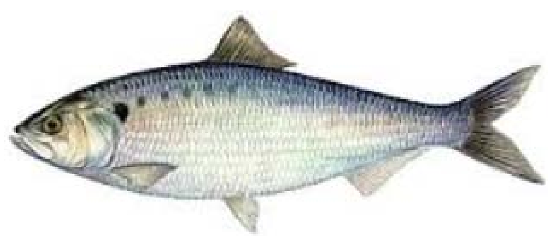
Proposed Study Plan for the Acoustic Evaluation of Juvenile American Shad and Adult American Eel Passage and Entrainment at Turners Falls Hydroelectric Project (No. 1889) and Northfield Mountain Pumped Storage Project (No.2485)



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Introduction

This document further describes FirstLight's proposed study plan for the acoustic evaluation of the downstream passage and entrainment of juvenile American shad (Study No. 3.3.3) and adult American eels (Study No. 3.3.5) at the Turners Falls Hydroelectric Project (No. 1889) and entrainment at the Northfield Mountain Pumped Storage Project (No. 2485). The objective of the acoustic study is to determine the timing and abundance of juvenile shad outmigrating through the Turners Falls power canal and their rate of entrainment at Cabot Station and Northfield Mountain, and to determine the timing of out migrating eels. Radiotelemetry methods will be employed to determine route of passage selection and delay. The study period will include the months of August through October 2015.

The purpose of this document is to expand further on equipment, equipment placement location, and details associated with Revised Study Plan (RSP) Nos. 3.3.3 and 3.3.5.

Juvenile American shad study plan (Study No. 3.3.3)

At Turners Falls, two locations will be monitored with hydroacoustics: Cabot Station and the power canal downstream of the gatehouse (Figure 1). At Northfield Mountain the tailrace will be monitored, which functions as the intake during pump-back operation (Figure 2).

Study Plan No. 3.3.3 describes the components of the acoustic equipment, where it will be installed, how it will be sampled and how the data will be analyzed. For American shad, a split-beam sonar (Figure 3) will be used, which is a technology well suited for estimating the abundance of schooling fish as well as the entrainment of individual fish (MacLennan and Simmonds 2005; Nestler et al. 1998). The two principal analysis methods for calculating fish abundance from split-beam data are target tracking and echo integration. Target tracking techniques are the preferred method when the echoes from individual fish are easily resolved. Target tracking methods provide information on individual fish, including acoustic size (which is related to physical size), position and velocity. When fish aggregate in tight schools, the echo returns often overlap. In this situation echo integration provides more robust estimates of fish abundance. Echo integration is a well-established fish quantification technique based on the concept that the total amount of echo energy is proportional to the density of targets in the ensonified volume of water. To calculate fish density, the total amount of backscattered echo energy is divided by the amount of acoustic energy contributed by an individual fish. The individual fish backscattering strength is estimated by measuring the strength of echoes from well-resolved fish in situ near the edges of schools.

A proposed study plan for the acoustic evaluation of out-migrating adult American eels (Study No. 3.3.5) is provided below. Confident species identification of the much less abundant eels will best be accomplished with imaging sonar.

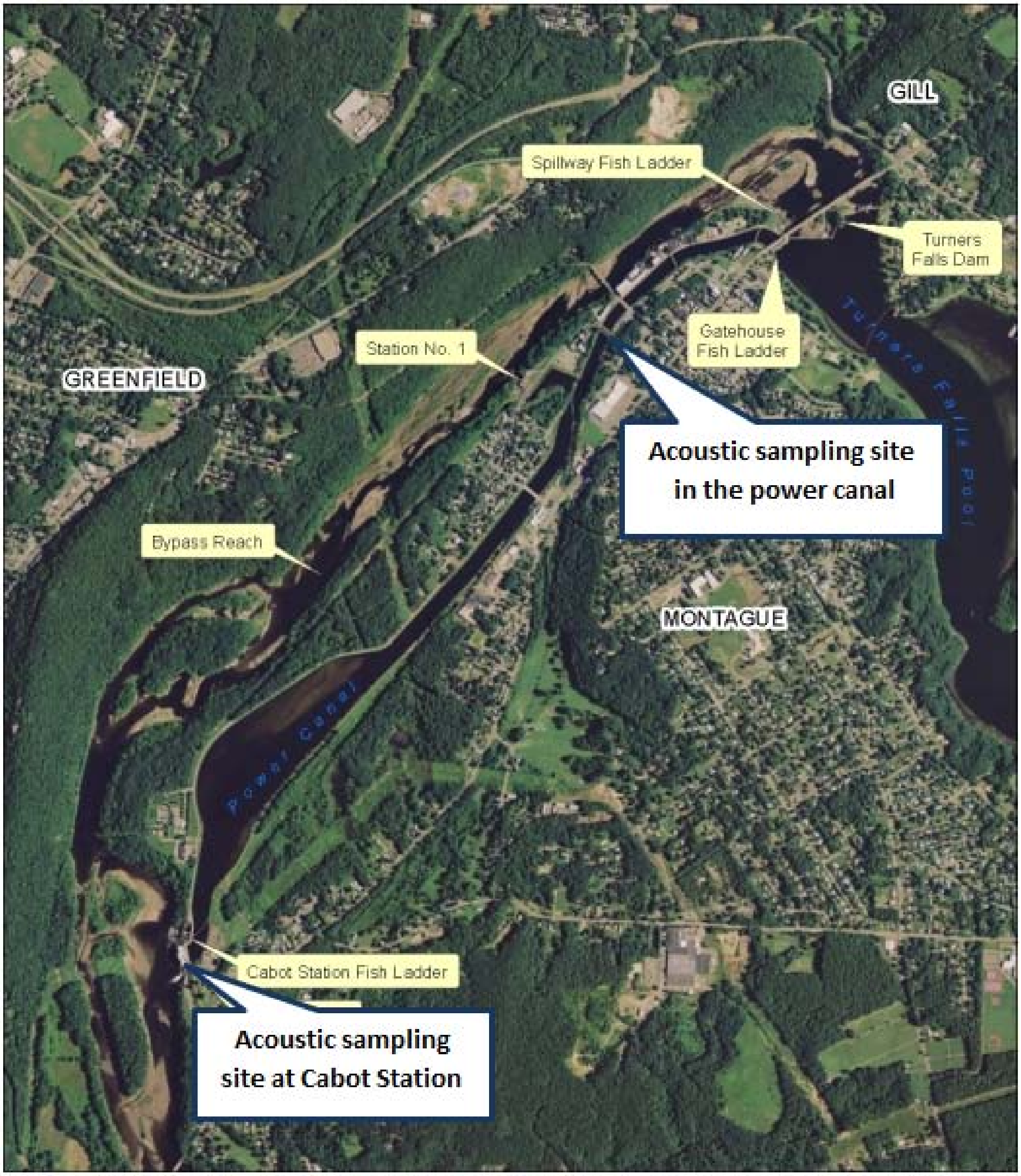

Figure 1. Proposed hydroacoustic sampling sites for monitoring passage and entrainment of juvenile American shad at Turners Falls.

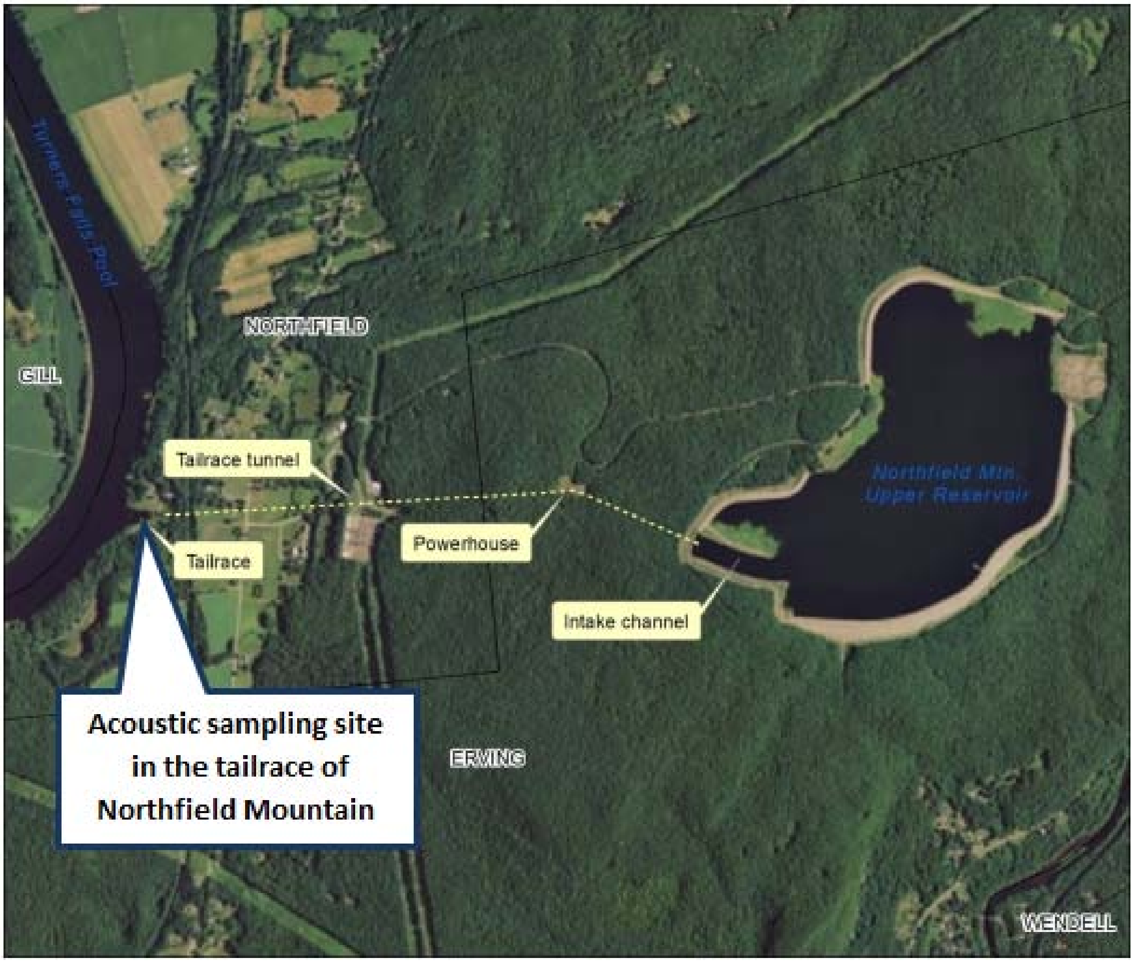

Figure 2. Proposed hydroacoustic sampling site for monitoring the entrainment of juvenile American shad at the Northfield Mountain Pumped Storage facility.

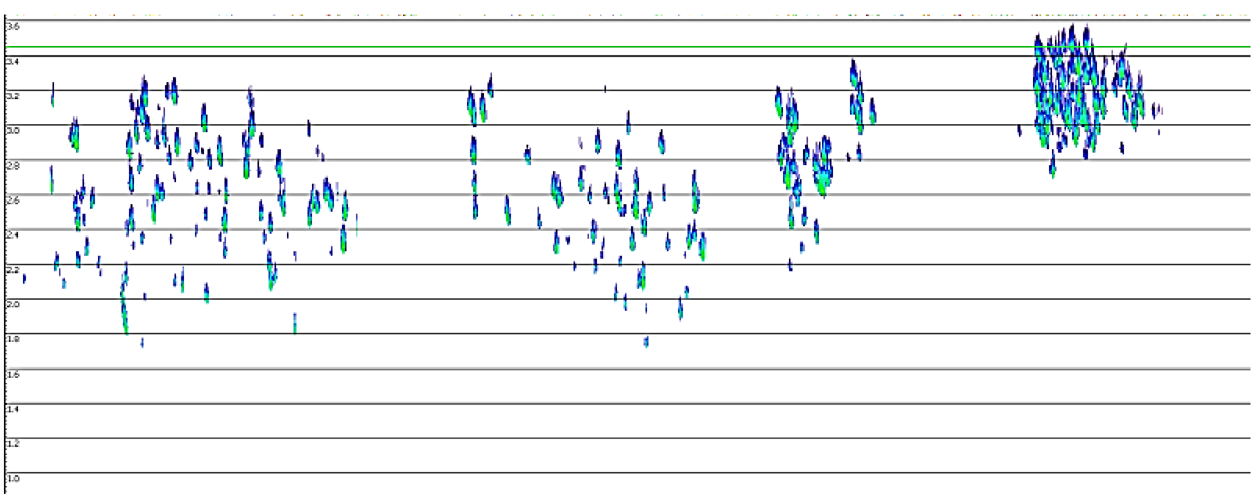

Figure 3. Echogram of schooling fish. The example shown are out-migrating salmon smolts recorded in the Kvichak River, Alaska. The echogram represents echo intensity over time (x-axis) and range (y-axis).

Turners Falls Hydroelectric Project — Cabot Station

Equipment

Equipment components to be installed at Cabot Station are listed in Table 1. The two data collection computers will run Simrad ER60 data collection software with a multiplexing utility that automatically switches between transducers. The acoustic data files will be written to a RAID drive, which provides an automatic backup of the data.

FirstLight will supply 110 V power and an internet connection with a minimum speed of 6 Mbps to each equipment cabinet.

Table 1. Acoustic equipment to be installed at Cabot Station.

	Units	Total	Description
General Purpose Transceiver (GPT)	2	2	Simrad EK60
Multiplexer	1 per GPT	2	Simrad EK60 multiplexer
Transducers	4 per GPT	8	7-degree 333 kHz splitbeam with 35 m cable
Transducer mounts	1 per transducer	8	pole mount
Power surge suppressor	1 per GPT	2	
Data collection computer	1 per GPT	2	
Ethernet switch	1 per GPT	1	
NAS RAID drives (1 TB)	1 per GPT	2	Data storage and backup
Weatherproof cabinet	1 per GPT	2	housing for GPT, multiplexer, computer, surge protector, Ethernet switch, and NAS RAID drive

Installation

The transducers will be installed in 8 of 18 intake bays. The selected bays are shown in Figure 4. The 4 transducers of GPT 1 will sample bays 1 and 2 of Unit 1, and bays 2 of Unit 2 and Unit 3. The 4 transducers of GPT 2 will sample bays 2 of Unit 4 and Unit 5 and bays 2 and 3 of Unit 6. This setup samples the center bay of each unit plus the outermost bay on each side of the forebay. Spatial coverage of the two outer units, Units 1 and 6, have been prioritized as the adjacent canal walls are likely to concentrate outmigrants in these areas. Further, Unit 1 is the most frequently operated unit (77%, calculated from generation data between 2011 and 2013) during the out migration period, August through October.

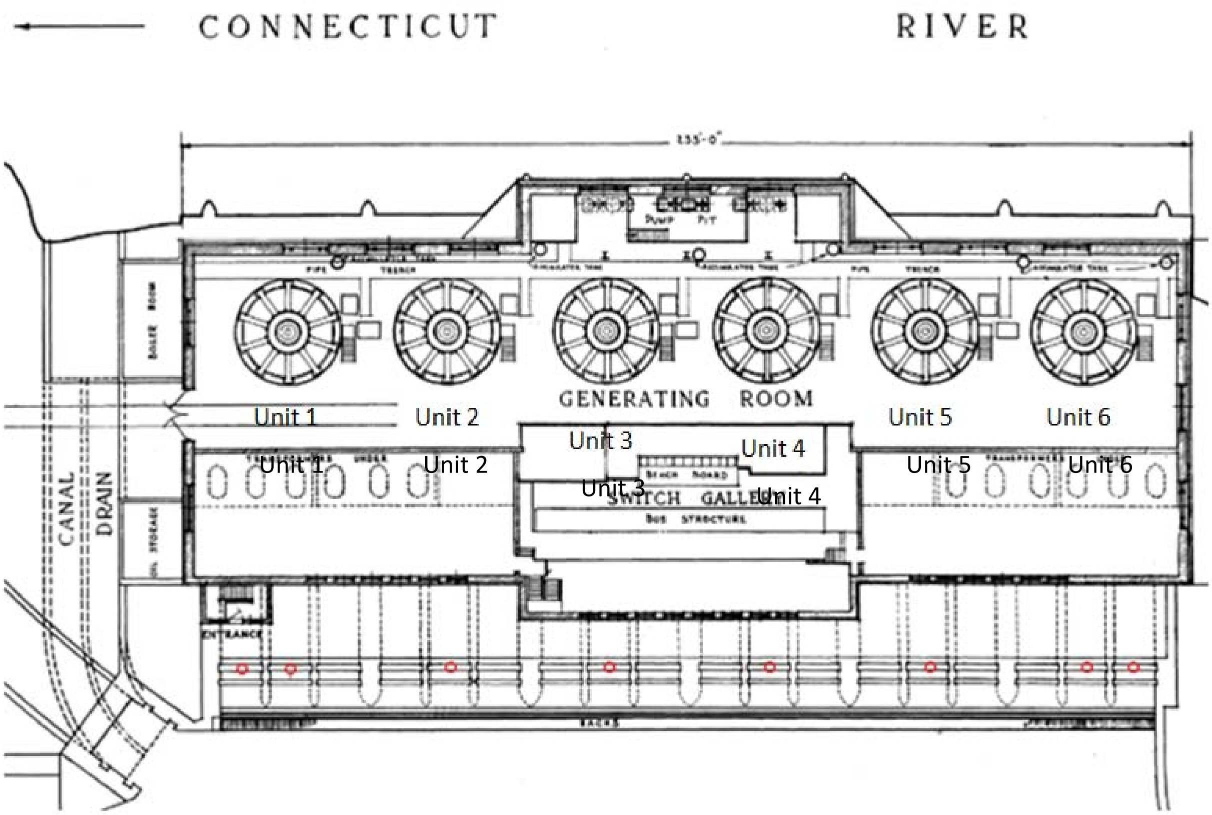

Figure 4. Cabot station plan view showing the location of the 8 transducers (red circles) sampling the intake bays.

To sample entrainment downstream of the trash rack each transducer will be installed on a pole mount (Figure 5) attached to the head gate such that the transducer is centered in the bay it samples aiming 4° - 6° upstream from straight down. In the final deployment the head gates will be lowered to their storage position with the transducers placed at an elevation of 96 - 100 ft (Figure 6). All transducers will be field calibrated after installation is complete, and again after sampling has been completed for the year. The placement of the two GPT cabinets will be determined after further discussion with FirstLight.

Figure 5. Transducer pole mount.

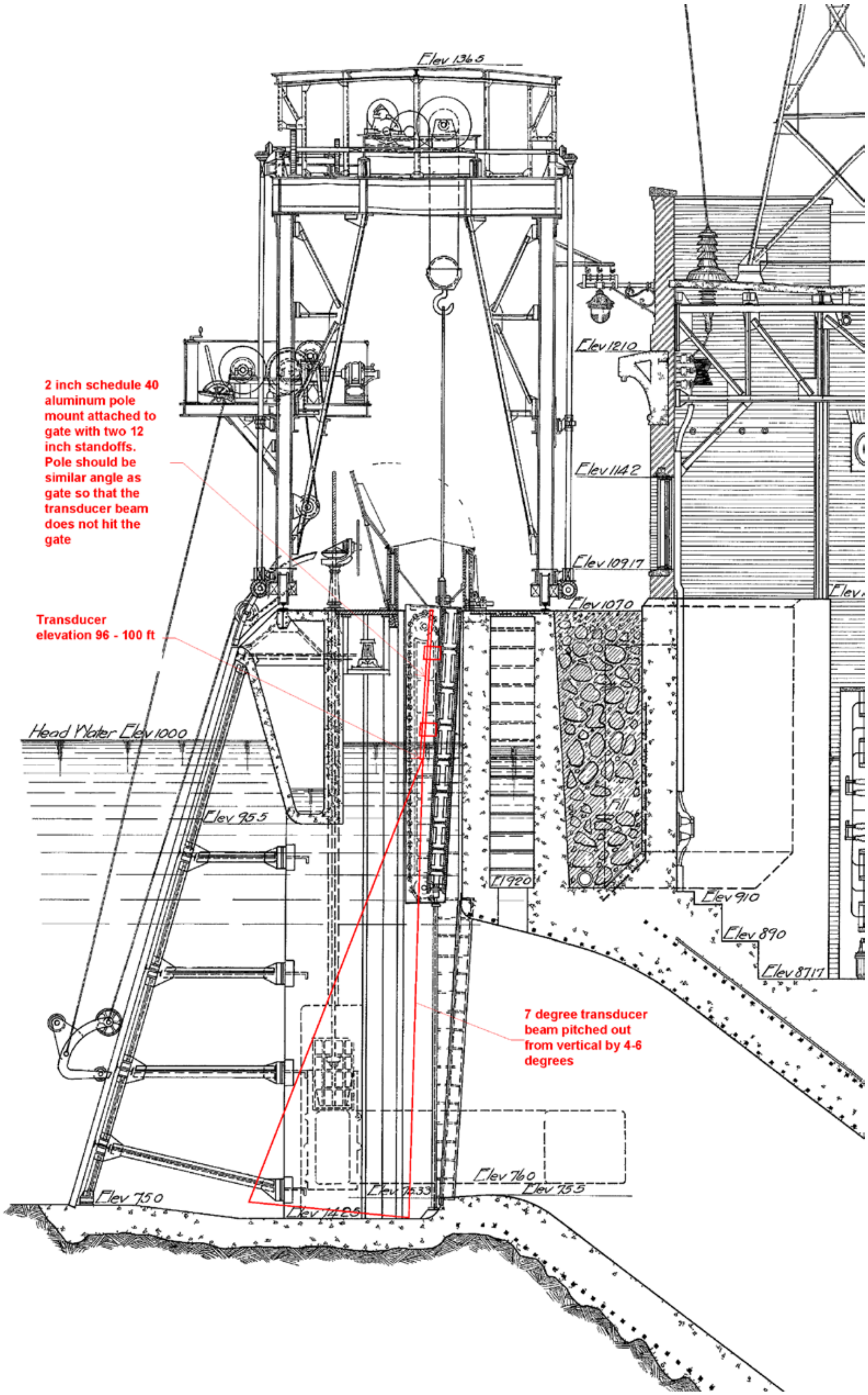

Figure 6. Cabot Station section view through the intake bay of Unit 3 showing the location of the transducer mount and an outline of the beam volume sampled.

Sampling scheme

In the configuration described above, the 8 transducers will sample a total of approximately 10 % of the Cabot Station intake area. Each transducer will sample 50 % of the time. Each GPT will ping on 2 transducers simultaneously (fast-multiplex), alternating every 15 minutes between 2 pairs (slow-multiplex). In this multiplexing scheme GPT 1 will start at the top of the hour with a fast-multiplex on transducers 1 and 3. After 15 minutes it will switch to a fast-multiplex on transducers 2 and 4, and so on. GPT 2 will start at the top of the hour with a fast-multiplex on transducers 5 and 7 and then switch to a fast-multiplex on transducers 6 and 8. Slow multiplexing is required since echo sounders currently available cannot ping fast enough in fast multiplex mode to sample all 4 transducers effectively. The data collection parameters, including power level, pulse duration, and ping interval will be optimized during installation to achieve the best signal to noise ratio and highest resolution.

Data analysis

While data will be collected continuously, only data collected during generation will be processed. Data will be analyzed with the fish tracking module of Myriax Echoview version 6, which uses an α-β tracking algorithm to identify the series of echoes generated by an individual fish as it is passing through the acoustic beam. The number of entrained fish detected will be expanded proportionately to account for bays not sampled, time not sampled, and for the unensonified portion of the sampled bays. The expansion factor that will be used to correct for the unensonified portion of a sampled bay will be based on the effective beam width (which is a function of fish size and range) relative to the width of the bay sampled. For example, if an entrained fish was observed at a range where the effective beam width for a fish of its size was half the width of the intake, it will be counted as 2 fish in the final estimate. Estimates of fish length will be calculated with Love's dorsal aspect equation (Love 1971) for a frequency of 333 kHz:

$$Fish\ length\ (inches) = 10\hat{}((TS + 23.9 - 0.9 * Log10(\lambda)))/19.1) * 1000)/25.4$$

where TS is the mean splitbeam-corrected acoustic size for all echoes within the given fish track, and λ is the wave length in meters.

The data will be summarized to provide an estimate of the number of entrained fish per hour, per date, and per bay. In addition we will examine the fish range and size distribution by season. The hydroacoustic data will be ground-truthed by concurrently sampling at the downstream bypass over 12-18 discrete sampling events as described in RSP Study No. 3.3.3.

Turners Falls Hydroelectric Project — Canal downstream of Gatehouse

Equipment

Equipment components to be installed at the power canal are listed in Table 2. The data collection computer will run Simrad ER60 data collection software with a multiplexing utility that automatically switches between transducers. The acoustic data files will be written to a RAID drive, which provides an automatic backup of the data.

FirstLight will supply 110 V power and an internet connection with a minimum speed of 6 Mbps to the equipment cabinet.

Table 2. Acoustic equipment to be installed at the power canal.

	Units	Total	Description
General Purpose Transceiver (GPT)	1	1	Simrad EK60
Multiplexer	1 per GPT	1	Simrad EK60 multiplexer
Transducers	4 per GPT	4	7-degree 333 kHz splitbeam with 35 m cable
Transducer mounts	1 per transducer	4	sled mount
Power surge suppressor	1 per GPT	1	
Data collection computer	1 per GPT	1	
Ethernet switch	1 per GPT	1	
NAS RAID drive (1 TB)	1 per GPT	1	Data storage and backup
Weatherproof cabinet	1 per GPT	1	housing for GPT, multiplexer, computer, surge protector

Installation

The 4 transducers sampling the power canal will be deployed immediately upstream of the Power Street Bridge (Figure 7). Each transducer will be mounted on a sled similar to the one shown in Figure 8. The transducers will be deployed in an up-looking orientation to maximize spatial coverage in the upper water column where shad migrate. During the installation the sleds will be lowered from the bridge when flows in the canal are reduced. The 4 sleds will be placed on the canal bottom, with the transducers aimed up towards the surface, approximately equally spaced across the width of the canal. The transducer cables will run to the GPT cabinet, which will be installed on the bridge. The sleds will be weighted to keep them in place and tethered to the bridge to allow easy retrieval. All transducers will be field calibrated using a standard tungsten carbide 22 mm calibration sphere after installation is complete, and again after sampling has been completed for the year. The calibration sphere will be held in the transducer beam to obtain target strength measures for the sphere and the system calibration for each transducer will be adjusted to correct for any deviations in the calibration.

Figure 7. Acoustic sampling site for monitoring the power canal at Power Street Bridge.

Figure 8. Up-looking transducer mounted on sled.

Sampling scheme

The total area sampled by the 4 transducers represents approximately 9 % of the canal cross-section (Figure 9). The GPT will alternate every 15 minutes (slow multiplex) between the 4 transducers, i.e. each transducer will sample 25 % of the time. A slow multiplexing scheme has been chosen to maximize the ping rate and minimize potential cross-talk between the transducers. The data collection parameters, including power level, pulse duration, and ping interval will be optimized during installation to achieve the best signal to noise ratio and highest resolution.

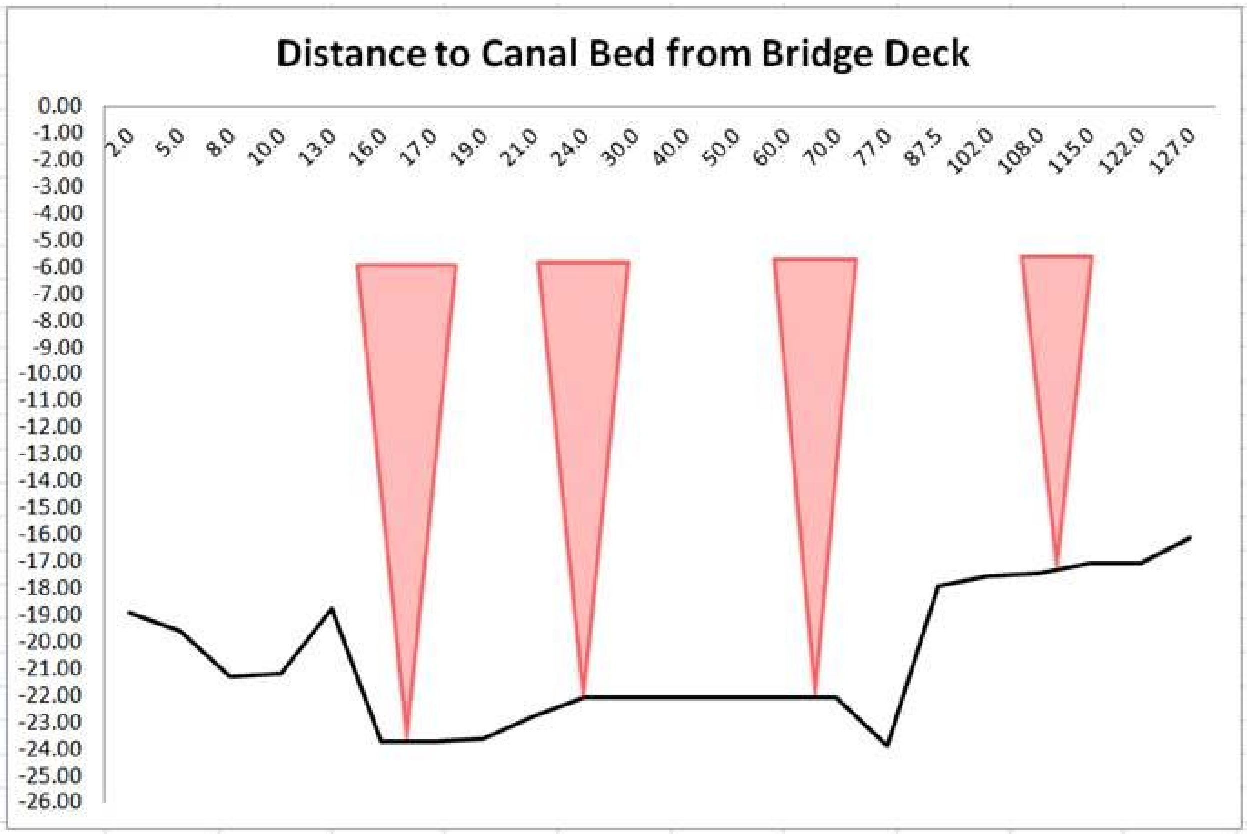

Figure 9. Sketch of the canal cross-section looking downstream at the Power Street Bridge showing the approximate sampling area covered by each transducer.

Data analysis

All data collected will be processed using Myriax Echoview version 6. The data will be edited visually to remove noise from non-fish targets. After noise removal the data will be echo integrated. Echo integration is a well-established analysis technique for estimating fish density based on the principle that the total acoustic energy reflected by a group of targets equals the sum of the energy reflected by each individual target. The results will be scaled with in situ mean target strength estimates derived from individual tracked fish. To convert the estimated fish density (fish/m^3) to an estimate of fish flux (fish/hour) we will use water velocity as a surrogate for fish speed. The fish flux estimate will be expanded in proportion to the cross-sectional area not sampled. The results will be summarized to provide the estimated number of fish per hour by date. In addition we will provide an analysis of the vertical fish distribution.

Northfield Mountain Pumped Storage Project

Equipment

Equipment components to be installed at the Northfield Mountain Pump Storage Project tailrace are listed in Table 3. The data collection computer will run Simrad ER60 data collection software with a multiplexing utility that automatically switches between transducers. The acoustic data files will be written to a RAID drive, which provides an automatic backup of the data.

FirstLight will supply 110 V power and an internet connection with a minimum speed of 6 Mbps to the equipment cabinet.

Table 3. Acoustic equipment to be installed at the Northfield Mountain Pump Storage Project tailrace

	Units	Total	Description
General Purpose Transceiver (GPT)	1	1	Simrad EK60
Multiplexer	1 per GPT	1	Simrad EK60 multiplexer
Transducers	4 per GPT	4	7-degree 333 kHz splitbeam with 35 m cable
Transducer mounts	1 per transducer	4	sled mount
Power surge suppressor	1 per GPT	1	
Data collection computer	1 per GPT	1	
Ethernet switch	1 per GPT	1	
RAID drive (1 TB)	1 per GPT	1	Data storage and backup
Weatherproof cabinet	1 per GPT	1	housing for GPT, multiplexer, computer, surge protector

Installation

The 4 transducers sampling the pump-back-intake of the Northfield Mountain Pumped Storage facility will be installed on the concrete wall of the intake, oriented downward and will cover the full depth of the intake (Figure 10). The transducers will be installed at an elevation of approximately 178 ft, aimed downward slightly away from the intake structure, approximately 10° up from vertically. Viewed from the front of the intake, each transducer will be aimed along the center line of one of the 4 intake bays (Figure 11). The transducer mounts, designed by Alden Research Laboratory, Inc., are shown in Figure 12. The weatherproof GPT cabinet will be installed at the location shown in Figure 13. All transducers will be field calibrated after installation is complete, and again after sampling has been completed for the year.

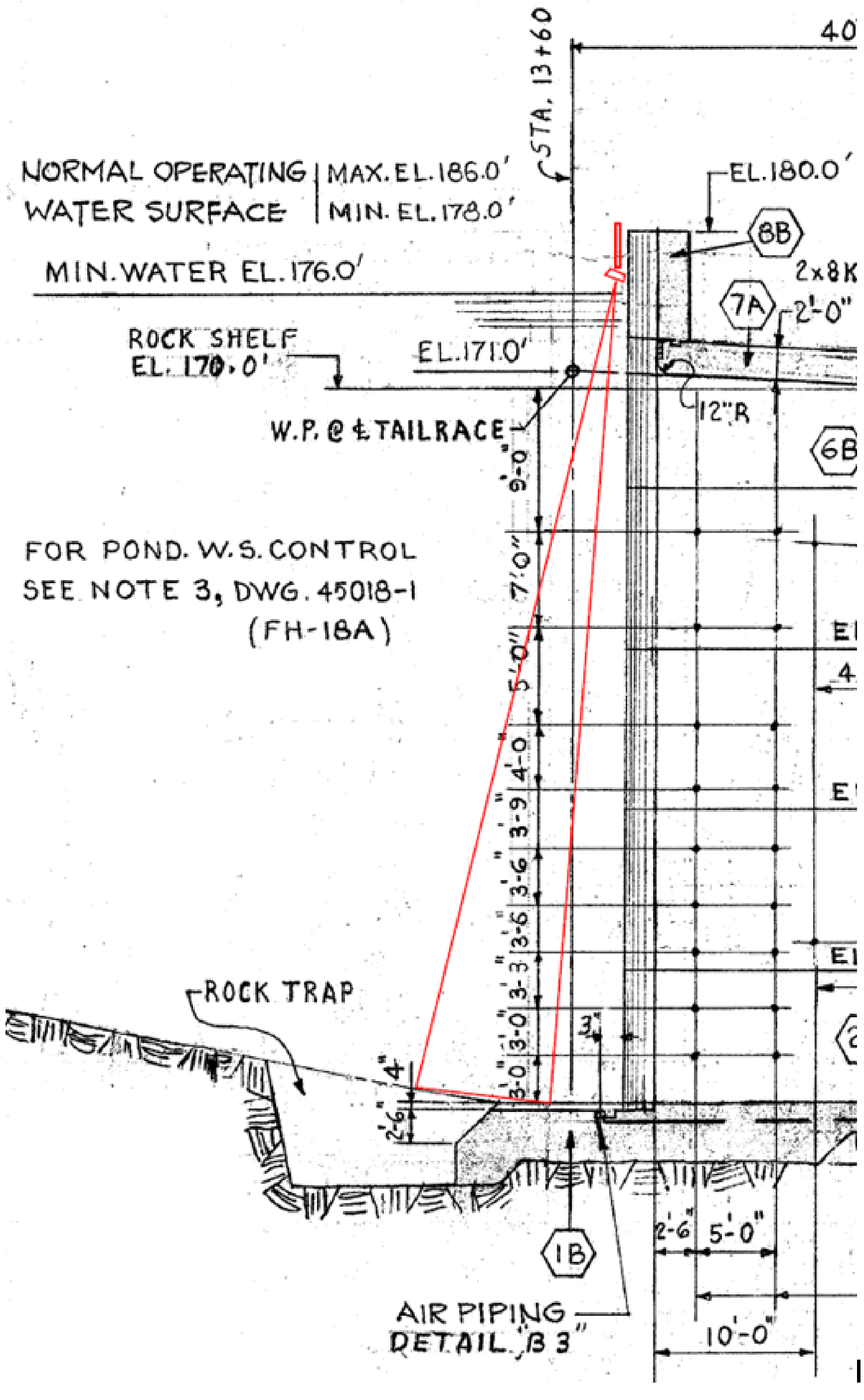

Figure 10. Elevation view (side section) of the Northfield Mountain Pumped Storage intake structure showing the location of the transducer mount and an outline of the beam volume sampled.

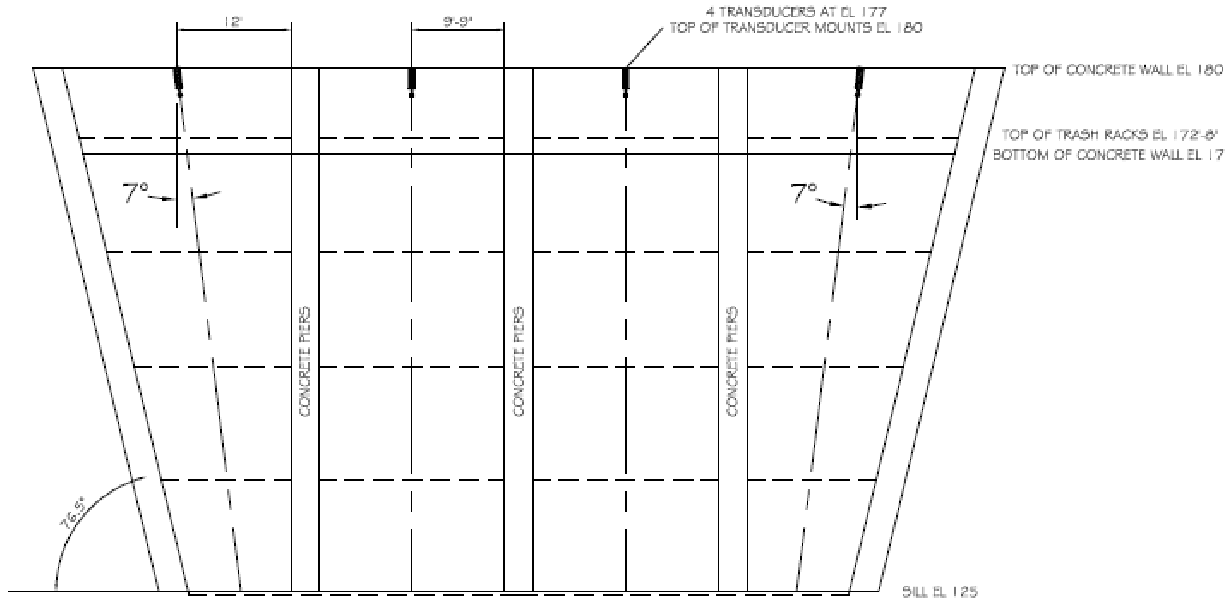

Figure 11. Elevation view (front) of the Northfield Mountain Pumped Storage intake structure showing the placement of the 4 transducers and their aiming angle.

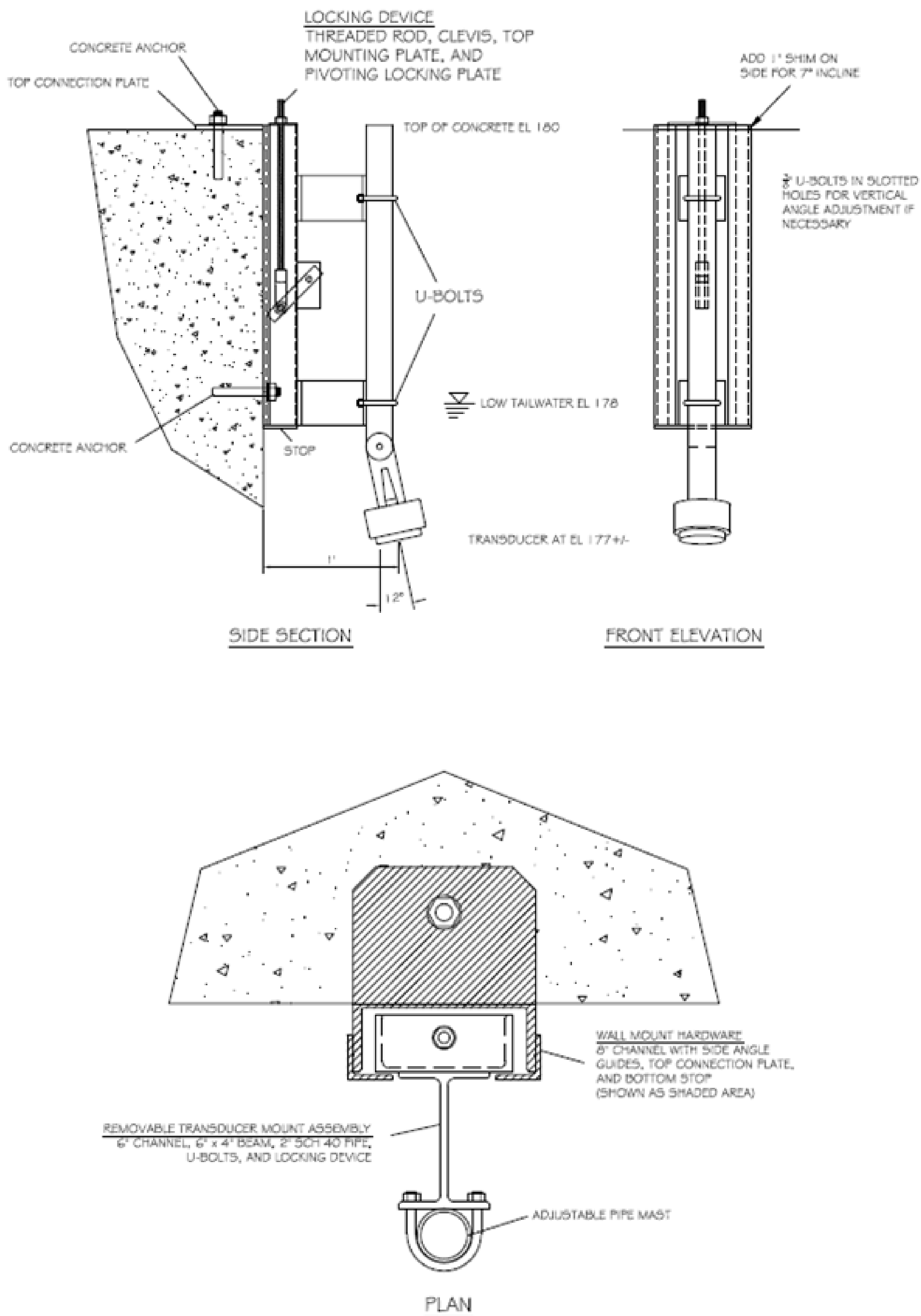

Figure 12. Transducer mount designed by Alden Research Laboratory, Inc.

Figure 13. Pump-back-intake of the Northfield Mountain Pumped Storage facility. The star marks the proposed location of the weatherproof housing for the GPT that controls the acoustic monitoring system.

Sampling scheme

The total volume sampled by the 4 transducers represents approximately 24 % of the intake area. Each transducer will sample 50 % of the time. The GPT will ping on 2 transducers simultaneously (fast-multiplex), alternating every 15 minutes between 2 pairs (slow-multiplex). In this multiplexing scheme the GPT will start at the top of the hour with a fast-multiplex on transducers 1 and 3. After 15 minutes it will switch to a fast-multiplex on transducers 2 and 4, and so on. The data collection parameters, including power level, pulse duration, and ping interval will be optimized during installation to achieve the best signal to noise ratio and highest resolution.

Data analysis

While data will be collected continuously, only data collected 1 hour prior to and during pump operation will be processed. This subset of the data will be analyzed and summarized as described for data collected at Cabot Station data (page 8).

American eel study plan (Study No. 3.3.5)

For American eels imaging sonar is recommended to provide information on run timing and duration. Route selection will be achieved using radio telemetry methods as described in the RSP Study No. 3.3.5. The imaging sonar will be located in a narrow section of the Turners Falls Impoundment (Impoundment) to achieve complete coverage. Proposed deployment is at the former suspension bridge location within the Impoundment (Figure 14). Imaging sonar is the most effective technology for confident species identification of adult eels (Mueller et al. 2005 and 2008, Mueller and Degan 2014), which are easily identified by their shape and anguilliform swimming motion (Figures 15 and 16). The RSP No. 3.3.5 describes the components of the acoustic equipment, where it will be installed, how it will be sampled, and how the data will be analyzed.

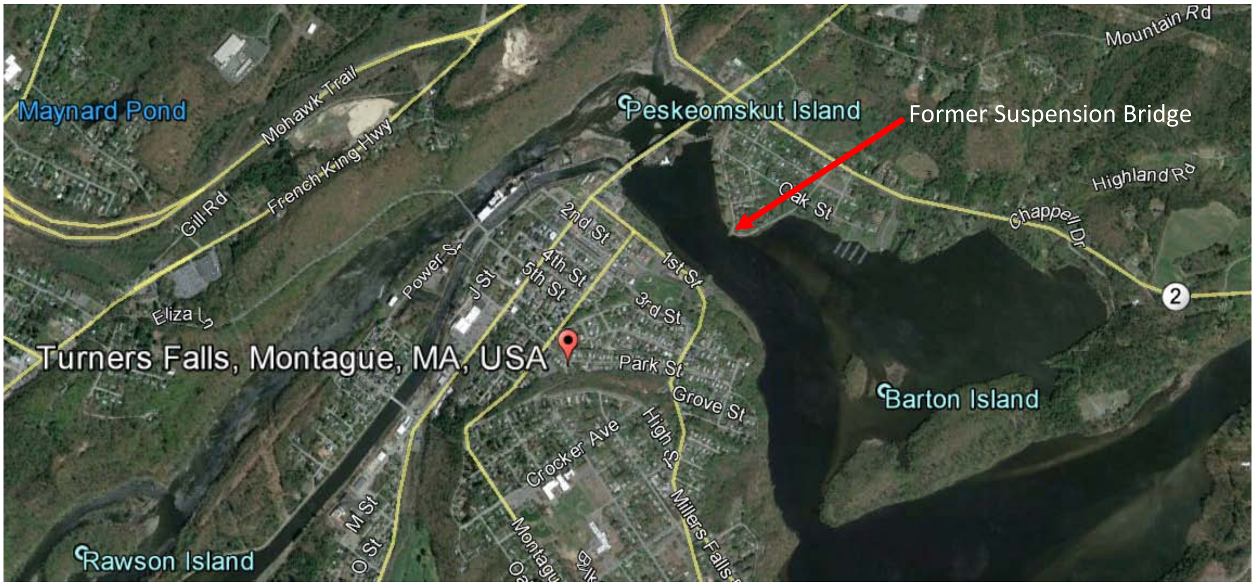

Figure 144. Proposed hydroacoustic sampling sites for monitoring run timing of adult American eels at Turners Falls.

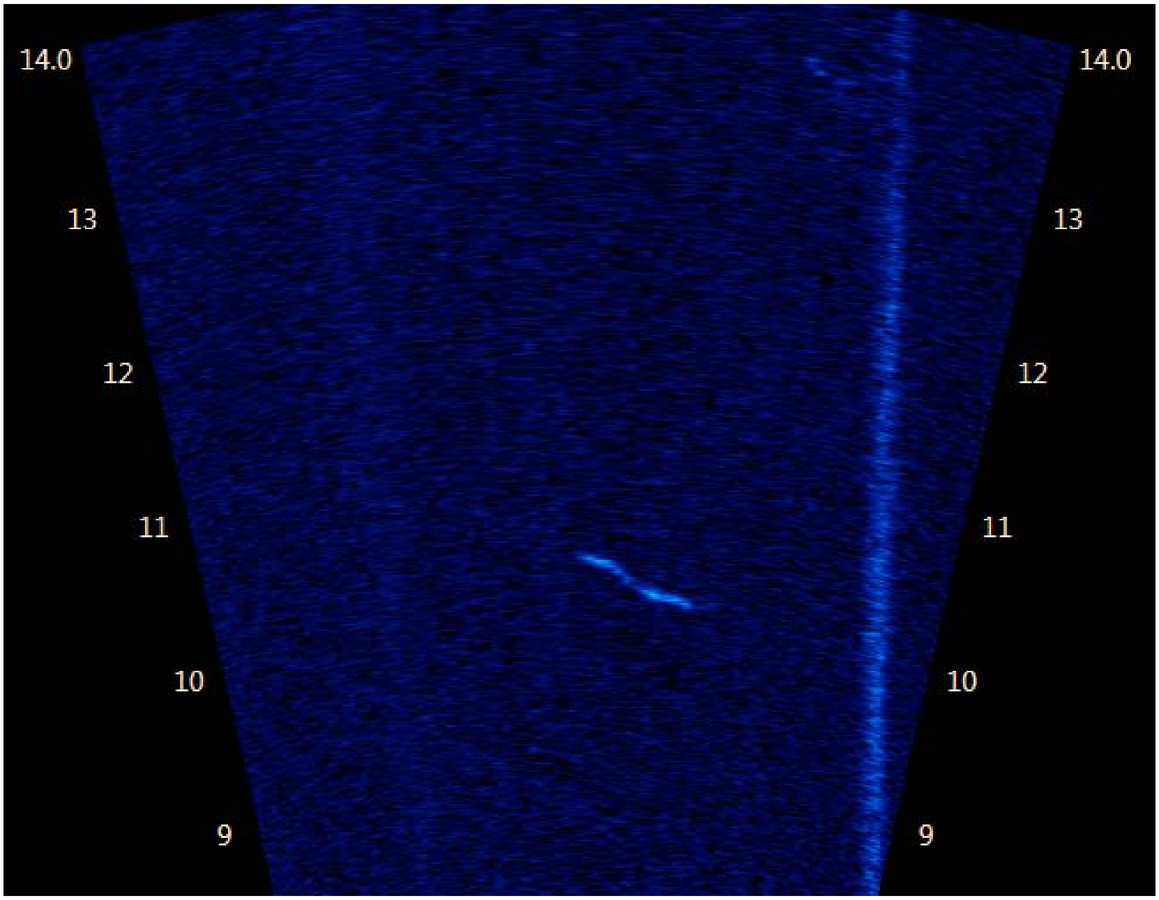

Figure 15. Acoustic image showing the elongated body shape of an adult eel approaching the trash rack of a hydro-electric facility.

Figure 16. Echogram of acoustic imaging data showing the pronounced tail beat pattern ("caterpillar legs") associated with the anguilliform swimming motion of eels. The echogram represents echo intensity over time (x-axis) and range (y-axis).

Turners Falls Hydroelectric Project — Impoundment site

Equipment

Equipment components are listed in Table 4. The data collection computer runs Sound Metrics ARIS Fish data acquisition software. The acoustic data files are written to a RAID drive, which provides an automatic backup of the data. FirstLight will supply 110 V power and an internet connection with a minimum speed of 6 Mbps.

Table 4. Acoustic imaging equipment to be installed at the impoundment site.

	Description
Imaging Sonar	Sound Metrics ARIS 1800
Transducer mount	pole mount
Power surge suppressor	
Data collection computer	
Ethernet switch	
NAS RAID drive (4 TB)	Data storage and backup
Weatherproof container	housing computer, ARIS surface control unit, surge protector, Ethernet switch, and NAS RAID drive

Installation

The imaging sonar will be installed at a location in the impoundment that will provide a representative sample of the river cross section, availability of a power supply and internet connection, and security for the equipment. The transducer will be mounted on a pole similar to the one shown in Figure 17. The placement of the weatherproof container housing the computer, ARIS surface control unit, surge protector and RAID drive will be determined after further discussion with FirstLight.

Figure 17. Transducer pole mount.

Sampling scheme and data analysis

The ARIS imaging sonar will sample two range strata, alternating between a stratum spanning from 1 – 10 m range, and a second stratum covering 10 – 20 m in range. For each stratum the system will record 10 minutes of the hour, for a total of 20 minutes of data collected per hour.

The analysis will focus on data recorded at night when eels actively migrate. We propose to analyze only data recorded between 17:00 and 5:00 during the migration period which is expected to include the months of August through October. Given the potential presence of out-migrating shad it may not be possible to fully automate data processing. However, ARIS Fish software provides a robust algorithm for the removal of empty frames (i.e. images taken when no target greater than a defined size was present), which will significantly decrease the file size and speed up the visual review and manual marking of eels. The results will provide hourly estimates of the number of eels that passed through the 19 m sampled, their direction of movement and distribution in range.

References

Love, R.H. 1971. Measurements of fish target strength: a review. Fisheries Bulletin, 69(4): 703-715.

MacLennan, D.N. and E.J. Simmonds. 2005. Fisheries Acoustics. Second Edition. Blackwell Science, Oxford, U.K., 437 pp.

Mueller, A.M., J. Wechsler, D. Degan and B. Kulik. 2005. Interim American Eel Downstream Passage 2005 Pilot Study Report. Report prepared for Madison Paper Industries, Madison, Maine.

Mueller, A. M., T. Mulligan, and P. K. Withler. 2008. Classifying Sonar Images: Can a Computer-Driven Process Identify Eels? North American Journal of Fisheries Management 28:1876–1886

Mueller, A.M. and D. Degan. 2014. The Analysis of Acoustic Images of Eels Collected at Trevallyn Power Station, Tasmania, Australia. Report prepared by Aquacoustics, Inc., for Hydro Tasmania.

Nestler, J. M., D. Dennerline, M. Weiland, G. Weeks, D. Degan and S. Howie, J. Sykes. 1998. Richard B. Russell Phase III Completion Report: Impacts of Four-unit Pumpback Operation. Technical Report EL-99-1, U.S. Army Engineer Engineering Research and Development Center, Vicksburg, MS.