GREAT RIVER HYDRO, LLC

ILP Study 21
American Shad Telemetry Study - Vernon

Supplement to Final Study Report

In support of Federal Energy Regulatory Commission Relicensing of:

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)

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EXECUTIVE SUMMARY

In 2015 TransCanada conducted a study to characterize the effects, if any, of project operations on behavior, approach routes, passage success, survival, and residency time by adult American Shad (*Alosa sapidissima*) as they move through the Vernon project during both upstream and downstream migration; and to characterize whether project operations affect shad spawning site use and availability, spawning habitat quantity and quality, and spawning activity in the river reaches downstream of Bellows Falls dam to downstream of Vernon dam (ILP Study 21). In response to natural resource agency concerns that the number of adult shad for which a downstream passage route could be determined was too low to draw reasonable conclusions, Great River Hydro, who acquired the project from TransCanada in 2017, conducted a supplemental study focused solely on downstream passage route selection at Vernon dam. The study supplement, reported herein, did not address project effects on survival or spawning.

The goal of this supplemental study was to characterize proportional downstream passage route selection of emigrating adult American Shad using radio telemetry techniques. The study was conducted in the spring and summer of 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. Sixty-one 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.

Of the 48 fish that passed downstream, definitive passage route was determined for 47. Route of passage could not be determined for one fish (2.1%). The dominant route of passage was the east fish pipe (N=16, Proportional route of passage included 33.3%). Collectively, 25% passed via hydroelectric units, 4.2% via units 1-4 (N=2), and 10.4% each via units 5-8 and units 9-10 (N=5 each). Another 6.3% (N=3) passed via the fish ladder. The remainder passed via spill gates (N=13, 27.1%) and the debris sluice (N=3, 6.3%). In general, passage occurred rapidly with an overall median residence time of 11.7 hours, and adjusted median residence time (to remove periods when fish had returned to a monitoring site upstream of Vernon) of 4.7 hours.

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cfs	Cubic Feet per Second
°C	Degrees Celsius
D.O.	Dissolved Oxygen
FERC	Federal Energy Regulatory Commission
Forebay	Area upstream of the Vernon powerhouse from the intakes to just outside of the debris boom
ft	Feet
ft/s	Feet per Second
FWS	U.S. Department of the Interior – Fish and Wildlife Service
ILP	Integrated Licensing Process
MHz	Mega-Hertz
MS	Monitoring Station
PSU	Practical Salinity Units
RPM	Revolutions per Minute
Study Area	Vernon project From approximately 200 ft upstream and downstream of the spillway, 300 ft upstream of the powerhouse and 75 ft downstream of the powerhouse.
TransCanada	TransCanada Hydro Northeast Inc.

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1.0 INTRODUCTION

This document provides supplemental results for ILP Study 21 – American Shad Telemetry Study at Vernon (Normandeau, 2017) conducted originally in 2015 in support of Federal Energy Regulatory Commission (FERC) relicensing for the Wilder Hydroelectric Project (FERC Project No. 1892), Bellows Falls Hydroelectric Project (FERC No. 1855), and the Vernon Hydroelectric Project (FERC No. 1904).

2.0 STUDY GOALS AND OBJECTIVES

Great River Hydro conducted this supplemental study in 2017 in response to agency concerns that the number of adult American Shad (*Alosa* sapidissima) for which a downstream passage route could be determined in 2015 was too low to draw reasonable conclusions. A consultation call was held with the Aquatics working group on May 11, 2017 in which the proposed scope of the 2017 supplemental study was discussed. The 2017 study was designed to focus solely on downstream passage route selection at Vernon, and unlike the 2015 study, did not include estimation of project survival or spawning. Therefore, the objective of this supplemental study was to characterize project operational effects on post-spawn downstream migration route selection, passage efficiency, and downstream passage timing/residence.

3.0 METHODS

3.1 Collection and Tagging

In the 2017 study a larger group (N=99), than in the 2015 study, of radio-tagged shad was released above Vernon dam and monitored for passage through the Project. Adult American Shad were captured at the Vernon fish trap (Vermont Fish and Wildlife Department Scientific Collection Permit #S-2017-CG(2) and New Hampshire Fish and Game Department Scientific License #F2017-92), radio-tagged, transported, and batch released at the Old Ferry boat launch, located in Brattleboro, Vermont approximately 11.3 river miles upstream of Vernon dam. Shad were collected by diverting fish to the Vernon fish trap in small numbers, then netting individually from the trap using a soft silicone-mesh dip net. Each netted fish was assessed for tagging suitability (general condition and scale loss [rejected if >20% on either side]), measured, and sex determined. Any fish rejected for tagging were returned to the Vernon fish ladder. Acceptable specimens were tagged by inserting a radio tag through the mouth, past the esophageal sphincter, and into the stomach using a plastic cannula. Immediately after tagging, each fish was released to a FWS transport truck tank that was filled with recirculating ambient river water, salted to approximately 6-11 psu, and with a constant flow of gaseous oxygen. Fish were held in the current until swimming out freely. Once a release group was tagged, it was transported to the release site, observed in the tank for general condition and behavior, and then released to the river via a knife-gate sluice and discharge pipe.

3.2 Radio Telemetry Equipment

3.2.1 Radio Tags

Uniquely coded radio transmitter tags (model number TX-PSC-1-80, Sigma-Eight Inc., SEI, Newmarket, Ontario, Canada) used for this study transmitted signals on two frequencies (channels): 150.540 MHz (channel 54), and 154.580 MHz (channel 58). Radio tags measured 9.6 mm in diameter, 26 mm in length, and had a 30 cm long whip antenna. Radio tags were programmed to transmit a signal every 2.0 seconds and had a minimum battery life of approximately 113 days.

3.2.2 Monitoring Locations and Antennas

The study area included the Vernon project from approximately 200 ft upstream and downstream of the spillway, 300 ft upstream of the powerhouse, and 75 ft downstream of the powerhouse. Seventeen radio-telemetry monitoring stations were installed. Radio telemetry monitoring equipment included either a Sigma-Eight Orion or Lotek SRX400 or SRX600 receiver, depending on site-specific requirements of desired range of detection and expected rate of travel. The broadband Orion receivers were capable of monitoring multiple frequencies simultaneously, but with limited calibration features. Those were used to monitor points of downstream passage where movement through the monitoring zone was expected to occur quickly and desired detection range was relatively small, primarily using underwater antennas. The Lotek SRX receivers had greater reception range and calibration capabilities, but required frequency switching (e.g., for decoding two frequencies a receiver would detect each half of the time). Those were used to monitor larger detection zones where transit times were expected to be slower and/or extended. All Lotek receivers were programmed to switch frequencies at a 2.6-second interval with a total scan time of 5.2 seconds for the two frequencies monitored in the study. The CRTO (Continuous Record Time Out) feature available on Lotek receivers was disabled so that, like the Orion receivers, each unique transmitter detection was represented by a single line of data. Each detection record included date, time, tag identification, and signal strength.

Three types of antennas, Laird P1504 four–element Yagi antennas (4-element Yagi), Laird PLC1426 six-element Yagi antennas (6-element Yagi), and custom-made underwater antennas (underwater dropper) were used depending on site-specific requirements. Yagi antennas are aerial antennas that provide directionality and a relatively large reception range. Dropper antennas are omni-directional and provide a relatively limited reception range; they were used to determine discrete movement within a specific location of interest.

Monitoring stations were installed upstream and downstream of the study area to delineate individual forays to the study area and post-passage departure from it. One was located at the Vermont Yankee Nuclear Power Station (“Vermont Yankee”) intake area and one was located downstream of the study area just upstream of Stebbins Island. Fifteen monitoring stations were deployed in the study area to detect approaches to the dam and route of passage. A description of monitoring stations follows, and locations and conceptual detection ranges of study area stations are depicted in Figures 3.2-1 and 3.2-2. Note that assigned monitoring station numbers from the 2015 study were retained and augmented. Upstream of the spillway (“spill

gate approach"") and downstream of the spillway ("spillway") were divided into two stations each to better define approach and spill passage and new monitoring site numbers were added there. In addition, in November 2016, TransCanada discovered that a wooden stoplog structure in front of a bypass used during dam construction had failed, creating a 4 ft x 4 ft opening below the trash sluice at approximately 28 ft below normal pond elevation. It was estimated to pass approximately 500 cfs, with an entrance velocity of approximately 31.25 ft/s. Because of its depth, the former construction bypass was considered an unlikely route of passage for emigrating post-spawn American Shad, but the volume and velocity of water entrained suggested that it may have been a passage route and confounding factor to the study, therefore, it was also monitored.

MS-01: Monitoring station 1 was located downstream of the study area at the Vermont Yankee water quality station #3, approximately 0.75 river miles downstream of Vernon dam and just upstream of Stebbins Island. The station consisted of a Lotek SRX receiver and a 6-element Yagi antenna oriented towards the east shore and perpendicular to the river channel. Antenna coverage spanned the width of the river and was used as a redundant station to confirm downstream passage.

MS-10: Monitoring station 10 detected radio-tagged shad in the western portion of the Vernon turbine discharge area. It consisted of a Lotek SRX receiver and a pair of combined 4-element Yagi antennas oriented directly downstream from the discharge catwalk.

MS-12: Monitoring station 12 detected radio-tagged shad in the eastern portion of the Vernon turbine discharge area. It consisted of a Lotek SRX receiver and a pair of combined 4-element Yagi antennas oriented directly downstream from the discharge catwalk.

MS-13: Monitoring station 13 detected radio-tagged shad in the western portion of the Vernon spillway. It consisted of a Lotek SRX receiver and three combined 4-element Yagi antennas.

MS-33: Monitoring station 33 detected radio-tagged shad in the eastern portion of the Vernon spillway. It consisted of a Lotek SRX receiver and three combined 4-element Yagi antennas.

MS-09: Monitoring station 09 detected radio-tagged shad approaching and passing over the trash sluice, located between the spillway structure and turbine Unit 1. It consisted of an SEI Orion receiver and a single downward looking 4-element Yagi antenna with its signal attenuated to isolate an approximately 20 ft approach zone and the point of passage.

MS-39: Monitoring station 39 detected radio-tagged shad approaching and entering the former construction bypass. It consisted of an SEI Orion receiver and a pair of underwater antennas, one located approximately 5 ft west and upstream and one located approximately 5 ft east and upstream of the deep gate. Antennas were set to a depth of approximately 15 ft.

MS-14: Monitoring station 14 detected radio-tagged shad in the western portion of the Vernon impoundment at the approach to the spill gates. It consisted of a Lotek SRX receiver and three combined 4-element Yagi antennas.

MS-34: Monitoring station 34 detected radio-tagged shad in the eastern portion of the Vernon impoundment at the approach to spill gates. It consisted of a Lotek SRX receiver and three combined 4-element Yagi antennas.

MS-15: Monitoring station 15 detected radio-tagged shad approaching and within the station forebay. It consisted of a Lotek SRX600 receiver and a pair of combined 4-element Yagi antennas mounted near the upstream extent of the fish guiding louver and the debris boom.

MS-16: Monitoring station 16 detected radio-tagged shad approaching and passing through the Unit 1-4 intakes. It consisted of an SEI Orion receiver and eight amplified and combined underwater dropper antennas (two per intake) affixed to the trash racks.

MS-17: Monitoring station 17 detected radio-tagged shad approaching and passing through the Unit 5-8 intakes. It consisted of an SEI Orion receiver and eight amplified and combined underwater dropper antennas (two per intake) fed through PVC conduits that were affixed to each intake bay's stop gate, approximately 10 ft downstream of the trash racks.

MS-18: Monitoring station 18 detected radio-tagged shad approaching and passing through the Unit 9-10 intakes. It consisted of an SEI Orion receiver and four amplified and combined underwater dropper antennas (two per intake) fed through PVC conduits that were affixed to each intake bay's stop gate (two per unit), approximately 10 ft downstream of the trash racks.

MS-19: Monitoring station 19 detected radio-tagged shad as they entered the downstream fish passage bypass known as the east fish pipe, located between turbine units 4 and 5. It consisted of an SEI Orion receiver and four combined underwater dropper antennas. Antennas were linearly spaced at 10 ft intervals so that they trailed from the fish pipe entrance to approximately 10, 20, and 30 ft into the pipe.

MS-21: Monitoring station 21 detected radio-tagged shad approaching and entering the downstream fish passage bypass known as the west fish tube, located adjacent to unit 10. It consisted of an SEI Orion receiver and a single underwater dropper antenna positioned approximately 10 ft inside of the west fish tube entrance.

MS-22: Monitoring station 22 detected radio-tagged shad entering the Vernon fish ladder from upstream. It consisted of an SEI Orion receiver and single underwater dropper antenna positioned approximately 30 ft inside of the fish ladder exit (defined for upstream migrating fish).

MS-26: Monitoring station 26 was located upstream of the study area to detect radio-tagged shad approaching and/or departing from/to upstream. It was located at the Vermont Yankee cooling water intake structure, approximately 0.8 river miles upstream of Vernon Dam, and consisted of a Lotek SRX receiver and a single 6-element Yagi antenna directed across the Vernon impoundment. This site was used to delineate forays to the study area.

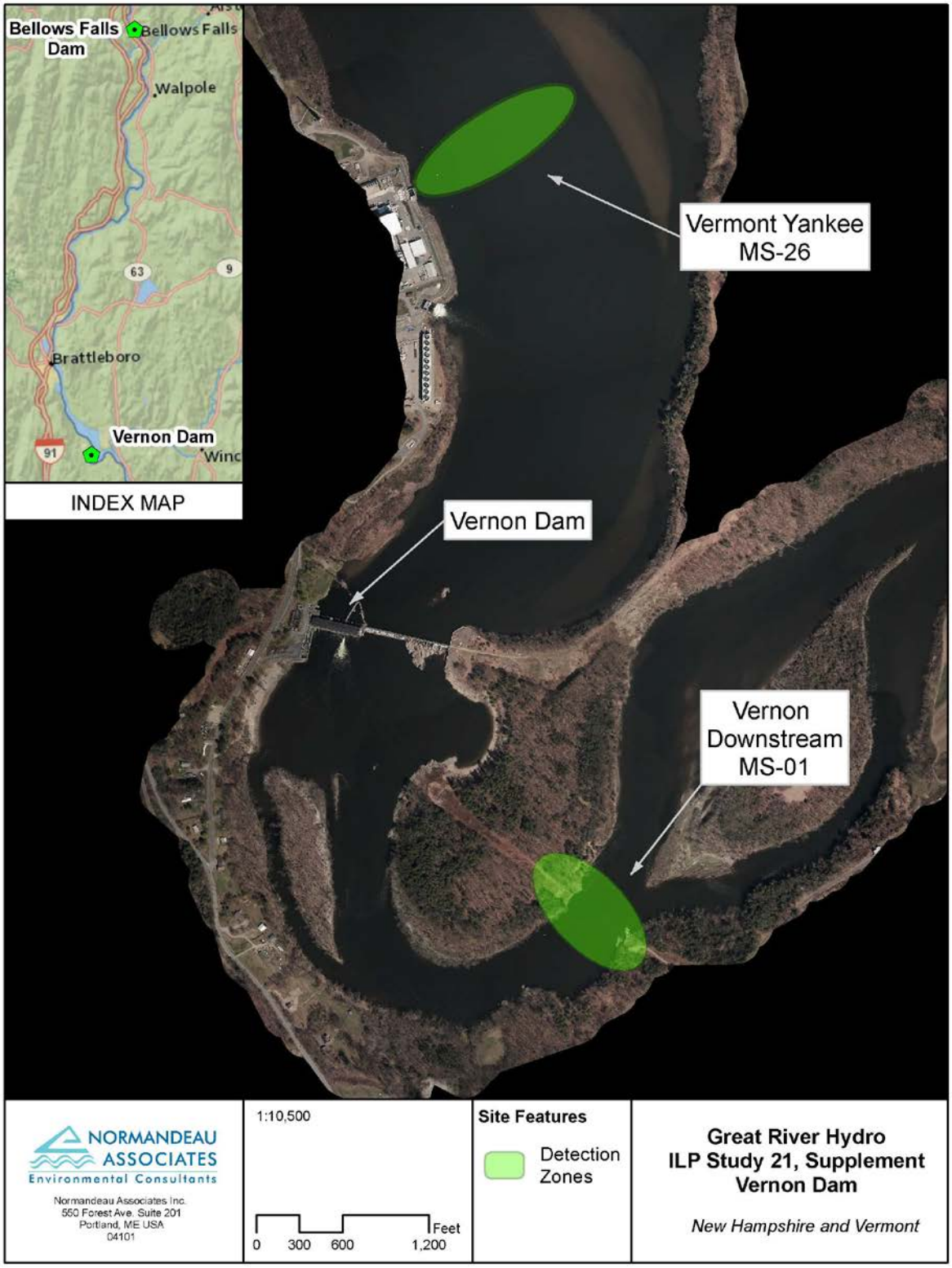

Figure 3.2-1. The Connecticut River in the vicinity of the Vernon project with conceptual detection zones for monitoring sites upstream and downstream of the study area.

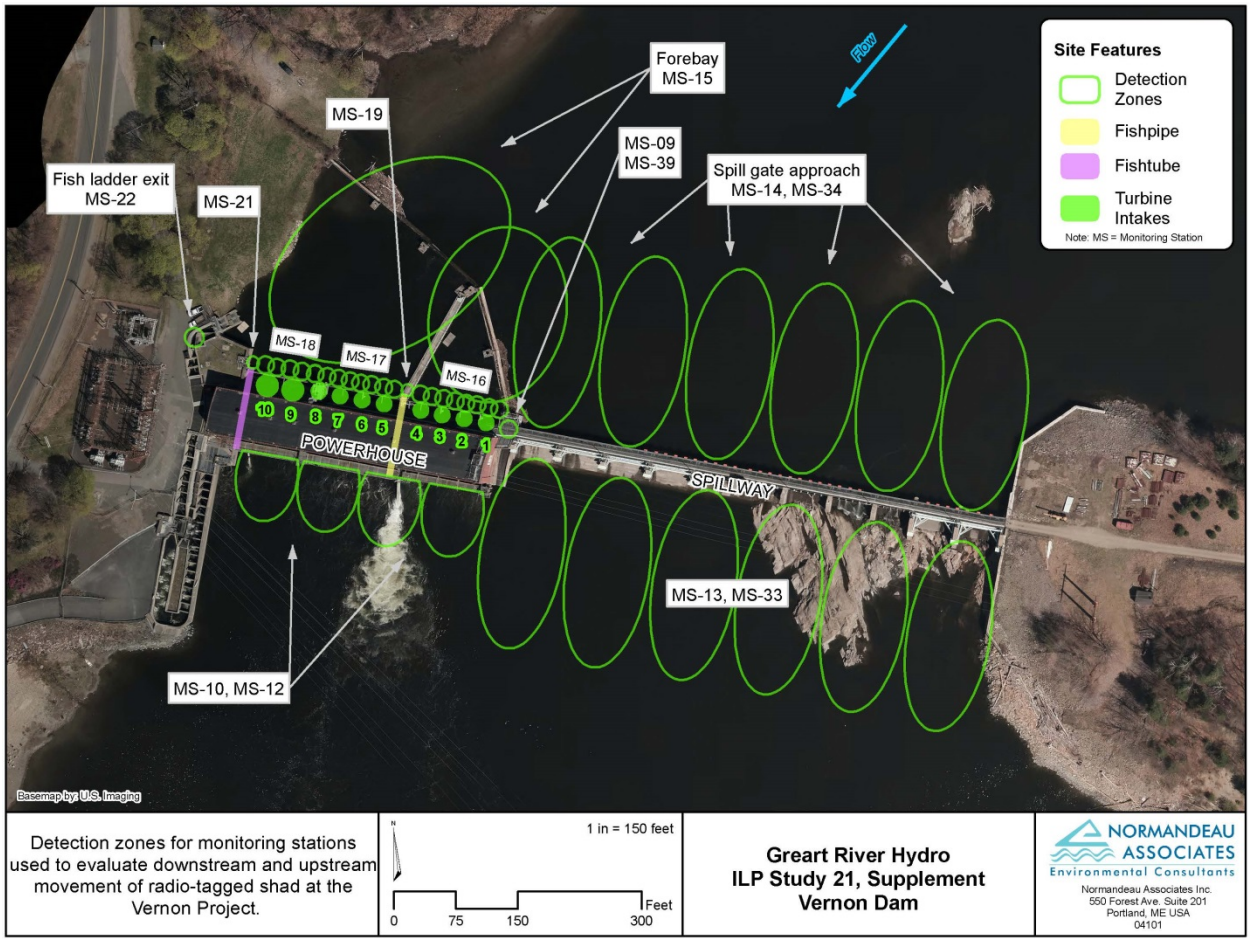

Figure 3.2-2. Study area monitoring stations and conceptual detection zones used to evaluate downstream movement of radio-tagged American Shad at Vernon.

3.3 Data Collection and Analysis

3.3.1 Monitoring Station Telemetry Data

Radio telemetry monitoring was initiated on May 30 and continued through August 2, and data were downloaded from stationary receivers three times per week. Back-up copies of all data files were immediately saved to a dedicated flash drive prior to re-initialization of the downloaded receiver. Data were then consolidated into a database for review and determination of passage routes and timing.

This study was specifically designed to supplement the 2015 study by assessing downstream passage route with a more robust telemetry array, and larger available sample size. To evaluate downstream passage route, detection information from monitoring stations 14, 34, and 15 was used to delineate return of radio-tagged shad to the Vernon forebay as well as their subsequent period of residency prior to downstream passage. The period of residency was defined as the first detection in the study area until the time of passage, where time of passage was defined as the

last detection at a passage point (upstream monitoring site) prior to verifying detections at a downstream site. Passage points included the fish ladder (MS-22), west fish tube (MS-21), turbine units 1-4 (MS-16), units 5-9 (MS-17), units 9-10 (MS-18), east fish pipe (MS-19), sluice (MS-09), former construction bypass (MS-39), and spillway gates (MS-14, MS-34). Downstream passage verification detections were from MS-10, MS-12, MS-13, MS-33, and MS-01. Project operations coinciding with the occurrence of downstream passage events at Vernon were examined graphically.

3.4 Manual Tracking

For this study, only fish that arrived at Vernon Dam, indicating attempt to migrate downstream, were of specific interest, however manual tracking was conducted and locations used to verify lack of return and upstream movements after a return to the dam. Manual tracking was conducted on several occasions and with multiple methods. Tracking was conducted from the shoreline in the vicinity of the release location to confirm movement away from it after each release. The entire 31.8 mile reach of the Connecticut River from Vernon Dam to Bellows Falls Dam was tracked by aircraft on one occasion. Manual locations by aircraft provide approximate locations within short river segments, such as between bends. On six occasions, tracking was conducted by boat from Vermont Yankee to either Bellows Falls Dam or the Westminster Bridge (approximately 3.75 miles downstream of Bellows Falls Dam) depending on flow conditions. Boat tracking provided more specific locations. When radio-tagged shad were located, the date and time, coordinates, and approximate distance to a convenient landmark were recorded.

4.0 RESULTS

4.1 Vernon Operations and Connecticut River Conditions

Radio-tagged shad were first detected upstream of the study area at MS-26 on May 31, and were detected in the study area from June 3 through July 18, 2017. Therefore, the study period was defined as May 31 through July 18, 2017.

The fish pipe, fish tube, and fish ladder operated for the duration of the study. Spill occurred episodically via the Tainter and flood gates (Figure 4.1-1). Overall, spill conditions occurred 33% of the time. The former construction bypass discharged approximately 500 cfs continuously and the sluice was operated on an as needed basis. Vernon has four 133 rpm single runner vertical Francis units (Units 1-4), four 144 rpm vertical axial flow Kaplan units (Units 5-8), and two 75 rpm single runner vertical Francis units (Units 9-10). Unit operational priority during the upstream anadromous fish passage season follows a first-on last-off order of Unit 10, Unit 8, Unit 7, Unit 9, Unit 6, Unit 5, Units 4-1. Operational variation was largely based on flows. Units were taken out of service for short periods for routine maintenance as required. Hourly discharge values for the duration of the study period are presented in Figures 4.1-2 through 4.1-4.

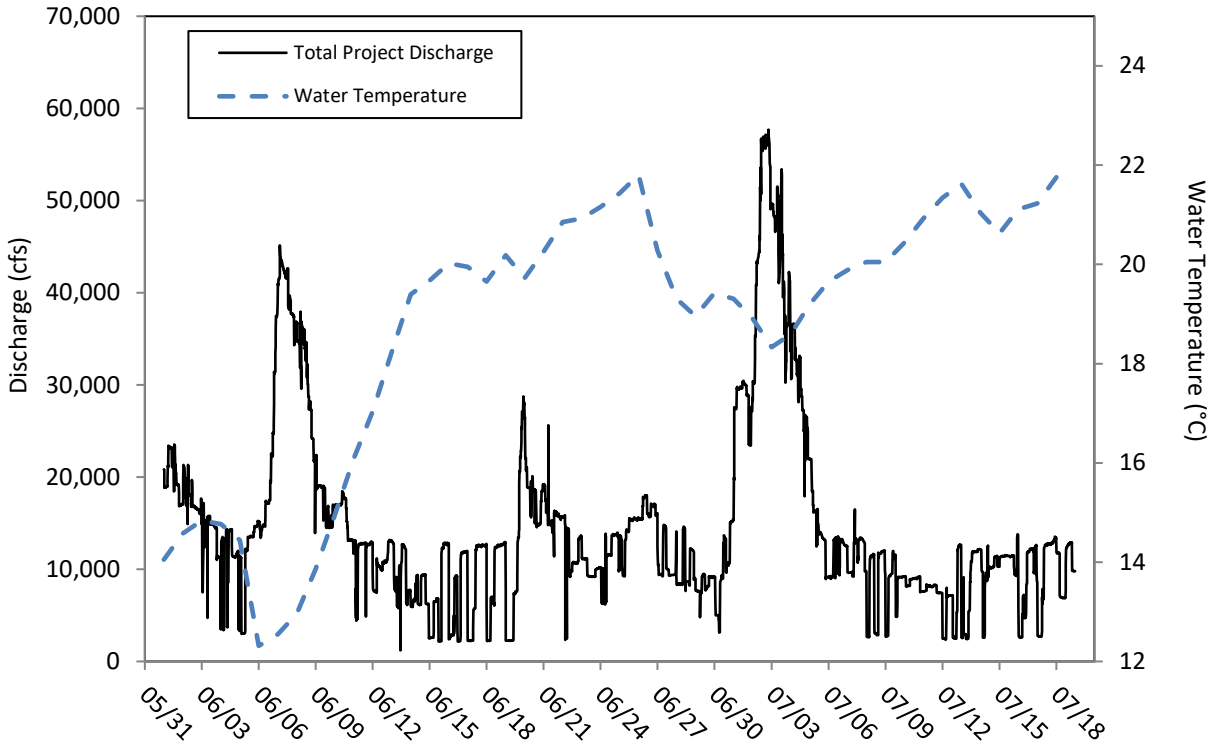

Figure 4.1-1. Total project discharge (cfs, 15-minute increment), and daily mean water temperature at Vernon, May 31 – July 18, 2017.

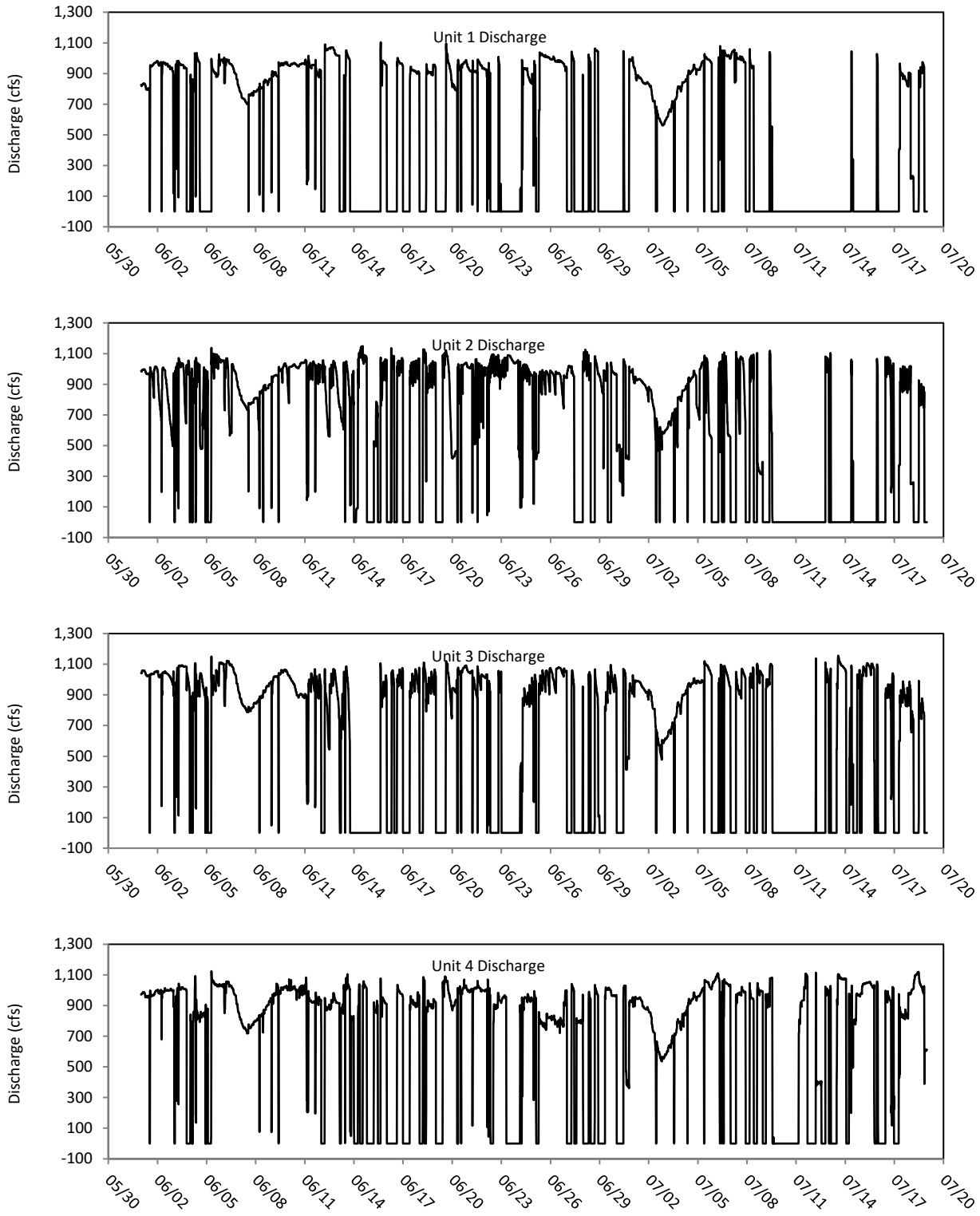

Figure 4.1-2. Hourly discharge for Units 1-4 (133 rpm single runner Francis units) at Vernon, May 31 – July 18, 2017.

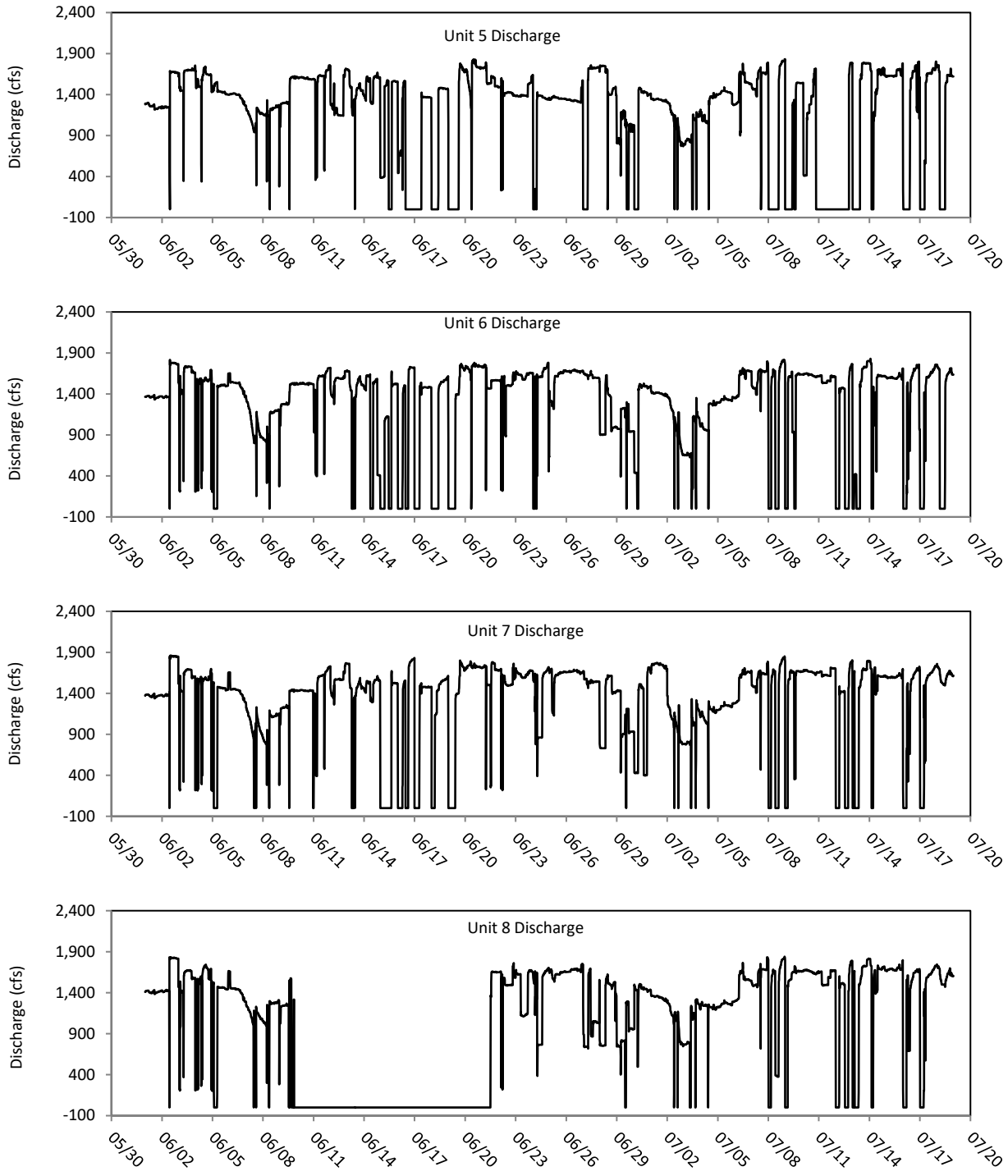

Figure 4.1-3. Hourly discharge for Units 5-8 (144 rpm axial flow Kaplan units) at Vernon, May 31 – July 18, 2017.

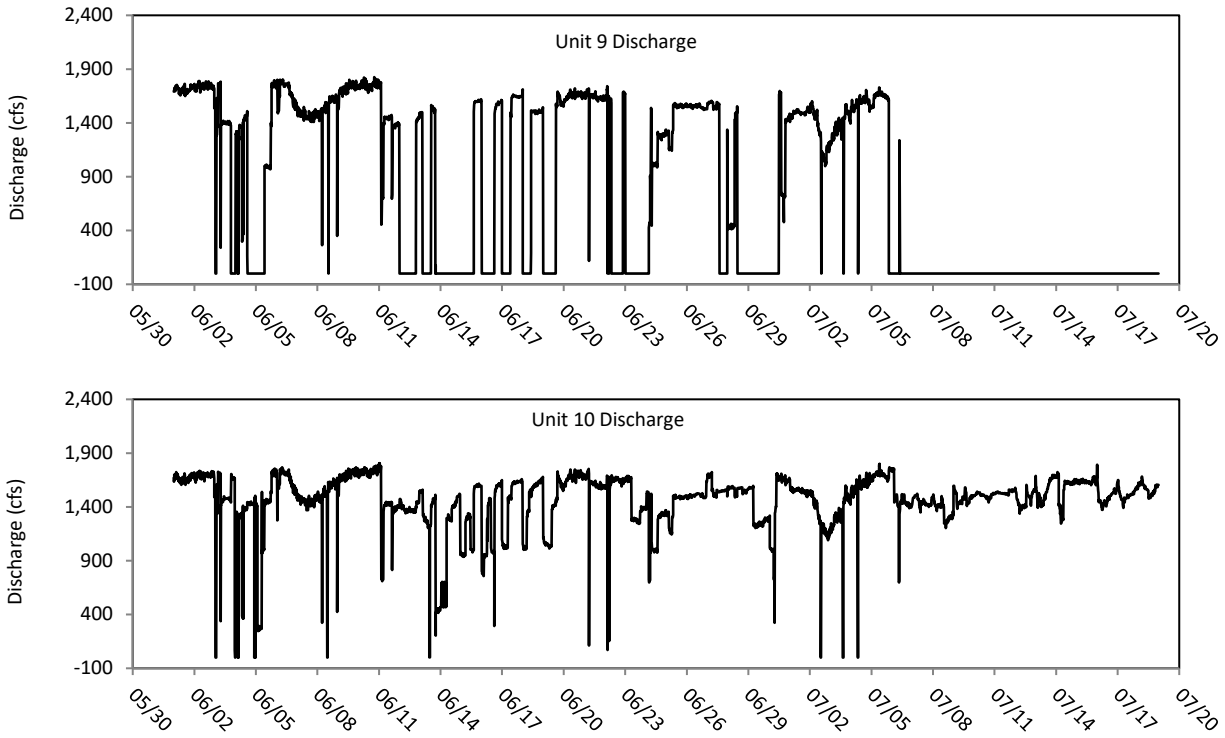

Figure 4.1-4. Hourly discharge for Units 9-10 (75 rpm single runner Francis units) at Vernon, May 31 – July 18, 2017.

4.2 Tagged Shad Releases

Overall, 101 shad were tagged on three dates, May 30, June 11, and June 13, 2017. Two regurgitated transmitters were recovered from the transport tank prior to release, so 99 tagged fish were released (Table 4.2-1). The maximum hold time from the time of tagging of the first fish in a release group to the time of group release was 2.3 hrs (Table 4.2-2).

Table 4.2-1. Summary of adult shad tagging and releases, Vernon 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**	

Table 4.2-2. Summary of shad transport from Vernon fish ladder to the Brattleboro, VT release site, 2017.

Date	30-May	11-Jun	13-Jun	13-Jun
Loading Time	14:25-15:40	11:00 – 12:19	10:00 – 11:10	13:40 – 14:43
Departure Time	16:05	12:38	11:20	15:15
Arrival Time	16:30	13:00	11:50	15:35
Release Time	16:49	13:20	12:05	15:50
Loading to Release Time	2.1 hrs (max)	2.3 hrs (max)	2.1 hrs (max)	2.2 hrs (max)
Tank Water Temperature at Capture (°C)	14.6	17.0	19.4	20.5
Tank Water Temperature at Arrival (°C)	15.3	18.0	20.9	21.3
Tank D.O. at Departure (mg/L)	8.7	17.6	11.79	11.65
Tank D.O. at Arrival (mg/L)	12.9	10.2	11.47	14.35
Tank Salinity (psu)	7.5	10.6	6.2	8.3
Release Water Temperature (°C)	14.7	17.7	20.2	20.7
No. of Shad Transported	25	30	23	23
No. of Shad Radio Tagged	25	30	23	21

4.3 Manual Tracking

Eighty-five fish were located in at least one manual tracking event. The remaining 14 fish that were not located in manual tracking were detected passing downstream at Vernon. Figure 4.3-1 (and Appendix B) identifies all tag detections made during manual tracking throughout the study period. In some cases, fish were detected in the study area, then upstream of the study area at MS-26. Several fish were located far upstream (e.g. to spawning habitat) after detection in the study area by manual tracking and were not subsequently detected returning to the study area. In those cases, fish were classified as having approached the study area without passage and then return upstream.

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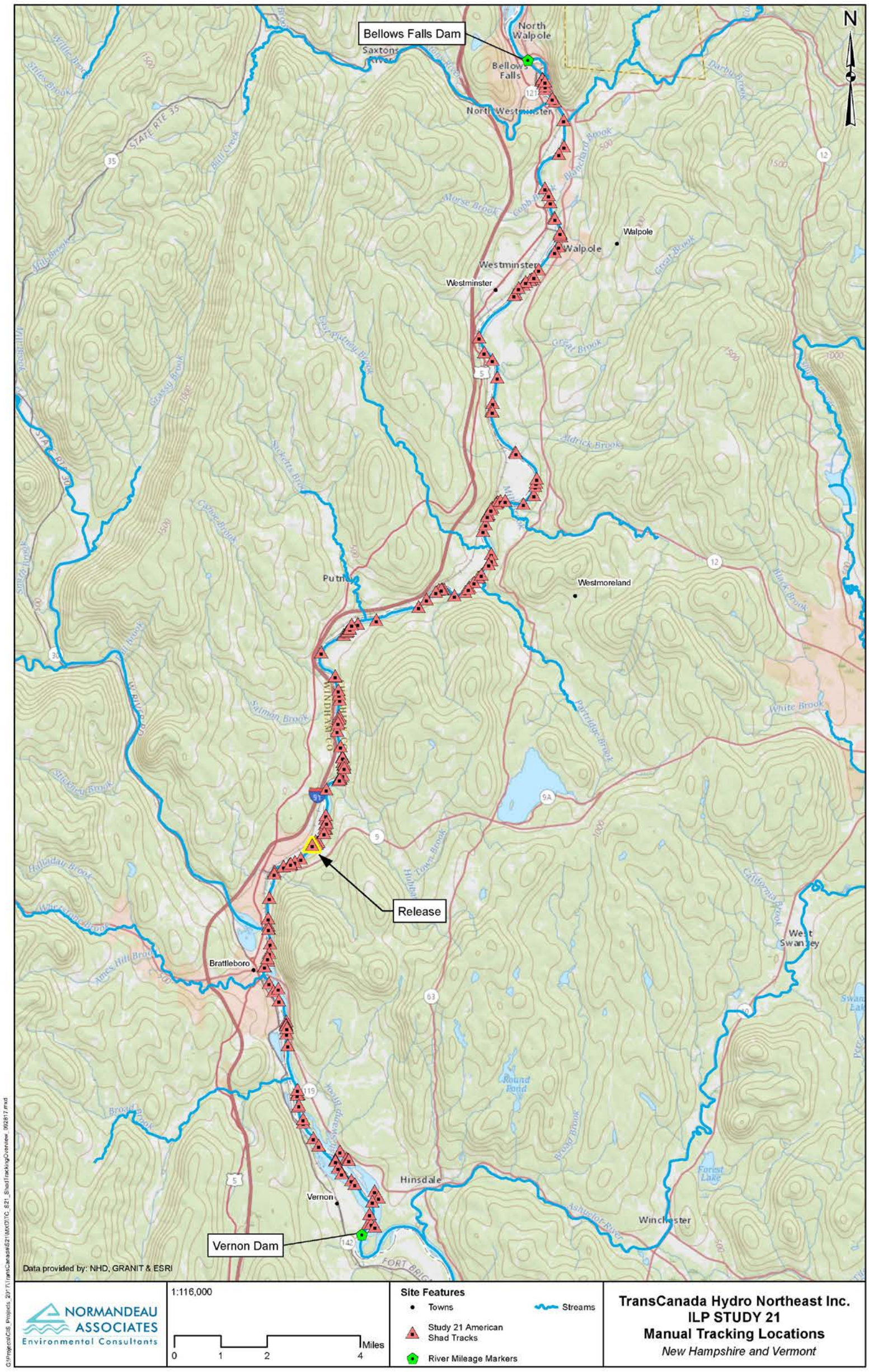

Figure 4.3-1. Adult American Shad locations detected via manual tracking, 2017.

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4.4 Downstream Passage

Downstream passage at Vernon was evaluated based on 99 radio-tagged adult shad that were released into the Vernon impoundment. Of those, 63 (64%) were available to enter the study area as determined by detections on the MS-26 receiver or within the study area itself. Ultimately 61 fish (62%) were detected in the study area and the remaining 38 (38%) were never detected in the study area.

Of the 61 individuals returning to Vernon, 13 were determined to have not passed downstream of the project. Six of those returned to points upstream (verified by manual tracking locations) that included areas of likely spawning concentrations identified in 2015, but did not subsequently return to Vernon to attempt downstream passage. Five (of 13) radio-tagged shad, or their transmitters, became stationary in the station forebay, and two were last detected in the station forebay. This supplementary route of passage assessment was therefore based on the downstream passage of 48 fish (i.e., 78.7% of individuals identified as having returned to the study area). A definitive passage route could not be determined for one individual (2.1%). The largest proportional route of passage was via the east fish pipe (N = 16, 33.3%). Thirteen (27.1%) passed via the spillway, 3 (6.3%) passed via the sluice gate, 5 (10.4%) passed via units 5-8, 5 (10.4%) passed via units 9-10, 2 (4.2%) passed via units 1-4, and 3 (6.3%) passed via the fish ladder. No outmigrating 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 4.4-1; Appendix A).

The majority of downstream passage events (N = 23) occurred when all 10 units were in operation, and most of those (N = 21) occurred when at least one spill gate was open as well. The most prevalent operational scenario observed was all units operating, accounting for 33% of the study period. Table 4.4-2 summarizes the frequencies of turbine unit operational scenario occurrences throughout the study period, and Appendix A presents operational status and discharge of each unit at the time of passage of each fish.

The temporal pattern of downstream passage events relative to total and spill discharge indicated that passage events generally tended to increase with total discharge and spill conditions, suggesting that elevated flows facilitated passage (Figure 4.4-1). Passage by all routes used occurred during some level of spill, though no fish pipe passages occurred during periods when spill discharge was more than 20,000 cfs (Figure 4.4-2). Downstream passage events were distributed throughout the day, but generally followed a diel pattern with the majority (~89%) occurring during daylight hours (Figure 4.4-3).

4.4.1 Return Timing and Forebay 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 (Figure 4.4-3). The majority (86%) of return events occurred during June.

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 (Table 4.4-3).

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. Figures 4.4-4 through 4.4-8 depict forebay residence times with total project discharge (cfs) and operational condition of Units 1-10. Table 4.4-4 includes the range, mean, and median total discharge, range, mean, and median spilling flows, percent of residency duration with spill, and percent of residency duration of each turbine unit (1-10) for each radio-tagged shad determined to have passed downstream at Vernon.

Table 4.4-1. Downstream passage routes of radio-tagged adult American Shad at 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**	**-**

a. Two fish, 58:153 and 58:180, may have been dead at time of passage

Table 4.4-2. Vernon unit operation scenarios[a] and percent of time of occurrence during the study period, May 31 – July 18, 2017.

Scenario[b]	Occurrence (%)
1111111111	33.4%
1111111011	12.8%
1111111101	6.5%
0000000001	5.4%
0111111101	4.3%
0000111101	3.9%
0011111101	3.5%
0100111101	2.9%
0001111101	2.7%
0001011101	1.8%
0000011101	1.8%
1111111001	1.5%
0000100001	1.4%
0101111101	1.3%
0101111001	1.2%
0100111111	1.0%

a. Several other operational scenarios occurred, but accounted for less than 1% of the time each, and 15% of the time in aggregate.

b. The 10 positions within the column "Operational Status" indicate Units 1 (left) through 10 (right) where 0 = offline and 1 = operational.

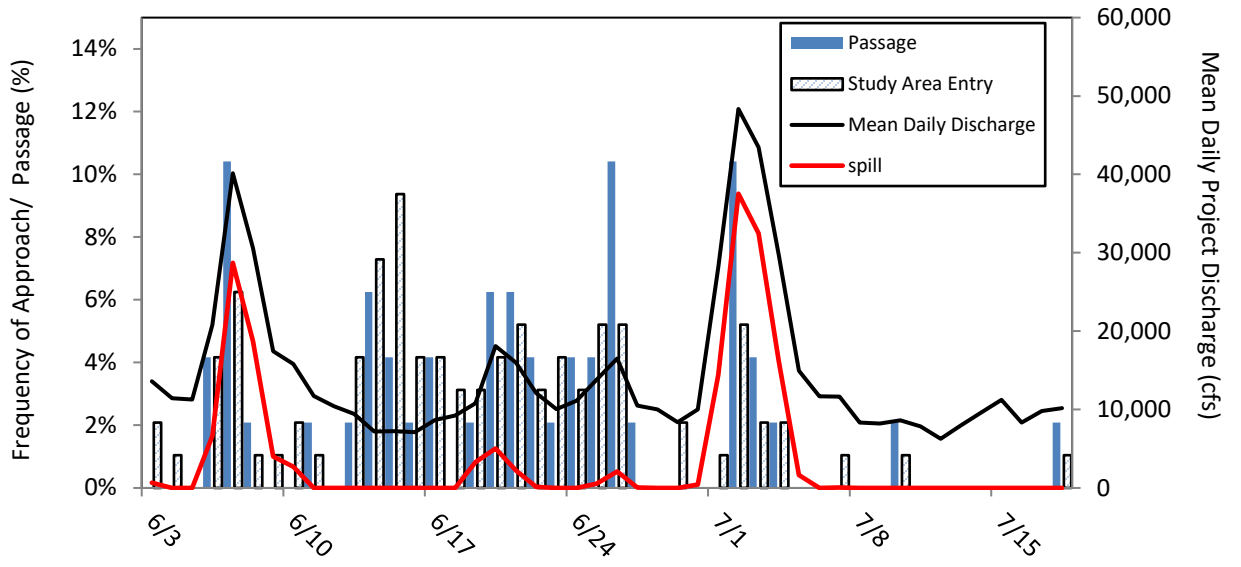

Figure 4.4-1. Temporal distribution of study area entry and downstream passage events of radio-tagged American Shad at Vernon with mean daily project discharge (cfs) and spilling flows (cfs), 2017.

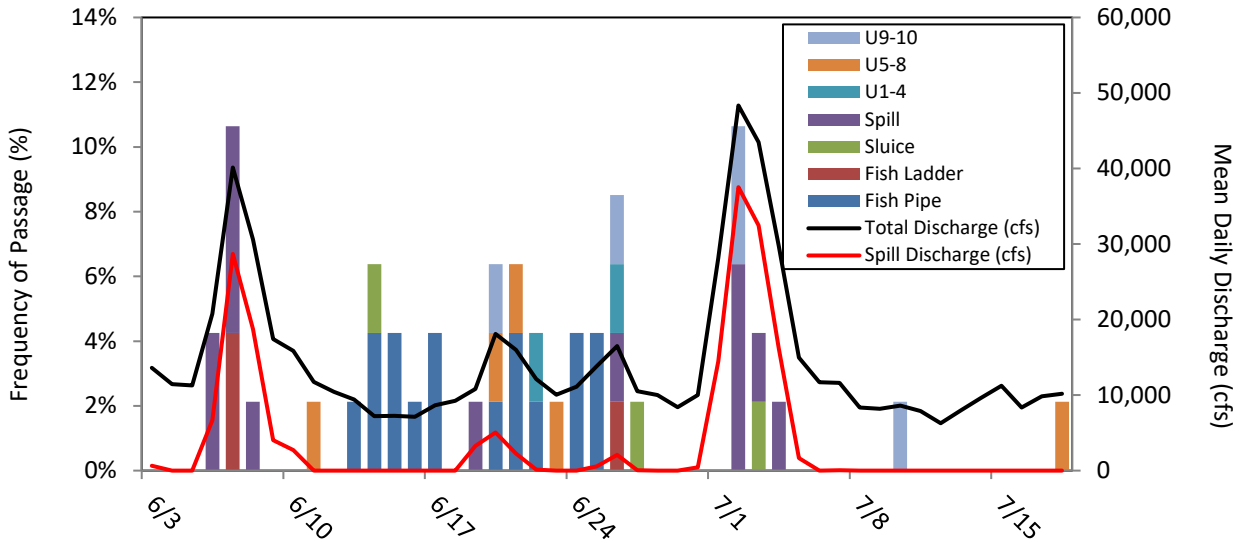

Figure 4.4-2. Temporal distribution of downstream passage of radio-tagged American Shad at Vernon by route of passage with mean daily project discharge (cfs) and spilling flows (cfs), 2017.

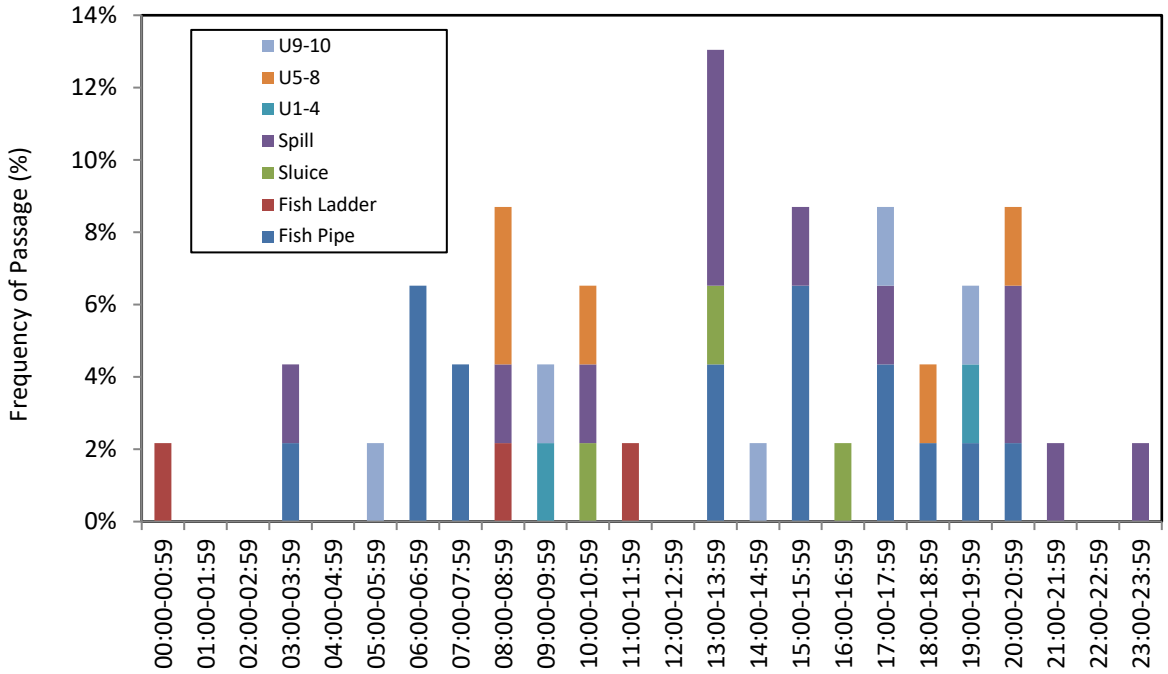

Figure 4.4-3. Temporal (time of day) distribution of downstream passage events of radio-tagged American Shad at Vernon by route of passage, 2017.

Table 4.4-3. Forebay residency duration (minimum, maximum, mean with standard deviation, 25th percentile, median, and 75th percentile) for radio-tagged shad prior to downstream passage at Vernon, 2017.

Downstream Passage Route	Residency[a]	Forebay Residency (hours)						
		N	Min	Max	Mean (SD)	25th Percentile	Median	75th Percentile
East Fish Pipe	Unadjusted	16	0.10	45.38	9.41 (11.97)	0.35	3.50	14.40
	Adjusted		0.10	25.93	6.24 (8.22)	0.35	2.03	7.41
Fish Ladder	Unadjusted	3	0.28	215.33	76.22 (98.5)	6.67	13.06	114.20
	Adjusted		0.28	75.23	29.52 (32.74)	6.67	13.06	44.15
Units 1-4	Unadjusted	2	13.30	13.96	13.63 (0.33)	13.47	13.63	13.80
	Adjusted		13.30	13.96	13.63 (0.33)	13.47	13.63	13.80
Units 5-8	Unadjusted	5	0.21	110.59	32.21 (39.9)	10.67	16.57	23.01
	Adjusted		0.21	19.53	12.28 (6.69)	10.67	14.43	16.57
Units 9-10	Unadjusted	5	0.30	21.65	5.54 (8.19)	0.48	0.94	4.32
	Adjusted		0.30	21.65	5.54 (8.19)	0.48	0.94	4.32
Sluice	Unadjusted	3	0.41	156.30	76.69 (63.69)	36.88	73.35	114.83
	Adjusted		0.41	155.33	76.36 (63.28)	36.88	73.35	114.34
Spill	Unadjusted	13	0.01	426.30	78.12 (122.62)	0.12	0.43	74.00
	Adjusted		0.01	67.85	13.8 (23.85)	0.12	0.43	15.41
Unknown	Unadjusted	1	263.32					
	Adjusted		247.27					
All	Unadjusted	48	0.01	426.30	43.84 (84.9)	0.32	11.69	29.13
	Adjusted		0.01	247.27	20.01 (43.46)	0.33	4.72	15.70

a. Unadjusted residency time is time from first detection in impoundment/ forebay to passage. Adjusted residence time excludes periods documented upstream of the project by detection at monitoring site 26 (Vermont Yankee intake).

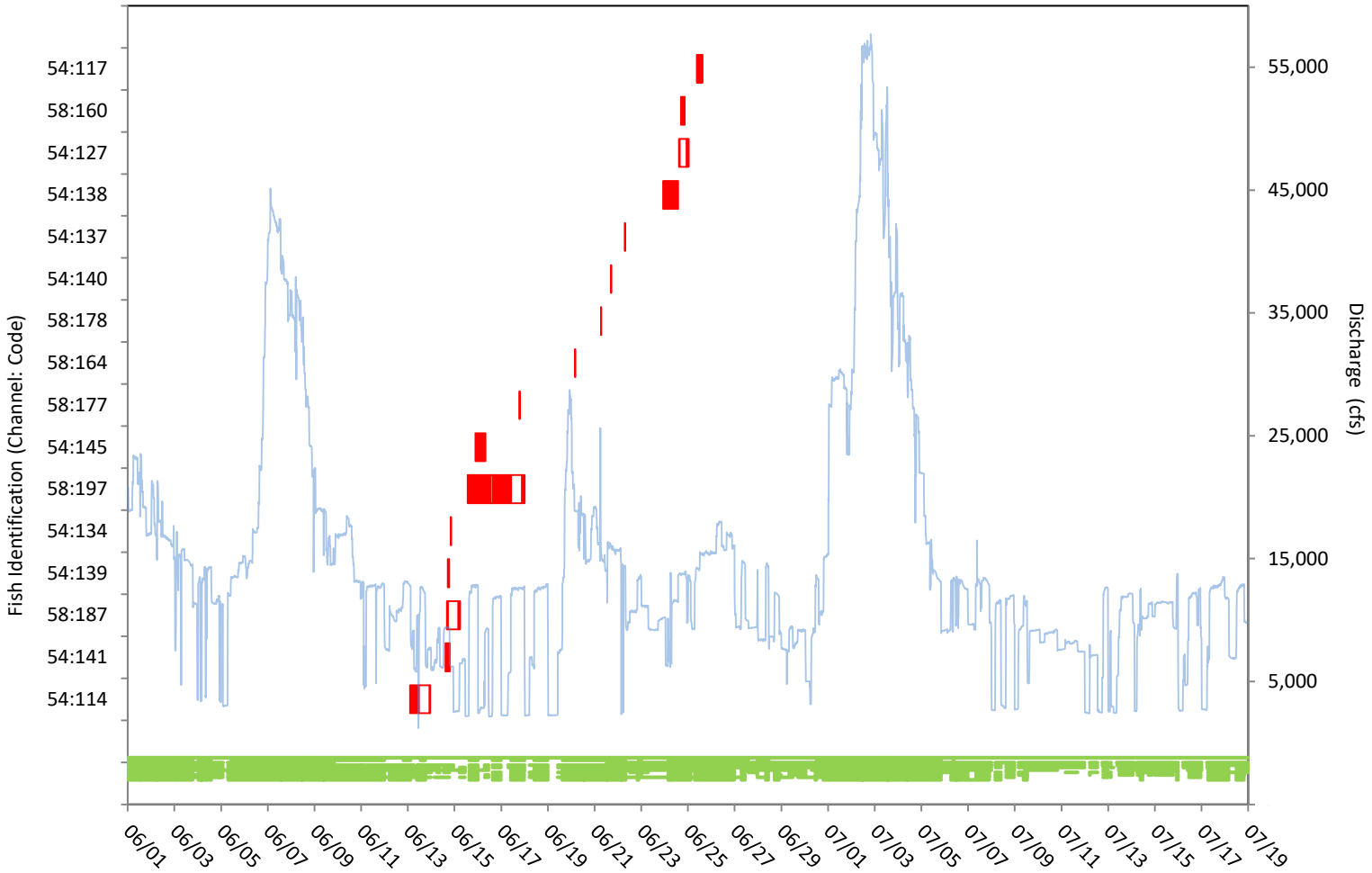

Figure 4.4-4. Forebay residence of radio-tagged adult shad emigrating past Vernon dam through the east fish pipe, 2017.

Figures 4.4-4 – 4.4-8, solid blue line = total project discharge; green lines = operational status of Units 1 (lower) through 10 (upper) where green = unit on and blank = unit off. Red bars = forebay residency periods where: unadjusted residency = overall length of the bar; and adjusted residency = sum of solid red segments (where solid red segments = durations spent in the study area and open segments = durations spent upstream of the study area).

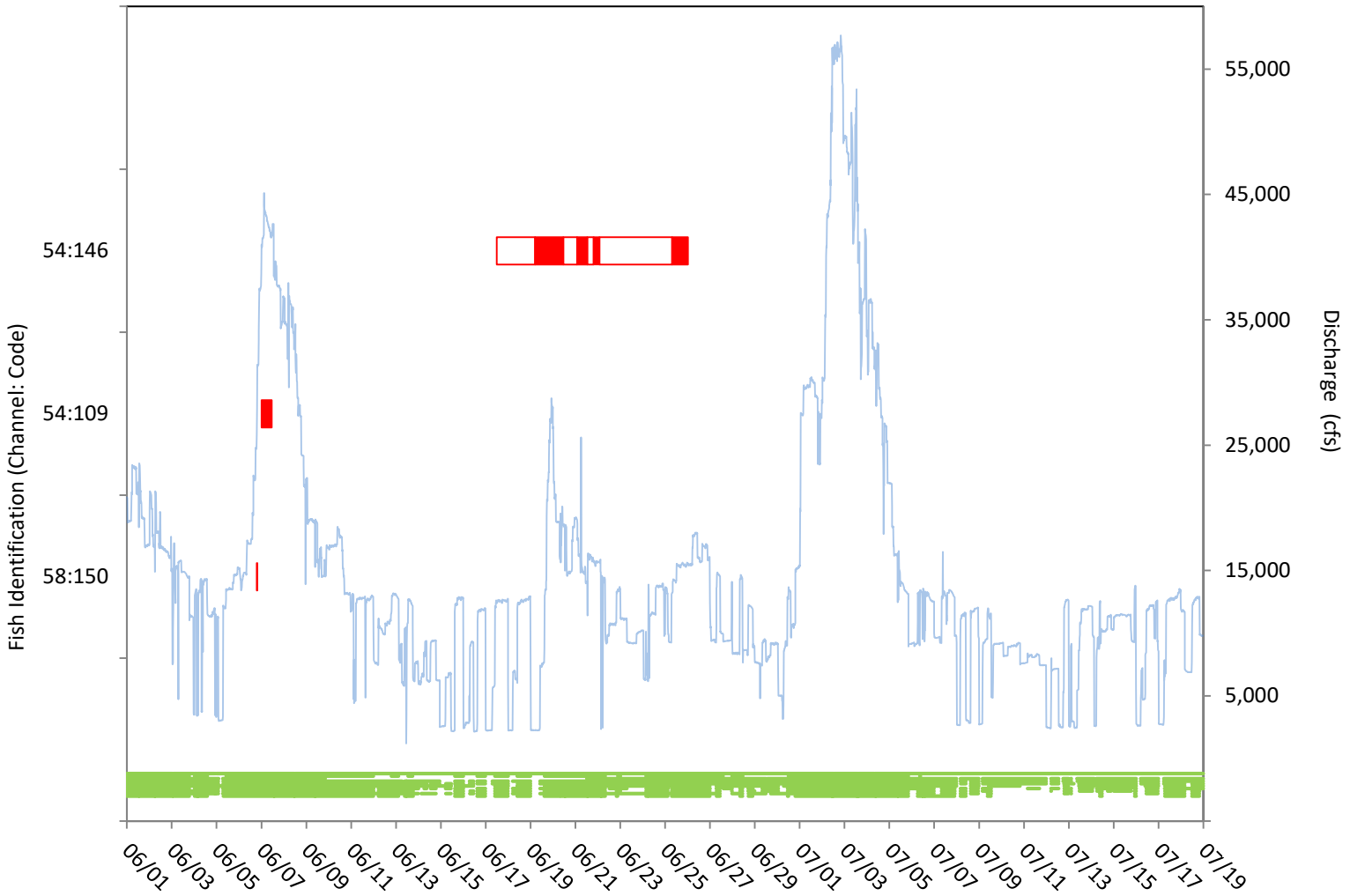

Figure 4.4-5. Forebay residence of radio-tagged adult shad emigrating past Vernon dam through the fish ladder, 2017.

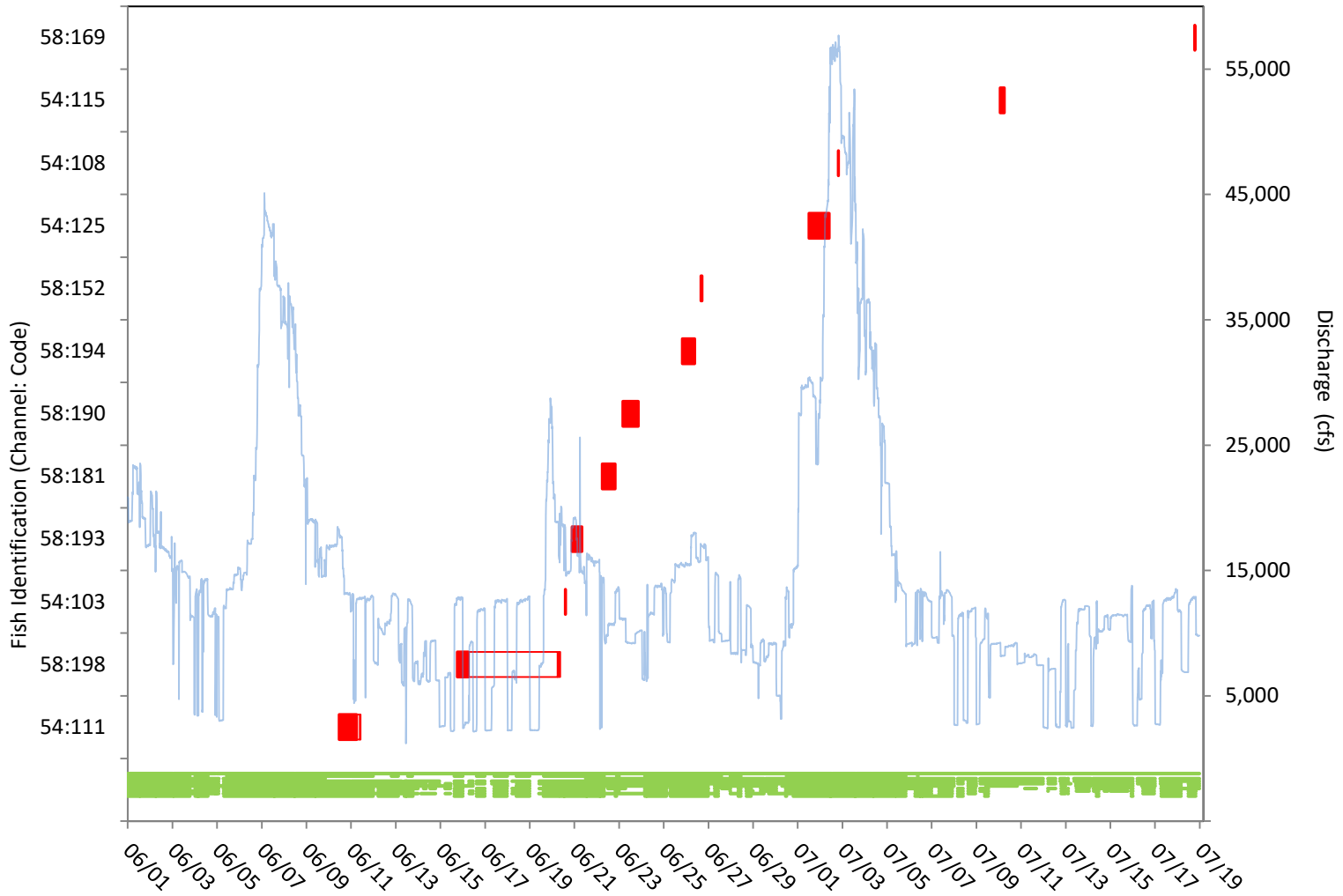

Figure 4.4-6. Forebay residence of radio-tagged adult shad emigrating past Vernon dam through the hydroelectric units, 2017.

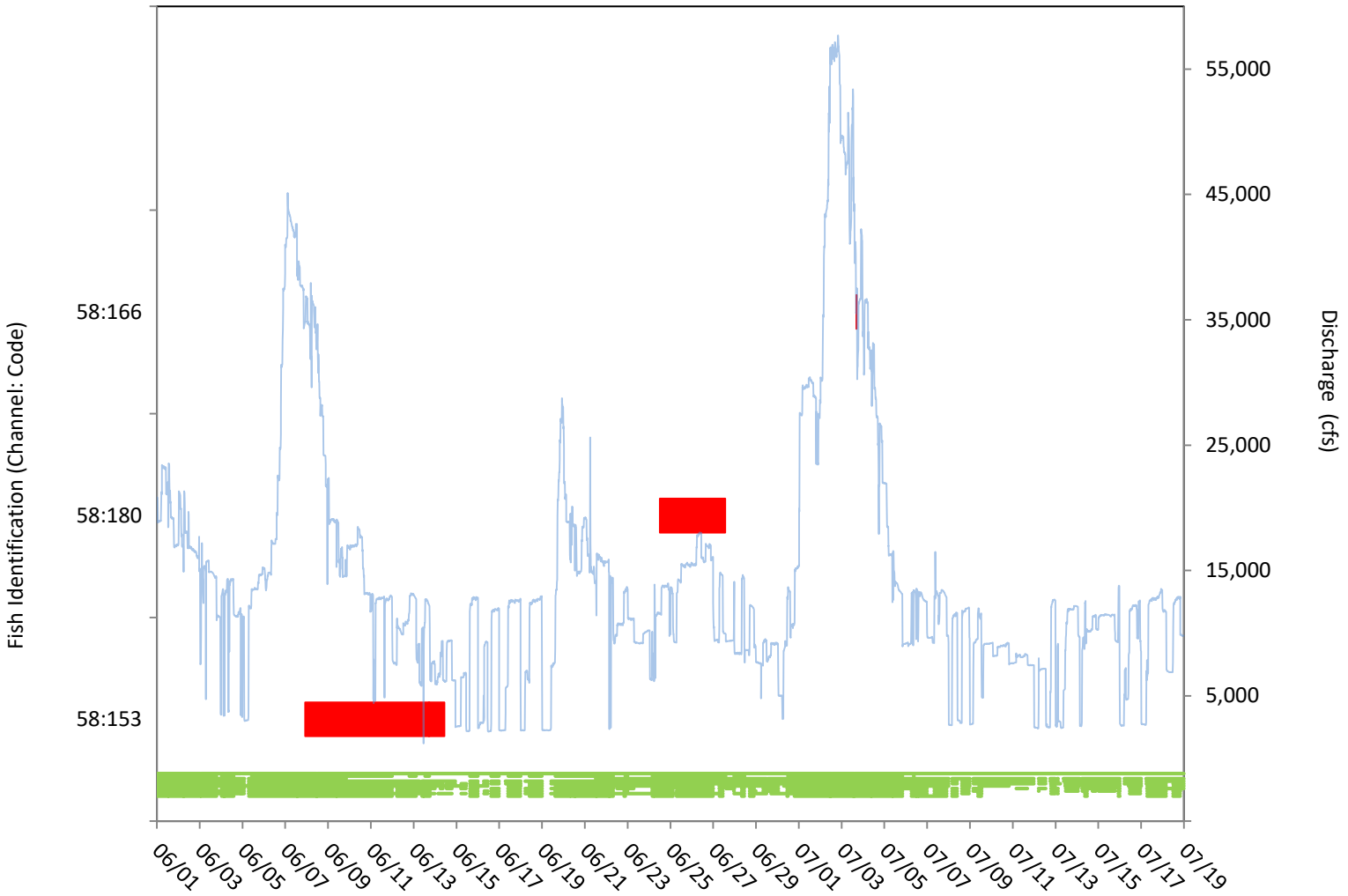

Figure 4.4-7. Forebay residence of radio-tagged adult shad emigrating past Vernon dam through the debris sluice, 2017.

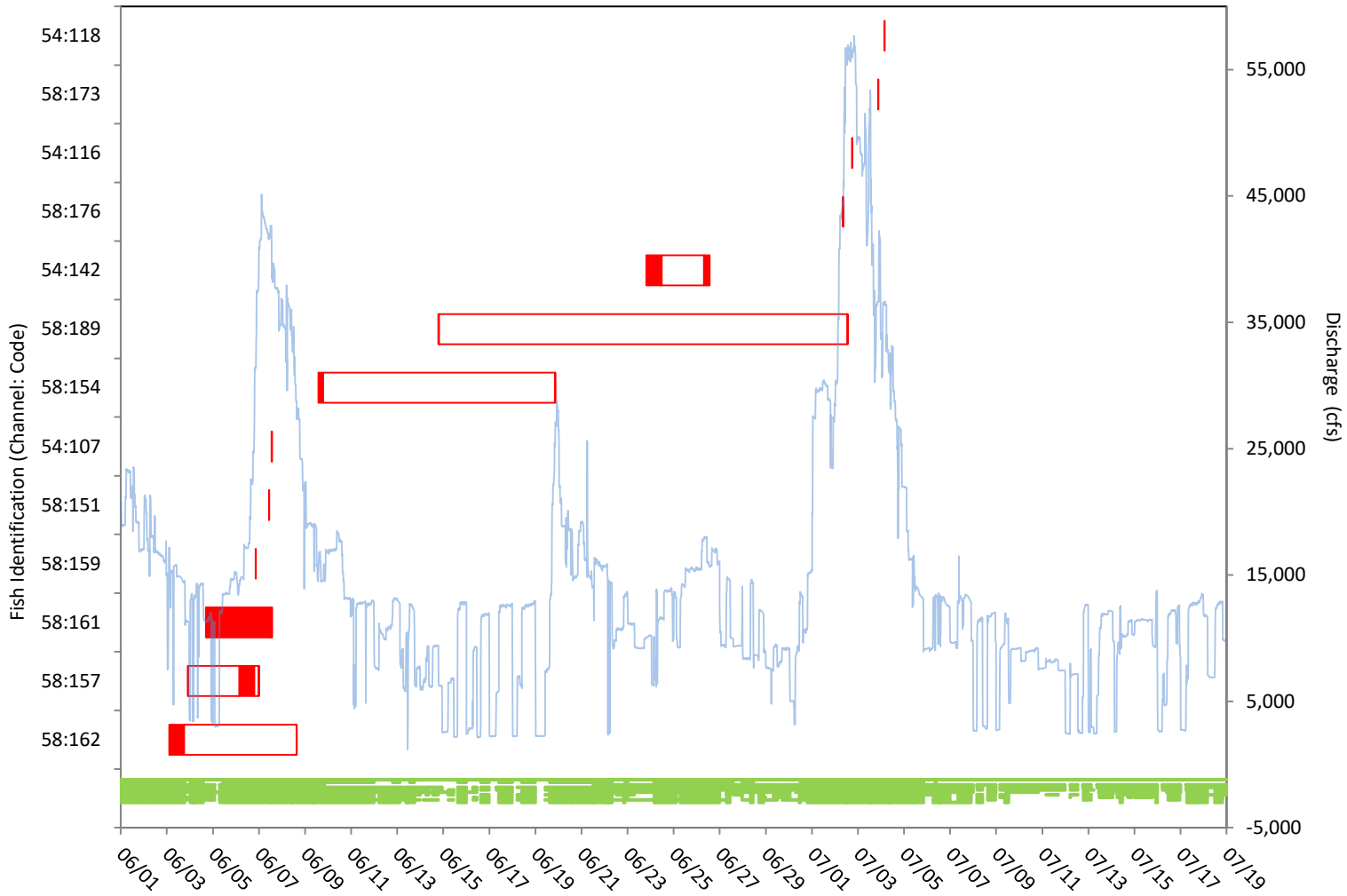

Figure 4.4-8. Forebay residence of radio-tagged adult shad emigrating past Vernon dam through the spillway, 2017.

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Table 4.4-4. Forebay residency durations by radio-tagged American Shad passed downstream at Vernon, 2017, with range, mean, and median total discharge, range, mean and median spilling flows, percent of residency duration with spill, and percent of residency duration of each turbine unit (1-10).

Fish ID	Date/Time of First Arrival	Date/Time of Passage	Passage Route	Forebay Residency		Total Discharge (cfs)				Spill Flow (cfs)					Percentage of Residence Duration with Unit in Operation									
				Duration (hrs)	Adjusted Duration (hrs)	Min	Max	Mean	Median	Min	Max	Mean	Median	% of Residency Duration	U1	U2	U3	U4	U5	U6	U7	U8	U9	U10
54:114	6/13/2017 2:20	6/13/2017 15:03	EastFishPipe	12.72	10.98	1,204	12,778	9,119	9,145	0	0	0	0	0	51	100	86	86	100	80	78	4	22	100
54:141	6/14/2017 14:43	6/15/2017 6:59	EastFishPipe	16.26	5.11	2,500	9,444	5,684	6,226	0	0	0	0	0	0	37	0	38	100	62	51	0	0	100
58:187	6/14/2017 16:09	6/14/2017 17:03	EastFishPipe	0.90	0.90	9,359	9,392	9,375	9,374	0	0	0	0	0	0	100	0	100	100	100	100	0	0	100
54:139	6/14/2017 17:07	6/15/2017 7:12	EastFishPipe	14.08	3.16	2,500	9,444	5,039	6,206	0	0	0	0	0	0	27	0	29	100	55	41	0	0	100
54:134	6/14/2017 19:58	6/14/2017 20:33	EastFishPipe	0.58	0.58	6,222	6,253	6,234	6,225	0	0	0	0	0	0	0	0	0	100	100	100	0	0	100
58:197	6/15/2017 13:23	6/16/2017 13:06	EastFishPipe	23.72	23.72	6,222	6,253	6,234	6,225	0	0	0	0	0	0	0	0	0	100	100	100	0	0	100
54:145	6/15/2017 21:27	6/17/2017 18:49	EastFishPipe	45.38	25.93	2,145	12,899	7,641	9,256	0	0	0	0	0	46	56	55	46	50	62	62	0	46	100
58:177	6/17/2017 18:48	6/17/2017 19:08	EastFishPipe	0.33	0.33	12,642	12,642	12,642	12,642	0	0	0	0	0	100	100	100	100	100	100	100	0	100	100
58:164	6/20/2017 3:50	6/20/2017 3:56	EastFishPipe	0.10	0.10	12,571	12,571	12,571	12,571	6,312	6,312	6,312	6,312	100	100	100	100	100	100	100	100	0	100	100
58:178	6/21/2017 6:36	6/21/2017 6:52	EastFishPipe	0.28	0.28	12,917	12,917	12,917	12,917	2,348	2,348	2,348	2,348	100	100	100	100	100	100	100	100	0	100	100
54:140	6/21/2017 16:48	6/21/2017 17:10	EastFishPipe	0.36	0.36	14,855	14,855	14,855	14,855	1,219	1,219	1,219	1,219	100	100	100	100	100	100	100	100	100	100	100
54:137	6/22/2017 7:01	6/22/2017 7:09	EastFishPipe	0.13	0.13	14,421	14,421	14,421	14,421	0	0	0	0	0	100	100	100	100	100	100	100	100	100	100
54:138	6/23/2017 22:31	6/24/2017 13:53	EastFishPipe	15.37	15.37	6,169	13,871	9,590	10,228	0	0	0	0	0	61	100	62	62	77	79	100	100	67	100
54:127	6/24/2017 14:42	6/24/2017 15:20	EastFishPipe	0.63	0.63	13,714	13,792	13,763	13,784	0	0	0	0	0	100	100	100	100	100	100	100	100	100	100
58:160	6/24/2017 16:43	6/25/2017 6:22	EastFishPipe	13.64	6.22	9,254	13,970	12,251	13,564	0	0	0	0	0	75	100	75	76	100	100	100	100	100	100
54:117	6/25/2017 9:02	6/25/2017 15:09	EastFishPipe	6.10	6.10	14,025	14,341	14,228	14,222	0	1,224	574	561	50	100	100	100	100	100	100	100	100	100	100
58:150	6/6/2017 19:10	6/7/2017 8:14	FishLadder	13.06	13.06	11,253	13,758	12,455	12,389	14,170	32,864	27,234	29,126	100	100	100	100	100	100	100	100	100	100	100
54:109	6/7/2017 0:12	6/7/2017 0:29	FishLadder	0.28	0.28	12,594	12,594	12,594	12,594	28,236	28,236	28,236	28,236	100	100	100	100	100	100	100	100	100	100	100
54:146	6/17/2017 11:52	6/26/2017 11:12	FishLadder	215.33	75.23	2,218	15,145	11,488	12,608	0	15,983	1,370	0	38	66	93	69	78	87	89	93	55	69	100
54:111	6/10/2017 11:04	6/11/2017 10:05	U5-8	23.01	19.53	4,412	13,229	12,015	12,998	0	5,200	886	0	24	100	100	100	100	100	100	96	0	100	100
58:198	6/15/2017 18:08	6/20/2017 8:44	U5-8	110.59	14.43	2,145	14,272	8,695	11,851	0	15,983	1,319	0	14	55	68	63	61	57	66	71	0	55	100
54:103	6/20/2017 14:06	6/20/2017 14:35	U9-10	0.48	0.48	13,574	13,620	13,597	13,597	3,193	4,877	4,035	4,035	100	100	100	100	100	100	100	100	0	100	100
58:193	6/20/2017 21:21	6/21/2017 8:01	U5-8	10.67	10.67	3,918	13,919	13,316	13,702	2,346	12,237	4,215	3,878	100	100	100	98	100	100	100	100	0	100	100
58:181	6/22/2017 5:54	6/22/2017 19:51	U1-4	13.96	13.96	9,165	14,440	10,898	10,707	0	0	0	0	0	14	100	14	71	100	100	100	100	14	100
58:190	6/23/2017 4:07	6/23/2017 20:41	U5-8	16.57	16.57	9,157	11,182	9,733	9,251	0	0	0	0	0	0	100	0	18	100	100	100	100	0	100
58:194	6/25/2017 20:02	6/26/2017 9:20	U1-4	13.30	13.30	14,144	14,507	14,361	14,389	1,020	3,577	1,821	1,122	100	100	100	100	100	100	100	100	100	100	100

Fish ID	Date/Time of First Arrival	Date/Time of Passage	Passage Route	Forebay Residency		Total Discharge (cfs)				Spill Flow (cfs)					Percentage of Residence Duration with Unit in Operation									
				Duration (hrs)	Adjusted Duration (hrs)	Min	Max	Mean	Median	Min	Max	Mean	Median	% of Residency Duration	U1	U2	U3	U4	U5	U6	U7	U8	U9	U10
58:152	6/26/2017 16:06	6/26/2017 17:02	U9-10	0.94	0.94	14,206	14,294	14,252	14,254	2,754	2,757	2,755	2,755	100	100	100	100	100	100	100	100	100	100	100
54:125	7/1/2017 12:04	7/2/2017 9:43	U9-10	21.65	21.65	10,718	13,809	12,877	13,230	9,957	39,956	19,869	16,416	100	100	100	100	100	100	100	100	100	100	100
54:108	7/2/2017 19:39	7/2/2017 19:57	U9-10	0.30	0.30	9,706	9,706	9,706	9,706	47,340	47,340	47,340	47,340	100	100	100	100	100	100	100	100	100	100	100
54:115	7/10/2017 1:38	7/10/2017 5:57	U9-10	4.32	4.32	8,139	9,248	8,248	8,193	0	0	0	0	0	0	0	0	0	100	100	100	100	0	100
58:169	7/18/2017 18:42	7/18/2017 18:55	U5-8	0.21	0.21	12,828	12,828	12,828	12,828	0	0	0	0	0	100	100	100	100	100	100	100	100	0	100
58:153	6/7/2017 22:15	6/14/2017 10:33	Sluice	156.30	155.33	12,828	12,828	12,828	12,828	0	0	0	0	0	100	100	100	100	100	100	100	100	0	100
58:180	6/24/2017 12:03	6/27/2017 13:24	Sluice	73.35	73.35	9,241	14,873	13,219	14,194	0	3,577	880	811	51	82	97	82	83	91	100	100	100	100	100
58:166	7/3/2017 16:30	7/3/2017 16:54	Sluice	0.41	0.41	10,350	11,039	10,695	10,695	25,309	25,380	25,345	25,345	100	100	100	100	100	100	100	50	100	100	100
58:162	6/3/2017 2:38	6/8/2017 15:23	Spill	132.73	15.41	2,984	15,258	12,216	12,675	0	32,864	9,058	0	47	82	94	94	91	100	96	95	96	80	98
58:157	6/3/2017 21:49	6/6/2017 23:49	Spill	74.00	67.85	2,984	15,258	12,198	13,496	0	25,810	2,156	0	21	72	89	89	88	100	93	93	94	68	97
58:161	6/4/2017 16:41	6/7/2017 13:24	Spill	68.71	67.28	2,984	15,258	12,200	13,401	0	32,864	8,380	0	43	79	92	91	92	100	93	91	93	75	99
58:159	6/6/2017 20:32	6/6/2017 20:50	Spill	0.31	0.31	13,515	13,515	13,515	13,515	17,930	17,930	17,930	17,930	100	100	100	100	100	100	100	100	100	100	100
58:151	6/7/2017 10:18	6/7/2017 10:21	Spill	0.05	0.05	10,770	10,770	10,770	10,770	30,764	30,764	30,764	30,764	100	100	100	100	100	100	100	100	100	100	100
54:107	6/7/2017 13:13	6/7/2017 13:39	Spill	0.43	0.43	10,578	10,640	10,609	10,609	27,854	27,928	27,891	27,891	100	50	100	100	100	100	100	100	100	100	100
58:154	6/9/2017 14:03	6/19/2017 20:53	Spill	246.83	5.25	1,204	14,804	9,306	10,821	0	13,986	483	0	12	58	79	63	71	79	78	79	2	50	100
58:189	6/14/2017 18:53	7/2/2017 13:11	Spill	426.30	0.75	2,145	15,145	10,539	11,794	0	46,528	2,553	0	33	54	83	63	70	83	88	89	62	60	100
54:142	6/23/2017 19:34	6/26/2017 13:25	Spill	65.84	21.73	6,169	14,532	12,521	13,765	0	3,577	633	0	38	80	100	81	81	95	95	100	100	88	100
58:176	7/2/2017 8:16	7/2/2017 8:19	Spill	0.06	0.06	11,546	11,546	11,546	11,546	33,008	33,008	33,008	33,008	100	100	100	100	100	100	100	100	100	100	100
54:116	7/2/2017 17:49	7/2/2017 17:50	Spill	0.01	0.01	9,736	9,736	9,736	9,736	46,399	46,399	46,399	46,399	100	100	100	100	100	100	100	100	100	100	100
58:173	7/3/2017 21:06	7/3/2017 21:17	Spill	0.18	0.18	12,984	12,984	12,984	12,984	23,647	23,647	23,647	23,647	100	100	100	100	100	100	100	100	100	100	100
54:118	7/4/2017 3:25	7/4/2017 3:32	Spill	0.12	0.12	12,979	12,979	12,979	12,979	23,367	23,367	23,367	23,367	100	100	100	100	100	100	100	100	100	100	100
58:172	6/15/2017 9:44	6/26/2017 9:03	Unknown	263.32	247.27	2,145	15,145	10,753	12,466	0	15,983	1,114	0	30	62	86	66	72	80	84	87	45	65	100

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5.0 DISCUSSION AND CONCLUSIONS

This document provides supplemental results for ILP Study 21 – American Shad Telemetry Study at Vernon (Normandeau, 2017) conducted in 2015 in support of FERC relicensing for the Wilder, Bellows Falls, and the Vernon Hydroelectric Projects. Agency comments on the study report indicated that the number of adult shad for which a downstream passage route could be determined in 2015 was too low to draw reasonable conclusions. Great River Hydro agreed, and conducted this supplemental study to enhance the understanding of downstream passage route selection by adult American Shad at Vernon. The results reported herein provide a more conclusive evaluation of proportional route of passage, therefore fulfilling that study objective.

In this supplemental study, 101 adult American Shad were collected from the Vernon fish ladder, tagged with uniquely coded radio transmitters and transported upstream where 99 were released. Two fish regurgitated their transmitters in the transport tank and were released untagged. The tag and release procedures differed from the 2015 study in that tagging was done at the time of collection and groups were batch released, whereas in 2015 the group was transported to the release site and individually tagged and released.

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. 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 ft 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.

Sixty-one (i.e., 62% of the total number tagged) tagged shad approached Vernon during the study, and 48 of the 61 (79% of fish that approached) were monitored passing downstream. Downstream passage route determination was made for 47 of those and one passed downstream via an unknown route. The designated downstream fish bypass, the east fish pipe, was the dominant route of passage (34% of known passage routes) and was used during both spill and non-spill conditions and among a range of operational conditions observed with the exception of high spill (> 20,000 cfs). In combination, passage via hydroelectric units contributed 25.5% of the known routes of passage.

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% of the study period. The average proportion of forebay residency that occurred during spill conditions was 47.9% (see Table 5.4-2). In comparison, the average proportion in 2015 was 51.5%. 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.

6.0 LITERATURE CITED

Normandeau. 2017. ILP Study 21 - American Shad Telemetry Study at Vernon Final Study Report. Prepared for TransCanada Hydro Northeast Inc. February 28, 2017.

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APPENDIX A, B FILED SEPARATELY EXCEL FORMAT

Appendix A: Downstream Passage Data

Appendix B: Manual Tracking Locations