic area.



Source: ESRI (2016), as modified by Louis Berger (2015) and Great River Hydro (2017a)

Note: This figure shows the Project boundary finalized after issuance of the PLP and study report for ILP Study 30, *Recreation Facility Inventory and Use & Needs Assessment*.

Figure 3.9-5. Lebanon (Wilder dam) picnic area, vista and trails.



Source: ESRI (2016), as modified by Louis Berger (2015) and Great River Hydro (2017a)

Note: This figure shows the Project boundary finalized after issuance of the PLP and study report for ILP Study 30, *Recreation Facility Inventory and Use & Needs Assessment*.

Figure 3.9-6. Wilder dam fish ladder and angler parking.

Source: ESRI (2016), as modified by Louis Berger (2015) and Great River Hydro (2017a)

Note: This figure shows the Project boundary finalized after issuance of the PLP and study report for ILP Study 30, *Recreation Facility Inventory and Use & Needs Assessment*.

Figure 3.9-7. Gilman Island, including Titcomb Cabin and primitive campsites.

Wilder Project Recreation Use

An in-depth study (Study 30) was conducted to assess the type and level of recreation use at formal recreation sites providing access and opportunities adjacent to and within the Project boundary from March 2014 through February 2015. Data collection objectives included determination of the amount of recreation use at both Project and non-Project recreation sites, user opinions about existing recreation sites, and user perceptions related to their use of the sites. Recreation use estimates were based on traffic counts, spot counts, interview data, and facility operator estimates where possible. Study staff deployed traffic counters at 10 access sites. Use is reported as *recreation days,* which FERC defines as each visit by a person to a development for recreational purposes during any portion of a 24-hour period. Data regarding user opinions were obtained through the recreation use survey and a regional mail survey.[49]

The total annual recreation use of all surveyed recreation sites at the Wilder Project was estimated to be 234,403 recreation days. Table 3.9-3 provides a breakdown of estimated use by season.

Table 3.9-3. Estimated use (in recreation days) at Wilder study area recreation sites from March 2014 through February 2015.

Site Name	Peak Season Use[a]	Off Season Use	Use from March 1, 2014 to February 28, 2015
Newbury-Haverhill Bridge	1,958	1,257	3,216
Bedell Bridge State Park	15,194	1,575	16,769
Bugbee Landing access point	1,478	1,117	2,596
Orford boat landing	12,381	1,685	14,066
North Thetford Landing	2,592	1,746	4,338
Hewes Brook car-top boat launch	250	210	459
Ompompanoosuc launch	1,459	140	1,599
Wilson's (Fullington) Landing	25,706	3,247	28,953
Ledyard Canoe Club	749	Closed	749
Norwich Landing	768	Closed	768
Wilder picnic area (Kilowatt Park North)	32,202	7,258	39,459
Hartford Park at (Kilowatt Park South)	56,624	2,173	58,797

[49] In support of Study 30, a mail-back survey was sent to randomly selected residents within the counties surrounding the Projects.

Site Name	Peak Season Use[a]	Off Season Use	Use from March 1, 2014 to February 28, 2015
East Wilder boat launch	1,517	Closed	1,517
Wilder dam fish ladder/fishing access	806	Closed	806
Wilder portage put-in	326	1,397	1,723
Lebanon (Wilder dam) picnic area vista and hiking trails	10,262	6,529	16,791
Lyman Point Park launch	1,498	Closed	1,498
Two Rivers Park and Lebanon public boat launch	5,910	1,024	6,935
Blood’s Brook launch (a.k.a. True's Landing) (Lebanon launch)	4,688	499	5,187
Ottaquechee boat launch	3,728	160	3,888
Sumner Falls (Hartland Rapids)	20,090	167	20,257
Cornish boat landing	4,032	Closed	4,032
		Total	**234,403**

Source: ILP Study 30, *Recreation Facility Inventory and Use & Needs Assessment*

Note: **Bold type face** – Great River Hydro-owned and operated Project recreation site

a. Peak season defined as May 1 to October 15

In addition to determining the type and amount of use at each of the surveyed sites, the degree to which each recreation site had the capacity to sustain the recreation activity occurring there was estimated. Table 3.9-4 summarizes the amount of formal and estimated informal parking spaces at each of the sites and the average and maximum number of vehicles observed during weekend spot counts between May 1 and October 15, 2014, the peak recreational season. Formal parking is defined as a hardened surface (either asphalt or concrete) with designated parking spaces (striping and/or concrete parking blocks). Table 3.9-4 shows which sites could be at or near capacity; however, because some sites provide supplemental informal parking such as or grassy areas that can accommodate vehicles, and space along the shoulders of local roads, on beaches, or in the woods, it is not always clear exactly when a site reaches, or exceeds its functional capacity. Parking at Great River Hydro-owned sites is described below.

Wilder picnic area at Kilowatt Park (North)—This site offers limited designated parking spaces; however, it also provides a large amount of maintained grassy area for additional parking, which at times receives use as noted in Table 3.9-4. The site receives regular use during peak season weekends, and the mowed grassy areas adjacent to the gravel parking lot provide more than sufficient space to accommodate visitor parking during peak demand periods.

Wilder dam (Olcott Falls) boat launch at Kilowatt Park (South)—This site provides multi-sport ball fields that receive extensive use during the spring and fall soccer and lacrosse seasons. Traffic counts captured the high concentrations of activity related to the sport practices and game use at this site. Spot counts confirmed that parking is adequate but could be limiting to trailer parking at the boat ramp during these times.

Wilder dam fish ladder—The fish ladder and angler parking area appear to be more than sufficient to accommodate the low amount of use occurring on the Vermont side downstream of the dam. However, the fish ladder was not operating during site visits and the gate to the viewing window was closed thus restricting public access.

Lebanon picnic area vista and hiking trail—This parking lot and picnic area is popular with hikers visiting the non-Project Boston Lot Lake (part of the Connecticut River Birding Trail) and day-users having lunch (often in their vehicles) while viewing the dam and impoundment. Great River Hydro staff use the adjacent parking lot for parking and storage of large equipment, which informally discourages public use.

Wilder dam canoe portage put-in—This site provides anglers use of the gravel access road and parking area just downstream of the dam and is most popular in the spring. The parking area is also used as a temporary staging area for river debris from the dam, which reduces the overall amount of parking available. The size of the debris pile varies throughout the year because Great River Hydro regularly removes debris from the powerhouse intakes and stores it at this location prior to final treatment and removal.

Gilman Island including Titcomb Cabin—Gilman Island is part of the Connecticut River Paddlers' Trail. Primitive camping is first come, first served and is used extensively by paddling groups. Titcomb Cabin rentals are administered by Dartmouth College. In 2014, the cabin was booked 116 nights during the open season (May 1–November 30).

Table 3.9-4. Wilder Project recreation site parking lot use.

Site Name	No. of Parking Areas	Has Formal Parking Spaces	No. of Designated Parking Spaces	Estimated No. of Informal Parking Spaces[a]	Average No. of Peak Season Weekend Vehicles	Max. Peak Season Vehicles	Date(s) of Maximum (2014)	Notes
Newbury-Haverhill Bridge	1	No		10	1.8	13	9/7	Additional parking available on mowed grass; capacity for 13 vehicles is likely
Bedell Bridge State Park	2	Yes	16	>80	4.2	25	5/18	Lots of additional parking available onsite; capacity for 80 to 100 vehicles
Bugbee landing access point	1	No		>100	1.6	12	7/12	Site has no designated spaces
Orford boat landing	2	Yes	24	Not applicable	4.7	20	6/21	Well-designed site completed in 2012–2013
North Thetford Landing	1	No		15+	2.5	9	6/28	Large, gravel parking area
Hewes Brook car-top boat launch	1	No		5	0.3	2	5/11, 9/24	Lightly used site
Ompompanoosuc Launch	1	No		9	1.5	9	9/21	Parking can be limited by parking in turnaround and by any vehicles with trailers
Wilson's (Fullington) Landing	1	No		15-20	5.2	18	7/20	Square, large gravel lot without designated spots
Ledyard Canoe Club	1	Yes	25+		0.9	6	5/17, 6/15, 6/21	Multi-use lot for Dartmouth College
Norwich Landing	1	No		5	1.1	7	6/7	Not designed for trailers

Site Name	No. of Parking Areas	Has Formal Parking Spaces	No. of Designated Parking Spaces	Estimated No. of Informal Parking Spaces[a]	Average No. of Peak Season Weekend Vehicles	Max. Peak Season Vehicles	Date(s) of Maximum (2014)	Notes
Wilder picnic area (Kilowatt Park North)	3	No		10+	3.1	13	9/21	Multi-use
Hartford Park (Kilowatt Park South)	3	No		100+	6.2	104	5/14	Multi-use
East Wilder boat launch	1	No		5+	1.7	9	6/22	Parking occurs along East Wilder Road shoulder on busiest days
Wilder dam fish ladder/fishing access	1	No		20+	0.8	4	6/8	Large area for a lightly used site
Wilder dam canoe portage put-in	1	No		5+	0.5	8	9/7	Parking area compromised by debris pile storage
Lebanon picnic area vista and hiking trail	1	No		20+	10.1	25	6/22	Gravel parking areas
Lyman Point Park launch	2	Yes	25		1.8	51	8/9	Parking shared with local office buildings on east and west side of railroad tracks; maximum number of vehicles recorded during Native American festival, not related to river access
Two Rivers Park and Lebanon public boat launch	2	No		20+	0.9	4	7/3, 7/12, 8/10	Large informal site with multiple parking areas

Site Name	No. of Parking Areas	Has Formal Parking Spaces	No. of Designated Parking Spaces	Estimated No. of Informal Parking Spaces[a]	Average No. of Peak Season Weekend Vehicles	Max. Peak Season Vehicles	Date(s) of Maximum (2014)	Notes
Blood's Brook Launch (a.k.a. True's Landing) (Lebanon Launch)	1	No		5	0.6	4	7/19	Dirt road with small openings alongside for parking
Ottaquechee boat launch	1	No		5	0.9	5	6/21, 6/22, 7/26	Dirt road with small opening for 2 to 3 vehicles; some users park along riverbank/woods during low flow periods
Sumner Falls (Hartland Rapids)	3	No		20	6.2	23	7/26	Various informal, multiple parking areas of different sizes; main parking area could accommodate 10 vehicles
Cornish Boat Landing	1	No		15+	4.4	35	7/19	Site hosts canoe events with overflow parking along New Hampshire Route 12

Source: ILP Study 30, *Recreation Facility Inventory and Use & Needs Assessment*

Note: **Bold type face** – Great River Hydro-owned and operated Project recreation site

a. Estimated numbers of informal parking spaces are based on gravel parking area; typically, these areas are surrounded by lawn by design, providing additional parking and much higher capacity while balancing maintenance costs.

Wilder Visitors' Opinions and Perceptions

In general, interview respondents expressed satisfaction with the condition of both Great River Hydro Project recreation facilities and existing public facilities associated with the Wilder Project. Eighty-four percent of the 49 visitors interviewed at Project recreation sites rated their satisfaction with the condition of Great River Hydro's Project recreation sites as either *moderately satisfied* or *extremely satisfied* (scores of 7, 8, or 9) (Table 3.9-5). Of the visitors who reported dissatisfaction with the condition of the existing Project and non-Project facilities, their primary reasons were the presence of trash, lack of toilets, and poor road/ramp surface conditions. Visitors interviewed reported dissatisfaction (scores of 1, 2, or 3) or *slightly satisfied* to *not at all satisfied*) with the condition of the following Great River Hydro Project recreation sites: Wilder dam picnic area (Kilowatt Park North and South [2 respondents]).

Table 3.9-5. Satisfaction with the condition of Wilder recreation sites.

Location	Extremely Satisfied		Moderately Satisfied		Neutral (percent)		Slightly Satisfied	Not at All Satisfied	
	9	8	7	6	5	4	3	2	1
Non-Project recreation sites (n=207)	49.5	15.0	21.4	2.9	6.3	1.5	1.9	1.5	0.0
Wilder Project recreation sites (n=49)	53.1	10.2	22.4	2.0	8.2	0.0	4.1	0.0	0.0

Source: ILP Study 30, *Recreation Facility Inventory and Use & Needs Assessment*

Approximately 81 percent of the 256 visitors interviewed reported being *extremely satisfied* or *satisfied* (scores of 7, 8, or 9) with the amount of recreation access provided to the Wilder Project. Table 3.9-6 presents visitor satisfaction with the number and type of recreation opportunities that provide access to the Wilder Project. Wilder Project area recreation sites were also rated as *extremely safe* by 79 percent of respondents. Safety concerns stemmed from broken glass at multiple sites, the condition of boat launches and the retaining wall at Hartford Park (Kilowatt Park South), and the presence of drug paraphernalia in the Wilder picnic area (Kilowatt Park North).

Table 3.9-6. Satisfaction with the number and type of recreational opportunities at Wilder.

Study Area	Extremely Satisfied		Moderately Satisfied		Neutral (percent)		Slightly Satisfied	Not at All Satisfied	
	9	8	7	6	5	4	3	2	1
All Wilder recreation sites (n=256)	32.0	13.8	35.2	5.1	10.7	0.4	1.6	0.8	0.4

Source: ILP Study 30, *Recreation Facility Inventory and Use & Needs Assessment*

Bellows Falls Project Recreation Resources

The Bellows Falls Project dam is located between Rockingham, Vermont, and Walpole, New Hampshire, at RM 173.7 on the Connecticut River and the powerhouse is located about 1,700 ft downstream of the dam (see Figure 1.0-1). The Project impoundment extends upstream about 26 miles to Chase Island at Windsor, Vermont, about 1 mile below the Windsor Bridge. Bellows Falls impoundment has a maximum WSE of 291.6 ft, resulting in about 74 miles of shoreline at full pond, which is predominantly surrounded by flat lands and agricultural fields. The lands immediately adjacent to the dam consist primarily of residential and industrial developments. Private landowners own most of the lands surrounding the impoundment; however, state, municipal, private entities, and Great River Hydro provide recreation access to Project lands and waters.

Developed recreation sites near the Project provide opportunities for camping, fishing, hiking, boating access (motorized and canoe/kayaking), swimming, hunting, and winter sports such as ice fishing, snowmobiling, cross-country skiing, and ice skating. Great River Hydro owns 835 acres of land within the Bellows Falls Project boundary, 86 acres of which are set aside for public outdoor recreational use. Developed recreation facilities at the Project include boat ramps, fishing platforms, picnic areas, marinas, visitor’s center, and portage trails (Table 3.9-7).

Numerous hiking trails are located in the surrounding areas. Although the Connecticut River is a migratory flyway, Herrick’s Cove in Rockingham, Vermont, is the only specified Connecticut River Birding Trail stop within the Project. The most popular recreation activities at the Bellows Falls impoundment are fishing from shore and by boat, picnicking/family gathering, canoeing/kayaking, and ice fishing.

Table 3.9-7. Public recreation areas at the Bellows Falls Project.

Site Name	River Mile	Town	Manager
Connecticut River Paddlers' Trail campsite: Wilgus State Park	191	Weathersfield, VT	State of VT
Ashley Ferry boat landing	187	Claremont, NH	State of NH
Connecticut River Paddlers' Trail campsite: Student Conservation Association	184	Charlestown, NH	Student Conservation Association
Hoyts Landing	179	Springfield, VT	State of VT
Patch Park	178	Charlestown, NH	Town of Charlestown, NH
Charlestown boat launch and picnic area	177	Charlestown, NH	Great River Hydro
Connecticut River Paddlers' Trail campsite: Lower Meadow	174	Charlestown, NH	Great River Hydro (non-Project)
Green Mountain Marina	173	Rockingham, VT	Private
Herrick's Cove boat launch and picnic area	173	Rockingham, VT	Great River Hydro
Pine Street boat launch and portage trail take-out	170	North Walpole, NH	Great River Hydro
Bellows Falls fish ladder visitor center	169	Rockingham, VT	Great River Hydro
Bellows Falls dam portage put-in	168	Walpole, NH	Town of Walpole, NH
Cold River hand-launch	168	North Walpole, NH	NHDOT
Connecticut River Paddlers' Trail campsite: Westminster Campsite	167	Westminster Station, VT	Vermont River Conservancy
NHDFG car-top access	166	Walpole, NH	NHDFG

Source: ILP Study 30, *Recreation Facility Inventory and Use & Needs Assessment*
Note: **Bold type face** – Great River Hydro-owned and operated Project recreation site

Bellows Falls Project Recreation Sites

Great River Hydro owns and operates 4 formal Project recreation sites at the Bellows Falls Project, including the Charlestown boat launch and picnic area, Herrick's Cove boat launch and picnic area, Pine Street boat launch and portage trail take-out, and the Bellows Falls fish ladder and visitor center (see Table 3.9-7). Table 3.9-8 shows Bellows Falls Project recreation sites and facilities, as described below.

Table 3.9-8. Bellows Falls Project recreation sites and facilities.

Recreation Site Name	Recreation Facilities
Charlestown boat launch and picnic area	Hand-carry boat launch; dock; 6 picnic tables; 6 grills; grass walking trail gravel/grass parking areas with capacity for 15 vehicles with trailers; 3 port-a-potties
Herrick's Cove boat launch and picnic area	Double-lane, concrete boat launch; 2 docks; 3 picnic areas with 26 picnic tables and 24 grills; shoreline walking trail); parking area with capacity for 20 vehicles; 5 port-a-potties
Pine Street boat launch and portage trail take-out	Single-lane, gravel boat launch; dock; picnic area with 1 picnic table and 2 benches; portage take-out[a]; grass parking area with capacity for 30 vehicles with trailers
Bellows Falls fish ladder and visitors center[b]	Visitor center with interpretive displays (historic and ecological); fish ladder viewing window

Source: ILP Study 30, *Recreation Facility Inventory and Use & Needs Assessment*

a. The portage take-out at Pine Street is within the Project boundary but the portage put-in is located below Bellows Falls dam on land owned by the Town of Walpole, NH, outside the Project boundary.

b. Operated by the Nature Museum at Grafton through an agreement with Great River Hydro.

The Charlestown boat launch and picnic area are located upstream of Bellows Falls dam on the east side of the river in Charlestown, New Hampshire (Figure 3.9-8). Project recreation facilities include a boat launch; a picnic area with 6 tables and grills; and grass walking trails. Other amenities include gravel and grass parking areas with capacity for 15 vehicles, and port-a-potties. The most popular recreation activities at this site are picnicking, grilling, and boating (motorized and non-motorized). The facility inventory condition assessment reported the site condition and visible condition scores for this site as *good*. Since the final Study 30 report was prepared and submitted to FERC, Great River Hydro replaced a grill, replaced the wood parking ties with boulders, re-graded the parking area, and temporarily converted the trailered boat launch to a hand-carry boat launch due to safety concerns. A new launch for trailered boats is being designed and construction is anticipated once design and permits are complete.

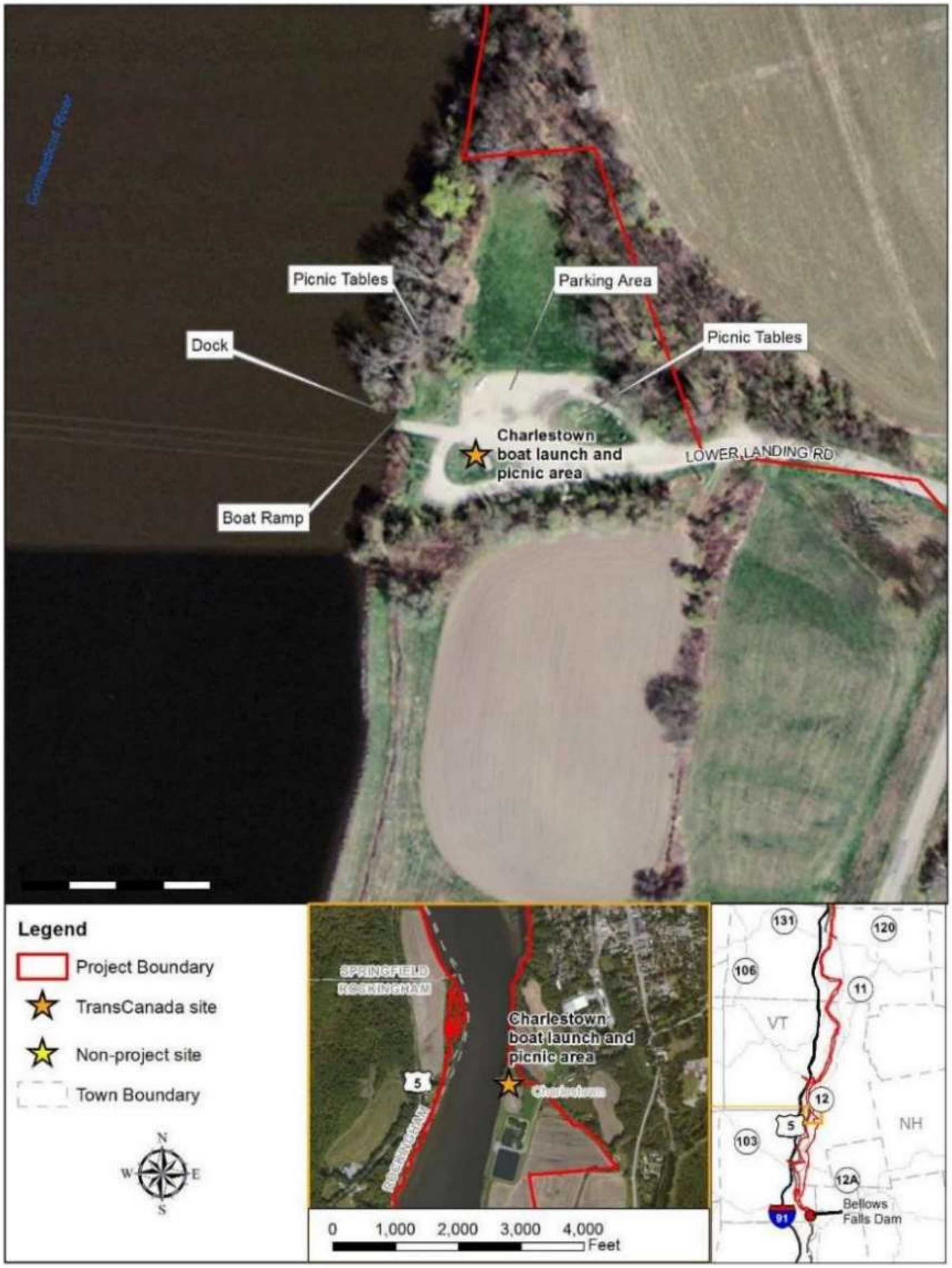
Herrick's Cove boat launch and picnic area is located upstream of Bellows Falls dam in Bellows Falls, Vermont, on the west side of the river (Figure 3.9-9). Project recreation facilities include a double-lane, concrete boat ramp with 2 docks; 3 picnic areas with 26 tables and 24 grills; and shoreline walking trails. Other amenities include a parking area with capacity for 20 vehicles and port-a-potties. Popular recreation activities at this site include birding, picnicking, walking/hiking, boating, and fishing. Great River Hydro sponsors the annual Wildlife Festival at Herricks Cove, an event that brings in hundreds of visitors to the park to learn about regional wildlife and their habitats. The facility inventory condition assessment reported the site condition and visible condition scores for this site as *excellent*.

Since the final Study30 report was prepared and submitted to FERC, Great River Hydro completed maintenance dredging of the launch area.

The Pine Street boat launch and portage trail take-out is located just upstream of the Bellows Falls dam in North Walpole, New Hampshire, on the east side of the river (Figure 3.9-10). This site is used primarily as the portage take-out for downriver canoe trips and for boat launching. Project recreation facilities include a single-lane, gravel boat launch; a dock; a picnic area with 1 table and 2 benches; and a portage take-out. Other amenities include a parking area with capacity for 30 vehicles with trailers. The facility inventory condition assessment reported the site condition and visible condition scores for this site as *good*. Since the final study report was prepared and submitted to FERC (Study 30), Great River Hydro dredged the boat ramp to improve the boat launch conditions.

The canoe portage around Bellows Falls dam is located on the New Hampshire side of the river. The portage take-out is at the Pine Street boat launch. The trail follows Pine Street, Spruce Street, and Church Street for about 0.4 mile to the Arch Bridge. The trail continues along Killeen Street and along the shoulder of Main Street (New Hampshire Route 12) for 1.1 mile, then turns down a paved access road to the river and the put-in location that is outside the Project boundary and located on land owned by the Town of Walpole, New Hampshire. The total length of the trail is about 1.5 miles with an elevation gain of 138 ft and an elevation loss of 189 ft. The average uphill slope is 3.6 percent and the average downhill slope is -4.2 percent.

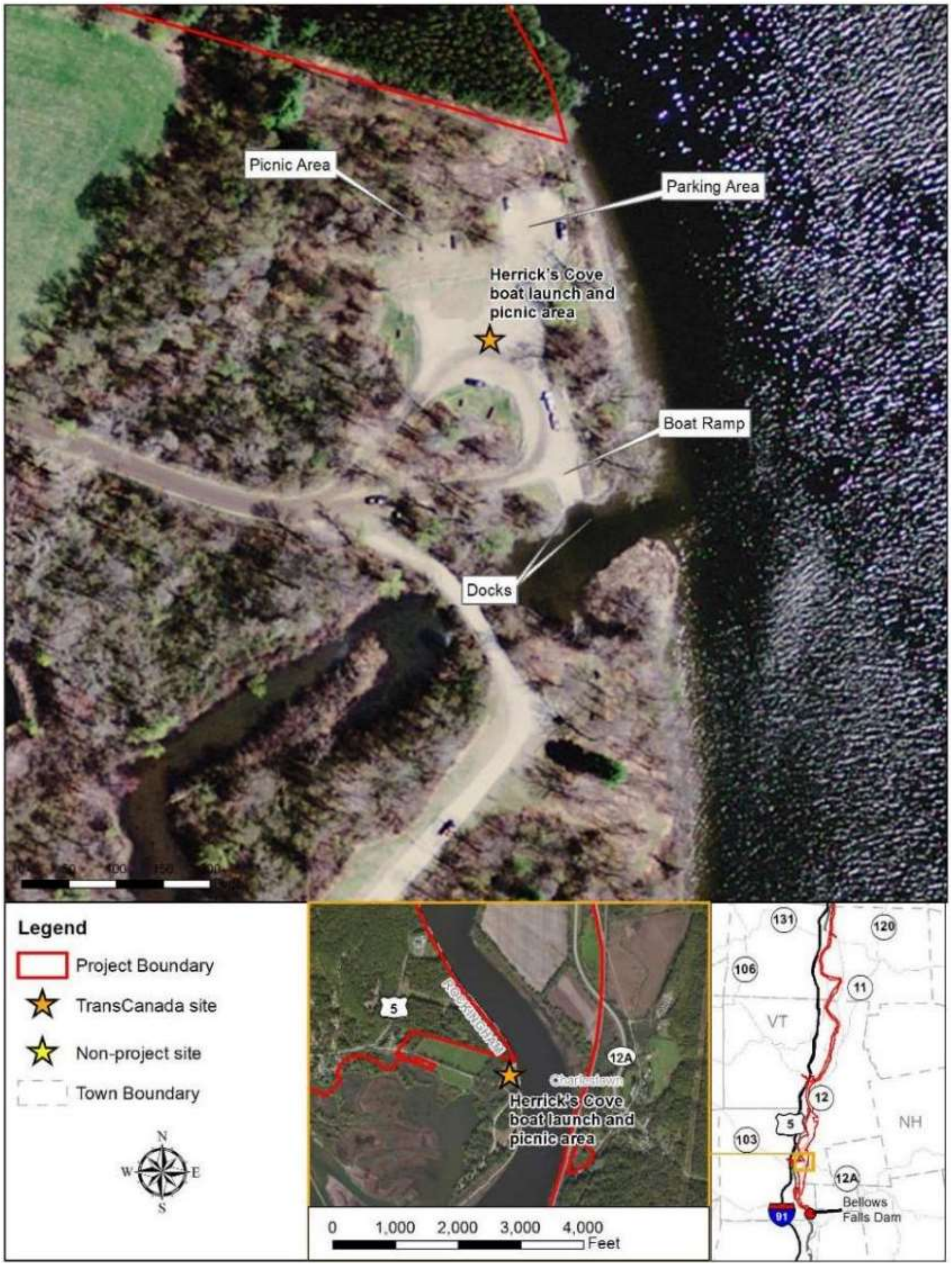
The Bellows Falls fish ladder and visitor center are located in Bellows Falls, Vermont, on the west side of the river (Figure 3.9-11). This site is primarily an educational center and nature museum run by the Nature Museum of Grafton, Vermont, under an agreement with Great River Hydro. Project facilities include a fish ladder viewing window and a visitor center with historic and ecological interpretive displays. The facility inventory condition assessment reported the site condition and visible condition scores for this site as *excellent*.



Source: ESRI (2016), as modified by Louis Berger (2015) and Great River Hydro (2017b)

Note: This figure shows the Project boundary finalized after issuance of the PLP and study report for ILP Study 30, *Recreation Facility Inventory and Use & Needs Assessment*.

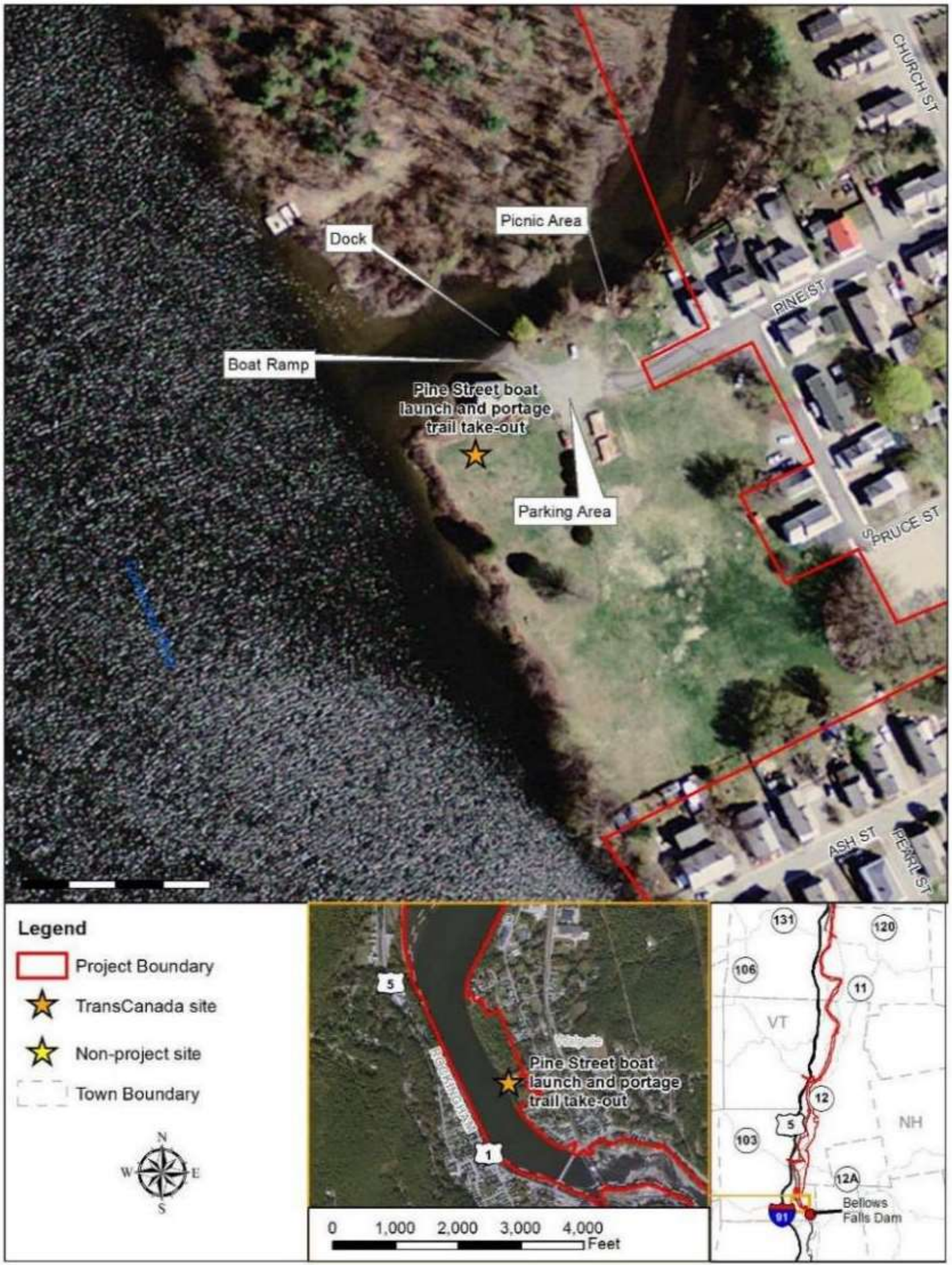
Figure 3.9-8. Charlestown hand-carry boat launch and picnic area.



Source: ESRI (2016), as modified by Louis Berger (2015) and Great River Hydro (2017b)

Note: This figure shows the Project boundary finalized after issuance of the PLP and study report for ILP Study 30, *Recreation Facility Inventory and Use & Needs Assessment*.

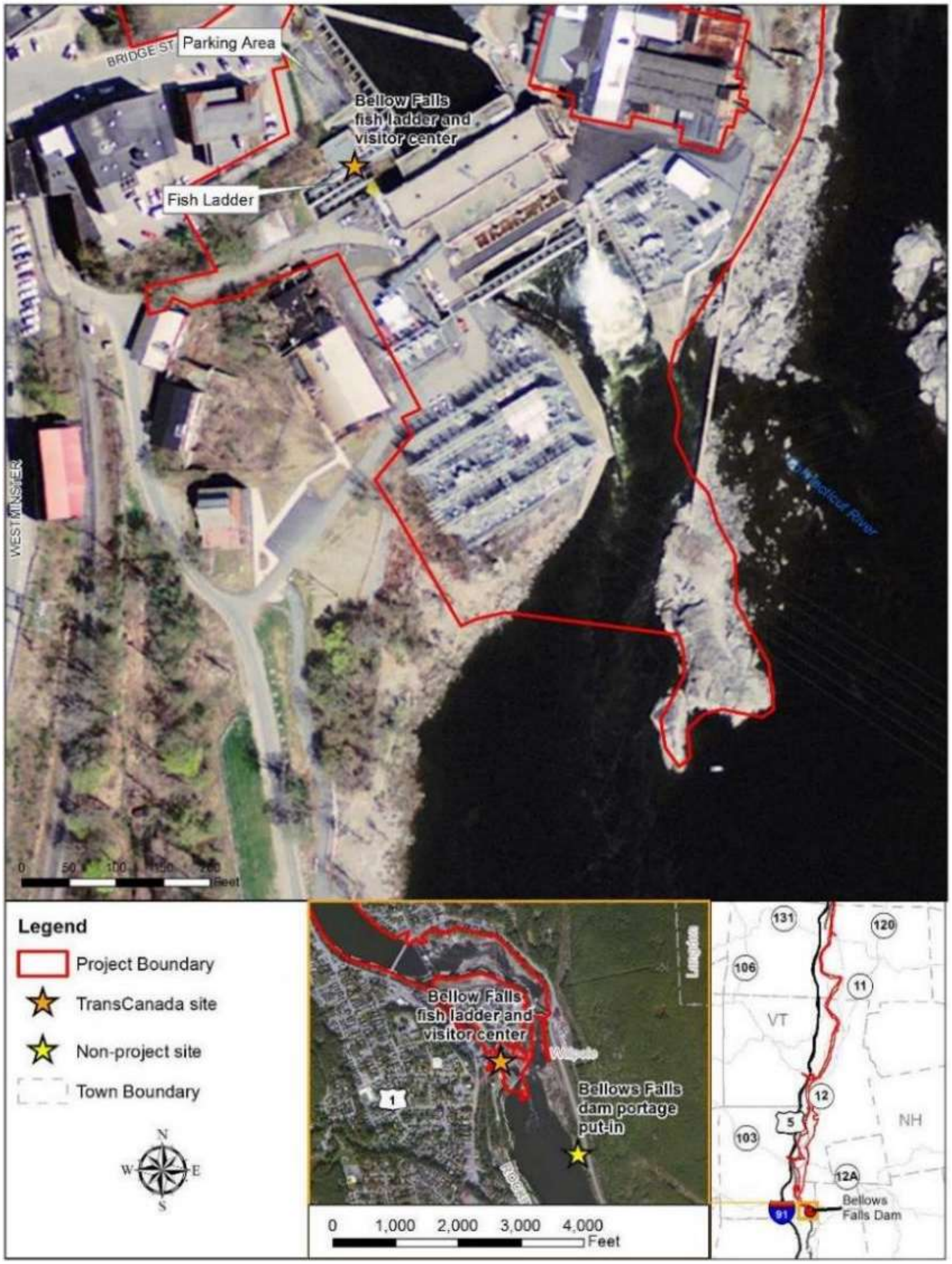
Figure 3.9-9. Herrick's Cove boat launch and picnic area.



Source: ESRI (2016), as modified by Louis Berger (2015) and Great River Hydro (2017b)

Note: This figure shows the Project boundary finalized after issuance of the PLP and study report for ILP Study 30, *Recreation Facility Inventory and Use & Needs Assessment*.

Figure 3.9-10. Pine Street boat launch and portage trail take-out.



Source: ESRI (2016), as modified by Louis Berger (2015) and Great River Hydro (2017b)

Note: This figure shows the Project boundary finalized after issuance of the PLP and study report for ILP Study 30, *Recreation Facility Inventory and Use & Needs Assessment*.

Figure 3.9-11. Bellows Falls fish ladder and visitor center.

Lower Meadow Campsite is one of the non-Project Great River Hydro-owned primitive campsites along the Connecticut River Paddlers' Trail. Lower Meadow is located in South Charlestown, New Hampshire on the east side of the river and is boat accessible only (see Figure 3.9-12). The campsite can accommodate four tents on two wooden platforms, and includes a fire pit with grilling grate, a river trail, and a privy.

Source: ESRI (2016), as modified by Louis Berger (2015) and Great River Hydro (2017b)

Note: This figure shows the Project boundary finalized after issuance of the PLP and study report for ILP Study 30, *Recreation Facility Inventory and Use & Needs Assessment*.

Figure 3.9-12. Lower Meadow campsite.

Bellows Falls Project Recreation Use

An in-depth study (Study 30) was conducted to assess the type and level of recreation use at formal recreation sites providing access and opportunities adjacent to and within the Project boundary from March 2014 through February 2015. Data collection objectives included determining the amount of recreation use at Project and non-Project recreation sites and user opinions with regard to existing recreation sites and user perceptions related to their use of the sites. Recreation use estimates for public recreation sites were based on traffic counts, spot counts, interview data, and facility operator estimates where possible. Study staff deployed traffic counters at 6 access sites. Data regarding user opinions were obtained through the recreation use survey and the regional mail survey. The total annual recreation use of all surveyed recreation sites at the Bellows Falls Project was estimated to be 312,126 recreation days. Table 3.9-9 provides a breakdown of estimated use by season.

Table 3.9-9. Estimated use (in recreation days) at Bellows Falls recreation sites from March 2014 through February 2015.

Site Name	Peak Season Use[a]	Off Season Use	Use from March 1, 2014 to February 28, 2015
Wilgus State Park	8,800	Closed	8,800
Ashley Ferry boat landing	37,299	17,040	54,339
Hoyts Landing	87,178	11,581	98,759
Patch Park	1,982	931	2,914
Charlestown boat launch and picnic area	**31,604**	**3,648**	**35,252**
Herrick's Cove boat launch and picnic area	**42,969**	**16,812**	**59,781**
Pine Street boat launch and portage take-out	**1,042**	**279**	**1,321**
Bellows Falls fish ladder and visitors center	**1,196**	**0**	**1,196**
Bellows Falls portage put-in	22,341	7,229	29,570
Connecticut River car-top access (NHFGD)	18,032	1,565	19,597
Cold River hand-launch site	504	93	597
		Total	**312,126**

Source: ILP Study 30, *Recreation Facility Inventory and Use & Needs Assessment*

Note: **Bold type face** – Great River Hydro-owned and operated Project recreation site

a. Peak season defined as May 1 to October 15.

In addition to determining the type and amount of use at each of the surveyed sites, the degree to which each site had the capacity to sustain the recreation activity occurring there was estimated. Table 3.9-10 summarizes the amount of formal and estimated informal parking spaces at each of the sites and the average and maximum number of vehicles observed during weekend spot counts between May 1 and October 15, 2014. Formal parking is defined as a hardened surface (either asphalt or concrete) with designated parking spaces (striping and/or concrete parking blocks). Table 3.9-10 shows which sites could be at or near capacity; however, because some sites provide supplemental informal parking such as or grassy areas that can accommodate vehicles, and space along the shoulders of local roads, on beaches, or in the woods, it is not always clear exactly when a site reaches, or exceeds its functional capacity. Parking at Great River Hydro-owned sites is described below.

Charlestown boat launch and picnic area—This site was well below capacity throughout the study period. Staff observed potential launch users arrive and assess the condition of the boat ramp and then leave without launching their boats. During the field study, the concrete blocks that form the boat ramp were broken and exhibited large potholes. This condition likely led to underuse throughout the study period. Great River Hydro has since removed the concrete blocks, modified the boat launch to hand-carry only, and renovated the parking and picnic areas.

Herrick's Cove boat launch and picnic area—Herrick's Cove is a popular recreation destination, in part, because of its location at the confluence of the Williams River with the Connecticut River and the site amenities which include the launch ramp, picnic areas, and ample space for relaxing along the river for birding and walking. This large site is popular throughout the year and is host to a number of events, the largest of which is the Herrick's Cove Wildlife Festival. Interview respondents indicated that more public safety patrols are needed at this site. Parking capacity is not an issue because the large expanses of grass adjacent to the gravel parking areas can accommodate additional parking. The boat launch was dredged in November 2016 after the field study concluded, in advance of the 2017 boating season.

Pine Street boat launch—This site is popular for launching boats into the Bellows Falls impoundment. Informal parking is provided on the grass of the multi-use field overlooking the Connecticut River, no formal parking exists. The boat ramp provides access to a small cove about 100 ft from the main channel of the Connecticut River. The boat launch area was dredged in December 2015 after the field study concluded, in advance of the 2016 boating season.

Bellows Falls fish ladder and visitor center—This site is in downtown Bellows Falls and has a dedicated parking lot with six spaces located between the Post Office and the canal on Bridge Street. Public parking is also available throughout downtown on the street and on the east side of the canal. Demand for visitor center parking typically doesn't reach capacity.

Table 3.9-10. Bellows Falls Project recreation site parking lot use.

Facility	No. of Parking Areas	Has Formal Parking Spaces	No. of Designated Parking Spaces	Estimated No. of Informal Parking Spaces[a]	Average No. of Peak Season Weekend Vehicles	Max. Peak Season Vehicles	Date(s) of Maximum (2014)	Notes
Ashley Ferry boat landing	1	No		20-30	4.9	25	7/19	Popular for lunch crowd and drive in/outs
Hoyts Landing	3	Yes	28	20+	21.0	51	8/24	Popular for fishing tournaments, ice access
Patch Park	3	No		50+	2.6	32	5/17	Multi-use park; lower parking area on large lawn
Charlestown boat launch and picnic area	1	No		15+	2.5	4	7/12	Poorly designed for parking with trailers, poor ramp conditions deterred boat launching
Herrick's Cove boat launch and picnic area	2	No		200+	7.3 boat launch 7.6 picnic area	41	6/21	Hosts festivals with overflow parking on grass fields
Pine Street boat launch and portage take-out	1	No		30+	1.5	9	6/22	Host fishing tournaments with overflow parking on grass field
Bellows Falls visitor center	1	Yes	6		1.9	6	7/13	Parking is also available on the street and in front of the post office
Bellows Falls Historic Park and trail system	1	Yes	15		0.6	3	5/4, 8/17, 9/28	Grass parking areas
Bellows Falls dam portage put-in	2	No		20+	1.9	6	6/21, 7/31	Various sized multiple parking areas along river

Facility	No. of Parking Areas	Has Formal Parking Spaces	No. of Designated Parking Spaces	Estimated No. of Informal Parking Spaces[a]	Average No. of Peak Season Weekend Vehicles	Max. Peak Season Vehicles	Date(s) of Maximum (2014)	Notes
Cold River hand-launch site	1	No		5+	2.0	3	8/6	Poor road condition, highway pull-off area used more frequently and has larger capacity
Connecticut River car-top access (NHFGD)	1	No		10	0.4	6	5/23, 6/22, 7/13, 9/10	Where people park depends on road condition; when road is in poor condition, people park along roadway entrance pull-offs

Source: ILP Study 30, *Recreation Facility Inventory and Use & Needs Assessment*

Note: **Bold type face** – Great River Hydro-owned and operated Project recreation site

a. Estimated numbers of informal parking spaces are based on gravel parking area; typically, these areas are surrounded by lawn by design, providing additional parking and much higher capacity while balancing maintenance costs.

Bellows Falls Visitors' Opinions and Perceptions

Visitors interviewed rated their satisfaction with the condition of both Great River Hydro's Project recreation facilities and existing public facilities associated with the Bellows Falls Project. In general, interview respondents expressed satisfaction with the condition of existing facilities. Results indicated that just over 88 percent of the 51 visitors interviewed at Great River Hydro's Project recreation sites rated their satisfaction with the condition of the Great River Hydro's Project recreation sites as either *moderately satisfied* or *extremely satisfied* (scores of 7, 8, or 9) (Table 3.9-11). Of the visitors who reported dissatisfaction with the condition of the existing Project and non-Project facilities, the primary reasons cited included trash, lack of toilets, poor road/ramp surface conditions. Dissatisfaction with the condition of Great River Hydro's Project recreation sites (scores of 1, 2, or 3, or *not at all satisfied* to *slightly satisfied*) were recorded at Charlestown boat launch and picnic area (2 respondents) and Pine Street boat launch and portage trail take-out (1 respondent).

Table 3.9-11. Satisfaction with the condition of Bellows Falls recreation sites.

Location	Extremely Satisfied		Moderately Satisfied		Neutral (percent)		Slightly Satisfied		Not at All Satisfied
	9	8	7	6	5	4	3	2	1
Non-Project recreation sites (n=89)	31.5	19.1	22.5	1.1	11.2	2.2	5.6	1.1	5.6
Bellows Falls Project recreation sites (n=51)	58.8	17.6	11.8	3.9	2.0	0.0	0.0	0.0	5.9

Source: ILP Study 30, *Recreation Facility Inventory and Use & Needs Assessment*

Approximately 71.4 percent of the 140 visitors interviewed reported being either *moderately satisfied* or *extremely satisfied* (scores of 7, 8, or 9) with the amount of recreation access provided to the Bellows Falls Project. Table 3.9-12 presents visitor satisfaction with the number and type of recreation opportunities that provide access to the Bellows Falls Project. The Bellows Falls Project area was also rated as extremely safe by 75 percent of respondents. Safety concerns related to suspicious individuals who were loitering at Herrick's Cove boat launch and picnic area and the lack of police presence at the site.

Table 3.9-12. Satisfaction with the number and type of recreational opportunities at Bellows Falls.

Study Area	Extremely Satisfied		Moderately Satisfied		Neutral (percent)		Slightly Satisfied	Not at All Satisfied	
	9	8	7	6	5	4	3	2	1
All Bellows Falls recreation sites (n=140)	32.1	14.3	25.0	2.9	17.1	0.7	2.9	2.1	2.9

Source: ILP Study 30, *Recreation Facility Inventory and Use & Needs Assessment*

Vernon Project Recreation Resources

The Vernon Project is located between Vernon, Vermont, and Hinsdale, New Hampshire, at RM 141.9 on the Connecticut River (see Figure 3.9-1). The Project impoundment extends approximately 26 miles upstream from the dam, terminating in the vicinity of the Walpole Bridge (Route 123) at Westminster Station, Vermont. Vernon impoundment has a maximum water surface elevation of 220 ft, resulting in about 69 miles of shoreline at full pond. Developed recreation facilities at the Project include boat ramps, car-top boat launches, marinas, picnic areas, campsites, and a portage take-out (Table 3.9-13). Developed recreation sites provide opportunities for camping, fishing, hiking, boating (motorized and canoe/kayaking), swimming, hunting, and winter sports such as ice fishing, snowmobiling, cross-country skiing, and ice skating. Great River Hydro owns 287 acres of land in the Vernon Project area, 34 acres of which are set aside for public outdoor recreational use.

Many towns adjacent to the Project boundary make avaiable hiking trails to the public. These trails include the Wantastiquet-Monadnock Greenway Trail in Chesterfield and Hinsdale, New Hampshire, and the Windmill Hill and Pinnacle Ridge connector trail from Rockingham, Vermont, to the Putney-Dummerston line in Vermont. The Connecticut River serves as a migratory flyway, though there are few bird hunting grounds surrounding the Vernon Project area. The most popular recreation activities at the Vernon impoundment are fishing from shore and by boat, ice fishing, and canoeing/kayaking.

Table 3.9-13. Public recreation areas at the Vernon Project.

Site Name	River Mile	Town	Manager
Putney boat landing	157	Putney, VT	State of VT
Dummerston Landing	152	Dummerston, VT	State of VT
River Road access	149	Chesterfield, NH	Town of Chesterfield, NH
Old Ferry Road access	147	Brattleboro, VT	State of VT
Retreat Meadows boat launch	145	Brattleboro, VT	Windham Foundation and Brattleboro Retreat
West River Marina	145	Brattleboro, VT	Private (open to public)
Norm's Marina	144	Hinsdale, NH	Private (open to public)
Hinsdale Island	144	Hinsdale, NH	State of NH
Fisherman access area	142	Vernon, VT	Private (open to the public, owned by Cersosimo Lumber Co.)
Prospect Street Launch	139	Hinsdale, NH	Town of Hinsdale, NH
Vernon canoe portage	138	Vernon, VT	Great River Hydro
Vernon Glen	138	Vernon, VT	Great River Hydro
Governor Hunt recreation area and boat launch	137	Vernon, VT	Great River Hydro
Vernon Neck open space	136	Hinsdale, NH	Great River Hydro
Windyhurst	159	Westmoreland, NH	Private landowner
Wantastiquet-Hinsdale Canoe rest area	142	Hinsdale, NH	Great River Hydro (non-Project)
Stebbins Island canoe rest area	137	Hinsdale, NH	Great River Hydro (non-Project)

Source: ILP Study 30, *Recreation Facility Inventory and Use & Needs Assessment*

Note: **Bold type face –** Great River Hydro-owned and operated Project recreation site

Vernon Project Recreation Sites

Great River Hydro owns and operates 4 formal Project recreation sites at the Vernon Project, including the Vernon canoe portage, Vernon Glen picnic area, Governor Hunt Recreation Area and boat launch, and Vernon Neck open space (Figure 3.9-13). Table 3.9-14 provides a summary of Great River Hydro-owned Project recreation sites and facilities which are described below.

Table 3.9-14. Vernon Project recreation sites and facilities.

Recreation Site Name	Recreation Facilities
Vernon canoe portage	Portage take-out area, parking along main road
Vernon Glen	Picnic area with 5 tables and 4 grills, parking area with capacity for 4 vehicles, and a port-a-potty
Governor Hunt Recreation Area and boat launch	Fish ladder viewing window (separate entrance), picnic area with 5 tables and 5 grills, beach, 3 port-a-potties, asphalt parking near fish ladder, and parking area near picnic and beach area
Vernon Neck open space	Undeveloped open space

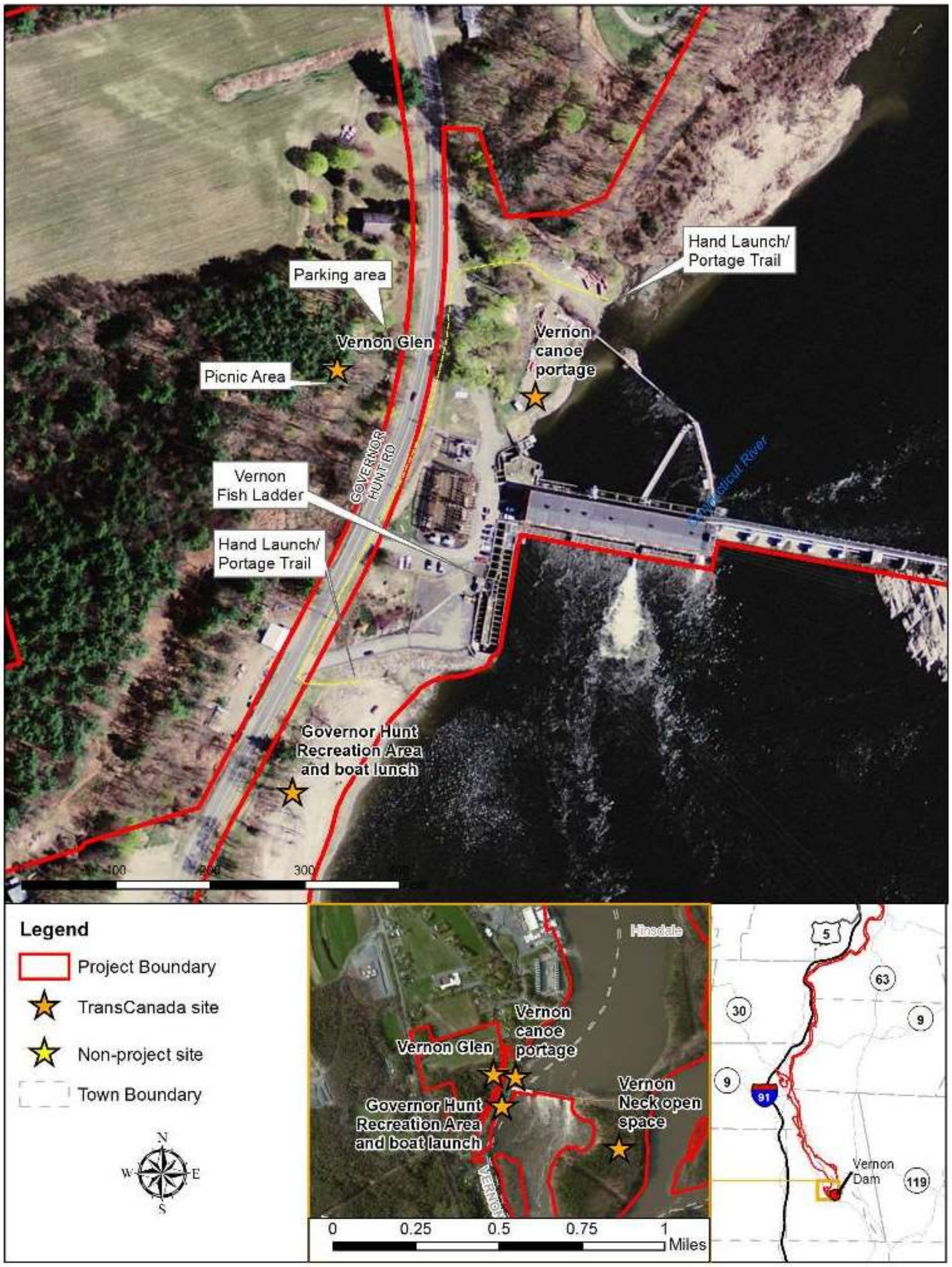
Source: ILP Study 30, *Recreation Facility Inventory and Use & Needs Assessment*

The Vernon canoe portage is located directly upstream of the Vernon powerhouse on the west side of the river in Vernon, Vermont. The portage take-out is just upstream up the log boom (debris barrier) located in the powerhouse forebay. The portage trail follows Governor Hunt Road, passes the Vernon Glen picnic area, and extends about 0.2 mile to the put-in on a sandy beach downstream of Vernon dam at the Governor Hunt Recreation Area. The existing trail has an elevation gain of 32 ft and an elevation loss of 47 ft. The average uphill slope is 9.8 percent and the average downhill slope is -5.5 percent. Recreation monitoring consisting of 54 spot counts did not observe any users at the take-out location.

Vernon Glen is located east of the canoe portage take-out site in Vernon, Vermont. This site has no access to the Connecticut River and is solely a picnic area consisting of 5 picnic tables and 4 grills. Informal parking, which can accommodate 4 vehicles, and a port-a-potty are also provided at the site. No users were observed during recreation monitoring at Vernon Glen.

Governor Hunt Recreation Area and boat launch are located directly downstream of Vernon dam on the west side of the river in Vernon, Vermont. This site also includes the Vernon fish ladder public viewing area, which is accessed from a separate vehicle entrance. Other Project recreation amenities include a picnic area with 5 tables and grills, a boat launch area that serves as a launch for trailered boats, a put-in for the canoe portage route, and a beach. Great River Hydro also provides a parking area near the picnic area and beach. The most common recreation activities at this site are swimming from shore, sunbathing along the sandy beach, fishing from shore, picnicking, car-top boat launching, motorboat launching, and visiting the fish viewing window when the fish ladder is operating. A concrete-tie boat ramp is located at the site, and is in need of repair and upgrades; but the site lends itself to launching despite this condition. The Vernon fish ladder is open mid-May through late June during the spring migration during which hours of operation may vary.

The Vernon Neck open space is located directly adjacent to the dam on the east side of the river in Hinsdale, New Hampshire. This site is undeveloped and only accessible by foot, although the site exhibits use from illegal all-terrain vehicle trail users. An informal primitive campsite on a bench overlooks the river but there are no Project facilities located at this site.

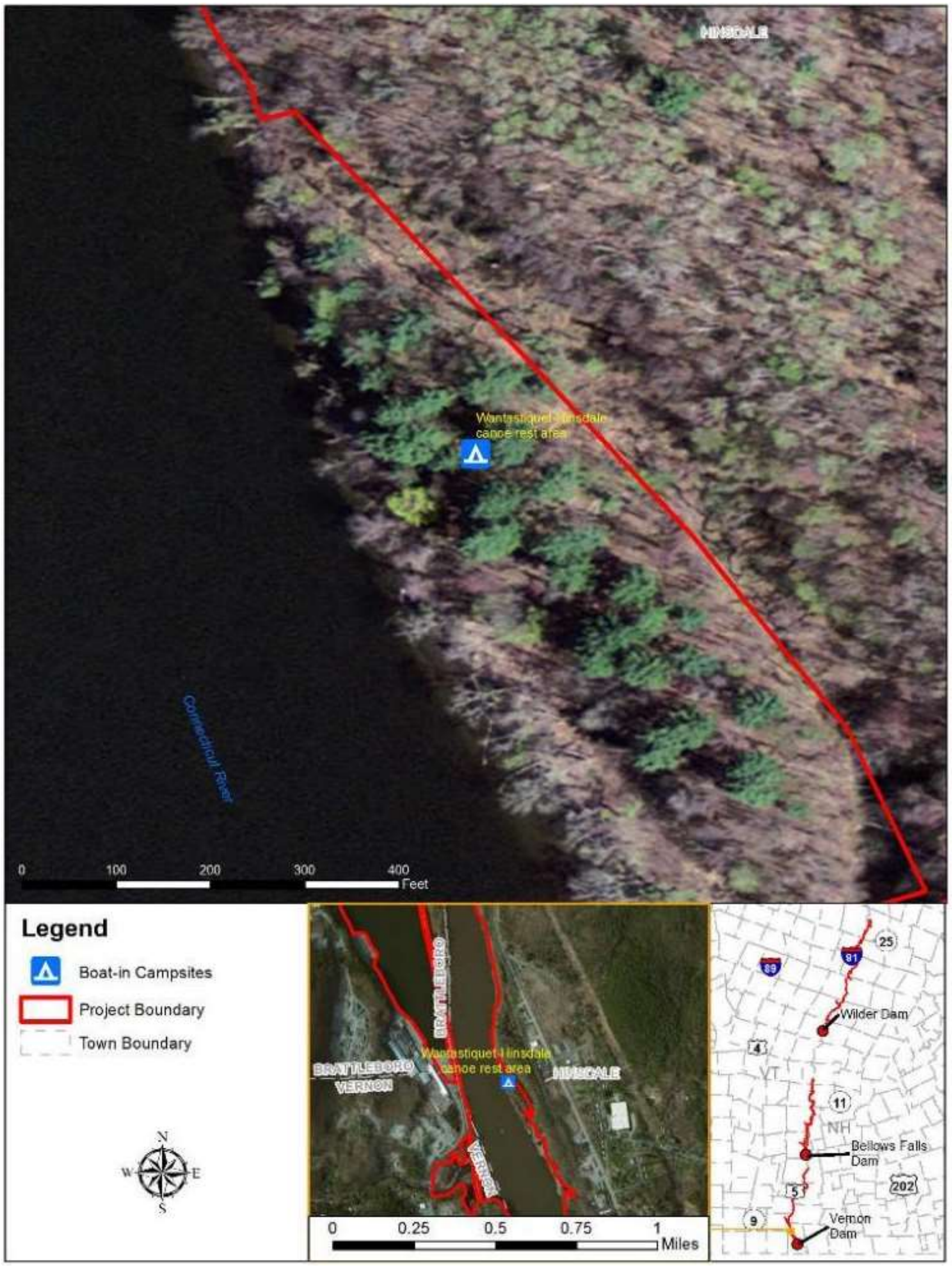


Source: ESRI (2016), as modified by Louis Berger (2015) and Great River Hydro (2017c)

Note: This figure shows the Project boundary finalized after issuance of the PLP and study report for ILP Study 30, *Recreation Facility Inventory and Use & Needs Assessment*.

Figure 3.9-13. Vernon Project recreation sites.

Great River Hydro also provides 2 non-Project primitive boat-in camping areas that are part of the Connecticut River Paddlers' Trail Campsites. The Wantastiquet-Hinsdale canoe rest area in North Hinsdale, New Hampshire, on the east side of the Connecticut River. It has capacity for 5 tents, along with a picnic table, fire pit, and privy house (Figure 3.9-14).



Source: ESRI (2016), as modified by Louis Berger (2015) and Great River Hydro (2017c)

Note: This figure shows the Project boundary finalized after issuance of the PLP and study report for ILP Study 30, *Recreation Facility Inventory and Use & Needs Assessment*.

Figure 3.9-14. Map of Wantastiquet canoe rest area (campsite).

Stebbins Island is another non-Project, primitive boat-in campsite located about a mile downstream of Vernon dam. It provides 4 to 5 primitive campsites as part of the Connecticut River Paddlers' Trail (Figure 3.9-15). Amenities at this site include 1 picnic table, a self-made fire pit (surrounding stones), and a privy.

Source: ESRI (2016), as modified by Louis Berger (2015) and Great River Hydro (2017c)

Note: This figure shows the Project boundary finalized after issuance of the PLP and study report for ILP Study 30, *Recreation Facility Inventory and Use & Needs Assessment*.

Figure 3.9-15. Stebbins Island canoe rest area.

Vernon Project Recreation Use

An in-depth study (Study 30) was conducted to assess the type and level of recreation use at formal recreation sites providing access and opportunities adjacent to and within the Project boundary from March 2014 through February 2015. Data collection objectives included the determination of the amount of recreation use at Project and non-Project recreation sites and user opinions on existing recreation sites and user perceptions related to their use of the sites. Recreation use estimates for study area public recreation sites were based on traffic counts, spot counts, interview data, and facility operator estimates where possible. Study staff deployed traffic counters at 2 access sites. Data on user opinions were obtained through the recreation use survey and the regional mail survey.

The total annual recreation use of all surveyed recreation sites at the Vernon Project was estimated to be 72,388 recreation days. Table 3.9-15 provides a breakdown of estimated use by season.

Table 3.9-15. Estimated use (in recreation days) at Vernon Project recreation sites from March 2014 through February 2015.

Site Name	Peak Season Use[a]	Off Season Use	Use from March 1, 2014, to February 28, 2015
Putney Boat Landing	2,035	1,474	3,510
Dummerston Landing	6,960	1,824	8,784
(Chesterfield) River Road access	1,555	Closed	1,555
Old Ferry Road access	3,629	Closed	3,629
Retreat Meadows boat launch	2,438	2,212	4,650
West River Marina	2,035	Closed	2,035
Norm's Marina	4,320	Closed	4,320
Fort Hill Rail Trail	2,803	2,212	5,015
Hinsdale access	518	Closed	518
Fisherman Access area	922	1,327	2,249
Broad Brook access	211	Closed	211
Prospect Street Launch	4,762	590	5,351
Vernon canoe portage	0[b]	0[b]	0[b]
Vernon Glen	0[b]	0[b]	0[b]
Governor Hunt Recreation Area and boat launch	27,274	3,287	30,561
		Total	**72,388**

Source: ILP Study 30, *Recreation Facility Inventory and Use & Needs Assessment*

Note: **Bold type face** – Great River Hydro-owned and operated Project recreation site

a. Peak season defined as May 1 to October 15
b. Spot counts were made but staff did not see anyone at the site during the visits that were made during the study period.

In addition to determining the type and amount of use at each of the surveyed study sites, the degree to which each recreation site had the capacity to sustain the recreation activity occurring there was estimated. Table 3.9-16 summarizes the amount of formal and estimated informal parking spaces at each of the Vernon Project sites and the average and maximum number of vehicles observed during weekend spot counts between May 1 and October 15, 2014. The table shows which sites could be at or near capacity; however, because some sites provide supplemental informal parking such as grassy areas that can accommodate vehicles, and space along the shoulders of local roads, on beaches, or in the woods, it is not always clear exactly when a site reaches, or exceeds its functional capacity. Parking at Great River Hydro-owned sites is described below.

Vernon canoe portage and Vernon Glen—These sites were part of the regular spot count and interview efforts and were sampled on 54 dates. No users were ever observed; the reason may be because of the popularity of the upstream Prospect Street launch, located about 1.2 RM upstream from Vernon dam in Hinsdale, New Hampshire, as the primary take-out by large groups that organize downriver trips (e.g., summer camps). The proximity of Vernon Glen to the Governor Hunt Recreation Area and boat launch also likely explains the lack of use observed at the Glen during the study.

Governor Hunt Recreation Area and boat launch—This site includes one of the largest beaches along the Connecticut River within the three Project areas and is a popular destination for families who wish to swim. During the study, Great River Hydro completed a number of improvements, including cutting down several dead trees, using the trunks to designate the limits of the parking area, and re-grading the parking area. Parking along the beach was popular before Great River Hydro made these improvements, and it continues to be popular with visitors who are picnicking near their vehicles on the beach. Because of the designated parking and the traditional practice of parking on the beach, crowding to the point of reaching capacity was not observed. Use of the fish ladder parking area was well below capacity, and parked vehicles were rarely observed in the lot. One instance was associated with an angler fishing from the shore in the tailrace.

Vernon Neck—The Vernon Neck Open Space and Demonstration Forest Area is designated as a natural area with only limited public use under Article 33 of the Project license. It is partially accessible by vehicle and by a rail trail.

Table 3.9-16. Vernon Project recreation site parking lot use.

Site Name	No. of Parking Areas	Has Formal Parking Spaces	No. of Designated Parking Spaces	Estimated No. of Informal Parking Spaces[a]	Average No. of Peak Season Weekend Vehicles	Max. Peak Season Vehicles	Date(s) of Maximum (2014)	Notes
Putney boat landing	1	No		5	2.0	9	7/5	Small parking area, limited to 2 trailers at time
Dummerston Landing	1	No		10	0.8	4	5/10	During low flows unable to launch; when Putney boat landing is full, serves as overflow parking area
(Chesterfield) River Road access	1	No		10	2.1	12	8/10	Rarely used site; informal gravel lot with shoulder parking on River Road
Old Ferry Road access	2	No		35	3.3	21	6/28	2 large informal parking areas
Retreat Meadows boat launch	1	No		5	2.8	11	6/8	Parking predominantly on shoulder of Route 30; ice access
West River Marina	2	Yes	25		2.3	8	8/24	Mixed parking with restaurant and businesses; 2 informal spaces by hand-launch area
Hinsdale access	2	No		15	0.5	20	6/7	Island with rarely used 2 parking areas; however, 20 vehicles onsite the day of the Brattleboro Parade (all parade attendees, not visitors to recreation site)
Norm's Marina	1	No		100	5.1	33	8/23	Large parking area and grass overflow areas

Site Name	No. of Parking Areas	Has Formal Parking Spaces	No. of Designated Parking Spaces	Estimated No. of Informal Parking Spaces[a]	Average No. of Peak Season Weekend Vehicles	Max. Peak Season Vehicles	Date(s) of Maximum (2014)	Notes
Fisherman access area	1	No		25+	0.8	10	5/10	Large parking area and grass overflow areas; popular because of fishing, ice access
Broad Brook access	1	No		3	0.2	2	7/12, 7/13	Concrete blocks restrict access and limit parking to 3 vehicles
Fort Hill Rail Trail	1	No		10	2.8	9	7/26	Gravel parking area popular with trail users and hand-launch area
Prospect Street launch	2	No		15+	4.6	15	9/7	Popular site with good parking and used by downriver canoe groups as main take-out
Vernon canoe portage	1	No		4+	0	0		Shoulder parking along access road
Vernon Glen	1	No		4+	0	0		Additional parking on grass field; did not spot any users during study
Governor Hunt Recreation Area and boat launch	3	No		30+	4.7	24	6/7	New formal parking area and consistent, historical practice of parking on beach

Source: ILP Study 30, *Recreation Facility Inventory and Use & Needs Assessment*

Note: **Bold type face** – Great River Hydro-owned and operated Project recreation site

a. Estimated numbers of informal parking spaces are based on gravel parking area; typically, these areas are surrounded by lawn by design, providing additional parking and much higher capacity while balancing maintenance costs

Vernon Visitors' Opinions and Perceptions

In general, interview respondents expressed satisfaction with the condition of existing facilities. Seventy-three percent of the 42 visitors interviewed at Project recreation sites rated their satisfaction with the condition of Great River Hydro's Project recreation sites as either *moderately satisfied* or *extremely satisfied* (scores of 7, 8, or 9) (Table 3.9-17). Of those who reported dissatisfaction with the condition of the existing Project and non-Project facilities, the primary reasons were the presence of trash, lack of toilets, and poor road/ramp surface conditions. Dissatisfaction with the condition of Great River Hydro's Project recreation sites (scores of 1, 2, 3, or 4, or *slightly satisfied* to *not at all satisfied*) were recorded at Governor Hunt Recreation Area (including the fish ladder) and boat launch (6 respondents).

Table 3.9-17. Satisfaction with the condition of Vernon recreation sites.

Location	Extremely Satisfied		Moderately Satisfied		Neutral (percent)		Slightly Satisfied	Not at All Satisfied	
	9	8	7	6	5	4	3	2	1
Non-Project recreation sites (n=139)	33.1	14.4	24.5	9.4	6.5	2.2	5.8	3.6	0.7
Vernon Project recreation sites (n=42)	14.3	21.4	38.1	4.8	7.1	4.8	4.8	0.0	4.8

Source: ILP Study 30, *Recreation Facility Inventory and Use & Needs Assessment*

Approximately 71.1 percent of 181 visitors interviewed reported being either *moderately satisfied* or *extremely satisfied (*scores of 7, 8, or 9*)* with the amount of recreation access provided to the Vernon Project. Table 3.9-18 presents visitor satisfaction with the number and type of recreation opportunities that provide access to the Vernon Project. The Vernon Project area was also rated as *extremely safe* by 73 percent of respondents. Safety concerns were limited to water safety (e.g., no lifeguards at Governor Hunt Recreation Area) and broken glass at multiple sites.

Table 3.9-18. Satisfaction with the number and type of recreational opportunities at Vernon.

Study Area	Extremely Satisfied		Moderately Satisfied		Neutral (percent)		Slightly Satisfied		Not at All Satisfied
	9	8	7	6	5	4	3	2	1
All Vernon recreation sites (n=181)	23.3	22.8	25.0	6.1	10.0	5.6	2.8	3.3	1.1

Source: ILP Study 30, *Recreation Facility Inventory and Use & Needs Assessment*

Whitewater Boating

Sumner Falls

Sumner Falls is a section of the Connecticut River about 9 miles downstream of Wilder dam outside the Project boundary, that presents a series of ledges that span the width of the river. The exposed bedrock in the area creates a 0.25-mile stretch of rapids used by whitewater boaters because the river drops 7 vertical ft in this short distance (Figure 3.9-16). According to Lessels (1998), Sumner Falls is runnable at almost any water level, and whitewater boaters find it interesting enough at most flows to spend the better part of a day in this location. Sumner Falls is not a classic river run where boaters put-in and take-out at a downstream location as many boaters tend to put in and take out at Sumner Falls repeatedly for play boating. It is reliable (often daily) and a popular summer play spot (Lessels, 1998). Open-faced boats and canoes typically portage around the ledges. Outfitters and kayak clubs (The Great River Outfitters, North Star Canoe rental, and Dartmouth Outing Club) commonly use this site, and during peak seasons, visit this site multiple times a day to drop off kayaks, canoes, tubes, and rafts.

Under the current FERC license, Great River Hydro generates a continuous minimum flow of 700 cfs (FERC requires 675 cfs or inflow) from Wilder dam. Discharges from Wilder dam are made in response to inflow, regional electric demand, and associated energy prices. During periods when average daily flows are less than maximum station flow capacity, the Project uses the limited daily storage in the impoundment to absorb upstream inflows 45 miles upstream of the dam as well as intermediate drainage, while generating at the dam. Generation schedules are established to meet the generation requirements by ISO-NE. During the course of any day, generation can vary between the required minimum flow and full capacity if high inflows flows are present. During periods of sustained high inflows that exceed station capacity, Project generation is dispatched in a must-run status to use available water for generation and flood control via spill. In all cases, the Project operates within the normal range of impoundment elevation or high water operating procedures.

Source: ILP Study 31, *Whitewater Boating Flow Assessment*

Figure 3.9-16. Sumner Falls rapids and features.

Local boaters frequently time their trips to Sumner Falls based on information from USGS gage no. 01144500, Connecticut River at West Lebanon, New Hampshire, which measures flow from Wilder dam and the White River just downstream of the dam. Unless other tributaries downstream of this gage contribute sufficient flows, Sumner Falls receives essentially the same flow as the Connecticut River at West Lebanon during the summer (as recorded by USGS gage no. 01144500). Travel time for releases from Wilder dam to Sumner Falls is about 2 hours. In addition, generation schedules as well as real-time flow information is available through phone (for boating 1-800-452-1737) or the "WaterLine" website (www.h2oline.com) providing opportunity flow information for boaters and public safety flow information for anglers that also use the Sumner Falls site for wading and fly fishing.

A controlled release whitewater boating study (Study 31) was conducted in 2014 to evaluate the whitewater boating resources at Sumner Falls. The study was designed to provide information about the boating conditions at various flows at Sumner Falls. Five flows—3,750; 4,700; 6,700; 7,800; and 13,000 cfs—were evaluated during a weekend in summer 2014. Participants paddled a variety of watercraft including kayaks, closed canoes, a squirt boat, a cataraft, and a stand-up paddle board. During the study, boaters used the International Scale of River Difficulty to rate whitewater in the bypassed reach under each of the flows.[50] Responses ranged from Class II at 3,700 cfs to Class IV- at 13,000 cfs (see Table 3.9-19). Most participants also suggested that at flows between 7,800 and 13,000 cfs, users should have at least an intermediate level whitewater boating skill set. At lower flows, between 3,750 and 6,700 cfs, novice and beginners could enjoy the whitewater opportunities throughout the area. However, based on the ratings, and observations of use at the site, a wide range of opportunities exist and a wide range of boaters use generation flows above minimum flow (from Wilder dam) at Sumner Falls.

[50] Class I – easy, Class II – novice, Class III – intermediate, Class IV – advanced, and Class V – expert rapids as rated by American Whitewater using the International Scale of River Difficulty (American Whitewater, 2016).

Table 3.9-19. Participant whitewater class difficulty ratings for Sumner Falls.

Watercraft	Flow				
	3,750 cfs	4,700 cfs	6,700 cfs	7,800 cfs	13,000 cfs
Canoe	Not evaluated	II+	III	III	III
Cataraft	II	II+	II+	III	III+
Kayak - creek boat	II to III	II to III+	II to III	II to III+	III to IV-
Kayak - hybrid	Not evaluated				
Kayak - play boat	II	II to III	II to III	II to III	II to III
Kayak - river boat	II	II+ to III-	II+ to III-	III-	III-
Squirt boat	II+ to III-	II+ to III-	II+ to III-	II to III	III
Stand up paddleboard	II	II to III	II to III	III	II to III

Source: ILP Study 31, *Whitewater Boating Flow Assessment*

Acceptable flow ranges for various whitewater experiences were developed using responses from study participants to a flow-acceptability survey. Study participants rated 9 characteristics of boating for each flow, including boatability, difficult rapids, large hydraulics, availability of playboating, potential instream hazards, and overall whitewater challenge. All boaters rated the Sumner Falls site and each flow as higher than acceptable across the entire range of flows.

Boatability by kayak, canoe, cataraft, stand-up paddle board, and squirt boat was evaluated during the study period. Kayak users had varying flow preferences between 3,700 and 13,000 cfs; canoe users generally preferred flows between 7,800 and 13,000 cfs; cataraft users preferred flows at both 6,700 and 13,000 cfs; stand-up paddle boarder preferred flows at 6,700 and 7,800 cfs; and the single squirt boater did not note a particular preference. The varying preferences highlight the wide boating interests and varying skill levels of whitewater recreationists in this area.

The Sumner Falls rapid complex has 2 well-known wave features—Main Wave and Sign Wave. During the field study, Main Wave was very popular at all flows below 13,000 cfs and very user-friendly because it provides routes through the ledge complex for those not interested in play-boating and opportunities for a wide range of boater skills and interests (Figure 3.9-16). Sign Wave, which develops at the head of the rapid complex on the New Hampshire side of the river, typically does not take shape until at least 11,500 cfs and becomes surfable at around 13,000 cfs. Flow in this range requires all Wilder units to be generating with additional flows either from spill or from contributing tributaries downstream of Wilder dam. During the whitewater boating study, participants also explored other areas throughout the Sumner Falls complex and generated names to describe these places during the survey portions of the study. Boaters of all types and abilities made runs through or attempted to surf in various waves and features throughout the area.

The Sumner Falls complex offers several opportunities as a park-and-play whitewater resource in a range of flows with some features coming into optimal conditions at certain levels and not at others. Generally, at flows between 3,800 to 5,000 cfs, Main Wave (or Summer Wave as it is known locally) is the preferred feature because of its shape and consistency, and its good eddy service (a hydraulic feature boaters can use to easily paddle upstream close to the rapid). Main Wave is so named because this is the primary feature when river flow is approximately 3,800 cfs to 5,000 cfs. This flow is within the range of operations of 1 of Wilder's 2 larger generating units. The name also refers to its consistency and the fact that other local rivers or streams in relative proximity to the Connecticut River often do not have enough water for boaters to play during summer in the absence of substantial precipitation, although through boating is still available.

Under typical project operations, boaters have about a half hour every day to boat the rising limb of the hydrograph in the 4,000- to 6,000-cfs range to surf the Main Wave, which typically is between 3:30 p.m. and 4:00 p.m. (adjusted for the 2-hour time lag) (Study 31). The same flow range also occurs during the falling limb of the hydrograph, after dark (between 10:00 p.m. to 10:30 p.m.). Great River Hydro (Study 31) estimates flows for Main Wave (assumed broadly to be between 4,000 and 6,000 cfs) will occur between roughly 30 to 40 percent of daylight hours between June 1 and October 31, and flows between 11,000 and 13,500 cfs (the preferred range for Sign Wave) will occur between about approximately 1 and 7 percent of the same period. As described above, these preferred flow ranges typically occur during the afternoon and evening hours. Primary factors that could result in deviations from these generalized trends during the warmer months addressed here include large precipitation events, changes in economic drivers from ISO-NE because of regional electric supply or demand, or outages at Wilder (e.g., rewinding a turbine, replacing runners). However, the data suggest that boating opportunities at the preferred levels for the 2 primary play spots at Sumner Falls occur regularly under current Project operations during the summer-fall daylight hours.

Bellows Falls Bypassed Reach

The Bellows Falls bypassed reach of the Connecticut River begins at Bellows Falls dam and extends downstream about 0.64 mile (3,500 ft) to the tailrace of the Bellows Falls powerhouse between the Village of Bellows Falls, Vermont, and North Walpole, New Hampshire. The bypassed reach is created by the diversion of river flow through the Bellows Falls powerhouse, leaving the natural river channel with diminished flow. Flows in the bypassed reach (leakage flow plus spill flow in excess of station capacity) vary depending on the time of the year, operational needs and constraints, and weather events. FERC does not have a current license requirement to provide flow into the bypassed reach. Great River Hydro estimates that leakage through the spillway is from about 125 to 300 cfs of flow into the bypassed reach. Although Great River Hydro owns a portion of the New Hampshire shoreline and holds the flowage rights on the remainder, it does not own the land necessary for adequate public access or safety to the bypassed reach. Boating has never been sanctioned or encouraged in the bypassed reach because of high flow danger concerns and lack of suitable ingress and egress. The reach receives substantial flows only during the spring freshet, large precipitation events, and outages at the powerhouse requiring water to be spilled at the dam. The fish barrier dam, located about 0.4 mile downstream of Bellows Falls dam, presents a serious and potentially fatal drowning hazard from the turbulence that boaters would encounter if they were to pass over the dam. Thus, the potential boatable section of the bypassed reach is the short section between the main dam and the fish barrier dam.

Public access to the bypassed reach is severely limited. The portage trail skirts the entire bypassed reach with the put-in location for downriver, multi-day canoe trips downstream of the confluence of the bypassed reach with the main channel downstream of the tailrace. There is no portage trail around the fish barrier dam that enables downstream navigation within the bypassed reach.

A controlled release whitewater boating study (Study 31) was conducted in 2015 to evaluate the potential of the bypassed reach to support whitewater boating. The study was designed to provide information about potential boating conditions at various flows in the bypassed reach. Nine flows—1,580, 2,020, 2,370, 2,900, 3,300, 4,370, 5,560, 7,400, and 9,660 cfs—were evaluated over a weekend in the late spring 2015. Participants selected for the study had, at a minimum, self-identified *advance* to *expert* whitewater boating experience. Participants paddled a variety of kayaks and closed canoes. During the study, boaters used the International Scale of River Difficulty to rate whitewater in the bypassed reach under each of the flows. Boaters rated the bypassed reach Class II to Class IV, depending on the type of boat, the level of flow, and the features of the bypassed reach.

Boater access to the reach for the whitewater boating study required descending a steep embankment from Great River Hydro's property on New Hampshire Route 12 in North Walpole and ascending via the east side of the riverbank up a similarly steep embankment across private property to the road shoulder about 0.5 mile from Great River Hydro's property on New Hampshire Route 12.

Although boating has not been allowed in this location, study participants reported that the reach was boatable at more than 1 flow demonstrated in Study 31. The Bellows Falls bypassed reach has 3 features of interest to boaters within the study reach—a large dome rock near the top of the run and 2 wave trains. For each flow studied, participants were asked to rate the difficulty and challenge of navigating whitewater in this reach (see Table 3.9-20). Responses ranged from a Class II rating at flows of 1,580 cfs to a Class IV rating at flows of 9,660 cfs, while the majority of boaters reported the difficulty as Class III. Based on average scores, the preferred flow level best suited for boating instruction was 2,020 cfs. At this flow, novices and beginners could boat in the bypassed reach, but at flows above 2,370 cfs, more advanced skills are required.

Table 3.9-20. Participant whitewater class difficulty ratings for Bellows Falls bypassed reach.

Flows	Participant Whitewater Class Ratings for Bellows Falls Bypassed Reach									
	II	II+	II to III	III-	III	III+	III to IV	III+ to IV-	IV-	IV
1,580	3	1	1	--	3	--	--	--	--	-
2,020	1	1	--	--	2	--	--	--	--	--
2,370	--	1	3	--	7	--	--	--	--	--
2,900	--	1	1	--	2	--	--	--	--	--
3,300	--	--	2	--	6	1	--	--	--	--
4,370	1	--	--	1	3	4	--	1	--	--
5,560	--	--	--	1	2	3	1	--	--	1
7,400	--	--	--	1	1	1	--	--	--	3
9,660	--	--	--	1	--	--	--	--	1	4

Source: ILP Study 31, *Whitewater Boating Flow Assessment*

While all flows were considered boatable by the participants, participants had different opinions regarding which flows were optimal, depending on skill level and craft. Survey respondents stated that the 2 optimal flows for playboating were between 2,020 to 2,900 cfs and between 4,370 to 5,560 cfs. The weighted average for highest quality flow was 3,880 cfs. Most participants agreed that the boating public would boat the Bellows Falls bypassed reach if sufficient flows and adequate access were available and the fish barrier dam were removed.

Boaters were asked to indicate what they consider the minimum acceptable flow (i.e., enough flow for an enjoyable recreation experience) and optimal flow relative to those they had just experienced. Both minimum and optimal flow ranges were different between canoe and kayak user groups. Canoe user scores for the minimum flow showed a convergence in scores at 2,370 cfs and below. For kayakers, scores for the minimum acceptable flow converged in 2 areas—the first between 2,020 and 3,300 cfs and a second, weaker overall response when the minimum acceptable flow was 4,370 cfs. These responses stemmed from the diversity in the boater interests—some were seeking more challenge while others were looking for play spots with easy eddy service into standing waves for surfing.

Boater responses to the optimal flow relative to the flow they just boated were similarly diverse; both canoer and kayaker results showed a spread in flows with a double convergence among the kayakers similar to the minimum flow responses. The greatest number of kayakers indicated that the flow that came closest to their preferred flow was somewhere between 2,370 cfs or slightly higher and 3,300 cfs and slightly lower. Interestingly, only 4 kayakers boated the 2,900 cfs flow, and only 1 of the 4 reported this as the preferred flow. The flow level just above this level, 3,300 cfs, was boated by 8 kayakers and 6 of them indicated the optimal flow as slightly lower, suggesting the 2,900 cfs level is relatively close to 1 of the optimal flows. Kayak participant scores also converged between 4,370 cfs and 5,560 cfs with a majority indicating slightly higher flow than 4,370 cfs, and a majority wanted slightly lower than 5,560 cfs suggesting an optimal flow around 5,000 cfs.

Kayakers found the length of the run to be too short but highly navigable. Many of the kayakers were highly skilled and preferred higher flows of 4,370 cfs. Canoeists also found the length of the run to be too short, and the majority preferred lower flows of 2,020 cfs. The length of the run, however, cannot be extended because of the fish barrier dam located just below the second wave train.

Although the boaters who participated in the study found the bypassed reach to provide an acceptable boating experience, in comparison with other opportunities within 2 hours and throughout New England as a whole, the reach was rated as average and below average for canoes. Furthermore, some key factors limit the potential of the reach as being a significant boating opportunity—shortness of length and dynamic play spots, public access, and safety concerns, which include not only the fish barrier dam at the downstream end of the reach but whether or not boaters at a novice or intermediate level could find themselves over their ability in many of the flows that were evaluated.

3.9.1.2 Land Use

Land use in the Connecticut River Valley is predominantly rural and agricultural, and a considerable portion of the land is undeveloped and forested. Much of the land in the valley has been preserved by property owners using various conservation easements for agriculture, open space, and habitat protection. Bottomland agriculture in the area is used for dairy, vegetable, and hay farming. Along the New Hampshire and Vermont sides of the Connecticut River, a majority of the land is zoned for limited residential use with infrequent commercial and industrial sites (NHDES, 1991). This development pattern was established in early settlement days and continues today, consisting of mosaic villages and small cities surrounded by rural areas. The juxtaposition of dense villages with working forestlands and agricultural fields defines the character of the Connecticut River Valley. While industrial land use is rare near the river, railroad tracks are commonly found along the banks of both sides of the river and in proximity to the Projects. The primary land uses adjacent to the Project boundaries are recreation, agriculture, and wildlife habitat.

Owned Lands

Great River Hydro holds fee ownership of 123 acres of land for the Wilder Project. Of this acreage, 43 acres are associated with the dam and generation, 59 acres are currently dedicated to public outdoor recreation use, 10 acres have been licensed to Dartmouth College for recreation use, and 11 acres of other lands along the shoreline just upstream and downstream of the dam on the New Hampshire side, and downstream of the dam on the Vermont side.

Great River Hydro holds fee ownership of 835 acres of land in the Bellows Falls Project. Of this, 62 acres are used for plant and related facilities; 86 acres for public outdoor recreational use; 60 acres of other shoreline lands in Charlestown, New Hampshire; and the remaining 627 acres currently support local agriculture, farming, and wildlife management, particularly grassland bird species habitat. These holdings, dispersed along the impoundment, include river setbacks, flood plains, marsh areas, large open pasture lands, abandoned and active (leased) farmlands, and moderately forested undeveloped lands.

Great River Hydro holds fee ownership of 287 acres of land in the Vernon Project. Of this, 16 acres are used for plant and related facilities; 34 acres are for public outdoor recreational use; 14 acres currently support local agriculture; and the remaining 223 acres are presently natural forest areas.

River and Land Designations

The Connecticut River is a very important aquatic resource in the region, and several agencies have recognized it for its scenic qualities, fisheries, and navigability.

National Wild and Scenic River System Designation

Under the National Wild and Scenic Rivers System, in January 1980, the Connecticut River from Newbury, Vermont, to Vernon, Vermont, was identified in the recreation rivers study under a preliminary list of rivers under evaluation for this designation. However, this reach of the Connecticut River is not free-flowing because of the 3 hydroelectric projects in this region (Wilder, Bellows Falls, and Vernon) and, to date, no segments of the river within the Project area have been designated under this program. Two segments are listed in the Nationwide Rivers Inventory, which identifies potential candidates for inclusion in the Wild and Scenic River System. The first segment is a 24-mile reach downstream of the Wilder Project from Windsor, Vermont, to the confluence of the Williams River in Rockingham, Vermont. *Hydrology* is the outstandingly remarkable value supporting this listing. The second segment is an 18-mile reach downstream of the Bellows Falls Project from the Route 23 Bridge in Walpole, New Hampshire, to the Route 9 Bridge in Brattleboro, Vermont, in the Vernon Project. *Hydrology*, *botanical*, and *historical* are the outstandingly remarkable values supporting this listing. Both segments were listed in 1982 (National Park Service, 2016). Federal agencies are required to assess whether a federal action could diminish the outstandingly remarkable values for which a segment is listed in the Nationwide Rivers Inventory. The Projects were constructed well before the listing of these two segments, and although Great River Hydro proposes to modify operations of the Projects, and it is highly likely that the changes proposed will maintain if not enhance the outstandingly remarkable values for which these segments of the Connecticut River were listed.

Project Lands under Study for Inclusion in National Trails System or Wilderness Area

The Appalachian Trail crosses the Wilder Project using the Ledyard Bridge (New Hampshire Route 10A and Vermont Route 10A) between Norwich, Vermont, and Hanover, New Hampshire. This 2,174-mile-long National Scenic Trail is a continuous marked footpath from Springer Mountain in Georgia to the summit of Katahdin in Maine's Baxter State Park. The Appalachian Trail is a component of both the National Trails System and a unit of the National Park System. The trail enters the Wilder Project area in Hartford and Norwich, Vermont; passes through downtown Hanover, New Hampshire; and continues north through Lyme, Orford, and Piermont, New Hampshire. No National Trails System segments are located in proximity to the Bellows Falls or Vernon Projects. No areas at or in the vicinity of the three Projects are included in or have been designated as wilderness areas, recommended for such designation, or designated as a wilderness study area under the Wilderness Act.

Silvio O. Conte National Fish and Wildlife Refuge

The Silvio O. Conte National Fish and Wildlife Refuge was established in 1997 to conserve, protect, and enhance the abundance and diversity of native plant, fish, and wildlife species and the ecosystems on which they depend throughout the entire 7.2-million-acre Connecticut River Watershed. The refuge was designed to include the entire Connecticut River Watershed because legislators realized that the whole river system and its watershed required protection to protect migratory fish and other aquatic species and that the health of any aquatic ecosystem is linked to the health of the whole watershed upstream. It is 1 of only 3 refuges in the National Wildlife Refuge System that has "Fish" in its title (FWS, 2014b).

To accomplish the purposes of the Conte Act,[51] areas that contribute substantially or in unique ways to protecting the fish, birds, federally listed species, wetlands, and overall biodiversity within the watershed were identified. Land acquisition, a traditional conservation tool, is limited to a few high priority sites or Special Focus Areas. As of August 2014, the refuge comprises more than 36,000 acres extending from northern Vermont and New Hampshire to southern Connecticut (FWS, 2014b). The Nulhegan Basin Division in Vermont's Northeast Kingdom is the largest and accounts for more than 26,000 acres. One additional division is located in Vermont, 2 divisions are located in northern New Hampshire, 10 are located in Massachusetts, and 3 are located in Connecticut. All of these areas are outside of and a considerable distance from the three Projects.

In December 2016, FWS issued a final Comprehensive Conservation Plan and EIS for the Conte National Wildlife Refuge (FWS, 2016d). The Comprehensive Conservation Plan and EIS presents 4 management alternatives that represent a range of different ways to achieve the refuge's purposes and 4 goals related to conservation, environmental education, recreation, and partnerships. Generally, the

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[51] Public Law 102-226 (105 Stat. 1655), approved December 11, 1991.

distinction between the alternatives lies in their proposed management objectives and strategies to achieve the refuge purposes and goals over the next 15 years. Once approved, the Comprehensive Conservation Plan will become the new master plan for the refuge, setting out goals, objectives, and strategies organized by 4 major categories of management activities: wildlife and habitat conservation; environmental education, outreach, and interpretation; recreation; and partnerships. The Comprehensive Conservation Plan also identifies FWS's best estimate of future needs. Specifically, alternatives in the EIS evaluated potential lands within conservation partnership areas or conservation focus areas for purchase and inclusion within the refuge; none of which included lands owned by Great River Hydro.

Other Designations

The Connecticut River is a designated river under the New Hampshire Rivers Management and Protection Program and was designated a National Blueway by the U.S. Department of the Interior (DOI) in May 2012. It was nominated and designated an American Heritage River in 1997 under Presidential Executive Order 13601, and, in 2005, the Connecticut River was designated a National Scenic Byway. In May 2012, DOI designated the Connecticut River as America's first National Blueway (a water trail). DOI will give the Connecticut River (and other to-be designated rivers) priority for the conservation and restoration programs that it administers, such as water conservation or recreation. The Connecticut River is also designated as an American Heritage River, which recognizes its historic and scenic value. The project is intended to highlight the way that rivers unite the regions through which they flow. The designation is an effort to give federal recognition and support to local conservation measures.

3.9.2 Environmental Effects

3.9.2.1 No-action Alternative

Recreation Resources

Great River Hydro would continue to operate and maintain the existing Project recreation facilities throughout the term of the new licenses and would continue to permit state and local entities to operate recreational facilities that provide access to Project lands and waters for recreational boating, fishing, picnicking, and environmental education. In comments on the PLP, stakeholders made recommendations for a variety of specific or general recreational enhancements including some related to portages and whitewater boating. Those recommendations are summarized in Appendix A, *Responses to PLP Comments*. Specific evaluations related to portages and whitewater boating that were conducted as part of Studies 30 and 31 and limitations to Great River Hydro's ability to make certain enhancements to them are described below.

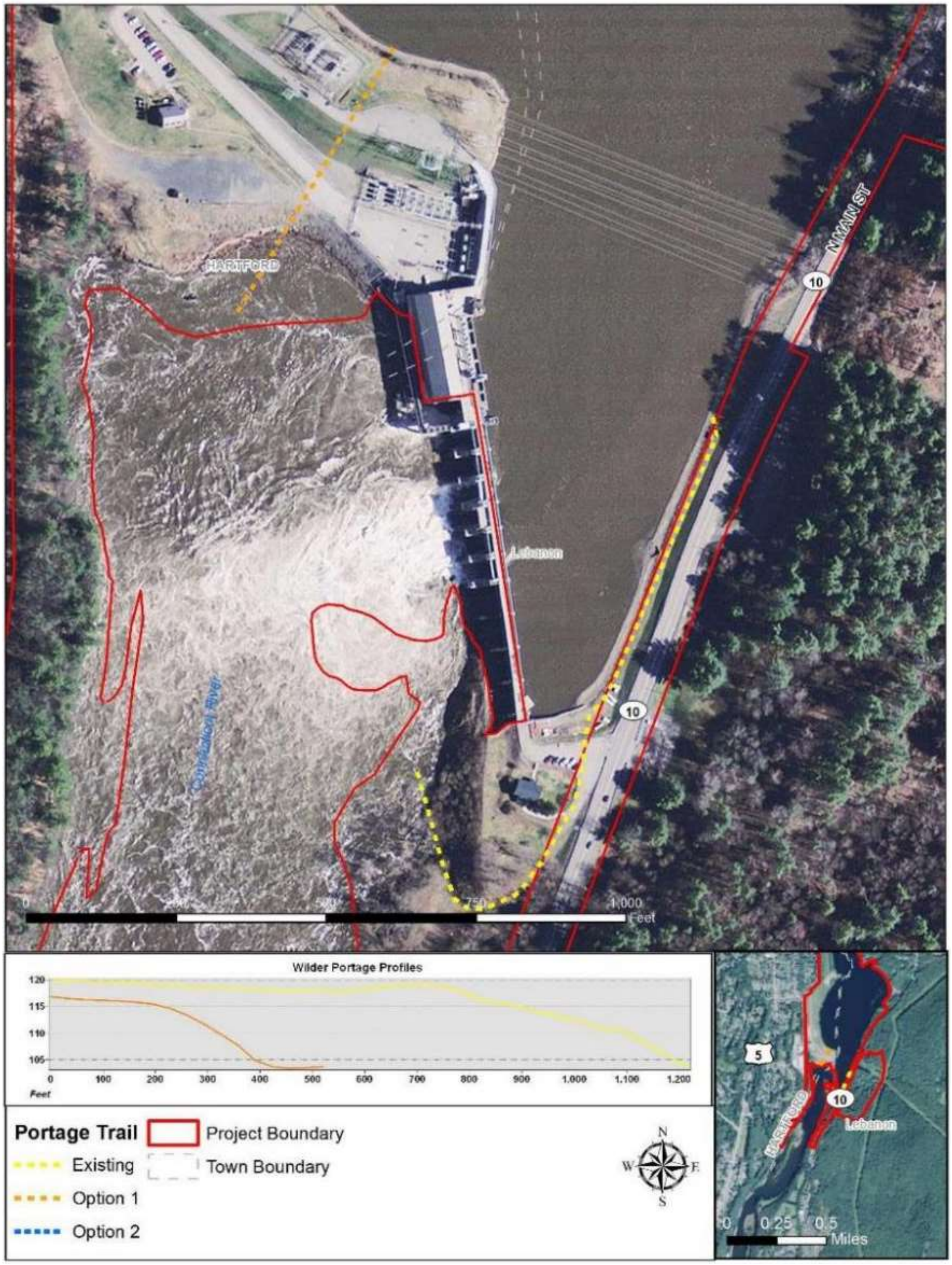
Wilder Portage

Potential alternative portage trail routes were evaluated in Study 30 using aerial imagery, publicly available elevation data, and photographs taken to document potential locations. The evaluations took a planning level look at the existing portage trail. The values for elevation gain and loss, as well as percent slope estimates were not field verified as part of this effort.

An evaluation of the potential for a portage trail option on the Vermont side of the river identified a shorter portage route (0.1 mile) around Wilder. Due to safety and security concerns associated with critical energy infrastructure and operation facilities located on the Vermont side of the dam, Great River Hydro does not propose changing the location of the Wilder portage trail. Figure 3.9-17 shows the existing portage trail and the alternative route evaluated.

Wilder Project/Sumner Falls Whitewater

Boating enthusiasts value the variable flow boating opportunities throughout the recreational boating season at Sumner Falls available under current operations. Continued operation of the Wilder Project will continue to support existing recreational use of Sumner Falls downstream of the Project. Sumner Falls will continue to experience a variety of flow levels throughout the year, particularly throughout the summer and fall seasons with flows predominantly originating from Wilder powerhouse. Study 31 results demonstrated that Sumner Falls is boatable at a wide range of flow conditions and provides something for everyone at almost all times. Boating literature indicates Sumner Falls is boatable even at flows lower than those studied. Preferred flow ranges are provided almost daily during the summer in response to regional power demand and Project generation. Consequently, numerous boating opportunities will continue to be available at the Sumner Falls complex for the duration of a future license. Additional whitewater boating opportunities exist throughout the region, including several reaches of the Deerfield River, the Ashuelot River, the West River, Millers River, and farther away on the Kennebeck River in Maine. Some of these boating opportunities depend on natural flows, but several are available through the recreation season because of scheduled flow releases, including reaches on the Deerfield River, the West River, and the Millers River. Great River Hydro’s proposal to continue to operate Wilder dam based upon schedules and requests from ISO-NE will continue to provide whitewater boating opportunities at Sumner Falls throughout the summer when other boating opportunities are unavailable because of the lack of natural flow.



Source: ESRI (2016), as modified by Louis Berger (2015) and Great River Hydro (2017a)

Note: This figure shows the Project boundary finalized after issuance of the PLP and study report for ILP Study 30, *Recreation Facility Inventory and Use & Needs Assessment*.

Figure 3.9-17. Wilder dam portage trail.

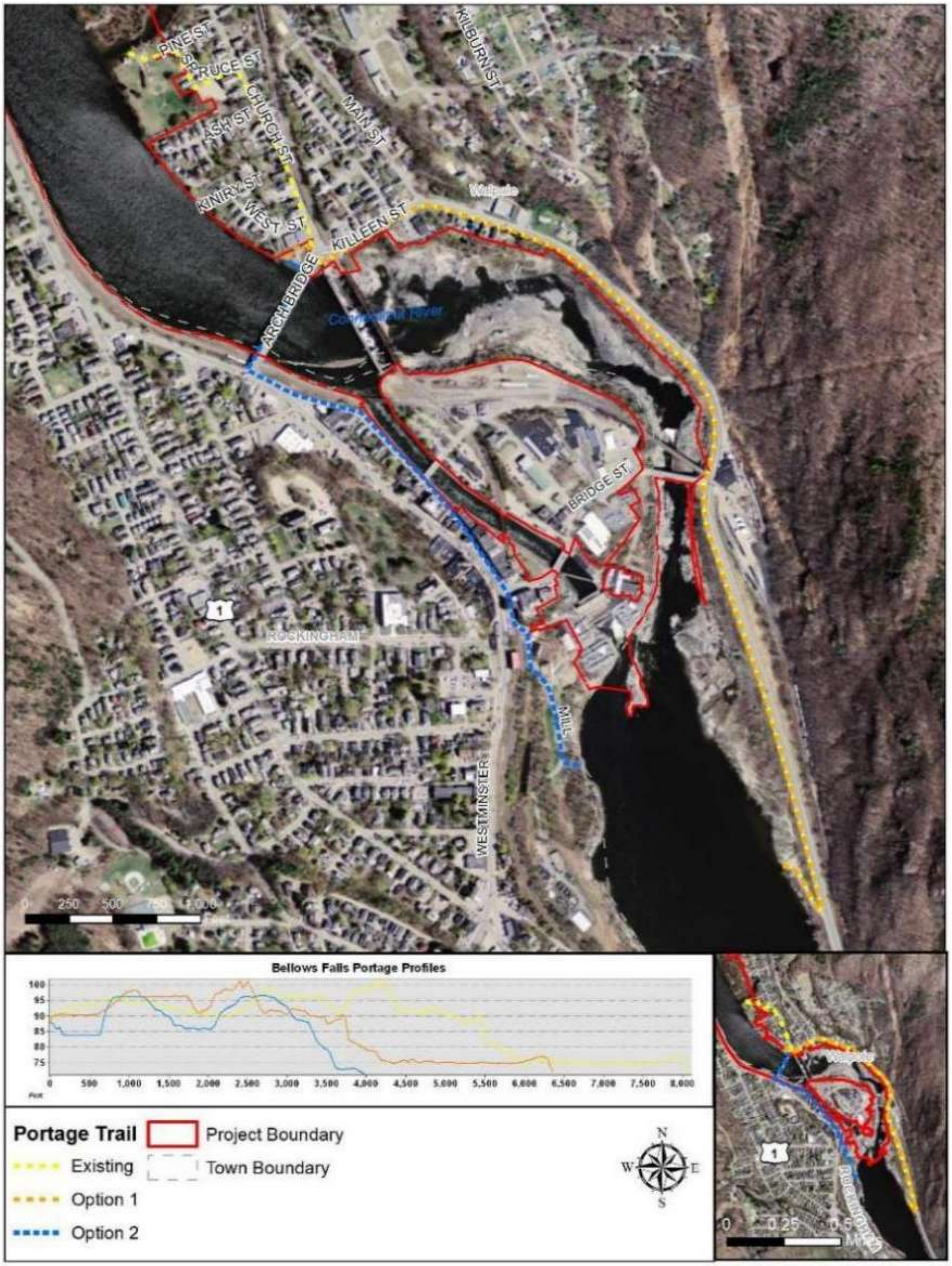
Bellows Falls Portage

Boater groups requested Great River Hydro identify and consider relocation options for the Bellows Falls portage. Potential alternative portage trail routes were evaluated in Study 30 using aerial imagery, publicly available elevation data, and photography taken to document potential locations. The evaluations took a planning level look at the existing portage trail. The values for elevation gain and loss, as well as percent slope estimates were not field verified as part of this effort. Figure 3.9-18 shows the portage trail and option routes evaluated.

Two potential alternatives for shortening the portage trail were investigated. Both options include moving the take-out location from Pine Street to just upstream of the Arch Bridge; however, this potential take-out location is not ideal because of its proximity to the dam spill gates and boat barrier and potential strong currents during spilling at the dam. Great River Hydro typically installs the boat barrier upstream of the dam and canal entrance across the river essentially under the Arch Bridge after the spring freshet. Boaters who are engaging in early downriver canoe trips and are looking to portage from the Arch Bridge before the boat barrier is in place run the risk of missing this take-out, which could be fatal if the dam were spilling. If the boat barrier were in place, and conditions lent themselves to using a theoretical take-out at the shoreline just upstream from the New Hampshire abutment of the Arch Bridge, boaters would be about 0.3 mile closer to the existing put-in if they followed the existing trail.

Another alternative would involve a take-out on the New Hampshire shore as stated above, but visitors would be required to cross the river via the Arch Bridge to Vermont and proceed through downtown Bellows Falls to Mill Street, across active railroad tracks, to the relatively new Heritage Trail located between the Bellows Falls switchyard and the wastewater treatment plant. This option would consist of a 0.8-mile hike with a total elevation gain of 115 ft and a total elevation loss of 156 ft. The average uphill slope is 6.0 percent, and the average downhill slope is −5.7 percent.

Moving the put-in location to the upper end of the Bellows Falls bypassed reach was dismissed as a viable option because of safety concerns. The only water intentionally released into the bypassed reach is spillage (i.e., spring freshet, heavy precipitation events, or during plant outages) when flows are too high for downriver canoes to navigate the bypassed reach. Furthermore, the fish barrier dam presents a substantial obstacle with limited portage options. This feature is extremely dangerous and was excluded from the whitewater boating study (Study 31), which included expert boaters who were assessing the feasibility of boating in the bypassed reach. Currently, the seals on the dam gates leak about 125 cfs and can give the impression of boatable water in the bypassed reach, shortening the portage trail; however, at this low volume of water, it is unlikely the trip would be enjoyable or even possible without numerous hits, stops, and drags along the bottom. Carrying a canoe and gear over the rocky shoreline of the bypassed reach for any distance would be challenging and pose risk of injury. For reference, the lowest flow studied under the whitewater boating study was 1,580 cfs, and at all



Source: ESRI (2016), as modified by Louis Berger (2015) and Great River Hydro (2017b)

Note: This figure shows the Project boundary finalized after issuance of the PLP and study report for ILP Study 30, *Recreation Facility Inventory and Use & Needs Assessment*.

Figure 3.9-18. Bellows Falls dam portage trail.

whitewater evaluation flows, boater safety relative to the fish barrier dam was paramount to other concerns about the potential for boating in the reach. Great River Hydro does not own any property along the route except at its office facility on New Hampshire Route 12, which as reported in Study 32 was used to access the bypassed reach through a temporary cut in the chain link fence and was characterized by study participants as very steep. For these reasons, putting in on the downstream side of the dam (in the bypassed reach) is not a viable portage trail option.

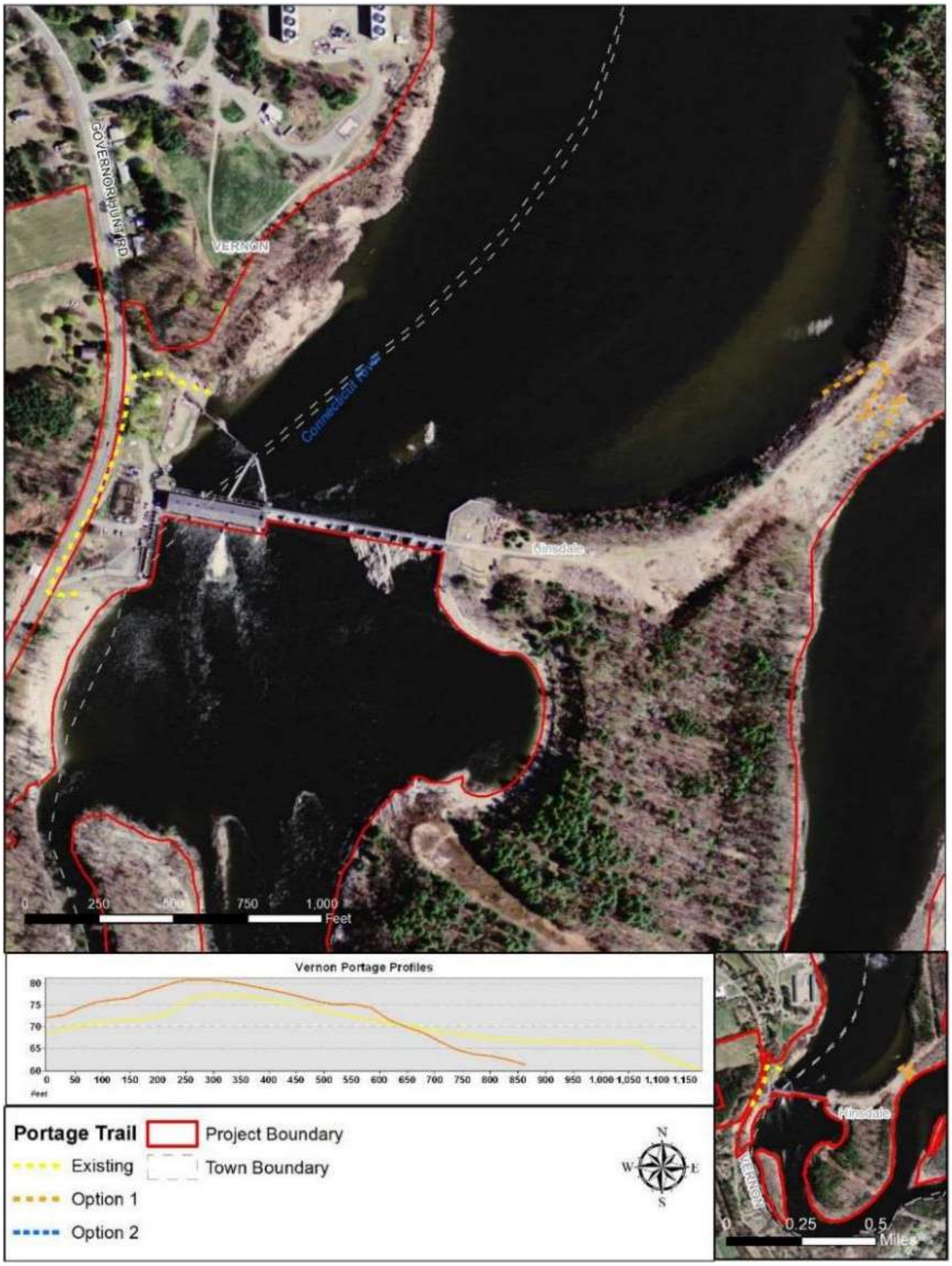
Portage options along the Vermont side of the river are similarly restricted. The railroad operates along the entire Vermont shoreline from the rail station in Bellows Falls north to the Williams River. Access across railroad property is prohibited. Similarly, boating past the Great River Hydro boat barrier and the log boom that protects the entrance to the power canal is extremely dangerous because no viable exit points are available along the canal, which is fenced off from the general public for safey reasons.

Bellows Falls Bypassed Reach Whitewater

Whitewater boating enthusiasts requested Great River Hydro consider year round boatable flows in the bypassed reach plus additional higher variable flows on weekends. Great River Hydro proposes to continue to operate the Project as it does currently. Consequently, boating will continue to be discouraged in the Bellows Falls bypassed reach because the area only receives extremely high flows during the spring freshet, during large precipitation events, and during outages at the powerhouse requiring water to be spilled. Typically, flows are unstable (rising) and peak at flows much higher than the 5,000 cfs flow identified as optimal. Safe boater access and egress to the bypassed reach will be difficult to develop given the majority riparian ownership is private residential, highway abutments and railroad. This, coupled with hazardous conditions created by the existing fish barrier dam, will create an unacceptable risk to the public. Because no public access into the bypassed reach currently exists, whitewater boating opportunities will not change at the Project.

Vernon Portage

In response to boater requests for improving the portage, an alternative portage route was evaluated in Study 30 using aerial imagery, publicly available elevation data, and photography taken to document potential locations. The evaluation took a planning level look at the existing portage trail. The values for elevation gain and loss, as well as percent slope estimates were not field verified as part of this effort. Figure 3.9-19 shows the portage trail and option routes evaluated. The optional route would require a set of switchbacks up and over the Vernon Neck peninsula on the New Hampshire side of the dam. A path in this location would reduce the overall portage distance by about 300 ft; however, the banks on the New Hampshire side are very steep and would require switchback trail construction. Construction on this steep but narrow portion of the Vernon Neck could raise structural concerns since although natural, the neck represents an embankment that is inspected and maintained as a water retention element in Great River Hydro's dam safety program. Negotiating switchbacks with canoes and gear on the steep slopes for such a modest reduction in overall portage trail length would provide little improvement over the existing portage trail, which provides gentle, flat access and a park with picnic tables, a situation that would be hard to replicate on the opposite side of the river without significant capital expenditure, making pursuit of such an alternative impractical.



Source: ESRI (2016), as modified by Louis Berger (2015) and Great River Hydro (2017c)

Note: This figure shows the Project boundary finalized after issuance of the PLP and study report for ILP Study 30, *Recreation Facility Inventory and Use & Needs Assessment*.

Figure 3.9-19. Vernon dam portage trail.

Land Use

Great River Hydro owns very little land around the impoundments beyond the property required to operate each dam, powerhouse, and appurtenant facilities and small parcels in the flood plain that are leased to area farmers but are required to consider grassland bird habitat management best practices. Great River Hydro does not propose any measures that will expand the footprints of, or alter the primary uses of the Project facilities at the Wilder, Bellows Falls, and Vernon Projects. Therefore, Great River Hydro does not propose changes in Project land use within the Project boundaries.

3.9.2.2 Great River Hydro Proposal

Great River Hydro is not proposing any changes to existing recreation access areas, portage trails or access into the Bellows Falls bypassed reach (portage or whitewater boating) and as such, effects to these resources will be the same as those described under the no-action alternative. Great River Hydro proposes to incorporate into their respective Projects three canoe campsites, currently non-project recreation areas on Great River Hydro fee-land; Lower Meadow Campsite in Charlestown NH (Bellows Falls Project); Wantastiquet-Hinsdale canoe rest area in North Hinsdale, and Stebbins Island in Hinsdale New Hampshire (Vernon Project).

Great River Hydro proposes to modify its operations as described in Section 2.2 that will change the characteristics of the water resources throughout the Project areas. The proposed operations will continue to offer a variety of boatable flows at the popular Sumner Falls site as desired by boating interests. Boater group comments on the PLP showed they were interested in higher base flows to improve navigation of the riverine reaches and impoundments. Higher instantaneous base flows, within impoundments and downstream are anticipated under the proposed operation. A year-round minimum flow of 300 cfs is proposed in the Bellows Falls bypassed reach to improve habitat in the main channel within the bypass. Such a flow is not boatable and Great River Hydro continues to discourage public access, use, and boating in the bypassed reach due to the safety concerns regarding flows and limitations on safe ingress and egress.

Flexible Operation at Wilder and responsive to ISO-NE schedule will continue to support a variety of boating conditions and opportunities at Sumner Falls. Under proposed IEO operations, changes in boating opportunities will occur as a function of the inflow hydrograph eliminating the cycling between low and high flows. Overall, this will provide higher base flows at Sumner Falls and the entire riverine reach and longer duration boating opportunities. Under IEO, hundreds of more hours of flows between 3,800 and 5,000 cfs (within the preferred boating flow for 'main wave') are modeled to occur in June and August (see Figure 3.3-3). Table 3.3-6 shows IEO operations will occur over 80 percent of the time in June and August increasing the duration of boatable flows.

Also of interest to boaters is the rate of change in flows which if are always rising and falling quickly produce windows of boatable flows. Under the IEO operations, the rate of change in flows will be dominated by the inflow hydrograph at Wilder dam. In addition, if Great River Hydro implements Flexible operation, the rate of change in magnitude would be tempered by Transitional Operation up-ramping, down-ramping and impoundment refill, so that boating flows would remain available longer than under current conditions. Overall, the proposed operations would have a positive impact on boating resources at Sumner Falls by providing more consistent boating conditions that would be most noticeable during summer when other area rivers are not boatable and during the lower range of flows since the hydrology would be more consistent throughout the day providing more steady flows in the 1,000 to 5,000 cfs range, which is ideal for Sumner Falls.

3.9.3 Cumulative Effects

FERC's SD2 identified the potential for multi-day canoeing opportunities, traveling the estimated 287-river mile stretch of the Connecticut River from downstream of Murphy dam to Holyoke dam, to be cumulatively affected by the 3 Great River Hydro's Projects and the 2 downstream FirstLight Projects. The riverine reaches of the Connecticut River become navigable downstream of Murphy dam in Pittsburg, New Hampshire, and multi-day canoe trips are marketed to summer camps, non-profit organizations, commercial canoe liveries, and academic programs along the Connecticut River Paddlers' Trail to the mouth at Long Island Sound. Primitive campsites are provided along most of the river for non-motorized boats via the Connecticut River Paddlers' Trail. The Paddlers' Trail currently has campsites on more than 300 miles of the river. Between Murphy dam and the most downstream dam in Holyoke, Massachusetts, paddlers must navigate around 10 dams, including the three Project dams located centrally within this reach. The presence of portage trails, take-outs, and put-ins around dams are essential elements to downstream paddler trips. Great River Hydro provides portage trails around each dam within this stretch of river, will add three formerly non-project primitive campsites to project recreation facilities and as a result of proposed operations will inclease average base flows in the river which will carry through all three project impoundments, downstream riverine portions below these dams and point further downstream.

3.9.4 Unavoidable Adverse Effects

Unavoidable adverse effects are those that may still occur after implementation of protection and mitigation measures. No unavoidable adverse effects on recreation resources or land use were identified in the environmental analysis. As discussed in Section 3.9.2.2, Great River Hydro evaluated alternatives for canoe portages at each Project and the potential for whitewater boating in the Bellows Falls bypassed reach. In all cases, alternatives were determined to be impractical, unsafe, or not feasible. Great River Hydro owns very little land around the impoundments beyond the property required to operate the dams, powerhouses, and appurtenant facilities, and various parcels adjacent to those facilities that include backwatered wetlands and floodplain terraces that are kept as natural areas or to support agriculture.

3.10 Aesthetic Resources

3.10.1 Affected Environment

3.10.1.1 General Description

The Projects are located along the border between Vermont and New Hampshire, spanning approximately 122 river miles from north to south. This area is known as the Connecticut River Valley and is acknowledged for its scenic views of mountains, historic villages, and open farmland. The Connecticut River Valley is surrounded by the Green Mountains to the west in Vermont and the White Mountains to the east in New Hampshire. The U.S. Department of Transportation's Federal Highway Administration recognizes the valley for its scenery and has designated various road segments along the river—most notably Vermont Route 5 and New Hampshire Routes 10, 11, and 12A and all Connecticut River bridge crossings—as part of the Connecticut River National Scenic Byway. Land use along the corridor of the Connecticut River is primarily rural and agricultural with considerable land forested and undeveloped. The river itself is an important landmark and destination, integral to the history of small towns and cities that lie along its shores and central to stimulating tourism throughout the valley. The mix of open space, villages, farms, country roads, mountainous terrain, historic architecture, and surface waters in the area provides for scenic vistas and a serene landscape.

The settlement patterns of Europeans in the Connecticut River Valley developed into a mosaic of villages and small cities surrounded by rural areas. This pattern of development persists in many areas in the Connecticut River Valley today, and it appeals to both visitors and residents (NHDES, 1997b). Town squares with white houses and churches, stately brick homes, and rows of brick mill buildings provide a historic architectural heritage of outstanding quality (NHDES, 1997b). The river provides views of long stretches of water, surrounding wetlands full of wildlife, views from the river of distant peaks, church steeples, vast agricultural fields and farmlands, and traditional New England homes such as those in Orford, North Walpole, the village of Bellows Falls, and Brattleboro.

The three Projects are located in the fertile soils of the Connecticut River Valley, so much of the surrounding land use types are agricultural and forested areas. Other land use types include rural residential areas; commercial, industrial, and transportation developments, and wetlands. Railroad tracks are commonly found along the banks and in proximity to the Projects along the New Hampshire and Vermont shorelines.

Overall, the three Project impoundments are aesthetically pleasing to view. Changes in scenic conditions associated with operations are limited to a narrow band of exposed bank associated with impoundment drawdown within the normal Project operating ranges (see Section 3.5, *Water Resources*). Exposed mudflats and shoal areas surrounding tributaries in the more downstream portions of the impoundments are the result of river profile operations implemented when inflows are anticipated to exceed Project generating capacity and necessary to contain high flows within the banks of the Connecticut River upstream. Temporal and seasonal changes in the amount of exposed shoreline are most noticeable where the riverbank slopes are gentle. This type of shoreline highlights the visual contrasts of changing impoundment elevations compared to steep or armored shorelines because the changes expose the native soils below the vegetation at the high water mark. Because of the size of the Connecticut River and its prominence within the greater landscape setting, a temporal change in impoundment elevation related to normal Project operations is likely barely perceptible to most observers in the vicinity of the Projects.

3.10.1.2 Wilder Project

The Wilder impoundment stretches about 45 miles between the towns of White River Junction, Vermont, and West Lebanon, New Hampshire, north to the villages of Newbury, Vermont, and Haverhill, New Hampshire. The River Road in New Hampshire, north of the East Thetford Bridge to the Orford town line, has been designated a town scenic road.

The mix of open space, villages, farms, country roads, mountainous terrain, historic architecture, and surface waters in the area provide for scenic vistas and an attractive landscape. Aquatic vegetation can be found in coves and shoal areas along the Wilder impoundment.

Wilder dam and powerhouse, which are adjacent to New Hampshire Route 10, are clearly visible to motorists from this road and to visitors at the scenic picnic overlook across from the dam on the same road. The brick construction of the powerhouse, although newer, is consistent with that of more historic buildings throughout the Connecticut River Valley because brick was a common building material during the era of construction for the area. The duration of the view to motorists on New Hampshire Route 10 is short because only about 0.25 mile of the road parallels the dam and impoundment before turning away from the river at the dam. The fish ladder provides a viewing area to people visiting the dam. Views of the Wilder Project are provided at public access points up and down the river and from the Haverhill-Newbury, Piermont-Bradford, Orford, Lyme-Thetford, and Ledyard (Hanover-Norwich) bridges and select sections of U.S. Interstate 91, U.S. Route 5, and local roads paralleling the river.

Operation of the Wilder Project is visible from numerous points around the Project. The normal operating range of the Wilder Project is 2.5 ft or less (between El. 382.0 and 384.5 ft, NGVD29), depending on inflow, as described in Section 2.1.3.4, *Existing Project Operations.* The primary effect on aesthetic resources is the amount of shoreline that is visible as the Project stores and releases water for generation needs. Great River Hydro mitigates these effects by voluntarily holding the impoundment level at a minimum elevation of 382.5 ft at the dam from Friday at 4:00 p.m. through Sunday at midnight during the summer recreation season (Memorial Day through the last weekend in September) and on holidays during the same period unless the Project is experiencing high flows above generating capacity.

Information about visitor needs related to the aesthetic resources of the Wilder Project was collected from surveys conducted in support of Study 30, *Recreation Facility Inventory and Use & Needs Assessment*. Of the 252 people who were surveyed at Wilder Project public recreation study sites as part of Study 30 and rated the scenery, 87 percent reported the aesthetic quality of the Wilder Project as *extremely appealing* or *appealing* (scores of 7, 8, or 9 on the 9-point Likert rating scale), while 12 percent (scores of 4, 5 or 6 on the rating scale) rated the aesthetic resources as *average*.

According to individuals surveyed at public recreation areas in the Wilder Project area, aesthetic attributes include being well maintained, private, clean, and quiet; having sufficient vegetation and foliage; having a view of the dam, river, and mountains, being near agricultural fields and farmhouses, and being able to see wildlife. Of the 252 respondents, only 1 listed the scenic quality of the Project as *unappealing*. Aesthetic detractors identified by visitors included insufficient seclusion, muddy riverbanks and dirty water, traffic noise, bank erosion, and vandalism.

3.10.1.3 Bellows Falls Project

Bellows Falls dam and powerhouse are located among the exposed rocky gorge and in the villages of Bellows Falls, Vermont, and North Walpole, New Hampshire. The Project was developed to capitalize on the notable drop in this section of the river, after which the village of Bellows Falls is named. The historic mill used the drop in the river for water power to run the mill. The commercial district developed around the mill and along Canal Street, which parallels the power canal that provides the water to the Bellows Falls powerhouse, all of which are part of the Bellows Falls Downtown Historic District. Because of the Project’s location and age, it is a prominent feature in the village with historic mill buildings adjacent to the canal and the Project works. The Bellows Falls visitor/environmental education center invites the public to the facility, enhancing education opportunities of the hydropower project within the Bellows Falls Downtown Historic District. The steep rocky hillsides surrounding the Project are heavily wooded with mixed hardwood interspersed with conifers.

Operation of the Project is visible from only a limited number of viewpoints because much of the land surrounding the Project is privately owned. The normal impoundment operating range is 1.8 ft between 289.6 and 291.4 ft (NGVD29). Great River Hydro mitigates these effects by voluntarily holding the impoundment level at a minimum elevation of 289.6 ft at the dam from Friday at 4:00 p.m. through Sunday at midnight during the summer recreation season (Memorial Day through the last weekend in September) and on holidays during the same period unless the Project is experiencing high flows above generating capacity.

During high flow periods, Great River Hydro uses what flow it can for power generation and releases the remaining water to the bypassed reach, creating turbulent whitewater that falls through the rocky gorge at the Project, as discussed in the *Bellows Falls Bypassed Reach* section, below.

Sources of information about visitor needs related to the aesthetic resources of the Bellows Falls Project are provided in Study 30, *Recreation Facility Inventory and Use & Needs Assessment*, and Study 32, *Bellows Falls Aesthetic Flow Study*. Respondents to the surveys in support of Study 30 gave Bellows Falls recreation sites and views of the Bellows Falls Project area good scores for visual aesthetics; 82 percent of respondents rated the scenic quality as *appealing* or higher. Respondents recommended (1) considering the scenic value of undeveloped lands for future development of any shoreline properties and (2) incorporating measures to protect areas of significant scenic value. U.S. Route 5 from Brattleboro to Bellows Falls parallels the river and is part of the Connecticut River National Scenic Byway. Of the 140 people surveyed at Bellows Falls public recreation study sites and rated the scenery, 82 percent of the respondents rated the scenic quality as *appealing* or *extremely appealing*, (scores of 7, 8, or 9 on the 9-point Likert rating scale), while 17 percent (scores of 4, 5, or 6 on the rating scale) of the respondents rated the scenery as *average*.

Aesthetic attributes from individuals surveyed included scenic views of mountains and the river, ability to see wildlife such as bald eagles, sandy beaches, sufficient trees and vegetation, quietness, lack of development, open space, and privacy. Aesthetic detractors included trash at the site of the interview and in the river and insufficient maintenance of trees and brush.

Bellows Falls Bypassed Reach

The Bellows Falls bypassed reach extends about 0.64 mile from the dam to the confluence with the tailrace of Bellows Falls powerhouse. Flows in the bypassed reach correspond with the spring freshet and large precipitation events when river flows exceed Project generating capacity, and during outages at the powerhouse that require water to be diverted to the dam and spilled into the bypassed reach. During the majority of the year, the only flows in the bypassed reach are the result of leakage through spillway gate seals and stanchion boards, which vary from year to year.

Great River Hydro conducted Study 32 to characterize aesthetic conditions in the Bellows Falls bypassed reach at various flows. The study included recording video footage and taking photographs from 3 key observation points (KOPs) at 8 different flow levels. A focus group evaluated 6 flows, and 4 of the lowest flows were qualitatively analyzed subsequent to the focus group. Demonstration flows included 125 cfs (leakage); 500 cfs; 1,000 cfs, 1,580 cfs; 2,370 cfs; 3,300 cfs; 4,370 cfs; and 5,560 cfs. At flows less than 1,580 cfs, the scenic quality of flows in the bypassed reach was not noticeably different. The station maximum hydraulic capacity (flows controllable by power generation) is about 11,400 cfs.

The 3 KOPs (Figure 3.10-1, Figure 3.10-2, and Figure 3.10-3) provide the primary opportunities for the public to view the bypassed reach. KOP 1 is located on Arch Bridge looking over the dam, through the train trestle, downstream into the reach. Pedestrian access is not limited at this KOP. Overall, views from this KOP are severely obstructed by the train trestle and it is almost impossible to view details of flow in the riverbed of the bypassed reach from this location.

KOP 2 is located along New Hampshire Route 12 looking upstream; no pedestrian access to the river side of the road is available at this location (the sidewalk is on the opposite side of the road from the bypassed reach); vehicles have an unobstructed viewing window of approximately 150 ft, which at common travel speeds between 30 to 50 mph along this route result in very short duration views into the bypassed reach. Drivers travelling north on New Hampshire Route 12 are provided the best views as they approach the viewing window—the gap in vegetation that provides clear views—to the bypassed reach. Drivers traveling south on the same road have to turn their heads and look over their shoulders as they pass the viewing window to see the bypassed reach. Focus group participants rated views from KOP 2 as much higher than KOP 1 because the view of the bypassed reach is improved compared to KOP 1; however, the focus group setting looked at photographs and video footage which do not represent the timing of the views from moving vehicles on New Hampshire Route 12.

KOP 3 is located on Vilas Bridge with views upstream over the top of the train trestle and downstream into the lower segment of the bypassed reach. This bridge is closed, and concrete jersey barriers prohibit public use, although locals occasionally use it. The total number of pedestrian users crossing Vilas Bridge is likely low because few residents along New Hampshire Route 12 potentially use it as a way into the village of Bellows Falls, but because these potential viewers are walking, their viewing times are likely longer than from the other KOPs. The train trestle obscures a portion of views upstream from this location, and foreground views immediately below the train trestle center on the fish barrier dam. Focus group participants indicated that differences between flows were most visible from KOP 3. All focus group participants, except 1, liked the view of the leakage (125 cfs) flow (typical existing conditions for much of the year) at this KOP.

Source: ILP Study 32, *Bellows Falls Aesthetic Flow Study*

Figure 3.10-1. View from KOP 1, Arch Bridge over the dam into the Bellows Falls bypassed reach at 125 cfs (typical existing conditions when not spilling).

Source: ILP Study 32, *Bellows Falls Aesthetic Flow Study*

Figure 3.10-2. View from KOP 2, New Hampshire Route 12 looking over the guard rail into the Bellows Falls bypassed reach at 125 cfs (typical existing conditions when not spilling).

Source: ILP Study 32, *Bellows Falls Aesthetic Flow Study*

Figure 3.10-3. View from KOP 3, Vilas Bridge looking upstream into the Bellows Falls bypassed reach at 125 cfs (typical existing conditions when not spilling).

Overall, focus group participants acknowledged that seasonal variation in flows are important. They noted that spring flows in the bypassed reach are appreciated because they reflect the seasonal nature of snow melt and runoff, while lower flows reflect the nature of summer conditions throughout the watershed. Most focus group participants reported enjoying the experience of viewing very high flows associated with spring runoff and flood conditions. The speed, sound, and power of water in the bypassed reach elicit a sense of awe of the natural forces of the water during the spring runoff. Focus group participants also believe that some flows, even leakage flows, are important to the aesthetics of the bypassed reach because flow brings the river to life. In all cases, flows were free of visible debris, foam, trash, and other constituents that could negatively affect overall aesthetics in the bypassed reach.

As noted in Study 32, focus group participants gave higher aesthetic value scores to flows in the bypassed reach than to leakage flow. Higher flows make the reach look more like an unregulated river, making the reach look more *alive*. Focus group participants also considered that aesthetic flows in the bypassed reach will be of low importance to the public under today’s conditions because access to viewing areas where the public could experience aesthetic flows is limited. Most of the land on the west side of the reach is privately owned and has heavy industrial use. The land on the east side of the reach largely comprises residential properties, and the Vilas Bridge across the bypassed reach between New Hampshire and Vermont is technically not open for public access. Consequently, access to viewing the bypassed reach requires visitors to trespass, limiting the ability of the public to view aesthetic flows. Even though public viewpoints are generally limited, the majority of the participants agreed that some flow, even low leakage flow, is important to the aesthetic value of the bypassed reach.

3.10.1.4 Vernon Project

Views of the Connecticut River at the Vernon Project area are provided at public access points up and down the river; from the Walpole-Westminster Bridge, Route 9 Bridge in Brattleboro, and Route 119 Bridge in Brattleboro, along some sections of Interstate 91, U.S. Route 5, Vermont Route 142, New Hampshire Route 119, and local roads; and along the rail trail paralleling the river in New Hampshire. Railroad tracks along the shoreline limit access to the river and corresponding views in the nearby Town of Brattleboro, which contains the largest concentration of population along this stretch of the river.

Vernon dam is located adjacent to Vermont Route 142. Motorists have an unobstructed view of the dam and Project facilities on this road. The fish ladder viewing area and Governor Hunt Recreation Area also provide direct views of the dam and tailrace areas. The powerhouse is composed of brick, a common building material used at the time of construction in 1909.

Operation of the Project is visible from several viewpoints near the Project and along many local scenic roads and highways. The normal operating range of the impoundment is 1.8 ft (between El. 218.3 and 220.1 ft, NGVD29). The primary effect of operations is the amount of shoreline that is visible as the Project stores and releases water for generation needs. Great River Hydro mitigates these effects by voluntarily maintaining a minimum impoundment level 218.6 ft at the dam from Friday at 4:00 p.m. through Sunday at midnight during the summer recreation season (Memorial Day through the last weekend in September) and on holidays during the same period unless the Project is experiencing high flows above generating capacity.

One-hundred seventy-nine of the 181 people who were surveyed at Vernon Project public recreation sites as part of Study 30 responded to the scenic quality. Of these respondents, 84 percent rated the scenic quality as *appealing* or *extremely appealing* (scores of 7, 8, or 9 on the 9-point Likert (rating) scale), while 15 percent (scores of 4, 5, or 6 on the rating scale) of the respondents rated the scenery as *average*. Aesthetic attributes at the Vernon Project area deemed by survey respondents to be important included scenic views of mountains and the river, ability to see wildlife such as bald eagles, sandy beaches, sufficient trees and vegetation, quietness, lack of development, open space, and privacy. Aesthetic detractors included trash at the site and in the river and insufficient maintenance of trees and brush.

3.10.2 Environmental Effects

3.10.2.1 No-action Alternative

The Connecticut River Valley is a significant landform and integral part of the towns along the river. Agricultural use of lands along the river as well as historic towns and associated industry and cultural uses maintain the historical mixed character of the valley. These types of uses and the resulting visual character are marketed by New Hampshire and Vermont tourism bureaus, towns, and businesses throughout the region and serve to stimulate tourism within the valley.

Because the facilities associated with the three Projects have already been constructed and no new facilities or changes in operations are proposed, no new effects on aesthetic resources will occur; therefore, there will be no incremental effects on aesthetic resources associated with the Projects as proposed.

3.10.2.2 Great River Hydro Proposal

Great River Hydro is not proposing any new PM&E measures specifically for aesthetic resources. Overall aesthetic value of flow in the Bellows Falls bypassed will theorectically improve with a sustained flow of 300 cfs or more maintained in the reach; in reality, however, aesthetic value in thereach depends on whether or not people can see it. Focus group participants noted that no reasonable public access to the bypassed reach is available, and the viewpoints from a car are fleeting. On foot, the viewpoints are hard to get to, often requiring trespassing on private land or train tracks. As a result of difficult access, focus group participants reported that designed aesthetic flows in the bypassed reach will not be readily viewable and therefore will be underappreciated. Extrapolating from the focus group discussion points that any flow in the bypassed reach is better than no flow, continuing the current leakage in the channel will maintain the aesthetic value in the bypassed reach. Characterizing which features are visible and which are submerged and no longer visible as the water rises, and relative aesthetic value, does not suggest any specific flow is more aesthetically pleasing than another.

3.10.3 Cumulative Effects

No cumulative effects related to aesthetic resources have been identified, so no cumulative effects on these species are evaluated as part of this environmental analysis.

3.10.4 Unavoidable Adverse Effects

Unavoidable adverse effects are those that may still occur after implementation of protection and mitigation measures. No unavoidable adverse effects on aesthetics were identified in the environmental analysis.

3.11 Cultural and Historic Resources

The issuance of new licenses by FERC for the continued operation of the Wilder, Bellows Falls, and Vernon Projects constitute undertakings that are subject to review under Section 106 of the NHPA of 1966, as amended, and its implementing regulations 36 C.F.R. § 800. Section 106 requires federal agencies to take into account the effects of their actions on historic properties and afford the Advisory Council on Historic Preservation (ACHP) an opportunity to comment on such undertakings. In consultation with the SHPOs in Vermont and New Hampshire (Vermont State Historic Preservation Officer [VTSHPO] and New Hampshire State Historic Preservation Officer [NHSHPO]), FERC is responsible for determining the Projects' Area(s) of Potential Effects (APEs), ensuring the identification of historic properties within the APEs, determining whether the relicensing of the Projects will impact any historic properties, and resolving any potential adverse effects by seeking ways to avoid, minimize, or mitigate the effects. The term "historic property" means any building, site, structure, object, or district that is listed or eligible for listing in the National Register. Traditional Cultural Properties (TCPs) are a type of historic property eligible for the National Register because of their association with cultural practices or beliefs of a living community that: (1) are rooted in that community's history; or (2) are important in maintaining the continuing cultural identity of the community (Parker and King, 1998).

In its December 21, 2012, NOI to file a license application, FERC designated TransCanada (now Great River Hydro) as its non-federal representative for carrying out informal consultation, pursuant to Section 106 of the NHPA. A number of studies have been conducted to identify National Register-listed and National Register-eligible archaeological sites, historic architectural resources, and TCPs within the APEs. The following information summarizes the results of those investigations and the status of consultation regarding the effects of the relicensing of the Projects on historic properties.

3.11.1 Affected Environment

3.11.1.1 Area of Potential Effects

The affected environment for historic and cultural resources conforms to the APE determined by FERC, in consultation with the VTSHPO, NHSHPO, Narragansett Indian Tribal Preservation Officer (NITHPO), and the Nolumbeka Project. An APE is "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" (36 C.F.R. § 800.16(d)). By letter dated November 27, 2013, FERC determined that the APEs for the Projects consist of all lands within the Project boundaries owned in fee simple by Great River Hydro and 33 ft (10 meters) of land inland from the top of bank in areas along the Connecticut River and affected portions of tributaries where Great River Hydro holds flowage rights (Figure 3.11-1 through Figure 3.11-3). In its letter, FERC requested concurrence on this determination from the VTSHPO and NHSHPO. On January 9, 2014, the VTSHPO filed its concurrence with the APE for lands located in Vermont (see Table 3.11-1 below). The NHSHPO did not respond with formal concurrence on the APE determination for lands located in New Hampshire but has indicated its agreement through the acceptance of the Phase IA and Phase IB cultural resources reports.

The Project APEs are further described by the cultural context in which the area developed. The cultural context is divided into three major temporal periods: Pre-Contact, Contact, and Post-Contact. The descriptions of the periods below were derived from cultural resource management reports that provide the findings of archaeological and historic architectural investigations that were conducted to identify historic properties within the Project APEs.

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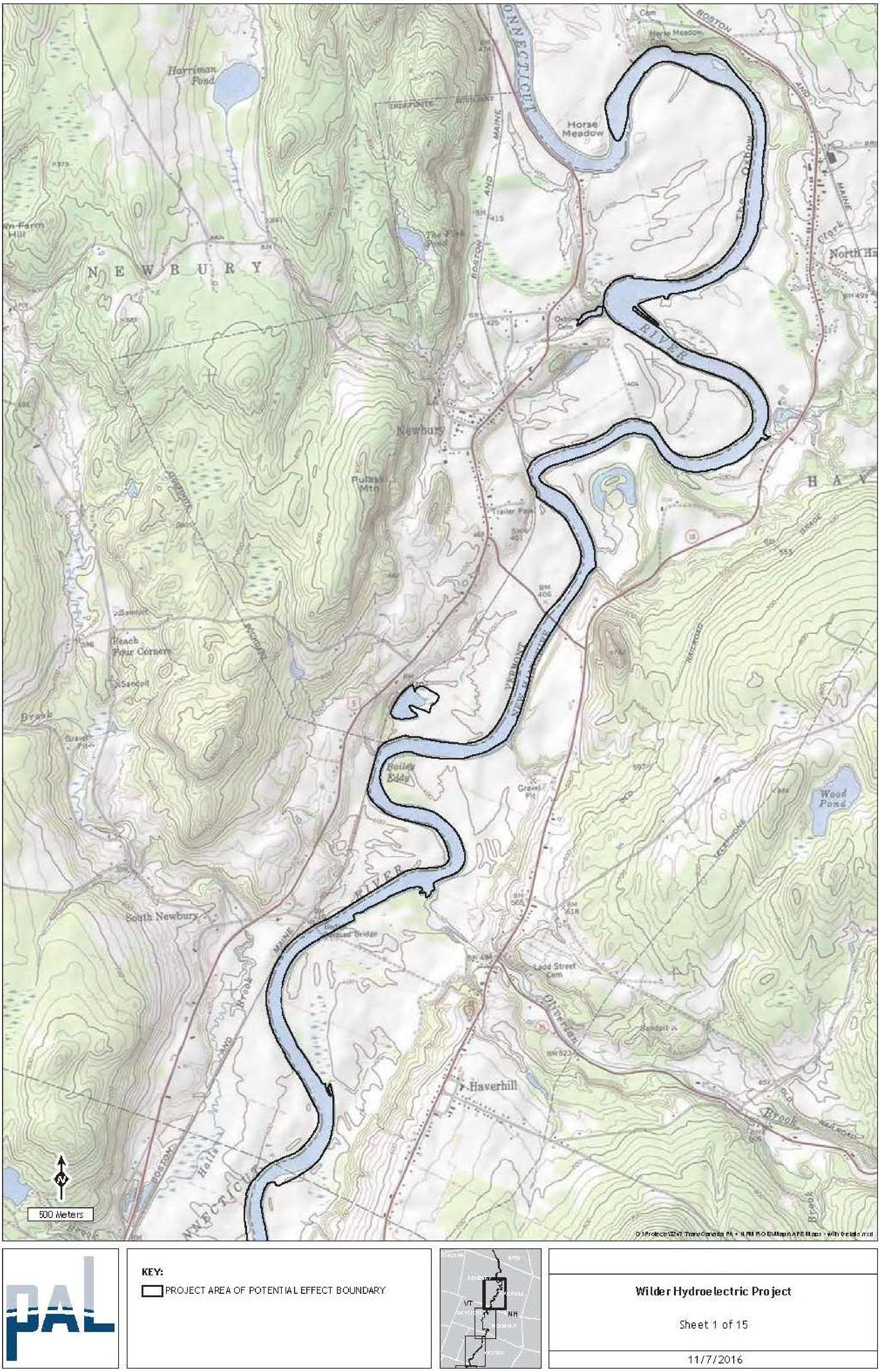

Source: ILP Study 33, *Cultural and Historic Resources Study*

Figure 3.11-1. Wilder Project Area of Potential Effects.

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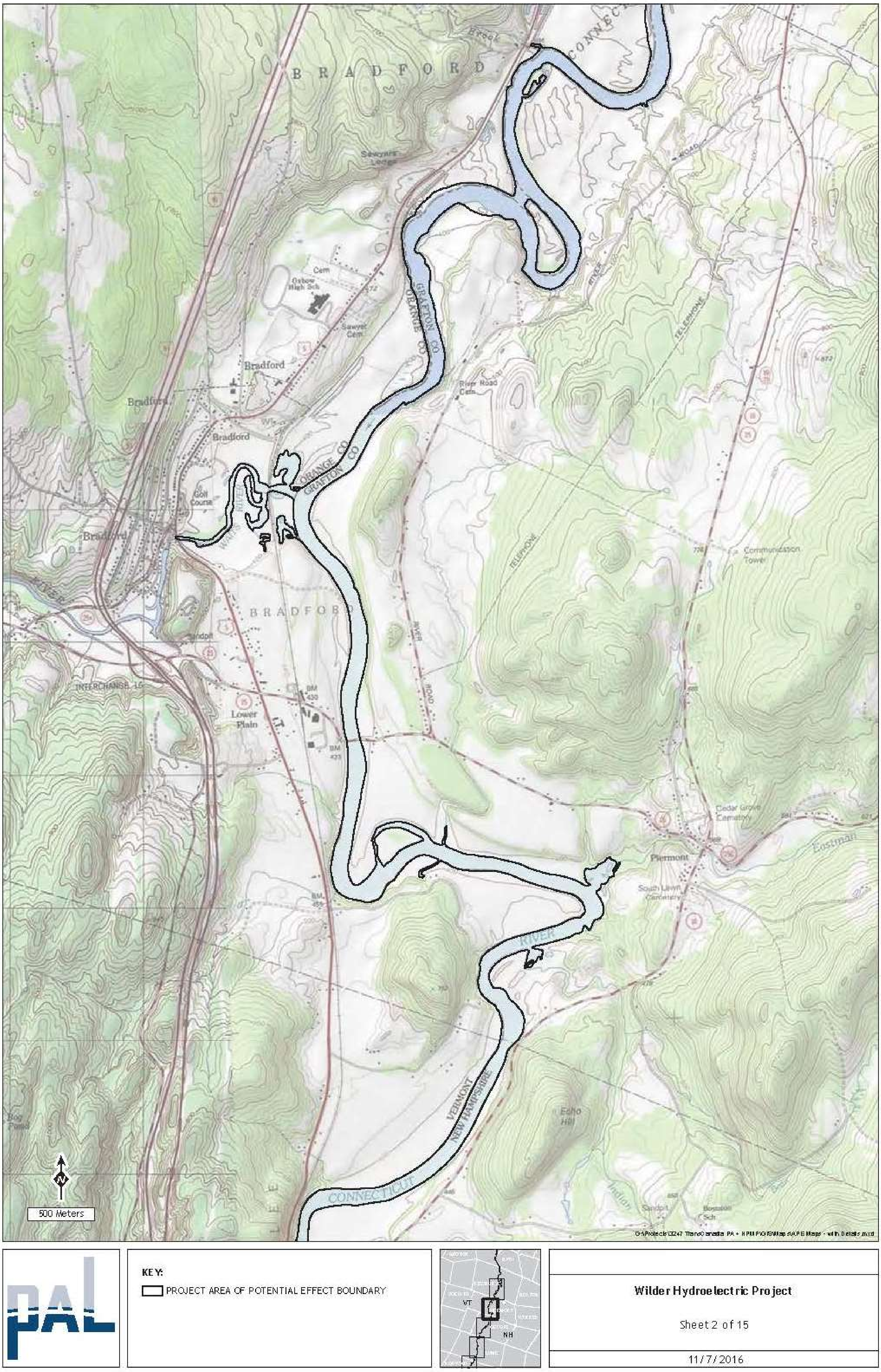

Source: ILP Study 33, *Cultural and Historic Resources Study*

Figure 3.11-1. Wilder Project Area of Potential Effects (continued).

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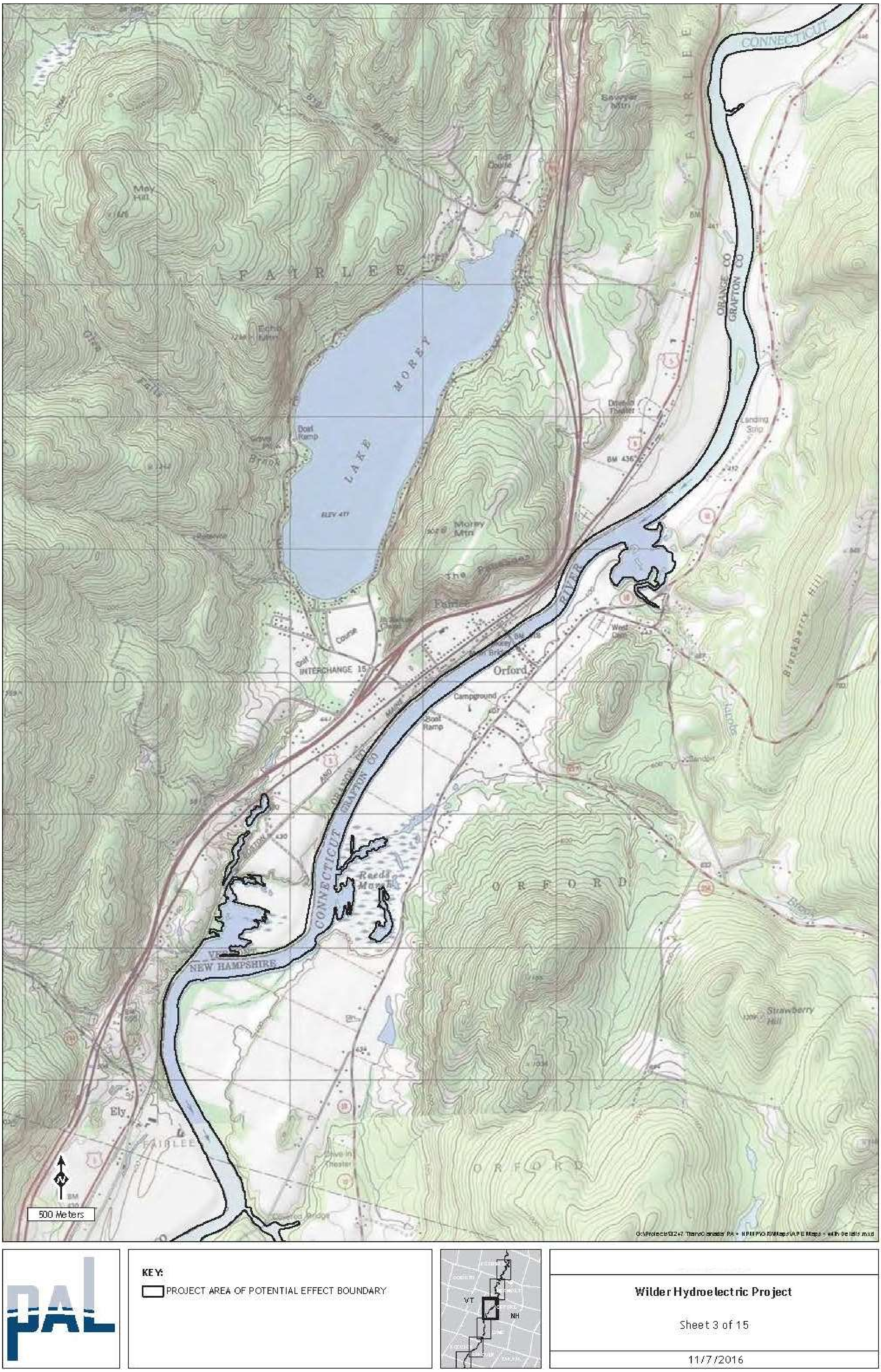

Source: ILP Study 33, *Cultural and Historic Resources Study*

Figure 3.11-1. Wilder Project Area of Potential Effects (continued).

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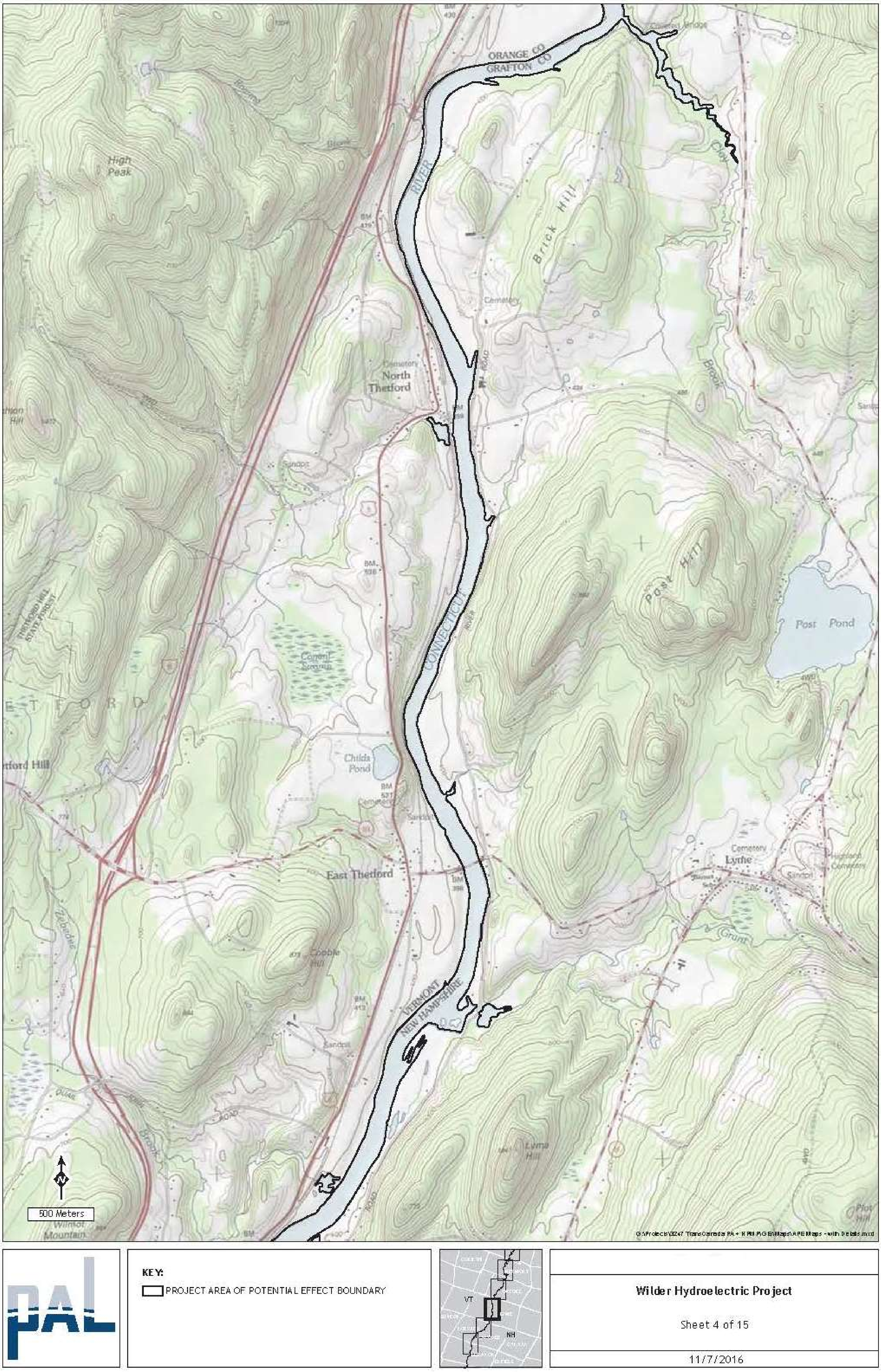

Source: ILP Study 33, *Cultural and Historic Resources Study*

Figure 3.11-1. Wilder Project Area of Potential Effects (continued).

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Source: ILP Study 33, *Cultural and Historic Resources Study*

Figure 3.11-1. Wilder Project Area of Potential Effects (continued).

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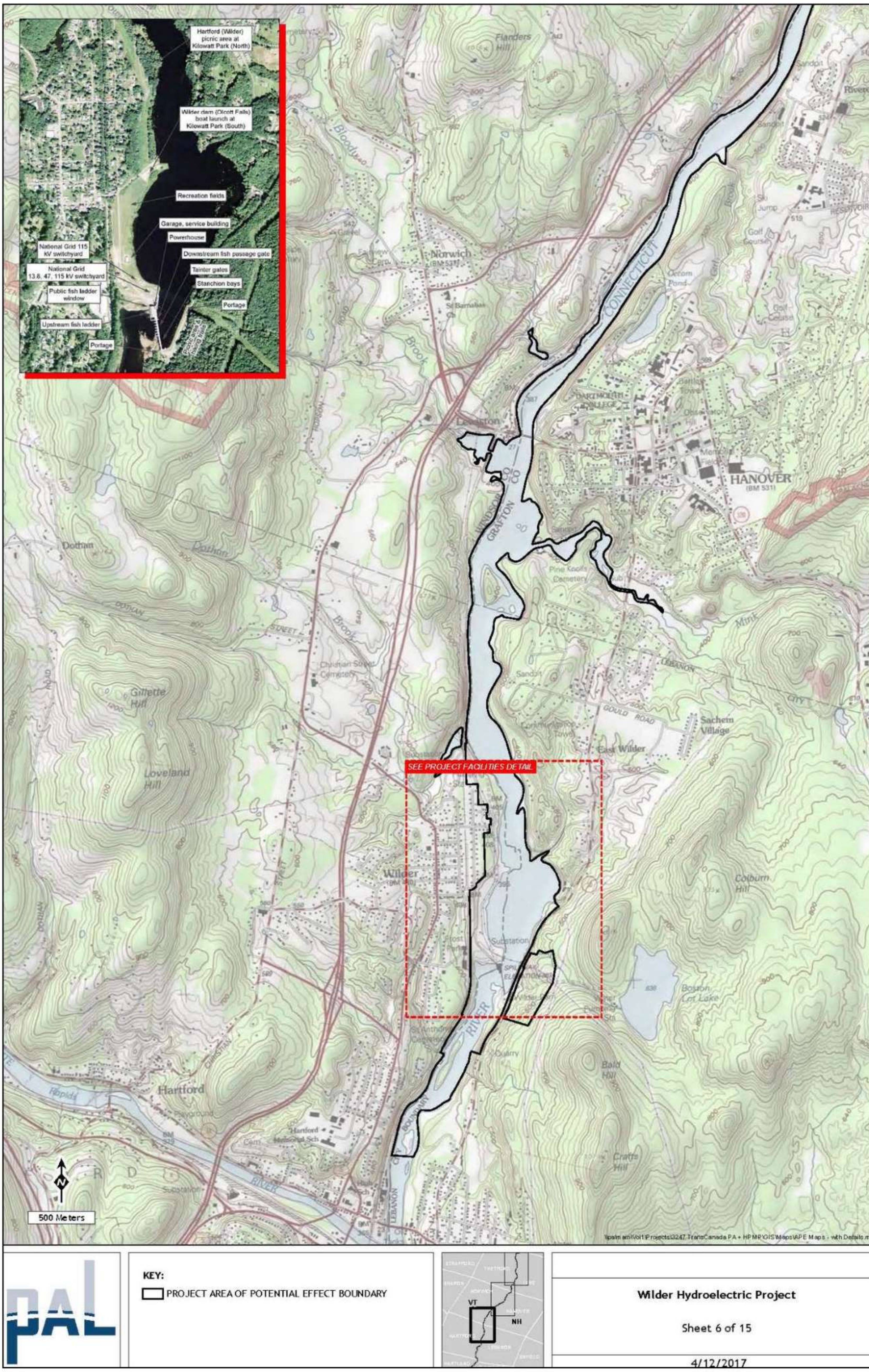

Source: ILP Study 33, *Cultural and Historic Resources Study*

Figure 3.11-1. Wilder Project Area of Potential Effects (continued).

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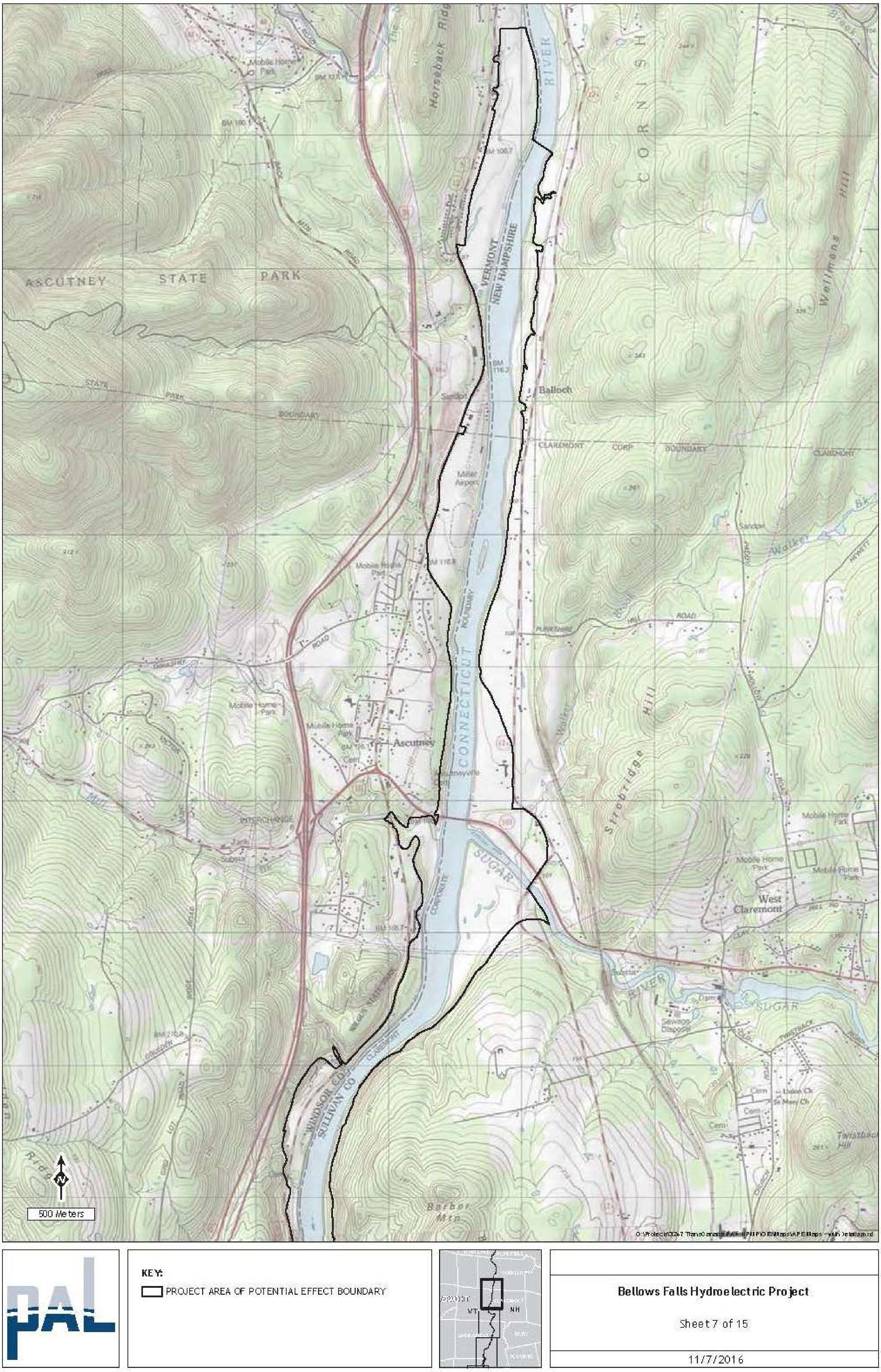

Source: ILP Study 33, *Cultural and Historic Resources Study*

Figure 3.11-2. Bellows Falls Project Area of Potential Effects.

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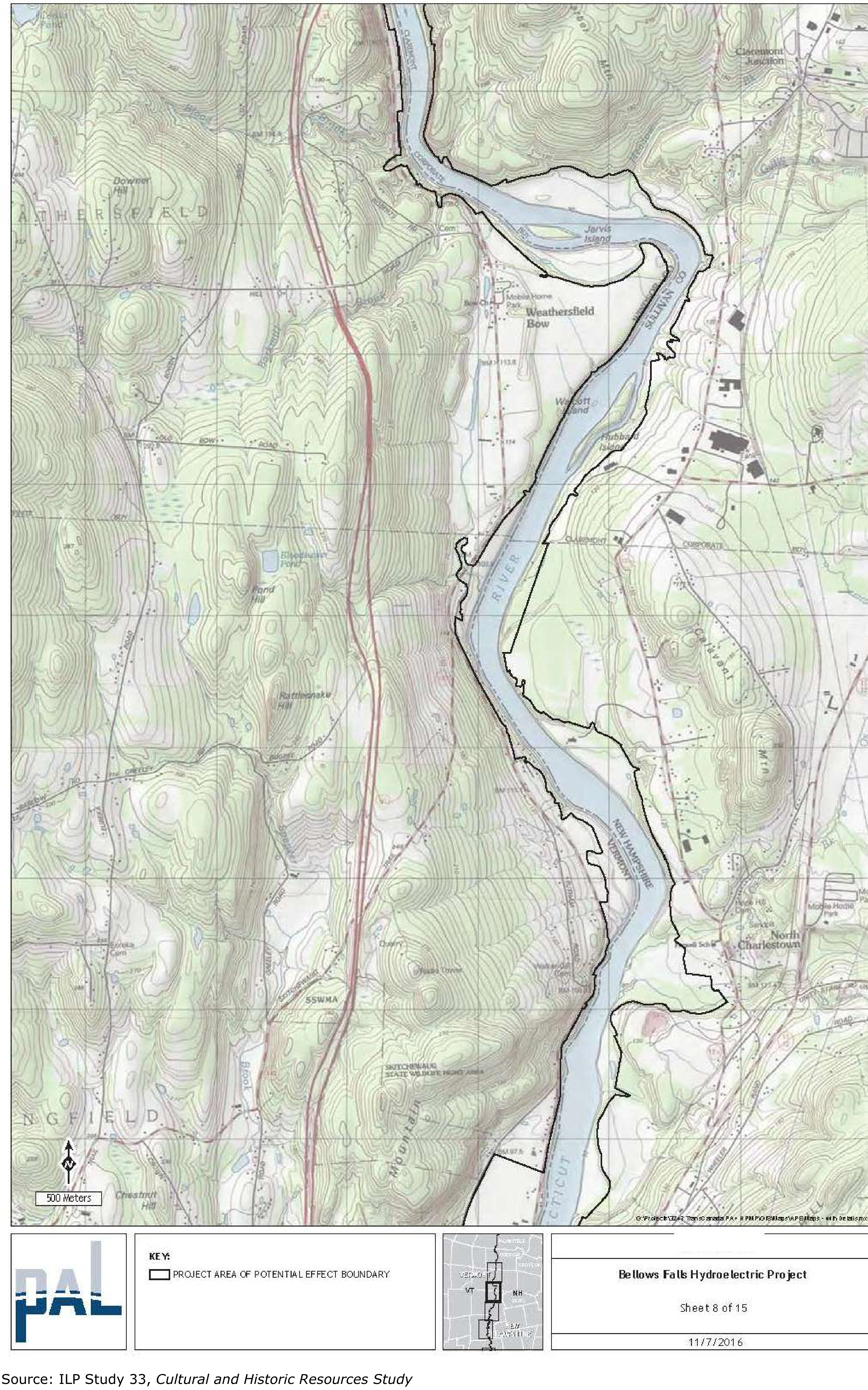

Source: ILP Study 33, *Cultural and Historic Resources Study*

Figure 3.11-2. Bellows Falls Project Area of Potential Effects (continued).

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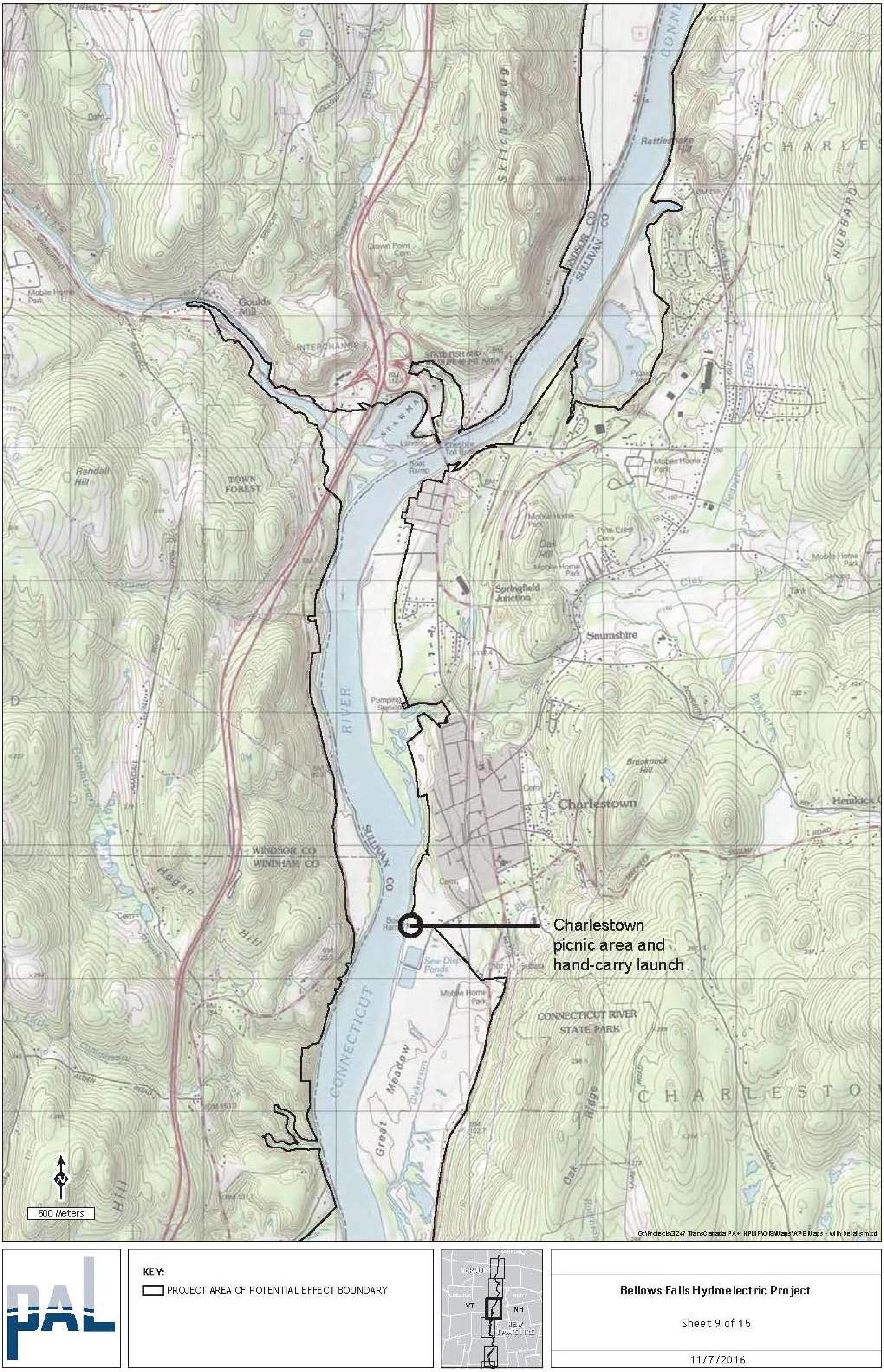

Source: ILP Study 33, *Cultural and Historic Resources Study*

Figure 3.11-2. Bellows Falls Project Area of Potential Effects (continued).

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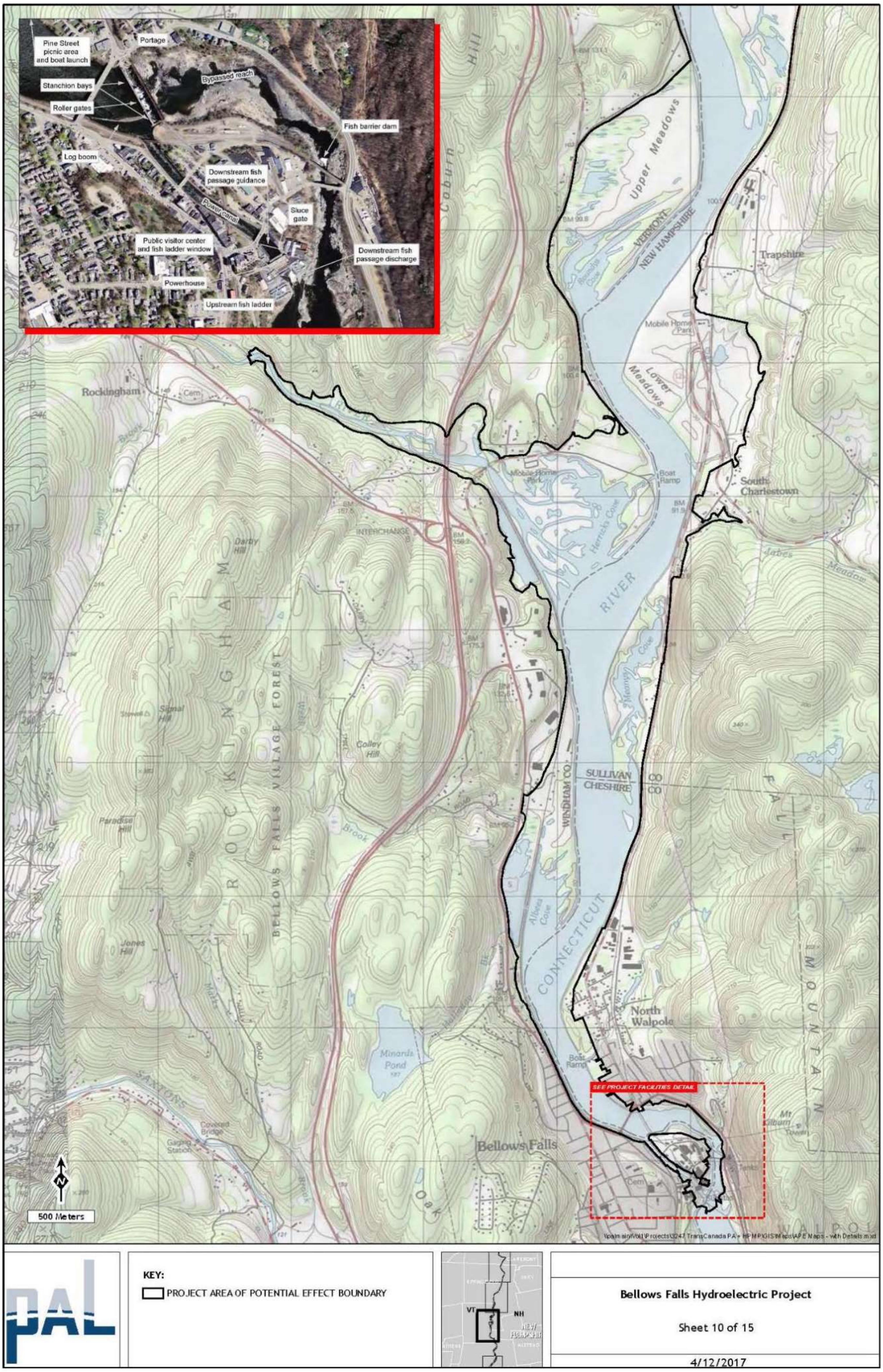

Source: ILP Study 33, *Cultural and Historic Resources Study*

Figure 3.11-2. Bellows Falls Project Area of Potential Effects (continued).

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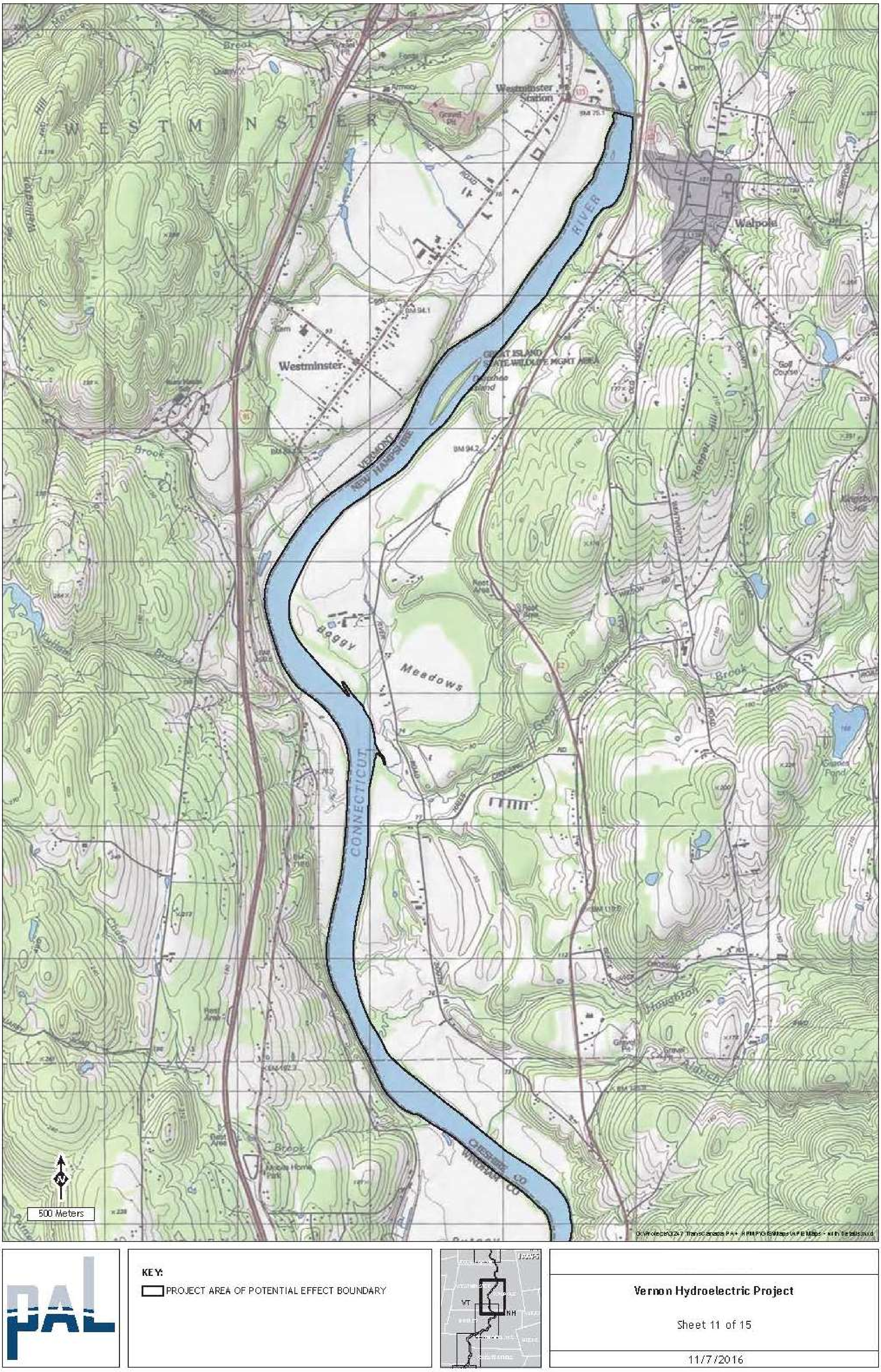

Source: ILP Study 33, *Cultural and Historic Resources Study*

Figure 3.11-3. Vernon Project Area of Potential Effects.

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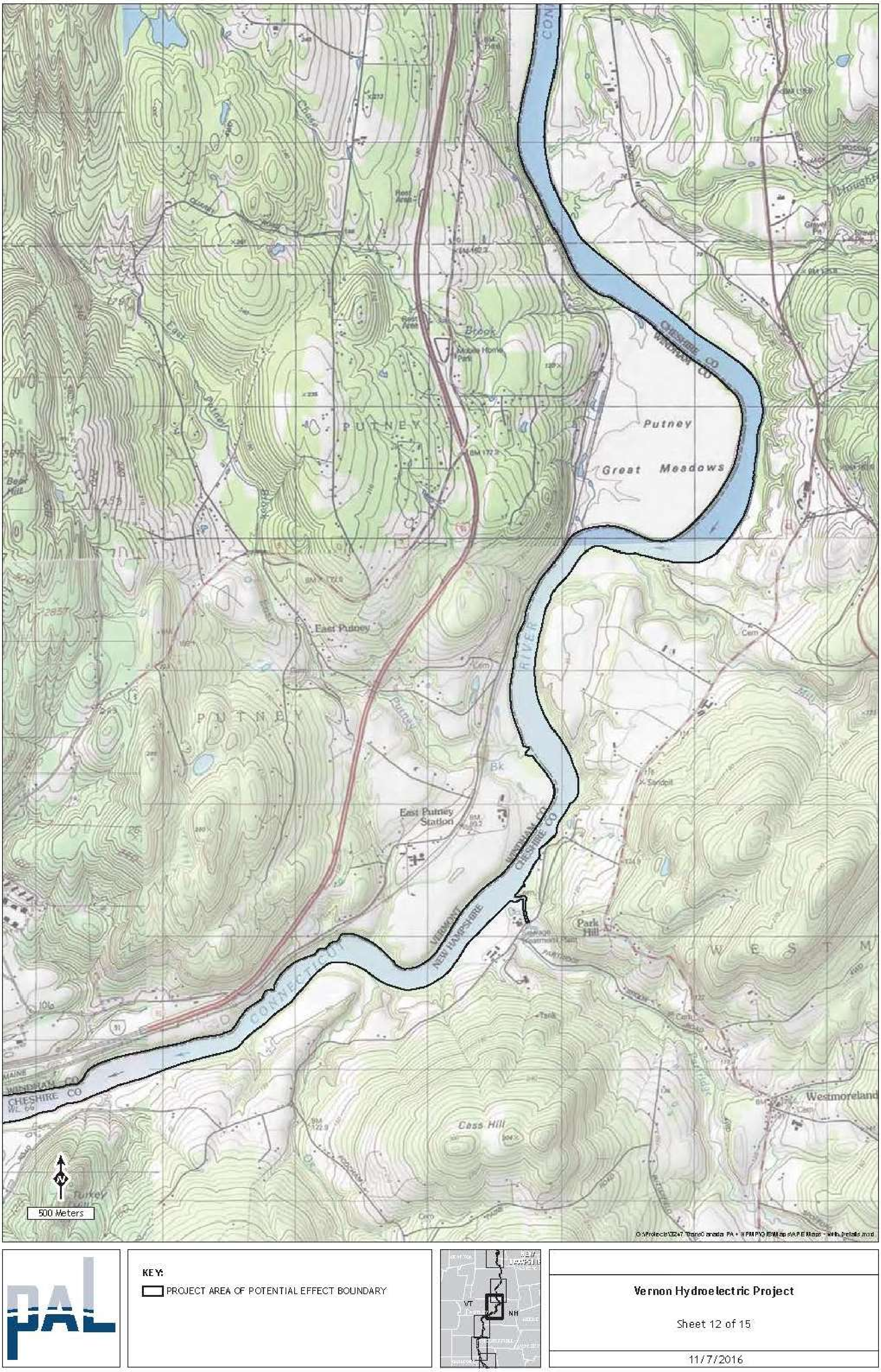

Source: ILP Study 33, *Cultural and Historic Resources Study*

Figure 3.11-3. Vernon Project Area of Potential Effects (continued).

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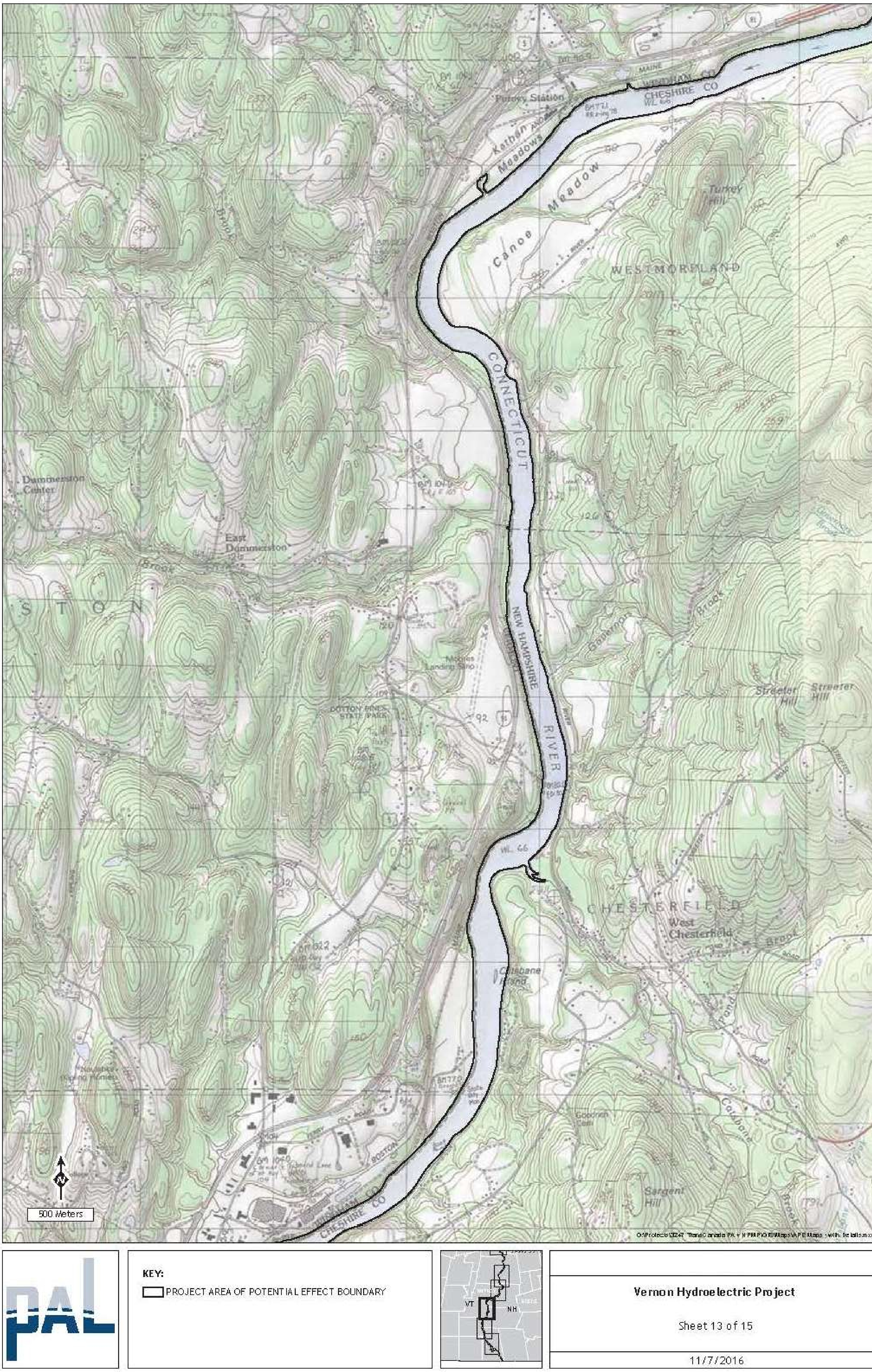

Source: ILP Study 33, *Cultural and Historic Resources Study*

Figure 3.11-3. Vernon Project Area of Potential Effects (continued).

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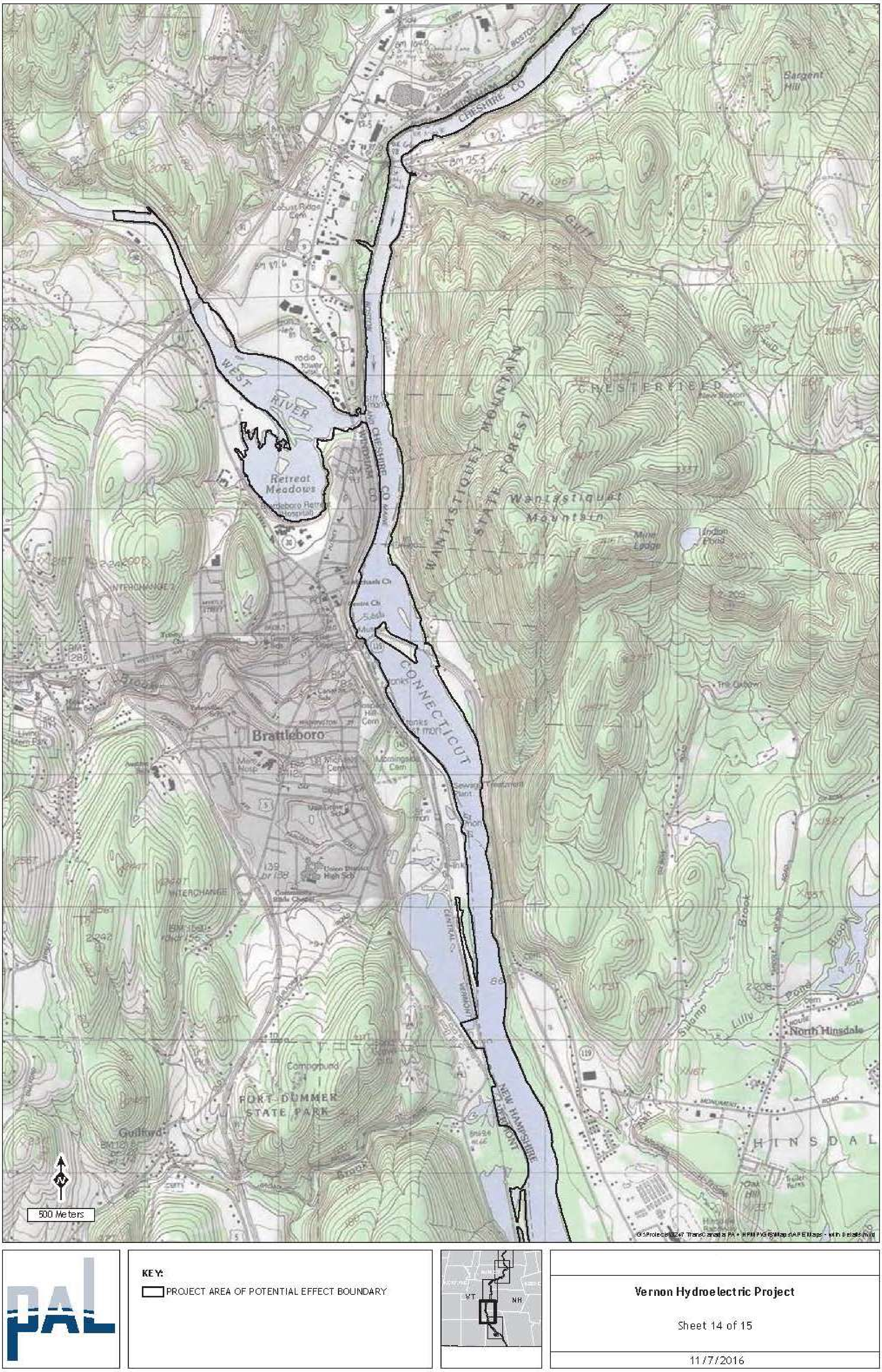

Source: ILP Study 33, *Cultural and Historic Resources Study*

Figure 3.11-3. Vernon Project Area of Potential Effects (continued).

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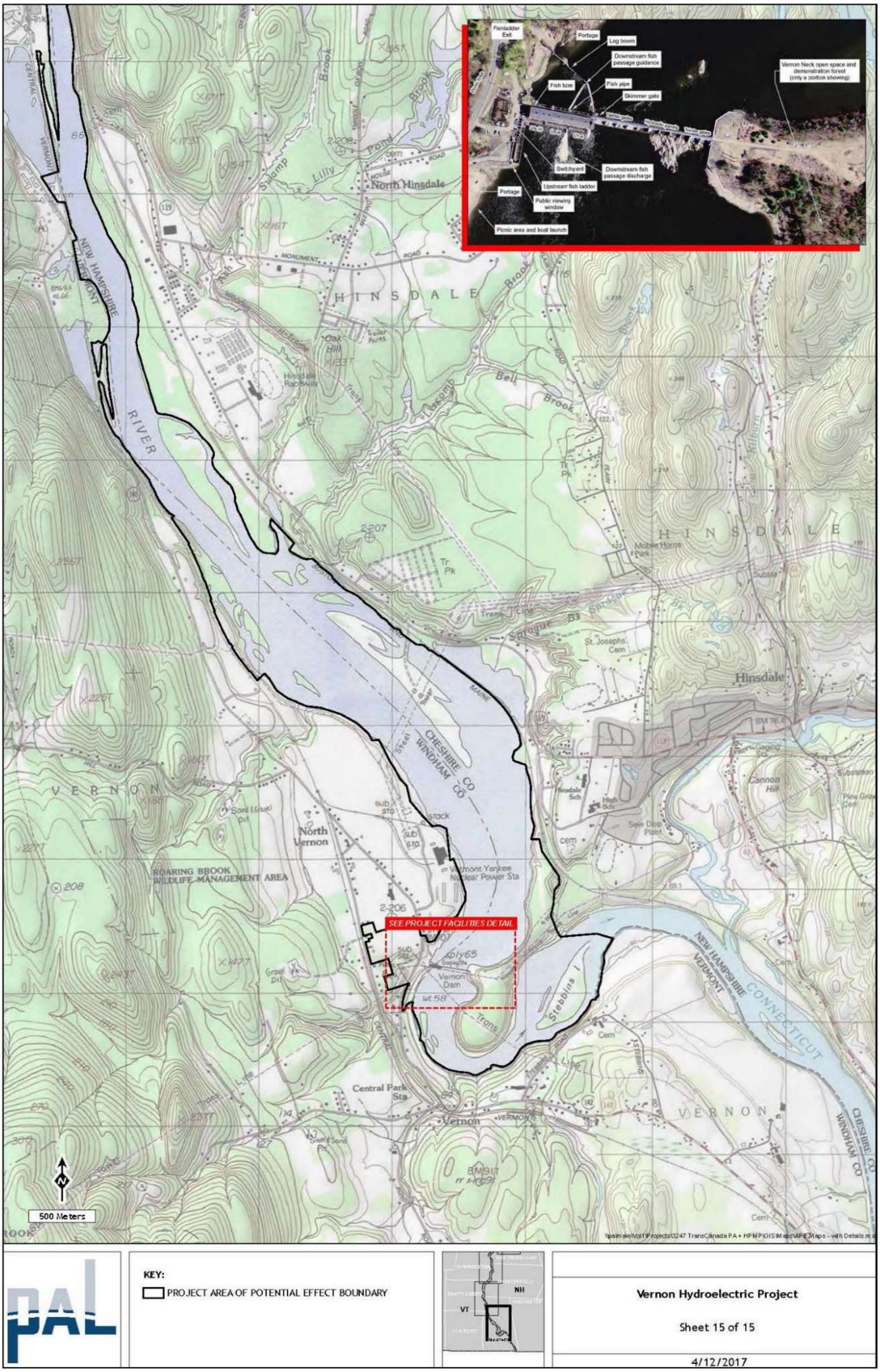

Source: ILP Study 33, *Cultural and Historic Resources Study*

Figure 3.11-3. Vernon Project Area of Potential Effects (continued).

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Pre-Contact Period Land Use and Settlement Patterns

PaleoIndian Period (9500–7000 Before Christ [B.C.])

The PaleoIndian Period in northern New England began about 9500 B.C. following the retreat north of the Wisconsin glaciation. It is hypothesized that PaleoIndian populations were highly mobile on the landscape and had an adaptive technology geared toward the intensive exploitation of a limited number of game species. This locational mobility would have increased the probability of resource encounters. Evidence to support this theory is derived from a scattered number of PaleoIndian sites, most of which reflect short-duration, ephemeral campsites. In the vicinity of the Wilder, Bellows Falls, and Vernon Projects, known sites containing evidence for PaleoIndian occupations are rare. These sites are typically recognized by the presence of fluted projectile points, exotic lithic materials, or assemblages including gravers, scrapers, and channel flakes. Northern New England PaleoIndian sites tend to be situated on sandy, well-drained landforms in broad Pleistocene valleys. Because of the continued incision of rivers and diminishing water levels, PaleoIndian sites can be somewhat remote from current waterways. These sites can also be deeply buried as a result of continued aeolian action in the sandy valleys.

Although no PaleoIndian sites have been discovered in the immediate vicinity of the Project APEs, several nearby finds document occupation of the region during the latter part of the period. One southern Vermont site yielded a Clovis-like fluted projectile point, and a site in the Missisquoi River Valley in northern Vermont contained a varied artifact assemblage including diagnostic Plano fluted points, knives, scrapers, gravers, hammer and anvil stones, and chipping debris.

The Archaic Period (7000–800 B.C.) in northern New England spans roughly 6,000 years and is marked by a gradual settling of the region by an influx of Native American groups. Archaeological evidence suggests that settlement and subsistence patterns during this period were somewhat dynamic and shifting and likely represent a response to the dynamic and shifting climatic conditions in the wake of the final retreat of the Laurentide ice sheet. The Early Archaic Period (7000–5500 B.C.) coincides with a substantial temperature increase referred to as the Hypsithermal period (6000–1500 B.C.). During this time, average temperatures were higher than they are now, and plant and animal communities reacted accordingly. Dry, warm summers and dry, cold winters encouraged the spread of pine-dominated forests but also precipitated the decline of the megafauna populations on which earlier human communities had depended. In their place, smaller prey, such as deer and bear, emerged, as well as a broader range of riverine, estuarine, and plant life that could not survive under the previously frigid conditions.

A small number of Early Archaic sites have been recorded in Vermont and New Hampshire. The John's Bridge Site (VT-FR-69) on the Missisquoi River dates to about 5900 B.C. The site contained five deep pits; a large assemblage of chert, quartzite, and quartz chipping debris; and a collection of tools, including Swanton Corner-Notched projectile points, skinning knives, perforators, scrapers, and abrading stones. In New Hampshire, recent studies indicate that the course of major waterways throughout the state changed dramatically from 10,000 to 7000 Before Present (B.P.) and did not stabilize into their current channels until ca. 7000 B.P. The sediment erosion and accumulation resulting from these hydraulic dynamics likely destroyed and/or deeply buried many cultural deposits, resulting in low archaeological visibility for sites dating to the Early Archaic Period. The identification of deeply buried Early Archaic sites on floodplains, including the Merrimack River and Lamprey River, provide evidence of this phenomenon.

The Middle Archaic Period (5500–4000 B.C.) corresponds with a shift from the dry conditions of the preceding period to a climate characterized by significant increases in precipitation, perhaps as much as 25–30 percent higher than current levels. Increased rainfall and snowmelt caused extensive flooding along major river systems, as observed through rapid sedimentation sequences and channel migration along portions of the Missisquoi River floodplain. Vegetation patterns also shifted in response to the increased rainfall as the pine-dominated landscape gave way to a deciduous forest of oak, beech, sugar maple, elm, ash, and beech, with smaller numbers of hemlock and white pine. With the emergence of this "mast" forest, deer populations expanded and likely became a major subsistence focus. Bear, wolf, otter, and wild turkey also emerged in greater numbers, while comparatively smaller populations of moose, elk, and caribou persisted in spruce-fir northern hardwood forests.

The Middle Archaic Period is defined by three stemmed projectile points that have their origin along the Atlantic coastal plain: Neville, Neville Variant, and Stark. The Neville type was identified at a site in Manchester, New Hampshire, that contained a substantial collection of these points, some with slightly bifurcate bases hinting at their Early Archaic lineage. Neville, Neville Variant, and Stark points are often found in association with steep-bitted scrapers, flake knives, perforators, adzes, axes, and choppers. In New Hampshire, there appears to have been an increasing reliance on the use of volcanic material in the production of tools quarried from such sources as Ossipee Mountain and the Boston Basin, although quartz remained the raw material of choice. Heavy woodworking tools also were common and suggest the manufacture of dugout canoes during this period, perhaps in response to the increased river travel concomitant with increased precipitation.

To date, only six Middle Archaic sites have been identified in Vermont on the basis of Stark or Neville points. These sites were identified along the shores of Lakes Bomoseen and Champlain near the outlet of Shelburne Pond. This limited database suggests that Middle Archaic sites were oriented toward ponds, lakes, and rivers with an attendant emphasis on seasonal rounds. Base camps and residential camps are provisionally hypothesized, although physical evidence of houses or shelters has yet to be identified in the Northeast and none have been identified within the Project APEs.

In New Hampshire, Middle Archaic components have been identified along large rivers and their tributaries, on secondary perennial streams, and on high terraces away from major rivers. The Robert Thorndike collection from Windham contained at least one Neville point as did the Harlan Marshall Collection from the shores of Lake Massabesic and along Cohas Brook. Archaeologically recorded Middle Archaic sites in New Hampshire include the Dickey Plains Site II in Manchester and NH 31-20-5 in Belmont. The Paul H. Holmes Site (NH46-10) is a small Middle to Terminal Archaic Period campsite in Plaistow, New Hampshire.

Environmental conditions during the Late Archaic Period (4000–900 B.C.) were marked by a climatic shift to drier and slightly warmer conditions with a significant decrease in precipitation. River and lake flooding became an uncommon event, as reflected in the lack of substantial alluvial deposits along the Missisquoi River and a dramatic drop in the Shelburne Pond water table. During this period, oak, pine, and beech reached their full extent, while hemlock became much scarcer in response to the increasing dryness. Wetlands also became more abundant along river margins. Animal communities remained essentially the same as the preceding period, but deer likely became even more plentiful with the full maturation of the mast forest. Wetland/estuarine resources became an even greater subsistence resource.

Perhaps in response to an increasingly resource-rich natural environment, Late Archaic populations underwent a substantial growth spurt relative to previous periods. This growth spurt, in turn, spurred an elaboration of settlement and subsistence models and a diversification in lithic technology unprecedented in the Pre-Contact Period record. As a means to better categorize and interpret the many local expressions of Late Archaic culture, the period has been divided into three traditions: the Laurentian, the Narrow Point, and the Susquehanna.

Several examples of Late Archaic Period sites within the Bellows Falls Hydroelectric Project area appear within Springfield, Vermont, clustered about Skitchewaug Mountain on the adjacent floodplain terrace. Site VT-WN-453, located on the north end of the terrace, produced two or three possible living surfaces and two projectile points. Site VT-WN-454, also located on the north end of the terrace, produced projectile points, chipping debris, hammerstones, and pottery dating to the Late/Terminal Archaic Periods.

The Hunter Archaeological Site at the confluence of the Connecticut and Sugar rivers in Claremont, New Hampshire, contains a Late Archaic component along with Middle and Late Woodland components within its seven identified occupational levels. The site was undisturbed and well-stratified and produced over 150 hearths, a human burial, pottery, and numerous lithic artifacts.

Woodland Period (900 B.C.–Anno Domini [A.D.] 1600)

The Woodland Period in New England is marked, in the earliest phases, by a remarkable degree of continuity with the previous Archaic Period traditions. By the end of the Woodland Period, a series of dramatic developments, including the development of horticulture and the earliest contacts with European populations, changed Native American culture in profound ways.

Climatic conditions during the Early Woodland Period (900–100 B.C.) remained essentially the same as those that marked the Late Archaic Period after 1000 B.C. Cooler, wetter conditions encouraged the decline of nut-bearing vegetation in favor of hemlock, pine, and birch and imposed limits on the biotic carrying capacity of the region relative to earlier periods. Human populations in Vermont responded to this change by continuing a broad-based hunting and gathering strategy, but one more explicitly oriented toward rivers, lakes, and ponds with limited seasonal use of upland settings. In short, general cultural settlement and subsistence patterns did not change dramatically from the Late Archaic to the Early Woodland. Group sizes are assumed to have been relatively small, perhaps 30–50 people, that in some cases splintered into even smaller residential camps of 5–15 individuals.

Diagnostic cultural material for the Early Woodland Period includes stemmed and side-notched Adena and Meadowood projectile points. Both point types are relatively rare and tend to occur in small numbers within Early Woodland assemblages. Lagoon points are also diagnostic of the period but are far more common in southern New England. Early Woodland lithic assemblages comprise a high percentage of "exotic" lithic materials, including Munsungen cherts from northern Maine and Onondaga cherts from New York State, and speak to an expansion and elaboration of long-distance trade networks. Low-fired Vinette I pottery, which seems to make its first appearance during the Late/Transitional Archaic periods, also becomes much more visible in the archaeological record of that time. Ceramic sherds recovered from the Eddy Site at Amoskeag Falls and the Beaver Meadow Brook at Sewall's Falls in Concord represent some of the earliest pottery in New Hampshire and appear to straddle the Late Archaic and Early Woodland periods. Artifacts and radiocarbon dates derived from the Stewartstown-Canaan Bridge Site (VT-ES-2) in Canaan, Vermont, represent a living site occupied during the Early and Middle Woodland periods. Pottery and lithic materials were recovered from the site, and the lithics were manufactured from cherts and rhyolites.

The occurrence of Early Woodland occupations is poorly represented in the archaeological record. Some have suggested that this low density of sites throughout New England indicates a population decline associated with any number of causal factors, including unfavorable environmental conditions and possible epidemic diseases. This assertion may be more a function of a lack of recognition of Early Woodland components from a cultural material perspective than of a real decline in numbers.

Beginning about 150 B.C., the climate appears to have stabilized, as the previously damp and cold environment gave way to generally drier and warmer conditions marking the beginning of the Middle Woodland Period (100 B.C.–A.D. 1050). If the number of identified sites is any guide, it appears that population densities increased during this period as well but were aggregated almost exclusively in the Champlain and Connecticut River valleys. This population expansion may have overtaxed the subsistence resources of the changing environment and led to a more diffuse hunting and gathering strategy that saw a return to a more intensive exploitation of the uplands.

Pottery also took on an increasingly diverse stylistic profile, including grit-tempered coil-built vessels with a stamped, incised, and dentate decoration of varying quality. The elaboration of pottery design may be related to the population expansion hypothesized for the period, when diverse groups may have felt a cultural imperative to distinguish themselves through decorative motifs.

The Middle Woodland Period in Vermont has been fairly well documented by several excavations in the Champlain Lowland. Perhaps for this reason, the period has taken on a degree of interpretive complexity that has resulted in the creation of four phases: the Winooski (100 B.C.–A.D. 300), Fox Creek (A.D. 300–500), Intervale (A.D. 500–800), and Colchester (A.D. 800–1050). Like the phases defined for the Late Archaic Period, these phases tend to overlap, if not coincide, and reflect regional variation on a basic adaptive suite. The Winooski Site, on the east bank of the Winooski River close to Lake Champlain, is the best known and most studied Middle Woodland Period site in western Vermont.

Technologically, Jack's Reef Corner-Notched projectile points function as the most diagnostic artifact for this period, although Levanna and Jack's Reef Pentagonal points are also common. Raw material types derive from both local and non-local sources. Pottery also became increasingly stylistically diverse and included grit-tempered, coil-built vessels with stamped, incised, dentate decoration of varying quality.

The Late Woodland Period (A.D. 1050–1600) represents a period of continuity and innovation, in which lithic technologies, an interpretive mainstay in archaeology, underwent very little change, while at the same time the development of horticulture dramatically altered the social and cultural landscape for Native American communities. During this period, archaeological and ethnohistorical writings begin to make reference to distinct Native American communities such as the Iroquois and the Abenaki. This distinction is not arbitrary but appears to indicate increasing levels of self-identification among these populations as reflected in distinctive ceramic styles and restricted trade networks relative to earlier periods.

The adoption of horticulture is undoubtedly the most significant cultural adaptation during the Late Woodland Period and had serious, identifiable repercussions for nearly every other aspect of Native American life. Settlement patterns became markedly more sedentary from A.D. 1100 to 1450 and residential groups became larger. Villages comprising small hamlets adjacent to cultivated fields began to emerge and appear to have been occupied during the growing season.

Large habitation sites concentrated along major river valley corridors appeared—a phenomenon that likely reflects the increased desirability of floodplain environments for horticultural purposes. The multicomponent Skitchewaug Site (VT-WN-41) in Springfield, Vermont, along the western bank of the Connecticut River, is one such site. It has yielded some of the most detailed and informative data, including carbonized maize, beans, and kernels dating as early as 1100, and the deeply buried remains of two semi-subterranean pit structures. These 4- to 6-meter wide oval structures are visible as a series of superimposed living surfaces separated by what are likely sterile flood deposits. Similar structures have been identified upriver in Windsor and Fairlee, Vermont. The Donohue Site (VT-CH-94) on the Winooski Intervale in Burlington contained the remains of a residential hamlet similar to that unearthed at Skitchewaug, although with less clear-cut evidence of habitation structures.

Despite the evidence for large habitation sites, small residential camps are the most common site type identified for the Late Woodland Period in Vermont. These small camps appear in every type of environmental niche and, while often containing restricted artifact assemblages, likely represent a broad range of functions. Small upland camps containing Levanna points have been interpreted as family hunting camps occupied for several months during the fall and winter to capitalize on hunting and trapping opportunities. Sites of this nature have been identified around Shelburne Pond and Sunderland Brook on the northwestern side of Vermont, along the Hoosic River floodplain in Pownal, along the Wallomsac River and Jewett Brook in the extreme southwestern corner of Vermont, and in upland locations along the West River in Jamaica (Salmon Hole Site) in the south-central portion of Vermont. All were dated by the presence of Levanna projectile points and are assumed to date to relatively early in the Late Woodland Period.

Contact, Exploration, and Conflict, and the Early Settlement Period (circa 1600–1730)

The *Wôbanakiak or Alnôbak (Abenaki)* was the dominant indigenous group in the Upper Connecticut River Valley at the time of European contact in the seventeenth century. *Kwanitekw* (Connecticut River) was a center of adaptation, subsistence, and exchange, operating as a major trade corridor, travel route, and gathering place for indigenous families. An extensive network of trails and waterways connected the Connecticut River Valley to native populations along the Atlantic Ocean and to the woodland interiors to the north and west. The "great falls" (Bellows Falls) on the river was a seasonal gathering place where indigenous people came together to harvest and smoke salmon and shad that made their way upstream from the ocean to spawn in the rapids. The fertile banks of the river provided good land for planting corn and squash (Brooks et al., 2009).

When the Europeans moved inland up the Connecticut River Valley, the Abenaki "attempted to incorporate them into their network of relations and trade," and agreements including deeds emerged to share the lands. However, as forts and settlements pushed farther upriver, the Abenaki and English tensions increased and Abenaki raiding parties traveled south to confront English settlements in what became a period of "recede, retreat, and return" for both the Abenaki and English. Gradually, the Abenaki sought permanent refuge in the upland hunting territories in the mountains, which were connected to the Connecticut River Valley by well-traveled trails and portages. Abenaki family groups survived in the "north country" throughout the eighteenth and nineteenth centuries and, today, have returned to their ancestral homelands in the fertile river valleys of the Upper Connecticut that had been supplanted by colonial towns during the Contact Period (Brown, 2009).

As noted above, Native Americans had long come to the "Great Falls" of present-day Bellows Falls on both sides of the Connecticut River to hunt and fish. Although not assigned a temporal or cultural affiliation, the Bellows Falls Petroglyph Site (VT-WD-8) on the west bank of the Connecticut River at the base of the Great Falls is similar to other petroglyphs that have been dated to the Woodland and Contact periods (Lenik, 2002; Mulholland et al., 1988). Two sets of petroglyphs (rock carvings) are located 35 and 55 feet south of the Vilas Bridge that crosses from Bellows Falls, Vermont, to Walpole, New Hampshire. The petroglyphs are carved into massive granite outcroppings. The petroglyphs depict life-size, oval or round, anthropomorphic "heads" with "eyes" and "mouths" and a number of them have "horn" or pronged projections. These projections are believed to represent superior power or attributes (i.e., shaman spirits). Any habitation or resource procurement site(s) associated with the petroglyphs would have been located on higher riverbanks and not in the down cut of the riverbed itself.

As the location of migrating salmon, the falls also marked the highest point of the river that migrating shad could swim, and they could be hunted in great numbers in the pools at the base of the falls. Though no permanent Native American settlement is known to have existed at Great Meadows or Westmoreland, it is known to have been a favorite campground for Natives traveling through the area and had some importance as a known site for pow-wows centered on a large rounded glacial erratic on the bank of the Ox Brook near where it flows into the Connecticut.

The only recorded Native American activity in the vicinity of Chesterfield, New Hampshire, is believed to have been centered on the Wantastiquet or West River Mountain. The summit affords an excellent view of the far bank, as well as the river itself, both north and south. During the successive frontier wars, Native Americans used the hill as a lookout from which they could see all river traffic, as well as keep an eye on the garrison in Fort Dummer on the western shore of the river. As a result of this activity, the summit of the mountain is referred to as "Indian's Great Chair." The rugged terrain of Chesterfield, and the fact that it was blocked from easy river access by the West River Mountain, meant that it was seldom used by the Native Americans as anything other than hunting grounds containing occasional small seasonal camps. Most known Native American activity was confined to the Connecticut River and its shores, including Catsbane Island, a point often used when Native Americans sought to ford the wide river.

Coopers Point in what is now Hinsdale, New Hampshire, had been the main home to the Squakheags for its strategic importance and because the bend in the river around it was known as an excellent fishing location ("squakheag" is thought to mean the spearing place, a reference to fishing for salmon). The Squakheags built an earthen fortification on the bluff to defend against attacking Mohawk war parties. Unfortunately, the fort proved worthless and the Squakheags suffered badly at the hands of the Mohawk. Consequently, by 1687, the Squakheags were obliged to migrate north into Canada to escape the Mohawk and signed their land over to the English settlers in Northfield, Massachusetts.

One of the most significant areas of Contact Period Native American activity in this section of the Connecticut River Valley (and possibly all of New Hampshire) is at the location of Fort Hill in Hinsdale and the surrounding countryside on both sides of the river. This fortified village of about 500 residents was built in the fall of 1663, attacked by a large Iroquois war party in December, and abandoned during the early months of 1664. It has been archaeologically sampled and a large inventory of artifacts was recovered, along with food remains from 97 features (mostly hearths and storage pits). The land base around the Squakheag village was largely intact, because the nearest colonial town was more than 40 miles away and English encroachment had not occurred at that time.

The area of "Great Meadows" in Vermont along the Connecticut River, later settled by the English as Putney, was well known to Native American populations for its good, alluvial clays, which fostered the growth of large stands of pine and butternut trees. Evidence of Contact Period Native American occupation in this region is scant, though it is known that there were seasonal encampments on the New Hampshire side of the river at Westmoreland. The area is thought to have belonged to the territory of the Squakheag, who may have used it as seasonal hunting grounds. Canoe Brook, a small rapid stream that flows down from the hills into the Connecticut River, is so called because a carved-out Native canoe was recovered from it, indicating the stream's use as part of a Native waterway transportation network.

The area that now encompasses Brattleboro, Vermont, contains evidence of Native American occupation in the form of engraved rocks bearing petroglyphs found in the vicinity of the West River where it joins with the Connecticut. It is believed that "the Cove" was a favorite hunting ground for Native Americans and probably the site of seasonal hunting camps. In 1850, a farmer plowing his fields uncovered a Native American burial that contained several artifacts, including a pipe, lithic points, and a pestle.

The Vernon, Vermont, vicinity near a significant bend in the Connecticut River, was the site of several substantial Native American settlements in the years before the arrival of Europeans. All of these sites are reported to contain Late Woodland/ Contact Period and early Post-Contact Period components.

Today, Abenaki indigenous populations have reemerged to claim their traditional cultural homelands in the Upper Connecticut River Valley in New Hampshire and Vermont. Some are recognized by the state of Vermont as representing the Abenaki Nation within the State: the Elnu Tribe of the Abenaki, the Nulhegan Band of the Coosuk-Abenaki Nation, the Koasek Traditional Band of the Koas Abenaki Nation, and the Sovereign Abenaki Nation of Missisquoi. There are no state-recognized Indian Tribes in New Hampshire; however, there are New Hampshire-based Tribal interests in the Upper Connecticut River Valley including the Abenaki Nation of New

Hampshire, the Cowasuck Band – Pennacook/ Abenaki People, and the Koasek Traditional Band of the Sovereign Abenaki Nation. Collectively, Abenaki Tribal members have indicated an interest in archaeological and ethnologic research implemented and maintained through Historic Resource Management Plans (HPMPs).

Post-Contact Period Land Use and Settlement Patterns (A.D. 1730–Present)

Until 1738, New Hampshire was part of the Massachusetts Bay Colony. European settlement north along the Connecticut River was sparse, and the area along the Connecticut River to Canada, east to the Merrimack River settlements and west to the Hudson River in New York, was a vast stretch of unbroken wilderness. By action of the General Court of Massachusetts in January 1735, surveyors were sent to establish townships from the Merrimack west to the Great Falls (now Walpole, New Hampshire) of the Connecticut and south to earlier grants. These fortified townships were intended to provide tiers of defense along the Connecticut River to protect the Bay Colony's western territory. Each of the towns was laid out to be 6 miles square from "Great Falls" on the east side of the river to Arlington (now Winchester, New Hampshire) and not to extend more than 6 miles from the river. The four original fortified townships on the east side of the river were established as No. 1 Chesterfield, No. 2 Westmoreland, No. 3 Walpole, and No. 4 Charlestown. Fortified towns were also authorized on the west side of the river in what became Vermont: No. 1 Westminster, No. 2 Putney, No. 3 Dummerston, and No. 4 Brattleboro.

Vermont received its first European settlement in the 1740s when New Hampshire Governor Benning Wentworth began issuing grants (later referred to as the New Hampshire Grants) to spur development west of the Connecticut River. Vermont's first town, Bennington, was chartered by Wentworth in 1749. The colony of New York also claimed Vermont and issued some grants for the same lands, sparking ownership disputes. The settlers of Vermont ultimately decided to make a break from both New York and New Hampshire by forming their own government. On July 8, 1777, a group of delegates met in Windsor and ratified Vermont's own version of the Declaration of Independence. At that time, the state was divided into two counties: Bennington to the west and Cumberland to the east. The next several decades saw the two parent counties split and re-amalgamate into a mosaic of smaller counties. In 1781, Cumberland County was subdivided to create the smaller counties of Windham, Windsor, and Orange. Chittenden County was incorporated in 1787. Vermont was admitted into the Union as the fourteenth state in March 1791.

With the exception of the fortified townships, most of the other towns and cities through which the Project APEs extend were established in the 1760s through the granting of land to groups of settlers who came from other colonies in search of fertile agricultural lands along the Connecticut River. These towns include Hartford and Norwich, Vermont, and Lyme, New Hampshire, which were all chartered in 1761 through grants from the New Hampshire colonial government. As their names reflect, the petitioners who received the grants were groups from Connecticut. Throughout the Colonial Period (1675–1775) and into the early nineteenth century, the settlements were relatively small and town populations seldom exceeded more than a few hundred persons. The settlements generally grew up along the Connecticut River and its tributaries, where the most productive farmland was to be found. Most were self-sufficient and had their own gristmills and sawmills to process grains and lumber for local consumption. The founding of Dartmouth College in Hanover, New Hampshire, in 1771 by Reverend Eleazar Wheelock was a major event the region's history and had a major impact on the settlement and development of Hanover and surrounding towns.

The pace of settlement quickened during the first half of the nineteenth century, when agricultural production was at its height and a diverse range of industrial operations was established throughout the Connecticut River Valley. The main agricultural products were grain crops and cattle. The raising of Merino sheep for wool became a significant industry when high tariffs were placed on British imports and became especially important in towns such as Fairlee and Weathersfield, Vermont, where poor soils could not support high-yield plant crops.

The progression of industrial operations at the numerous mill privileges along the Connecticut River and its tributaries began with tanneries, gristmills, and sawmills that were put in place to process local agricultural and lumber products. During the early nineteenth century, textile spinning and carding operations began to appear. By the mid-nineteenth century, industrial production in the region was characterized by a profusion of specialized factories that often utilized previously developed mill privileges. The vast lumber reserves of the Connecticut River Valley contributed to the establishment of numerous wood processing industries. Paper production became important after the region's first paper mill was established in the village of Bellows Falls in Rockingham, Vermont. Other towns that developed significant paper industries in the nineteenth century were Newbury, Thetford, Hartford, Putney and Brattleboro, Vermont, and Haverhill and Hinsdale, New Hampshire. Furniture was another prominent wood-product industry, especially in Newbury and Windsor, Vermont, and Lebanon, New Hampshire. Other major industries in the valley included metal-working and textiles.

The establishment of rail service to the Connecticut River Valley in New Hampshire and Vermont during the late 1840s spurred new settlement and development in the area's industrial and agricultural sectors. The Cheshire Railroad, which connected the area to the port of Boston via the Fitchburg Railroad, was completed through Westmoreland and Walpole, New Hampshire by 1847. White River Junction became the area's most important transportation crossroads when five different railroads (the Vermont Central Railway and Connecticut River Railroad in 1847, the Connecticut and Passumpsic Rivers Railroad in 1848, the Northern New Hampshire Railroad in 1849, and the Woodstock Railroad in 1863) were laid through the village. The arrival of the railroads contributed to making tourism an important industry in many Connecticut River communities. Later in the century, sculptor Augustus Saint-Gauden and 100 artists, sculptors, writers, designers, and politicians turned Cornish, New Hampshire, into one of the nation's most famous art colonies.

The populations of most area towns increased substantially from 1830 to 1870 as newcomers came to farm or take jobs in the new factories in the valley. Immigrants from Europe and Canada made up a large percentage of the new population. During the last quarter of the nineteenth century, however, most of the towns in the region suffered drastic population declines as residents moved west in search of better agricultural lands or to find work in urban industrial centers. That trend was not reversed until the second half of the twentieth century when the area attracted new commercial and residential development. The construction of interstate Highways 89 and 91 were major contributors to that reversal. Nearly all the communities have increased their population because of new commercial or industrial developments or as residential bedroom communities to the larger urban centers such as Hanover and Lebanon, New Hampshire, and Springfield, Vermont, and construction sparked new development.

3.11.1.2 Pre-Contact and Post-Contact Archaeological Properties

Archaeological Investigations that have been conducted for the relicensing of the Wilder, Bellows Falls, and Vernon Projects consist of Phase IA archaeological reconnaissance surveys to identify known archaeological sites and areas of archaeological sensitivity where documented and previously unrecorded sites are likely to exist; Phase IB archaeological identification surveys to locate and identify known and undocumented archaeological resources in archaeologically sensitive areas where active erosion was identified during the Phase IA surveys, including the 2013 monitoring program for the Vernon Project; and Phase II site evaluations to evaluate the National Register eligibility of identified archaeological sites in active erosion areas. The archaeological investigations were not designed to ascertain the cause, extent, or mechanics of the observed erosion at the Wilder, Bellows Falls, and Vernon Projects (see Section 3.4, *Geologic and Soil Resources*, for details about erosion within the Project areas).

The results of the archaeological investigations are presented in the following technical reports that comprise the bulk of ILP Study 33, *Cultural and Historic Resources Study*:

- Phase IA Archaeological Reconnaissance Survey, Vernon Hydroelectric Project (FERC No. 1904), Windham County, Vermont and Cheshire County, New Hampshire (Cherau and O’Donnchadha, 2008);
- Phase IA Archaeological Reconnaissance Survey, Wilder Hydroelectric Project, Windsor and Orange Counties, Vermont, and Grafton County, New Hampshire (Hubbard et al., 2013a);
- Phase IA Archaeological Reconnaissance Survey, Bellows Falls Hydroelectric Project, Windham and Windsor Counties, Vermont, and Cheshire and Sullivan Counties, New Hampshire (Hubbard et al., 2013b);
- Phase IA Archaeological Reconnaissance Survey Update, Vernon Hydroelectric Project, Windham County, Vermont, and Cheshire County, New Hampshire (Cherau and Duffin, 2014);

- Phase IB Archaeological Identification Survey, Wilder Hydroelectric Project), Bellows Falls Hydroelectric Project, and Vernon Hydroelectric Project, New Hampshire (Elquist and Cherau, 2015);
- Phase IB Archaeological Identification Survey, Wilder Hydroelectric Project, Bellows Falls Hydroelectric Project, and Vernon Hydroelectric Project, Vermont (Elquist and Cherau, 2016a);
- Archaeological Phase II Determination of Eligibility, Lampshire Meadow Site (27-GR-232), Wilder Hydroelectric Project, Lyme, Grafton County, New Hampshire (Elquist and Cherau, 2016b); and
- Phase II Archaeological Site Evaluations, Wilder Hydroelectric Project and Vernon Hydroelectric Project, Orange and Windham Counties, Vermont (Elquist and Cherau, 2016c).

The archaeological report submittal dates and agency responses received to date are presented in Table 3.11-1.

Phase IA, Phase IB, and Phase II Survey Methodologies

The Phase IA surveys consisted of archival research, pedestrian surveys (where access was permitted) and boat-over visual inspections to identify documented resource locations,[52] recorded archaeological sites,[53] and areas sensitive for undocumented sites along the impoundment shorelines upstream and downstream of the Project dams. A Phase 1A survey of the Vernon Project was completed in 2008 during the course of Project repowering and amendment of the Project's license. The Phase 1A surveys for the Wilder and Bellows Falls Projects and an update of the 2008 Phase 1A survey for the Vernon Project were completed in 2013 and 2014. All observable impacts to identified archaeological sites and within sensitive areas were also noted during the Phase IA surveys whenever possible.

The scope of the Phase 1B surveys for the current relicensing effort was determined through consultation among FERC, the SHPOs, and TransCanada (now Great River Hydro). As specified in Study Plan 33, the parties agreed that Phase IB surveys

[52] "Documented resources" are defined here as post-contact period resources that appear on historic town and county maps or are known through local history. These types of resources have not been verified on-the-ground or archaeologically, and no New Hampshire or Vermont state historic or archaeological site inventory number has been assigned. Resource numbers (e.g., HA-1) were assigned during the Phase IA archaeological surveys and are used for tracking purposes only until physical remains are identified archaeologically and state inventory numbers are assigned.

[53] "Recorded sites" are defined here as archaeological resources that have been assigned New Hampshire and Vermont state inventory numbers through avocational and professional archaeological surveys and reporting efforts. Not all recorded sites have been confirmed on-the-ground, or "identified archaeologically," but for the purposes of this report, all sites that have assigned state inventory numbers, even those that were not "identified archaeologically" during the Phase IA, IB, and II surveys, are included in this category.

would be conducted in archaeologically sensitive areas on land owned in fee simple and on privately owned lands in flowage areas where active erosion had been observed during the Phase IA surveys. The Phase IB surveys consisted of hand excavations in the form of 1.6-x-1.6-ft (50-x-50-cm) test pits to locate and identify belowground pre- and post-contact cultural deposits. The amount of Phase 1B survey conducted on privately owned land was limited to areas where landowner permission was granted to conduct the investigations.

Phase II investigations were conducted in active erosion areas where the Phase IB surveys identified and recommended previously recorded and newly identified pre-contact archaeological sites as being potentially eligible for listing in the National Register. The investigations consisted of hand excavations in the form of additional test pits and larger test units measuring 3.3-x-3.3 ft (1-x-1 meter) in an attempt to determine the age, size, integrity, and internal composition and complexity of the archaeological deposits. Radiocarbon dating of wood charcoal and seed remains recovered in cultural feature contexts (i.e., fire pits, hearths, and storage pits) was completed as part of the Phase II investigations to assist in dating the site occupations.

The findings of the Phase IA, Phase IB, and Phase II archaeological investigations are summarized below. This summary includes tables of all the documented resources (potential post-contact archaeological sites) and recorded archaeological sites within the three APEs and their survey and National Register-eligibility status.

Table 3.11-1. Historic and archaeology report submittals and agency responses, Wilder, Bellows Falls, and Vernon Projects.

Report	Submittal Date	Recipient(s)	Reviewer Response
Phase IA Reconnaissance Survey for Vernon Project, NH and VT	April 10, 2008	NHSHPO, VTSHPO	NHSHPO concurrence, letter dated May 22, 2008. No VTSHPO response.
	June 19, 2013	NITHPO	No comment.
	July 1, 2013	FERC	No comment.
Phase IA Reconnaissance Survey for Wilder and Bellows Falls Projects, NH and VT	May 29, 2013	NHSHPO, VTSHPO, NITHPO	NHSHPO concurrence on Phase IA survey results and request for phased archaeological surveys in erosion areas, letter dated June 25, 2013. VTSHPO concurrence on Phase IA survey results and APE determination and request for Phase IB and Phase II surveys in erosion areas, letter dated July 15, 2013.
	July 1, 2013	FERC	No comment.
Phase IA Reconnaissance Survey Update, Vernon Project, NH and VT	December 23, 2014	FERC, NHSHPO, VTSHPO, NITHPO, and The Nolumbeka Project	NHSHPO concurrence on Phase IA survey update results, email dated February 26, 2015. No FERC, VTSHPO, NITHPO, or The Nolumbeka Project response.

Report	Submittal Date	Recipient(s)	Reviewer Response
Historic Architectural Resources Survey: Wilder Hydroelectric Project, Hartford, Vermont, and Lebanon, New Hampshire; Vernon Hydroelectric Project, Vernon, Vermont, and Hinsdale, New Hampshire; Bellows Falls Hydroelectric Project, Bellows Falls, Rockingham, Vermont, and Walpole, NH	May 28, 2015	FERC, NHSHPO, and VTSHPO	NHSHPO requested that the information be broken out into its Project Area Form format, letter dated June 29, 2015. VTSHPO did not comment.
New Hampshire Division of Historical Resources Project Area Forms for the Wilder Hydroelectric Project, Bellows Falls Hydroelectric Project, and Vernon Hydroelectric Project	June 30, 2015	NHSHPO	NHSHPO concurred that the Wilder dam is eligible for the National Register and recommended that the relicensing of the Projects will have no adverse effect on historic architectural properties, letter dated August 27, 2015.
Phase IB Archaeological Identification Survey, Wilder, Bellows Falls, and Vernon Projects, NH, portions	October 29, 2015	NHSHPO	NHSHPO concurrence on Phase IB survey results and proposal for Phase II site determination of eligibility, letter dated December 16, 2015.
	March 23, 2016	FERC, NITHPO, and The Nolumbeka Project	No response.

Report	Submittal Date	Recipient(s)	Reviewer Response
Phase IB Archaeological Identification Survey, Wilder, Bellows Falls, and Vernon Projects, VT, portions	March 14, 2016	VTSHPO	VTSHPO approval of Phase II evaluations of the recommended potentially eligible pre-contact sites, with the caveat that the "concurrence does not represent concurrence by the VTSHPO that this level of Phase II effort constitutes the full scope of Phase II study necessary within the three Projects subject to re-licensing at this time. We fully expect that a much broader Phase II effort will be required to satisfy the Section 106 requirements for these projects," email dated April 20, 2016.
	March 23, 2016	FERC, NITHPO, and The Nolumbeka Project	No response.
Archaeological Phase II Determination of Eligibility, Lampshire Meadow Site (27-GR-232), Wilder Project, NH	August 3, 2016	FERC, NHSHPO, NITHPO, and The Nolumbeka Project	NHSHPO concurrence on Phase II National Register eligibility recommendations and development of protective measures and establishment of a site monitoring program, letter dated August 18, 2016.
Phase II Archaeological Site Evaluations, Wilder and Vernon Projects, VT	December 1, 2016	FERC, VTSHPO	Verbal concurrence on National Register-eligibility site recommendations from VTSHPO on March 30, 2017 (letter pending).
	December 5, 2016	Elnu Tribe of the Abenaki, Nulhegan Band of the Coosuk-Abenaki Nation, Koasek Traditional Band of the Koas Abenaki Nation[a]	No comments on the archaeology reports.

Report	Submittal Date	Recipient(s)	Reviewer Response
	December 8 2016	NITHPO, The Nolumbeka Project, and Donna and John Moody[b]	No comments on the archaeology reports (TCP study report comment letter and mitigation proposal, NITHPO, dated January 15, 2017). No comments on the archaeology reports (TCP study report comments in email, John Moody, January 13, 2017).
	March 30, 2017	Cowasuck Band of the Pennacook- Abenaki People[a]	No comments on the archaeology reports to date.

a. Electronic copies of all Phase IA and Phase IB archaeology reports, and the NH Phase II archaeology report previously sent on September 19, 2016.

b. Received hard copies of all Phase IA, Phase IB, and Phase II archaeology reports, mailed on December 8, 2016.

Wilder Project

Archival research including an analysis of historic maps and town histories undertaken for the 2013 Phase IA survey of the Wilder Project documented 56 resource locations within or immediately adjacent to the Project APE that could contain post-contact archaeological sites (27 in Vermont and 29 in New Hampshire; Table 3.11-2 and Table 3.11-3). Of these 56 documented resource locations, 5 were identified archaeologically in the field during the Phase IA survey and assigned state inventory archaeological site numbers. The other 51 documented resources have not been identified archaeologically and their National Register eligibility is currently undetermined. These documented resource locations were not accessible, are outside of the surveyed areas, contain standing structures, or did not have any visible archaeological remains.

As a result of the Phase IA field survey and research, 48 archaeological sites were identified within the Project APE, 27 of which had been recorded by others prior to the Phase IA survey of the Wilder Project. The other 21 sites (including the 5 documented resource locations noted above) were identified archaeologically in the field during the Phase IA survey and assigned state inventory numbers. The 48 recorded sites consist of 31 sites in Vermont (28 on flowage lands including river shoreline and 3 on fee-owned lands), and 17 sites in New Hampshire (16 on flowage lands and 1 on fee-owned lands) (Table 3.11-4). Prior to the Phase IA survey, 2 of the recorded sites had been determined potentially eligible for listing in the National Register (VT-OR-34 and VT-OR-35) and 1 had been determined ineligible for the National Register (VT-OR-67). The National Register eligibility of the other 45 recorded sites within the Wilder Project APE had not been determined at the time of the Phase IA survey.

The Phase IA survey also identified approximately 86 miles of the Wilder Project shoreline (on both sides of the river) as archaeologically sensitive, including the locations of documented resources and recorded sites, of which approximately 7 miles (35 areas) were identified as being in active erosion areas. On the Vermont side of the river, 18 sensitive areas of active erosion were identified, and on the New Hampshire side of the river, 17 sensitive areas of active erosion were identified. However, subsequent Phase IB field surveys of eroding shoreline were only conducted on lands owned in fee or on private flowage lands where landowner permissions for access were obtained. This resulted in Phase IB surveys being conducted in only 8 of the 18 archaeologically sensitive active erosion areas on the Vermont side of the river, and in 6 of the 17 archaeologically sensitive active erosion areas on the New Hampshire side of the river, totaling approximately 2 miles of shoreline. Phase IB investigations of the remaining 21 archaeologically sensitive erosion areas were not conducted because property owners either did not respond to inquiries or denied access for study purposes. As a result, approximately 84 miles of archaeologically sensitive shoreline within the Wilder Project APE was not surveyed; 5 miles of this shoreline also contained active erosion.

On the Vermont side of the river, the 18 archaeologically sensitive erosion areas targeted for Phase IB surveys in the Wilder Project APE contained 8 recorded sites

(VT-OR-21, VT-OR-34, VT-OR-35, VT-OR-62, VT-OR-72, VT-OR-97, VT-OR-101, and VT-WN-479). Landowner permission to conduct Phase IB surveys was only granted on private lands that contain four of the recorded sites (VT-OR-34, VT-OR-35, VT-OR-62, and VT-OR-72).

During the Phase IB survey, the pre-contact Farrell Site (VT-OR-34) in Fairlee yielded evidence of multiple living features including possible house floors and storage pits, aboriginal pottery, lithic debitage (byproducts of chipped stone tool making), and chipped stone tools, indicating the presence of a potentially significant and National Register-eligible Woodland Period habitation site. The pre-contact Kenneth Carson Site (VT-OR-35) in Bradford did not yield any significant cultural deposits in the Project APE and was recommended as not eligible for listing in the National Register. The pre-contact Site VT-OR-62 in Bradford yielded lithic debitage and a cooking pit feature of unknown temporal affiliation and was recommended potentially eligible for listing in the National Register. Phase II site evaluation of this site was recommended to determine National Register eligibility. The post-contact D. Ross Residence (VT-OR-72) in Fairlee was determined to have poor physical integrity and was not recommended eligible for listing in the National Register.

The Phase IB surveys also identified three new sites: VT-OR-108, VT-OR-109, and VT-OR-110. The pre-contact Lower Plain Site (VT-OR-108) in Bradford yielded aboriginal pottery sherds, lithic debitage, calcined animal bone, and chipped stone tools, indicating the presence of a potentially National Register-eligible Woodland Period camp site. Phase II site evaluation of this site was recommended to determine National Register eligibility. The pre-contact Parcel 454/390 Site (VT-OR-109) in Bradford did not yield any significant cultural deposits in the Project APE and was recommended as not eligible for listing in the National Register. The pre-contact Roaring Brook Site (VT-OR-110) in Thetford yielded lithic debitage, indicating the presence of a short-term hunting camp of unknown temporal affiliation, and was recommended as potentially eligible for listing in the National Register. Phase II site evaluation of this site was recommended to determine National Register eligibility.

The VTSHPO did not provide formal concurrence on the National Register-eligibility recommendations for the sites investigated during the Phase IB surveys. However, on April 20, 2016, the VTSHPO concurred with the recommended Phase II evaluations and approved the proposed Phase II evaluation methodology at the four pre-contact sites recommended as potentially National Register eligible in active erosion areas in Bradford, Fairlee, and Thetford, Vermont (VT-OR-34, VT-OR-62, VT-OR-108, and VT-OR-110). The Phase II site evaluations resulted in the recovery of additional cultural materials (lithic debitage, diagnostic chipped stone tools, organics, and aboriginal pottery) and radiocarbon-dated features that indicate occupations in the Late Archaic through Late Woodland Periods. The Phase II evaluations have resulted in the recommendation that all four of these Vermont pre-contact sites in the Wilder Project APE are eligible for listing in the National Register since they possess good physical integrity and have the potential to address research questions related to Late Archaic and Woodland Period settlement and subsistence patterns in the Connecticut River Valley. The Phase II evaluation report was submitted to the VTSHPO for review on December 1, 2016; no written comments have yet been received.

On the New Hampshire side of the river, the 17 archaeologically sensitive erosion areas targeted for Phase IB surveys in the Wilder Project APE contain 7 previously-recorded sites (27-GR-112, 27 GR-208, 27-GR-224, 27-GR-228, 27-GR-229, 27-GR-232, and 27-GR-234) identified during the Phase IA surveys. Landowner permission to conduct Phase IB surveys was only granted on private lands that contain two of the 7 previously recorded pre-contact sites (27-GR-228 and 27-GR-232).

The Clay Bank Site (27-GR-228) in Piermont was first recorded during the Phase IA survey as a possible pre-contact camp site based on the presence of fire-reddened soils eroding out of the riverbank. The Phase IB investigations determined that the fire-reddened soils were the result of natural processes and the Clay Bank Site does not contain potentially significant cultural deposits and was not recommended for listing in the National Register. The Phase IB surveys also identified one new site designated Parcel 208/390 Site (27-GR-268) in Piermont, which yielded pre-contact lithic materials in a redeposited alluvium subsurface context in the Project APE. The lithic deposits in the tested area were not recommended as being National Register eligible, but the potential exists for more intact pre-contact deposits to be present north and outside of the active erosion area in the Project APE. On December 16, 2015, the NHSHPO concurred that site 27-GR-228 is not eligible for listing on the National Register and that the tested portion of site 27-GR-268 within the eroding area does not contribute to the potential of the site to be eligible for listing (see Table 3.11-1).

The pre-contact Lampshire Meadow Site (27-GR-232) in Lyme was also first recorded during the Phase IA survey on the basis of lithic cultural materials eroding out of the riverbank. The Phase IB testing recovered lithic debitage and chipped stone tools, and the site was recommended potentially eligible for listing in the National Register. Phase II site evaluation was recommended to determine National Register eligibility. The Phase II site evaluation of the site yielded additional cultural materials (lithic debitage and chipped stone tools) and features from four distinct activity loci, one of which (Locus 1) produced an early Middle Archaic Period radiocarbon date. The Locus 1 cultural deposits were determined to possess good physical integrity and high research potential, and were recommended significant and eligible for listing in the National Register. The other three activity Loci (2, 3, and 4) were not recommended as being eligible for listing in the National Register. On August 18, 2016, the NHSHPO concurred that the pre-contact Lampshire Meadow Site (27-GR-232) as a whole is eligible for listing in the National Register (see Table 3.11-1).

Table 3.11-2. Documented post-contact resources within or directly adjacent to the Wilder Project APE (Vermont).

Survey ID Number	Description	Identification on Historic Maps					Other References and Comments	National Register Eligibility
		Doolittle (1796)	Beers (1869; 1877)	USGS (1931)	USGS (1933)	Other USGS		
NE-1	Toll house		(1877) appears as *Toll Ho.*			(1935a, 1941)	Identified as standing structure during Phase IA survey; no identified project impact	Undetermined
BR-1	Dwelling or mill?		(1877) may appear as *mill*			(1935a, 1941)		Undetermined
BR-2	Dwelling		(1877) appears as *E. Smalley*		(1933)			Undetermined
FA-1	Ferry launch	X	(1877)					Undetermined
TH-1	Ferry launch	X	(1877)					Undetermined
TH-2	Bridge		(1877)	Appears in use	Appears in use		Located in Phase IA survey (VT-OR-100)	See Table 3.11-4
TH-3	Ferry launch	X	(1877)					Undetermined
TH-4	Ferry launch	X	(1877)					Undetermined
TH-5	Toll house		(1877) appears as *Toll H.*					Undetermined

Survey ID Number	**Description**	**Identification on Historic Maps**					**Other References and Comments**	**National Register Eligibility**
		Doolittle (1796)	**Beers (1869; 1877)**	**USGS (1931)**	**USGS (1933)**	**Other USGS**		
TH-6	Dwelling		(1877) appears as *C.D. Dimick*					Undetermined
TH-7	Bridge		(1877) roads end at bank indicating possible bridge location					Undetermined
NO-1	Ferry launch	X	(1869)					Undetermined
NO-2	Ferry launch	X	(1869)			(1906, 1908)		Undetermined
NO-3	Dwelling		(1869) appears as *D. Huckett*			(1906, 1908)		Undetermined
NO-4	Ferry launch	X	(1869)			(1906, 1908)		Undetermined
NO-5	Bridge	X	(1869)			(1906, 1908)		Undetermined
NO-6	Bridge		(1869) appears in use			(1906, 1908) appears in use	Located in Phase IA Survey (VT-WN-477)	See Table 3.11-4
NO-7	Saw mill		(1869) appears as *S. Mill*			(1906, 1908)	Located in Phase IA Survey (VT-WN-478)	See Table 3.11-4

Survey ID Number	Description	Identification on Historic Maps					Other References and Comments	National Register Eligibility
		Doolittle (1796)	Beers (1869; 1877)	USGS (1931)	USGS (1933)	Other USGS		
NO-8	Dwelling		(1869) appears as *M. Bartlett*			(1906, 1908)		Undetermined
NO-9	Grist mill		(1869) appears *S G. Mill*			(1906, 1908)		Undetermined
NO-10	Native American burial ground		(1869)				Goddard and Partridge (1905); J. Moody (pers. comm.)	Undetermined
NO-11	Dwelling		(1869)			(1906, 1908)	First settlement (1765); based on historical marker	Undetermined
NO-12	Bridge		(1869) appears with road			(1906, 1908) replaced with steel truss bridge		Undetermined
NO-13	Ferry launch		(1869)				Goddard and Partridge (1905)	Undetermined

Survey ID Number	**Description**	**Identification on Historic Maps**					**Other References and Comments**	**National Register Eligibility**
		Doolittle (1796)	**Beers (1869; 1877)**	**USGS (1931)**	**USGS (1933)**	**Other USGS**		
HA-1	Saw mill		(1869)			(1906, 1908)	Whitelaw (1769) appears as Phelps Saw Mill Adjacent to fee-owned lands in FERC Project recreation area; site submerged or destroyed based on 2013 Phase IA survey	Undetermined
HA-2	Bridge		(1869)			(1906, 1908)	Adjacent to fee-owned lands in FERC Project recreation area; no bridge remains or abutments identified during 2013 Phase IA survey	Undetermined

Survey ID Number	**Description**	**Identification on Historic Maps**					**Other References and Comments**	**National Register Eligibility**
		Doolittle (1796)	**Beers (1869; 1877)**	**USGS (1931)**	**USGS (1933)**	**Other USGS**		
HA-3	Paper mill		(1869) appears *French as Chandler Paper Mill*			(1906, 1908)	Located in Phase IA survey (VT-WN-480); fee-owned lands in FERC Project recreation area	See Table 3.11-4

Table 3.11-3. Documented post-contact resources within or directly adjacent to the Wilder Project APE (New Hampshire).

Survey ID Number	Description	Identification on Historic Maps						Other References and Comments	National Register Eligibility
		Walling (1860)	USGS (1931)	USGS (1933)	Other USGS	Hurd (1892)	Holland (1784)		
HA-1	Dwelling				(1935a, 1941, 1984)				Undetermined
HA-2	Dwelling				(1935a, 1941)			Cellar hole identified outside project area during Phase IA survey	Undetermined
HA-3	Toll house	Appears as *Toll House*			(1935a, 1941)	Appears as *Toll House*		Identified as standing architecture during Phase IA survey	Undetermined
OR-1	Dwelling	Appears as *First Settlement*							Undetermined

Survey ID Number	Description	Identification on Historic Maps						Other References and Comments	National Register Eligibility
		Walling (1860)	USGS (1931)	USGS (1933)	Other USGS	Hurd (1892)	Holland (1784)		
OR-2	Native American burial ground	Appears as *Indian Burial Ground*						Identified possible pre-contact cultural features in this area during Phase IA survey (27-GR-234)	See Table 3.11-4
LY-1	Bridge	Appears in use as *Lime Bridge*	Appears in use	Appears in use		Appears in use as *Lime*		Located in Phase IA survey (27-GR-230)	See Table 3.11-4
LY-2	Toll house	Appears as *Toll House*							Undetermined
LY-3	Dwellings (3)	One appears as *J. Butler,* other two unnamed							Undetermined
LY-4	Toll house and ferry launch	Appears as *Toll House*	Appears (toll house only)	Appears (toll house only)		Appears as *Toll House*		Beers (1877) appears as Toll Ho.; ferry in Doolittle (1796)	Undetermined
LY-5	Dwelling		X	X					Undetermined

Survey ID Number	Description	Identification on Historic Maps						Other References and Comments	National Register Eligibility
		Walling (1860)	USGS (1931)	USGS (1933)	Other USGS	Hurd (1892)	Holland (1784)		
LY-6	Bridge	X				Appears as *Thetford Bridge*		Beers (1877)	Undetermined
LY-7	Ferry launch							Doolittle (1796)	Undetermined
LY-8	Ferry launch							Doolittle (1796)	Undetermined
HN-1	Dwelling	Appears as *Dr. Smalley*							Undetermined
HN-2	Dwelling	Appears as *I. & H.B. Lord*							Undetermined
HN-3	Dwelling	Appears as *J. Hemenway*			(USGS 1906, 1908)				Undetermined
HN-4	Dwelling	Appears as *E.S. Coswell*			(USGS 1906, 1908)				Undetermined
HN-5	Bridge				(USGS 1906, 1908)			Doolittle (1796)	Undetermined
HN-6	Ferry launch				(USGS 1906, 1908)			Doolittle (1796)	Undetermined
HN-7	Ferry launch				(USGS 1906, 1908)			Doolittle (1796)	Undetermined

Survey ID Number	Description	Identification on Historic Maps						Other References and Comments	National Register Eligibility
		Walling (1860)	USGS (1931)	USGS (1933)	Other USGS	Hurd (1892)	Holland (1784)		
HN-8	Ferry launch				(USGS 1906, 1908)			Doolittle (1796)	Undetermined
HN-9	Ferry launch				(USGS 1906, 1908)			Doolittle (1796)	Undetermined

Survey ID Number	**Description**	**Identification on Historic Maps**						**Other References and Comments**	**National Register Eligibility**
		Walling (1860)	**USGS (1931)**	**USGS (1933)**	**Other USGS**	**Hurd (1892)**	**Holland (1784)**		
HN-10	Dwelling				(USGS 1981, 1989, 2001)			Fee-owned lands leased to Dartmouth Outing Club (Dartmouth College) Original one room “Titcomb Cabin” built in 1952 by Dartmouth Outing Club; destroyed by fire in 2009; rebuilt by Dartmouth College students and dedicated in 2012; no visible remains of 1952 cabin identified during 2013 Phase IA survey	Undetermined

Survey ID Number	**Description**	**Identification on Historic Maps**						**Other References and Comments**	**National Register Eligibility**
		Walling (1860)	**USGS (1931)**	**USGS (1933)**	**Other USGS**	**Hurd (1892)**	**Holland (1784)**		
LE-1	Bridge	X			(USGS 1906, 1908)				Undetermined
LE-2	Mills (2)	Appears as *White River Falls Carp Mills*			(USGS 1906, 1908)				Undetermined
LE-3	Saw mill	Appears as *saw mill*			(USGS 1906, 1908)				Undetermined
LE-4	Dwellings (7)				(USGS 1906, 1908)				Undetermined
LE-5	Mill				(USGS 1906, 1908)	Appears as *Olcott Falls Pulp Co.*			Undetermined

Survey ID Number	**Description**	**Identification on Historic Maps**						**Other References and Comments**	**National Register Eligibility**
		Walling (1860)	**USGS (1931)**	**USGS (1933)**	**Other USGS**	**Hurd (1892)**	**Holland (1784)**		
LE-6	Canal				(USGS 1906, 1908)			Near city of Lebanon boat launch; post-2013 Phase IA survey discovery of possible wood lock remains on NH shoreline in normally inundated area	Undetermined

Table 3.11-4 presents the current status of recorded archaeological sites in the Wilder Project APE, including 4 newly recorded pre-contact sites (3 in Vermont and 1 in New Hampshire). Of the 52 recorded archaeological sites, 1 site has been determined as eligible for listing in the National Register, 4 sites are recommended as eligible for listing in the National Register, and 5 sites are determined or recommended to be ineligible. The National Register eligibility of the other 42 recorded sites is currently undetermined because these sites are not located in active erosion areas, are not threatened by current Project operations, or are in areas that were not accessible for further study (i.e., no landowner access granted).

Table 3.11-4. Recorded pre-contact and post-contact archaeological sites within or directly adjacent to the Wilder Project APE.

State Inventory Number/Name	Town	Site Type[a]	Brief Description[b]	Temporal/ Cultural Affiliation	Location Relative to the Project/ Effects	National Register Eligibility
27-GR-112/ Ingalls	Haverhill, NH	P	Recorded in 1994 as multiple stratified components; burnt maize, beans, and a large important ceramic assemblage*	Pre-contact (Late Woodland)	Flowage (in active erosion area; no landowner access for Phase IB survey	Undetermined
27-GR-141/ unnamed	Haverhill, NH	P	Recorded in 1951 as a mortar and 80-pound pestle*	Pre-contact (unknown)	Flowage (no active erosion; no Project threats)	Undetermined
27-GR-143/ unnamed	Haverhill, NH	P	Recorded in 1978 as human skeletal remains*	Pre-contact (unknown)	Flowage (no active erosion; no Project threats)	Undetermined
27-GR-144/ Bedell Bridge State Park	Haverhill, NH	PH	*Pre-contact:* Recorded in 1977 and 1993 as quartz and quartzite chipping debris, soapstone fragments, an adze, and pottery sherds * *Post-contact:* Recorded in 1977 and 1993 as historic bridge abutment and central pier. Documentary evidence of a French Fort at location*	Pre-contact (unknown); EuroAmerican (bridge ca. 1805–1979; fort ca 1704–1761)	Flowage (no active erosion; no Project threats)	Undetermined

State Inventory Number/Name	Town	Site Type[a]	Brief Description[b]	Temporal/ Cultural Affiliation	Location Relative to the Project/ Effects	National Register Eligibility
27-GR-151/ unnamed	Lyme, NH	P	Recorded in 1951 as a campsite, no other information available*	Pre-contact (unknown)	Flowage (no active erosion; no Project threats)	Undetermined
27-GR-178/ unnamed	Hanover, NH	P	Recorded in 1951 as pottery sherds and a probable Levanna projectile point*	Pre-contact (Middle-Late Woodland)	Flowage (no active erosion; no Project threats)	Undetermined
27-GR-202/ Orford Toll House	Orford, NH	H	Recorded in 2000 as nails, glass, brick, animal bones, ceramics, buttons, pipe stems and bowls, coal and coal slag*	EuroAmerican (mid-nineteenth to early twentieth century)	Flowage (no active erosion; no Project threats)	Undetermined
27-GR-208/ Robie Farm	Piermont, NH	P	Recorded in 1996 as two probable hearth features containing fire-cracked rock and rhyolite shatter*	Pre-contact (unknown)	Flowage (in active erosion area; no landowner access for Phase IB survey)	Undetermined
27-GR-224/Fenn	Haverhill, NH	P	Recorded in 2008 as three Levanna projectile points and quartz biface fragment*	Pre-contact (Middle-Late Woodland)	Flowage (in active erosion area; no landowner access for Phase IB survey)	Undetermined

State Inventory Number/Name	Town	Site Type[a]	Brief Description[b]	Temporal/ Cultural Affiliation	Location Relative to the Project/ Effects	National Register Eligibility
27-GR-228/ Clay Bank	Piermont, NH	H	Recorded in 2013, Phase IA survey: Lenticular feature with fire-reddened soils and charcoal; re-interpreted in 2015 Phase IB survey as post-contact and/or natural soil anomalies+	Post-contact (or natural)	Flowage (in active erosion area)	Ineligible; Phase IB (NHSHPO concurrence December 16, 2015)
27-GR-229/ Cotton Stone Meadow	Orford, NH	P	Recorded in 2013, Phase IA survey: Two parallel burn layers separated by alluvium with reddish soils, charcoal, and calcined bone. Five pieces of hornfels chipping debris	Native American (unknown)	Flowage (in active erosion area; no landowner access for Phase IB survey)	Undetermined
27-GR-230/ North Thetford Bridge	Lyme, NH	H	Recorded in 2013, Phase IA survey: Both abutments and central pier still standing; abutment on Vermont side is concrete, while other two elements are mortared stone	EuroAmerican originally built in 1896; closed to traffic in the 1950s; span collapsed in 1972–1973	Flowage (no active erosion; no Project threats)	Undetermined
27-GR-231/ Post Hill Riverside Dump	Lyme, NH	H	Recorded in 2013, Phase IA survey: Historic trash dump with automobile parts, enamelware, cans, and scrap metal	EuroAmerican (mid-twentieth century)	Flowage (no active erosion; no Project threats)	Undetermined

State Inventory Number/Name	Town	Site Type[a]	Brief Description[b]	Temporal/ Cultural Affiliation	Location Relative to the Project/ Effects	National Register Eligibility
27-GR-232/ Lampshire Meadow	Lyme, NH	P	Recorded in 2013, Phase IA, 2015 Phase IB, and 2016 Phase II: Four activity areas or loci; Locus 1 is high density concentration of lithic debitage, chipped stone tools, and fire pit feature with wood charcoal radiocarbon-dated to Middle Archaic Period+	Pre-contact (Middle Archaic)	Flowage (in active erosion area)	Eligible Phase II (NHSHPO concurrence August 18, 2016)
27-GR-233/ Gilman Island Dump	Hanover, NH	H	Recorded in 2013, Phase IA survey: Bottles, ceramics, machine-wrought square nails, cans	EuroAmerican (early to mid-twentieth century)	Fee-owned (Parcel #16) (outside and not affected by the primitive camp site and "Titcomb Cabin" on land leased to the Dartmouth Outing Club [Dartmouth College]; no active erosion or other Project impacts or threats noted during the 2013 Phase IA survey)	Undetermined

State Inventory Number/Name	Town	Site Type[a]	Brief Description[b]	Temporal/ Cultural Affiliation	Location Relative to the Project/ Effects	National Register Eligibility
27-GR-234/ Red Cliff	Orford, NH	P	Recorded in 2013, Phase IA survey: A 15–20 cm deep feature containing orange soils underlain by thin black layer; no artifacts; not unequivocally cultural, but historic maps call the area the "Indian Burial Ground" (Walling, 1860)	Native American (unknown)	Flowage (in active erosion area; no landowner access for Phase IB survey)	Undetermined
27-GR-235/ Olcott Falls East	Lebanon, NH	H	Recorded in 2013, Phase IA survey: Multiple structures, including a grist and saw mill, canal, paper mill and associated structures, several dams, and a bridge	EuroAmerican (early late eighteenth to mid-twentieth century)	Flowage (no active erosion; no Project threats)	Undetermined
27-GR-268/ Parcel 208/390 (new)	Piermont, NH	P	Recorded in 2015, Phase IB survey: Lithic debitage recovered in redeposited alluvial soils+	Pre-contact (unknown)	Flowage (in active erosion area)	Undetermined Phase IB (ineligible in tested erosion area only—NHSHPO concurrence December 16, 2015)
VT-OR-15/ unnamed	Bradford, VT	P	Recorded in 1981 as surface-collected lithic tools including points, drills, a scraper, and a hoe*	Pre-contact (unknown)	Flowage (no active erosion; no Project threats)	Undetermined

State Inventory Number/Name	Town	Site Type[a]	Brief Description[b]	Temporal/ Cultural Affiliation	Location Relative to the Project/ Effects	National Register Eligibility
VT-OR-18/ Carson Farm	Newbury, VT	P	Recorded in 1985 as pottery sherds, lithics, charred nuts, and charcoal*	Pre-contact (Early Woodland)	Flowage (no active erosion; no Project threats)	Undetermined
VT-OR-19/ Harriman Brook	Newbury, VT	P	Recorded in 1989 as nine hearth features, large assemblage of lithics (including tools and points), pottery, fire cracked rock, and organics*	Pre-contact (Middle-Late Woodland)	Flowage (no active erosion; no Project threats)	Undetermined
VT-OR-21/ Lord Farm	Bradford, VT	P	Recorded in 1989 as one chert flake, one rhyolite flake*	Pre-contact (unknown)	Flowage (in active erosion area; no landowner access for Phase IB survey)	Undetermined
VT-OR-22/ Carson Farm 2	Newbury, VT	PH	*Prehistoric:* Recorded in 1989 as one quartzite flake* *Historic:* Recorded in 1989 as unspecified historic artifacts*	Pre-contact (unknown) EuroAmerican (ca 1609-1790)	Flowage (no active erosion; no Project threats)	Undetermined

State Inventory Number/Name	Town	Site Type[a]	Brief Description[b]	Temporal/ Cultural Affiliation	Location Relative to the Project/ Effects	National Register Eligibility
VT-OR-34/Farrell	Fairlee, VT	P	First recorded in 1992; 2015 Phase IB and 2016 Phase II: Lithic debitage, aboriginal pottery, chipped stone tools, calcined animal and bird bone; charred tobacco seeds, large refuse pit feature with Late Woodland radiocarbon date+	Pre-contact (Late Woodland)	Flowage (in active erosion area)	Recommended eligible Phase II (pending VTSHPO concurrence)
VT-OR-35/ Carson	Bradford, VT	H	Recorded in 2003 as 37 organic features of possible pre-contact origin*; in 2015, Phase IB survey: Organic stains were reinterpreted as post-contact plow zone scars+	Post-contact (plow zone)	Flowage (in active erosion area)	Recommended ineligible Phase IB (pending VTSHPO concurrence)
VT-OR-36/ unnamed	Newbury, VT	H	Unspecified* (no VTSHPO form on file)	EuroAmerican (unknown)	Flowage (no active erosion; no Project threats)	Undetermined
VT-OR-38/ Fairlee Pond Grist Mill	Fairlee, VT	H	Recorded in 1993 as a grist mill with intact walls but no roof*	EuroAmerican (ca 1760-1790)	Flowage (no active erosion; no Project threats)	Undetermined
VT-OR-41/ Palmer	Thetford, VT	P	Recorded in 1991 as numerous and diverse lithic assemblage	Pre-contact (unknown)	Flowage (no active erosion; no Project threats)	Undetermined

State Inventory Number/Name	Town	Site Type[a]	Brief Description[b]	Temporal/ Cultural Affiliation	Location Relative to the Project/ Effects	National Register Eligibility
VT-OR-45/ Bradford-Piermont Toll House	Bradford, VT	PH	*Prehistoric:* Recorded in 1994 as three rhyolite flakes, one fragment of fire cracked rock, and a culturally undetermined human burial nearby* *Historic:* Recorded in 1994 as a large assemblage of brick, metal, glass, ceramic, bone, etc.*	Pre-contact (unknown); EuroAmerican (ca 1826–1930s)	Flowage (no active erosion; no Project threats)	Undetermined
VT-OR-62/ unnamed	Bradford, VT	P	First recorded in 1999; 2015 Phase IB and 2016 Phase II: Lithic debitage, chipped stone tools, fish bone, calcined bone; four features including cooking pits and a fire pit, radiocarbon dates from Late Archaic, Middle and Late Woodland periods+	Pre-contact (Late and Terminal Archaic; Middle and Late Woodland)	Flowage (active erosion area)	Recommended eligible Phase II (pending VTSHPO concurrence)
VT-OR-63/ unnamed	Bradford, VT	H	Recorded in 1999 as granite blocks, brick, and ceramic sherds; possible subsurface evidence of a foundation*	EuroAmerican (unknown)	Flowage (no active erosion; no Project threats)	Undetermined

State Inventory Number/Name	Town	Site Type[a]	Brief Description[b]	Temporal/ Cultural Affiliation	Location Relative to the Project/ Effects	National Register Eligibility
VT-OR-67/ Davenport	Fairlee, VT	P	Recorded in 2001 as one chert flake and possible fire cracked rock*	Pre-contact (unknown)	Flowage (no active erosion; no Project threats)	Ineligible (2001 VTSHPO determination for bridge rehabilitation project)
VT-OR-72/ D. Ross Residence	Fairlee, VT	H	First recorded in 2000; 2015 Phase IB as cellar hole with few disarticulated foundation fieldstones; mid-late nineteenth century domestic and structural debris+	EuroAmerican (ca. late nineteenth century)	Flowage (in active erosion area)	Recommended ineligible Phase IB (pending VTSHPO concurrence)
VT-OR-95/Bedell Covered Bridge	Newbury, VT	H	Recorded in 2013, Phase IA survey: Both abutments and center pier (still standing); the abutment on the Vermont bank consists of dry-laid stone with wooden and cement elements	EuroAmerican (first of five bridges at location was built in 1806; most recent bridge 1866-1979)	Flowage (no active erosion; no Project threats)	Undetermined
VT-OR-96/ Double Draw Dump	Bradford, VT	H	Recorded in 2013, Phase IA survey: Automobile parts, appliances, bottles and cans, scrap metal, farm equipment, an unidentified belt-drive assembly which may be related to a nearby historic mill	EuroAmerican (early to mid-twentieth century)	Flowage (no active erosion; no Project threats)	Undetermined

State Inventory Number/Name	Town	Site Type[a]	Brief Description[b]	Temporal/ Cultural Affiliation	Location Relative to the Project/ Effects	National Register Eligibility
VT-OR-97/ Palisades	Fairlee, VT	P	Recorded in 2013, Phase IA survey: Living surface feature with fire cracked rock, a rhyolite biface, and a cow molar found in the slump	Pre-contact (unknown)	Flowage (in active erosion area; no landowner access for Phase IB survey)	Undetermined
VT-OR-98/ Fairlee Dump	Fairlee, VT	H	Recorded in 2013, Phase IA survey: Cans and bottles, enamel cookware, ceramics, etc.	EuroAmerican (mid-twentieth century)	Flowage (no active erosion; no Project threats)	Undetermined
VT-OR-99/ Roaring Brook Dump	Thetford, VT	H	Recorded in 2013, Phase IA survey: Cans and bottles, stoneware jugs, automobile parts, scrap metal, etc.	EuroAmerican (early to mid-twentieth century)	Flowage (no active erosion; no Project threats)	Undetermined
VT-OR-100/ North Thetford Bridge	Thetford, VT	H	Recorded in 2013, Phase IA survey: Bridge features; both abutments and the center pier still standing; both elements in NH are mortared stone, and the VT abutment is made of concrete	EuroAmerican (Built in 1896; closed to traffic in the 1950s; destroyed in 1972–1973)	Flowage (no active erosion; no Project threats)	Undetermined

State Inventory Number/Name	Town	Site Type[a]	Brief Description[b]	Temporal/ Cultural Affiliation	Location Relative to the Project/ Effects	National Register Eligibility
VT-OR-101/East Thetford River Dump	Thetford, VT	H	Recorded in 2013, Phase IA survey: Early machine-made bottles, flat iron trivet, bronze/copper kerosene lamp, ceramics	EuroAmerican (early twentieth century)	Flowage (in active erosion area; no landowner access for Phase IB survey)	Undetermined
VT-OR-102/Pavillion Road Dump	Thetford, VT	H	Recorded in 2013, Phase IA survey: Automobiles, tires, appliances	EuroAmerican (mid-twentieth century)	Flowage (no active erosion; no Project threats)	Undetermined
VT-OR-108/ Lower Plain (new)	Bradford, VT	P	Recorded in 2015 Phase IB and 2016 Phase II: Lithic debitage, chipped stone tools, and aboriginal pottery+	Pre-contact (Middle to Late Woodland)	Flowage (in active erosion area)	Recommended eligible Phase II (pending VTSHPO concurrence)
VT-OR-109/ Parcel 454/390 (new)	Bradford, VT	P	Recorded in 2015 Phase IB: Single lithic debitage in alluvial soils+	Pre-contact (unknown)	Flowage (in active erosion area)	Recommended ineligible Phase IB (pending VTSHPO concurrence)
VT-OR-110/ Roaring Brook (new)	Thetford, VT	P	Recorded in 2015 Phase IB and 2016 Phase II: Lithic debitage, aboriginal pottery, and chipped stone tools+	Pre-contact (Woodland)	Flowage (in active erosion area)	Recommended eligible Phase II (pending VTSHPO concurrence)

State Inventory Number/Name	Town	Site Type[a]	Brief Description[b]	Temporal/ Cultural Affiliation	Location Relative to the Project/ Effects	National Register Eligibility
VT-WN-237/ Gleason	Norwich, VT	H	Recorded in 1995 as the buried remains of two or more structures related to a previous building on this spot*	EuroAmerican (late nineteenth century)	Flowage (no active erosion; no Project threats)	Undetermined
VT-WN-477/ Lower Ompompanoosuc Bridge	Norwich, VT	H	Recorded in 2013, Phase IA survey: Bridge abutments; both abutments extant; dry-laid stone with cement elements	EuroAmerican (first of several bridges at location built in either 1771 or 1787; latest bridge from 1866–1954)	Flowage (no active erosion; no Project threats)	Undetermined
VT-WN-478/ Patterson Chair Factory	Norwich, VT	H	Recorded in 2013, Phase IA survey: Dry-laid foundation wall and associated wooden shed (left bank) and corresponding L-shaped cement wall projecting into river (right bank)	EuroAmerican (early to mid-nineteenth century)	Flowage (no active erosion; no Project threats)	Undetermined
VT-WN-479/ Wilder Falls	Hartford, VT	P	Recorded in 2013, Phase IA survey: Hearth feature, chipping debris (rhyolite, hornfels, chert), one hornfels biface, and calcined bone	Native American (unknown)	Fee-owned/ flowage (in active erosion area, boat access not possible, safe access only by land through adjacent private properties—not granted for Phase IB survey	Undetermined

State Inventory Number/Name	Town	Site Type[a]	Brief Description[b]	Temporal/ Cultural Affiliation	Location Relative to the Project/ Effects	National Register Eligibility
VT-WN-480/ Olcott Falls Industrial Complex	Hartford, VT	H	Recorded in 2013, Phase IA survey: Multiple structures including a paper mill and associated structures, several dams and dam improvements, and a bridge	EuroAmerican (late eighteenth century to mid-twentieth century)	Fee-owned/flowage (in FERC Project recreation area- no active erosion or other Project impacts or threats noted during the 2013 Phase IA survey)	Undetermined
VT-WN-481/ Kilowatt Park	Hartford, VT	H	Recorded in 2013, Phase IA survey: Bottle glass, ceramics, and metal fragments	EuroAmerican (early to mid-nineteenth century)	Fee-owned/ flowage (in FERC Project recreation area- no active erosion or other Project impacts or threats noted during the 2013 Phase IA survey)	Undetermined
F.S. 3 (OR)/ “Indian Mounds”	Bradford, VT	P	Recorded in 1976 as "some" projectile points located in "Indian mounds" *	Pre-contact (unknown)	Flowage (no active erosion; no Project threats)	Undetermined
F.S. 21 (WN)/ unnamed	Norwich, VT	U	Recorded in 1991 as low density deposit of lithic debitage *	Unknown	Flowage (no active erosion; no Project threats)	Undetermined

a. P – strictly pre-contact, PH – multi-component site with pre-contact and post-contact components, H – strictly post-contact.

b. * – No exposed cultural materials identified during Phase IA reconnaissance survey (Hubbard et al., 2013a).
[+] – Cultural deposits identified during Phase IB identification surveys (Elquist and Cherau, 2016a, 2015) and Phase II site evaluations (Elquist and Cherau, 2016b, 2016c).

Bellows Falls Project

Archival research including an analysis of historic maps and town histories undertaken for the 2013 Phase IA survey of the Bellows Falls Project documented 26 resource locations within or immediately adjacent to the Project APE that could contain post-contact archaeological sites (12 in Vermont and 14 in New Hampshire; Table 3.11-5 and Table 3.11-6). Of these 26 documented resource locations, 7 were identified archaeologically in the field during the Phase IA survey and assigned state inventory archaeological site numbers. The other 19 documented resources have not been identified archaeologically and their National Register eligibility is currently undetermined. These documented resource locations were not accessible, are outside of the surveyed areas, or did not have any visible archaeological remains.

As a result of the Phase IA field survey and research, 43 archaeological sites were identified within the Project APE, 29 of which had been recorded by others prior to the Phase IA survey of the Bellows Falls Project. The other 14 sites (including the 7 documented resource locations noted above) were identified archaeologically in the field during the Phase IA survey and assigned state inventory numbers. The 43 recorded sites consist of: 26 sites in Vermont (16 on private flowage lands, 8 on fee-owned lands and adjacent private flowage, and 2 on fee-owned lands); and 17 sites in New Hampshire (6 on private flowage lands, 5 on fee-owned and adjacent private flowage, and 6 on fee-owned lands) (Table 3.11-7). Prior to the Phase IA survey, 3 of the recorded sites had been listed in the National Register, 3 had been determined eligible for listing in the National Register, and 1 site had been determined ineligible for the National Register. The National Register eligibility of the other 36 recorded sites in the Bellows Falls Project had not been determined at the time of the Phase IA survey.

The Phase IA survey also identified approximately 59 miles of the Bellows Falls Project shoreline (on both sides of the river) as archaeologically sensitive, including the locations of documented resources and recorded sites, of which approximately 5 miles (21 areas) were identified as being in active erosion areas. On the Vermont side of the river, 10 sensitive areas of active erosion were identified, and on the New Hampshire side of the river 11 sensitive areas of active erosion were identified. However, subsequent Phase IB field surveys of eroding shoreline were only conducted on lands owned in fee or on private flowage lands where landowner permissions for access were obtained. This resulted in Phase IB surveys being conducted in only 4 of the 10 archaeologically sensitive active erosion areas on the Vermont side of the river, and in 10 of the 11 archaeologically sensitive active erosion areas on the New Hampshire side of the river, totaling approximately 4 miles of shoreline. Phase IB investigations of the remaining 7 archaeologically sensitive erosion areas were not conducted because property owners either did not respond to inquiries or denied access for study purposes. As a result, approximately 55 miles of archaeologically sensitive shoreline within the Bellows Falls Project APE was not surveyed; 1 mile of this shoreline also contained active erosion.

Table 3.11-5. Documented post-contact resources within or directly adjacent to the Bellows Falls Project APE (Vermont).

Survey Number	Description	Identification on Historic Maps					Notes	National Register Eligibility
		Walling (1860)	Beers (1869A)	USGS (1929)	USGS (1930)	USGS (1957a,b)		
RO-1	Dwelling		Appears as *D.K. Barry*		X		Fee-owned, above shoreline; no archaeological evidence of site identified during 2013 Phase IA survey; no Project impacts or threats noted	Undetermined
RO-2	Dwelling		Appears as *G.C. Bidwell*				Fee-owned, above shoreline; no archaeological evidence of site identified during 2013 Phase IA survey; no Project impacts or threats noted	Undetermined

Survey Number	Description	Identification on Historic Maps					Notes	National Register Eligibility
		Walling (1860)	Beers (1869A)	USGS (1929)	USGS (1930)	USGS (1957a,b)		
RO-3	Cabins (13)				(8 cabins)	(10 cabins)	Fee-owned, above shoreline; no archaeological evidence of site identified during 2013 Phase IA survey; no Project impacts or threats noted	Undetermined
SP-1	Schoolhouse			Appears as *River School*				Undetermined
SP-2	Dwelling		Appears as *D.A. Gill*	X		X		Undetermined
SP-3	Wentworth Ferry and Crown Point Road	X	Road only					Undetermined
SP-4	Bridge abutments	X	X	X			Phase IA Survey identified as Site VT-WN-476	See Table 3.11-7
SP-5	Schoolhouse		Appears as *School No, 19*					Undetermined

Survey Number	**Description**	**Identification on Historic Maps**					**Notes**	**National Register Eligibility**
		Walling (1860)	**Beers (1869A)**	**USGS (1929)**	**USGS (1930)**	**USGS (1957a,b)**		
WE-1	Dwelling (Probably destroyed by new Ascutney Bridge)		Appears as *H.H. Graves*	X		X	Probably destroyed by new Ascutney Bridge	Undetermined
WE-2	Ferry launch and ferry house	X	Ferry only appears as *Ashley's Ferry*	X				Undetermined
WE-3	Tuttle Cemetery (In use between 1772-1882)					X	In use 1772-1882; visible gravestones	Undetermined
WE-4	Bridge abutments	Appears as *Claremont Bridge*	X	X		X		Undetermined

Table 3.11-6. Documented post-contact resources within or directly adjacent to the Bellows Falls Project APE (New Hampshire).

Survey ID Number	Description	Identification on Historic Maps						Notes	National Register Eligibility
		Holland (1784)	Walling (1860)	Hurd (1892)	USGS (1929)	USGS (1930)	USGS (1957a,b)		
CH-1	Dwelling			X	X		X	Phase IA survey identified as possible Site 27-SU-34	See Table 3.11-7
CH-2	Dwelling				X		X	Phase IA survey identified as likely Site 27-SU-4	See Table 3.11-7
CH-3	Dwelling						X	Phase IA survey identified as likely Site 27-SU-4	See Table 3.11-7
CH-4	Dwelling					X	X		Undetermined
CH-5	Dwelling					X		Phase IA survey identified as Site 27-SU-46	See Table 3.11-7
CH-6	Possible trout pond			X				Phase IA survey identified as Site 27-SU-49	See Table 3.11-7

Survey ID Number	Description	Identification on Historic Maps						Notes	National Register Eligibility
		Holland (1784)	Walling (1860)	Hurd (1892)	USGS (1929)	USGS (1930)	USGS (1957a,b)		
CH-7	Ferry launch		Appears as *Ferry*						Undetermined
CL-1	Dwelling			Appears as *C.V. Paddock II*					Undetermined
CL-2	Bridge abutment		X	X	X		X		Undetermined
CL-3	Toll house		Appears as *Toll House*	Appears as *Toll House*	X				Undetermined
CL-4	Dwelling	X							Undetermined
CL-5	Ferry launch (Appears as *Ashley's Ferry* on Carrigain 1816 map)		Appears as *Ashley's Ferry*		Appears as *Ashley's Ferry*			Carrigain (1816) map appears as Ashley's Ferry	Undetermined
CL-6	Dwelling		Appears as *I. Hubbard Esq.*	Appears as *L.H. Long*					Undetermined
WA-1	Rail spur					X	X	Phase IA survey identified as Site 27-CH-169	See Table 3.11-7

On the Vermont side of the river, the 10 archaeologically sensitive erosion areas targeted for Phase IB survey in the Bellows Falls Project APE contained nine sites (VT-WN-46, VT-WN-61, VT-WN-102, VT-WN-186, VT-WN-192, VT-WN-453, VT-WN-473, VT-WN-474, and VT-WD-291) identified during the Phase IA surveys. Landowner permission to conduct Phase IB surveys was granted on private lands that contained five of the recorded pre-contact sites (VT-WN-46, VT-WN-102, VT-WN-192, VT-WN-453, and VT-WD-291). Three of these sites (VT-WN-102, VT-WN-192, and VT-WN-453) overlap Erosion Area 5 in Springfield and are downslope from three other recorded pre-contact sites (VT-WN-45, VT-WN-55, and VT-WN-454) located on an adjacent upper terrace. The lithic debitage recovered along the riverbank during the Phase IB survey appears to be redeposited from the adjacent upper terraces and recorded sites outside the Project APE. The lower terrace containing the three Project sites (VT-WN-102, VT-WN-192, and VT-WN453) also has the potential to contain deeply buried cultural deposits below roadfill and alluvial strata so their National Register eligibility remains undetermined. The Phase IB survey tested the southern portion of the Cheshire Bridge Site (VT-WN-46) in Springfield, but no cultural materials were found. The site's National Register eligibility remains undetermined, however, because of the possible presence of intact cultural deposits in the untested areas to the north of the tested portion of Erosion Area 6 in the Project APE. The Phase IB survey of the Upper Meadows Site (VT-WD-291) in Rockingham did not yield any cultural deposits in the upper alluvial strata. The potential for deeply buried pre-contact cultural deposits in this area (Erosion Area 9) exists, and the site's National Register eligibility remains undetermined. No new archaeological sites were identified during the Phase IB survey on the Vermont side of the Connecticut River. The VTSHPO has not yet formally commented on the findings and recommendations of the Phase IB survey in the Bellows Falls Project APE where no potentially significant archaeological sites were identified. No Phase II site evaluations have been recommended.

On the New Hampshire side of the river, the 11 archaeologically sensitive erosion areas targeted for Phase IB surveys in the Bellows Falls Project APE contain seven sites (27-SU-7, 27-SU-43, 27-SU-44, 27-SU-45, 27-SU-47, 27-SU-48, and 27-CH-170). Landowner permission to conduct Phase IB surveys was granted on private lands that contain all seven of the recorded pre- and post-contact period sites. The Phase IB survey at the pre-contact Red Flake Site (27-SU-7) in Charlestown did not yield any pre-contact cultural deposits, and it was considered possible that the portion of the riverbank previously identified as containing cultural deposits has been lost through erosion and/or that the site area was actually located farther to the north and outside the active erosion area. The National Register eligibility of this site, therefore, remains undetermined. The cluster of three recorded pre-contact sites in the Great Meadows section of Charlestown (27-SU-43, 27-SU-44, and 27-SU-45) identified during the Phase IA survey on the basis of burn layers or hearth-like features was re-examined during the Phase IB investigations and determined to be natural and/or post-contact in origin, and not eligible for the National Register. The Phase IB survey at the pre-contact Lower Meadows Site (21-SU-47) in Charlestown did not recover any pre-contact cultural deposits in intact soils, and the site was not recommended as National Register eligible. The Phase IB survey at the pre-contact Meaney's Cove II Site (21-SU-48) in Charlestown did not yield any pre-contact cultural, but localized flooding at the time of the Phase IB fieldwork prevented full access to the erosion area. The potential remains for pre-contact cultural deposits in the untested portion of the erosion area and the site's National Register eligibility remains undetermined. The one post-contact site, the Marshall Street Trash Dump (21-CH-170) in Walpole, was investigated during the Phase IB survey and determined to contain nineteenth-century domestic materials redeposited in a twentieth-century dumping area and is not eligible for the National Register. The Phase IB surveys also identified two new sites: the pre-contact Parcel B.F. 265 Site (27-SU-53) in Claremont, which yielded one piece of lithic debitage in redeposited alluvium; and the pre-contact Lower Meadows II Site (21-SU-54) in Charlestown, which yielded low densities of nondiagnostic lithic chipping debris in redeposited alluvium. Neither site was recommended significant or eligible for listing in the National Register. No new archaeological sites were identified during the Phase IB survey on the New Hampshire side of the Connecticut River. On December 16, 2015, the NHSHPO concurred with the findings and recommendations of the Phase IB survey in the New Hampshire portion of the Bellows Falls Project APE. No Phase II site evaluations were conducted.

Table 3.11-7 presents the current status of recorded archaeological sites in the Bellows Falls Project APE, including two newly recorded pre-contact sites in New Hampshire. Of the 45 recorded archaeological sites, 3 are listed in the National Register, 3 are eligible for listing, and 8 are ineligible. The National Register eligibility of the other 31 recorded sites remains undetermined because these sites are not located in active erosion areas, are not threatened by current Project operations, or are in areas that were not accessible for further study (i.e., no landowner access granted).

Table 3.11-7. Recorded pre-contact and post-contact archaeological sites within or directly adjacent to the Bellows Falls Project APE.

State Inventory Number/ Name	Town	Site Type[a]	Brief Description[b]	Temporal/ Cultural Affiliation	Location Relative to the Project/ Effects	National Register Eligibility
27-CH-169/ North Walpole Rail Spur and Yard	Walpole, NH	H	Recorded in 2013, Phase IA Survey: Evidence of old rail beds, concrete foundations, and stored railroad equipment (e.g., ties, track)	Euro-American (nineteenth/ twentieth century)	Fee-owned (partially in FERC Project recreation area; no active erosion or other Project impacts or threats noted during the 2013 Phase IA survey)	Undetermined
27-CH-170/ Marshall Street Trash Dump	Walpole, NH	H	Recorded in 2013, Phase IA Survey: Historic trash dump with glass, ceramics, and an abundance of coal ash; 2015 Phase IB survey identified nineteenth-century domestic debris intermixed+	Euro-American (early to mid-twentieth Century	Flowage (in active erosion areas)	Ineligible Phase IB (NHSHPO concurrence December 16, 2015)
27-SU-4/ unnamed	Charlestown, NH	PH	Recorded in 1959 as two culturally unaffiliated human burials, stone drill, scraper, and projectile point. Also two historic cellar holes.*	Pre-contact (unknown); Euro-American	Flowage (no active erosion; no Project threats)	Undetermined

State Inventory Number/ Name	Town	Site Type[a]	Brief Description[b]	Temporal/ Cultural Affiliation	Location Relative to the Project/ Effects	National Register Eligibility
27-SU-5/ Hunter	Claremont, NH	P	Recorded in 1952 as stratified site with seven identified occupation levels, 150+ hearths, one human burial, numerous lithic artifacts and pottery.*	Pre-contact (Late Archaic, Middle and Late Woodland)	Flowage (no active erosion; no Project threats)	Listed (June 7, 1976)
27-SU-7/ Red Flake	Charlestown, NH	P	Recorded in 1989 as four hearths, a possible living surface (65m long), fire-cracked rock, pottery, calcined bone, chipping debris*; 2015 Phase IB testing recovered no new cultural materials+	Pre-contact (Middle Woodland)	Flowage (partly in active erosion area; no landowner access for Phase IB survey)	Undetermined
27-SU-12/ Highter Farm	Charlestown, NH	P	Recorded in 1952 as six pieces of chipping debris*	Pre-contact (unknown)	Flowage (no active erosion; no Project threats)	Undetermined
27-SU-16/ unnamed	Claremont, NH	P	Recorded in 1958 as low density of quartz chipping debris on the surface*	Pre-contact (unknown)	Flowage (no active erosion; no Project threats)	Undetermined
27-SU-34/ Lovers Lane I	Charlestown, NH	H	Recorded in 2003 as a square earthen structure or possible military gun emplacement	Euro-American (possibly eighteenth century)	Fee-owned (no active erosion or other Project impacts or threats noted during the 2013 Phase IA survey)	Undetermined

State Inventory Number/ Name	Town	Site Type[a]	Brief Description[b]	Temporal/ Cultural Affiliation	Location Relative to the Project/ Effects	National Register Eligibility
27-SU-35/ Lovers Lane II	Charleston, NH	H	Recorded in 2003 as a square earthen "foundation"	Euro-American (unknown)	Fee-owned (no active erosion or other Project impacts, potential threat from unauthorized pedestrian use noted during the 2013 Phase IA survey)	Undetermined
27-SU-41/ Meany's Cove	Charlestown, NH	P	Recorded in 2010 as quartz chipping debris and cores, a chert flake, hammerstone, projectile point, calcined bone, fire-altered rock, possible hearth feature*	Pre-contact (unknown)	Fee-owned (no active erosion or other Project impacts or threats noted during the 2013 Phase IA survey)	Eligible (NHSHPO concurrence date unknown)
27-SU-43/ Great Meadows I	Charlestown, NH	H	Recorded in 2013, Phase IA survey: Hearth feature with reddened soils and abundant charcoal; reinterpreted in 2015 Phase IB as post-contact and/or natural in origin+	Post-contact (or natural)	Fee-owned/flowage (in active erosion area)	Ineligible Phase IB (NHSHPO concurrence December 16, 2015)

State Inventory Number/ Name	Town	Site Type[a]	Brief Description[b]	Temporal/ Cultural Affiliation	Location Relative to the Project/ Effects	National Register Eligibility
27-SU-44/ Great Meadows II	Charlestown, NH	H	Recorded in 2013, Phase IA survey: Burn layer with one piece of fire-cracked rock; re-interpreted in 2015 Phase IB as post-contact and/or natural in origin+	Post-contact (or natural)	Fee-owned/flowage (in active erosion area)	Ineligible Phase IB (NHSHPO concurrence December 16, 2015)
27-SU-45/ Great Meadows III	Charlestown, NH	H	Recorded in 2013, Phase IA survey: Burn layer with 57 fragments of fire-cracked rock; reinterpreted in 2015 Phase IB as post-contact and/or natural in origin+	Post-contact (or natural)	Fee-owned/flowage (in active erosion area)	Ineligible Phase IB (NHSHPO concurrence December 16, 2015)
27-SU-46/ Great Meadow Farmhouse Foundation	Charlestown, NH	H	Recorded in 2013, Phase IA survey: Dry-laid farmhouse foundation and associated farm equipment	Euro-American (late nineteenth to early twentieth century)	Fee-owned (no active erosion; no Project threats)	Undetermined
27-SU-47/ Lower Meadows	Charlestown, NH	P	Recorded in 2013, Phase IA survey: One lithic debitage recovered in eroded soils; 2015 Phase IB no additional cultural materials+	Pre-contact (unknown)	Fee-owned/flowage (in active erosion area)	Ineligible Phase IB (NHSHPO concurrence December 16, 2015)

State Inventory Number/ Name	Town	Site Type[a]	Brief Description[b]	Temporal/ Cultural Affiliation	Location Relative to the Project/ Effects	National Register Eligibility
27-SU-48/ Meany's Cove II	Charlestown, NH	P	Recorded in 2013, Phase IA survey: Three burn features with reddened soils, charcoal, and an unmodified shistose manuport; 2015 Phase IB no new cultural deposits+	Pre-contact (unknown)	Fee-owned/flowage (in active erosion area)	Undetermined Phase IB (ineligible in tested erosion area only—NHSHPO concurrence December 16, 2015)
27-SU-49/ Meany's Cove Historic	Charlestown, NH	H	Recorded in 2013, Phase IA survey: Well-constructed, dry-laid stone wall, apparently structural, and an oversized groundwater well. Function unknown, but interpreted as a possible trout farm	Euro-American (mid/late nineteenth century)	Fee-owned (no active erosion or other Project impacts or threats noted during the 2013 Phase IA survey)	Undetermined
27-SU-53/ Parcel B.F. 265 (new)	Claremont, NH	P	Recorded in 2015, Phase IB: 1 lithic debitage in redeposited alluvial soils+	Pre-contact (unknown)	Flowage (in active erosion area)	Ineligible Phase IB (NHSHPO concurrence December 16, 2015)
27-SU-54/ Lower Meadows II (new)	Charleston, NH	P	Recorded in 2015, Phase IB: 2 lithic debitage in plowed soils over alluvium+	Pre-contact (unknown)	Flowage (in active erosion area)	Ineligible Phase IB (NHSHPO concurrence December 16, 2015)

State Inventory Number/ Name	Town	Site Type[a]	Brief Description[b]	Temporal/ Cultural Affiliation	Location Relative to the Project/ Effects	National Register Eligibility
VT-WD-8/ Bellows Falls Petroglyphs	Rockingham, VT	P	Recorded in 1977 as numerous aboriginal face petroglyphs arranged into two clusters	Pre-contact (unknown)	Fee-owned (no active erosion or other Project impacts, but past natural and human alterations noted during the 2013 Phase IA survey)	Listed (National Register nomination March 30, 1981; contributing element of the Bellows Falls Island Multiple Resource Area (Mulholland et al., 1988)
VT-WD-23/ Conn. River Flowback (Pinello's Site #16)	Rockingham, VT	P	Recorded in 1977 as a groundstone celt*	Pre-contact (Woodland)	Flowage (no active erosion; no Project threats)	Undetermined
VT-WD-76/ John Robertson and Son Paper Co.	Springfield, VT	H	Recorded in 1988 as exterior brick wall and large outflow pipe associated with documented pulp mill (circa 1895/1891)	Euro-American (late nineteenth century)	Fee-owned (no active erosion or other Project impacts or threats noted during the 2013 Phase IA survey)	Undetermined (located within the Bellows Falls Island Multiple Resource Area Mulholland et al., 1988)

State Inventory Number/ Name	Town	Site Type[a]	Brief Description[b]	Temporal/ Cultural Affiliation	Location Relative to the Project/ Effects	National Register Eligibility
VT-WD-291/ Upper Meadows	Rockingham, VT	P	Recorded in 2013, Phase IA survey: Three fragments of fire-cracked rock; 2015 Phase IB survey did not identify any cultural deposits at top of embankment+	Pre-contact (unknown)	Fee-owned/flowage (in active erosion area)	Undetermined Phase IB (potential for deeply buried cultural deposits, pending VTSHPO concurrence
VT-WN-38/ Caches Blades	Springfield, VT	P	Recorded in 1977 as fourteen large cache blades, one human burial, chipping debris, groundstone adze and pestle-shaped object, pottery, scraper, and point fragments*	Pre-contact (Middle Woodland)	Fee-owned/flowage (no active erosion or other Project impacts or threats noted during the 2013 Phase IA survey)	Undetermined
VT-WN-39/ Wilgus Park (Pinello's Site #5)	Weathersfield, VT	P	Recorded in 1978 as two "fish spears" and numerous other artifacts*	Pre-contact (unknown)	Flowage (no active erosion; no Project threats)	Undetermined
VT-WN-41/ Skitchewaug	Springfield, VT	P	Recorded in 1978 (with multiple updates through 1998) as a stratified village site, many features (living surfaces, hearths, storage pits), two human burials, early evidence of agriculture, many artifacts*	Pre-contact (Late Archaic to Woodland)	Fee-owned/flowage (no active erosion or other Project impacts or threats noted during the 2013 Phase IA survey)	Listed in State Register and determined National Register eligible (December 18, 1987)

State Inventory Number/ Name	Town	Site Type[a]	Brief Description[b]	Temporal/ Cultural Affiliation	Location Relative to the Project/ Effects	National Register Eligibility
VT-WN-45/ Locus 16-1	Springfield, VT	P	Recorded in 1977 and 1983 as three hearths, projectile points, bifaces, grinding stone, scraper, chipping debris (2000+), pottery*	Pre-contact (Late Archaic to Woodland)	Flowage (no active erosion; no Project threats)	Undetermined
VT-WN-46/ Cheshire Bridge	Springfield, VT	P	Recorded in 1978 as one to two hearth features, fire-cracked rock, pottery, chipping debris, projectile points, "pitted stones"*; 2015 Phase IB survey did not identify any cultural deposits at top of embankment in erosion area+	Pre-contact (Middle to Late Woodland)	Fee-owned/flowage (in active erosion area)	Undetermined Phase IB survey (ineligible in tested erosion area only, pending VTSHPO concurrence)
VT-WN-47/ unnamed	Springfield, VT	P	Recorded in 1978 as unidentified Native American artifacts found based on informant interview*	Pre-contact (unknown)	Flowage (no active erosion; no Project threats)	Undetermined
VT-WN-49/ Pinello's Site #14	Springfield, VT	P	Recorded in 1978 as three alleged human burials and 30 stone artifacts*	Pre-contact (unknown)	Flowage (no active erosion; no Project threats)	Undetermined

State Inventory Number/ Name	Town	Site Type[a]	Brief Description[b]	Temporal/ Cultural Affiliation	Location Relative to the Project/ Effects	National Register Eligibility
VT-WN-61/ Hoyt's Landing	Springfield, VT	P	Recorded in 1986 as two hearths, chipping debris, fire-cracked rock, potter, calcined bone, charred nutshells*	Pre-contact (Woodland)	Flowage (no active erosion; no Project threats)	Eligible (November 24, 1990)
VT-WN-102/ Blais 16-NV1 and 16-NV2	Springfield, VT	P	Recorded in 1983 as five hearths, fire-cracked rock, potter, chipping debris, burnt butternut shells, calcined bone*	Pre-contact (unknown)	Fee-owned/flowage (partially in active erosion area)	Undetermined Phase IB (potential for deeply buried cultural deposits, pending VTSHPO concurrence)
VT-WN-103/ Blais 16-NV3	Springfield, VT	P	Recorded in 1983 as three hearths, fire-cracked rock, pottery, calcined bone, chipping debris, shell*	Pre-contact (unknown)	Flowage (no active erosion; no Project threats)	Undetermined
VT-WN-186/ Oak Knoll Farm	Windsor, VT	P	Recorded in 1992 as multiple features (living surfaces/ hearths, chipping debris, fire-cracked rock, calcined bone, shell, burnt maize, one human burial (relocated)	Pre-contact (Woodland)	Flowage (no active erosion; no Project threats)	Eligible (June 4, 1997)

State Inventory Number/ Name	Town	Site Type[a]	Brief Description[b]	Temporal/ Cultural Affiliation	Location Relative to the Project/ Effects	National Register Eligibility
VT-WN-187/ Colonel Barrett's	Springfield, VT	PH	*Pre-contact*: Recorded in 1993 as one projectile point, pestle, anvil stones, chipping debris, and pottery.* *Historic*: Recorded in 1993 as nails, ceramics, and glass, possibly associated with the eighteenth century blockhouse nearby*	Pre-contact (Middle Woodland); Euro-American (early eighteenth century)	Fee-owned/flowage (no active erosion or other Project impacts or threats noted during the 2013 Phase IA survey)	Undetermined
VT-WN-192/ Blais	Springfield, VT	P	Recorded in 1998 as hearths*	Pre-contact (unknown)	Fee-owned/flowage (partially in active erosion area)	Undetermined Phase IB (potential for deeply buried cultural deposits, pending VTSHPO concurrence)
VT-WN-260/ Reddick	Windsor, VT	P	Recorded in 1998 as three pieces of quartz chipping debris*	Pre-contact (unknown)	Flowage (no active erosion/no Project threats)	Undetermined
VT-WN-450/ unnamed	Springfield, VT	P	Recorded in 2003 as two hearths*	Pre-contact (unknown)	Flowage (no active erosion/no Project threats)	Undetermined

State Inventory Number/ Name	Town	Site Type[a]	Brief Description[b]	Temporal/ Cultural Affiliation	Location Relative to the Project/ Effects	National Register Eligibility
VT-WN-453/ unnamed	Springfield, VT	P	Recorded in 2008 as two to three possible living surfaces, two projectile points*	Pre-contact (Late Archaic)	Fee-owned/flowage (partially in active erosion area)	Undetermined Phase IB (potential for deeply buried cultural deposits, pending VTSHPO concurrence)
VT-WN-454/ unnamed	Springfield, VT	P	Recorded in 2008 as projectile points, chipping debris, hammerstones, pottery, mostly surface collected*	Pre-contact (Late/Terminal Archaic)	Flowage (no active erosion; no Project threats)	Undetermined
VT-WN-464/ River Fog	Weathersfield, VT	P	Recorded in 2010 as chipping debris, possibly in a secondary context*	Pre-contact (unknown)	Flowage (no active erosion; no Project threats)	Ineligible (June 28, 2011)
VT-WN-473/ Oak Knoll Farm II	Windsor, VT	P	Recorded in 2013, Phase IA survey: Three pieces of quartz chipping debris	Pre-contact (unknown)	Flowage (no active erosion; no Project threats)	Undetermined
VT-WN-474/ Jarvis	Weathersfield, VT	P	Recorded in 2013, Phase IA survey: Five-meter-long, black soil stain with a localized fire-reddened patch; probably hearth and/or living surface	Pre-Contact (unknown)	Flowage (no active erosion; no Project threats)	Undetermined

State Inventory Number/ Name	Town	Site Type[a]	Brief Description[b]	Temporal/ Cultural Affiliation	Location Relative to the Project/ Effects	National Register Eligibility
VT-WN-475/ Skitchewaug River Road	Springfield, VT	P	Recorded in 2013, Phase IA survey: Low density of quartz and quartzite chipping debris originally identified by the Licensee in 1997	Pre-contact (unknown)	Flowage (no active erosion; no Project threats)	Undetermined
VT-WN-476/ Lower Black River Bridge	Springfield, VT	H	Recorded in 2013, Phase IA survey: A pair of old bridge abutments	Euro-American (1860-1929; may be earlier, but no later than 1959	Flowage (no active erosion; no Project threats)	Undetermined

a. P – Strictly pre-contact, PH – Multi-component site with pre-contact and post-contact components, H – strictly post-contact.

b. * – No exposed cultural materials identified during Phase IA reconnaissance survey (Hubbard et al., 2013b).
   [+] – Cultural deposits identified during Phase IB identification surveys (Elquist and Cherau, 2016a, 2015).

Vernon Project

Archival research including an analysis of historic maps and town histories undertaken for the 2008 Phase IA survey of the Vernon Project documented 26 resource locations within or immediately adjacent to the Project APE that could contain post-contact archaeological sites (18 in Vermont and 8 in New Hampshire; Table 3.11-8 and Table 3.11-9). The 26 documented resources have not been identified archaeologically and their National Register eligibility is currently undetermined. These documented resource locations were not accessible, are outside of the surveyed areas, contain standing structures, or did not have any visible archaeological remains.

The 2008 Phase IA survey and research identified 13 recorded archaeological sites in the Project APE: 11 in Vermont on fee-owned and private flowage lands and 2 in New Hampshire on fee-owned and private flowage lands (Table 3.11-10). Prior to the Phase IA survey, 2 of these recorded sites had been determined eligible for listing in the National Register (1 of which could also be an unlisted National Historic Landmark), and 1 site had been determined potentially eligible for listing in the National Register. The National Register eligibility of the other 10 previously recorded sites within the Vernon Project APE is currently undetermined. The 2008 Phase IA survey also identified one other archaeological site reported in 1991 as part of a cultural resources management survey for a private utility company. The site consists of a seventeenth century "Indian encampment," possibly on fee-owned lands at Coopers Point in Hinsdale, NH. The site area was not assigned a NH state archaeological site inventory number because it has not been verified through subsurface testing and its National Register eligibility is undetermined. The 2014 Phase IA survey update for the Vernon Project APE identified one pre-contact site (27-CH-197/Find Spot #1 [Site number assigned by NHSHPO]) on private flowage lands in Chesterfield, NH, based on the presence of two pieces of lithic debitage eroding out of the riverbank. The National Register eligibility of this site is undetermined because landowner access was not granted to conduct Phase IB survey.

The 2008 and 2014 Phase IA surveys also identified approximately 43 miles of the Vernon Project shoreline (on both sides of the river) as archaeologically sensitive, including the locations of documented resources and recorded sites, of which approximately one mile (11 areas) was identified as being in active erosion areas. On the Vermont side of the river, 6 sensitive areas of active erosion were identified, and on the New Hampshire side of the river, 5 sensitive areas of active erosion were identified. However, subsequent Phase IB field surveys of eroding shoreline were only conduced on lands owned in fee or on private flowage lands where landowner permissions for access were obtained. This resulted in Phase IB surveys being conducted in 3 of the 6 archaeologically sensitive active erosion areas on the Vermont side of the river, and in none of the 5 archaeologically sensitive active erosion areas on the New Hampshire side of the river, totaling approximately 0.3 mile of shoreline. Phase IB investigations of the remaining 8 sensitive erosion areas were not conducted because property owners either did not respond to inquiries or denied access for study purposes. As a result, approximately 42.7miles of archaeologically sensitive shoreline within the Vernon Project APE was not surveyed; 0.7 mile of this shoreline also contained active erosion.

On the Vermont side of the river, the 6 archaeologically sensitive erosion areas targeted for Phase IB surveys in the Vernon Project APE contained 1 site (VT-FS-6 [WD]) in Putney. Landowner permission to conduct Phase IB surveys was granted on private lands that did not contain any previously recorded sites. The Phase IB surveys identified 2 new pre-contact sites in Putney. The Putney Brook North Site (VT-WD-354) yielded lithic debitage and ground and chipped stone tools and the Putney Brook South Site (VT-WD-355) yielded lithic debitage. Both sites were considered to represent small resource procurement camps that had the potential to provide information relating to pre-contact riverine adaptations along the Lower Connecticut River Valley in Vermont. They were recommended potentially eligible for listing in the National Register and Phase II site evaluation was recommended. No new archaeological sites were identified during the Phase IB survey on the Vermont side of the Connecticut River.

The VTSHPO did not provide formal concurrence on the National Register-eligibility recommendations for the Vermont sites identified during the Phase IB surveys. However, on April 20, 2016, the VTSHPO concurred with the recommended Phase II evaluations and approved the proposed Phase II evaluation methodology at the two pre-contact sites recommended as potentially National Register eligible (see Table 3.11-1). The Putney Brook North Site (VT-WD-354) yielded a high density concentration of lithic debitage, designated Locus 1 and less amounts of lithic materials and a shallow pit feature designated Locus 2. The feature produced a radiocarbon date to the Middle Woodland Period and the cultural deposits possess good physical integrity, and the site is recommended as eligible for listing in the National Register. The Putney Brook South Site (VT-WD-355) produced lithic debitage, chipped stone tools including a Late Woodland projectile point, and aboriginal pottery. However, the cultural deposits were recovered in a questionable subsurface context that includes re-deposition from an upper terrace landform. Because of the poor physical integrity of the cultural deposits in the erosion area, and the potential for intact, significant deposits on the upper terrace outside the Project APE, the site's National Register eligibility remains undetermined. The Phase II evaluation report was submitted to the VTSHPO for review on December 1, 2016; no written comments have yet been received.

On the New Hampshire side of the river, one of the 5 archaeologically sensitive erosion areas targeted for Phase IB surveys in the Vernon Project APE contained recorded site 27-CH-197. No landowner permission to conduct Phase IB surveys was granted for any of the sensitive areas with active erosion, so no Phase IB or Phase II surveys have been conducted on the New Hampshire side of the river in Vernon Project APE.

Table 3.11-8. Documented post-contact resources within or directly adjacent to the Vernon Project APE (Vermont).

Survey ID Number	Description	Identification on Historic Maps					Notes	National Register Eligibility
		McClellan (1856)	Beers (1869)	USGS (1893)	USGS (1930)	USGS (1957a)		
B-1	Dwelling	Appears as *A. Steward*		X				Undetermined
B-2	Mill building	Appears as *Hines Newman & Co. machine shop and steam mill*	Appears as *E. Tyler Foundry*					Undetermined
B-3	Industrial building	Appears, unlabeled	Appears as *Gas Works SMW*					Undetermined
B-4	Industrial building	Appears, unlabeled	Appears as *Flour & Grain Store House Coal Shed SMW*					Undetermined
B-5	Industrial building	Appears, unlabeled						Undetermined
B-6	Industrial building		Appears as *SMW Coal Shed*	X		X		Undetermined
B-7	Industrial building		Appears as *E. Crosby & Co. Flour Store*					Undetermined

Survey ID Number	Description	Identification on Historic Maps					Notes	National Register Eligibility
		McClellan (1856)	Beers (1869)	USGS (1893)	USGS (1930)	USGS (1957a)		
B-8	Industrial building		Appears as *Flour & Salt Store Frost & Goodhue*					Undetermined
B-9	Industrial building		Appears, unlabeled					Undetermined
B-10	Railroad spur		Appears					Undetermined
B-11	Dwelling (?)	Part of Mrs. S. Brooks Dummer Farm?	Appears, unlabeled	X			Partial fee-owned, near shoreline; no archaeological evidence of site identified during 2008 or 2014 Phase IA surveys; no Project impacts or threats noted during either survey including the 2014 archaeological monitoring program under the existing 2008 Vernon Project HPMP	Undetermined
D-1	Dwelling/ferry landing	Appears as *M. Smith*	Appears					Undetermined

Survey ID Number	Description	Identification on Historic Maps					Notes	National Register Eligibility
		McClellan (1856)	Beers (1869)	USGS (1893)	USGS (1930)	USGS (1957a)		
D-2	Dwelling/ferry landing	Appears as *T. Clark*	Appears as *E. Clark*	X	X	X		Undetermined
P-1	Dwelling	Appears as *T. White*						Undetermined
P-2	Ferry landing	No structures	No structures					Undetermined
P-3	Dwelling, associated with ferry landing?	Appears as *M. Pierce*	Appears as *M. Pierce*					Undetermined

Survey ID Number	Description	Identification on Historic Maps					Notes	National Register Eligibility
		McClellan (1856)	Beers (1869)	USGS (1893)	USGS (1930)	USGS (1957a)		
V-1	Vernon dam worker's camp				X	X	Fee-owned, above shoreline; no archaeological evidence of site identified during 2008 or 2014 Phase IA surveys; no Project impacts or threats noted during either survey including the 2014 archaeological monitoring program under the existing 2008 Vernon Project HPMP	Undetermined
W-1	Bridge abutments							Undetermined

Table 3.11-9. Documented post-contact resources within or directly adjacent to the Vernon Project APE (New Hampshire).

Survey ID Number	Description	Identification on Historic Maps						Notes	National Register Eligibility
		Fagan (1858)	Hurd (1892)	USGS (1893/98)	USGS (1935b)	USGS (1954)	USGS (1957a)		
Wa-1	Bridge	Appears	Appears		X	X	X	New bridge built in 1910	Undetermined
We-1	Ferry	Appears as *Britton's Ferry*	Appears	Appears as *Wares Ferry*					Undetermined
We-2	Ferry	Appears	Appears as *Wares Ferry*	Appears?					Undetermined
C-1	Ferry	Appears as *Davis Ferry*	Appears as *Gibsons Ferry*	Appears					Undetermined
C-2	Dwelling	Appears as *R.H. Davis*	Appears as part of ferry	Appears, unlabeled	X	X			Undetermined
C-3	Ferry	Appears as *Norcross Ferry*	Appears as *Houghton Ferry*	Appears, unlabeled	X	X			Undetermined
C-4	Eighteenth century log cabin (Moses Smith)							Town histories	Undetermined
H-1	Shattucks Fort (eighteenth century)	Appears as *"site"*						1930 submerged by dam constructed in 1907	Undetermined

Table 3.11-10 presents the current status of 16 recorded archaeological sites at the Vernon Project, including 3 newly identified pre-contact sites (2 in Vermont and 1 in New Hampshire). Of the 16 recorded sites, 2 are eligible for listing in the National Register, 1 is recommended eligible, and 1 is recommended potentially eligible. The National Register eligibility of the other 12 recorded sites is currently undetermined because these sites are not located in active erosion areas, are not threatened by current Project operations, or are in areas that were not accessible for further study (i.e., no landowner access granted).

Table 3.11-10. Recorded pre-contact and post-contact archaeological sites within or directly adjacent to the Vernon Project APE.

State Inventory Number /Name	Town	Site Type[a]	Brief Description[b]	Temporal/ Cultural Affiliation	Location Relative to the Project	National Register Eligibility
27-CH-85/ Squakheag Fort/Fort Hill	Hinsdale, NH	P	Features, projectile points, ceramics. glass trade beads, chipping debris (chert, schist)*	Late Woodland/ Contact period village	Fee-owned (included in existing 2008 Vernon Project HPMP-surveillance program in place between the Licensee, NHSHPO and local police; no active erosion or Project impacts or threats noted during the 2008 and 2014 Phase IA surveys including the 2014 archaeological monitoring program)	Eligible; possible National Historic Landmark (not listed)
VT-FS-06 (WD)/ Fort Putney	Putney, VT	H	Recorded location somewhere in Great Meadows-no identified remains*	ca 1755 to ca 1760	Flowage (no active erosion; no Project threats)	Undetermined
VT-FS-15 (WD)/ King Philip's Encampment	Vernon, VT	P	Reported Native American encampment during King Philip's War—no finds, local tradition*	17th Century King Philips War 1675-1676	Flowage (no active erosion; no Project threats)	Undetermined

State Inventory Number /Name	Town	Site Type[a]	Brief Description[b]	Temporal/ Cultural Affiliation	Location Relative to the Project	National Register Eligibility
VT-WD-01/ unnamed	Vernon, VT	P	Recorded in the late 1950s/early 1960 as groundstone pestle, copper beads, poundstone, pottery, burials*	Contact/early historic period?	Fee-owned (exact site location below the dam is unconfirmed) (in FERC Project recreational area; no active erosion or other Project impacts or threats noted during the 2008 and 2014 Phase IA surveys including the 2014 archaeological monitoring program)	Undetermined
VT-WD-03/ "North Bridge" or West River	Brattleboro, VT	P	Recorded in the late 1950s/early 1960s as ground and chipped stone tools, aboriginal pottery*	Early Archaic; Late Archaic (Laurentian); Middle Woodland; Late Woodland	Flowage (no active erosion; no Project threats)	Undetermined
VT-WD-05/ unnamed	Vernon, VT	P	Recorded in the late 1950s/early 1960s as groundstone hammer, pestle, mortar, projectile points*	Unknown	Flowage (no active erosion; no Project threats)	Undetermined
VT-WD-07/ West River Petroglyphs	Brattleboro, VT	P	Recorded in 1968 as the West River petroglyphs	Unknown	Flowage (submerged)	Undetermined

State Inventory Number /Name	Town	Site Type[a]	Brief Description[b]	Temporal/ Cultural Affiliation	Location Relative to the Project	National Register Eligibility
VT-WD-08 (WD)/ unnamed	Vernon, VT	P	Recorded in 1978 as aboriginal pottery, unknown artifacts in Needham Collection*	Unknown	Flowage (no active erosion; no Project threats)	Undetermined
VT-WD-10/ Great Bend Site	Vernon, VT	P	Recorded in 1978 as projectile points, glass trade bead, copper beads, copper "Thunderbird," gorge, gorget, nutting stones, pestle, pottery*	Archaic through Woodland periods; Squakheag Village—contact/early historic period	Flowage (no active erosion/no Project threats)	Eligible (August 2, 1990)
VT-WD-13/ Fort Dummer	Brattleboro, VT	H	Recorded in 1976 as stone foundation remains of fortification and possible nineteenth century building; associated artifact assemblage*	Nineteenth century	Partial Fee-owned and Flowage (submerged in impoundment; no shoreline impacts or Project threats noted during the 2008 and 2014 Phase IA surveys including the 2014 archaeological monitoring program)	Undetermined
VT-WD-18/ unknown	Dummerston, VT	P	No form on file-location only*	No information	Flowage (no active erosion; no Project threats)	Undetermined

State Inventory Number /Name	Town	Site Type[a]	Brief Description[b]	Temporal/ Cultural Affiliation	Location Relative to the Project	National Register Eligibility
VT-WD-34/ unnamed	Brattleboro, VT	P	Recorded in 1984 as two loci: Northern one heavily disturbed, southern one yielded quartz and quartzite flakes, large quartzite scraper and fire-cracked rocks*	Paleoindian and/or Early Archaic Period (?)	Flowage (no active erosion; no Project threats)	Recommended Potentially Eligible
VT-WD-354/ Putney Brook North (new)	Putney, VT	P	Recorded in 2015 and 2016, Phase IB and Phase II: lithic debitage, chipped stone tools, cooking pit that produced a Middle Woodland radiocarbon date+	Pre-contact (Middle Woodland)	Flowage (in active erosion area)	Recommended Eligible Phase II (pending VTSHPO concurrence)
VT-WD-355/ Putney Brook South (new)	Putney, VT	P	Recorded in 2015 and 2016, Phase IB and Phase II: Lithic debitage, chipped stone tools, and aboriginal pottery+	Pre-contact (Late Woodland)	Flowage (in active erosion area)	Undetermined Phase II (redeposited materials in tested portion) (Pending VTSHPO concurrence)

State Inventory Number /Name	Town	Site Type[a]	Brief Description[b]	Temporal/ Cultural Affiliation	Location Relative to the Project	National Register Eligibility
None yet assigned	Hinsdale, NH	P	Reported in 1991 by UMass for Northeast Utilities Project, as an "Indian encampment"	Suspected part of King Philip's winter encampment 1676-1676	Fee-owned (exact site location is unconfirmed) (in FERC Project designated open space area-only accessible by foot; no active erosion or other Project impacts or threats noted during the 2008 and 2014 Phase IA surveys including the 2014 archaeological monitoring program)	Undetermined
27-CH-197/ Find Spot #1 (new), Site number assigned by NHSHPO	Chesterfield, NH	P	2014 Phase IA update: 2 lithic debitage+	Pre-contact (unknown)	Flowage (in active erosion area; no landowner access for Phase IB survey)	Undetermined

a. P – Strictly pre-contact, H – strictly post-contact.

b. * – No exposed cultural materials identified during Phase IA reconnaissance survey (Cherau and O'Donnchadha, 2008).
[+] – Cultural deposits identified during the Phase IA update (Cherau and Duffin, 2014), Phase IB identification surveys (Elquist and Cherau, 2016a, 2015), and Phase II site evaluations (Elquist and Cherau, 2016c).

3.11.1.3 Historic Architectural Properties

The Wilder, Bellows Falls, and Vernon Projects have been the subject of a number of studies that have resulted in their identification as historic districts that are eligible for listing in the National Register. Components of the Bellows Falls Project were evaluated for National Register eligibility in 1982, when a portion of the Bellows Falls Canal was listed in the National Register as a contributing resource within the Bellows Falls Downtown Historic District (Henry, 1981). The Bellows Falls Island Multiple Resource Area was subsequently listed in the National Register in 1990 and included a number of historic resources on Bellows Falls Island associated with the industrial development of the area during the nineteenth and early twentieth centuries. The Bellows Falls Hydroelectric Powerhouse was named in the documentation as a contributing resource but was not listed in the National Register because of owner objections (Mulholland et al., 1988). In accordance with the Section 101(a)(6) of the NHPA, the Keeper of the National Register determined the property to be eligible for listing.

In 1992, the Bellows Falls and Vernon Projects were identified as properties eligible for listing in the National Register as historic districts under the Hydroelectric Generating Facilities in Vermont Multiple Property Submission (Bowers, 1992). The Vermont Multiple Property Submission, which was signed by the Keeper of the National Register in 2004, provides the overall context and registration requirements for listing individual hydroelectric power facilities constructed in Vermont between 1882 and 1941. However, documentation to add the Bellows Falls and Vernon Projects to the National Register under the Vermont Multiple Property Submission was never prepared.

The first comprehensive inventory of historic architectural resources within the FERC boundaries of the Wilder, Bellows Falls, and Vernon Projects was compiled in the Deerfield and Connecticut River Hydroelectric Projects System-wide Historical and Photographic Documentation completed in 1999 (Doherty and Kierstead, 1999, hereinafter referred to as the "system-wide documentation"). The purpose of the system-wide documentation was to identify and evaluate historic architectural resources within the FERC boundaries of all the hydroelectric developments owned by the Licensee on the Deerfield and Connecticut rivers in Massachusetts, New Hampshire, and Vermont. Survey information was used to prepare state-level written and photographic archival documentation as a permanent record of the historic developments and to serve as a baseline for assessing the impacts of subsequent Project-related undertakings. The system-wide documentation included a historic context statement for the development of hydroelectric power facilities on the two rivers and information about all individual aboveground resources within the Project boundaries that contribute to their historical significance. Copies of the documentation for the Connecticut River Projects, including the Wilder, Bellows Falls, and Vernon Projects, were submitted to the VTSHPO and NHSHPO for transmittal to the states' archives and local archival repositories in the vicinity of the Projects.

In 2006–2008, a project to upgrade the generating capacity at the Vernon Project required an amendment to the FERC license. In accordance with Section 106 of the NHPA, FERC and the Licensee at that time consulted with the VTSHPO and NHSHPO and other parties regarding the upgrade's effects on historic properties and determined that the Vernon Project was eligible for listing in the National Register as a historic district. The effects of the proposed 2006–2008 upgrade on the historic powerhouse were resolved through the execution of a Memorandum of Agreement that specified a variety of mitigation activities, including the preparation of an HPMP. Completed and approved in 2008, the HPMP specifies the treatment and management of historic properties within the Vernon Project boundaries (Olausen and Cherau, 2008).

The most recent study was a historic architectural resources survey conducted for the current relicensing effort as part of Study 33. The study report included a summary of past investigations, assessed the current condition of the resources, and evaluated the potential eligibility of the Projects for listing in the National Register as historic districts. The report was submitted to the VTSHPO and NHSHPO for review in May 2015. By a letter dated June 29, 2015, the NHSHPO requested that the information be broken out into its Project Area Form format. A separate form was prepared for each of the three Projects and submitted to the NHSHPO for review on July 30, 2015. By letter dated August 27, 2015, the NHSHPO evaluated the resources of the Wilder Project within New Hampshire as eligible for listing in the National Register. The VTSHPO did not comment on the report. We therefore assume the VTSHPO's concurrence with the report's conclusions that the resources associated with the development and operation of the Wilder, Bellows Falls, and Vernon Projects are eligible for listing in the National Register as part of a potential historic district at each Project. The findings of the evaluation are summarized below.

Wilder Project

The Wilder Hydroelectric Project Historic District was evaluated eligible for listing in the National Register under Criteria A and C at the state level in the areas of Industry, Engineering, and Architecture. Under Criterion A, the district derives its primary significance from its contribution to the broad patterns of economic and social history in New Hampshire and Vermont. The Wilder Project was an important component of the system of six hydroelectric facilities designed to serve the southern New England electrical market that were built by the New England Power Company and related corporations on the Connecticut River in 1909–1957. Vermont hydroelectric stations historically served as the principal source of electricity in the state and thus have contributed to its industrial and economic development. Under Criterion C, the district is significant for its embodiment of mid-twentieth-century hydroelectric project engineering, as evidenced by its massive dam consisting of a 2,200-ft-long, curving, earth-berm section and straight 680-ft-long, concrete spillway; a steel and brick powerhouse; and a vertical-shaft turbine and generator configuration using Kaplan-type, variable-pitch propeller turbines set in specially cast concrete spiral scroll cases and draft tubes. This type of purpose-built, hydroelectric project represented the maturation of large-scale, river-powered, electrical generation facilities and, in its adoption of Kaplan turbines, the Project's continued refinement.

Completed in 1950, the Wilder Project was the second to last in the series of 14 hydroelectric projects constructed along the Connecticut and Deerfield rivers and the fifth of six Connecticut River projects constructed by Great River Hydro's predecessor companies in 1907–1957. The Wilder Project was designed to supply additional electrical generating capacity to meet peak demands during the post-World War II period when energy consumption spiked upward. The Project was built on the site of an existing hydroelectric plant at Olcott Falls that had been built in 1910 by the International Paper Company. The New England Power Association purchased the property in 1942 and obtained a license to operate the existing hydroelectric facility in 1943. It filed plans with the Federal Power Commission (predecessor of FERC) to build a new 33-MW facility in 1944. The $16-million project faced significant public opposition, however, because of the expansion of the area that would be flooded for the new impoundment. The proposed 2,000-ft-wide dam would raise the water level by 15 ft, extending the existing pond 27 miles upstream near McIndoes Hydroelectric Station. Ultimately, 1,200 acres of land, including 335 acres of farmland, were affected by flooding. In an effort to mitigate damages, the New England Power Association agreed to pay for any submerged land and to move any affected utilities, including railways and roads. Conflicts over estimates of flooding had to be resolved in court, interrupting construction on several occasions, and the Wilder redevelopment was not completed until 1950. Design and construction of the Wilder Project were completed by the New England Power Service Company and the New England Power Construction Company, respectively. Both of those firms were subsidiaries of the New England Power Association.

The completed Wilder Project ranked as the fourth largest hydroelectric development in the New England Power Association system. Technologically, the Wilder Project is typical of mid-twentieth-century hydroelectric generating facilities, which were characterized by a variety of water management techniques and standardized equipment configurations that were interconnected to provide electricity to larger areas. The Wilder powerhouse incorporates the major elements that characterize large-scale hydroelectric generating technology at the time, including multiple, vertical-shaft, variable-pitch, adjustable-blade, Kaplan-type, single-runner, large-diameter, high-horsepower, low-rpm turbines with scroll cases cast into foundations; oil-pressure vertical thrust bearings; improved tailrace draft arrangements; and electromagnetic "cabinet"-type speed governors. Architecturally, the powerhouse demonstrates the continuing evolution of the historicism that typified the design of such facilities since the electrical industry was established. Power companies had favored high-style, dignified designs that could be used to legitimize and dignify their industry by conveying a positive public image. Earlier powerhouses constructed by the New England Power Company and others favored the Renaissance Revival Style, and sometimes Romanesque Revival or Gothic styles. By the mid-twentieth century, however, the Colonial Revival Style, as evidenced at Wilder, was increasingly favored for public and utility buildings as an expression of American patriotism and ideals.

Original components of the development included the dam, powerhouse, visitors' house, two switchyards, garage, and an oil storage shed. The dam, powerhouse, and switchyards are directly related to electrical generation and distribution, while the garage and oil storage shed are ancillary utilitarian storage structures. The visitors' house is one of two such visitor facilities constructed in the New England Power Association's hydroelectric power system (the other was constructed at the Moore development in the FMF Project in 1957) (Table 3.11-11, Figure 3.11-4).

Table 3.11-11. Contributing and non-contributing resources within the Wilder Hydroelectric Project Historic District.

Resource Name	Location	Year Built	National Register Status[a]
Wilder dam	351 Wilder Dam Road, Hartford, VT; Route 10, Lebanon NH	1950	C
Wilder powerhouse	351 Wilder Dam Road, Hartford, VT	1950	C
Visitors' house	Route 10, Lebanon, NH	1950	C
Garage	Wilder Dam Road, Hartford, VT	ca. 1950	C
National Grid 13.8 kV, 47 kV, and 115 kV switchyard	Wilder Dam Road, Hartford, VT	1950	C
National Grid 115-kV switchyard	Wilder Dam Road, Hartford, VT	1950	C
Fish ladder	351 Wilder Dam Road, Hartford, VT	1987	NC

Source: Daly (2015)

a. C – resource that contributes to the significance of the historic district; NC – non-contributing resource.

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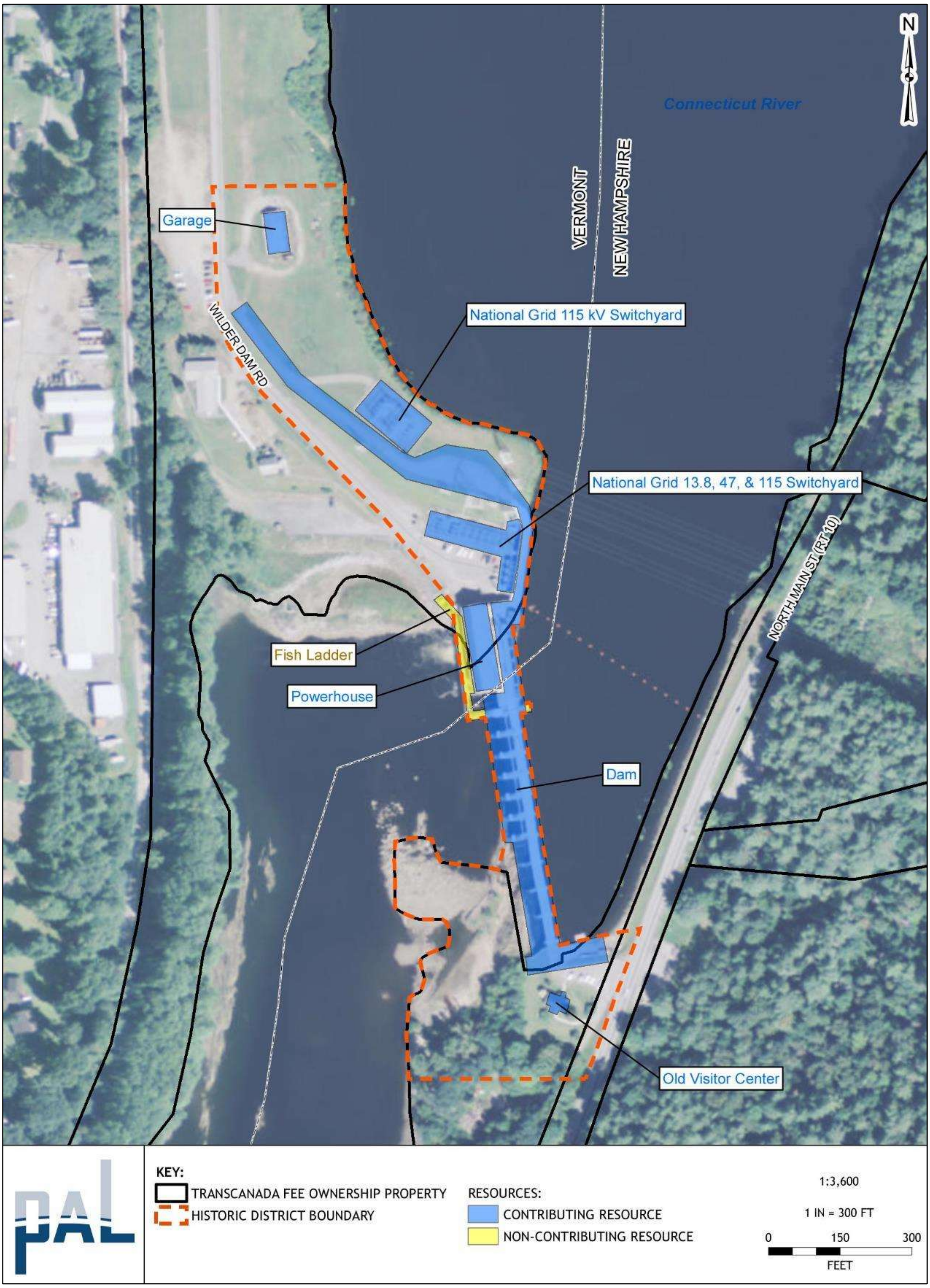

Source: Daly (2015)

Figure 3.11-4. Wilder Hydroelectric Project Historic District.

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Bellows Falls Project

The Bellows Fall Hydroelectric Project Historic District has been determined eligible for listing in the National Register under Criteria A and C at the state level in the areas of Industry, Engineering, and Architecture. Under Criterion A, the district possesses significance as an important component of the system of hydroelectric facilities constructed by the New England Power Company and its predecessor corporations on the Connecticut River in 1909–1957. Those hydroelectric stations historically served as the principal source of electricity in the region and thus contributed to its industrial and economic development during the twentieth century. Under Criterion C, the district is significant for its embodiment of early twentieth-century hydroelectric project engineering, specifically as a divided-fall project that incorporated a concrete ogee-profile dam with roller gates, a steel and brick powerhouse, and a vertical-shaft turbine and generator configuration using 1920s Francis-type, single-runner, fixed-blade turbines set in specially cast concrete spiral scroll cases and draft tubes. The development of this type of purpose-built hydroelectric project represented a significant step forward in the evolution of modern, large-scale electrical generation facilities.

The Bellows Falls Project was completed in 1928 on the site of the former Bellows Falls Canal, one of the first transportation canals constructed in the United States. The canal was chartered in 1792 to open the river to navigation around Bellows Falls and was completed in 1802. That same year, Vermont's first paper mill opened on the canal and papermaking soon became Bellows Falls' most important industry. During the ensuing years of the nineteenth century, a dense complex of water-powered mills was constructed along the canal at the south end of Bellows Falls Island and immediately adjacent areas to the west. In 1912, Chace & Harriman purchased the canal company and two small hydroelectric companies and reorganized them into a subsidiary called the Bellows Falls Power Company. In 1918, Chace & Harriman enlarged the canal and erected a new and larger power station with a share of the resultant electricity to be guaranteed to the paper mills.

The paper industry suffered a significant decline in the 1920s. Seeking another form of investment to stay viable, International Paper Company, the area's largest paper manufacturer, merged with Chace & Harriman to become the New England Power Association in 1926. By that time, the construction of the Bellows Falls Project was already underway. During the following 2 years, a dam and gauge house were constructed near the head of the canal and the canal itself was straightened and modified to supply water to a new powerhouse. When the Project was completed in 1928, it had a generating capacity of 40,800 kW, making it one of the region's most important electrical generation facilities.

The three primary contributing resources in the Bellows Fall Hydroelectric Development Historic District are the dam, canal, and powerhouse that are associated with the facility's function as a hydroelectric power generating facility. Various ancillary structures also contribute to the significance of the district: the red barn, gauge house, six-man garage, line shed, two switchyards, crew shack, and tailrace. Non-contributing structures consist of the fish ladder and visitors' center, both completed in 1984 (Table 3.11-12, Figure 3.11-5).

Table 3.11-12. Contributing and non-contributing resources within the Bellows Falls Hydroelectric Project Historic District.

Resource Name	Location	Year Built	National Register Status[a]
Red barn	Pine Street at CT River, North Walpole, NH	1894–1901	C
Six man garage	Bridge Street, east of Canal, Bellows Falls, Rockingham, VT	1875–1880	C
Gauge house	Intersection of Church and River Sts., North Walpole, NH	ca. 1927	C
Bellows Falls dam	Intersection of Church and River Sts., North Walpole, NH	1927	C
Canal	Canal Street, between Green Mountain RR Bridge and Powerhouse, Bellows Falls, Rockingham, VT	1927	C
Bellows Falls powerhouse	12 Mill Street, Bellows Falls, Rockingham, VT	1928	C
115-kV switchyard	12 Mill Street, Bellows Falls, Rockingham, VT	1928	C
46/69-kV switchyard	12 Mill Street, Bellows Falls, Rockingham, VT	1928	C
Tailrace	CT River, south of Powerhouse, Bellows Falls, Rockingham, VT, and North Walpole, NH	1928	C
Crew shack	Intersection of Church and River Sts., North Walpole, NH	ca. 1930	C
Line shed	Mill Street, Bellows Falls, Rockingham, VT	ca. 1955	C
Visitors' center	17 Bridge Street, Bellows Falls, Rockingham, VT	1984	NC
Fish ladder	17 Bridge Street, Bellows Falls, Rockingham, VT	1984	NC

Source: Daly (2015)

a. C – resource that contributes to the significance of the historic district; NC – non-contributing resource.

Source: Daly (2015)

Figure 3.11-5. Bellows Falls Hydroelectric Historic District.

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Vernon Project

The Vernon Hydroelectric Project Historic District has been determined eligible for listing in the National Register under Criteria A and C at the state level in the areas of Industry, Engineering, and Architecture. Under Criterion A, the district derives its primary significance as the first large-scale hydroelectric development constructed in New England. Developed by Chase & Harriman, which went on to form the largest power generating concern in the region, Vernon dwarfed the output of any hydroelectric plant east of Niagara Falls at the time of its completion in 1909. It was the first hydroelectric plant in the Northeast built to deliver energy via long-distance transmission lines and therefore contributed substantially to the economic development of central Massachusetts and southeastern Vermont. Under Criterion C, the district embodies early twentieth-century hydroelectric engineering concepts through its concentrated-fall type arrangement consisting of an incorporated concrete ogee-profile dam and a connected Renaissance Revival-style steel and brick powerhouse.

The development of this type of purpose-built hydroelectric development represented a significant step in the evolution of modern, large-scale electrical generation facilities. The Vernon Hydroelectric Development Historic District powerhouse and dam also possess significance under Criterion C in the area of Engineering as a work of the significant hydroelectric designer Charles (Chas.) T. Main, Inc.

In the early part of the twentieth century, several bankers and merchants in Brattleboro, Vermont, had obtained New Hampshire and Vermont charters to develop hydroelectric power along the Connecticut River which, with its many waterfalls, had attracted mills since the Colonial Period. In 1907, when the charter holders identified Vernon as a potential site for development, Chace & Harriman took control of the development project, convincing local investors to sign over their charters in exchange for a share of the power. Chace & Harriman's ambitious plan was to build a facility that could send power over high-voltage lines to industries in north-central Massachusetts, a great deal farther than the maximum 35 miles recommended by engineers at the time. Chace & Harriman founded the Connecticut River Power Company and received special permission to enter the Massachusetts market, provided that they establish a Massachusetts-based company as well. Thus they established the Connecticut River Transmission Company of Massachusetts.

Construction began at the Vernon site in 1907, after Chace & Harriman had obtained the land and flowage rights to raise the river 30 ft and flood all or parts of 150 farms. The design of the facility was largely the work of the engineering firm of Charles (Chas.) T. Main, Inc., of Boston. The dam was the first structure of the facility to be completed. Main employed a concrete gravity design that relied on the dam's weight and bedrock foundation to hold back the water behind it. This type of dam was a departure from the rock-filled wooden crib dams that were typical in New England at the time and came into standard use in the region during the first quarter of the twentieth century. When the powerhouse was completed in 1909, its eight generating units produced 20,000 kW, a far greater output than any other hydroelectric station then in operation east of the Niagara Falls Hydroelectric Project. Transformers at Vernon raised the line voltage to 66 kV, enabling it to be transmitted more than 60 miles to Gardner and Fitchburg, Massachusetts, a voltage and distance unprecedented in New England at the time. Capacity was further expanded in 1920 when the powerhouse was extended 112 ft to the west to accommodate two new General Electric 4,200-kW vertical-shaft generators. The most significant hydroelectric components of the Vernon Hydroelectric Project Historic District are the powerhouse and dam. An additional six ancillary structures—the switchyard, crew shack, hoister house, pump house, superintendent's house, and superintendent's garage—are contributing structures. Non-contributing elements consist of the fish ladder constructed in 1981 (Table 3.11-13, Figure 3.11-6).

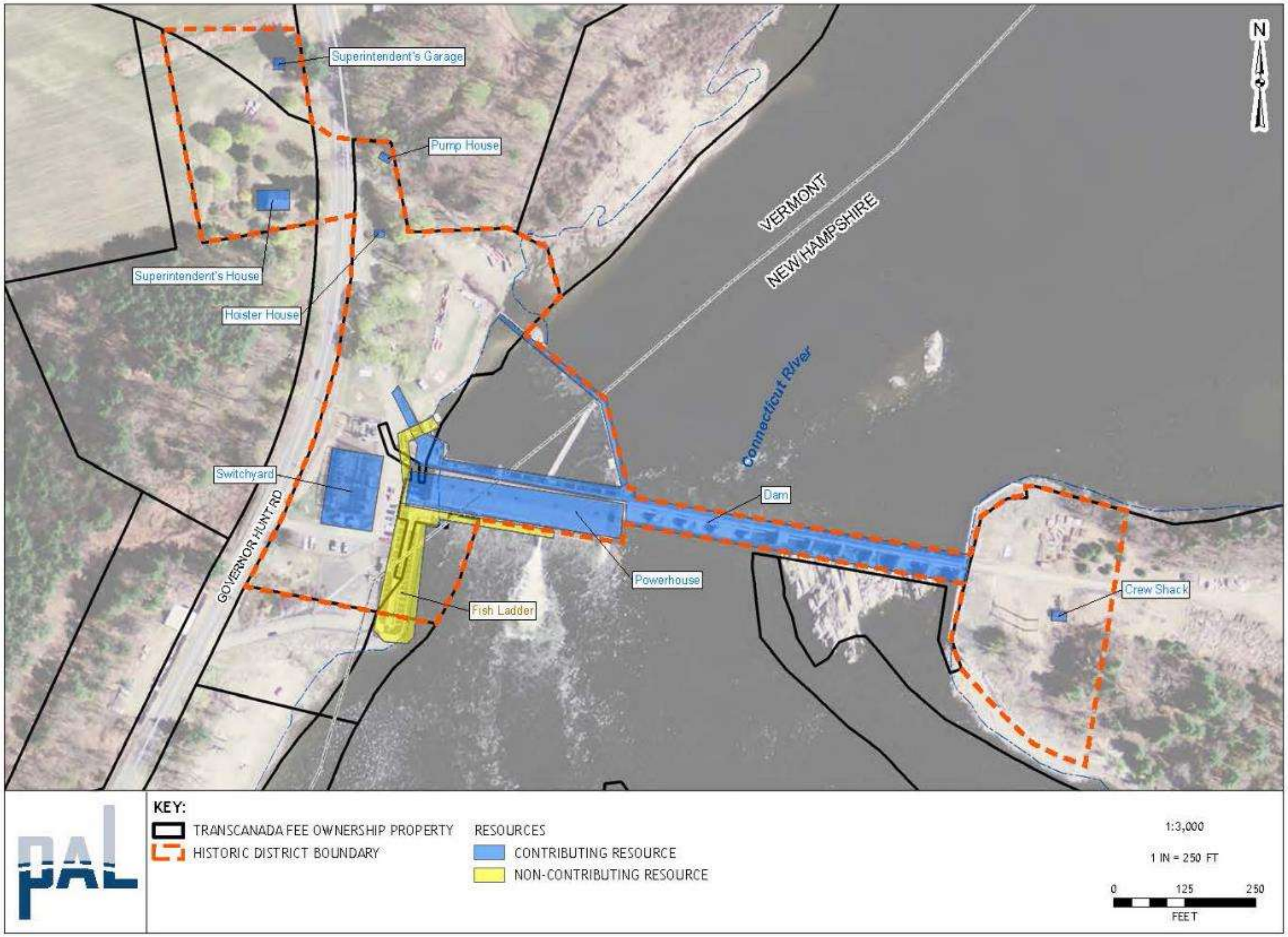
Although the Vernon Project has had substantial modifications of its dam and power generation units, the historic district retains the physical features (as defined in Hydroelectric Generating Facilities in the Vermont Multiple Property Submission) to demonstrate its associations with early twentieth-century hydroelectric power generation and its engineering and architectural significance. The development retains its location and setting on the Connecticut River. The facility's overall design, materials, and workmanship as a concentrated-fall facility with vertical-shaft generation infrastructure within a Renaissance Revival Style powerhouse is preserved, with the spatial and functional relationship among the development's principal components readily discernible. The property expresses its feeling as an early twentieth-century hydroelectric development and its associations with the development of the hydroelectric power generation industry during that era.

Table 3.11-13. Contributing and non-contributing resources within the Vernon Hydroelectric Project Historic District.

Resource Name	Location	Year Built	National Register Status[a]
Superintendent's house	255 Governor Hunt Road, Vernon, VT	1907	C
Superintendent's garage	255 Governor Hunt Road, Vernon, VT	1907	C
Crew shack	East end of Vernon dam, Hinsdale, NH	1909	C
Vernon powerhouse	152 Governor Hunt Road, Vernon, VT	1909, 1920	C
Vernon dam	152 Governor Hunt Road, Vernon, VT	1909	C
Hoister house	Governor Hunt Road, Vernon, VT	1909	C
Pump house	Governor Hunt Road, Vernon, VT	1909	C
Switchyard	152 Governor Hunt Road, Vernon, VT	1909, 1920	C
Fish ladder	152 Governor Hunt Road, Vernon, VT	1981	NC

Source: Daly (2015)

[a] C – Resource that contributes to the significance of the historic district; NC – non-contributing resource.



Source: Daly (2015)

Figure 3.11-6. Vernon Hydroelectric Project Historic District.

3.11.1.4 Traditional Cultural Properties

ILP Study 33, *Cultural and Historic Resources Study* required conducting a Traditional Cultural Properties (TCP) study for the Wilder, Bellows Falls, and Vernon Projects. The purpose of the study was to review existing literature and provide baseline information that could be used in consultation and coordination with Tribes to identify TCPs and Historic Properties of Cultural and Religious Significance to Indian Tribes.

Letters dated October 30, 2012, accompanying the Notices of Intent (NOI) to File Application of New License, including hyperlinks to the Preliminary Application Documents (PADs) for each Project together with a postage-paid return postcard for indicating interest in continued participation in the relicensing process were sent to: Sovereign Abenaki Nation of Missisquoi; Cowasuck Band – Pennacook/ Abenaki People; Koasek Traditional Band of the Koas Abenaki Nation; and the Koasek Traditional Band of the Sovereign Abenaki Nation in an effort to reach out to leaders of Abenaki Tribes or Bands. No return postcards or any return written correspondence or verbal communication indicating interest were received.

Solicitation of Interest letters dated November 8, 2012, and November 17, 2012, were sent by FERC to the Mashpee Wampanoag Tribe and Wampanoag Tribe of Gay Head. Follow-up conversations and voice messages were made by FERC staff in December 2012. Neither Tribe indicated an interest in the relicensing proceeding. The Narragansett Indian Tribe of Rhode Island expressed an interest in the relicensing proceeding in response to FERC's February 3, 2013, letter of solicitation. Subsequent study requests were filed by the Narragansett Tribe and the Nolumbeka Project.

The Study Plan for Cultural and Historical Resources (Study 33) was filed on April 15, 2013, but did not include a TCP in its scope. A meeting was held on June 7, 2013, with representatives of the Narragansett Tribe, Nolumbeka Project, FERC, and TransCanada (now Great River Hydro) to discuss the proposed cultural and historic resources study plan, and yielded clarification and additional information about their study requests. On July 8, 2013, TransCanada filed an updated PSP for Study 33 for additional stakeholder review and comment that included a TCP study. Further clarification was provided through additional meetings and conference calls with FERC, the Narragansett Tribe and the NHSHPO and VTSHPO, and considering comments provided by the VTSHPO and Nolumbeka Project. Following the conclusion of study plan meetings and receipt of comments on its updated PSP, TransCanada filed its RSP on August 14, 2013. FERC approved the RSP for Cultural and Historic Resources without modifications in the SPD letter of September 13, 2013.

By letter dated May 14, 2014, TransCanada reached out to the Narragansett Tribe, introducing the selection of an experienced TCP consultant, requesting an opportunity to meet and discuss Tribal participation in the TCP study and planned archaeology studies to be performed in 2014. No response was received. By email dated July 11, 2014, to the NITHPO and Deputy NITHPO, TransCanada reiterated its interest and invitation to meet and consult on the TCP and archaeology studies. No response was received. Lastly, by letter dated December 23, 2014, to the Narragansett Tribe providing a copy of the Phase 1A Archaeological Reconnaissance Survey Update for the Vernon Project, TransCanada further inquired about Tribal interest in meeting and participating in the TCP study. Again, no response was received. Despite three attempts to meet, consult, and engage the Narragansett Tribe in the development of a TCP, TransCanada received absolutely no response.

The TCP study was therefore conducted absent Tribal input and largely based on documented information available from a variety of sources and published works. The initial TCP study report was completed and filed May 16, 2016. At the subsequent Study Report meeting held on June 1, 2016, representatives of the Elnu Tribe of the Abenaki and John Moody expressed a desire to set up meetings between TransCanada, its TCP consultant, and Abenaki Tribal leaders and representatives to further develop and address recommendations on the TCPs listed in the report. Consultation meetings were held with interested Vermont Abenaki Tribal representatives and with John Moody individually on October 26 and 27, 2016 respectively, to discuss providing comments on the TCP report and opportunities for acquiring ethnologic information. Comments and proposals in response to the TCP report and the October meetings were filed with FERC by the Elnu Tribe of the Abenaki (on behalf of itself, the Nulhegan Band of the Coosuk-Abenaki Nation, and the Koasek Traditional Band of the Koas Abenaki Nation), and the NITHPO. John and Donna Moody submitted email comments directly to TransCanada. Comments received in January 2017 included additional information and lists of publications containing additional or more accurate traditional cultural information for review. No further consultation is being sought although any additional information provided by Tribal interests could, to the extent suitable, be incorporated into the HPMPs for each Project.

3.11.2 Environmental Effects

3.11.2.1 No-action Alternative

Pursuant to 36 C.F.R. §800.5, following the completion of the historic property identification phase, Great River Hydro will consult with the VTSHPO and NHSHPO to determine whether the relicensing, and future operation and maintenance of the Wilder, Bellows Falls, and Vernon Projects under new licenses will result in adverse effects to historic properties. The following, therefore, constitutes a preliminary assessment of the potential effects of the Projects.

3.11.2.2 Historic Architectural Properties

Great River Hydro does not propose to change in Project operations; therefore, it is unlikely that the undertaking will result in adverse effects on historic architectural resources. After its review of information regarding historic architectural resources submitted as part of Study 33, the NHSHPO concurred with that assessment and offered its opinion that the relicensing of the Projects will have no adverse effect on historic architectural resources in New Hampshire. The VTSHPO has not issued an opinion on effects. During the term of the new licenses, Great River Hydro may propose improvement or maintenance projects that include alterations to historic buildings or structures. The following is a list of typical types of activities that have the potential to cause effects on historic properties:

- Removal and/or replacement of major mechanical, electrical, and generating equipment that have been in place for more than 50 years and contribute to the understanding of the historical operation of the Projects;
- Alterations to the exterior appearance, including the removal or modification of original architectural details, application of synthetic or other incompatible materials, additions, and permanent partitioning of interiors of historic buildings; and
- New construction that is incompatible with the historic appearance of the Projects.

3.11.2.3 Archaeological Sites

As is the case with historic architectural properties, Great River Hydro may in the future propose improvement or maintenance projects that could affect archaeological resources during the term of the license. The following is a list of typical types of activities that have the potential to cause effects on archaeological resources:

- Ground disturbing activities (e.g., construction, grading, and tree clearing) in archaeological sites and sensitive areas that are considered to have the potential to impact significant belowground cultural deposits;
- Shoreline modifications resulting from proposed projects that could impact archaeological sites and sensitive areas; and

Recreational enhancement projects that require construction or provide public access that could result in vandalism of significant archaeological sites or sensitive areas.

As discussed above, not all documented resource locations (potential post-contact archaeological sites), recorded archaeological sites, and archaeologically sensitive areas within the Project APEs have been subject to Phase IB or Phase II studies and the National Register eligibility and potential Project-related effects to these resources are not known. Additionally, and in accordance with Section 106, additional consultation with the VTSHPO is needed to obtain concurrence on outstanding Phase II site eligibility recommendations; and with the VTSHPO and NHSHPO on the assessment of Project effects and resolution of those effects deemed to be adverse.

Over any new license terms, for Great River Hydro fee-owned lands, Phase IB and Phase II surveys to locate, identify, and evaluate archaeological sites for their National Register eligibility will be conducted in consultation with the VTSHPO and

NHSHPO, if and when any of the above-listed activities are proposed in sensitive areas and at documented resource locations and recorded sites. No significant archaeological resources are expected in non-recorded sites or sensitive areas, and therefore, no further archaeological studies are required in these areas on fee-owned lands in the Project APEs.

For private flowage lands, Phase IB and Phase II surveys will be completed in active erosion areas not completed in the 2015—2016 investigations if landowner permissions are granted to access these areas. In the meantime, these erosion areas will be included in an archaeological monitoring program to be established in the Wilder, Bellows Falls, and Vernon Project HPMPs. All other archaeologically sensitive shoreline areas in the Project APEs where no active erosion or Project effects have been observed will also be included in the archaeological monitoring program. Phase IB and Phase II surveys, and Phase III mitigation, as needed, will be conducted for any impacts to sensitive areas and sites identified during the monitoring program in consultation with the VTSHPO, NHSHPO, and Abenaki Tribal leaders. No significant archaeological resources are expected in non-recorded sites or sensitive areas, and therefore, no further archaeological studies are required in these areas on private flowage lands in the Project APEs. Specific measures for the completion of the outstanding consultation and survey and site evaluation and mitigation tasks will be outlined in the HPMPs.

Wilder Project

As a result of the Phase IA and Phase IB surveys, there are a total of 51 documented resources and 52 recorded archaeological sites within the Wilder Project APE. Five of the documented resources (HA-1, HA-2, HA-3, HN-10, and LE-6) and 4 of the recorded archaeological sites (27-GR-233, VT-WN-479, VT-WN-480, and VT-WN-481) are partially or entirely on fee-owned lands (see Table 3.11-2, Table 3.11-3, and Table 3.11-4). The National Register eligibility of the documented resources and recorded sites on fee-owned lands is currently undetermined for the reasons stated in Section 3.11.1.2. One of the sites (VT-WN-479) in Hartford, Vermont, is in an area of active erosion where Phase IB archaeological survey was proposed; however, the site is only safely accessible by land across private property (because of the steep and unstable river embankment), and no landowner permission has been granted for land access.

One recorded site (27-GR-233) is in the vicinity of a Project camping area, and 2 other recorded sites (VT-WN-480 and VT-WN-481) are in Project recreation areas and no Project effects or potential threats including recreational activities were observed at these sites.

Also in the Wilder Project APE, 46 documented resources and 48 recorded sites are entirely on private flowage lands (see Table 3.11-2, Table 3.11-3, and Table 3.11-4). One of the recorded sites (27-GR-232) has been determined eligible for listing in the National Register and 4 (VT-OR-34, VT-OR-62, VT-OR-108, and VT-OR-110) have been recommended as eligible. All 5 of the National Register eligible or recommended eligible recorded sites on private flowage lands are in active erosion areas. Two of the recorded sites (27-GR-228 and VT-OR-67) are ineligible for the National Register and no further archaeological studies are needed. Three of the recorded sites (VT-OR-35, VT-OR-72, and VT-OR-109) are recommended ineligible for the National Register and no further archaeological studies are needed pending VTSHPO concurrence. The National Register eligibility of the 46 documented resources and the other 38 recorded sites on private flowage lands in the Wilder Project APE is currently undetermined for the reasons stated in Section 3.11.1.2. Nine of the recorded sites (27-GR-112, 27-GR-208, 27-GR-224, 27-GR-229, 27-GR-234, 27-GR-268, VT-OR-21, VT-OR-97, and VT-OR-101) are on private flowage lands where active erosion was identified, but no landowner access permission was obtained for a Phase IB survey.

Bellows Falls Project

As a result of the Phase IA and Phase IB surveys, there are a total of 19 documented resources and 45 recorded archaeological sites within the Bellows Falls Project APE. Three of the documented resources (RO-1, RO-2, and RO-3) and 21 of the recorded archaeological sites (27-CH-169, 27-SU-34, 27-SU-35, 27-SU-41, 27-SU-43, 27-SU-44, 27-SU-45, 27-SU-46, 27-SU-47, 27-SU-48, 27-SU-49, VT-WD-8, VT-WD-76, VT-WD-291, VT-WN-38, VT-WN-41, VT-WN-46, VT-WN-102, VT-WN-187, VT-WN-192, and VT-WN-453) are partially or entirely on fee-owned lands (see Table 3.11-5, Table 3.11-6, and Table 3.11-7). Two of the recorded sites (VT-WD-8 and VT-WD-41) are listed in the State and/or National Registers and one recorded site (27-SU-41) has been evaluated as being eligible for listing on the National Register. No Project effects were observed at recorded site VT-WD-8 (Bellows Falls Petroglyphs), but its location near public areas of the village of Bellows Falls makes it vulnerable to potential vandalism and the site has been altered over time both by human and natural forces. No Project effects or potential threats including recreational activities were observed at recorded sites VT-WD-41 (Skitchewaug) or 27-SU-41 (Meany's Cove). The National Register eligibility of the 3 documented resources and 18 other recorded sites on fee-owned lands in the Bellows Falls Project APE is currently undetermined for the reasons stated in Section 3.11.1.2.

Also in the Bellows Project APE, 16 documented resources and 24 recorded sites are entirely on private flowage lands (see Table 3.11-5, Table 3.11-6, and Table 3.11-7). One of the recorded sites (27-SU-5) is listed on the National Register, 2 have been determined eligible for listing in the National Register (VT-WN-61 and VT-WN-186) and 3 are ineligible for listing in the National Register (27-SU-53, 27-SU-54, and VT-WN-464). None of the National Register eligible sites on private flowage lands in the Bellows Falls Project APE are in active erosion areas. The National Register eligibility of the 16 documented resources and the other 18 recorded sites on private flowage lands in the Bellows Falls Project APE is currently undetermined for the reasons stated in Section 3.11.1.2. Only one recorded site (27-SU-7) of undetermined National Register eligibility is on private flowage lands where active erosion was identified during the Phase IA survey, but no landowner access permission was obtained for Phase IB survey.

Vernon Project

As a result of the Phase IA and Phase IB surveys, there are a total of 26 documented resources and 14 recorded archaeological sites within the Bellows Falls Project APE. Two of the documented resources (B-11 and V-1) and 4 of the recorded sites (27-CH-85, VT-WD-01, VT-WD-13, and "Indian Encampment" [no NH site inventory number]) are partially or entirely on fee-owned lands (see Table 3.11-8, Table 3.11-9, and Table 3.11-10). The only recorded site that has been determined eligible for listing in the National Register is 27-CH-85 (Squakheag Fort/Fort Hill) located in Hinsdale, New Hampshire. The site is well known and has previously experienced disturbances by clandestine looting activities. The most recently documented looting dates to the spring/summer of 2008 and involved the laying out of testing grids or units with string and flagging tape and the unauthorized excavation and screening of artifacts. The NHSHPO is aware of these activities and has worked with the Licensee and local police to reduce and eliminate unauthorized site access and excavations. The fee-owned lands in this area are not open to the public for recreational use and the existing maintenance roads follow along 80-year-old overhead electric transmission lines that are gated and locked. No evidence of looting was observed at the site during the 2014 Phase IA reconnaissance survey update and archaeological site monitoring program conducted in accordance with the existing 2008 Vernon Project HPMP. The protection of Site 27-CH-85 is included in the existing 2008 Vernon Project HPMP and will continue to be part of the Vernon Project HPMP update.

The National Register eligibility of the two documented resources and three other recorded sites on fee-owned lands in the Vernon Project APE is currently undetermined for the reasons stated in Section 3.11.1.2. The fee-owned lands are included in the 10-year archaeological monitoring program schedule established in the existing Vernon Project HPMP. The most recent monitoring program conducted in 2014 did not identify any Project effects or potential threats including recreational activities to any of the documented resource locations, recorded sites, or associated sensitive areas (Cherau and Duffin, 2014).

Also in the Vernon Project APE, 23 documented resources and 12 recorded sites are entirely on private flowage lands (see Table 3.11-8, Table 3.11-9, and Table 3.11-10). Two of the recorded sites (VT-WD-10 and VT-WD-354) have been determined eligible for listing in the National Register and one is potentially eligible for listing in the National Register (VT-WD-34). One of the National Register eligible sites (VT-WD-354) on private flowage lands is in an active erosion area. The National Register eligibility of the 23 documented resources and the other 8 recorded sites on private flowage lands in the Vernon Project APE is currently undetermined for the reasons stated in Section 3.11.1.2. Only one recorded site (19-CH-197/Find Spot #1 [as identified by NHSHPO]) of undetermined National Register eligibility is on private flowage lands where active erosion was identified during the Phase IA survey, but no landowner access permission was obtained for Phase IB survey.

3.11.2.4 Traditional Cultural Properties

No Project effects on TCPs have been identified at this time. As described in Section 3.11.1.4, *Traditional Cultural Properties*, no further consultation is being sought although any additional information provided by Tribal interest could, to the extent suitable, be incorporated into the HPMPs for each Project. Should additional information be collected, other than what is identified through archaeological investigation, an evaluation and determination of Project effects would be made.

Great River Hydro Proposal

The process to establish measures to avoid, minimize, or mitigate effects to historic properties is defined in Section 106 of the NHPA. In accordance with those regulations, Great River Hydro will consult with the Section 106 consulting parties. and circulate a draft programmatic agreement for each Project that identifies immediate and long-term measures that will be carried out to resolve the effects. The execution of the final programmatic agreements by the consulting parties will conclude the Section 106 process.

One of the measures that will be stipulated in the programmatic agreements will be the implementation of an HPMP for each Project that identifies how historic properties will be treated over the term of licenses. The HPMPs will be developed in accordance with the joint document prepared by FERC and the ACHP titled: *Guidelines for the Development of Historic Properties Management Plans for FERC Hydroelectric Projects* (ACHP and FERC, 2002). It is expected that the implementation or development of the HPMPs will be required in accordance with stipulations contained within Programmatic Agreements that FERC will execute with the consulting parties. The HPMPs will define how historic properties within each Project APE will be treated throughout the term of each license. The HPMPs will include but not be limited to the following:

- Identify goals for the long-term monitoring and preservation of historic properties;
- Be integrated with existing management plans and the overall master planning process for the Projects;
- Identify types of maintenance, operation, and new construction activities that have the potential to cause effects on historic properties;
- Establish procedures for consulting with the SHPOs, Indian Tribes, historic preservation experts, and the interested public in the event that a historic property may be affected by Project-related activities;
- Specify measures that would be carried out to resolve adverse effects; and
- Identify the responsible Great River Hydro officer in charge of executing the HPMP and establishing procedures for training plant operators, maintenance staff, and other employees in its implementation.

3.11.3 Cumulative Effects

No cumulative effects related to cultural and historic resources including TCPs have been identified, so no cumulative effects on those resources are evaluated as part of this environmental analysis.

3.11.4 Unavoidable Adverse Effects

Unavoidable adverse effects are those that may still occur after implementation of protection and mitigation measures. Great River Hydro proposes to modify its operation as described in Section 2.2, but no changes in the project boundary, its power generating facilities, recreation and public access sites or maintenance practices, therefore no adverse effects on any known historic property or TCPs are not expected. In the event that a future undertaking is determined to have potential adverse effects on a historic property, the consultation process established in the HPMPs will be followed to resolve those effects. The process to establish measures to avoid, minimize, or mitigate adverse effects to historic properties is defined in Section 106 of the NHPA. In accordance with those regulations, Great River Hydro will consult with the VTSHPO and NHSHPO to determine whether Project-related effects are adverse. In the event that that the relicensing and proposed operations and maintenance of the Projects are determined to have an adverse effect on historic properties, Great River Hydro will consult with the VTSHPO, NHSHPO, FERC, and other consulting parties such as Tribes to seek ways to avoid, minimize, or mitigate the effects through the development of HPMPs for each Project.

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3.12 Socioeconomics

3.12.1 Affected Environment

Because the affected environment areas for the Wilder, Bellows Falls, and Vernon Projects overlap, the counties within each of the three Project areas are described together to avoid duplication of Project area descriptions. The Wilder Project is located in Orange and Windsor counties, Vermont, and Grafton County, New Hampshire; the Bellows Falls Project is located in Windsor and Windham counties, Vermont, and Sullivan and Cheshire counties, New Hampshire; and the Vernon Project is located in Windham County, Vermont, and Cheshire County, New Hampshire. Collectively, these counties represent the Projects' socioeconomic analysis area.

3.12.1.1 Population and Demographics

Between 2000 and 2010, the total population increased across all counties in the Project areas, except Windsor County. Cheshire, Orange, and Windham counties have grown more slowly than their respective states during the last 15 years. Orange County with 42 residents per sq. mi. is the least densely populated county within the Project areas, while Cheshire County with 109 residents per sq. mi. is the most densely populated. All six counties have lower population densities than their respective state's average overall population densities (U.S. Census Bureau, 2014b). Total county and state populations are shown in Table 3.12-1.

The closest communities to Wilder dam are the city of Lebanon, New Hampshire, located 3 miles to the east with a population of 13,474 persons, and the town of Hanover, New Hampshire, located 3 miles to the north with a population of 8,411 persons.

Several small communities are located near the Bellows Falls Project. The town of Rockingham, Vermont, has a population of almost 5,200 and includes the village of Bellows Falls. Other larger communities in the area include Springfield, Vermont, 11 miles north of the Bellows Falls dam and Charlestown, New Hampshire, about 7 miles north of the Bellows Falls dam.

The largest municipality within the portion of the Connecticut River affected by the Vernon Project is the town of Brattleboro, Vermont, located approximately 6 miles to the north of Vernon dam. Brattleboro has a population of approximately 12,000. The city of Keene, New Hampshire, has a population of 23,300 and is located approximately 16 miles east of Vernon dam and 16 miles south of Bellows Falls dam. The communities of Vernon, Vermont, and Hinsdale, New Hampshire, are the closest communities to Vernon dam (U.S. Census Bureau, 2014b).

Table 3.12-1. Population trends in the Project areas, 1990–2014.

State/County	1990	2000	2010	2010–2014 5-Year[a] Average	% Change in Population (2000–2010)	% of State Population (2010–2014 average)	Population per Sq. Mi. (2010)
New Hampshire	**1,109,252**	**1,235,786**	**1,316,470**	**1,321,069**	**7**		**147**
Grafton	74,929	81,743	89,118	89,360	9	7	52
Sullivan	38,590	40,458	43,742	43,291	8	3	81
Cheshire	70,121	73,825	77,117	76,596	4	6	109
Vermont	**562,758**	**608,827**	**625,741**	**626,358**	**3**		**67**
Orange	26,149	28,226	28,936	28,927	3	5	42
Windsor	54,055	57,418	56,670	56,328	-1	9	58
Windham	41,588	44,216	44,513	44,050	1	7	57

Source: U.S. Census Bureau (2010, 2014b)

a. 2010–2014 5-year annual average data were obtained from U.S. Census 5-year American Community Survey statistics. These data, which show the average population over the 5-year period beginning in 2010 and ending in 2014, are more recent that than 2010 decennial census data but are presented as a 5-year average. American Community Survey data should not be directly compared against decennial census data, such as the data presented in columns 1990, 2000, and 2010 because they were collected under a different set of conditions than the decennial census. However, American Community Survey data are more recent and therefore relevant to present here.

3.12.1.2 Total Employment and Labor Force

Median household income is more than $10,000 less in Grafton County, New Hampshire, when compared to New Hampshire's median household income. Sullivan and Cheshire counties' income levels are only slightly higher than Grafton County's. Grafton County has the lowest median household income relative to its respective state's median household income of all the counties in the Project areas. The median household income in Orange and Windsor counties is only slightly lower than the median household income in the state of Vermont, while Windham County's median household income is approximately $4,000 lower than the state median.

The employed labor force in the counties in which the Projects are located was 172,952 on average annually between 2010 and 2014. The employed workforce in the three New Hampshire counties accounts for 15 percent of New Hampshire's workforce, and in the three counties in Vermont accounts for 21 percent of Vermont's employed workforce. Unemployment rates in these counties are approximately equal to or slightly higher than those in their respective states. Overall, the 6 counties in the Project area had an unemployment rate of 6.5 percent on average annually between 2010 and 2014 (U.S. Census Bureau, 2014c). Table 3.12-2 presents a summary of labor force and income figures.

Table 3.12-2. Average county and state labor force and income, 2010–2014.

Location	Civilian Labor Force	Employed	Unemployed	Percent Unemployed	Median Household Income (2010$)
New Hampshire	741,358	693,329	48,029	6	$65,986
Grafton County	47,498	44,957	2,541	5	$55,045
Sullivan County	23,425	21,860	1,565	7	$56,851
Cheshire County	42,854	39,483	3,371	8	$56,139
Vermont	346,979	325,336	21,643	6	$54,447
Orange County	16,274	15,341	933	6	$53,114
Windsor County	30,508	28,745	1,763	6	$53,610
Windham County	24,386	22,566	1,820	7	$50,526

Source: U.S. Census Bureau (2014c)

Of particular note in the Project area is the recent closure of VY near Vernon, Vermont, located in Windham County. In 2013, the plant supported 625 workers. However, power generation operations were suspended indefinitely in 2014, and decommissioning activities commenced in 2015, when the plant's workforce declined to 316 workers (MassLive, 2016). As of May 2016, around 150 workers remain at the plant. According to an economic analysis produced by the University of Massachusetts, the closure of VY "and the loss of its high-pay and benefits to workers will have a significant impact on the largely rural…region." The study found that approximately 1,186 direct, indirect, and induced jobs supported by the plant would be lost in the local region, amounting to more than $105 million in lost labor income (University of Massachusetts, Donahue Institute, 2014).

3.12.1.3 Jobs by Industry

Across all 6 counties, the educational services/healthcare/social assistance market accounted for between 29 and 34 percent of all jobs on average annually between 2010 and 2014. During this same period, the next largest markets in terms of total jobs in Grafton, Sullivan, and Cheshire counties were manufacturing (10.2 percent, 19 percent, and 14.7 percent, respectively) and retail trade (11.2 percent, 12.4 percent, and 11.8 percent, respectively). The next largest market in Orange and Windsor was retail trade (11.9 percent and 10.3 percent, respectively) followed by manufacturing (8.8 percent and 10.0 percent, respectively). Windham County's next largest market was manufacturing (10.0 percent) followed by retail trade (9.5 percent). The arts, entertainment, and recreation, and accommodation and food services market; construction market; and professional, scientific, and management, and administrative and waste management services market also made up sizeable portions of the remaining jobs in the Project areas' counties during this period (U.S. Census Bureau, 2014a). Table 3.12-3 presents jobs by industry.

Table 3.12-3. Jobs by industry, 2010–2014.

Industry	New Hampshire	Grafton, NH	Sullivan, NH	Cheshire, NH	Vermont	Orange, VT	Windsor, VT	Windham, VT
Civilian employed population 16 years and over	693,329	44,957	21,860	39,483	325,336	15,341	28,745	22,566
Agriculture, forestry, fishing and hunting, and mining	0.9%	1.7%	1.5%	1.1%	2.7%	3.1%	2.8%	2.2%
Construction	7.1%	6.9%	7.1%	7.9%	7.4%	9.5%	7.7%	9.1%
Manufacturing	12.7%	10.2%	19.0%	14.7%	10.7%	8.8%	10.0%	10.0%
Wholesale trade	3.0%	1.7%	2.7%	4.9%	2.1%	2.0%	2.3%	3.7%
Retail trade	12.6%	11.2%	12.4%	11.8%	11.6%	11.9%	10.3%	9.5%
Transportation and warehousing, and utilities	3.9%	2.9%	2.9%	4.0%	3.2%	3.6%	3.2%	4.0%
Information	2.1%	1.9%	1.7%	1.6%	1.9%	1.6%	2.0%	2.3%
Finance and insurance, and real estate and rental and leasing	6.4%	3.5%	4.9%	5.3%	4.7%	4.2%	4.4%	4.6%
Professional, scientific, and management, and administrative and waste management services	10.2%	8.6%	6.2%	5.9%	8.6%	7.2%	9.1%	7.5%
Educational services, and health care and social assistance	24.4%	33.6%	28.3%	28.2%	28.4%	30.7%	29.6%	29.5%
Arts, entertainment, and recreation, and accommodation and food services	8.5%	11.1%	6.4%	7.7%	9.2%	6.4%	11.1%	9.9%

Industry	New Hampshire	Grafton, NH	Sullivan, NH	Cheshire, NH	Vermont	Orange, VT	Windsor, VT	Windham, VT
Other services, except public administration	4.3%	3.3%	4.1%	4.2%	4.6%	5.3%	3.5%	4.9%
Public administration	3.9%	3.4%	2.7%	2.8%	4.9%	5.6%	4.0%	2.8%

Source: U.S. Census Bureau (2014a)

3.12.2 Environmental Effects

No-action Alternative

The operation of the Projects has, and would continue to have, a positive effect on local economies in the area. Great River Hydro employs:

- 28 people at the Wilder Project, including the administrative offices—3 maintenance technicians, 6 specialists, 14 operators, 2 engineers, 2 managers, and 1 administrative staff;
- 14 people at the Bellows Falls Project, including the office in North Walpole, New Hampshire—8 maintenance technicians, 3 specialists, 2 managers, and 1 administrative staff; and
- 7 people at the Vernon Project—5 maintenance technicians, 1 specialist, and 1 manager.

It is anticipated that this employment would continue without interruption.

Great River Hydro also has a positive impact on local economies by its outside contracted services that are often locally sourced; by provision of recreational access and resources to the public; and by local property tax payments of over $11 million annually for the three Projects combined.

Because Great River Hydro is not proposing to construct new facilities, construction effects and economic effects from construction-related spending will not change. Project operations and maintenance will continue as normal and project economics will be supported by the proposed operations. Operation of the three Projects will continue to support current employment associated with the Projects and will continue to support current recreation opportunities encouraging visitation to the Projects and Project areas. Those employed by Great River, contractors used for routine work, and visitors to the Projects will continue to support the local economy as a result of their spending, which will further support additional jobs, income, and sales in the Project areas.

Great River Hydro Proposal

Great River Hydro proposes to modify the current operation of each of the Wilder, Bellows Falls and Vernon Projects under the terms of a new License, as the preferred alternative over the No-Action Alternative. The proposed alternative focuses on creating more stable reservoir water surface elevations, reducing the magnitude and frequency of sub-daily changes in discharge from the stations, increasing the amount of time that the project is operated as inflow equals outflow and at full reservoir, and reducing the magnitude and rate of change in flows downstream of the dams.

Great River Hydro's proposed changes in operations do not require construction contractor support so effects on the number of jobs directly provided by the Project's would be similar to the no-action alternative.

Proposed changes in operations will have benefits to Fish and Aquatic Resources and Recreation Resources; however, the conversion of the benefit to a natural resource to a direct economic benefit is likely modest. Operational benefits to recreation resources such as stable flows at Sumner Falls could result in greater number of recreation hours; however this is unlikely to translate into increased recreation spending since access to the site is free and the bulk of the associated recreational spend is associated with the initial purchase of the boating equipment.

3.12.3 Unavoidable Adverse Effects

Unavoidable adverse effects are those that may still occur after implementation of protection and mitigation measures. No unavoidable adverse effects on socioeconomics were identified in the environmental analysis; however, socioeconomic effects that create an environmental benefit include:

- Great River Hydro's direct employment and outside contracted services;
- Recreational opportunities;
- Local property tax payments; and
- Provision of dispatchable renewable power, which also supports variable energy resources through reserve capacity (both of which displace fossil-fired generation and reduce power plant emissions), as well as ancillary services from hydropower generation.

4. DEVELOPMENTAL ANALYSIS

4.1 Power and Economic Benefits of the Projects

4.1.1 Economic Assumptions

Under its approach to evaluating the economics of hydropower projects as articulated in Mead Corporation, Publishing Paper Division (72 FERC ¶61,027, July 13, 1995), FERC employs an analysis that uses current costs to compare the costs of a project and likely alternative power with no consideration for potential future inflation, escalation, or deflation beyond the license issuance date. FERC's economic analysis provides a general estimate of the potential power benefits and costs of a project and reasonable alternatives to project-generated power. The estimate helps to support an informed decision concerning the public interest with respect to a proposed license. For the economic analysis of the Wilder, Bellows Falls, and Vernon Projects, financial parameters common to all Projects are shown in Table 4.1-1, and financial parameters specific to each Project are shown in Tables 4.1-2, 4.1-3, and 4.1-4.

Table 4.1-1. Parameters for economic analysis common to all Projects.

Assumption	Value	
Period of economic analysis (years)	30	
Term of financing (years)	20	
Long-term interest rate (%)	4.94	
Short-term interest rate (during construction) (%)	8.0	
Discount rate (%)	10	
Federal tax rate (%)	21	
Forward Capacity rate ($/kW-year) (averaged FCA #9 and #10[a] clearing bids)	99.49	
Ancillary services value	**2019 Estimated Market Values—Wilder**	
	Forward capacity	$3,882,940
	Real-time reserves	$301
	Volt-ampere-reactive support	$37,823
	Renewable energy credit	$252,883
	2019 Estimated Market Values—Bellows Falls	
	Forward capacity	$4,651,394
	Real-time reserves	$245
	Volt-ampere-reactive support	$33,320
	Renewable energy credit	425,215
	2019 Estimated Market Values—Vernon	
	Forward capacity	$3,127,129
	Real-time reserves	$679
	Volt-ampere-reactive support	$19,534
	Renewable energy credit	$1,465,382

a. FCA #97 and #10 capacity rates are the 2019 and 2020 Forward Capacity Auction clearing prices or rates for 2019 and 2020, respectively.

Table 4.1-2. Parameters for the economic analysis of the Wilder Project.

Assumption	Value
Project [authorized] capacity (MW)	35.6
10-year (2010–2019) Average annual generation (MWh/year)	156,303
On-peak 10-year (2010–2019) Average annual generation (MWh/year)	87,308 or 55.9% of total above
Off-peak 10-year (2010–2019) Average annual generation (MWh/year)	68,994 or 44.1% of total above
On-peak energy rate ($/MWh), estimated average annual New England Independent System Operator (ISO-NE) location-specific price for 2019	$39.06
Off-peak energy rate ($/MWh), estimated average annual ISO-NE location-specific price for 2019	$35.56
Annual operating and maintenance cost ($/year), 2019 (also includes insurance, FERC administrative charges, and cost of existing environmental measures)	$2,662,000
Cost to prepare license application ($)	$4,300,000
Local, state, and federal taxes (estimated for fiscal year 2019) ($)	$2,642,000
Annual depreciation and amortization expense ($)	$1,345,000
Dependable capacity (MW) ISO-NE average summer-winter capacity supply obligation for the 11th Forward Capacity Auction (FCA #11, 2020-2021).	41.0

Table 4.1-3. Parameters for the economic analysis of the Bellows Falls Project.

Assumption	Value
Project [authorized] capacity (MW)	40.8
10-year (2010–2019) Average annual generation (MWh/year)	239,070
On-peak 10-year (2010–2019) Average annual generation (MWh/year)	121,881 or 51% of total above
Off-peak 10-year (2010–2019) Average annual generation (MWh/year)	117,189 or 49% of total above
On-peak energy rate ($/MWh) estimated average annual ISO-NE location-specific price for 2019	$37.79
Off-peak energy rate ($/MWh) estimated average annual ISO-NE location-specific price for 2019	$32.14
Annual operating and maintenance cost ($/year), 2019 (also includes insurance, FERC administrative charges, and cost of existing environmental measures)	$3,827,000
Cost to prepare license application ($)	$4,300,000
Local, state, and federal taxes (estimated for fiscal year 2019) ($)	$4,516,000
Annual depreciation and amortization expense ($)	$2,141,000
Dependable capacity (MW) ISO-NE average summer-winter capacity supply obligation for the 11th Forward Capacity Auction (FCA #11, 2020-2021).	49.0

Table 4.1-4. Parameters for the economic analysis of the Vernon Project.

Assumption	Value
Project [authorized] capacity (MW)	32.4
10-year (2010–2019) Average annual generation (MWh/year)	158,028
On-peak 10-year (2010–2019) Average annual generation (MWh/year)	80,983 or 51.2% of total above
Off-peak 10-year (2010–2019) Average annual generation (MWh/year)	77,044 or 48.8% of total above
On-peak energy rate ($/MWh) estimated average annual ISO-NE location-specific price for 2019	$30.55
Off-peak energy rate ($/MWh) estimated average annual ISO-NE location-specific price for 2019	$26.77
Annual operating and maintenance cost ($/year), 2019 (also includes insurance, FERC administrative charges, and cost of existing environmental measures)	$2,136,000
Cost to prepare license application ($)	$4,300,000
Local, state, and federal taxes (estimated for fiscal year 2019) ($)	$3,851,000
Annual depreciation and amortization expense ($)	$2,005,000
Dependable capacity (MW) ISO-NE average summer-winter capacity supply obligation for the 11th Forward Capacity Auction (FCA #11, 2020-2021).	35.0

4.1.2 Costs and Value of PME Measures

Great River Hydro is not proposing any changes to the dams Pending concurring final agency prescriptions for upstream and downstream fish passage at the Projects under the new licenses pursuant to Section 18 of the Federal Power Act (“FPA”)1 and recommended terms and conditions related to fish passage under Sections 10(a) and 10(j) of the FPA, Great River Hydro proposes fish passage related PME measures as outlined in the Settlement Agreemenot on Fish Passage filed with the FERC on August 2, 2022. Costs associated with these measures were identified in revised Application Exhibit D Table D-1’s for each of the respective Projects filed on August 2, 2022.

Great River Hydro proposes to install a new 680kW minimum flow unit at the Bellows Falls dam to recover lost generation associated with the 300 cfs minimum flow into the Bellows Falls Project bypassed reach, as described in its operation proposal for the Project.

The Great River Hydro proposal as described in Sections 2.2 and 3.3 includes an alternative operation proposal as the primary PME measure addressing stakeholder preferences and mitigating for a variety of potential and identified resource issues and a number of additional non-operational PME measures and enhancements.

In Tables 4.1-5, 4.1-6, and 4.1-7 for comparison, the projected effect of proposed operation on actual 2019 energy, capacity, and ancillary service values as well as energy and capacity is presented. Other metrics used to assess and compare the Proposed Operation against current operations are also shown.

In addition to the comparison between current operations and the proposed operation, Table 4.1-8 identifies the estimated costs associated with the other non-operational proposed PME measures. Annual (operation and maintenance) and one-time costs are estimated for these measures. They represent 2020 Net Present Value costs within the specified 30-year period of economic analysis (Table 4.1-1), allocated to the year incurred at an inflation rate of 2.5 percent per year and discount rate of 10 percent.

Table 4.1-5. Comparison of energy, capacity, RECs and ancillary service value, energy production, and available capacity between current and proposed operation of the Wilder Project.

Metric	Current Operation	Proposed Operation
Revenue (2019 $)		
On-peak Energy	$3,420,911	$2,736,729
Off-peak Energy	$2,728,601	$3,438,037
Forward Capacity	$3,882,940	$3,882,940
Renewable Energy Credit	$252,883	$252,883
Real-time Reserves	$301	$301
Volt-ampere-reactive support	$37,823	$37,823
Total Value	$10,323,459	$10,348,713
Total Value per MWh	$62.82	$62.98
Capacity (MW)	41	41
Energy (MWh)	164,330	164,317

Table 4.1-6. Comparison of energy, capacity, RECs and ancillary service value, energy production, and available capacity between

current and proposed operation of the Bellows Falls Project.

Metric	Current Operation	Proposed Operation
Revenue (2019 $)		
On-peak Energy	$4,830,138	$4,202,220
Off-peak Energy	$4,041,831	$4,243,923
Forward Capacity	$4,651,394	$4,651,394
Renewable Energy Credit	$425,215	$425,215
Real-time Reserves	$245	$245
Volt-ampere-reactive support	$33,320	$33,320
Proposed bypassed reach minimum flow unit	n/a	$156,406
Total Value	$13,982,143	$13,712,725
Total Value per MWh	$55.14	$54.08
Capacity (MW)	49	49.68
Energy (MWh)	253,565	253,579

Table 4.1-7. Comparison of energy, capacity, RECs and ancillary service value, energy production, and available capacity between current and proposed operation of the Vernon Project.

Metric	Current Operation	Proposed Operation
Revenue (2019 $)		
On-peak Energy	$2,473,939	$2,172,539
Off-peak Energy	$2,154,321	$2,436,709
Forward Capacity	$3,127,129	$3,127,129
Renewable Energy Credit	$679	$679
Real-time Reserves	$19,534	$19,534
Volt-ampere-reactive support	$1,465,382	$1,465,382
Total Value	$9,240,984	$9,221,972
Total Value per MWh	$57.23	$57.11
Capacity (MW)	49	49

Energy (MWh)	253,565	253,579

Table 4.1-8. Estimated costs for proposed PMEs for the Wilder, Bellows Falls and Vernon Projects.

Measure	Value 2020 $s		
	Wilder	Bellows Falls	Vernon
Cultural Resource Surveys, HPMP measures	$600,000	$600,000	$600,000
Recreation O&M	$555,000	$555,000	$555,000
Impoundment WSE monitoring/Inflow forecasting enhancements and O&M	$1,200,000	$1,200,000	$1,200,000
Recreation Area Improvements	$182,000	$386,000	$110,000
WSE monitoring Inflow forecasting equipment and installation	$650,000	$650,000	$650,000
Eel Surveys and Studies	$310,000	$450,000	$410,000
Upstream Fish Passage enhancementsa	$1,110,000	$1,445,000	$1,920,000
Downstream Fish Passage enhancementsa	$3,750,000	$2,500,000	$3,950,000
Expanded Fish Passage O&Ma	$1,790,000	$2,090,000	$3,190,000
Bellows Falls bypassed reach minimum flow unit		$6,500,000	
TOTAL			$12,585,000

Measure	**Value 2020 $s**		
	Wilder	**Bellows Falls**	**Vernon**
	$10,147,000	$16,376,000	

a. Costs for fish passage are estimates based upon enhancement and mitigation stipulated in the Fish Passage Settlement agreement filed with the Commission on August 2, 2022. Agreement resolves among Great River Hydro, US Fish and Wildlife Service, Nh Fish and Game Dept. and VT Fish an d Wildlife Dept. (the Parties) all issues related to the appropriate prescriptions for fish passage at the Projects under the new licenses pursuant to Section 18 of the Federal Power Act ("FPA")1 and the Parties' recommended terms and conditions related to fish passage under Sections 10(a) and 10(j) of the FPA. Costs for fish passage were provided in the August 2, 2022 filing in a revised Exhibit D Table D-1.

Over the term of the new licenses, the Projects will continue to directly provide renewable non-carbon emitting fast-start electric generation, reserve capacity and power system support services that support and facilitate the further penetration of additional variable energy (wind and solar) resources into the region. Project generation displaces fossil-fired generation, reduces power plant emissions, and provides substantial environmental benefit. The Projects also provide forward capacity, real-time reserves, VAR support, and in the case of Vernon, RECs within the ISO-NE power pool.

5. CONCLUSIONS

5.1 Environmental Measures

In this section, we compare the developmental and non-developmental effects of the no-action alternative (representing current operations) and the Great River Hydro proposal supported by federal and state agencies and key NGOs.

We estimate the average annual generation of the three Projects under the two alternatives identified above. Our Section 4, *Developmental Analysis*, compared actual energy, capacity, reserves, RECs, and ancillary services between actual 2019 revenues and projected 2019 revenues. In this section, our annual generation comparison between the no-action alternative and the Great River Hydro proposal relies on the Study 5 operations model. The Study 5 operations model produced weighted average annual generation outputs using five representative inflow datasets. The weights assigned to the 3, 8, 15, 22, and 28 ranking years were 5/30, 5/30, 9/30, 5/30, and 6/30 respectively.

Table 5-1 shows the average annual generation for the three Projects.

Table 5-1. Average annual energy based on operations model.

Project	No-action Alternative (MWh)	Proposed Alternative (MWh)	% Change
Wilder	173,900	177,650	2%
Bellows Falls	255,867	253,307	-1%
Vernon	170,573	173,414	2%
Total	600,340	604,371	1%

A summary of the environmental effects of the different alternatives follows.

Aquatic Resources

Under the current, no-action alternative, impoundment habitat including littoral spawning habitat, Project-affected riverine reaches, and backwater YOY rearing habitat will experience a degree of WSE fluctuations 90 percent of the time. Average monthly WSE fluctuations under current operations ranged from 0.45 ft to 1.67 ft with an overall average change of 1.03 ft.

Project-affected riverine reaches, including backwater YOY rearing habitat, experience station discharge matching inflow less than 10 percent of the time. Station discharge is often maintained at minimum flow levels and changes to high flows and vice versa within 10 minutes, which affects shallow gravel and cobble-bars associated with mid-stream islands.

Under the Great River Hydro proposal, the proposed operation will reduce the frequency of impoundment WSE fluctuations by 58-100 percent, the with the greatest reduction occurring during critical spawning periods. The magnitude of WSE change is expected to be less than 0.4 ft in most month and year scenarios (average 0.23 ft).

Station discharge will match inflow 67-100 percent of the time in spring, summer, and fall months, and 39-60 percent of the time during winter. Increases in base flow levels and the reduction in frequency, occurrence, and amount of change in flow, particularly during critical seasonal periods under the proposed operation, will reduce the frequency and magnitude of gravel and cobble-bar wetting and dewatering and provide a more stable environment for riverine species. The proposed flow regime is expected to increase success of spawners using shallow shoal habitats, including Smallmouth Bass, Fallfish, and Sea Lamprey.

The higher base flow and Transition Operation of up-ramping and down-ramping preceding and following Flexible Operation will also provide more consistency for mussel recruitment and less likelihood of stranding for mussels and other less mobile species, including fry. Similarly, reduction in frequency, occurrence and amount of change in flow, particularly during critical seasonal periods will reduce nest scour or abandonment due to high velocities, reduce displacement of newly emerged fry of many species, and should provide extended periods of more stable flow for nest construction by Fallfish and Sea Lamprey.

Fish Passage

Under the current, no-action alternative, fish passage is provided for migratory species at the Vernon and Bellows Falls Project and technically at the Wilder Project as requested in the annual schedule issued by CRASC. The cancellation of Atlantic Salmon restoration efforts has largely eliminated the need to operate the Wilder fish ladder due to the lack of upstream migrating adults. American Shad and Sea Lamprey successfully pass the Vernon ladder, and there is evidence suggesting that American Eel also attempt to pass Vernon ladder due to studies indicating significant numbers reaching the counting window. The Bellows Falls fish ladder has operated in response to 100 Sea Lamprey counted at the Vernon ladder, and a limited number of shad have also ben observed to use the ladder. Resident fish species were observed in each of the ladders during periods of operation.

Downstream passage for juvenile and adult American Shad is provided at Vernon. More recently, the CRASC schedule has requested Great River Hydro operate facilities to pass American Eel and American Shad through mid-November.

Under the Great River Hydro proposal, all three fish ladders would operate from April 1, or as soon as practicable thereafter considering weather and fish ladder maintenance, to May 15 to pass White Sucker and Walleye. In addition, the fish ladders would be operated from May 15 to July 15 to pass Sea Lamprey and American Shad at Vernon. Resource agencies have requested that the ladder remain open through November 15 for upstream migrating American Eel. Great River Hydro, in conjunction with resource agencies, will continue to develop upstream passage improvements for American Eel.

Under the Great River Hydro proposal, significant enhancement and mitigation for upstream and downstream passage is proposed, based on a Settlement Agreement on Fish Passage between US Fish and Wildlife, New Hampshire Fish and Game Department, Vermont Fish and Wildlife Department and Great River Hydro (the Parties). The Settlement Agreement on Fish Passage provides for the systematic approach, plan, and schedule for addressing all fish passage needs, issues and improvements related to appropriate prescriptions for fish passage at the Projects under the new licenses pursuant to Section 18 of the Federal Power Act ("FPA")1 and the Parties' recommended terms and conditions related to fish passage under Sections 10(a) and 10(j) of the FPA. On August 2, 2022 Great River Hydro filed the Settlement Agreement on Fish Passage with the FERC, together with updated costs for fish passage in revised Exhibit D Table D-1's for each of the respective License applications for Wilder. Bellows Falls and Vernon Projects.

Threatened and Endangered Species

Under the current no-action alternative, DWM and shallow DWM habitat in upper portions of the Bellows Falls impoundment most affected by change will experience continue potential effects due to fluctuating WSE as a result of WSE fluctuation at Bellows Falls dam. Although not directly observed, hibernating DWM in shallow portions of the Bellows Falls and Wilder impoundments may be exposed to drawdown or freezing.

Cobblestone tiger beetle study sites currently occupied by adults become fully inundated by current operations during the adult daily active period no more than 20 percent of the days during the summer, based on modeled data. Therefore, while current Project operations may have some effect, overall, these operations are unlikely to negatively affect current cobblestone tiger beetle populations. During the spring freshet, when 8 of the 12 study sites have modeled mean WSEs above presumed burrowing elevations, cobblestone tiger beetles likely occur exclusively in their burrows and can tolerate the inundation. Although larval habitat and behavior have yet to be described, the presence of adults at 7 of the 13 study sites indicates at least moderate larval success.

Under the Great River Hydro proposal, specifically, Bellows Falls DWM protection provisions will further reduce the limited potential for WSE-related effects by reducing the Flexible Operation maximum drawdown range 33 percent or to a 1 ft maximum range. Winter DWM protection measures to prevent overwinter dewatering are provided by temporarily reducing the Target WSE in the DWM occupied habitat in the Wilder and Bellows Falls impoundments when water temperatures fall from 15° C to 10°C. Once sustained water temperatures are at or below 10°C, impoundment Target WSE will return to normal, and the IEO/Flexible operation will limit drawdown by remaining above the previously established reduced Target WSE to prevent overwinter dewatering.

Under Great River Hydro's proposal, more stable water levels at the dam are expected to result in less water level fluctuation at the cobblestone tiger beetle sites within the influence of the Bellows Falls impoundment (Chase, Ascutney). The remaining sites on the riverine sections of Wilder and Bellows Falls (Johnston, Burnaps, Sumner Falls, Hart, and Walpole), which currently experience greater water level fluctuation than the impoundment sites, are expected to see a reduction in daily WSE under Great River Hydro's proposed Project operation. The effect will be mostly at the lower water surface elevations but will reduce operational flow events (Flexible Operations) by as much as 0.5 ft and reduce the frequency of those events by as much as 90 percent in June. The combination of reduced frequency and magnitude of high water surface elevations will result in less inundation of cobblestone tiger beetle habitat.

Terrestrial Resources

Under the current no-action alternative, submerged aquatic vegetation occurs almost exclusively below the lower limit of daily and sub-daily water level fluctuations associated with cyclical inflow and current Project operations. Emergent and scrub-shrub wetlands are also most commonly found within the zone influenced by current Project operations.

Under the Great River Hydro proposal, more stable water levels at the dam will likely result in an expansion of deep and shallow marsh species, as well as SAV in coves and other protected areas. This effect will diminish with distance upstream from the dam, as the water levels and flows are more affected by riverine conditions. The sparse aquatic vegetation in the main channels is expected to persist because IEO Operations will limit the development of additional SAV.

Recreation and Land Use Resources

Under the current no-action alternative, Great River Hydro would continue to operate and maintain the existing Project recreation facilities throughout the term of the new licenses and continue to permit state and local entities to operate recreational facilities that provide access to Project lands and waters for recreational boating, fishing, picnicking, and environmental education.

Sumner Falls will continue to experience a variety of flow levels throughout the year, particularly throughout the summer and fall seasons with flows predominantly originating from Wilder powerhouse.

Under the Great River Hydro proposal, Great River Hydro will also continue to operate and maintain the existing Project recreation facilities throughout the term of the new licenses and continue to permit state and local entities to operate recreational facilities that provide access to Project lands and waters for recreational boating, fishing, picnicking, and environmental education. Great River Hydro proposes to incorporate into its respective Projects three canoe campsites, currently non-Project recreation areas on Great River Hydro fee-owned land.

The Great River Hydro proposal will continue to offer a variety of boatable flows at the popular Sumner Falls site as desired by boating interests. Flexible Operation at Wilder and responsive to ISO-NE schedule will continue to support a variety of boating conditions and opportunities at Sumner Falls. Under proposed IEO Operations, changes in boating opportunities will occur as a function of the inflow hydrograph eliminating the cycling between low and high flows. Boater group comments on the PLP showed they were interested in higher base flows to improve navigation of the riverine reaches and impoundments. Higher instantaneous base flows, within impoundments and downstream are anticipated under the proposed operation. Overall, this will provide higher base flows at Sumner Falls and the entire riverine reach and longer duration boating opportunities. Under IEO, hundreds of more hours of flows between 3,800 and 5,000 cfs (within the preferred boating flow for 'main wave') are modeled to occur in June and August. IEO Operations will occur over 80 percent of the time in June and August, increasing the duration of boatable flows.

5.2 Consistency with Comprehensive Plans

Section 10(a)(2) of the FPA requires a review of applicable federal and state comprehensive plans, and consideration of the extent to which the Projects are consistent with the federal or state plans for improving, developing, or conserving a waterway or waterways affected by the Projects. A list of existing FERC-approved State of New Hampshire, State of Vermont, and federal comprehensive plans was provided in FERC's SD2 and updated in November 2020.[54] Great River Hydro identified and reviewed the plans that were determined to be applicable or potentially applicable to one or more of the Projects. No inconsistencies were found between the goals and objectives stated in those plans, and Great River Hydro's proposed Project operations and the contributions of data through implementation of the 33 relicensing studies that support greater understanding of the relevant resources. A summary of each plan's goals and objectives and a statement of applicability to the Projects is provided in Table 5-2.

[54] Available at https://www.ferc.gov/industries/hydropower/gen-info/licensing/complan.pdf. Accessed March 1, 2017.

Table 5-2. Summary of comprehensive plans and consistency review.

Comprehensive Plan	**Summary of the Plan and Consistency Review**
American Eel	
Atlantic States Marine Fisheries Commission. 2000. Interstate Fishery Management Plan for American eel (*Anguilla rostrata*).(Report No. 36). April 2000. Atlantic States Marine Fisheries Commission. 2008. Addendum II to the Fishery Management Plan for American Eel. Arlington, Virginia. October 23, 2008. Pages 1-7. The following addendums referred to here are now listed in the July 2020 FERC list of comp plans. Atlantic States Marine Fisheries Commission. 2013. Addendum III to the Fishery Management Plan for American Eel. Arlington, Virginia. August 2013. Atlantic States Marine Fisheries Commission. 2014. Addendum IV to the Fishery Management Plan for American Eel. Arlington, Virginia. October 2014. Note: Addendum I, 2006 to the Interstate Fishery Management Plan for American Eel is not included in FERC's July 2020 list of Comprehensive Plans	Guidance in this Management Plan and Addenda I – IV collectively, include the following objectives applicable to the Projects: • Increasing the knowledge of eel harvest at all life stages through coordinated mandatory reporting and monitoring of recreational and commercial fisheries. • Improving and protecting the existing American Eel abundance/habitat as well as restoring eels to regions where they were previously present/more abundant through improved upstream/downstream access, water quality and habitat protection/enhancement/restoration. • Increasing the understanding of factors affecting life history, population dynamics, abundance at various life stages necessary for support of the ecosystem and food chain structure health.
American Shad and River Herring	
Atlantic States Marine Fisheries Commission. 1999. Amendment 1 to the Interstate Fishery Management Plan for	Amendment 1 of the Management Plan is focused on American shad regulations and monitoring programs. The Amendment 1 Goal was to protect, enhance, and restore east coast migratory spawning stocks of American shad, hickory shad, and river herrings in order to achieve stock restoration and maintain sustainable levels of spawning stock biomass.

Comprehensive Plan	**Summary of the Plan and Consistency Review**
Shad and River Herring. (Report No. 35). April 1999.	Development of several objectives consistent with this goal which are not applicable to the Projects include: • Prevent overfishing by reduction of mortality below F_{30}. • Define stock restoration, appropriate target mortality rates and specify rebuilding schedules for American Shad populations. • Maintain existing or more conservative regulations for Hickory Shad and river herring until new stock assessments suggest changes are necessary. One objective that includes some elements applicable to the Projects is: • Promote improvements in degraded or historic alosine habitat throughout the species range: a) Improve or install passage facilities at dams and other obstacles to provide upstream passage to historic spawning areas, or remove these obstacles entirely; b) Improve water quality in areas where water quality degradation may have affected alosine stocks; c) Evaluate current fish passage facilities for efficiency; d) ensure that decisions on river flow allocation (e.g., irrigation, evaporative loss, out of basin water transport, hydroelectric operations) take into account flow needs for alosine migration, spawning, and nursery usage; e) ensure that water withdrawal (e.g., cooling flow, drinking water) effects (e.g., impingement and entrainment mortalities, turbine mortalities) do not affect alosine stocks to the extent that they result in stock declines, f) evaluate and improve downstream passage for adults and juveniles; g) promote and coordinate alosine stocking programs for reintroduction to historic spawning area, expansion of existing stock restoration programs, initiation of new strategies to enhance depressed stocks; h) Promote cooperative interstate research monitoring and law enforcement.
Atlantic States Marine Fisheries Commission. 2000. Technical Addendum 1 to Amendment 1 of the Interstate Fishery Management Plan for shad and river herring. February 9, 2000. Atlantic States Marine Fisheries Commission. 2009. Amendment 2 to the Interstate Fishery Management Plan for shad and river herring, Arlington, Virginia. May 2009.	Amendment 1 includes technical corrections to the 1999 Amendment 1 only. Amendment 2 is specific to alewife and blueback herring, which are not present in the Project areas.
Atlantic States Marine Fisheries Commission. 2010. Amendment 3 to the Interstate Fishery Management Plan for shad and river herring, Arlington, Virginia. February 2010.	Amendment 3 to the Management Plan is specific to American Shad with a goal of protecting, enhancing and restoring Atlantic coast migratory stocks and critical habitat in order to achieve sustainable levels of spawning stock biomass; can produce a harvestable surplus; and can withstand unforeseen threats. Plan objectives include: a) maximizing juvenile emigration from freshwater complexes; b) restoring and maintaining spawning stock biomass and age structure

Comprehensive Plan	**Summary of the Plan and Consistency Review**

	to achieve maximum juvenile recruitment; and c) managing harvest so that objectives 1 and 2 are not compromised. Strategies pertinent to the Projects and operations include:
	• General Fish Passage: Coordinate a focused, well supported effort among federal, state, and associated interests to evaluate the effectiveness of upstream and downstream passage and develop new technologies and approaches to improve passage efficiency for the purpose achieving restoration and the management goal.
	• Upstream Passage: American shad must be able to locate and enter the passage facility with little effort and without stress. Where appropriate, improve upstream fish passage effectiveness through operational or structural modifications at impediments to migration. Fish that have ascended the passage facility should be guided/routed to appropriate areas so they can continue upstream migration and avoid being swept back downstream below obstruction.
	• Downstream Passage: Evaluate survival of post spawning and juvenile fish passed via each route at a given facility and implement measures to pass fish via route with best survival rate.
	• Additional dam issues:
	  ○ Mitigate hydrological changes from dams by considering operational changes (turbine venting, aerating reservoirs upstream of hydroelectric plants, aerating flows downstream and adjusting in-stream flows).
	  ○ Due to the importance to migratory fish, consider natural river discharge when instream flow alterations are being made to a river.
	  ○ Consider options for restoring alosine habitat, include study of impacts and possible alteration of dam related operations to enhance river habitat.

Connecticut River Atlantic Salmon Commission. 1992. A management plan for American shad in the Connecticut River Basin. Sunderland, Massachusetts. February 1992. Connecticut River Atlantic Salmon Commission. 2020. Connecticut River American Shad Management Plan. Sunderland, Massachusetts. June 9, 2017, updated February 28, 2020.	The Connecticut River American Shad Management Plan (1992) was updated June 9, 2017 to reflect current management and restoration goals based on new information available. An additional addendum, approved on February 28, 2020, was developed to provide shad passage performance criteria in support of achieving the goals and objectives from the 2017 Plan. The goal of this Management Plan is to restore and maintain a spawning American Shad population to its historic range in the Connecticut River basin at targeted management levels whileproviding and maintaining sport and the traditional in-river commercial fisheries for the species. Objectives are categorized by 1) Population, 2) Fisheries, 3) Ecological, 4) Monitoring and Research, and 5) Public Outreach and Education. Objectives which are not applicable to the Projects include: • Achieve and sustain an adult population of 1.7 million individuals entering the mouth of the Connecticut River annually. • Achieve and sustain a management target adult return of at least 111 adults per hectare in targeted tributaries

Comprehensive Plan	**Summary of the Plan and Consistency Review**

	• Enhance and/or maintain/establish a sustainable spring shad recreational fishery throughout the historical range with harvest opportunities guided by population size and fish passage objectives from this Plan
	• Participate in other fisheries management organizations to support science-based management of Connecticut River American Shad fisheries.
	• Provide communications and education for the public regarding the Plan and the benefits of American shad throughout their historic range.
	Objectives with aspects applicable to the Projects include:
	• Achieve and sustain an adult return rate of at least 203 adults per hectare in the mainstem with passage of >227,000 shad at Vernon Dam
	• Achieve a returning stock structure with repeat spawning adults comprising a minimum of 15% for each sex and composed of a diverse age structure.
	• Maintain an American Shad population providing diverse ecological contributions at all life stages in all environments based on targeted population sizes.
	• Conduct fishery independent and dependent monitoring to assess population status, trends and for the sake of determining long and short-term research needs for achieving Plan Goals and Objectives.
	• Identify and develop mitigation to anthropogenic impacts limiting the achievement of Plan Objectives
	An addition to the updated Plan, the addendum (approved February 28, 2020) provides American Shad passage performance criteria to support achieving specific goals and objectives outlined in the 2017 Plan. The goals from the plan are applicable to Project and include:
	• Establishing safe, timely, and effective upstream and downstream fish passage for returning adults, post spawn adults, and juveniles.
	  ○ Specifically, the addendum states that upstream migrating adult must pass within 48 hours after approaching within 1 kilometer of a Project area and out-migrating juveniles and adult must pass within 24 hours or less after entering the Project area
	• Establish upstream passage performance measures, addressing fishway effectiveness
	  ○ The addendum states that a minimum efficiency rate of 75% passage for adult shad approaching within 1 kilometer of the Project area
	• Establish downstream passage performance measures for adult and juvenile life stages maximizing survival and minimizing delay
	  ○ The addendum states adult and juvenile shad must have a minimum passage efficiency of 95% based on the number approaching within 1 kilometer of the Project area and the number determined alive post passage (minimum 48 hour evaluation).

Comprehensive Plan	Summary of the Plan and Consistency Review
Atlantic Salmon	
U.S. Fish and Wildlife Service. 1989. Atlantic salmon restoration in New England: Final environmental impact statement 1989-2021. Department of the Interior, Newton Corner, Massachusetts. May 1989.	This EIS discusses the stated goal of the FWS to restore self-sustaining populations of Atlantic Salmon by the year 2021 to several New England Rivers, including the Connecticut River. Due to the end of the salmon restoration program, this EIS is no longer applicable to the Projects.
Connecticut River Atlantic Salmon Commission. 1998. Strategic plan for the restoration of Atlantic salmon to the Connecticut River. Sunderland, Massachusetts. July 1998.	This Strategic Plan's goal was to: protect, conserve, restore, and enhance the Atlantic Salmon population in the Connecticut River basin for public benefit, including recreational fishing. Due to the end of the salmon restoration program, this EIS is no longer applicable to the Projects.
National Marine Fisheries Service. 1998. Final Amendment #11 to the Northeast Multi-species Fishery Management Plan; Amendment #9 to the Atlantic sea scallop Fishery Management Plan; Amendment #1 to the monkfish Fishery Management Plan; Amendment #1 to the Atlantic salmon Fishery Management Plan; and Components of the proposed Atlantic herring Fishery Management Plan for Essential Fish Habitat. Volume 1. October 7, 1998.	Only Amendment #1 to the Atlantic Salmon Fishery Management Plan is potentially applicable to the Projects. The Amendment's purpose is to identify and describe the Essential Fish Habitat (EFH) for salmon to better protect, conserve, and enhance this habitat. The objectives for the EFH amendment are to: • identify and describe all essential fish habitat for those species of finfish and mollusks managed by the Council, to the maximum extent possible; • identify all major threats (fishing and non-fishing related) to the essential fish habitat of those species managed by the Council; and, • identify existing and potential mechanisms to protect, conserve and enhance the essential fish habitat of those species managed by the Council, to the extent practicable. Pursuant to the Magnuson-Stevens Fishery Conservation and Management Act, amended in 1996 (Public Law 94-265), habitats essential to federally managed commercial fish species are to be identified, and measures taken to conserve and enhance that habitat. EFH is 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" (NEFMC, 1998), which includes the entire Connecticut River. Due to the end of the salmon restoration program, this EIS is no longer applicable to the Projects.
Fisheries - Other	
Vermont Department of Fish and Wildlife. 1993. The Vermont management plan for brook, brown and rainbow trout. Waterbury, Vermont. September 1993.	The 1993 Management Plan addresses trout management issues including habitat protection and enhancement, wild trout management, the use of cultured trout, and angler harvest regulations. The highest priority is placed on managing for wild self-sustaining trout populations through habitat protection, restoration, and enhancement. Specifically, riparian vegetation protection/enhancement and habitat connectivity are key considerations for maintaining healthy brook trout populations.

Comprehensive Plan	Summary of the Plan and Consistency Review
Vermont Fish and Wildlife Department. 2018. The Vermont Plan for Brook, Brown, and Rainbow Trout. Montpelier, Vermont. January 2018.	The 2018 update to the original 1993 management plan reflects advances in knowledge of salmonid population biology and management, threats, and public opinion. Ultimately, the goal of managing the state's resources to support wild trout populations while maintaining a diversity of quality recreational opportunities remains consistent with the 1993 plan. The objectives from the 2018 plan designed to achieve this goal consist of: • Consistently and effectively participate in environmental regulatory processes to protect and restore aquatic habitat. • Effectively advocate for habitat protection with other agencies, developers, private land owners and the public. • Develop a program to restore damaged trout habitat. Evaluate the effectiveness of habitat enhancements. • Maintain or improve angler access to streams, rivers, lakes and ponds supporting trout fisheries.
These two plans are included in the July 2020 FERC list of comp plans for MA. The 1998 plan is listed for NH. Neither is listed for VT. Someone will need to determine if they apply to these projects. Atlantic States Marine Fisheries Commission. 1995. Interstate Fishery Management Plan for Atlantic Striped Bass. (Report 24). March 1995. Atlantic States Marine Fisheries Commission. 1998. Interstate Fishery Management Plan for Atlantic Striped Bass. (Report 34). January 1998.	Report 24 and 34 are specific to Striped Bass, a species not encountered in the Project influence reaches of the Connecticut River.
This plan is included in the July 2020 FERC list of comp plans for MA & NH, but not VT. Someone will need to determine if it applies to these projects. Atlantic States Marine Fisheries Commission. 1998. Amendment 1 to the Interstate Fishery Management Plan for	Amendment 1 is specific to Atlantic Sturgeon, a species not encountered in Project influenced reaches of the Connecticut River.

Comprehensive Plan	**Summary of the Plan and Consistency Review**
Atlantic Sturgeon (*Acipenser oxyrhynchus oxyrhynchus*). (Report 31). July 1998.	
This plan is included in the July 2020 FERC list of comp plans for MA & NH, but not VT. Someone will need to determine if it applies to these projects. National Marine Fisheries Service. 1998. Final Recovery Plan for the shortnose sturgeon (Acipenser brevirostrum). Prepared by the Shortnose Sturgeon Recovery Team for the National Marine Fisheries Service. Silver Spring, Maryland. December 1998.	This Final Recovery Plan is specific to Shortnose Sturgeon, a species not encountered in Project influenced reaches of the Connecticut River.
U.S. Fish and Wildlife Service. 1989. Fisheries USA: the recreational fisheries policy of the U.S. Fish and Wildlife Service. Washington, D.C. December 5, 1989. 13 pp. https://www.fws.gov/policy/a1npi89_25.pdf	The Recreational Fisheries Policy sets forth FWS's national goals and strategies for recreational fisheries management. These goals include; • The preservation/increase in productivity of fisheries resources through conservation and enhancement as well as promoting support an conducting research and development in support of fisheries management. • Ensure and enhance the quality, quantity, and diversity of recreational fishing opportunities through access, designation of additional lands, development, increased productivity and conservation. • Develop and enhance partnerships with agencies and private sector to manage and conserve fisheries • Cooperate to maintain a healthy recreation fishing industry through management and conservation.
This plan is included in the July 2020 list of comp plans for VT. Vermont Fish and Wildlife Department. 2017. Statewide Management Plan for Largemouth and Smallmouth Bass. Montpelier, Vermont. August 2017.	Plan recommendations applicable to the projects include: • Before engaging in water level manipulation efforts, the state should actively participate in the review process for hydroelectric dam and reservoir operations such as Vermont 401 Water Quality Certifications, Dam Safety Permits and Federal Energy Regulatory Commission (FERC) licensing, to ensure that fisheries and fish habitat considerations are represented. The state should also require permit conditions that maintain a stable pool to protect bass reproduction and aquatic habitat.
This plan is included in the July 2020 list of comp plans for MA, VT and NH.	Given the increased understanding of this native species' role, it has been designated as a "Species of Greatest Conservation Need" by all four basin states (as stated in the comprehensive State Wildlife Action Plans1). This designation recognizes the need to develop

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Connecticut River Atlantic Salmon Commission. 2018. Connecticut River Anadromous Sea Lamprey Management Plan. Sunderland, Massachusetts. June 29, 2018.	and implement conservation strategies and actions to improve Sea Lamprey's status in the Connecticut River basin.
	This Plan reflects knowledge gained through empirical investigations and long-term monitoring that has occurred over nearly two decades within the watershed. It is believed to be the first management plan for Sea Lamprey in North America that is focused on restoration and recovery rather than on control of nuisance populations.
	Objectives from the 2018 plan not applicable to the Project include:
	• Research - Periodically determine and support short- and long-term research needs to achieve or evaluate the Plan Goal and Objectives
	• Monitoring - Conduct and/or support monitoring programs to assess population status and trends
	
	Objectives from the 2018 plan applicable to the Projects include:
	• Population - Restore and/or enhance Sea Lamprey runs within the watershed
	  ○ Provide lamprey passage at barriers to migration within targeted habitat
	  ○ Operate fishways as appropriate for Sea Lamprey (i.e., season, time of day, upstream and downstream)

This plan is included in the July 2020 list of comp plans for MA but may not apply to these projects. Technical Committee for Fisheries Management of the Connecticut River. 1981. Connecticut River Basin fish passage, flow, and habitat alteration considerations in relation to anadromous fish restoration. Hadley, Massachusetts. October 1981.	The 1981 plan focuses exclusively on Atlantic Salmon passage on the Connecticut River and is outdated (Plan was written prior to fish passage at Wilder). With the discontinuation of the salmon restoration program in 2012, this Plan is not applicable to the Projects.
This plan is included in the July 2020 list of comp plans for MA but may not apply to these projects. Vermont Agency of Natural Resources. 1990. Vermont's lake trout management plan for inland waters. Waterbury,	The focus of this plan is on the management of Lake Trout populations in Vermont inland waters. Lake Trout are not typically found within Project impacted waters nor are waters within the Project boundaries managed for this species. This Plan is not applicable to the Projects.

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Vermont. May 1990. St. Johnsbury, Vermont. July 1990.	
Rivers and Wetlands	
National Park Service. The Nationwide Rivers Inventory. Department of the Interior, Washington, D.C. 1993.	The Nationwide Rivers Inventory is an inventory of free-flowing river segments in the U.S. that are believed to possess one or more "outstandingly remarkable" natural or cultural values judged to be of more than local or regional significance. No segments of the Connecticut River have been designated for inclusion in the Wild and Scenic River System. However, three segments are listed in the Nationwide Rivers Inventory, which identifies potential candidates for inclusion in the Wild and Scenic River System. Hydrology is the "outstandingly remarkable" value supporting listing for the segment from South Newbury, Vermont to the confluence with the Ompompanoosuc River and from Windsor, Vermont to the confluence with the Williams River; and hydrology, botanical, and historical are the values for the segment from the Route 123 bridge in Walpole New Hampshire to one mile above the Route 9 bridge in Brattleboro, Vermont.
New Hampshire Office of State Planning. 1977. Wild, scenic, & recreational rivers for New Hampshire. Concord, New Hampshire. June 1977.	This document contains guidance for establishing a state-level rivers program in accordance with the Nationwide Rivers Inventory (see above) and for preparing detailed individual river studies and plans for potential wild, scenic, and recreational rivers. The plan does not include any specific management guidance for the Connecticut River. State-or basin-level plans with relevant and specific guidance relating to wild and scenic rivers are listed below (see Connecticut Joint River Commission regional recreation management plans below).
New Hampshire Office of State Planning. 1989. New Hampshire wetlands priority conservation plan. Concord, New Hampshire.	The Wetlands Priority Conservation Plan provides information on the current state (as of 1988) of wetlands in New Hampshire and the existing federal, state, and non-governmental framework that exists with the goal of prioritizing and protecting wetland resources. Specific objectives of this plan, beyond wetland protection, are not clear, however the document was written to meet the requirements of the Emergency Wetland Resources Act and it is assumed that prioritization was related to acquisition under the guidelines of the Federal Land and Water Conservation Fund (LWCF) Program. This Plan is not applicable to the Projects.
State of New Hampshire. 1991. New Hampshire rivers management and protection program [as compiled from NH RSA Ch. 483, HB 1432-FN (1990) and HB 674-FN (1991)]. Concord, New Hampshire.	This legislation created the New Hampshire Rivers Management and Protection Program. Portions of the Connecticut River were designated under this program in 1992 (see Connecticut River comprehensive plans below).
Vermont Agency of Environmental Conservation. 1986. Vermont Rivers Study. Waterbury, Vermont.	The Rivers Study is a compilation of river-related natural, physical, and cultural resources on the 17 river basins of Vermont. An outcome of this document was the development of "Basin Plans", four of which include small sections of Project-affected reaches of tributaries to the Connecticut River (see Vermont Basin Plans below).

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Vermont Agency of Natural Resources. 1988. Hydropower in Vermont: an assessment of environmental problems and opportunities. Waterbury, Vermont. May 1988.	Guidance in this document includes environmental assessments of the impacts from hydropower projects in rivers throughout Vermont. Assessments of water quality and fisheries are included along with recommendations for environmental improvements. From the list of hydropower stations included in the plan, only those on the Ottauquechee River and Black River eventually feed into Project-affected reaches of the Connecticut River. However, the plans are specific to each hydroelectric project on that tributary river, and all are far upstream from the Connecticut River confluence where operations at one of the Projects and are therefore, not applicable.
Vermont Agency of Natural Resources. 1988. Wetlands component of the 1988 Vermont recreation plan. Waterbury, Vermont. July 1988.	Similar to the New Hampshire wetlands priority plan, this Vermont plan is limited to identifying wetland resources that can be prioritized for acquisition under the guidelines of the Federal Land and Water Conservation Fund (LWCF) Program. This Plan is not applicable to the Projects.
Connecticut River	
State of New Hampshire. 1992. Act designating segments of the Connecticut River for New Hampshire's rivers management and protection program. Concord, New Hampshire. May 15, 1992.	NH R.S.A. 483:15 VIII designated sections of the Connecticut River in New Hampshire as protected under the NH Rivers Management and Protection Program. The designation includes a listing of river sections classified as natural, rural, or community sections with varying levels of protection as defined in NH RSA 483:9 through 483:9-c. An outcome of this designation was the development of a River Management Plan by CRJC in five regional plans for the Connecticut River (Headwaters, Riverbend, Upper Valley, Mount Ascutney, and Wantastiquet). These sub-basin plans are not included on FERC's December 2016 list of Comprehensive Plans, beyond the "Connecticut River Recreation Management Plan" for each sub-basin (see recreation comprehensive plans below).
Vermont Agency of Environmental Conservation. 2002. White River Basin Plan. Waterbury, Vermont. November 2002. Vermont Agency of Natural Resources. 2013. White River Tactical Basin Plan. Montpelier, Vermont. July 2013. Vermont Agency of Natural Resources. 2018. White River Tactical Basin Plan. Montpelier, Vermont. December 2018.	The 2002 White River Basin (Basin 9) Plan (Basin Plan) describes the water quality and water resources within the basin for the purpose of improving water quality through the examination of streambank erosion, stream channel stability, awareness of water quality issues, extent and quality of public access and impacts to fisheries. The purpose of the plan is to improve the understanding of threats to the watershed and water resources through: • Developing project ideas related to water quality and water resource improvement • Finding technical or financial resources • Identifying technical or financial needs of potential partners • Supporting grant proposals • Providing guidance to regional/local planning and zoning processes. Tactical basin plans are developed according to the goals and objectives of the Vermont Surface Water Management Strategy to protect, maintain, enhance, and restore the biological, chemical, and physical integrity, and public use and enjoyment of Vermont's water resources, and to protect public health and safety.

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	The 2013 White River Tactical Basin Plan (Tactical Plan) was developed by building on the Basin Plan and promoting specific geographically explicit actions in areas of the basin identified for action based on monitoring and assessment data. The top priorities of the this plan include: • Determining the source of e. coli, nutrient loading and establishing BMP's for agricultural zones • Reducing non-point pollution from gravel roads by reducing erosion through BMP's • Minimizing floodplain encroachment • Restoring stream equilibrium and support aquatic organism passage and habitat • Protecting targeted river corridors and wetlands • Protecting the White River as a free flowing undammed river • Protecting public access • Raising awareness and contribute to the prevention of aquatic invasives in the basin. In 2018, The White River Tactical Basin Plan updates the original 2013 Plan. The major difference from previous versions is the clear identification of the primary stressors that have contributed to the continued decline in water quality. Those stressors are: • Encroachment of unpermitted stream alterations, non-buffered agricultural fields, and development within river corridors, floodplains, wetlands, and lake shores • Stream channel erosion due to undersized crossing structures, lack of riparian vegetation for bank stabilization, and unmitigated increases in stormwater flow and volume • Land erosion due to unmanaged stormwater runoff from roads, developed lands, and agricultural lands • Pathogens from sources that likely stem from bacterial communities in soils, waste runoff from domesticated animals and livestock, and out-of-date and failed septic systems While the majority of the goals and strategies associated with the Basin Plan and Tactical Basin Plan are not applicable to the Projects or their operations, some, such as water quality, aquatic organism passage, erosion, and rare, threatened, or endangered (RTE) species may be applicable to the Project-affected reaches of the White River. The 'Lower White River' includes the section of the White River from the confluence with the Connecticut River to a point well upstream of any possible impacts due to Project operations. In this segment, concern over water quality was established due to the potential of pathogens based on sampling from the 1990's. The Tactical Plan specifically indicated that 14 significant natural communities, 25 RTE plants and the cobblestone tiger beetle were present in the Lower White River segment.
Vermont Agency of Natural Resources. 2012. Basin 10 Water quality management plan: Ottauquechee River & Black River. Montpelier, Vermont. May 2012.	The goal of the Basin 10 (Ottauquechee and Black Rivers) Water Quality Management Plan is to provide watersheds of sufficient quality to support the people, wildlife, and landscape uses that are most valued. The Plan includes recommended actions and offers strategies to improve and protect these waters, some of which are applicable to the limited portions of the Project-

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	affected reaches of the Ottauquechee and Black Rivers. Recommendations, of which over 90 were included in the written plan, are prioritized with the 10 most important listed as: • Complete a full set of River Corridor/Fluvial Erosion Hazard (RC/FEH) and Special Flood Hazard (SFH) area maps for Basin 10. • Provide outreach to select boards, zoning administrators, planning commissions, etc. on planning and zoning strategies for minimizing encroachments into River Corridor and SFH areas. • Plan for the future of current infrastructure in the hazard zones. • Breach or remove the Springfield Reservoir Dam in Weathersfield which has been listed as being in poor condition or damaged since 1969. • Prevent further buffer loss. Preserve and enhance existing buffers. Focus areas include some tributaries and the Black and Ottauquechee rivers. • Control invasive plants in riparian buffers to allow native woody vegetation to become established. • Maintain and expand bacteria monitoring program to cover the entire basin, focus on locations where contact recreation commonly occurs. • Work with local groups to locate hazardous materials left behind by Tropical Storm Irene and coordinate their removal. • Increase awareness of non-point source pollution and the accepted agricultural practices within the equine community, with special focus on Kedron Brook. • Work with towns to address the highest priority bridge and culvert structures for replacement as identified in the Black River Corridor Plan, including re-sizing culverts to better accommodate flood-flows.
Vermont Agency of Natural Resources. 2018. Black and Ottauquechee Rivers Tactical Basin Plan. Montpelier, Vermont. June 2018.	The 2018 Plan updates the previous 2012 Basin Plan focusing on the goal of identifying state and local water quality issues and prioritizing the implementation of on the ground watershed protection and restoration projects. Top Objectives from the 2018 plan that do not pertain to the Projects include: • Protect riparian areas from encroachment and degradation • Mitigate sources of stormwater runoff causing water quality impairments through the development and implementation of stormwater master plans, • Implement agricultural Best Management Practices (BMPs) • Protect very high-quality surface waters • Prioritize and implement wetland and floodplain restoration projects on agricultural lands • Inventory and prioritize municipal road erosion that affects surface water and implement high priority projects that are identified in municipal road erosion inventories. • Promote and implement shoreland protection and restoration

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	Top Objectives from the 2018 plan that are applicable to the Projects include: • Protect river corridors to allow rivers to reach equilibrium and increase flood resilience • Mitigate flow alterations by working with dam operators to lessen flow variations and work toward run-of-river management.
Vermont Department of Environmental Conservation. 2008. Basin 11 management plan: West River, Williams River, Saxtons River. Waterbury, Vermont. June 2008. Vermont Agency of Natural Resources. 2015. Tactical Basin Plan for the West, Williams, and Saxons Rivers and Adjacent Connecticut River Tributaries (Basin 11/13). Montpelier, Vermont. December 2015.	The 2008 Basin 11 (West, Williams, and Saxtons Rivers) Management Plan provides an overview of a watershed's health and a description of the prospective and ongoing steps to restore and protect its waters for the purpose of improving both water quality and aquatic habitat. The Plan presents recommendations and lists the primary concerns for the Basin 11 including: • Thermal modification or a change in temperature from the natural condition of the stream • Sedimentation • Habitat alteration • Flow alterations • Pathogens These top five concerns along with nutrient loading, atmospheric deposition of pollutants and invasive species are addressed in the Plan. The related 2016 Tactical Plan differs from the 2008 Management Plan in that it incorporates Basin 13 (including the mainstem Connecticut River and some tributaries located between the mouths of the Williams River and the West River). Recent additions to the plan include repairing damage from Hurricane Irene (2011) and actions more specific than the broadly based concerns declared in the 2008 plan. The actions that are applicable to the Projects include: • Protect the land and habitat along the Connecticut River to enhance survival of the high concentration of rare, threatened, or endangered (RTE) species in Brattleboro and Rockingham. • Implement restoration projects prioritized in River Corridor Plans for applicable tributaries. • Implement stormwater control projects and green infrastructure practices to reduce flows and sediment. Focus areas within the Project-affected area include: Brattleboro and Bellows Falls. • Reduce sediment inputs from Commissary Brook to the Connecticut River from mass failures and erosion. • Additional specific goals are listed in a Tactical Plan Implementation table. One Priority action from the 2015 plan is applicable to the Projects. That action is: • Increase conservation flows below the Wilder Dam and reduce the magnitude of peaking operations and water level fluctuations in the impoundment which would

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	improve aquatic habitat in the Connecticut River, as appropriate related to the Wilder Dam on the Connecticut River through the FERC re-licensing and 401 process.
Vermont Department of Environmental Conservation. 2008. Basin 14 "Little Rivers" water quality management plan, covering the Stevens, Wells, Waits and Ompompanoosuc river watersheds. Waterbury, Vermont. June 2008. Vermont Agency of Natural Resources. 2015. Basin 14 Tactical Basin Plan. Montpelier, Vermont. August 2015.	The only geographic areas of the Basin 14 "Little Rivers" Management Plan applicable to the Projects is the Waits and Ompompanoosuc Rivers. The 2008 Water Quality Management Plan describes strategies to restore and protect the values and beneficial uses of surface waters in Basin 14, such as swimming, boating and aquatic habitat. Specific goals for the two tributaries within the Project-affected reaches that are applicable to the Projects include the following Waits River: • Address needs for further assessment from the South Branch to confluence with Connecticut River for sediment, temperature stress due to habitat alteration, channel widening, erosion, and runoff. • Develop a good understanding of watershed water quality. • Reduce sediment and non-point pollution entering the river. • Protect and restore wetlands and aquatic habitat in the watershed, prevent future degradation. Ompompanoosuc River: • Reduce sediment and non-point pollution entering the river. • Protect and restore wetlands and aquatic habitat in the watershed, and prevent future degradation. • Minimize erosion from land use/ transportation. • Restore impaired waters and manage them to prevent future degradation. The related 2015 Tactical Basin Plan for the Waits and Ompompanoosuc Rivers and all direct tributaries to the Connecticut River between the White River Watershed and the Passumpsic River (enters the Connecticut River upstream of the Wilder Project) provides an overview of the basin health and defines current and future actions needed to continue protection of the watershed and address high priority stressors (encroachments, channel erosions, invasive species, land erosion, pathogens, toxins, nutrient loading, thermal stress, acidity, and flow alteration). Additional specific objectives and needs that are applicable or potentially applicable to the Projects include the following Waits River: • Reduce thermal stress in mainstem waters. • Evaluate the feasibility of instream fish habitat improvements.

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	Ompompanoosuc River: • Monitor water quality to determine source of bacteria for Baseline TMDL remediation. Connecticut River mainstem and direct tributaries: • Identify sources of nitrogen pollution. • Protect/restore adjacent wetlands. • Assess and inventory riparian buffer needs along the Connecticut River corridor. • Increase conservation flows below the Wilder dam and reduce the magnitude of peaking operations and water level fluctuations in the impoundment which would improve aquatic habitat in the Connecticut River through the FERC re-licensing and 401 Water Quality Certification process. • One Priority action from the 2015 plan is applicable to the Projects. That action is: • Increase conservation flows below the Wilder Dam and reduce the magnitude of peaking operations and water level fluctuations in the impoundment which would improve aquatic habitat in the Connecticut River, as appropriate related to the Wilder Dam on the Connecticut River through the FERC re-licensing and 401 process.
Vermont Agency of Natural Resources. 2014. Deerfield River and Southern Connecticut River Tributaries of Vermont (Basin 12/13) Tactical Basin Plan. Montpelier, Vermont. March 2014. Vermont Agency of Natural Resources 2020. Deerfield River and Lower Connecticut Tactical Basin Plan. Montpelier, Vermont. May 2020.	The 2014 Southern Connecticut River Tributaries of Vermont (Basin 12/13) tactical basin plan includes tributaries that enter within Project influenced reaches of the Connecticut River. The management plan provides a watershed-wide perspective on water quality and aquatic resources as well as tactical means to protect, maintain and improve surface waters impacted by known stressors and activities. Among waterbody/watershed specific goals, broad based goals for all waterbodies within Basin 12/13 include: • Incorporating fluvial erosion hazard corridors and flood resiliency strategies into regional development plans and municipal zoning. • Protect the land and habitat along the Connecticut River to enhance survival of the high concentration of RTE species. The 2020 Deerfield Tactical Basin Plan was designed to provide an assessment of watershed condition and provide strategies to protect and restore surface waters within these basins. The Plan is includes 5 chapters providing information on 1) Basin Descriptions, 2) Priority waters for surface water protection, 3) Priority waters for surface water restoration, 4) Water quality regulations and strategies and, 5) Implementation actions, strategies, and monitoring recommendations. Tributary watersheds falling within within the zone of Project influence include Whetstone Brook, Broad Brook, and some smaller streams designated as 'Vernon Direct Drainage'. Actions designed for these

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	watersheds that fall within the Project zone of influence may include actions applicable to the Project. Implementation actions included in the 2020 plan that are applicable to the Projects include: • Mitigate potential impacts of climate change on species survival by working to maintain connectivity with populations to the south in Massachussetts • Work with dam operators to mitigate flow variations and work toward run-of-river management
The July 2020 FERC list of comp plans for VT includes the following plan. Vermont Agency of Natural Resources. 2019. Passumpsic Basin Plan. Montpelier, Vermont. October 2019.	The confluence of the Passumpsic River with the Connecticut River is upstream of McIndoes Project north of Wilder Project's zone of influence. This Basin Plan is not applicable to the Projects.
Wildlife	
New Hampshire Fish and Game Department, New Hampshire Wildlife Action Plan. 2005 (updated 2015).	This Action Plan is not included on FERC's List of Comprehensive Plans; however, guidance in the Wildlife Action Plan (WAP) includes summaries of 117 actions that serve to enable the continued management and protection of the state's wildlife resources and supporting habitats. Several broad action categories are identified to meet this objective. Those that are applicable to the Projects include: • Species and Habitat Actions – Work performed directly with the species and habitats at various spatial scales, including monitoring, research, population and habitat management, land protection, and landowner outreach. • Planning Actions – Including data collection and analyses regarding land use at local, regional, and national scales. Data collected is to be used to aid organizations to identify and plan action necessary to protect key habitat. • Agency Coordination, Regulation, and Policy - Actions taken by federal and state agencies in a cooperative effort to regulate activities deleterious to sensitive habitats and promote environmental stewardship with stakeholders such as developers, farmers and industry.
Vermont Agency of Natural Resources. 2005. Vermont's Wildlife Action Plan. Waterbury, Vermont. November 2005 (update in draft 2015).	The 2005 Vermont Wildlife Action Plan (WAP) was updated in 2015 and remains in draft form at this time. The stated goal of the Plan is "to prevent wildlife from becoming endangered through early, strategic efforts to conserve wildlife and habitat." The Plan identifies Species of Greatest Conservation Need (SGCN) species and focuses upon them in implementation of the WAP. The state developed six classes of strategies intended to address the problems facing the SGCNs. Three strategies that are applicable to the Projects include:

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	• Land and Water Protection – This strategy aims to designate lands where wildlife conservation is a primary objective of management. These include public reserves, privately-owned protected areas, and easements. • Land/Water/Species Management – Implementation of this strategy involves actively managing for wildlife, such as prescribed burns, habitat restoration, and invasive species control. • Research, Education, and Awareness – This strategy involves continued collection of data concerning SGCNs, as well as the dissemination of those data to stakeholders to promote awareness of conservation concerns and increase the sharing of information.
Vermont Natural Heritage Program and New Hampshire Natural Heritage Inventory. 1988. Natural shores of the Connecticut River: Windham County, Vermont, and Cheshire County, New Hampshire. December 1988.	This document presents the results of an inventory that surveyed sites along portions of the Connecticut River that possess valuable natural features. Sensitive habitats were identified, specifically floodplain forests and riverside seeps, that represent unique and valuable natural communities. The communities were ranked according to their priority for protection. This Plan is applicable to the Projects but superseded by more current data including surveys conducted for Study 27 and the 2012 RTE study (Normandeau, 2013c).
Recreation	
New Hampshire Office of Energy and Planning. New Hampshire Statewide Comprehensive Outdoor Recreation Plan (SCORP): 2008-2013. Concord, New Hampshire. December 2007.	The NH SCORP focuses on enhancing and increasing the supply of urban parks, diversifying the type of recreational opportunities available, and promoting health and wellness through local outdoor recreation opportunities in the state of New Hampshire. The Projects are consistent with this Plan because they provide 14 FERC Project recreational areas with a variety of activities, amenities, and facilities.
New Hampshire Office of State Planning. 1991. Public access plan for New Hampshire's lakes, ponds, and rivers. Concord, New Hampshire. November 1991.	The NH Public Access Plan contains guidance on improving year-round public access to state waters, increasing public access to facilities and support services for boaters and non-boaters, and enhancing access for the handicapped. The Projects are consistent with this Plan because they provide access to recreational opportunities for both boaters and non-boaters alike without discrimination and with many barrier free options.
Vermont Department of Forests, Parks and Recreation. Vermont State Comprehensive Outdoor Recreation Plan (SCORP): 2005-2009. Waterbury, Vermont. July 2005. Vermont Department of Forests, Parks and Recreation. 2013. Vermont State Comprehensive Outdoor Recreation Plan (SCORP): 2014-2018. Montpelier, Vermont. August 2013.	The 2005 VT SCORP was updated in 2013 (Vermont State Comprehensive Outdoor Recreation Plan (SCORP): 2014 – 2018. Waterbury, VT) with the goal of assessing the supply, demand, quality, priorities, and issues surrounding outdoor recreation in Vermont. Guidance in these Plans includes increasing awareness of recreational and natural resource-based activities, providing direction on funding support for these types of programs, and encouraging partnerships and coordination for recreation programs. To the extent that these Plans are applicable to the Projects, the Projects are consistent with these Plans because Great River Hydro maintains partnerships with entities including the Town of Hartford to provide recreational opportunities at Hartford (Wilder) picnic area at Kilowatt Park (North) and Wilder dam (Olcott Falls) boat launch at Kilowatt Park (South) and with the Dartmouth College Outing

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	Club to provide camping facilities at Titcomb Cabin. Great River Hydro assists in ensuring continuity of access to the Connecticut River Paddlers Train, spanning 240 miles in total.
Connecticut River Joint Commission. New Hampshire Department of Environmental Services. 2013. Connecticut River Recreation Management Plan: Headwaters Region. Concord, New Hampshire.	This CRJC Headwaters Region Recreation Plan does not contain any specific guidance related to recreation at or near the Projects since the Headwaters Region is located well upstream of the Wilder Project impoundment.
Connecticut River Joint Commission. New Hampshire Department of Environmental Services. 2013. Connecticut River Recreation Management Plan: Upper Valley Region. Concord, New Hampshire.	This CRJC Upper Valley Region Recreation Plan includes one recommendation applicable to the Wilder Project which is that Great River Hydro continue to maintain the canoe campsite at Gilman Island or to consider donating it to the Upper Valley Land Trust. Great River Hydro maintains the canoe campsite at Gilman Island.
Connecticut River Joint Commission. New Hampshire Department of Environmental Services. 2013. Connecticut River Recreation Management Plan: Wantastiquet Region. Concord, New Hampshire.	This CRJC Wantastiquet Region Recreation Plan includes some recommendations applicable to the Bellows Falls and Vernon Projects, namely: • Installing permanent signage at boat launches. • Reminding the public about boat speed laws, bank erosion, nuisance aquatic species, and boater responsibilities. • Continuing to maintain the canoe campsites at Stebbins Island and Wantastiquet/Hinsdale. • Continuing to maintain portages around the Bellows Falls and Vernon dams. Great River Hydro maintains the canoe campsites at Stebbins Island and Wantastiquet/Hinsdale and the portages around the Bellows Falls and Vernon dams. Boating safety signs are posted at all FERC Project recreation sites having boating facilities.
Connecticut River Joint Commission. New Hampshire Department of Environmental Services. 2013. Connecticut River Recreation Management Plan: Riverbend Region. Concord, New Hampshire.	This CRJC Riverbend Region Recreation Plan includes recommendations for continuing to maintain facilities and to open communication about the management of the Moore, Comerford, and McIndoes Falls reservoirs (the FMF Project). This Plan does not contain any specific guidance related to recreation at or near the Projects although the Plan encompasses the region at the upper end of the Wilder impoundment.
Connecticut River Joint Commission. New Hampshire Department of Environmental Services. 2013. Connecticut River Recreation Management Plan: Mt. Ascutney Region. Concord, New Hampshire.	This CRJC Mt. Ascutney Region Recreation Plan includes some recommendations applicable to the Projects, namely: • Ensuring continued public access to the Connecticut River at Sumner Falls, providing safety signage indicating the level of skill needed to negotiate the rapids, and working with the Town of Hartland to discourage vandalism and overnight use. • Providing limited signage at river access points, especially Herrick's Cove aesthetically in keeping with the rural nature of the region. • Continuing to maintain public river access at Herrick’s Cove and the primitive canoe campsite at Lower Meadow.

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	• Posting notices at boat ramps before a scheduled draw down of the Bellows Falls impoundment. The plan also states that boat trailer launch opportunities are sufficient in this region. Great River Hydro provides signage at its FERC Project recreational facilities; discourages vandalism and overnight use by not allowing overnight parking at Project facilities; and maintains public river access at Herrick’s Cove and the Lower Meadow campsite.

6. CONSULTATION DOCUMENTATION

Great River Hydro has engaged in consultation with numerous federal, state, and interstate resource agencies, Indian tribes, and members of the public throughout the entire ILP process since the filing of the NOIs and PADs, during scoping and study plan development, during study implementation, in study report meetings, and during public comment periods on studies and the PLP (see Section 1.3, *Public Review and Comment*). Great River Hydro has filed all related licensing materials with FERC. Names and addresses (where provided to Great River Hydro) for those consulted during relicensing up to and including this amended FLA filing are listed below in accordance with 18 C.F.R. §5.18(b)(5)(ii)(G).

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APPENDIX A: RESPONSES TO COMMENTS ON THE PRELIMINARY LICENSING PROPOSAL

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APPENDIX B: COASTAL ZONE MANAGEMENT ACT CONCURRENCE

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From: Williams, Chris
To: Jennifer Griffin
Subject: RE: CZM review
Date: Monday, April 27, 2020 3:14:25 PM

[EXTERNAL EMAIL] DO NOT CLICK links or attachments unless you recognize the sender and know the content is safe.

Hello Ms. Griffin,

There have been no changes to the New Hampshire Coastal Program since my correspondence with Ms. Fischer in November 2016 that would subject the FERC relicensing of Great River Hydro's Wilder, Bellows Falls, and Vernon hydroelectric facilities to Coastal Zone Management Act (CZMA) federal consistency review by the New Hampshire Coastal Program (NHCP). These facilities are located on the Connecticut River, well outside of New Hampshire's coastal zone. As such, the relicensing of these facilities by FERC is not subject to federal consistency review by the NHCP.

Please feel free to contact me should you have any further questions.

Regards,

Christian Williams|Program Coordinator
Coastal Program
Watershed Management Bureau
Water Division, NH Department of Environmental Services
222 International Drive, Suite 175
Portsmouth, NH 03801
Phone: 603-559-0025
Christian.Williams@des.nh.gov
Follow us on Twitter
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From: Jennifer Griffin <jgriffin@greatriverhydro.com>
Sent: Monday, April 27, 2020 2:53 PM
To: Williams, Chris <Christian.Williams@des.nh.gov>
Subject: CZM review

EXTERNAL: Do not open attachments or click on links unless you recognize and trust the sender.

Hello Mr. Williams,

I'm writing to you from Great River Hydro, LLC (GRH) the current owner of the Wilder, Bellows Falls, and Vernon hydroelectric projects on the Connecticut River in Grafton, Sullivan, and Cheshire Counties. In November 2016 you corresponded with Ms. Maryalice Fischer on behalf of the previous owner, TransCanada, in advance of a FERC license application filing (see attached). At the time you indicated that FERC relicensing of the projects was not subject to federal consistency review by the New Hampshire Coastal Program.

FERC did not act on the application filed in 2016 in anticipation of an amended application that would include additional study data and analysis. GRH anticipates filing that amended application in July 2020. To that end, I am requesting confirmation that no changes have been made to the NH Coastal Zone regulations that would subject the FERC relicensing of Great River Hydro's Wilder, Bellows Falls, and Vernon projects to federal consistency review by the New Hampshire Coastal Program.

Should you have any questions, please don't hesitate to contact me.

Sincerely,

Jennifer Griffin

FERC Compliance and Relicening
Great River Hydro, LLC
P: 603-445-6806
M: 603-966-0477 (best option)
jgriffin@greatriverhydro.com

APPENDIX C: PRIVILEGED EAGLE NESTING MAPS

[The bald eagle nesting maps are filed separately as privileged information.]

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