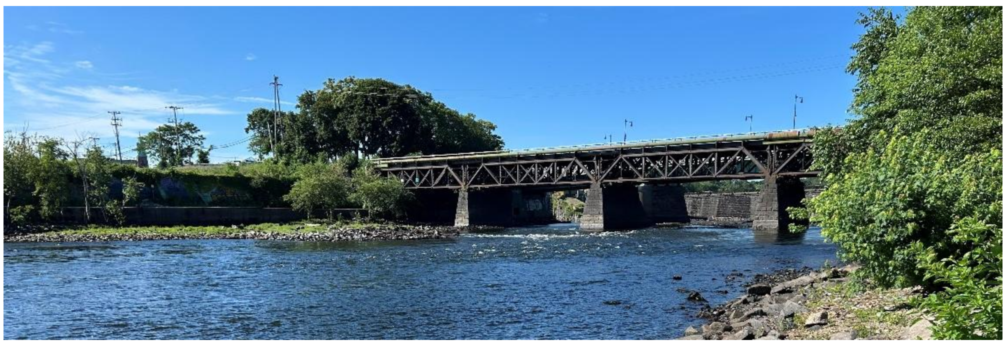
# STURGEON HABITAT MAPPING AND ASSESSMENT

Lawrence Hydroelectric Project (FERC No. 2800)



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# 1. INTRODUCTION

## 1.1 BACKGROUND

Essex Company, LLC (Essex), a subsidiary of Patriot Hydro, LLC, is the Licensee, owner, and operator of the Lawrence Hydroelectric Project (Project or Lawrence Project), which is Federal Energy Regulatory Commission (FERC or Commission) Project No. 2800. The Lawrence Project is located on the Merrimack River in the City of Lawrence in Essex County, Massachusetts. The Project was licensed by the Commission on December 4, 1978 (with an effective date of December 1, 1978), and the license expires on November 30, 2028. Essex is pursuing a new license for the Project using the Commission's Integrated Licensing Process (ILP) as defined in 18 Code of Federal Regulations (C.F.R.) Part 5.

In accordance with 18 C.F.R. § 5.15, Essex has initiated studies and information gathering activities as provided in the study plan and schedule approved by the Commission. Among the studies completed during 2025 was the Sturgeon Habitat Mapping and Assessment Study (Study 17), the methodologies of which were outlined in the Study Plan in Appendix K of the Initial Study Report (ISR) filed by Essex with the Commission on April 28, 2025. The study plan was based on recommendations by FERC in the Study Plan Determination (SPD) filed May 10, 2024. This report describes the Licensee's implementation of the study plan and schedule, the data collected, and any variances from the study plan and schedule.

## 1.2 EXISTING INFORMATION

The Merrimack River, downstream from the Lawrence Project (Essex Dam), has an amphidromous population of shortnose sturgeon (Kieffer and Kynard 1993). A study of the overwintering population of sturgeon in the Merrimack River counted 3,786 individuals in 2020-2021 season and 3,424 individuals in the 2022-2023 season (Stantec 2023). Shortnose sturgeon movement in the lower Merrimack has been documented up to the I-495 Bridge in Lawrence (Stantec 2023) with documented spawning occurring near Haverhill between river mile (RM) 18.6 and 19.9 (Kieffer and Kynard 1996). The detections at the I-495 Bridge in Lawrence occurred during the spawning season, suggesting that habitat between the I-495 bridge and the Essex Dam may be used for spawning or pre-spawning habitat. Post-spawn and juvenile shortnose sturgeon are present in the river throughout the year (Kieffer and Kynard 1993).

The Merrimack River downstream from the Lawrence Project is utilized by Atlantic sturgeon from late May to early October for foraging (Kieffer and Kynard 1993; Wippelhauser et al. 2017). Kieffer and Kynard (1993) found that sub-adult Atlantic sturgeon used only one discrete section of the Merrimack River each year. Sub-adult Atlantic sturgeon during that study were determined to frequent the "lower islands" section of the Merrimack River, located between RM 3.1-6.2 and approximately 15.5 miles (25 km) downstream from Essex Dam.

Previous studies have assessed the movements and habitat use of shortnose and Atlantic sturgeon in the Merrimack River (Kieffer and Kynard 1993; 1996). In those studies, shortnose sturgeon began to move from overwintering to spawning sites in April when river temperature reached 7°C and discharges decreased to 570 $m^3/s$ (approximately 20,000 cfs). Shortnose sturgeon spawned in the Haverhill area when river temperature warmed to 9.6–14.0 °C and river discharge decreased to 240–390 m3/s (approximately 8,500–14,000 cfs). Foraging habitat for shortnose sturgeon was characterized as areas with silty or muddy bottom that were optimal for its predominant prey (freshwater mussels). Although Kieffer and Kynard (1993; 1996) did not observe spawning habits or characterize spawning habitat of Atlantic sturgeon in the Merrimack

River, spawning habitat for Atlantic sturgeon is typically freshwater reaches just upriver of the salt front in the main channel areas with flowing oxygenated (>6 mg/L) waters over hard substrate (rock, cobble, boulder, gravel) in depths of 4 ft (1.2 m) or more (NMFS 2017). Juvenile and adult Atlantic sturgeon forage on benthic prey items found in soft substrate (NMFS 2017).

## 1.3 STUDY AREA

The study area included the section of the Merrimack River located immediately downstream of the Project (Essex Dam, also known as Great Stone Dam), extending approximately 10.1 river miles downstream to RM 19 at Basiliere Bridge on Route 125 in Haverhill, Massachusetts (Figure 1-1). Red areas in Figure 1-1 indicate approximate portions of the planned section of river that could not be accessed due to low water levels and navigation hazards. These areas included planned sampling near the O'Leary Bridge on Broadway, Essex Dam and tailrace, and the planned stations approximately between Mitchell's Falls, the furthest downriver bridge crossing of I-495, and the just downriver of Stanley Island.

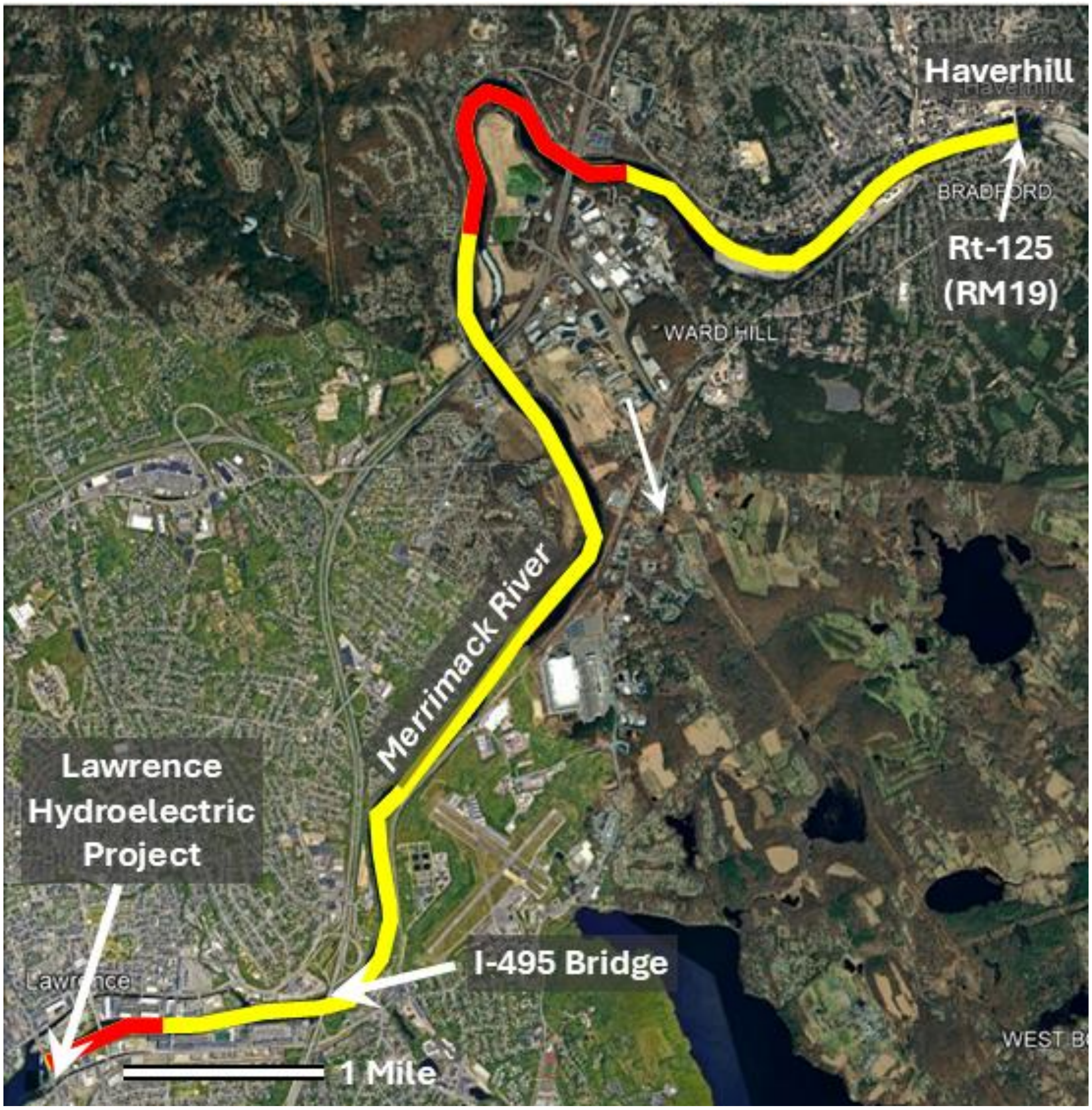


**Figure 1-1 The 10-river-mile reach (yellow and red polylines) for the Sturgeon Habitat Mapping and Assessment Survey on the Merrimack River downstream of the Lawrence Hydroelectric Project to River Mile 19 in Haverhill. Red sections indicate areas that were not accessible due to navigation hazards (i.e., low water and exposed rocks).**

# 2. STUDY AND OBJECTIVES

The Sturgeon Habitat Mapping and Assessment Study was designed in response to recommendations by FERC in the SPD to conduct a side-scan sonar (SSS) survey separate from the Sturgeon Distribution and Project Interaction Study (Study 5), in order to meet the study objectives. The primary objectives were to (1) map the benthic habitat features of the Merrimack River downstream from the Project Dam (Essex Dam) to RM 19 (Basiliere Bridge on Route 125), and (2) quantify the area of juvenile rearing habitat, spawning habitat, and foraging habitat for Atlantic *(Acipenser oxyrinchus oxyrinchus*) and shortnose sturgeon (*A. brevirostrum*) in this reach based on substrate type and water depth.

The SPD further recommended that substrate size and embeddedness be verified using grab samples, an underwater camera, or SCUBA diving/snorkeling, if safety allows. Essex chose to conduct verification using a Petite Ponar grab and an underwater camera. Secondary objectives included locating and estimating size of any sturgeon observed during the study, to the extent possible.

# 3. METHODOLOGY

## 3.1 SURVEY DESIGN

The Sturgeon Habitat Mapping and Assessment Study was designed to use side-scan sonar (SSS) to collect data for mapping benthic habitat features and quantifying the nursery, spawning, and foraging habitat for Atlantic and Shortnose Sturgeon, based on substrate type and depth. Substrate type, size and embeddedness, as inferred from visual classification of SSS imagery, was planned to be verified by underwater video and sediment grab samples. Additionally, bathymetric data were planned to be collected to create a gridded GIS depth and substrate layer.

Substrate classification (type, size and embeddedness) of the SSS imagery was designed to be informed and verified by two direct sampling methods: underwater video and sediment grab sampling. The verification samples were collected along 10 transects through the survey area ("verification transects"), where each verification transect consisted of 3 sampling stations: one near each riverbank and one approximately in the center of the river channel, as navigation allowed (Figure 3-1). The initial goal was to collect 30 sediment grab samples and underwater video recordings to supplement the SSS and bathymetric data. The survey was planned to be completed following this study plan with real-time field adjustments to the methods described herein only if needed (e.g., navigational hazards, safety, data quality and coverage).

Figure 3-1 illustrates the configuration of SSS and bathymetry transects and video/grab verification sampling stations. The survey was planned to be completed over four to five days (weather and river discharge permitting) during July 21-25, 2025 with an additional day for additional targeted verification sampling in August−September 2025. The first day of the survey week was planned to be used for testing survey operations and reconnaissance of field conditions. The second day was planned to be used to conduct the SSS survey. The third day was planned to be spent collecting the verification samples (water quality measurements, underwater video, and sediment grab samples). The fourth day was planned to be dedicated to collecting bathymetry data with the single-beam echosounder, and a fifth day was reserved as a contingency day to fill in any data gaps are additional sampling required.

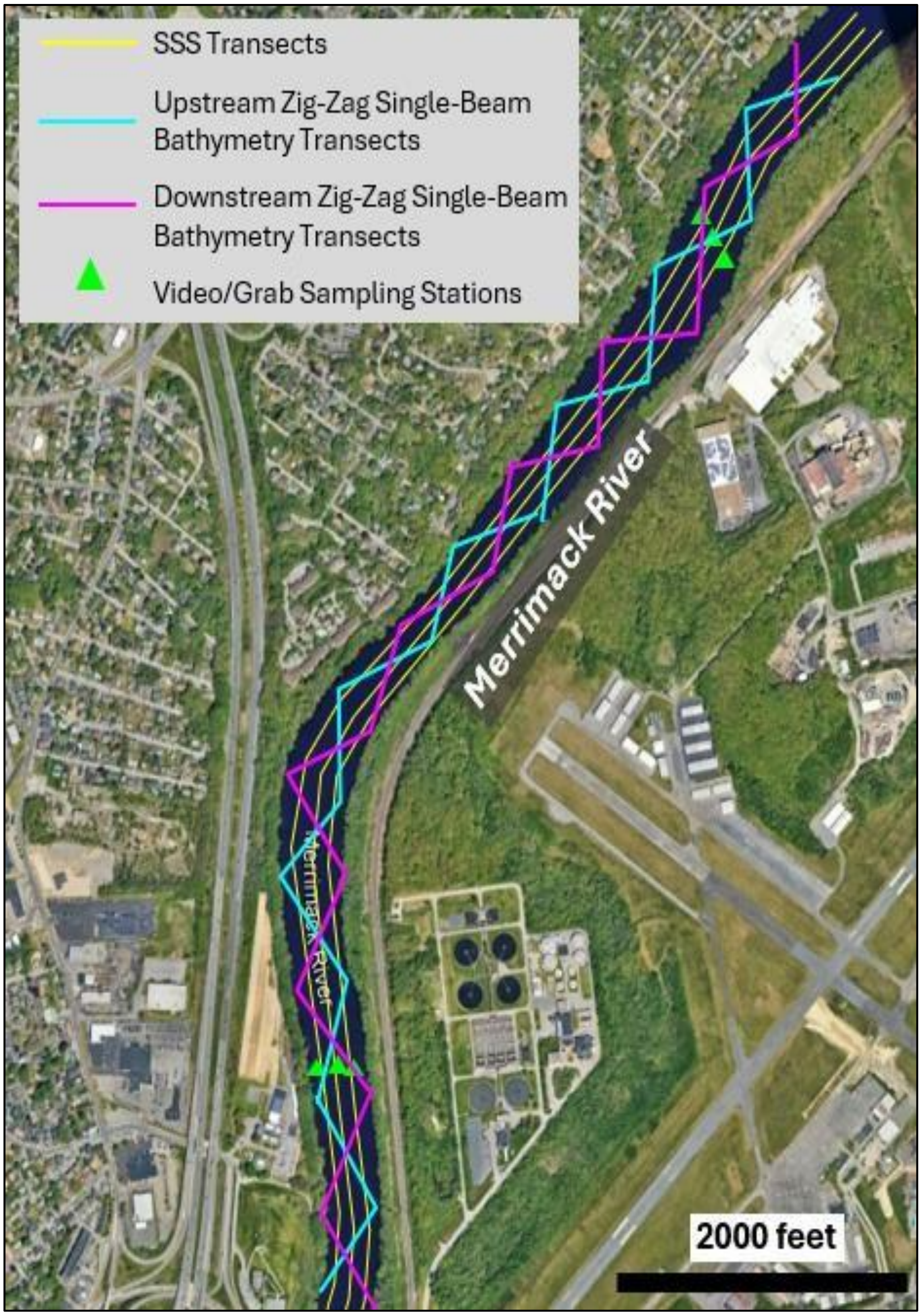


**Figure 3-1 Example of planned sampling transects and verification stations for the Sturgeon Habitat Mapping and Assessment). The above schematic was for illustration purposes only and not actual survey lines.**

### 3.1.1 Water Quality

Water quality measurements (temperature, conductivity, dissolved oxygen [DO]) were collected during the verification sampling survey with an In Situ Aqua Troll 500 ("CTD" or "sonde"). The conductivity sensor was calibrated prior to the site reconnaissance survey. The DO sensor was calibrated each day, prior to launching the vessel. Upon arriving at each verification station, water quality measurements were collected prior to the other sampling activities. Due to the shallow depths encountered, spot measurements were collected at approximately mid-depth in the water column, as judged by the vessel's depth-finder and the length of the sonde's cable. Data were logged using the Bluetooth® controller for the sonde which stored a data record for each station, along with GPS information. These data were downloaded and backed up to a secondary hard drive at the end of each survey day.

### 3.1.2 Underwater Video

After recording the water quality measurements at a station, underwater video was collected with a GoPro Hero 13 underwater camera model, mounted in a custom-fabricated aluminum frame in a downward-facing orientation, approximately 24 inches above the river bottom (Figure 3-2). The camera deployment frame also included dual lasers spaced 85 mm apart (<5mW; BALP-LG05-B150) to provide a reference scale and LED lights (700 lumens) for framing and illuminating the field of view. A square-shaped yellow SCUBA weight (10 cm long) attached to the bottom camera frame also provided a reference scale. At each verification station, the video frame system was lowered to the river bottom to collect short video recordings (15-30 seconds). Prior to deploying the system over the side of the vessel, a large label containing the station ID and channel location and local time was recorded at the beginning of each station's video. Data from the camera were downloaded and backed up to a secondary hard drive at the end of each survey day.

### 3.1.3 Sediment Grabs

After recording the underwater video at a station, sediment grabs were collected with a 6"x6" (0.024 $m^2$) stainless steel Petite Ponar grab). At each station, at least three valid grab attempts were made before determining whether or not a sediment sample could be collected. Notes were recorded with each grab attempt (e.g., empty, void, or sample collected, along with description of the environment and/or if grass or single rocks were found in a grab). A subsample of approximately 100 mL of the upper 2 cm layer of the sediment grab was transferred to a 250 mL jar to be sent to a laboratory for sediment grain size analysis. A deck-side photograph with a whiteboard (labeled with date, time, and station) was taken for each verification sampling station (except where the substrate was considered a hard substrate as defined by three consecutive empty valid grab samples). Successfully collected sediment samples were handled following established guidelines from Pace Analytical Laboratory (e.g., sample handling and custody protocols).

### 3.1.4 Side-scan Sonar

Sonar imagery of the riverbed was planned to be collected by a Humminbird Xplore 10 CMSI+ Fish Finder, a recreational-grade SSS, following established methods for sturgeon habitat characterization in riverine systems (Litts & Kaeser 2016; Walker and Alford 2016; Andrews et al. 2020; Battaile et al. 2024). The Humminbird SSS was selected because of ease of deployment in shallower habitats/conditions (smaller transducer, lighter weight housing, reduced sonar interface). This selection was consistent with the sonar methods recommended by NMFS in their comments to PAD and PSP (Kaeser et al. 2012; Litts and Kaeser 2016). SSS survey transects were planned to include three transects along the river axis; one in approximately center channel and one offset to each bank (e.g., Figure 3-1). Low-water conditions prevailed over the multi-day survey, which resulted in shallow depths, exposed rocks, and non-navigable waters in which to conduct this component of the study.

**Figure 3-2 Photo of the underwater video frame during mobilization (left) and deployment (right).**

### 3.1.5 Bathymetric Data

To classify sturgeon habitat based on substrate type and depth, the SSS survey was complemented with bathymetric data collection in the surveyed river reach. In absence of known bathymetric data sources, this study was designed to collect single-beam bathymetry to be integrated with the SSS imagery for mapping sturgeon habitat. Bathymetric survey data were collected with a 200-kHz, Teledyne Odom CV100 single-beam echosounder, Trimble MPS566 GNSS Receiver and Trimble GA830 GPS antenna, with network-RTK GPS corrections. Data were streamed into HYPACK Survey (v. 2024) software at a sampling rate of 10 Hz. The vertical offset applied corrections for recording depth soundings in elevation relative to NAVD88 vertical datum. The bathymetry system was mounted on the port side of the survey vessel and recorded riverbed elevations and depth soundings during the verification sampling, to the extent practicable to ensure personnel safety, protection from damage to the transducer, and acceptable data quality (e.g., shallow depths, low water, and exposed rocks).

## 3.2 DATA ANALYSIS

### 3.2.1 Analysis of Environmental Conditions

River conditions during the survey (i.e., stage and flow) were assessed from data gathered by the Project. River stage (ft, NAVD88) and river flow (cfs) were plotted for assessment of conditions encountered during the survey and for the rest of the 2025 field season. River stage data were converted from NGDV29 to NAVD88 using an offset provided by NOAA VDatum Online (-0.794 ft; NOAA 2026).

### 3.2.2 Processing of Water Quality Data

Water quality measurements were downloaded from the instrument following each field day and data were compiled in Excel and reviewed for suspect data/quality. Summary statistics for water temperature, conductivity, and DO were determined for each verification transect and all water quality data collected.

### 3.2.3 Underwater Video Processing

Still shots (“frames”) of underwater video files were used both to classify benthic substrate types by particle size and to quantify percent area covered by the identified substrates. Particles larger than sand (≥2 mm) were visually examined and measured using ImageJ software, version 2.16.0. To establish an accurate size scale for measuring particles, either a SCUBA weight measuring 95 mm in width was used, or parallel scaling lasers (projecting two green dots that appeared in the underwater videos) were used with a fixed distance of 85 mm apart. Benthic particles were then measured and classified by substrate type, according to size: boulder (256-4096 mm), cobble (64-256 mm), pebble (464 mm), and gravel (2-4 mm). Particles <2 mm in size (generally sand and silt; clay was not observed), were also visually classified. Benthic particles were then outlined using ImageJ’s polygon tool (**Error! Reference source not found.**) and measured, and percent area covered by each substrate type was determined. A single substrate type was considered “dominant” if it covered 50% or more of the observed stream bed surface, “sub-dominant” if it covered 10-49% of the stream bed surface, or “other” if it covered <10% of the stream bed surface.

Embeddedness is the degree to which fine sediment particles accumulate around larger rocks on the surface of a stream bed (Sennatt et al. 2006). A high degree of embeddedness correlates with reduced habitat suitability for many aquatic species (Sennatt et al. 2006; Hargett 2025), including sturgeon spawning habitat. In this study, embeddedness was determined by estimating percent area covered by grain particles <2 mm in size (sand and finer particles, collectively; Sennatt et al. 2006). Visual analysis methods used are similar to those described by Du et al. (2014).

### 3.2.4 Substrate Size Classification

Sediment grab samples were analyzed by Pace Analytical Laboratory for grain size distribution (ASTM D6913/D7923, Wentworth scale). The substrate types classified in the field and underwater video analysis were based on the Wentworth scale (Table 3-1).

### 3.2.5 Table 3-1Bathymetric Data Processing

Depth soundings were merged with the GPS data during data collection in HYPACK Survey software. MATLAB was used post-process the HYPACK data files to extract water surface elevation (ft, NAVD88), river bottom elevation (ft, NAVD88), and water depth at time of sample collection (ft) for each station from the HYPACK data files. The transducer depth was 33.6 cm, which was added to the raw soundings (range from the transducer). Data were then smoothed with box-car filter and linked to each station by timestamp for an estimate of depth and elevation to associate with the substrate data for the purpose of sturgeon habitat classification.

### 3.2.6 Sturgeon Habitat Classification

Suitable habitat area for Atlantic and Shortnose foraging, juvenile rearing, and spawning between Lawrence Hydroelectric Project and RM 19 was determined using depths and dominant and sub-dominant substrate types identified during this study compared against species-specific literature-based values for foraging, juvenile rearing, and spawning habitat in fresh waters of the northeastern U.S. and Canada (Table 3-2).

ArcGIS Pro 3.6.1 was utilized to characterize river segments as having suitable or non-suitable for Atlantic and Shortnose Sturgeon foraging, juvenile rearing, and spawning habitat. Each sampling station was considered the mid-point of a river segment that was 1 mile long (0.5 mile long at ends of the study area) and approximately one-third of the river channel width. On average, surveyed river segments were 150 ft wide. A buffer zone of 25 feet from the banks was used, and manual adjustments were made as river width fluctuated. River segments were classified as sturgeon habitat if the associated sampling station was classified with their respective suitable substrate type and depth. At stations where either substrate type or depth provided suitable habitat, but not both, the associated 1-mile reach was considered not to be suitable sturgeon habitat.

**Table 3-1 Substrate type was based on grain size (diameter) classes following the Wentworth scale (Wentworth 1922).**

| Diameter (mm) | Wentworth Size Class | |
|---|---|---|
| 256 | Boulder | Gravel |
| 64 | Cobble | |
| 4 | Pebble | |
| 2.00 | Granule | |
| 1.00 | Very coarse sand | Sand |
| 0.50 | Coarse sand | |
| 0.25 | Medium sand | |
| 0.125 | Fine sand | |
| 0.0625 | Very fine sand | |
| 0.031 | Coarse silt | Silt |
| 0.0156 | Medium silt | |
| 0.0078 | Fine silt | |
| 0.0039 | Very fine silt | |
| 0.00006 | Clay | Mud |

**Table 3-2 Habitat classification for Atlantic Sturgeon and Shortnose Sturgeon foraging, juvenile rearing, and spawning in fresh waters of the northeastern U.S. and Canada. Suitable substrate types and depths are based on literature-derived values.**

| Sturgeon Habitat | Substrate Types [Ref.] | Depth (ft) [Ref.] |
|---|---|---|
| Atlantic Sturgeon Foraging Habitat | Juveniles and adults require soft substrates (e.g., sand, mud) for foraging, which provide benthic prey [1,2,3,7] | 4-164 [1,2,3] |
| Atlantic Sturgeon Juvenile Rearing Habitat | Same as Above | Same as Above |
| Atlantic Sturgeon Spawning Habitat | Hard bottom substrates (e.g. shell bottom, pebble, cobble, gravel, limestone, boulder, bedrock, rubble, etc.) [1,2,3,7,9] | 4-89 [1,2,3] |
| Shortnose Sturgeon Foraging Habitat | Soft bottom substrates (e.g. mud, sand) and gravel [4,10] | 3-16 [4] |
| Shortnose Sturgeon Juvenile Rearing Habitat | Mud, silt, sand and gravel [4,5,6] | >23 [5,7] |
| Shortnose Sturgeon Spawning Habitat | Gravel, pebble, cobble, rubble and boulder [4,7,8,10] | 6-18 [8] |

1. NMFS 2017
2. NMFS 2020
3. NOAA 2017
4. Dadswell et al. 1984
5. Haley et al. 1996
6. Kynard et al. 2000
7. Gilbert 1989
8. Kieffer and Kynard 1996
9. Hartel et al. 2002
10. MassWildlife 2026

# 4. RESULTS

## 4.1 SAMPLING ACHIEVED

A summary of each field day is provided in Table 4-1. The first day, July 21, 2025, was used for testing survey operations and reconnaissance of field conditions. This consisted of rigging and launching the vessel from the boat ramp at the Crescent Yacht Club in Haverhill, and testing the electronics and sampling gear to confirm the equipment was operating as planned. Due to the available schedule and concern over the low water levels, the second day (July 22, 2025) was initially dedicated to collecting verification samples (water quality, underwater video, and grab samples), starting from the downriver end of the survey area, as opposed to conducting the SSS survey. The rationale was to collect direct substrate information while the water was low and wait for more suitable water-level conditions for acoustic surveys of planned transects in the subsequent days. During the verification sampling, verification transects #10 and #9 were sampled but verification transect #8 could not be completed. Only one station (24-R) was able to be sampled at this cross-section due to low water and navigation hazards. Vessel navigation from this location in the upriver direction was unexpectedly not possible and would require splitting the survey area into two trips (with additional mobilization, launching, and demobilization).

During the third day (July 23, 2025), the field crew mobilized from the upriver end of the survey area, at the boat ramp in Lawrence adjacent to Broadway, approximately 800 ft downriver of the Essex Dam. Prior to conducting any sampling, the vessel attempted to transit both upriver towards verification transect #1 and downriver to see if all the verification transects were accessible from the opposite end of the survey area. The first transect, at the train bridge before the Broadway Bridge was not accessible due to the very low water. Traveling downriver, at approximately 6.5 miles downriver from Essex Dam, near Mitchell's Falls, the vessel could not navigate any further. This left an approximately 1.5-mile section of the Merrimack River around the downriver-most I-495 bridge crossing unable to be accessed or sampled by the field crew. Figure 4-1 provides some examples of the low water, navigation hazards, and impacts on equipment. The rest of the third day was dedicated to collecting as many of the verification samples as possible, sampling verification transects #6 through #3. The fourth survey day (July 24, 2025) included completion of the verification sampling at the accessible stations (verification transect #2). Table 4-2 presents a summary of the verification sampling achieved during the survey. A fifth survey day was not used due to the extremely low water levels and the impact on sonar data quality and ability to conduct the SSS and bathymetric surveys as designed.

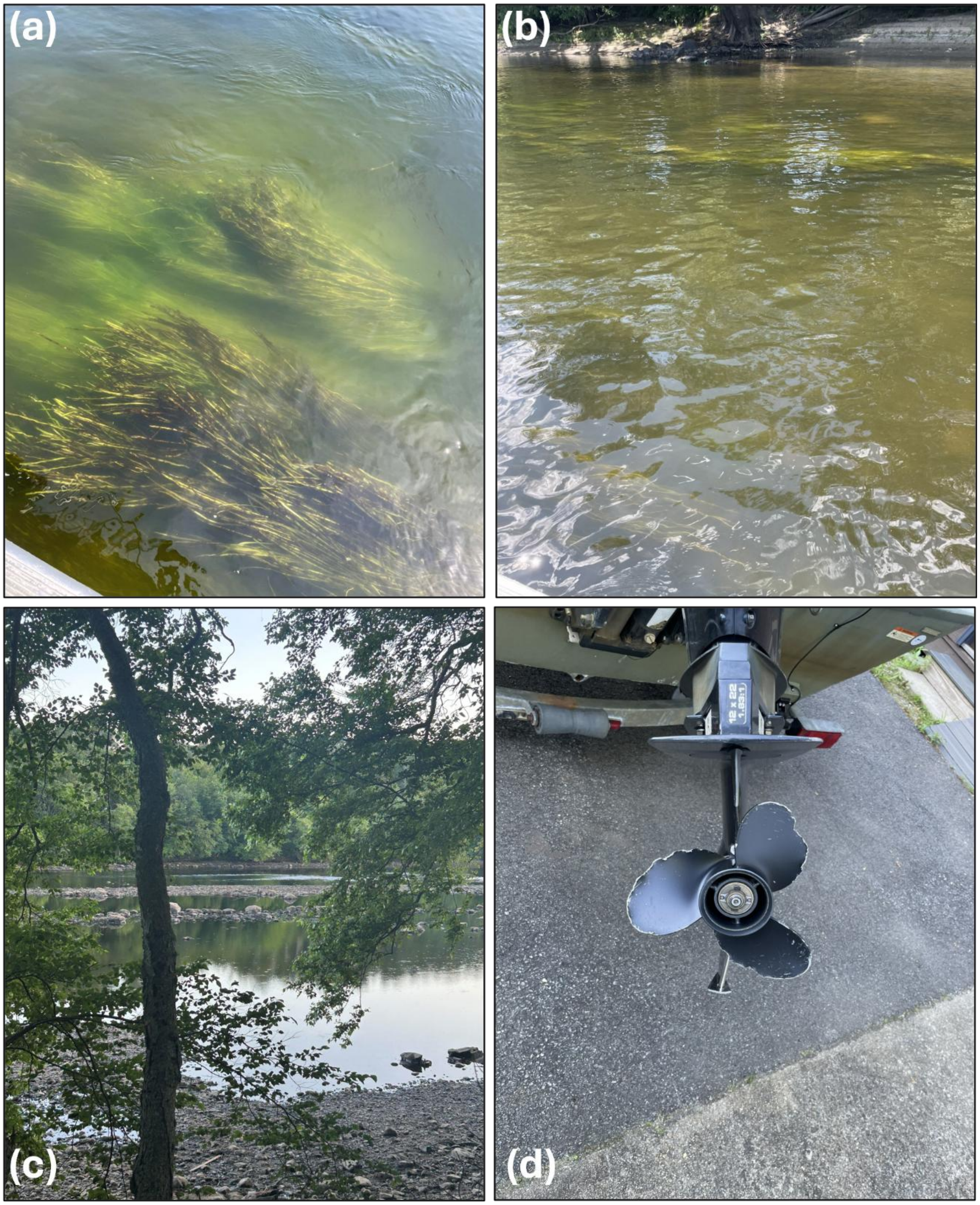


**Figure 4-1** **Photos showing low water conditions encountered during the habitat survey. (a) Eel grass near the surface as seen from vessel. (b) Grassy shallows near a bank station. (c) View from shore just upriver from Verification Transect 3, where the river became impassable on Field Day 1. (d) Damaged propeller at the end of Field Day 2.**

**Table 4-1 Summary of field survey days. Start and End times (HH:MM) are start of rigging/mobilization and departure time from the respective boat ramp.**

| Date | Start | End | Summary |
|---|---|---|---|
| 7/21/2025 | 08:00 | 18:55 | Field reconnaissance, access and site checks, equipment testing on water at the boat ramp. |
| 7/22/2025 | 07:30 | 18:30 | Field Day 1. Rigged and launched vessel in Haverhill, mounted and setup survey equipment. Transited from Haverhill upriver during the survey. Sampled Verification Transects 9 and 10 and one Station on Verification Transect 8. Could not access two Stations on Verification Transect 8 or any of Verification Transect 7 due to low water levels and rocks causing navigation issues. |
| 7/23/2025 | 08:00 | 16:30 | Field Day 2. Rigged and launched vessel in Lawrence, mounted and setup survey equipment. Transited from Lawrence downriver as far as possible. Could not access Verification Transect 7 from upriver either. Sampled Verification Transects 3 through 6. |
| 7/24/2025 | 08:25 | 15:50 | Field Day 3. Rigged and launched vessel in Lawrence, mounted and setup survey equipment. Sampled Verification Transect 2. Could not access Verification Transect 1 due to low water and exposed rocks inhibiting safe navigation. |

**Table 4-2 Summary of verification sampling achieved. Verification Transects are sorted from upriver to downriver locations.**

| Transect | Station | Date/Time (EDT) | Lat | Lon | WQ (Y/N)? | Video (Y/N)? | N Grab Attempts | Benthic Grab (Y/N)? |
|---|---|---|---|---|---|---|---|---|
| 1 | 01-L | 7/24/2025 11:30 | 42.701608 | -71.165214 | NA[1] | NA | NA | NA |
| | 02-C | 7/24/2025 11:30 | 42.701381 | -71.164972 | NA | NA | NA | NA |
| | 03-R | 7/24/2025 11:30 | 42.701029 | -71.164613 | NA | NA | NA | NA |
| 2 | 04-L | 7/24/2025 10:27 | 42.705991 | -71.144535 | Y | Y | 3 | N |
| | 05-C | 7/24/2025 10:50 | 42.705598 | -71.144055 | Y | Y | 3 | N |
| | 06-R | 7/24/2025 11:17 | 42.705187 | -71.143583 | Y | Y | 3 | N |
| 3 | 07-L | 7/23/2025 13:29 | 42.717222 | -71.135433 | Y | Y | 3 | Y |
| | 08-C | 7/23/2025 13:49 | 42.716957 | -71.134706 | Y | Y | 3 | N |
| | 09-R | 7/23/2025 13:57 | 42.716752 | -71.134113 | Y | Y | 3 | N |
| 4 | 10-L | 7/23/2025 12:44 | 42.731249 | -71.125671 | Y | Y | 3 | N |
| | 11-C | 7/23/2025 12:54 | 42.731012 | -71.125152 | Y | Y | 3 | N |
| | 12-R | 7/23/2025 13:04 | 42.730594 | -71.124831 | Y | Y | 3 | N |
| 5 | 13-L | 7/23/2025 11:56 | 42.744862 | -71.117958 | Y | Y | 3 | N |
| | 14-C | 7/23/2025 12:05 | 42.744810 | -71.117345 | Y | Y | 3 | N |
| | 15-R | 7/23/2025 12:19 | 42.744481 | -71.116410 | Y | Y | 3 | N |
| 6 | 16-L | 7/23/2025 11:12 | 42.758063 | -71.130733 | Y | Y | 3 | N |
| | 17-C | 7/23/2025 11:25 | 42.757717 | -71.130073 | Y | Y | 3 | N |
| | 18-R | 7/23/2025 11:36 | 42.757406 | -71.129259 | Y | N[2] | 0[2] | N |
| 7 | 19-L | 7/22/2025 15:30 | 42.773863 | -71.130720 | NA | NA | NA | NA |
| | 20-C | 7/22/2025 15:30 | 42.773614 | -71.130223 | NA | NA | NA | NA |
| | 21-R | 7/22/2025 15:30 | 42.773395 | -71.129733 | NA | NA | NA | NA |
| 8 | 22-L | 7/22/2025 15:00 | 42.768373 | -71.112467 | NA | NA | NA | NA |
| | 23-C | 7/22/2025 15:00 | 42.767904 | -71.112097 | NA | NA | NA | NA |
| | 24-R | 7/22/2025 14:52 | 42.767222 | -71.111737 | Y | Y | 3 | N |
| 9 | 25-L | 7/22/2025 14:05 | 42.765232 | -71.094301 | Y | Y | 3 | N |
| | 26-C | 7/22/2025 13:56 | 42.764583 | -71.094105 | Y | Y | 3 | N |
| | 27-R | 7/22/2025 13:41 | 42.764058 | -71.093938 | Y | Y | 3 | N |
| 10 | 28-L | 7/22/2025 13:11 | 42.774313 | -71.076676 | Y | Y | 3 | N |
| | 29-C | 7/22/2025 13:00 | 42.773812 | -71.076502 | Y | Y | 3 | N |
| | 30-R | 7/22/2025 12:45 | 42.773305 | -71.076359 | Y | Y | 3 | N |

*[1]NA indicates the Station was not accessible due to river conditions (low water, navigation issues). The latitude and longitude for these unsampled stations were the planned coordinates.*

*[2]Station was accessed but too shallow to deploy video frame and benthic grab.*

## 4.2 ENVIRONMENTAL CONDITIONS

As described above in Section 6.1, river conditions (i.e., flow and stage) prevented access to all the planned verification stations and survey transects for the SSS and bathymetric surveys due to the navigation hazards from exposed rock and generally shallower than planned river depths. River stage at Duck Bridge and USGS flow data at the Project Dam during the survey period were shown in Figure 4-2 to Figure 4-5. Both stage and flow were below the recent 5-year averages (2020-2024) during the survey period and extended through October 2025, which led to difficult field conditions for conducting the habitat survey. Summary statistics of the flow and stage during the survey period are provided in Table 4-3.

Water quality data from each of the verification stations successfully sampled are provided in Appendix A. Summary statistics of the data from the verification transects are provided in Table 4-4. Water temperature ranged from 25.9 to 28.4 °C, specific conductance ranged from 249 to 284.4 µS/cm and DO ranged from 7.2 to 10.0 mg/L. Temperature and DO generally decreased from upriver to downriver, while specific conductance increased from upriver to downriver.

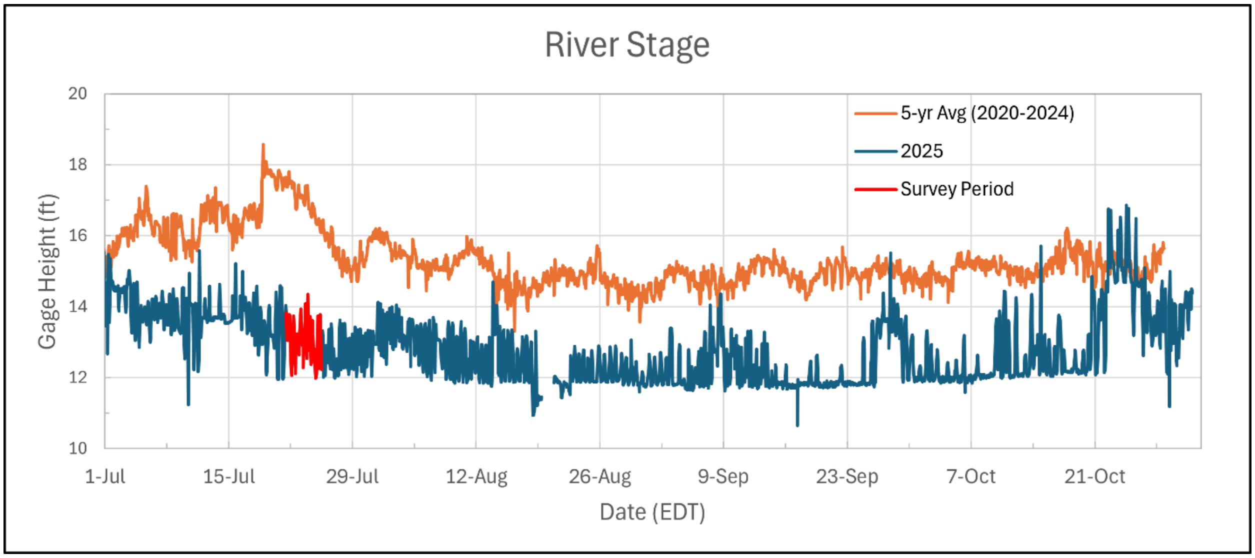


**Figure 4-2 Hourly river stage (ft, NAVD88) measured in the tailrace at Essex Dam. The red highlighted section indicates the period during the sturgeon habitat survey.**

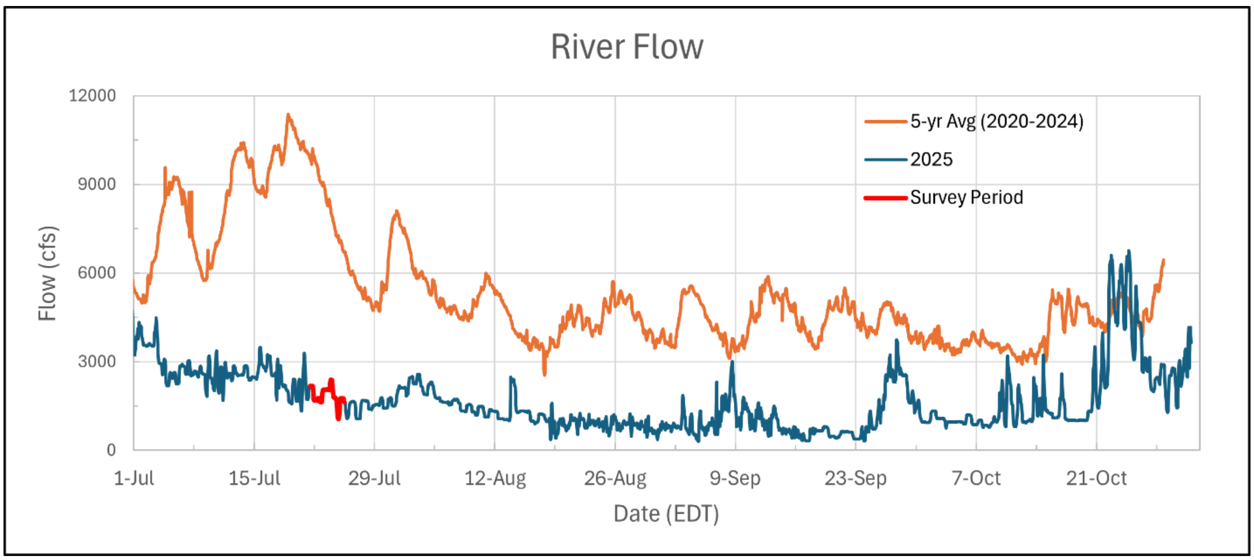


**Figure 4-3 Hourly river flow (cfs) extrapolated from the Lowell USGS Station 011000000 (scaled by 2% to account for additional freshwater inputs between the station and Essex Dam). The red highlighted section indicates the period during the sturgeon habitat survey.**

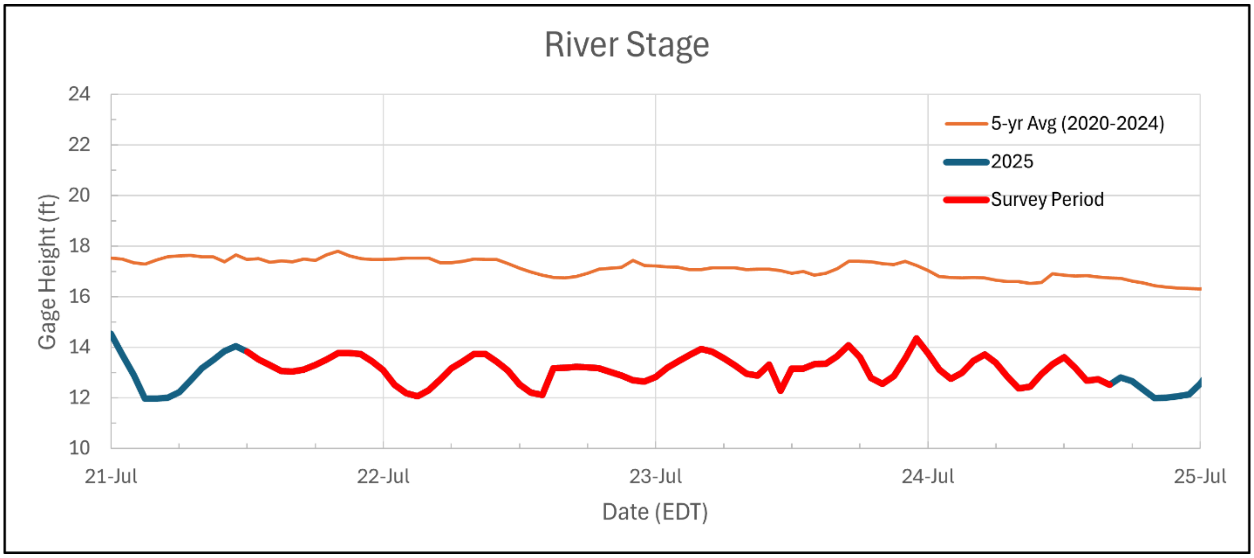


**Figure 4-4** **Hourly river stage (ft, NAVD88) measured in the tailrace at Essex Dam, zoomed to the dates of the habitat survey. The red highlighted section indicates the period during the sturgeon habitat survey.**

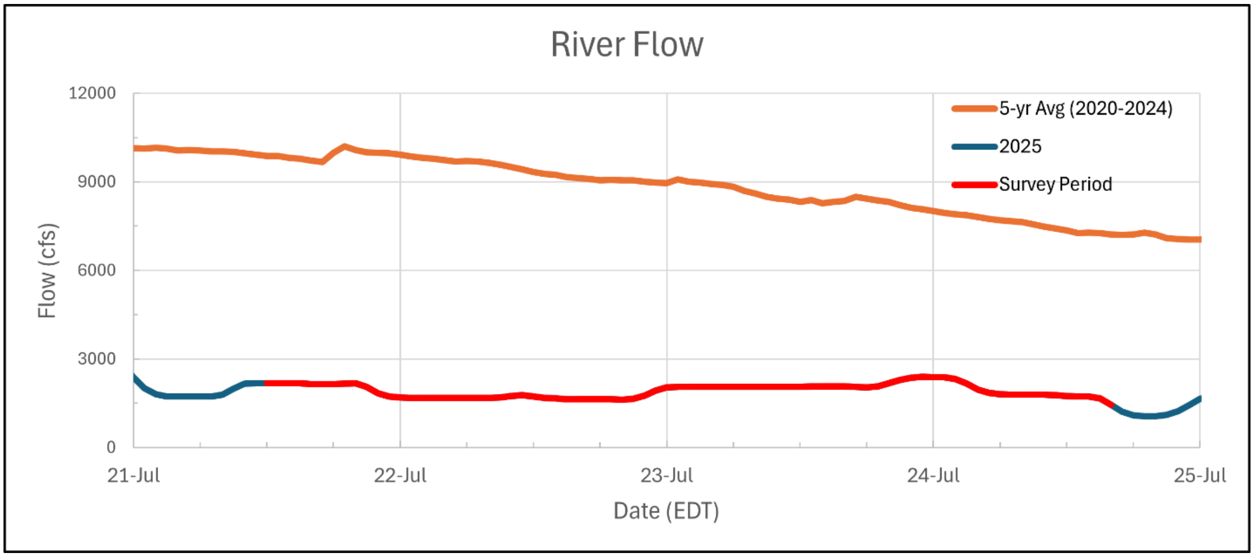


**Figure 4-5** **Hourly river flow (cfs) extrapolated from the Lowell USGS Station 011000000 (scaled by 2% to account for additional freshwater inputs between the gage and Essex Dam). Zoomed to dates of the habitat survey. The red highlighted section indicates the period during the sturgeon habitat survey.**

**Table 4-3 Summary statistics of river stage (ft, NAVD88) and flow (cfs) from the Essex Dam, during the sturgeon habitat survey on the Merrimack River July 21-24, 2025 (and July 21-24, 2020-2024). Minimum (min), maximum (max), and mean of stage and flow.**

| Statistic | 2025 | | 5-yr Avg (2020-2024) | |
|---|---|---|---|---|
| | River Stage (ft, NAVD88) | River Flow (cfs) | River Stage (ft, NAVD88) | River Flow (cfs) |
| min | 12.06 | 1,453.5 | 16.53 | 7,221.6 |
| max | 14.35 | 2,391.9 | 17.80 | 10,207.1 |
| mean | 13.15 | 1,924.0 | 17.15 | 8,818.7 |

**Table 4-4 Summary statistics of water quality measurements the verification transects during the sturgeon habitat survey on the Merrimack River July 22-24, 2025. Number of data points (N), minimum (min), maximum (max), mean, and standard deviation (SD) of water temperature (ºC), specific conductance (µS/cm), and dissolved oxygen (mg/L) measured from an In Situ Aqua Troll 500 multiparameter sonde at each verification station. Transects are sorted from upriver to downriver locations; Transects 1 and 7 were not sampled due to accessibility.**

| Verification Transect | Temperature (°C) | | | | | Specific Conductance (µS/cm) | | | | | Dissolved Oxygen (mg/L) | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | N | Min | Max | Mean | SD | N | Min | Max | Mean | SD | N | Min | Max | Mean | SD |
| **1**[1] | | | | | | | | | | | | | | | |
| **2** | 3 | 26.89 | 27.14 | 26.98 | 0.14 | 3 | 249.1 | 250.9 | 249.8 | 1.0 | 3 | 9.63 | 9.98 | 9.75 | 0.20 |
| **3** | 3 | 27.54 | 28.40 | 27.83 | 0.49 | 3 | 249.0 | 284.4 | 268.4 | 17.9 | 3 | 9.30 | 9.83 | 9.56 | 0.26 |
| **4** | 3 | 27.12 | 27.22 | 27.19 | 0.06 | 3 | 262.8 | 269.5 | 266.8 | 3.5 | 3 | 8.51 | 8.69 | 8.59 | 0.09 |
| **5** | 3 | 26.75 | 26.95 | 26.82 | 0.11 | 3 | 260.8 | 266.3 | 264.1 | 2.9 | 3 | 8.02 | 8.43 | 8.23 | 0.21 |
| **6** | 3 | 26.47 | 26.70 | 26.55 | 0.13 | 3 | 255.4 | 265.7 | 261.5 | 5.5 | 3 | 8.15 | 8.64 | 8.33 | 0.27 |
| **7**[1] | | | | | | | | | | | | | | | |
| **8**[2] | 1 | 26.62 | 26.62 | 26.62 | | 1 | 279.9 | 279.9 | 279.9 | | 1 | 8.13 | 8.13 | 8.13 | |
| **9** | 3 | 26.26 | 26.57 | 26.40 | 0.16 | 3 | 278.2 | 279.2 | 278.7 | 0.5 | 3 | 7.41 | 8.27 | 7.79 | 0.44 |
| **10** | 3 | 25.90 | 26.07 | 25.96 | 0.10 | 3 | 277.8 | 281.5 | 279.4 | 1.9 | 3 | 7.20 | 8.21 | 7.56 | 0.57 |
| **All** | 22 | 25.90 | 28.40 | 26.81 | 0.59 | 22 | 249.0 | 284.4 | 267.5 | 11.5 | 22 | 7.20 | 9.98 | 8.53 | 0.82 |

*[1]Transects 1 and 7 were not accessible due to low water.*
*[2]One Station was sampled on Transect 8; the others were not accessible due to low water.*

## 4.3 SEDIMENT GRAB SAMPLING

As shown above in Table 4-2, only one sediment sample was able to be collected for grain size analysis (Station 07-L). At each verification station that was accessible by boat, at least three valid grab attempts were made with the Petite Ponar grab. Most of the grab attempts were empty or contained a few small rocks and/or pieces of grass (Figure 4-6). The sample from Station 07-L that was collected, was mostly water in the Ponar grab but did contain enough sediment to collect a sample (Figure 4-6(d)). The laboratory results for the grain size analysis are provided in Appendix B. Table 4-5 summarizes the grain size analysis results. The lone sample was mostly fine sand, but as evident from the majority of empty samples (Figure 4-6) was not necessarily representative of most of the habitat substrate in the survey reach.

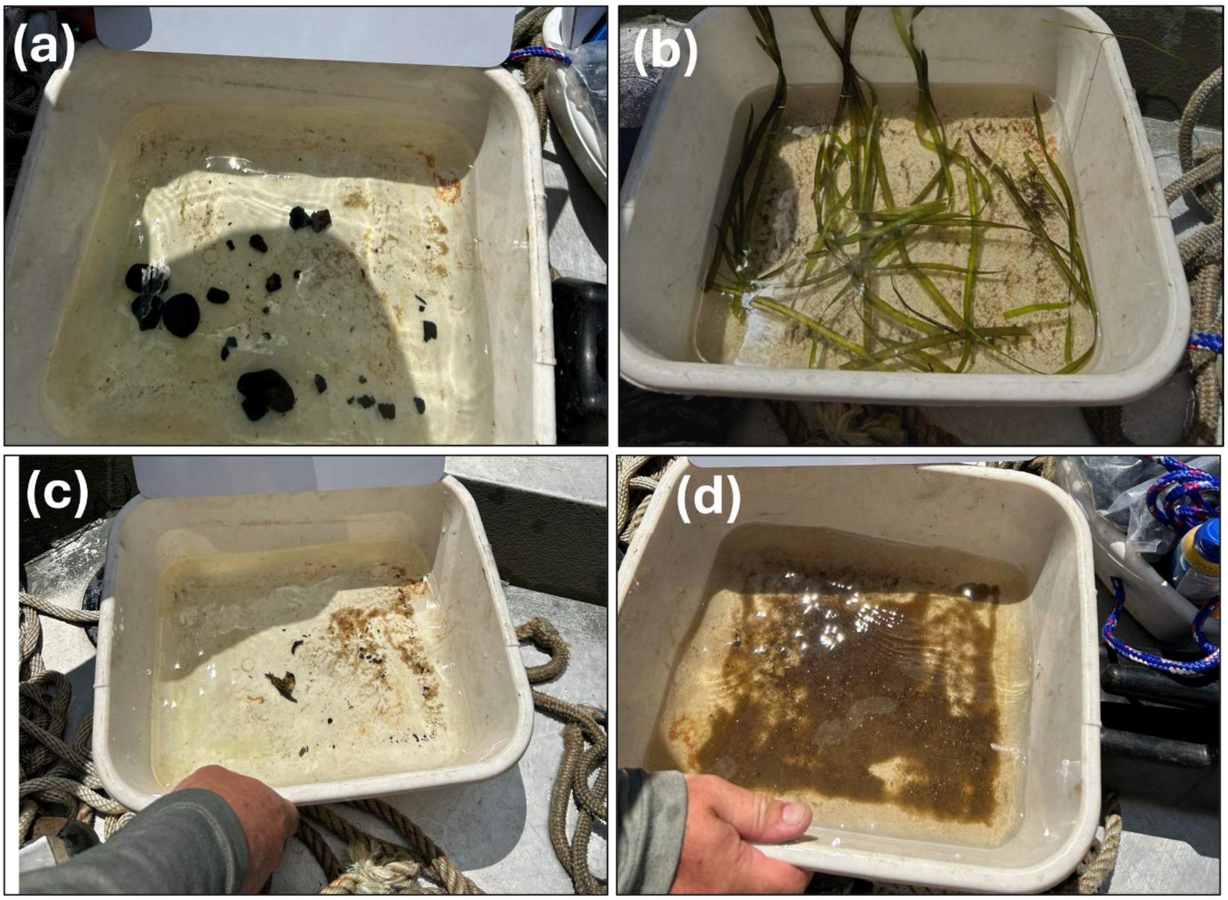


**Figure 4-6 Photos showing examples of benthic grab contents. Image (d) shows the sediment collected for the grain size analysis from Station 07-L.**

**Table 4-5 Grain size analysis from Station 07-L, collected on July 23, 2025, during the sturgeon habitat mapping and assessment study downstream of Lawrence Hydroelectric Project on the Merrimack River.**

| Sediment Classification | % of Sample | | Grain Size Parameter | Sample Percentile | Diameter (mm) |
|---|---|---|---|---|---|
| Boulder (>256 mm) | ND | | D95 | 95 | 0.2241 |
| Cobbles (64-256 mm) | ND | | D90 | 90 | 0.2042 |
| Pebble (4.0-64 mm) | ND | | D85 | 85 | 0.1925 |
| Granule (2.0-4.0 mm) | ND | | D80 | 80 | 0.1838 |
| % Very Coarse Sand (1.0-2.0 mm) | ND | | D60 | 60 | 0.1603 |
| % Coarse Sand (0.5-1.0mm) | 0.1 | | D50 | 50 | 0.1509 |
| % Medium Sand (0.25-0.5 mm) | 2 | | D40 | 40 | 0.1418 |
| % Fine Sand (0.125-0.25 mm) | 74.6 | | D30 | 30 | 0.1322 |
| % Very Fine Sand (0.0625-0.125 mm) | 21.7 | | D20 | 20 | 0.1208 |
| Silt (3.9-62.5 µm) | 1.4 | | D15 | 15 | 0.1136 |
| Clay (<3.9 µm) | 0.2 | | D10 | 10 | 0.104 |
| | | | D05 | 5 | 0.0885 |

## 4.4 UNDERWATER VIDEO OBSERVATIONS

Examples of underwater video observations and subsequent benthic substrate characterization are provided in Figure 4-7. Benthic underwater video observations were conducted at a total of 21 stations (Appendix C). Among all stations sampled by underwater video, three dominant substrate types (i.e., substrates covering 50% or more of the stream bed surface) were observed: pebble, cobble, and submerged aquatic vegetation (SAV). Pebble was the dominant substrate type at 12 stations, while cobble and SAV were each the dominant substrate type at 4 stations (Table 4-7). Sub-dominant substrate types (i.e., substrates covering 10-49% of the stream bed surface) among all stations included pebble, sand, boulder, cobble, and gravel (Table 4-7). Dominant and sub-dominant benthic substrate types for each station are presented in Figure 4-9 through Figure 4-12. Among all stations, measured percent embeddedness ranged from 0% to 18% (Table 4-6). Embedding particles (i.e., particles <2 mm in size) consisted of sand and silt; clay was not observed.

**Table 4-6 Substrate type and percent cover in underwater video of the Merrimack River riverbed, downstream of Lawerence Hydroelectric Project, based on image analysis of video collected July 22-24, 2025, using ImageJ software.**

| Station | Date | Depth (ft) | Percent Cover by Substrate Type[1] | | | | | | | | Embeddedness |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | BO (256-4096 mm) | CO (64-256 mm) | PE (4-64 mm) | GR (2-4 mm) | SA (NC) | SI (NC) | SAV | Other | |
| 01-L | 7/24/2025 | - | - | - | - | - | - | - | - | - | - |
| 02-C | 7/24/2025 | - | - | - | - | - | - | - | - | - | - |
| 03-R | 7/24/2025 | - | - | - | - | - | - | - | - | - | - |
| 04-L | 7/24/2025 | 8.7 | 0% | 0% | 0% | 0% | 0% | 0% | 100% | 0% | Unk |
| 05-C | 7/24/2025 | 5.3 | 0% | 2% | 46% | 0% | 0% | 0% | 52% | 0% | Unk |
| 06-R | 7/24/2025 | 5.4 | 0% | 0% | 0% | 0% | 0% | 0% | 100% | 0% | Unk |
| 07-L | 7/23/2025 | 5.8 | 0% | 0% | 88% | 0% | 11% | 0% | 0% | 1% | 11% |
| 08-C | 7/23/2025 | 7.9 | 19% | 16% | 60% | 0% | 0% | 4% | 0% | 1% | 4% |
| 09-R | 7/23/2025 | 8.6 | 26% | 69% | 0% | 0% | 0% | 5% | 0% | 0% | 5% |
| 10-L | 7/23/2025 | 9.8 | 0% | 92% | 2% | 0% | 1% | 6% | 0% | 0% | 7% |
| 11-C | 7/23/2025 | 7.9 | 0% | 58% | 40% | 0% | 1% | 0% | 0% | 1% | 1% |
| 12-R | 7/23/2025 | 6.0 | 0% | 89% | 0% | 0% | 0% | 8% | 4% | 0% | 8% |
| 13-L | 7/23/2025 | - | 0% | 3% | 39% | 0% | 0% | 0% | 58% | 0% | 0% |
| 14-C | 7/23/2025 | 7.8 | 13% | 39% | 47% | 0% | 1% | 0% | 0% | 0% | 1% |
| 15-R | 7/23/2025 | 5.2 | 10% | 24% | 61% | 0% | 3% | 2% | 0% | 1% | 5% |
| 16-L | 7/23/2025 | 5.1 | 0% | 17% | 73% | 0% | 8% | 0% | 0% | 2% | 8% |
| 17-C | 7/23/2025 | 4.7 | 0% | 5% | 81% | 0% | 12% | 1% | 0% | 1% | 13% |
| 18-R | 7/23/2025 | - | - | - | - | - | - | - | - | - | - |
| 19-L | 7/22/2025 | - | - | - | - | - | - | - | - | - | - |
| 20-C | 7/22/2025 | - | - | - | - | - | - | - | - | - | - |
| 21-R | 7/22/2025 | - | - | - | - | - | - | - | - | - | - |
| 22-L | 7/22/2025 | - | - | - | - | - | - | - | - | - | - |
| 23-C | 7/22/2025 | - | - | - | - | - | - | - | - | - | - |
| 24-R | 7/22/2025 | 6.8 | 0% | 47% | 49% | 0% | 0% | 3% | 0% | 1% | 3% |

| Station | Date | Depth (ft) | Percent Cover by Substrate Type[1] | | | | | | | | Embeddedness |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | BO (256-4096 mm) | CO (64-256 mm) | PE (4-64 mm) | GR (2-4 mm) | SA (NC) | SI (NC) | SAV | Other | |
| 25-L | 7/22/2025 | 13.3 | 0% | 13% | 67% | 0% | 18% | 0% | 0% | 2% | 18% |
| 26-C | 7/22/2025 | 8.0 | 0% | 36% | 60% | 0% | 2% | 1% | 0% | 1% | 3% |
| 27-R | 7/22/2025 | 8.4 | 25% | 10% | 50% | 0% | 10% | 4% | 0% | 1% | 14% |
| 28-L | 7/22/2025 | 11.2 | 0% | 8% | 84% | 0% | 6% | 1% | 0% | 1% | 7% |
| 29-C | 7/22/2025 | 16.0 | 0% | 12% | 81% | 0% | 6% | 0% | 0% | 0% | 6% |
| 30-R | 7/22/2025 | 6.1 | 0% | 23% | 60% | 13% | 3% | 0% | 0% | 0% | 3% |

1. BO=boulder; CO=cobble; PE=pebble; GR=gravel; SA=sand; SI=silt; SAV=submerged aquatic vegetation/eelgrass; NC=not classified; Unk=unknown.

**Table 4-7 Depth, measured by a single-beam echosounder, and substrate classification by sampling station. Substrate classification was determined by image analysis of underwater videos of the riverbed and depth was collected by July 22-24, 2025, in the Merrimack River downstream of the Lawrence Hydroelectric Project. Identified substrate types included: boulder (BO); cobble (CO); pebble (PE); gravel (GR); sand (SA); silt (SI); submerged aquatic vegetation/eelgrass (SAV), and shell (SH).**

| Station | Depth (ft) | Substrate Classification | | | |
|---|---|---|---|---|---|
| | | Dominant (≥50%) | Sub-Dominant (10-49%) | Other (<10%) | Final Substrate Type |
| 01-L | - | - | - | - | - |
| 02-C | - | - | - | - | - |
| 03-R | - | - | - | - | - |
| 04-L | 8.7 | SAV | - | - | SAV |
| 05-C | 5.3 | SAV | PE | CO | SAV-PE |
| 06-R | 5.4 | SAV | - | - | SAV |
| 07-L | 5.8 | PE | SA | SH | PE-SA |
| 08-C | 7.9 | PE | BO, CO | SH, SI | PE-BO-CO |
| 09-R | 8.6 | CO | BO | SH, SI | CO-BO |
| 10-L | 9.8 | CO | - | SI, PE, SA, SH | CO |
| 11-C | 7.9 | CO | PE | SA, SH | CO-PE |
| 12-R | 6.0 | CO | - | SI, SAV, SH | CO |
| 13-L | - | SAV | PE | CO, SH | SAV-PE |
| 14-C | 7.8 | - | PE, CO, BO | SA, SH | PE-CO-BO |
| 15-R | 5.2 | PE | CO, BO | SA, SI, SH | PE-CO-BO |
| 16-L | 5.1 | PE | CO, BO | SA, SH | PE-CO-BO |
| 17-C | 4.7 | PE | SA | CO, SH, SI | PE-SA |
| 18-R | - | - | - | - | - |
| 19-L | - | - | - | - | - |
| 20-C | - | - | - | - | - |
| 21-R | - | - | - | - | - |
| 22-L | - | - | - | - | - |
| 23-C | - | - | - | - | - |
| 24-R | 6.8 | PE | CO | SI, SH, GR | PE-CO |
| 25-L | 13.3 | PE | SA, CO | SH | PE-SA-CO |
| 26-C | 8.0 | PE | CO | SA, SI, SH | PE-CO |
| 27-R | 8.4 | PE | BO, SA, CO | SI, SH | PE-BO-SA-CO |
| 28-L | 11.2 | PE | - | CO, SA, SI, SH, GR | PE |
| 29-C | 16.0 | PE | CO | SA, SH, GR | PE-CO |
| 30-R | 6.1 | PE | CO, GR | SA | PE-CO-GR |

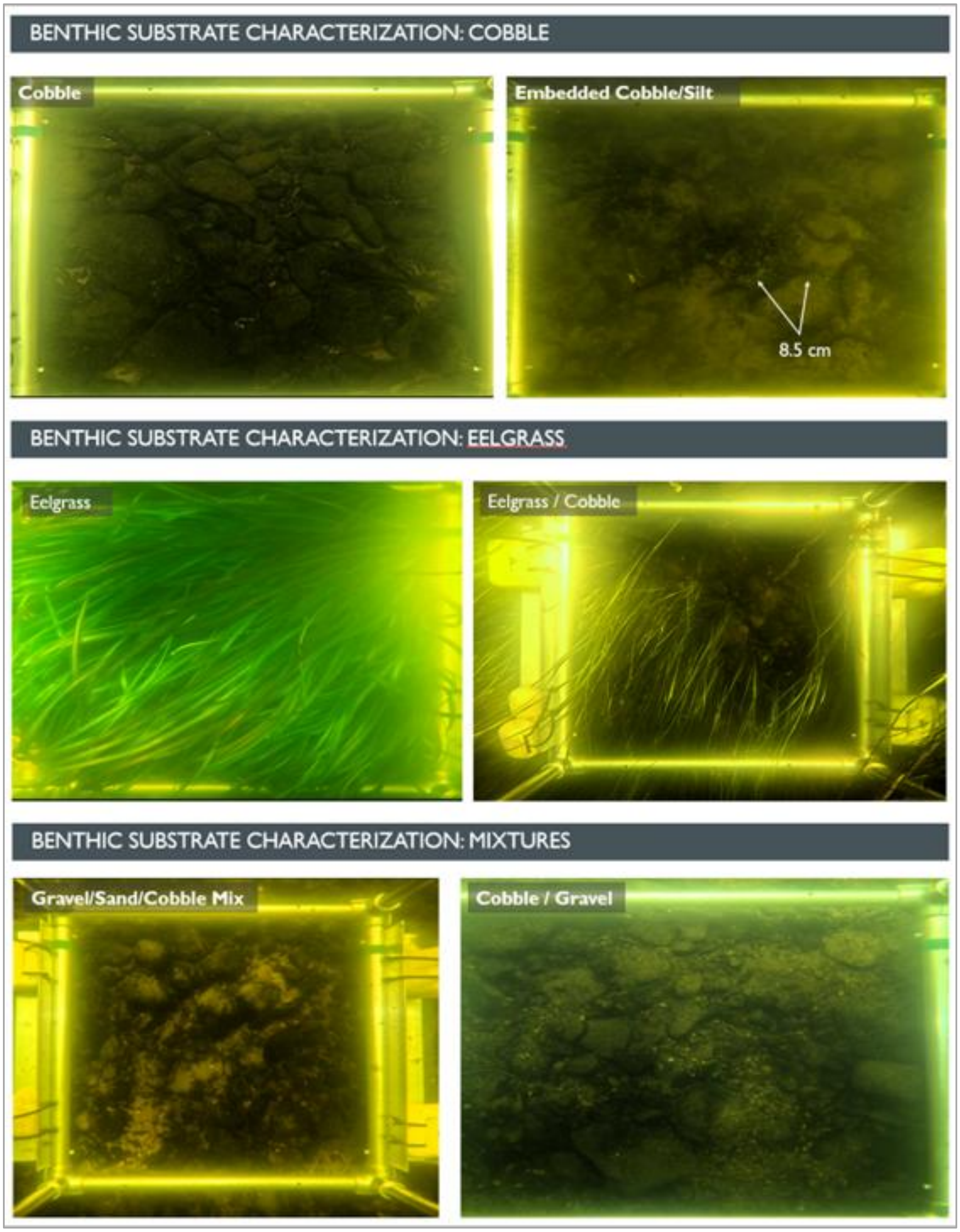


**Figure 4-7 Examples of benthic substrate characterization. Images from underwater video depict cobble (top left), cobble embedded in silt (top right), submerged aquatic vegetation (eelgrass; center left), eelgrass with cobble (center right), a gravel/sand/cobble substrate mixture (bottom left), and a cobble/gravel substrate mixture (bottom right).**

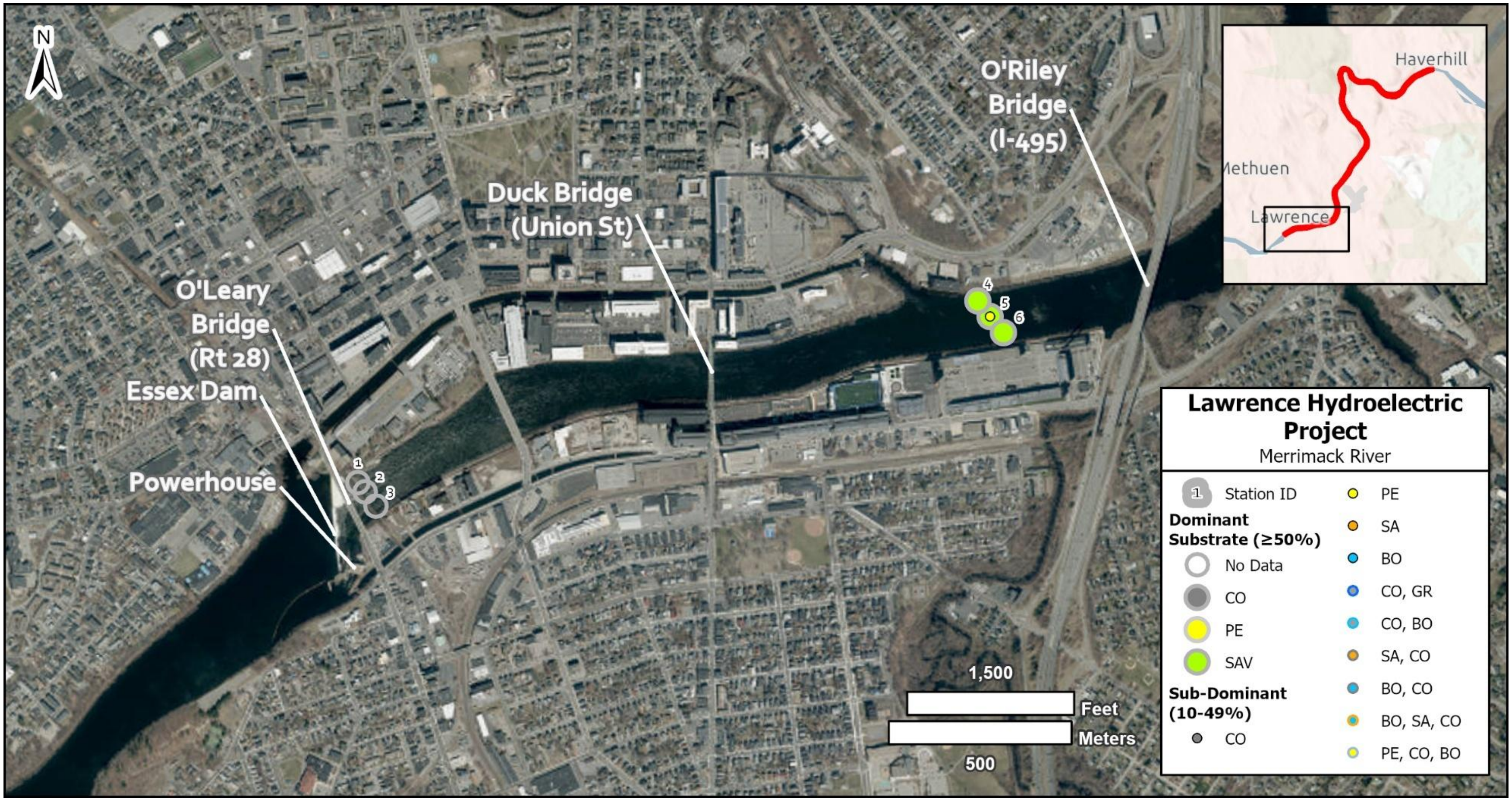


**Figure 4-9** **Benthic substrates at Stations 1-6, sampled on July 24, 2025 at the Lawrence Hydroelectric Project on the Merrimack River. For substrate classification: BO=boulder; CO=cobble; PE=pebble; GR=gravel; SA=sand; SI=silt; SH=shell; and SAV=submerged aquatic vegetation (primarily eelgrass).**


Figure 4-10 Benthic substrates at Stations 7-15, sampled on July 23, 2025 at the Lawrence Hydroelectric Project on the Merrimack River. For substrate classification: BO=boulder; CO=cobble; PE=pebble; GR=gravel; SA=sand; SI=silt; SH=shell; and SAV=submerged aquatic vegetation (primarily eelgrass).

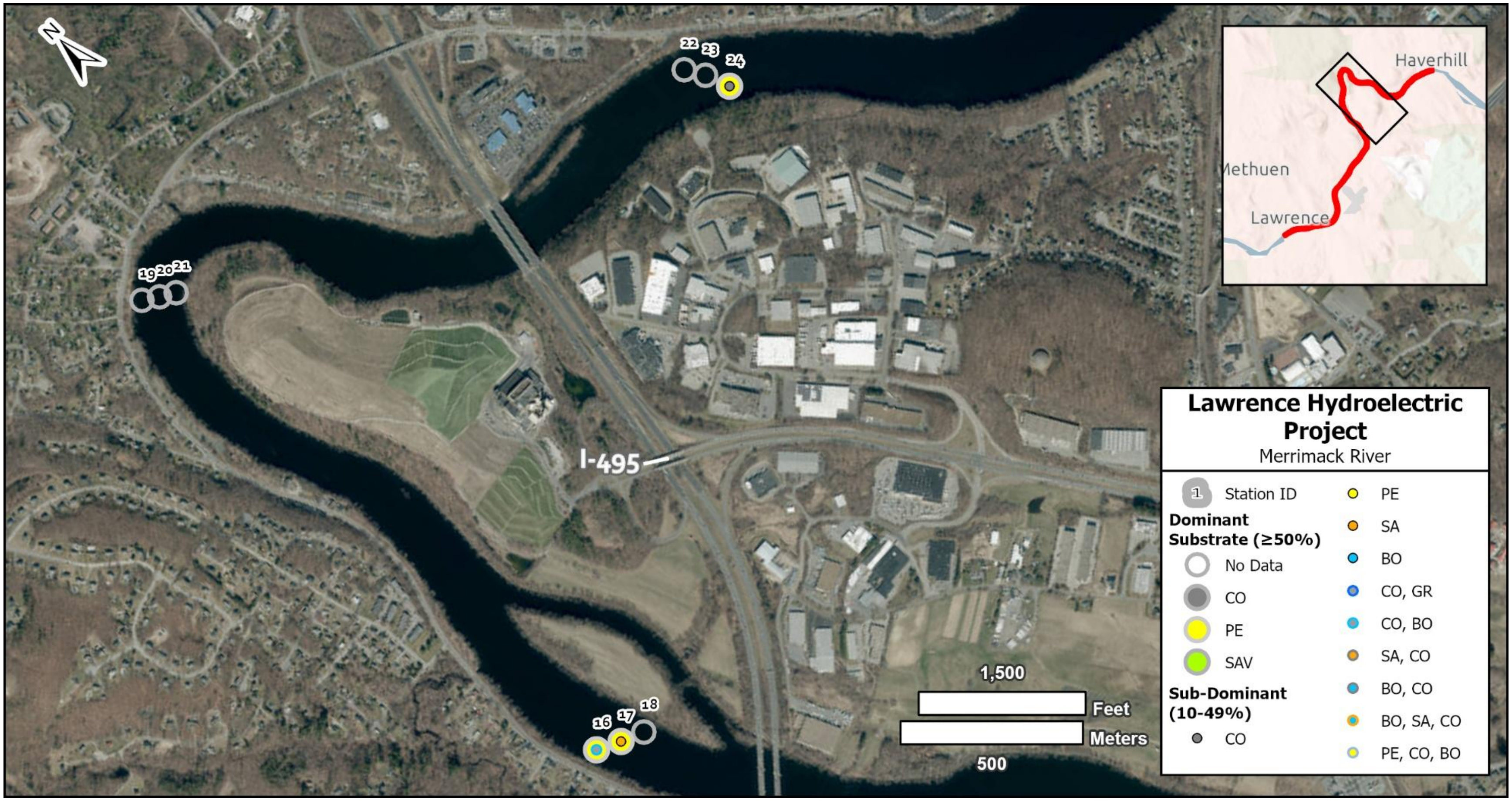


**Figure 4-11** Benthic substrates at Stations 16-24, sampled on July 22, 2025 at the Lawrence Hydroelectric Project on the Merrimack River. For substrate classification: BO=boulder; CO=cobble; PE=pebble; GR=gravel; SA=sand; SI=silt; SH=shell; and SAV=submerged aquatic vegetation (primarily eelgrass).

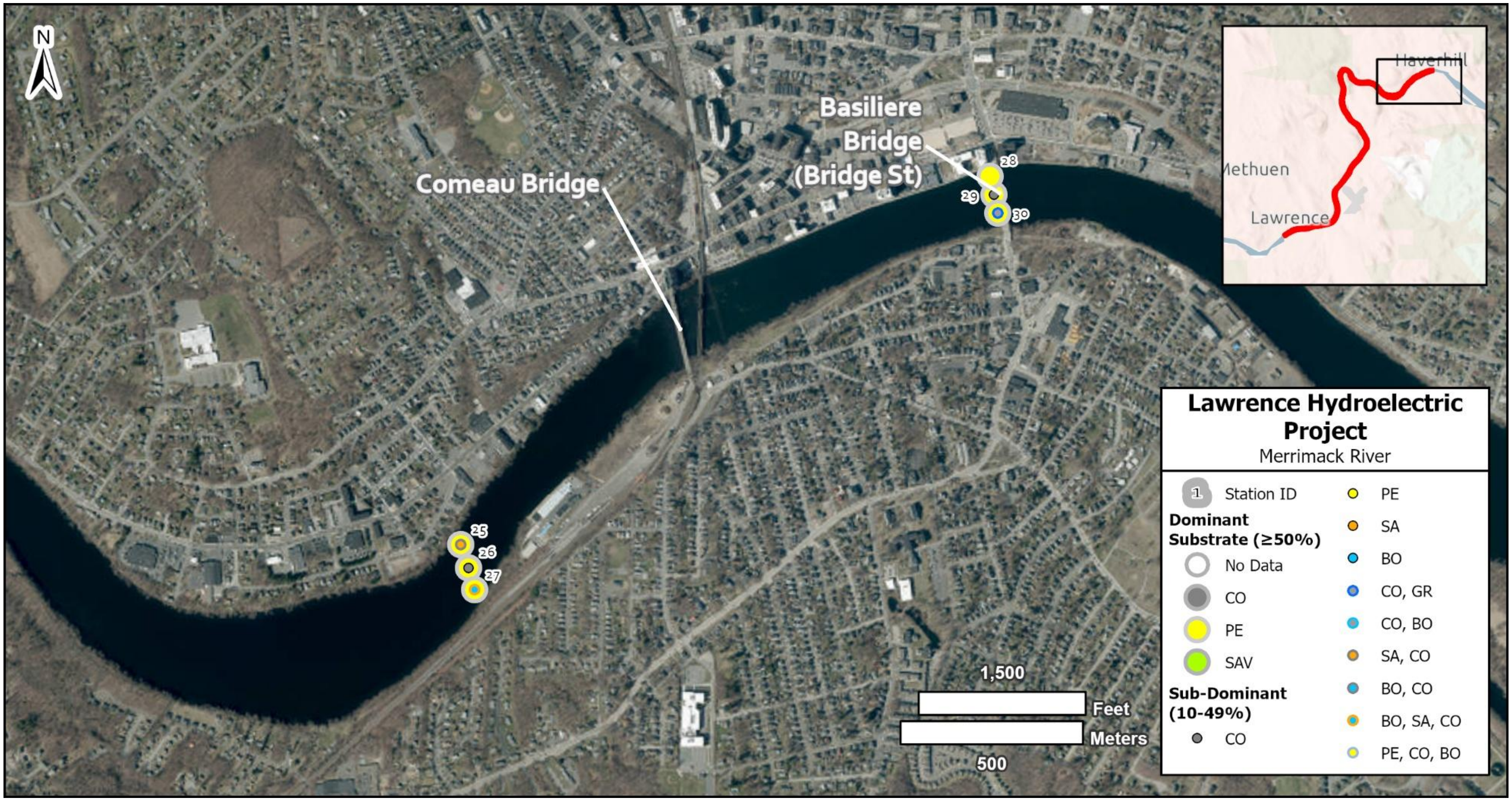


**Figure 4-12** Benthic substrates at Stations 25-30, sampled on July 22, 2025 at the Lawrence Hydroelectric Project on the Merrimack River. For substrate classification: BO=boulder; CO=cobble; PE=pebble; GR=gravel; SA=sand; SI=silt; SH=shell; and SAV=submerged aquatic vegetation (primarily eelgrass).

## 4.5 SIDE-SCAN SONAR IMAGERY

Side-scan sonar imagery was not collected or analyzed due to river conditions.

## 4.6 BATHYMETRY

Water depth during the survey ranged from 4.7 ft to 16 ft and riverbed elevation ranged from -13.3 ft to 3.6 ft (relative to NAVD88). The distribution of these soundings at the verification sampling stations are shown in Figure 4-13 to Figure 4-16.

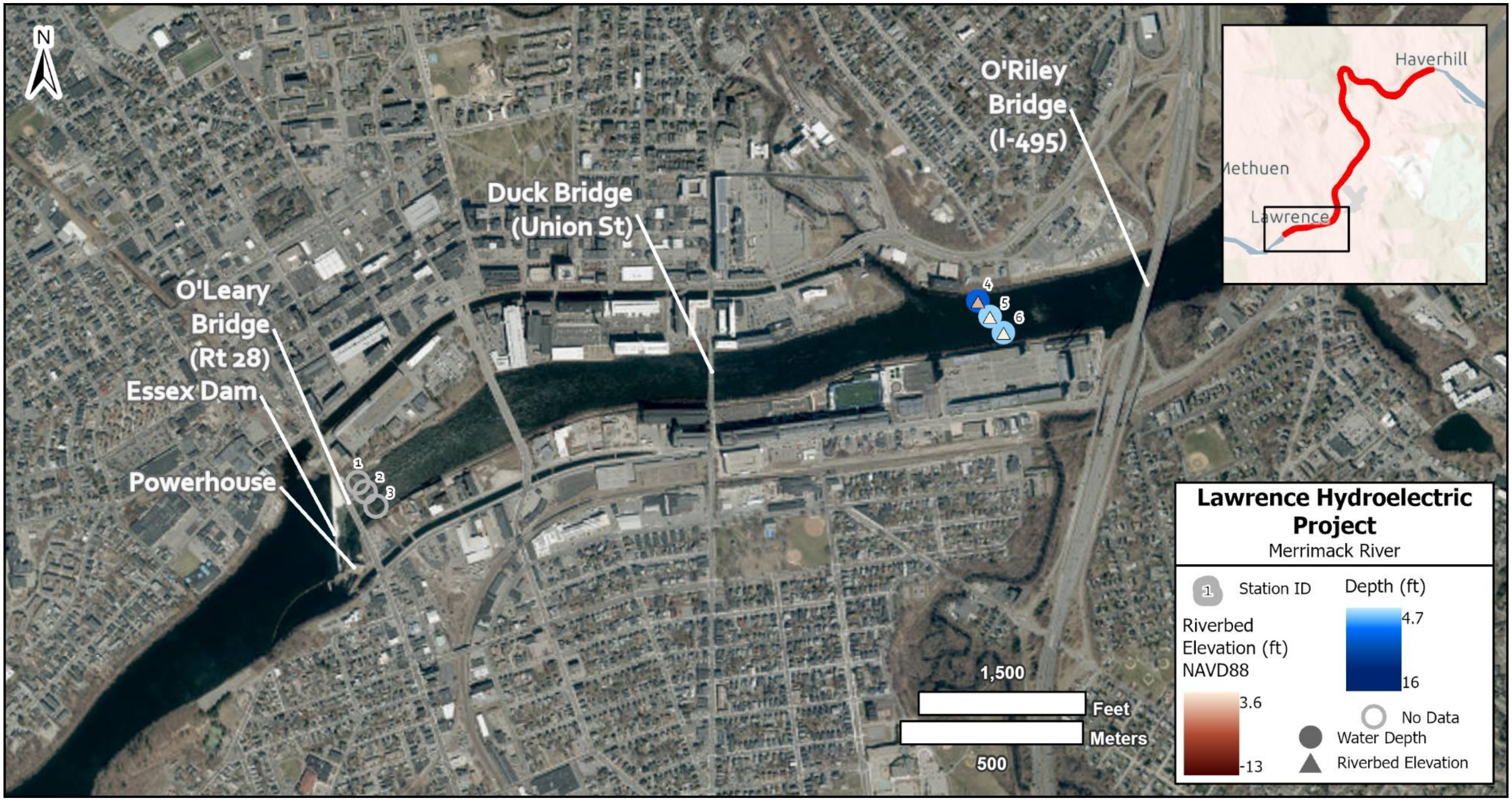


**Figure 4-13 Depth and riverbed elevation at Stations 1-6, sampled on July 24, 2025 at the Lawrence Hydroelectric Project on the Merrimack River.**


**Figure 4-14 Depth and riverbed elevation at Stations 7-15, sampled on July 23, 2025 at the Lawrence Hydroelectric Project on the Merrimack River.**


**Figure 4-15 Depth and riverbed elevation at Stations 16-24, sampled on July 22, 2025 at the Lawrence Hydroelectric Project on the Merrimack River.**

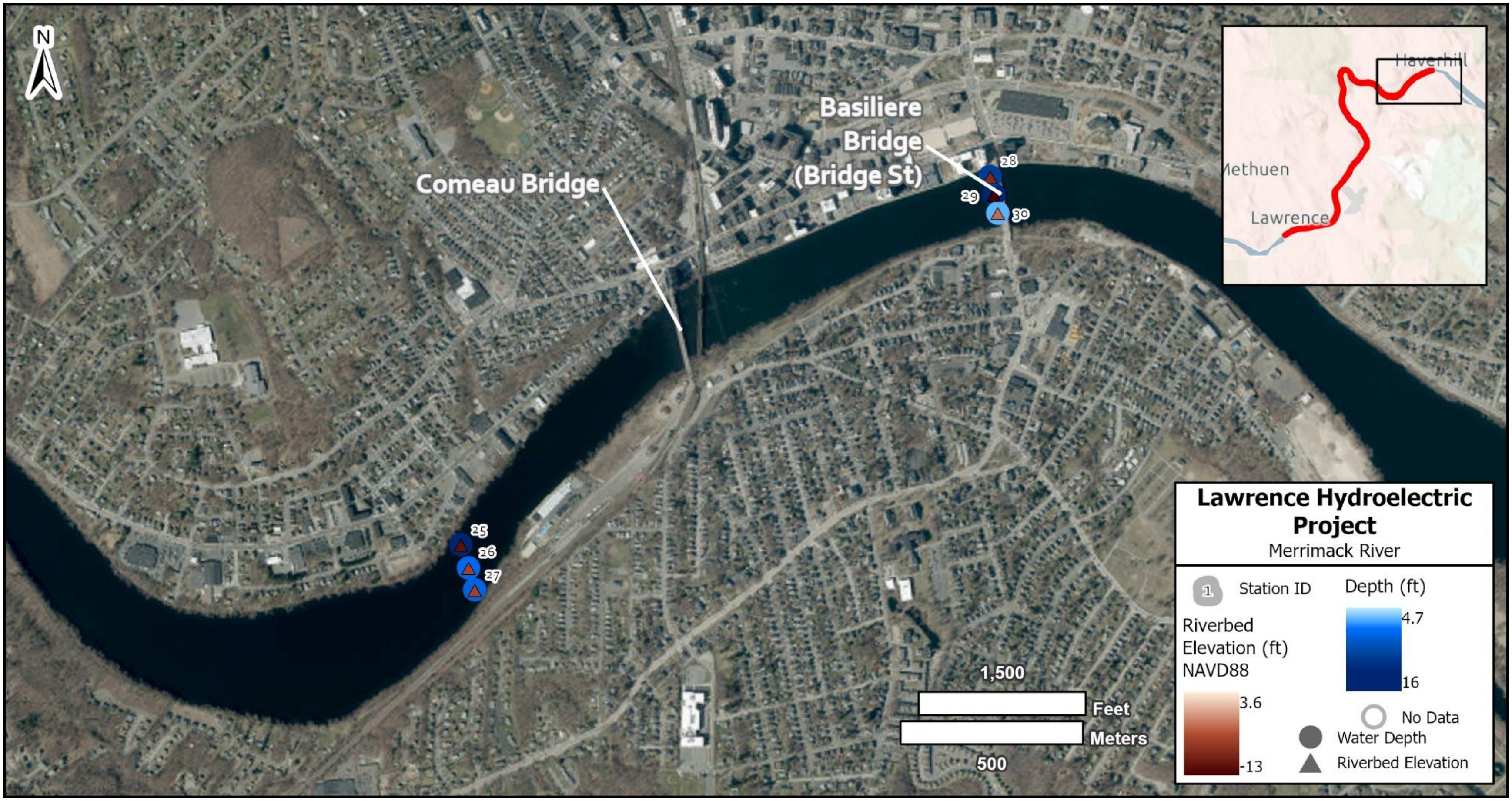


**Figure 4-16 Depth and riverbed elevation at Stations 25-30, sampled on July 22, 2025 at the Lawrence Hydroelectric Project on the Merrimack River.**

## 4.7 STURGEON HABITAT CLASSIFICATION

The area and distribution of sturgeon habitat are shown in Figure 4-17 to **Error! Reference source not found.**. Cumulative suitable habitat area for Atlantic and Shortnose Sturgeon foraging, juvenile rearing, and spawning is presented in Table 4-8. Cumulative habitat area was determined based on a total surveyed habitat area of 596.7 acres.

**Table 4-8 Cumulative habitat area for Atlantic and Shortnose Sturgeon foraging, juvenile rearing, and spawning. Percent habitat area is based on a total surveyed habitat area of 596.7 acres. On average, surveyed river segments were 150 ft wide; a buffer zone of 50 feet from the banks was used, and manual adjustments were made as river width fluctuated.**

| Species | Foraging Area | | Juvenile Rearing Area | | Spawning Area | |
|---|---|---|---|---|---|---|
| | Acres | % | Acres | % | Acres | % |
| Atlantic Sturgeon | 95.0 | 15.9% | 95.0 | 15.9% | 385.6 | 64.6% |
| Shortnose Sturgeon | 113.6 | 19.0% | 18.5 | 3.1% | 307.4 | 51.5% |
| No Data | 164.5 | 27.6% | 164.5 | 27.6% | 164.5 | 27.6% |

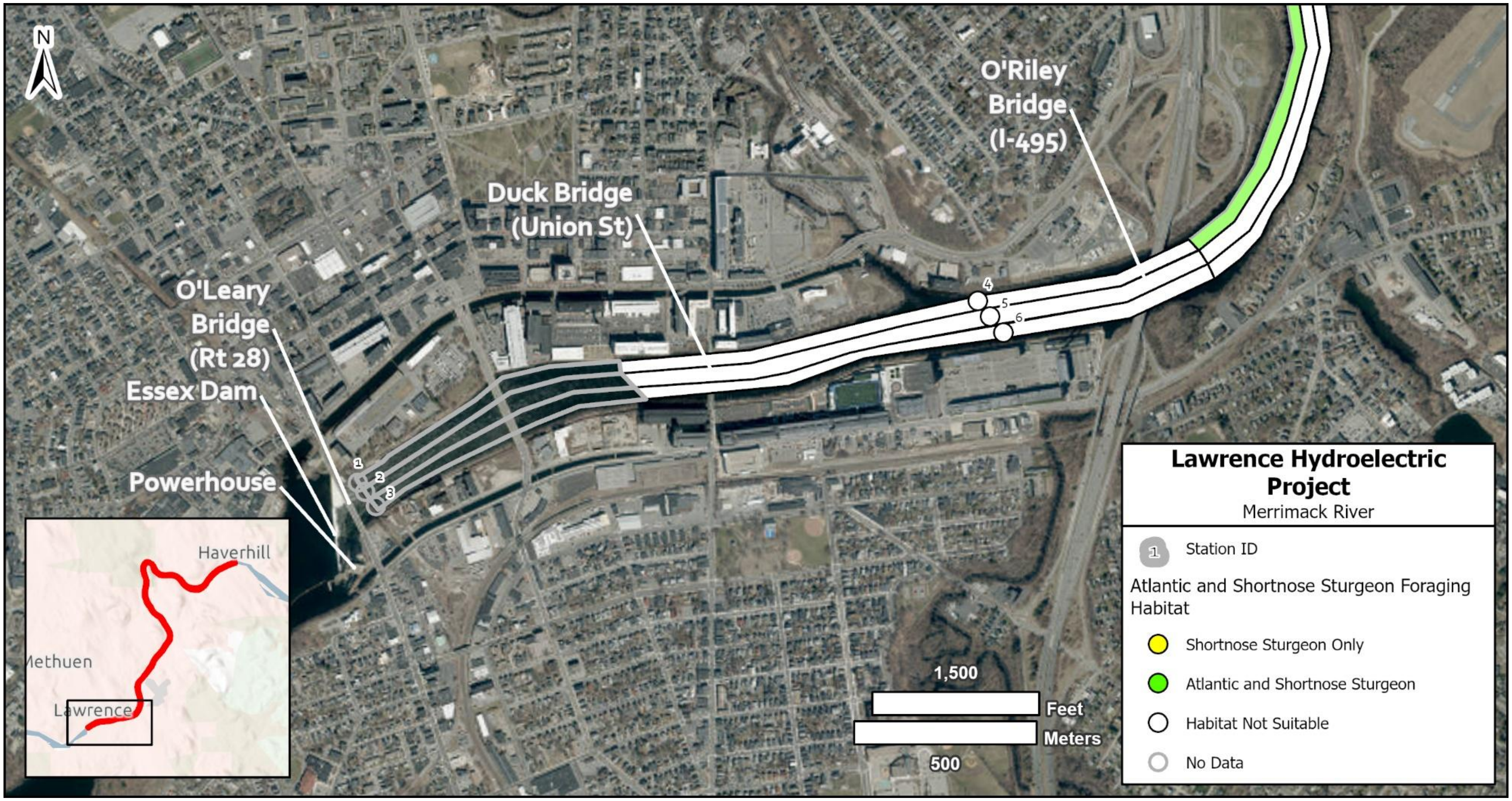


**Figure 4-17 Sturgeon foraging habitat at Stations 1-6 at the Lawrence Hydroelectric Project on the Merrimack River. Suitable habitat for foraging was determined using substrate types and depths identified during this study and species-specific literature-based values for foraging substrate type and foraging depth.**


**Figure 4-18 Sturgeon foraging habitat at Stations 7-15 at the Lawrence Hydroelectric Project on the Merrimack River. Suitable habitat for foraging was determined using substrate types and depths identified during this study and species-specific literature-based values for foraging substrate type and foraging depth.**

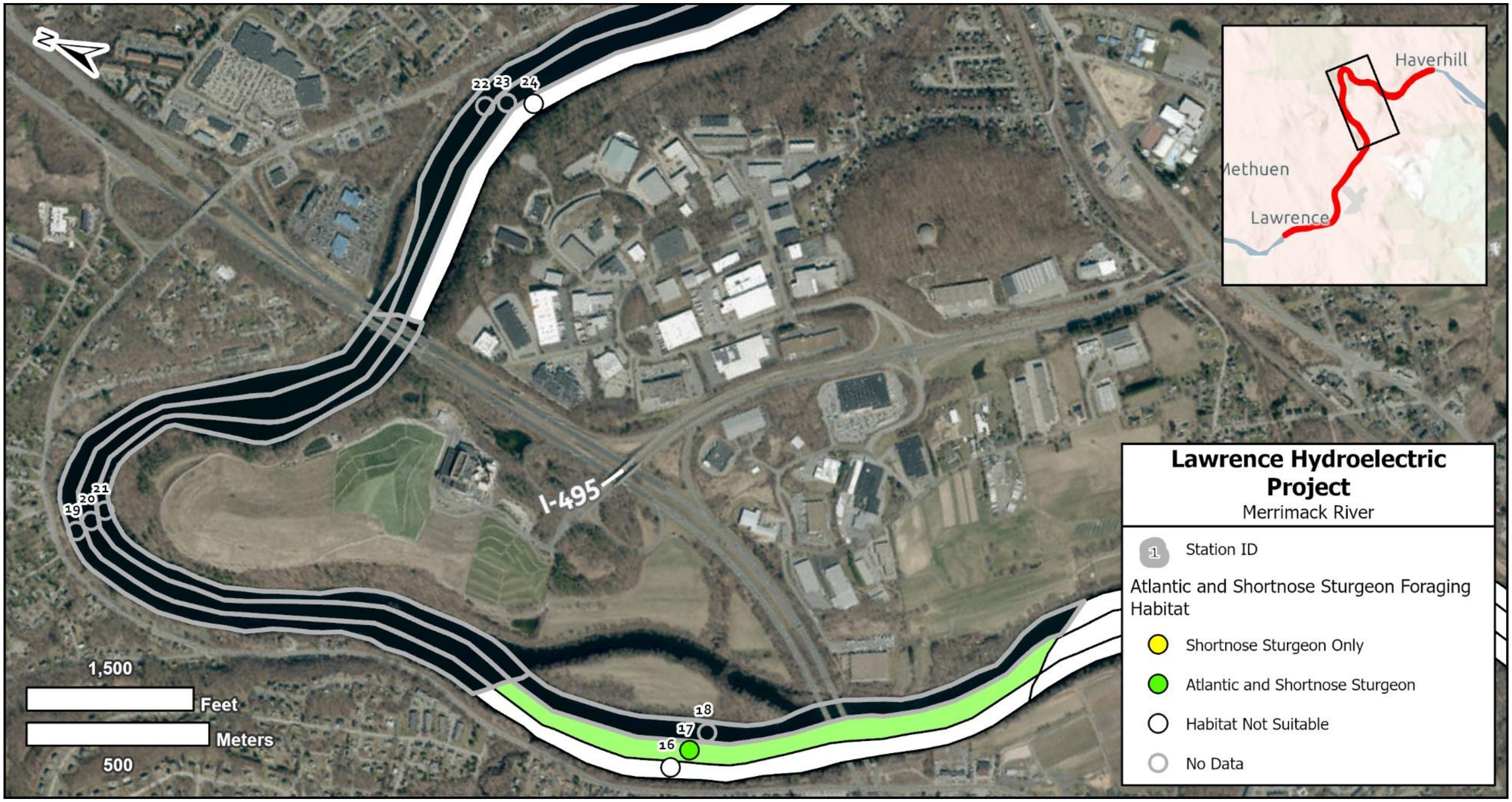


**Figure 4-19 Sturgeon foraging habitat at Stations 16-24 at the Lawrence Hydroelectric Project on the Merrimack River. Suitable habitat for foraging was determined using substrate types and depths identified during this study and species-specific literature-based values for foraging substrate type and foraging depth.**

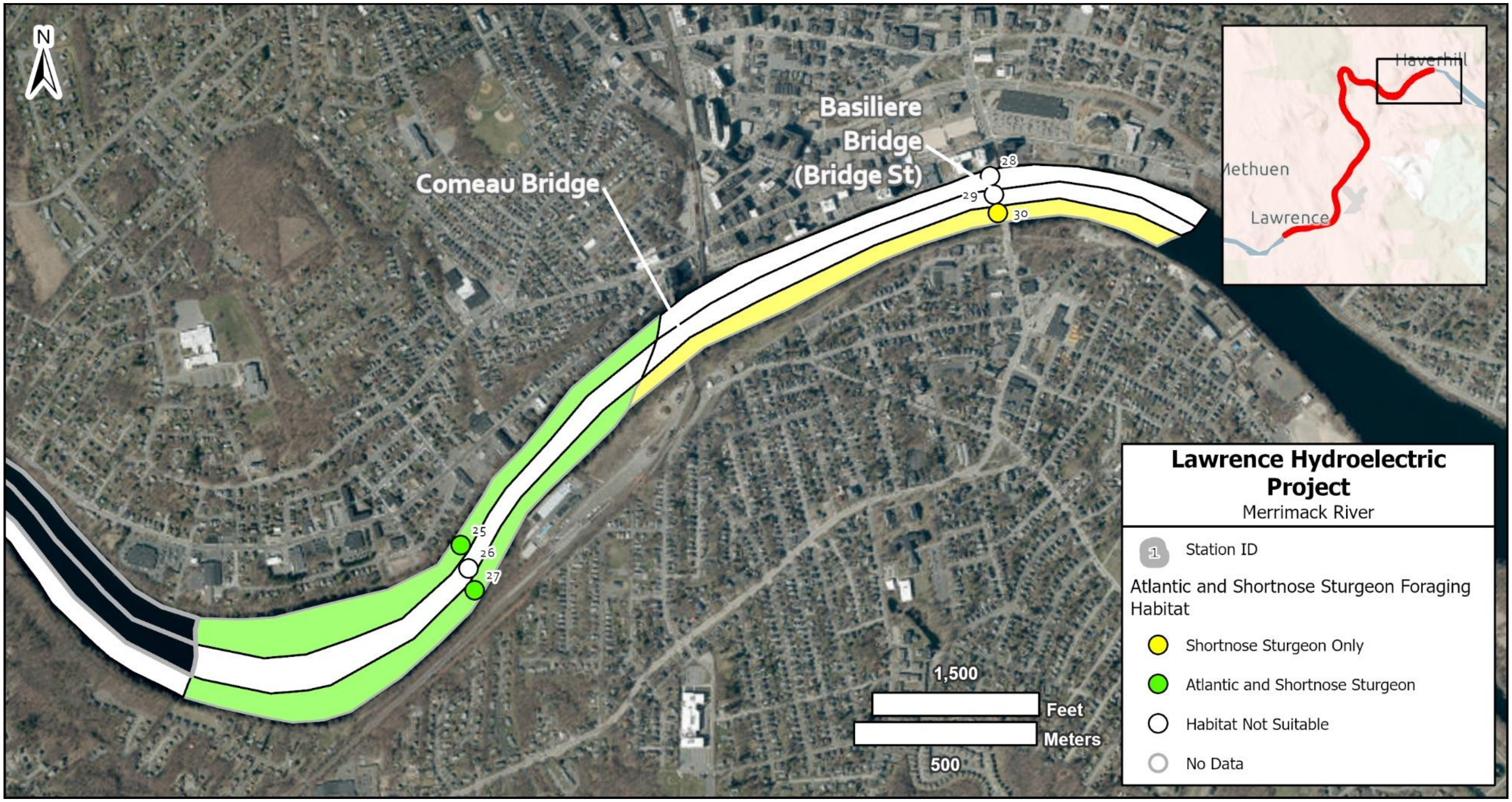


**Figure 4-20 Sturgeon foraging habitat at Stations 25-30 at the Lawrence Hydroelectric Project on the Merrimack River. Suitable habitat for foraging was determined using substrate types and depths identified during this study and species-specific literature-based values for foraging substrate type and foraging depth.**

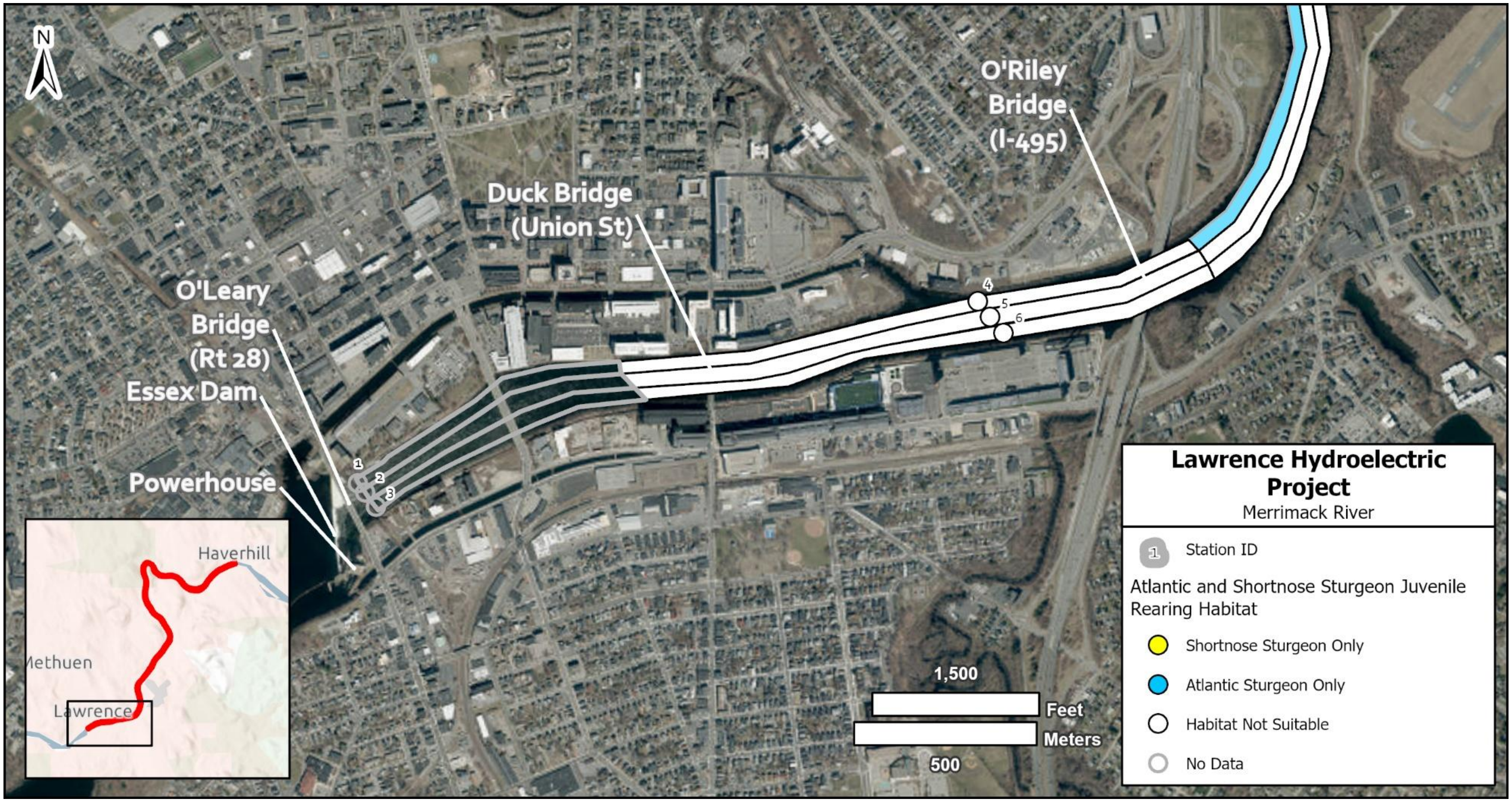


**Figure 4-21 Sturgeon juvenile rearing habitat at Stations1-6 at the Lawrence Hydroelectric Project on the Merrimack River. Suitable habitat for juvenile rearing was determined using substrate types and depths identified during this study and species-specific literature-based values for juvenile rearing substrate type and juvenile rearing depth.**

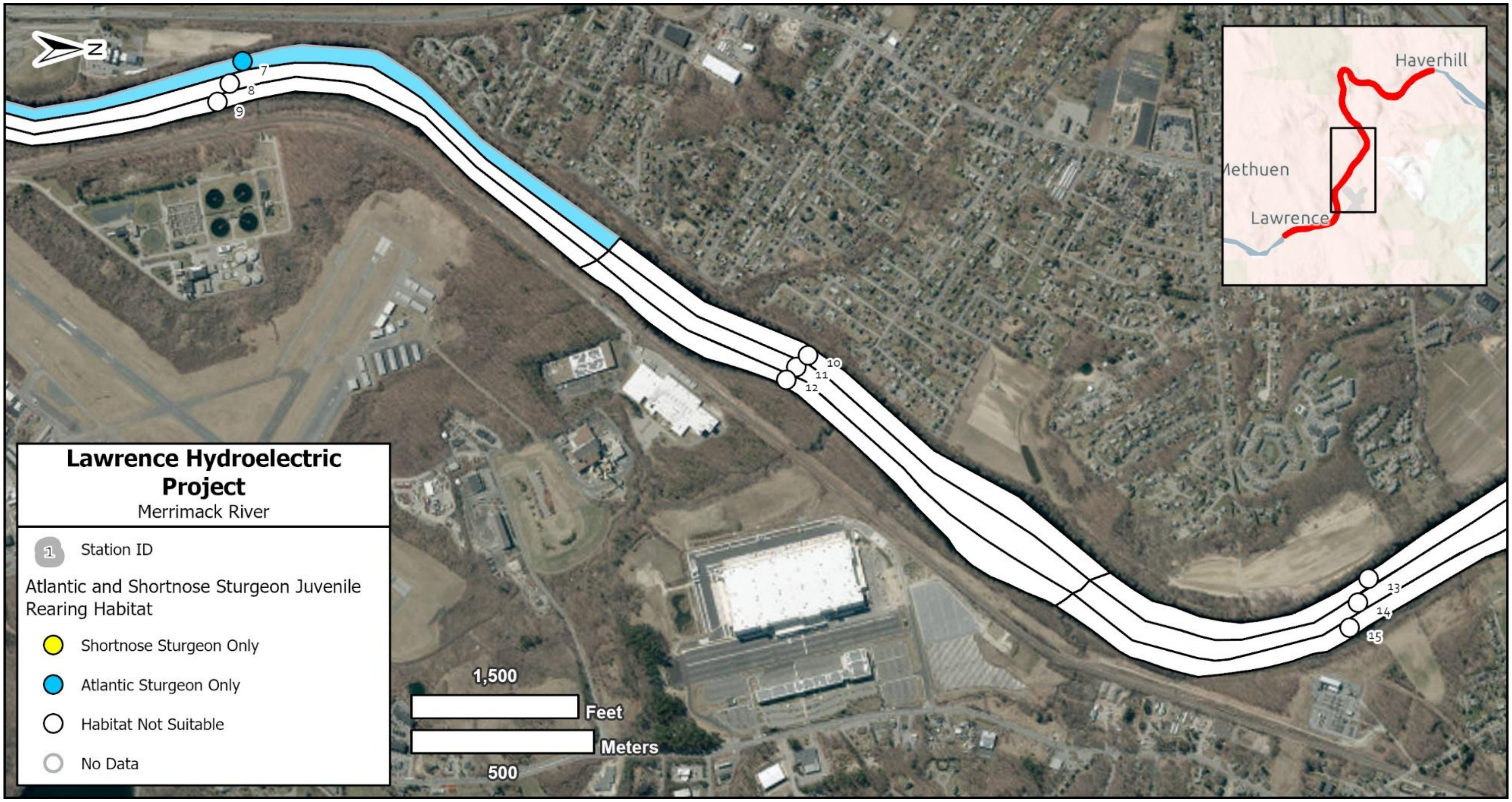


**Figure 4-22 Sturgeon juvenile rearing habitat at Stations 7-15 at the Lawrence Hydroelectric Project on the Merrimack River. Suitable habitat for juvenile rearing was determined using substrate types and depths identified during this study and species-specific literature-based values for juvenile rearing substrate type and juvenile rearing depth.**

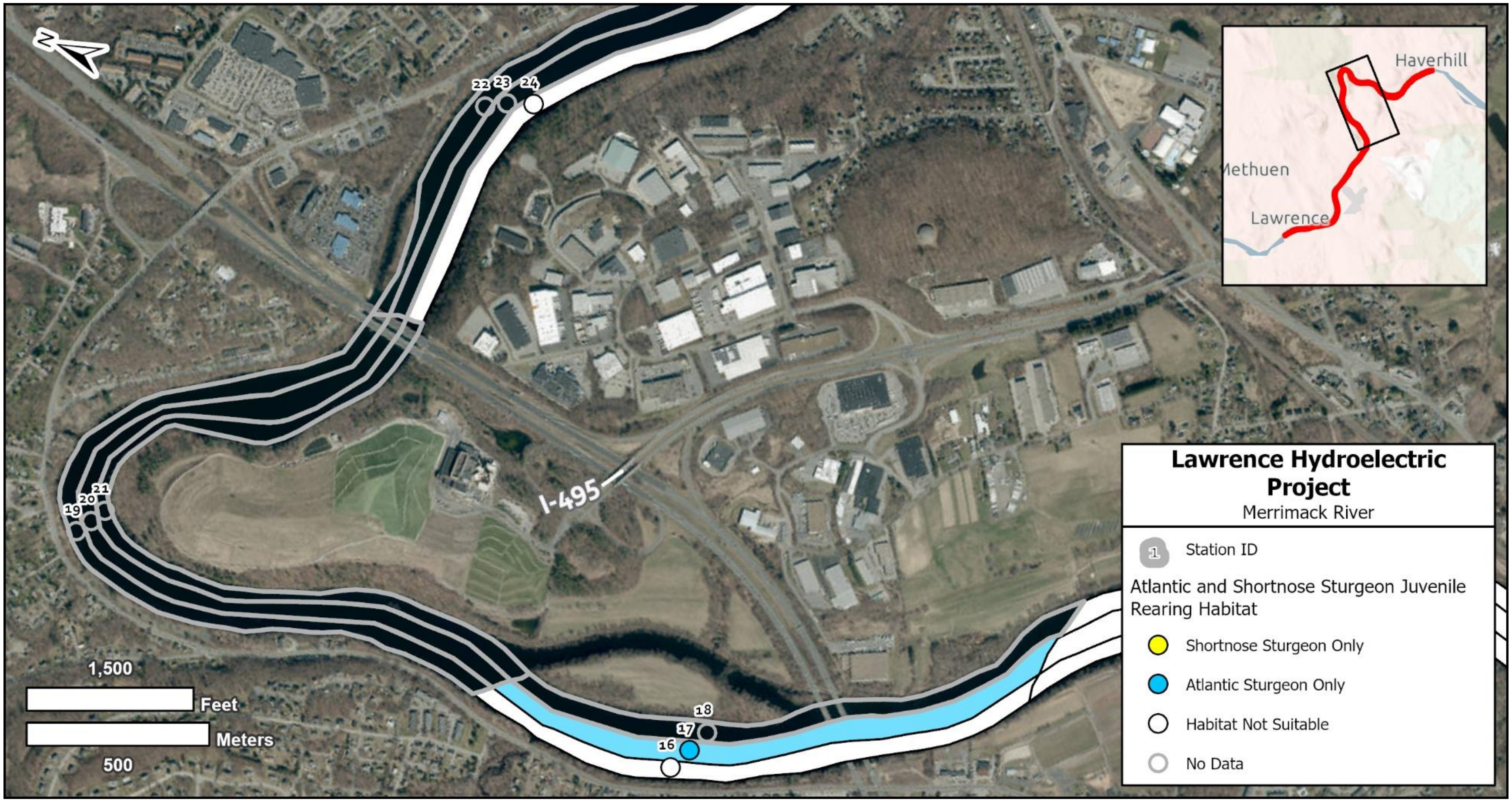


**Figure 4-23 Sturgeon juvenile rearing habitat at Stations 16-24 at the Lawrence Hydroelectric Project on the Merrimack River. Suitable habitat for juvenile rearing was determined using substrate types and depths identified during this study and species-specific literature-based values for juvenile rearing substrate type and juvenile rearing depth.**

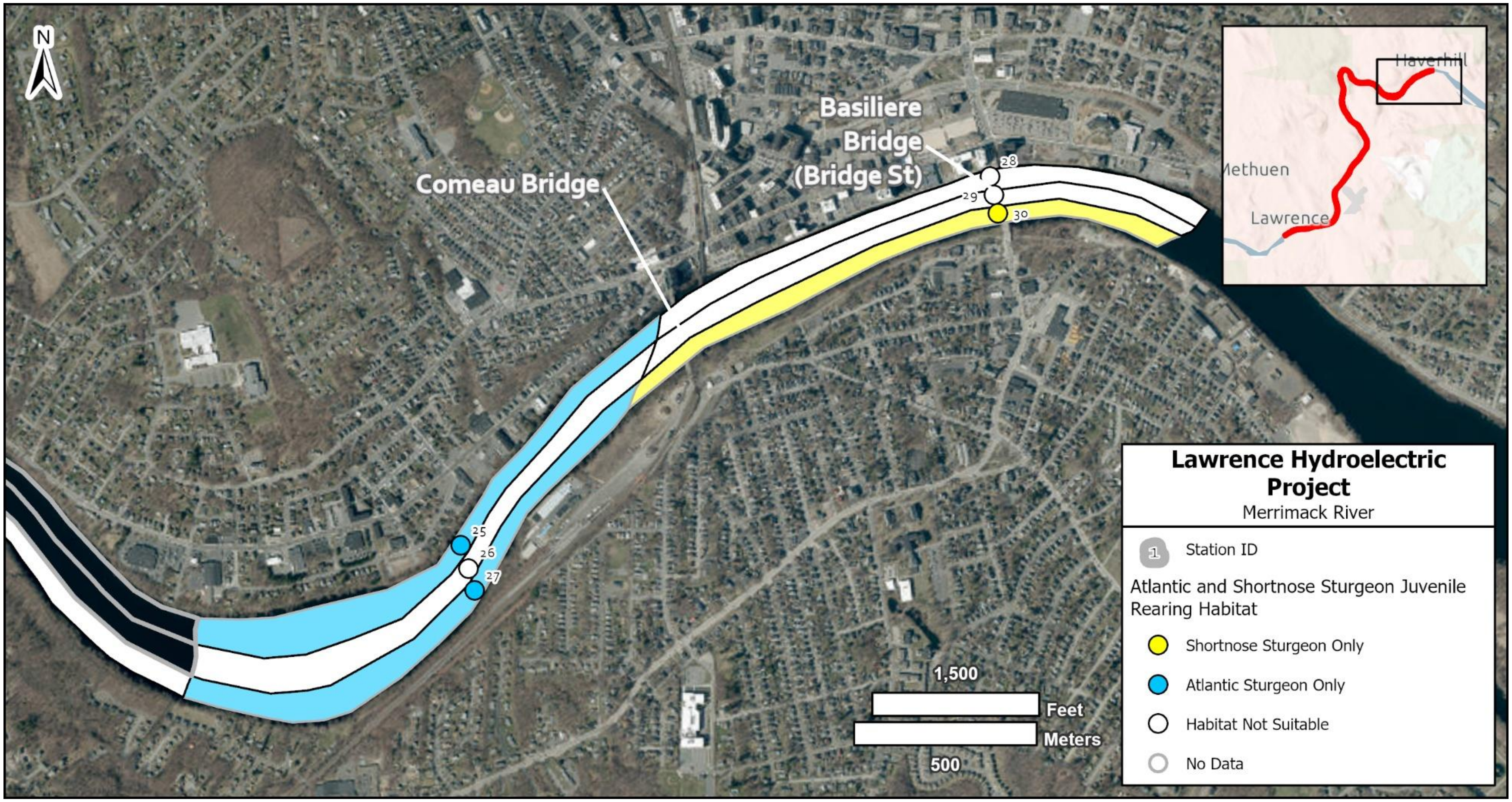


**Figure 4-24 Sturgeon juvenile rearing habitat at Stations 25-30 at the Lawrence Hydroelectric Project on the Merrimack River. Suitable habitat for juvenile rearing was determined using substrate types and depths identified during this study and species-specific literature-based values for juvenile rearing substrate type and juvenile rearing depth.**

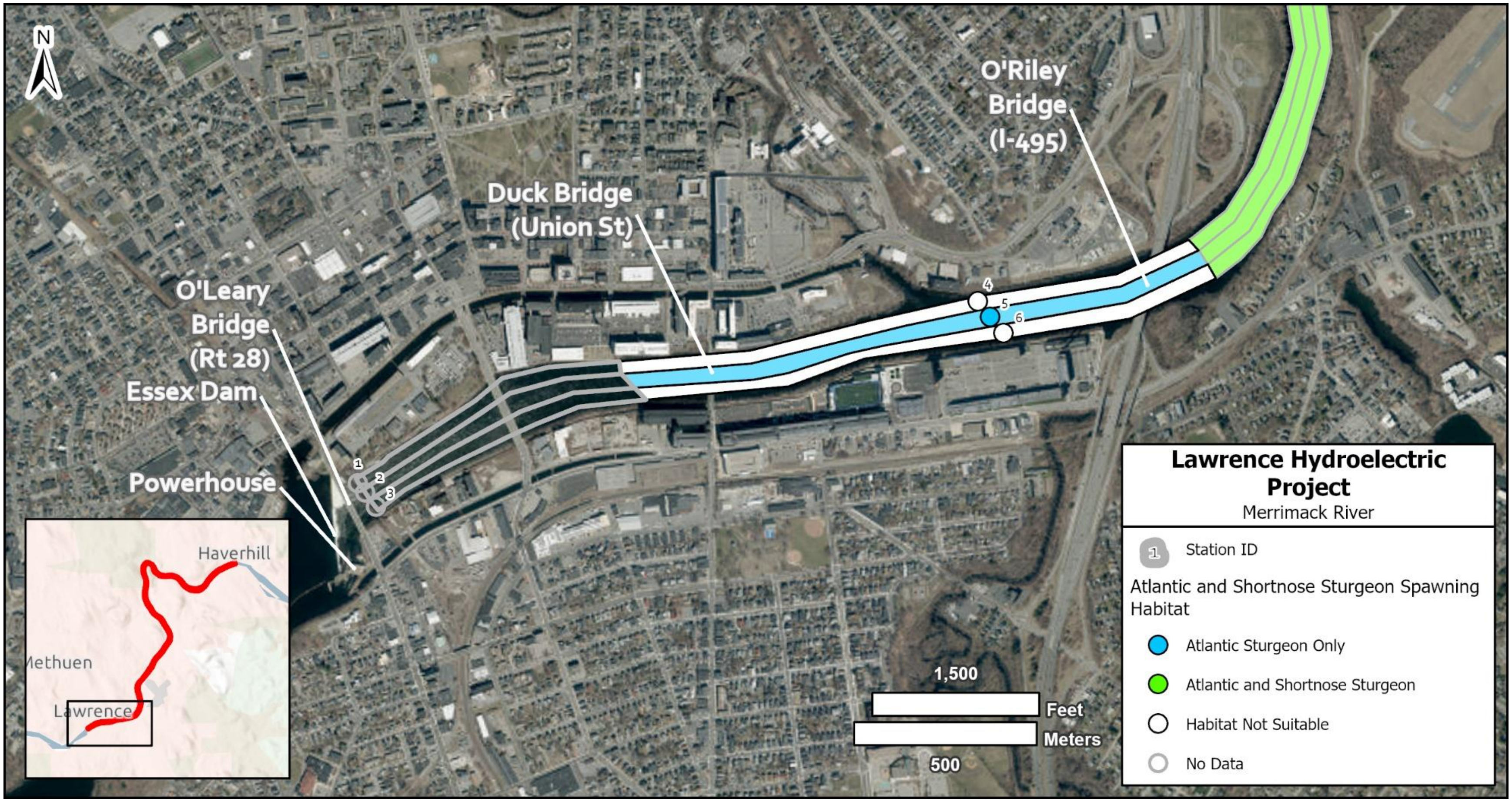


**Figure 4-25 Sturgeon spawning habitat at Stations 1-6 at the Lawrence Hydroelectric Project on the Merrimack River. Suitable habitat for spawning was determined using substrate types and depths identified during this study and species-specific literature-based values for spawning substrate type and spawning depth.**

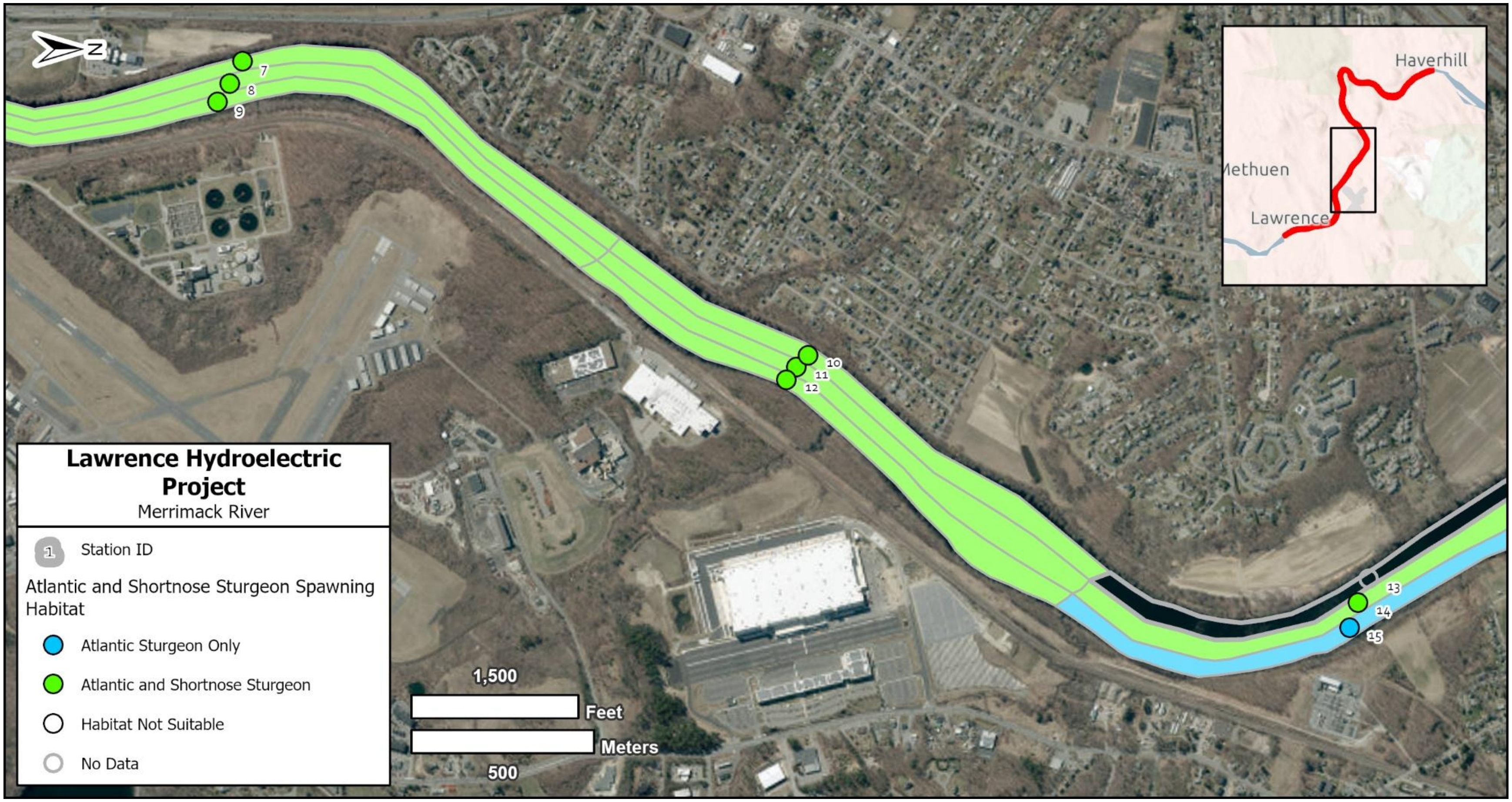


**Figure 4-26 Sturgeon spawning habitat at Stations 7-15 at the Lawrence Hydroelectric Project on the Merrimack River. Suitable habitat for spawning was determined using substrate types and depths identified during this study and species-specific literature-based values for spawning substrate type and spawning depth.**

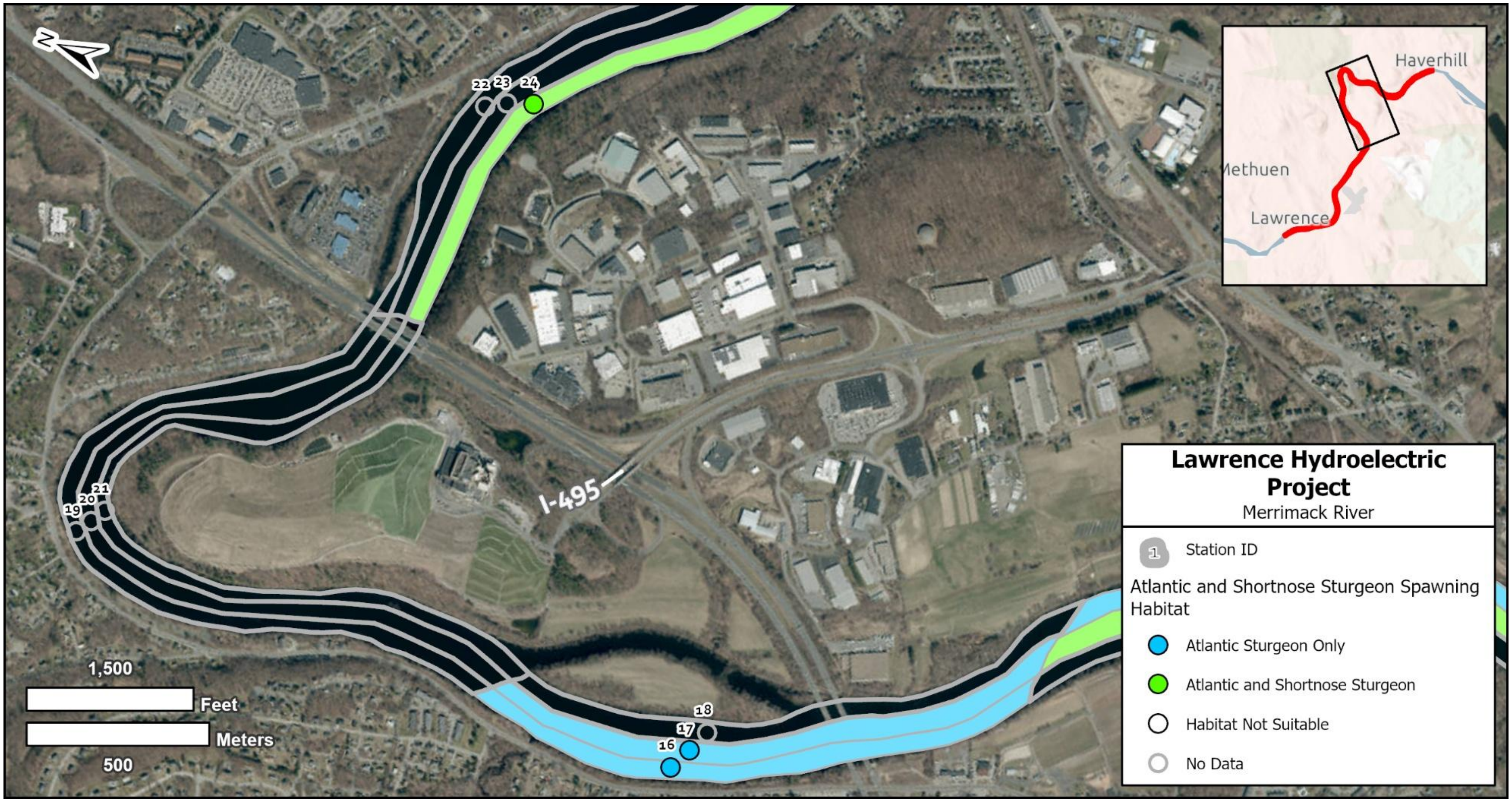


**Figure 4-27 Sturgeon spawning habitat at Stations 16-24 at the Lawrence Hydroelectric Project on the Merrimack River. Suitable habitat for spawning was determined using substrate types and depths identified during this study and species-specific literature-based values for spawning substrate type and spawning depth.**

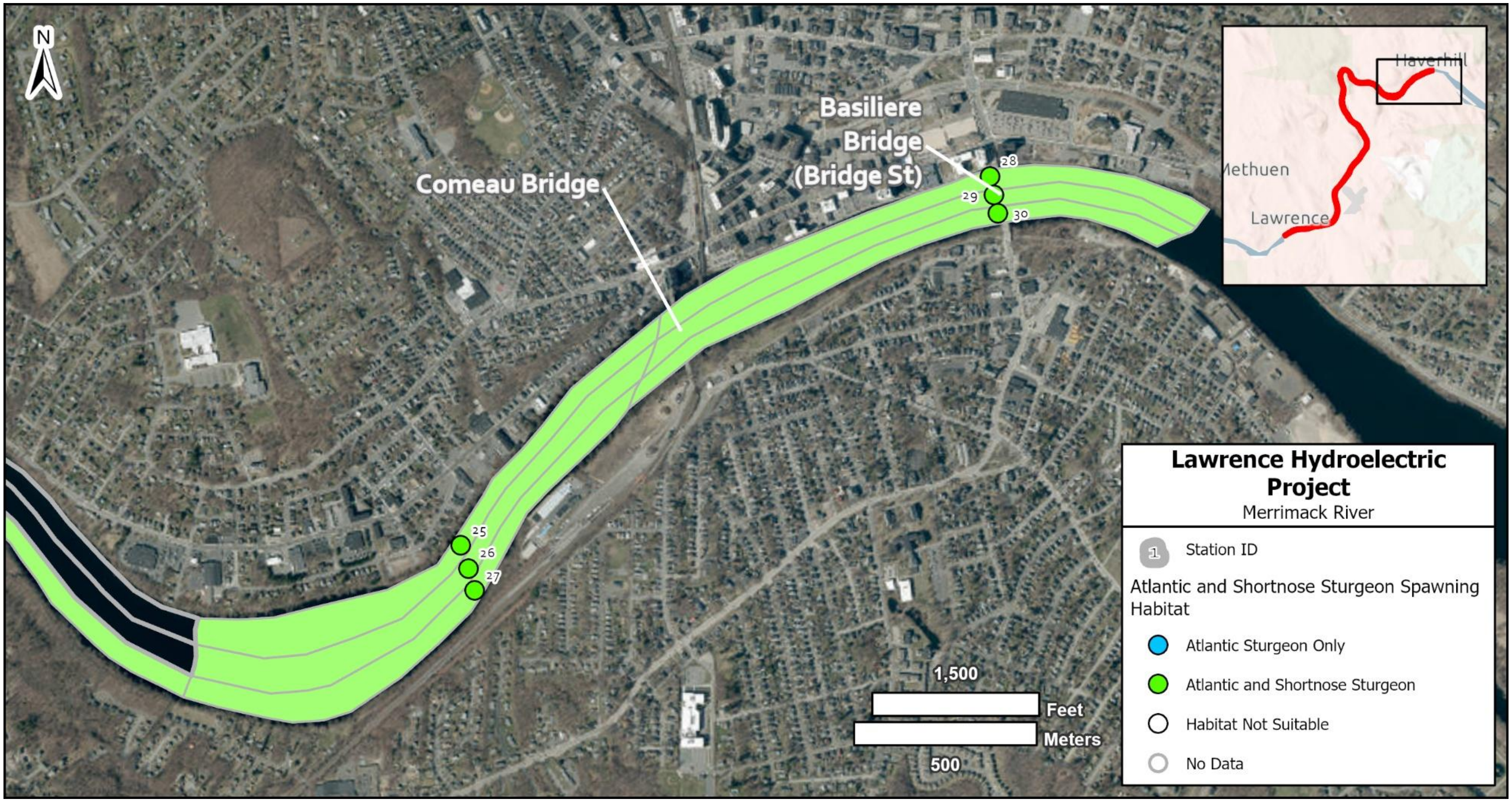


**Figure 4-28 Sturgeon spawning habitat at Stations 25-30 at the Lawrence Hydroelectric Project on the Merrimack River. Suitable habitat for spawning was determined using substrate types and depths identified during this study and species-specific literature-based values for spawning substrate type and spawning depth.**

# 5. SUMMARY

For the Sturgeon Habitat Mapping and Assessment Study, data were collected by direct sampling during July 22-24, 2025, between the Project tailrace and Basiliere Bridge at RM 19 in Haverhill, MA. Data collection resulted in the following findings to meet the study objectives:

1. Benthic habitat features, such as dominant and sub-dominant substrate type and depth, were collected and mapped across the Merrimack River in one-third segments (left, middle and right) along the study reach by each mile where valid sample information could be safely collected. These habitat features are presented in Figure 4-13 to Figure 4-16 for bathymetry and Figure 4-9 to Figure 4-12 for substrate type. Depths ranged from 4.7 to 16.0 ft. Dominant substrates were pebble, cobble and SAV. Substrate appeared to be minimally embedded (0-18%) into the riverbed by sand and silt. Substrate classification by size and embeddedness were estimated from data collected by a Petite Ponar Grab and underwater video.

2. The total surveyed area from the railroad bridge near the Project tailrace downstream to Basiliere Bridge (RM19) was approximately 596.7 acres. Within the surveyed area, Atlantic Sturgeon habitat comprised 16% for both foraging and juvenile rearing purposes, while spawning habitat accounted for 65%.Shortnose Sturgeon habitat area was classified as 19% for foraging, 3% for juvenile rearing, and 52% for spawning. Habitat classification was not assigned to approximately 28% of the total surveyed area due to a lack of available data.

3. Sturgeon was not observed while sampling during July 22-25, 2025.

# 6. VARIANCES FROM THE STUDY PLAN

The Sturgeon Habitat Mapping and Assessment Study (Study 17) deviated slightly from the SPD and the Study Plan in Appendix K of the Initial Study Report, as modifications to the survey approach were required due to environmental conditions beyond Essex's control. Modification to the planned survey design and data processing were required due to the environmental conditions encountered during the sturgeon habitat mapping survey (Sections 4.1 and 4.2). The main limitation being an environmental constraint, specifically low water due to low river flows, which was generally 4 ft below the recent 5-year average for the survey period (Figure 4-4; Table 4-3). The planned study design described in the Study Plan focused on collecting SSS) data for the 10-mile survey reach along three axial transects (i.e., along the river axis), to be combined with bathymetric survey data collected along "zig-zag" transects throughout the 10-mile survey reach, and supplemented with verification sampling/ground truthing at stations along 10 cross-river transects (approximately one transect with three stations per river mile).

Due to the extremely low water levels encountered during the surveys, it was not practicable or safely navigable to fully perform the sonar surveys as intended, and as a result some portions of the surveys could not be completed (i.e., SSS and bathymetry). The vessel could not sample along transects for SSS and bathymetry because the vessel was consistently having to navigate to avoid shallow and/or exposed rocks. This presented a hazard not only to navigation but to equipment as well, as the over-the-side mounted equipment (single-beam sonar and SSS) and the vessel's propeller struck rocks multiple times (Figure 4-1(d)). Because of this, the habitat survey primarily focused on conducting the verification sampling with bathymetry at each station to provide insight into distribution and quantity of sturgeon habitat where possible.

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# A. APPENDIX A – WATER QUALITY DATA

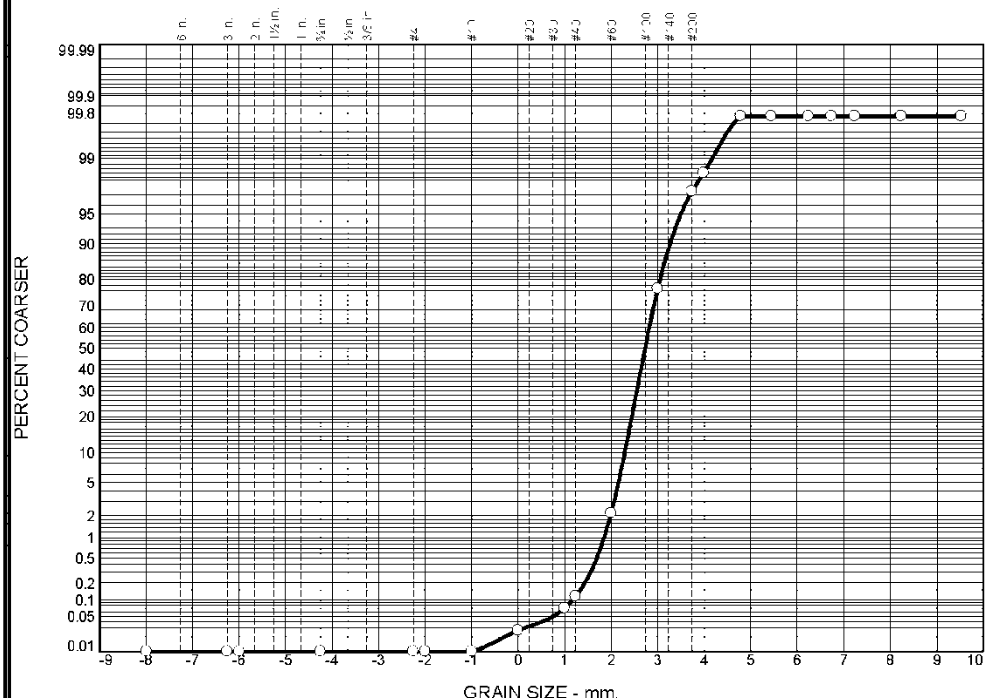
**Table A-1 Water quality measurements from each verification station during the sturgeon habitat survey on the Merrimack River July 22-24, 2025. Water temperature (ºC), specific conductance (µS/cm), and dissolved oxygen (DO, mg/L) measured from an In Situ Aqua Troll 500 multiparameter sonde at each verification station.**

| Transect | Station | Date/Time (EDT) | Latitude | Longitude | Water Temperature (°C) | Specific Conductance (µS/cm) | DO (mg/L) |
|---|---|---|---|---|---|---|---|
| 1 | **01-L** | 7/24/2025 11:30 | 42.701608 | -71.165214 | NA[1] | NA | NA |
| | **02-C** | 7/24/2025 11:30 | 42.701381 | -71.164972 | NA | NA | NA |
| | **03-R** | 7/24/2025 11:30 | 42.701029 | -71.164613 | NA | NA | NA |
| 2 | **04-L** | 7/24/2025 10:27 | 42.705991 | -71.144535 | 26.913 | 249.2 | 9.63 |
| | **05-C** | 7/24/2025 10:50 | 42.705598 | -71.144055 | 26.892 | 249.1 | 9.64 |
| | **06-R** | 7/24/2025 11:17 | 42.705187 | -71.143583 | 27.143 | 250.9 | 9.98 |
| 3 | **07-L** | 7/23/2025 13:29 | 42.717222 | -71.135433 | 28.399 | 284.4 | 9.83 |
| | **08-C** | 7/23/2025 13:49 | 42.716957 | -71.134706 | 27.554 | 249.0 | 9.30 |
| | **09-R** | 7/23/2025 13:57 | 42.716752 | -71.134113 | 27.536 | 271.8 | 9.55 |
| 4 | **10-L** | 7/23/2025 12:44 | 42.731249 | -71.125671 | 27.224 | 268.0 | 8.69 |
| | **11-C** | 7/23/2025 12:54 | 42.731012 | -71.125152 | 27.122 | 262.8 | 8.51 |
| | **12-R** | 7/23/2025 13:04 | 42.730594 | -71.124831 | 27.215 | 269.5 | 8.57 |
| 5 | **13-L** | 7/23/2025 11:56 | 42.744862 | -71.117958 | 26.772 | 260.8 | 8.24 |
| | **14-C** | 7/23/2025 12:05 | 42.744810 | -71.117345 | 26.755 | 266.3 | 8.02 |
| | **15-R** | 7/23/2025 12:19 | 42.744481 | -71.116410 | 26.947 | 265.3 | 8.43 |
| 6 | **16-L** | 7/23/2025 11:12 | 42.758063 | -71.130733 | 26.480 | 263.5 | 8.15 |
| | **17-C** | 7/23/2025 11:25 | 42.757717 | -71.130073 | 26.467 | 255.4 | 8.20 |
| | **18-R** | 7/23/2025 11:36 | 42.757406 | -71.129259 | 26.697 | 265.7 | 8.64 |
| 7 | **19-L** | 7/22/2025 15:30 | 42.773863 | -71.130720 | NA | NA | NA |
| | **20-C** | 7/22/2025 15:30 | 42.773614 | -71.130223 | NA | NA | NA |
| | **21-R** | 7/22/2025 15:30 | 42.773395 | -71.129733 | NA | NA | NA |
| 8 | **22-L** | 7/22/2025 15:00 | 42.768373 | -71.112467 | NA | NA | NA |
| | **23-C** | 7/22/2025 15:00 | 42.767904 | -71.112097 | NA | NA | NA |
| | **24-R** | 7/22/2025 14:52 | 42.767222 | -71.111737 | 26.619 | 279.9 | 8.13 |
| 9 | **25-L** | 7/22/2025 14:05 | 42.765232 | -71.094301 | 26.356 | 279.2 | 7.70 |
| | **26-C** | 7/22/2025 13:56 | 42.764583 | -71.094105 | 26.262 | 278.2 | 7.41 |
| | **27-R** | 7/22/2025 13:41 | 42.764058 | -71.093938 | 26.574 | 278.6 | 8.27 |
| 10 | **28-L** | 7/22/2025 13:11 | 42.774313 | -71.076676 | 26.068 | 281.5 | 7.20 |
| | **29-C** | 7/22/2025 13:00 | 42.773812 | -71.076502 | 25.903 | 278.8 | 7.26 |
| | **30-R** | 7/22/2025 12:45 | 42.773305 | -71.076359 | 25.899 | 277.8 | 8.21 |

*[1]NA indicates the Station was not accessible due to river conditions (low water, navigation issues)*

# B. APPENDIX B – SEDIMENT GRAIN SIZE REPORT

# Particle Size Distribution Report




| | % Boulders | % +3" | % Pebbles | % Granules | % Sand V. Crs. | % Sand Crs. | % Sand Med. | % Sand Fine | % Sand V. Fine | % Silt Crs. | % Silt Med. | % Silt Fine | % Silt V. Fine | % Clay |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| ○ | | | 0.0 | 0.0 | 0.0 | 0.1 | 2.0 | 74.6 | 21.7 | 1.4 | 0.0 | 0.0 | 0.0 | 0.2 |

| X | LL | PL | $D_{85}$ | $D_{60}$ | $D_{50}$ | $D_{30}$ | $D_{15}$ | $D_{10}$ | $C_c$ | $C_u$ |
|---|---|---|---|---|---|---|---|---|---|---|
| ○ | | | 0.1925 | 0.1603 | 0.1509 | 0.1322 | 0.1136 | 0.1040 | 1.05 | 1.54 |

| | Material Description | USCS | AASHTO |
|---|---|---|---|
| ○ | | SP | |

Project No. Client:
Project:

○ Source of Sample: 07-L Sample Number: L2546948-01

Remarks:

Pace

Mansfield, MA

Figure

**Figure B-1 Particle size distribution results from the Pace Analytical Laboratory report for verification station 07-L, collected during the sturgeon habitat survey on the Merrimack River July 22-24, 2025. Particle size distribution by sieve size is presented in the cumulative distribution function plot. The first table provides the percentages and sediment classifications per Wentworth scale. The second table provides grain size percentiles (mm) from the sample.**

# C. APPENDIX C – UNDERWATER VIDEO FRAMES FOR SUBSTRATE CLASSIFICATION

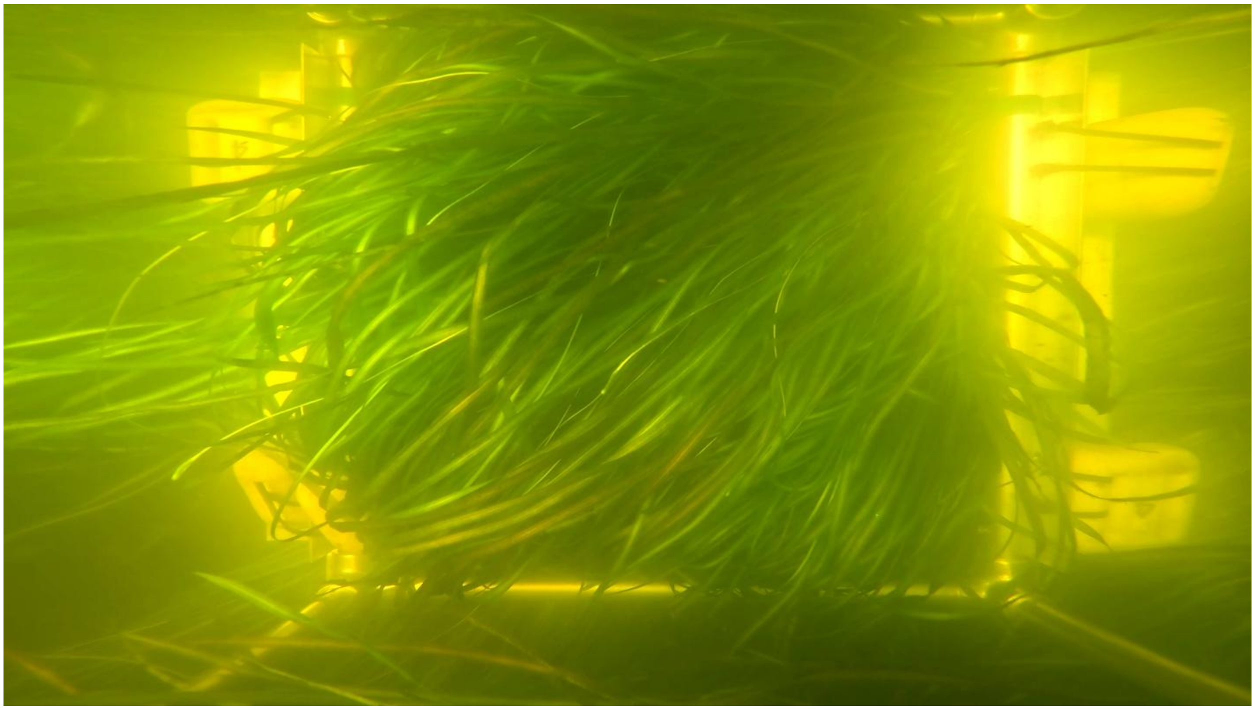


**Figure C-1 Underwater video frame for Station 04L used for benthic substrate classification.**

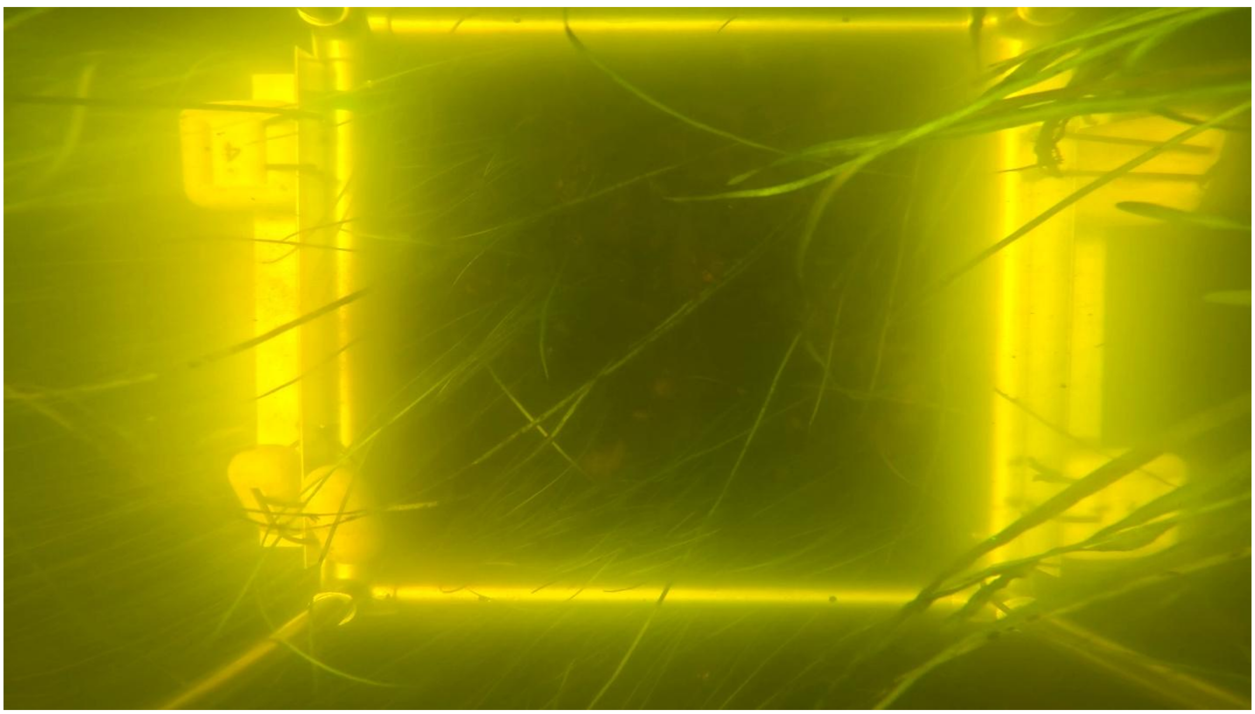


**Figure C-2 Underwater video frame for Station 05C used for benthic substrate classification.**

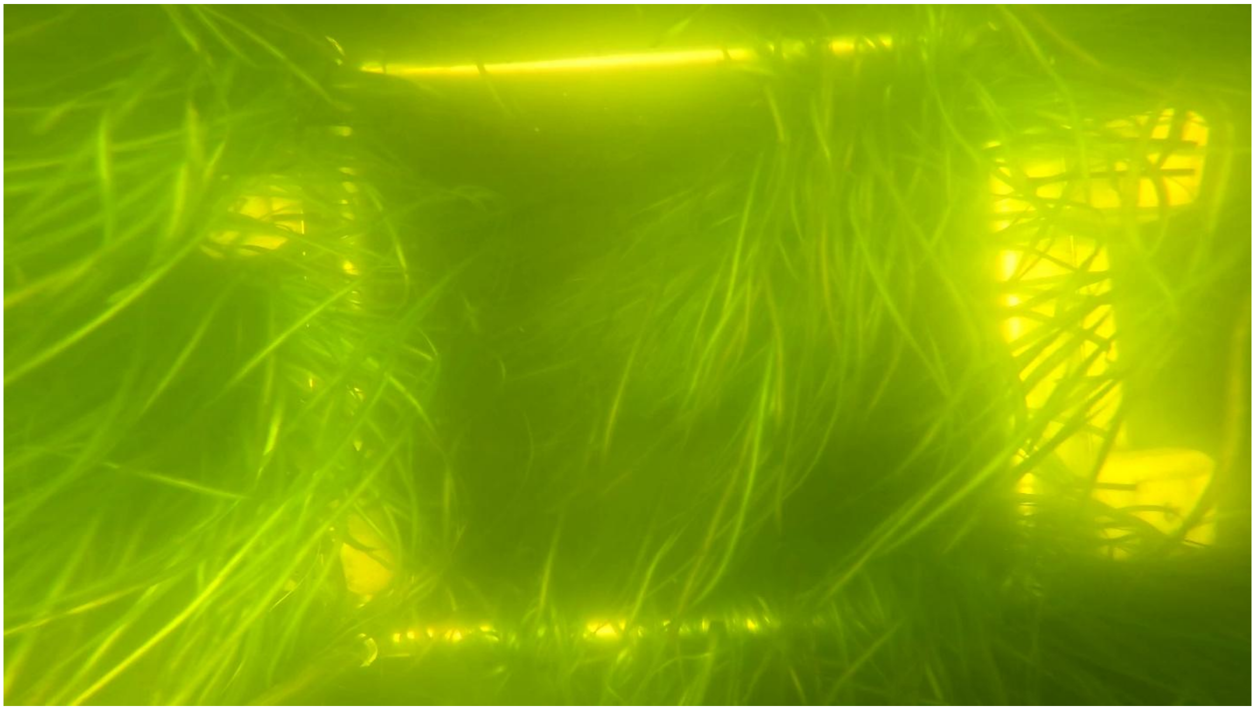


**Figure C-3 Underwater video frame for Station 06R used for benthic substrate classification.**

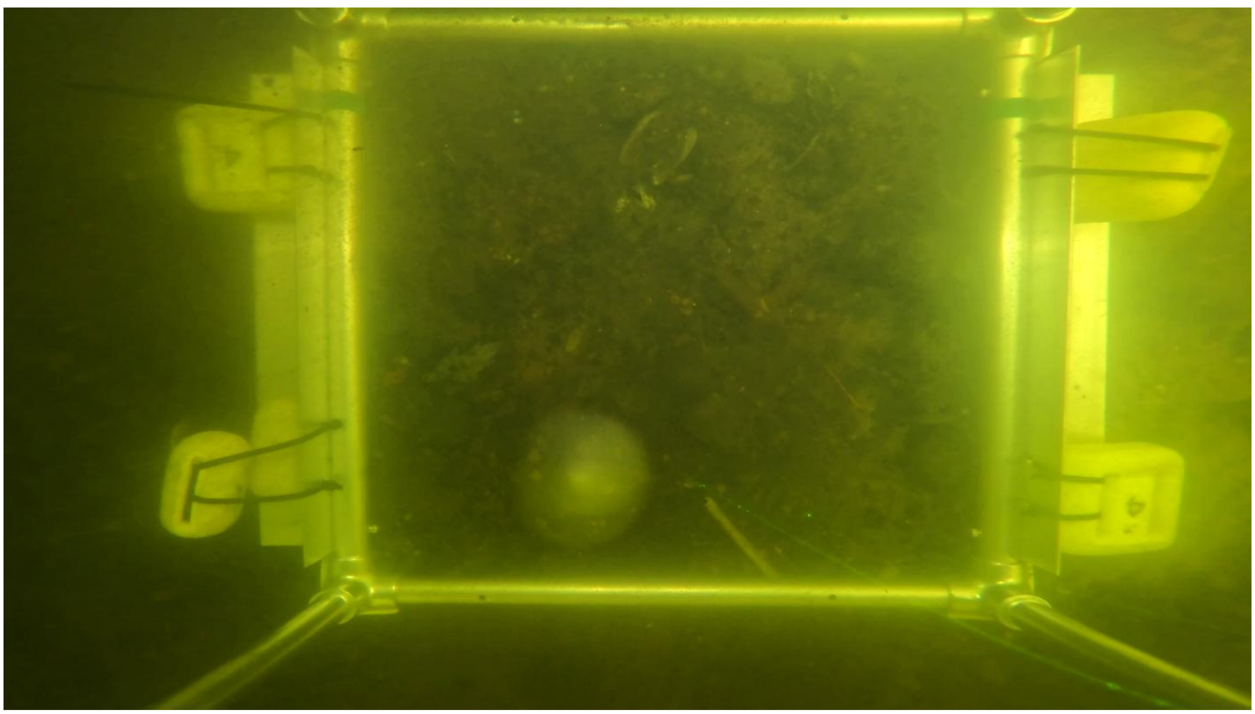


**Figure C-4 Underwater video frame for Station 07L used for benthic substrate classification.**

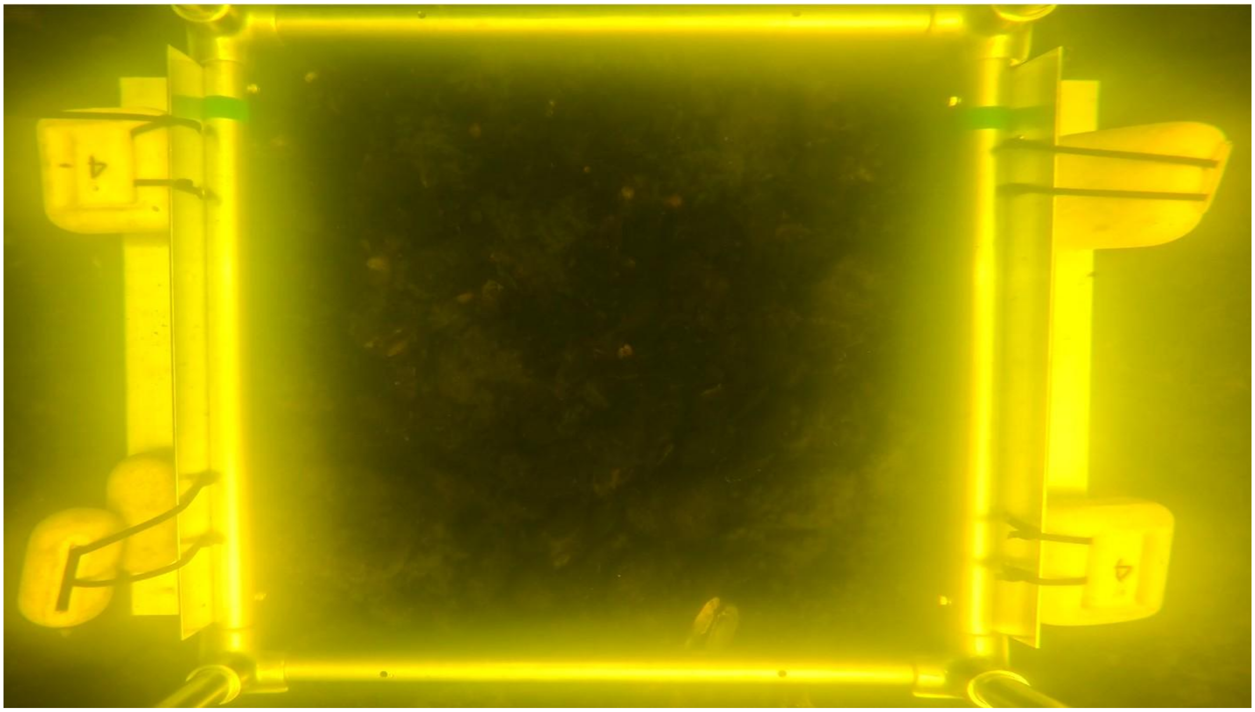


**Figure C-5 Underwater video frame for Station 08C used for benthic substrate classification.**

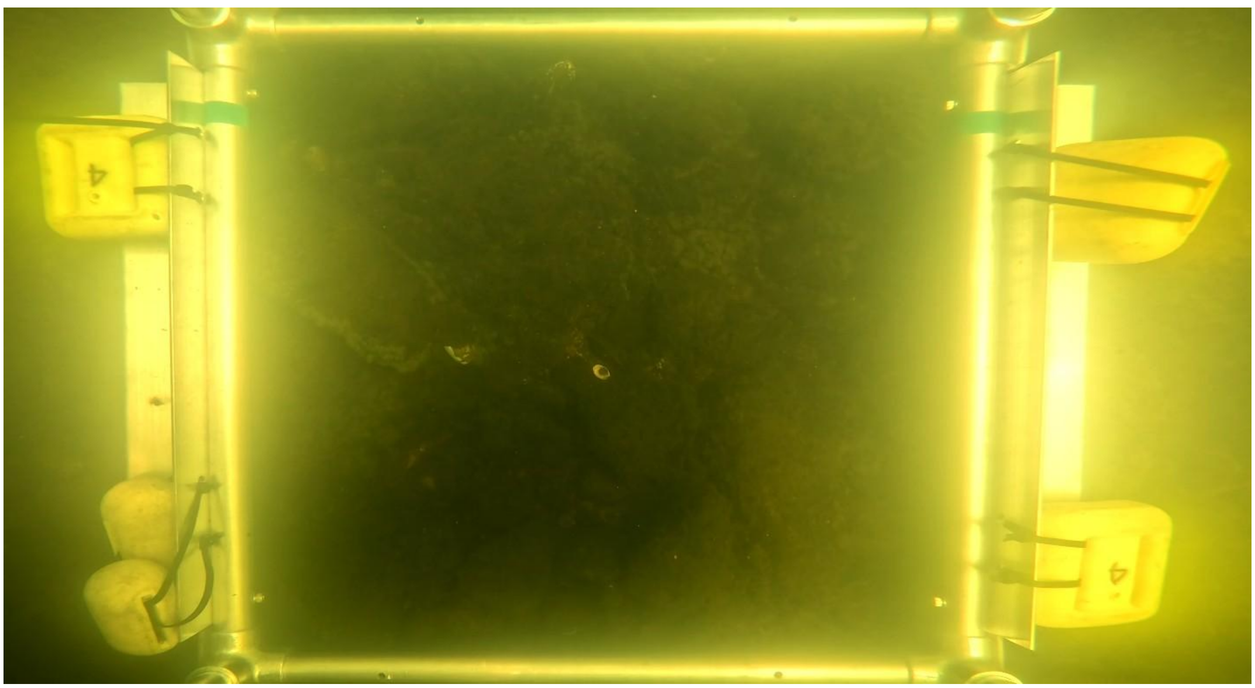


**Figure C-6 Underwater video frame for Station 09R used for benthic substrate classification.**

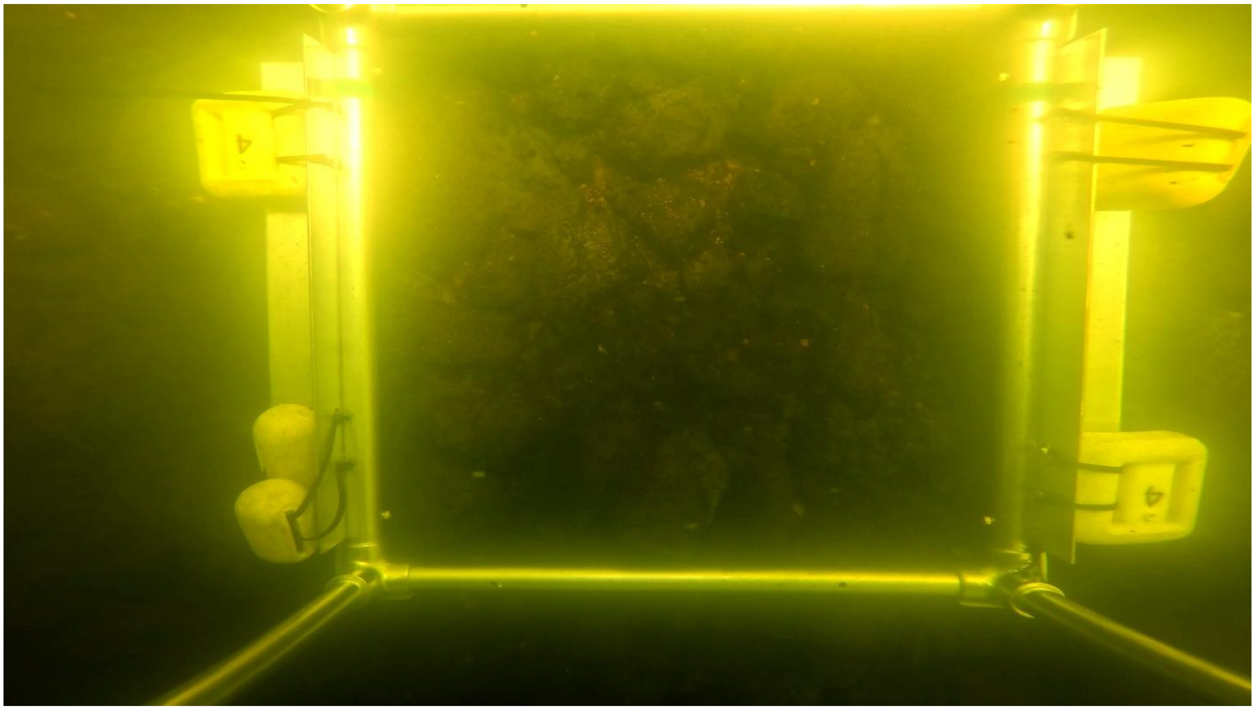


**Figure C-7 Underwater video frame for Station 10L used for benthic substrate classification.**

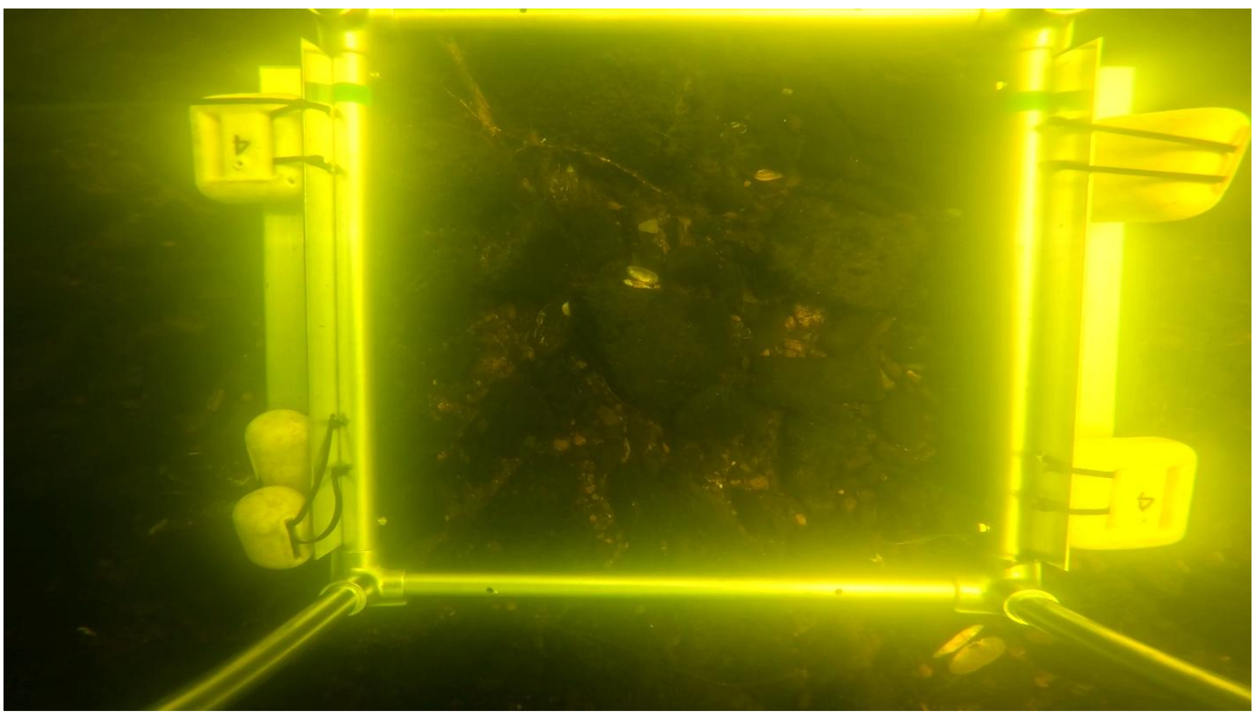


**Figure C-8 Underwater video frame for Station 11C used for benthic substrate classification.**

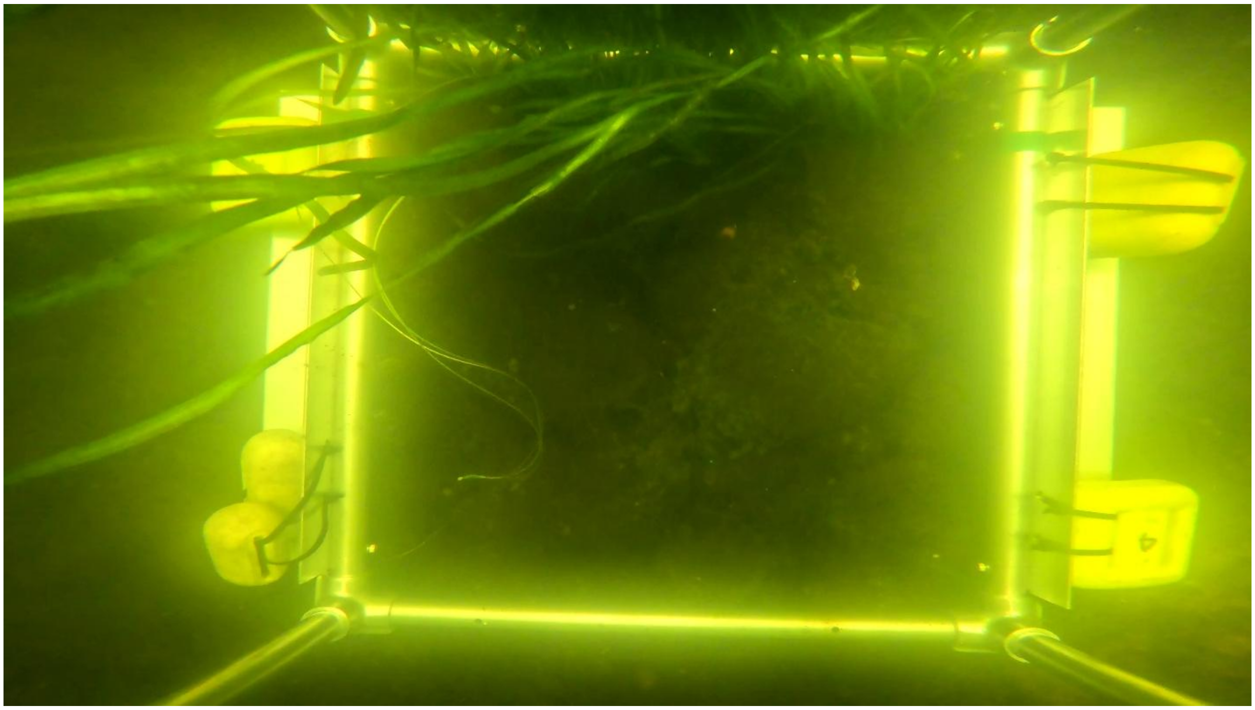


Figure C-9 Underwater video frame for Station 12R used for benthic substrate classification.

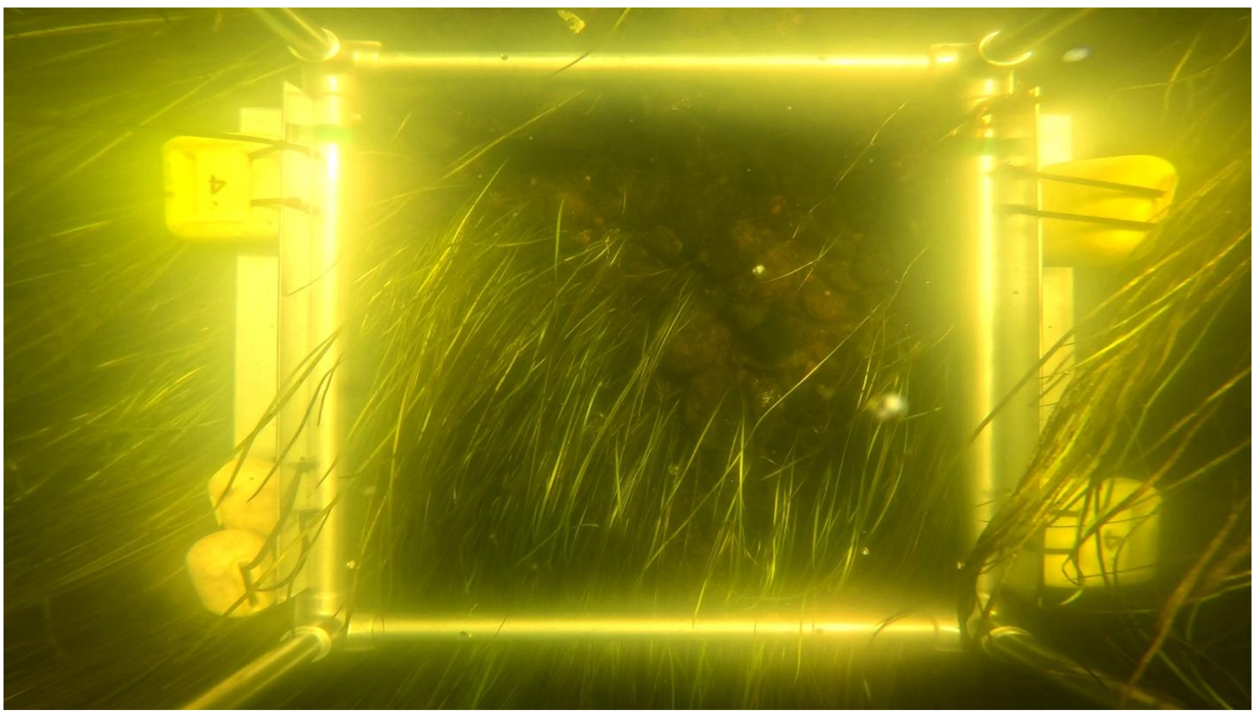


Figure C-10 Underwater video frame for Station 13L used for benthic substrate classification.

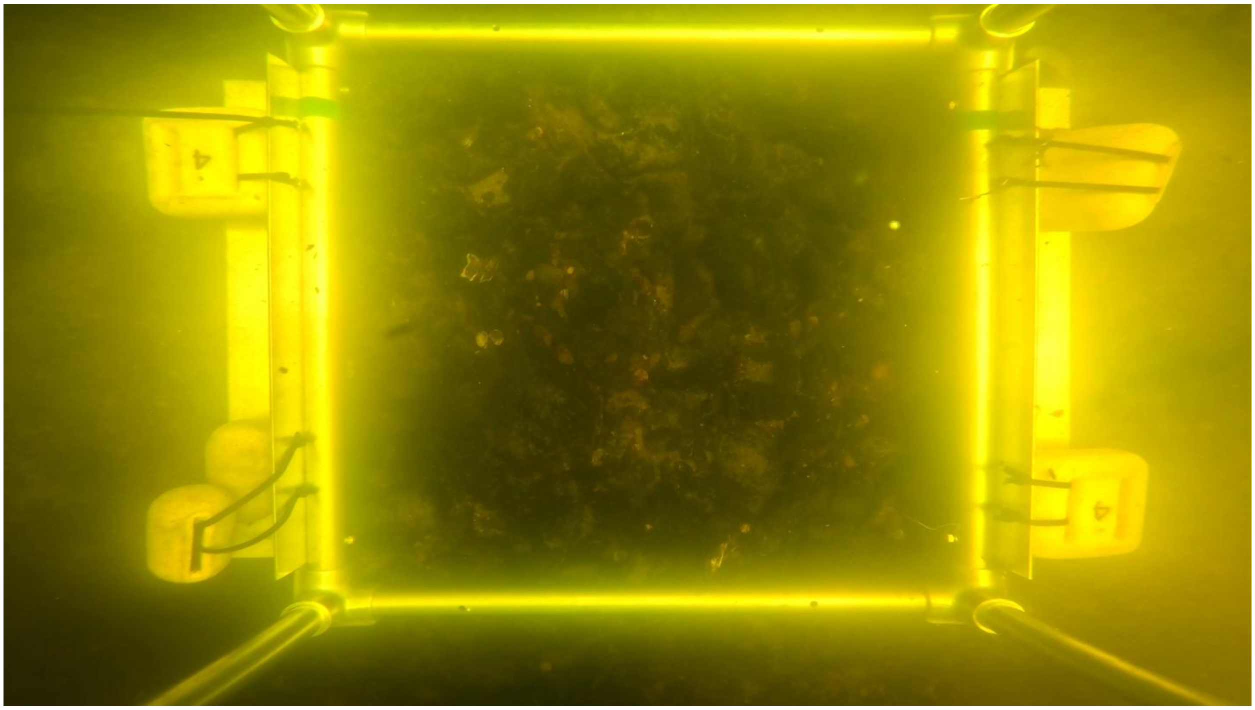



**Figure C-11 Underwater video frame for Station 14C used for benthic substrate classification.**

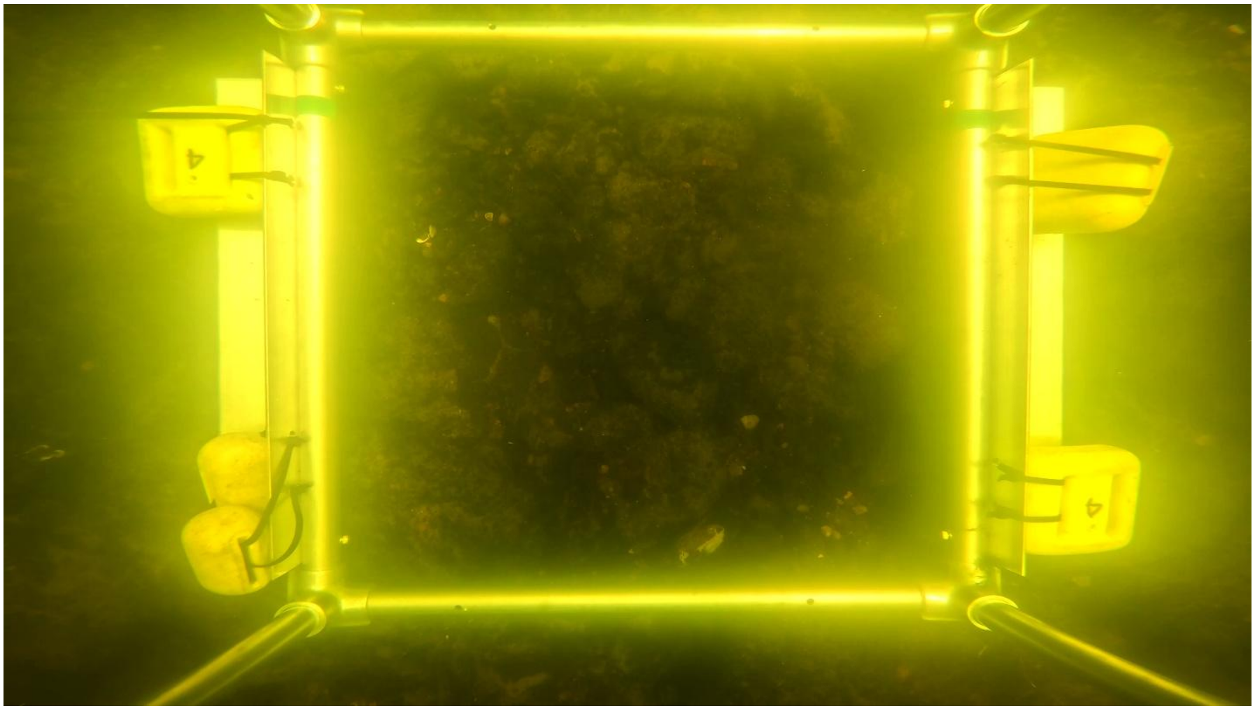



**Figure C-12 Underwater video frame for Station 15R used for benthic substrate classification.**

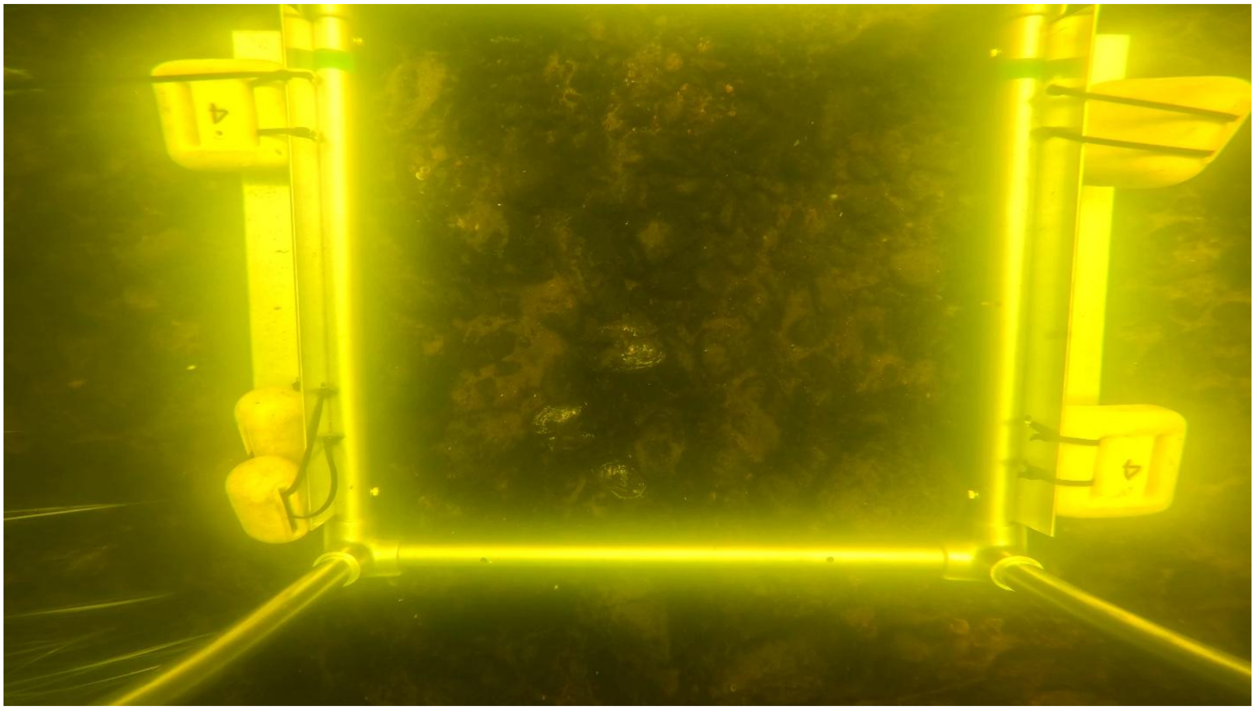


**Figure C-13 Underwater video frame for Station 16L used for benthic substrate classification.**

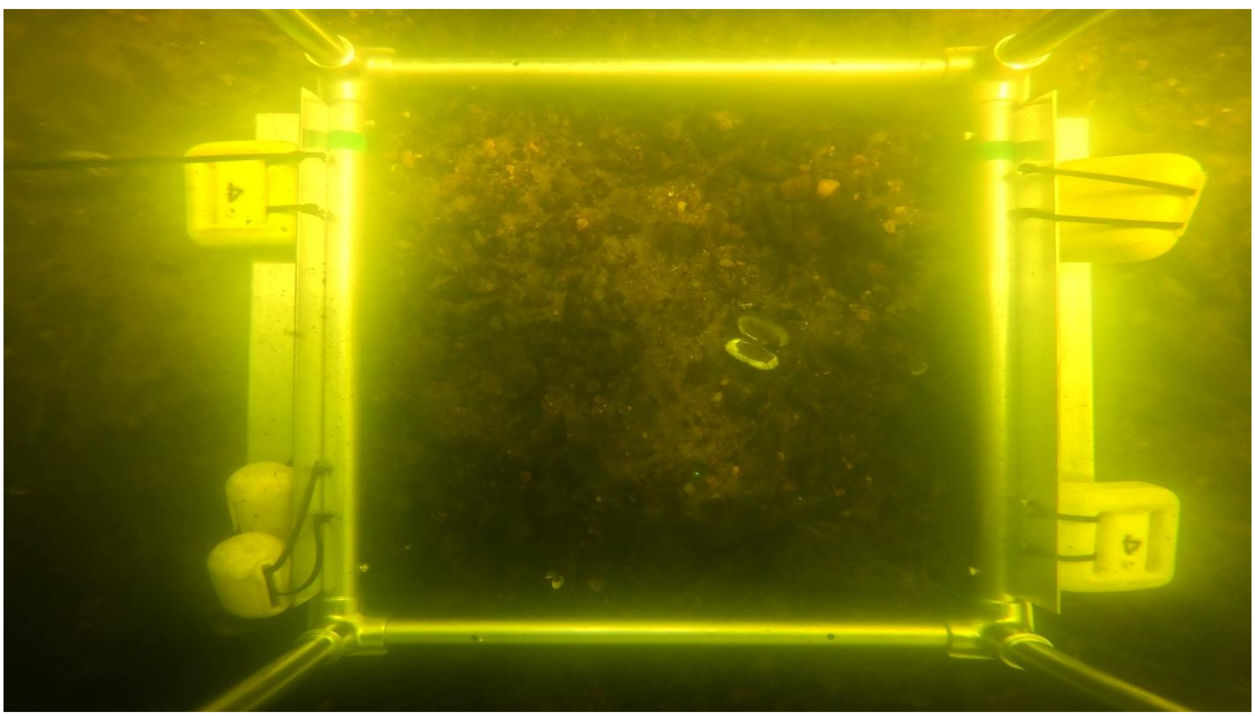


**Figure C-14 Underwater video frame for Station 17C used for benthic substrate classification.**

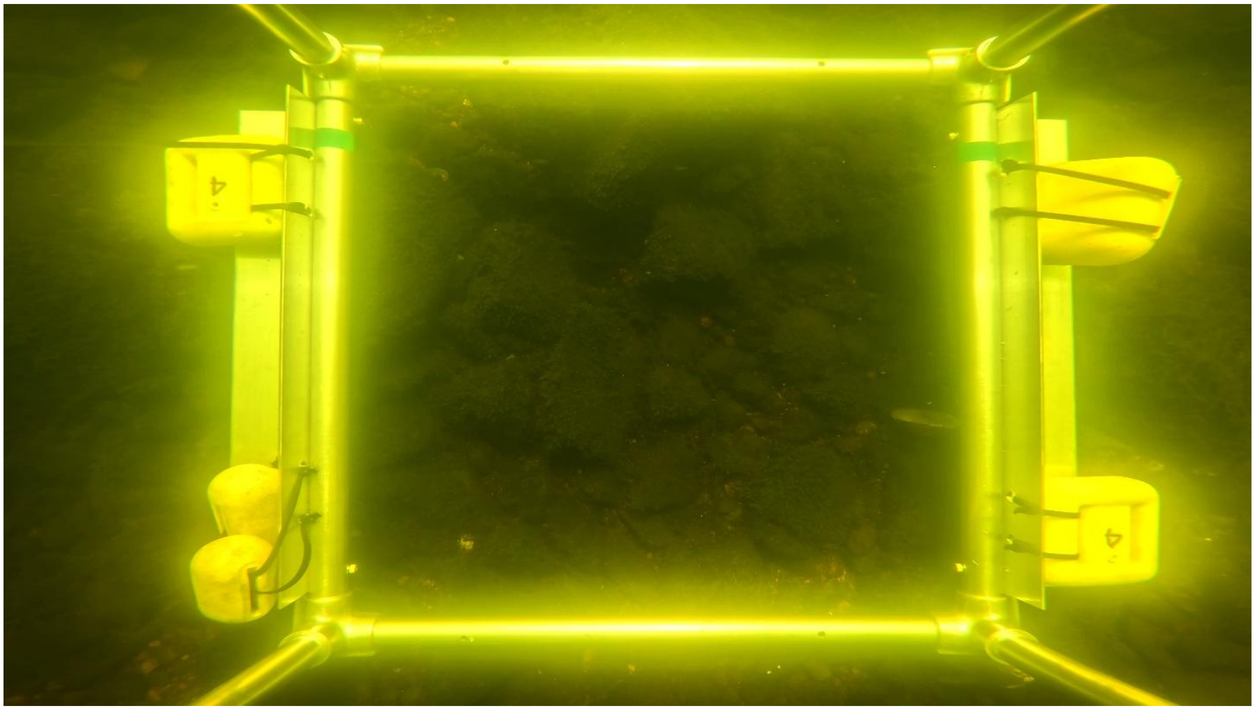


**Figure C-15 Underwater video frame for Station 24R used for benthic substrate classification.**

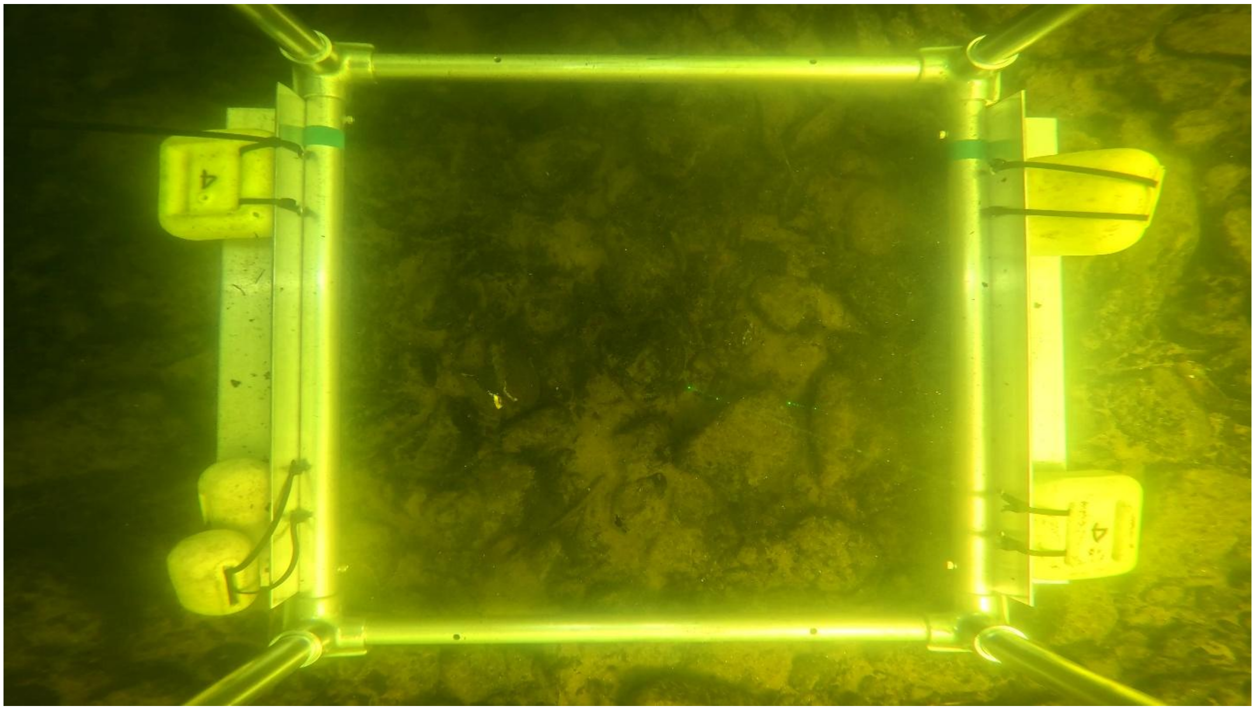


**Figure C-16  Underwater video frame for Station 25L used for benthic substrate classification.**

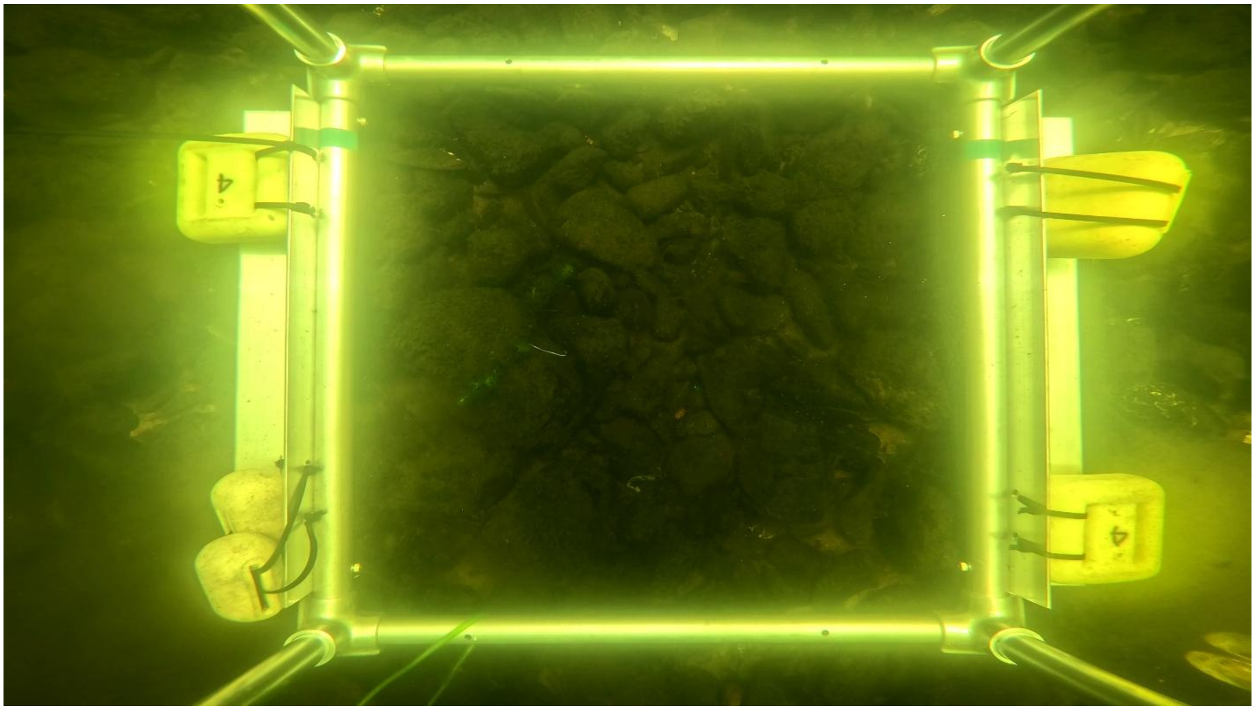


Figure C-17 Underwater video frame for Station 26C used for benthic substrate classification.

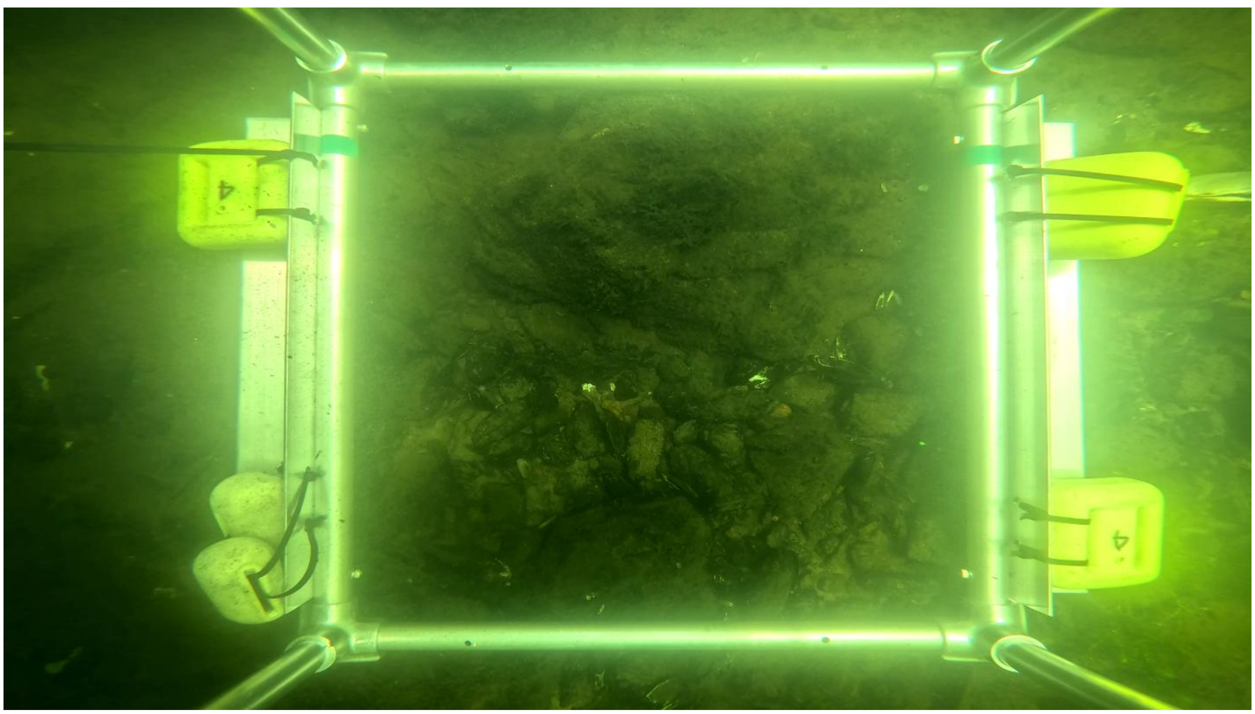


Figure C-18 Underwater video frame for Station 27R used for benthic substrate classification.

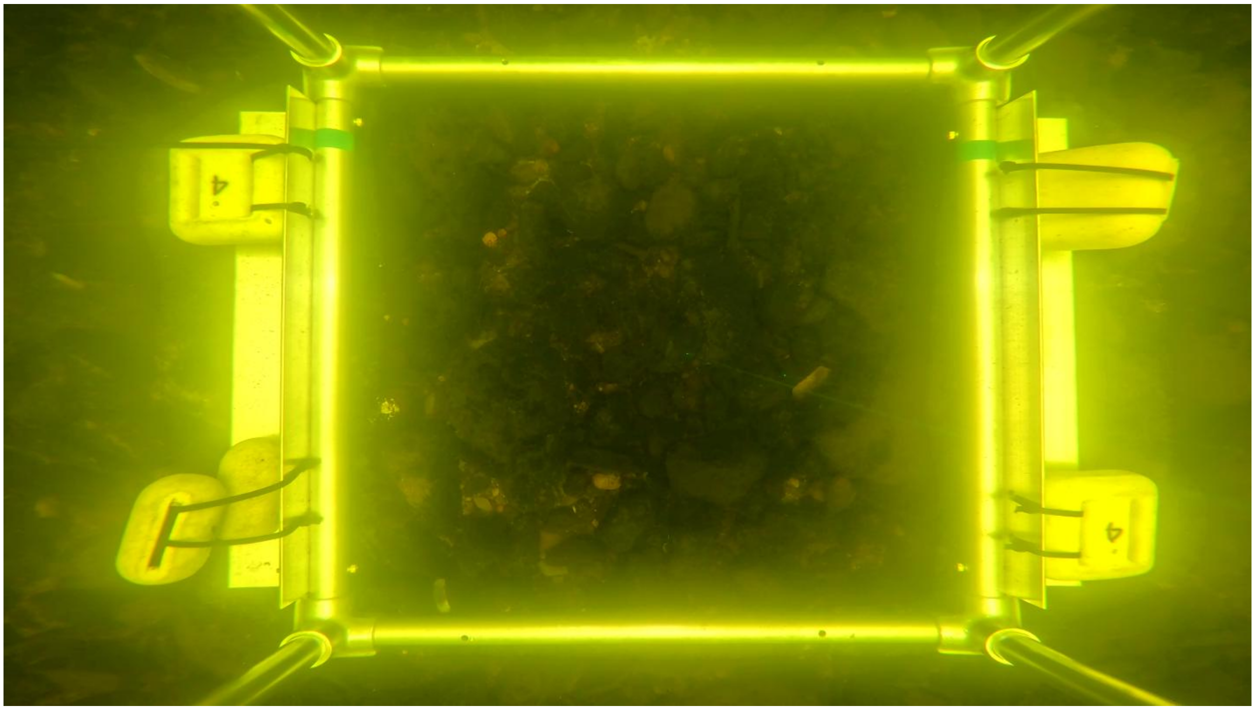


Figure C-19 Underwater video frame for Station 28L used for benthic substrate classification.

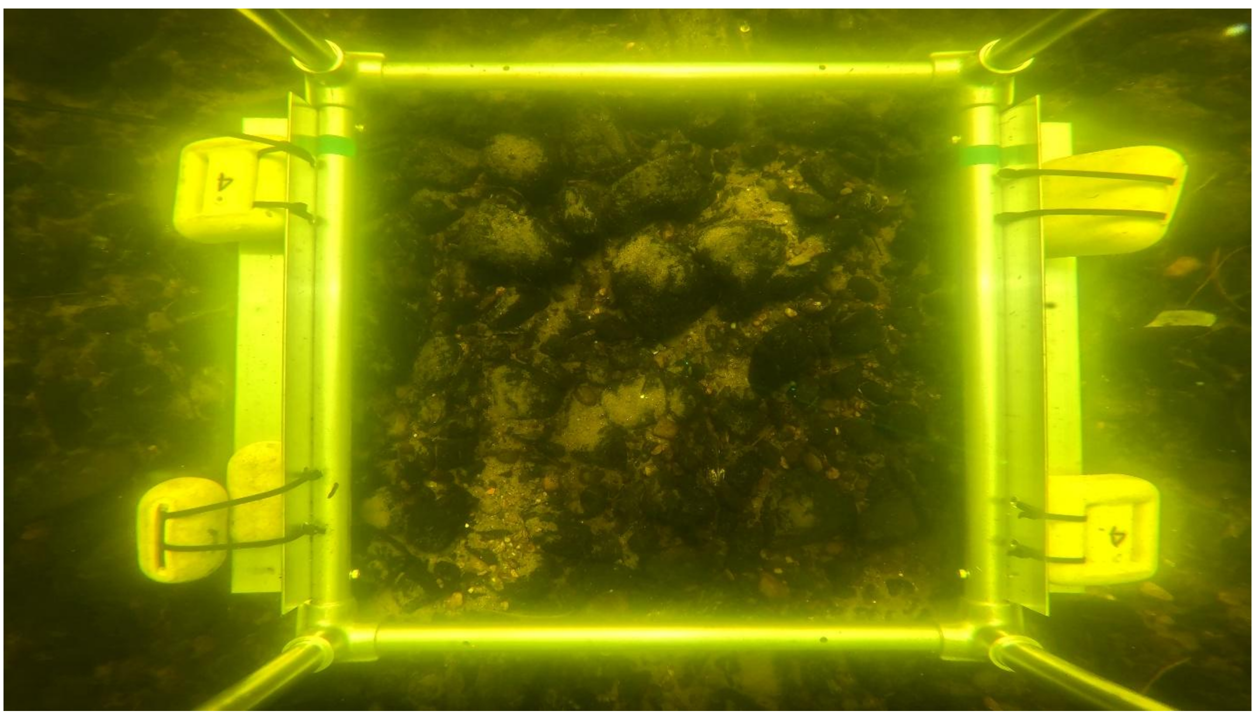


Figure C-20 Underwater video frame for Station 29C used for benthic substrate classification.

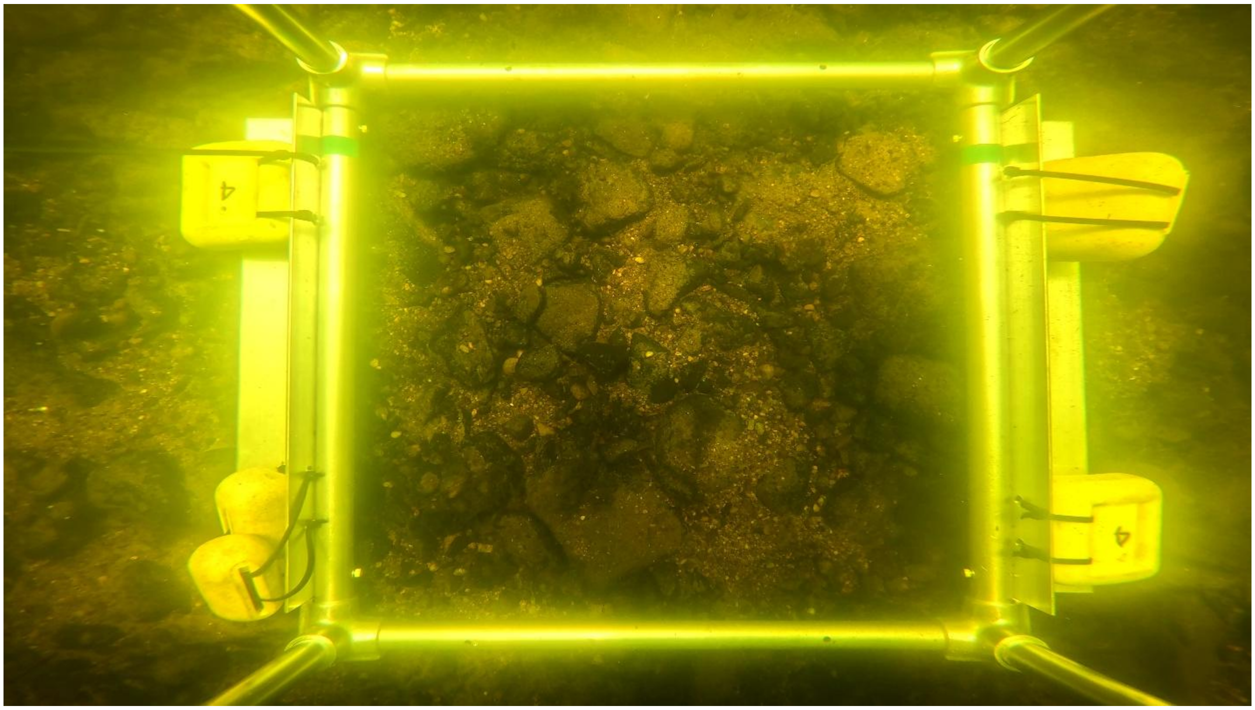


**Figure C-21 Underwater video frame for Station 30R used for benthic substrate classification.**