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QUANTIFICATION OF THE PHYSICAL HABITAT WITHIN GARVINS, HOOKSETT, AND AMOSKEAG POOLS OF THE MERRIMACK RIVER

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Table of Contents

Page

List of Figures

Page

List of Tables

Page

1.0 INTRODUCTION

Public Service of New Hampshire ("PSNH") owns and operates two separate generating units, Unit 1 and Unit 2, known together as Merrimack Station, in Bow, New Hampshire. Merrimack Station is located on the west bank of the Merrimack River adjacent to Hooksett Pool, approximately 2.9 miles upstream from the Hooksett Dam and Hydroelectric Station and about 2.9 miles downstream from the Garvins Falls Dam. Merrimack Station withdraws and discharges once-through cooling water from the Merrimack River subject to and with the benefits of National Pollutant Discharge Elimination System ("NPDES") Permit No. NH001465 (the "Permit"). Unit 1, which became operational in 1960, generates at a rated capacity of 120 MW, and withdraws once-through cooling water from the waters of the Merrimack River using a cooling water intake structure ("CWIS") located in a bulkhead along the shoreline. Unit 2, which became operational in 1968, generates at a rated capacity of 350 MW, and withdraws once-through cooling water from the Merrimack River using a separate CWIS located in a bulkhead approximately 120 feet downstream from the Unit 1 CWIS.

The habitat survey described in this report was performed in 2010 to provide current data regarding the type, quality, quantity, spatial location and extent of the physical habitat in Garvins, Hooksett and Amoskeag Pools of the Merrimack River.

2.0 SOURCE WATER BODY DESCRIPTION

Merrimack Station withdraws non-contact cooling water from, and discharges it back into, a reach of the Merrimack River called Hooksett Pool (Figure 2-1). Garvins Falls Dam forms the upstream boundary of Hooksett Pool while Hooksett Dam forms the lower boundary. Hooksett Pool averages between 6 and 10 feet deep under most flow conditions, and has a surface area of 350 acres and a storage volume of 130 million cubic feet at full pond elevation. Hooksett Dam has two spillway sections; both sections have a crest at elevation 187 feet (USGS Datum), and both are topped with 2-foot flashboards, making the full pool elevation 189 feet (USGS Datum). Headpond elevation in Hooksett Pool is maintained within one foot of the full pond elevation as specified in the FERC operating license for the relevant hydroelectric facility.

Hooksett Dam is one of three hydroelectric facilities in the immediate vicinity of Merrimack Station known collectively as the Merrimack River Hydroelectric Project (FERC No. 1893 - NH) (the "Merrimack Project"). In addition to Hooksett Dam and Garvins Falls Dam, the Amoskeag Dam represents the next downstream impoundment below Hooksett Dam (Figure 2-1). The Hooksett Dam tailwaters discharge into the upper reach of Amoskeag Pool. Merrimack Station is located 2.9 miles downstream from Garvins Falls Dam, 2.9 miles upstream from the Hooksett Dam, and 10.7 miles upstream from Amoskeag Dam. The Merrimack River Project was relicensed by the Federal Energy Regulatory Commission in 2007 and currently operates in a run-of-the-river mode that strives to maintain a constant headpond elevation with an allowable variation.

3.0 METHODOLOGY

Aquatic habitat cover types were mapped within Garvins, Hooksett, and Amoskeag Pools of the Merrimack River (Figure 2-1). The mapped portion of Garvins Pool extended from Garvins Falls Hydroelectric Project on the downstream end to the vicinity of Sewell's Falls on the upstream end, a run-of-river distance of approximately 9.8 miles. Habitat cover types were mapped for the full reach of Hooksett Pool extending from the Hooksett Hydroelectric Project on the downstream end to Garvins Falls on the upstream end, a run-of-river distance of approximately 5.8 miles. Habitat types within the 790 foot bypass-reach located below the Garvins Falls Hydroelectric Project were previously mapped (Normandeau 2003) and those findings are summarized in this report. Habitat cover types were mapped for the full reach of Amoskeag Pool extending from the Amoskeag Hydroelectric Project on the downstream end to Hooksett Hydroelectric on the upstream end, a run-of-river distance of approximately 8.0 miles. Habitat types within the 410 foot bypass-reach located below the Hooksett Hydroelectric Project were previously mapped (Normandeau 2003) and a summary of those findings are included in this report.

3.1 SONAR DATA ACQUISITION

Sonar data was collected from Garvins, Hooksett, and Amoskeag Pools using a Humminbird™ 1197c, side imaging unit. The Humminbird unit was used in conjunction with a Trimble GeoXT™ dGPS to provide the precise coordinate information necessary for geo-referencing captured images with 12-24 inches of accuracy in the horizontal plane. The Humminbird transducer was positioned at the bow of 20-ft flat-bottom work-boat and was attached using a custom mount (Figure 3-1). The operating frequency for the unit was set at 455 kHz for all surveys. Prior to data collection, survey lines within each pool were established in ArcGIS and were laid out in a manner which would provide full coverage of the bottom substrate within each pool during data collection. The number of survey lines needed for a particular reach of river was based on a combination of river width and the transducer's effective range. Data collection along shoreline areas for each pool was conducted by recording using a single side beam set at a range of 90 to 100 ft (Figure 3-2). Data collection along survey lines within the central portions of the three pools were conducted with the side beam range set at 100 to 140 ft per side (Figure 3-3). Collected data images were allowed to overlap to ensure full coverage of the bottom habitat. Boat speed was maintained at 3-5 mph during all data collection.

A small portion of the total acreage of the three Merrimack River pools could not be surveyed using side scan sonar due to shallow water depths or thick growth of aquatic vegetation. These areas comprised less than one acre for the three pools combined and habitat types were either confirmed through assessment in the field or verification from existing high definition aerial photography. In shallow areas where water clarity allowed for inspection of the habitat, field assessments were conducted visually. In other areas where visibility was impaired, it became necessary to wade onto the substrate to assign a habitat type.

3.2 SONAR DATA PROCESSING

Sonar image data was processed by placing each individual sonar image into the area that it represents on a map, interpreting their content and finally, creating polygons representing each unique habitat area. Sonar images were georectified using a combination of ArcGIS (version 9.3), IrfanView graphic editor and scripted software tools developed at the Georgia Department of Natural Resources (Kaeser and Litts 2010).

Sonar images were post-processed by cropping to remove display information, then cropped again based on overlap with previous and next images along the boat's path. Accurate waypoint and track data were imported into ArcGIS 9.3 and were cropped to reflect the areas where valid data was obtained. The positional information is used to reference the sonar imagery to its place on the river bottom. The positional information and the distance from the center of the boat that was observed was entered into one of the scripted sidescan processing tools to create a network of points for each image. This resulted in a text file for each habitat survey image containing points used to rectify each image to their corresponding location on the ground. The text files and images were then merged into mosaic groups of 10-15 images. The SPLINE transformation solution (Powell 1995) was applied to these mosaics so that they fit with the points assigned to the images along the curve of the tracks. Each group of georectified images became a 2-4 inch resolution GIS layer file in JPEG format with an associated world file that contains information used to project the image onto a map. The resulting layer files were subjected to visual quality control inspection for positional accuracy and image quality. A total of 290 of these layer files were created to map the three impoundments.

Lines were drawn as borders between the habitat types as observed from scales ranging from 1:300 to 1:427 (Figure 3-4). Borders were interpreted by observing changes in surface texture, signal amplitude, and habitat indicator patterns (e.g. sand waves). Slant range correction was not performed on sonar imagery to correct distortion. The dark area in the center of a side scan image represents the water column, this total area has a direct relationship with the depth. Distortion occurs near the beams interface with the bottom as the image is compressed to represent the area near the boat path and the water column in the same space. Therefore in deeper areas (>10 ft), it became necessary to interpret substrates that appear just outside the water column as if they extended under the boat's position. Border lines were converted into polygons and habitat types were assigned to each created polygon unit. Natural rocky substrate sizes were classified using a modified Wentworth scale (Wentworth 1922) shown in Table 3-1. The final product produced from this process was a GIS layer containing the aquatic habitat types for each of the three pools. Figure 3-5 provides an example screenshot of the polygon creation process and the corresponding GIS habitat layer.

A total of six substrate types were identified at the resolution of 2-4 inches in imagery from the Humminbird unit; sand/silt/clay, gravel/cobble, boulder, rip-rap, ledge, and woody debris. Figures 3-6 through 3-11 provide examples for the six habitat types classified from the sonar imagery. The habitat types were delimited with a predetermined precision of ±100 sq ft (0.0023 acres). However, in most cases habitats smaller than this area or habitat borders were discernable at a greater resolution and were mapped at a higher precision. The total area (acres) for the six habitat types found in each of the three surveyed pools was quantified. Areas of aquatic vegetation were identified separately as an individual vegetation bed can occur over more than one substrate type. An example of submerged aquatic vegetation as identified by sonar imagery can be found in Figure 3-12.

Sonar classifications of all habitat types were verified while in the field. Validations consisted of visual assessment within shallow water habitats and/or clear water conditions as well as pole and ponar grab samples for deeper water areas.

3.3 BYPASS REACH DATA ACQUISITION AND PROCESSING

Habitat within the Garvins Falls and Hooksett Hydroelectric bypass reaches (the extreme upstream end of Hooksett (Figure 4-2) and Amoskeag (Figure 4-3) Pools, respectively, was mapped during October, 2002 as part of environmental studies conducted for the PSNH FERC Licence (No. 1893) renewal (Normandeau 2003). A total of 4.18 acres along 790 ft. of Garvins Falls bypass reach and 2.09 acres along 410 ft. of the Hooksett bypass reach were mapped at that time. At both bypass reaches, boundaries surrounding specific areas containing similar habitat characteristics were identified. Points along each habitat boundary were recorded using a global positioning system (GPS). For each habitat type, the dominant substrate was described as boulder, bedrock, or cobble.

Latitude and longitude measurements were plotted on a digitized aerial photograph of each bypass reach. Polygons were drawn around each identified habitat type based on these points, and the surface area of each polygon was calculated based on the scale of the aerial photograph.

The polygons created for habitat types within the Garvins Falls and Hooksett bypass reaches during 2003 had similar and concurrent habitat classifications and were incorporated into the same polygon set created for the 2010 sonar data. The boulder habitat class was the same for both studies, the cobble class from 2003 was classified as gravel/cobble for the side scan study, and the bedrock class from 2003 was classified as ledge. Bypass reach data and side scan data were both at the same resolution and scale. The bypass reach data is very accurate because it is based on direct observation.

4.0 RESULTS

Side scan field surveys were conducted between the dates of 24 September through 25 October 2010 within Garvins Pool, 16 September through 25 October 2010 within Hooksett Pool and 22 September through 2 November 2010 within Amoskeag Pool. Merrimack River flow conditions (as measured at Goff’s Falls USGS Gauge Station) ranged from 571 to 13,200 cfs for the survey period. Field surveys were conducted during non-spill conditions (as determined at the upstream hydroelectric project), when flows ranged from 649 to 4,970 cfs (Table 4-7). Survey times were chosen to minimize signal loss and bias due to interference created by high flow events. The run-of-river operation assured that the headpond elevation will not fluctuate in any significant way that would affect the results of this survey. The Merrimack River project was maintained at a prescribed headpond level with an allowable variation. From the beginning of the survey effort until 5 October 2010 this variation was set at ±1.5 inches, thereafter it was increased to ±3 inches through the end of the study. The elevation of the headponds during the surveys ranged from 222.88-223.18 ft for Garvins, 191.30-191.60 ft for Hooksett and 181.04-181-14 ft for Amoskeag (Table 4-7).

4.1 GARVINS POOL

Within Garvins Pool, 563.9 acres of total aquatic habitat was mapped during the survey performed from 24 September through 25 October 2010 (Table 4-1, Figure 4-1). The majority (472.8 acres; 83.8%) of the mapped area consisted of the sand/silt/clay habitat type. Boulder (61.6 acres; 10.9%), gravel/cobble (5.4 acres; 1.0%), ledge (0.5 acres; 0.1%) and woody debris (16.6 acres; 2.9%) were also present in lesser amounts (Table 4-1, Figure 4-1). Artificially created rip-rap habitat comprised a total of 7.0 acres (1.2% of total habitat) within Garvins Pool. A total of 36.8 acres of submerged aquatic vegetation (SAV) was also identified within Garvins Pool, covering 6.5% of the total habitat. The majority (34.7 acres; 94.3 %) of SAV was observed to occur over portions of Garvins Pool characterized by the sand/silt/clay habitat type (Table 4-2).

4.2 HOOKSETT POOL

A total of 423.5 acres of habitat was mapped within Hooksett Pool during the survey performed from 16 September through 25 October 2010, and the majority (382.1 acres; 90.2%) of the mapped area consisted of the sand/silt/clay habitat type (Table 4-3; Figure 4-2). Boulder (22.0 acres; 5.2%), gravel/cobble (4.2 acres; 1.0%), ledge (1.9 acres; 0.4%), and woody debris (11.3 acres; 2.7%) were also present. Artificially created rip-rap habitat comprised a total of 2.0 acres (0.5% of total habitat) within Hooksett Pool, and was found along the shoreline, particularly on the western shore near Merrimack Station (Table 4-3; Figure 4-2). Within Hooksett Pool, a total of 21.3 acres of SAV was also identified, covering 5.0% of the total habitat (Table 4-4; Figure 4-2). The majority (17.2 acres; 80.8 %) of the SAV was observed to occur over portions of Hooksett Pool characterized by the sand/silt/clay habitat type (Table 4-4; Figure 4-2).

4.3 AMOSKEAG POOL

A total of 520.6 acres of habitat was mapped within Amoskeag Pool during the survey performed from 22 September through 2 November 2010 (Table 4-5; Figure 4-3). The majority (424.4 acres; 81.5%) of the mapped area consisted of the sand/silt/clay habitat type. Boulder (68.5 acres; 13.1%), gravel/cobble (13.6 acres; 2.6%), ledge (3.1 acres; 0.6%) and woody debris (8.8 acres; 1.7%) were also present. Artificially created rip-rap habitat was limited to littoral shoreline areas and comprised a total of 2.2 acres (0.4% of total habitat) within Amoskeag Pool (Table 4-5; Figure 4-3). An additional total of 17.2 acres of SAV was also identified within Amoskeag Pool, covering 3.3% of the total habitat (Table 4-6; Figure 4-3). The majority (83.6 %) of the SAV was observed to occur over portions of Amoskeag Pool characterized by the sand/silt/clay habitat type (Table 4-6; Figure 4-3).

5.0 SUMMARY

No unique or rare habitat was observed within Garvins Pool, Hooksett Pool, or Amoskeag Pool from the information gained by the habitat survey conducted during the fall of 2010 using side scan sonar. Water depths varied by station with the deepest water typically found along the eastern bank of each pool. The resulting product from these surveys was a GIS layer containing six aquatic substrate types and the SAV distribution observed in each of the three pools. The field and processing methods used during the Merrimack River survey were based on those described by Kaeser and Litts (2010). They found that their habitat surveys with similar classifications had a habitat area accuracy of 92%. It was determined that much of the habitat area accuracy depends on the accuracy of the waypoints used to reference the images to the ground. The Merrimack River survey used highly accurate dGPS equipment in an area with less canopy interference. This resulted in more accurate positional information with a least stated accuracy of 24 inches, compared to the 197 inch least stated accuracy of the original method. Kaeser and Litts (2010) also demonstrated that sonar mapping provides estimates of substrate area similar to those generated by the traditional field approach while quantifying 90% more habitat without interpolation of data between transects.

The sand/silt/clay habitat type was the most abundant habitat observed within each of the three Merrimack River pools, comprising 81.5% in Amoskeag, 83.8% in Garvins and 90.2% in Hooksett. Higher quality aquatic habitat types such as gravel/cobble, boulder, rip-rap and woody debris comprised a larger percent of the total acreage of Garvins (16.1%) and Amoskeag (17.9%) than was observed in Hooksett Pool (9.3%). Total acreage of submerged aquatic vegetation mapped during sonar surveys represented a lower percent of the total acreage in Amoskeag than was observed for Garvins or Hooksett Pools.

6.0 REFERENCES

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TABLES

Table 3-1. The Wentworth scale (Wentworth 1922) of substrate particle sizes modified for use with side scan sonar.

Millimeters		µm	Phi (ϕ)	Wentworth size class		Side scan size class
			-20	Boulder (-8 to -12ϕ)		Boulder
	4096		-12			
	1024		-10			
	256		-8			
	64		-6	Pebble (-6 to -8ϕ)	Gravel	Gravel/Cobble
	16		-4	Pebble (-2 to -6ϕ)		
	4		-2			
	3.36		-1.75			
	2.83		-1.50	Gravel		
	2.38		-1.25			
	2.00		-1.00			
	1.68		-0.75		Sand	Sand/Silt/Clay
	1.41		-0.50	Very coarse sand		
	1.19		-0.25			
	1.00		-0.00			
	0.84		0.25			
	0.71		0.50	Coarse sand		
	0.59		0.75			
1/2	0.50	500	1.00			
	0.42	420	1.25			
	0.35	350	1.50	Medium sand		
	0.30	300	1.75			
1/4	0.25	250	2.00			
	0.210	210	2.25			
	0.177	177	2.50	Fine sand		
	0.149	149	2.75			
1/8	0.125	125	3.00			
	0.105	105	3.25			
	0.088	88	3.50	Very fine sand		
	0.074	74	3.75			
1/16	0.0625	63	4.00			
	0.0530	53	4.25			
	0.0440	44	4.50	Coarse silt		
	0.0370	37	4.75			
1/32	0.0310	31	5	Medium silt	Mud	
1/64	0.0156	15.6	6	Fine silt		
1/128	0.0078	7.8	7	Very fine silt		
1/256	0.0039	3.9	8			
	0.0020	2.0	9			
	0.00098	0.98	10			
	0.00049	0.49	11	Clay		
	0.00024	0.24	12			
	0.00012	0.12	13			
	0.00006	0.06	14			

Table 4-1. Total area (acres) and percent of total area for six habitat types mapped using sonar imagery within Garvins Pool during 24 September through 25 October 2010.

Habitat Type	Area (acres)	% of Total
sand/silt/clay	472.8	83.8%
gravel/cobble	5.4	1.0%
boulder	61.6	10.9%
rip-rap	7.0	1.2%
ledge	0.5	0.1%
woody debris	16.6	2.9%
TOTAL	**563.9**	**100.0%**

Table 4-2. Total area (acres) and percent of total area for habitat types covered by submerged aquatic vegetation (SAV) and mapped using sonar imagery within Garvins Pool during 24 September through 25 October 2010.

Habitat Type	SAV Area (acres)	% of Total
sand/silt/clay	34.7	94.3%
gravel/cobble	0.6	1.6%
boulder	0.8	2.2%
woody debris	0.7	1.9%
TOTAL	**36.8**	**100.0%**

Table 4-3. Total area (acres) and percent of total area for six habitat types mapped using sonar imagery within Hooksett Pool during 16 September through 25 October 2010.

Habitat Type	Area (acres)	% of Total
sand/silt/clay	382.1	90.2%
gravel/cobble	4.2	1.0%
boulder	22.0	5.2%
rip-rap	2.0	0.5%
ledge	1.9	0.4%
woody debris	11.3	2.7%
TOTAL	**423.5**	**100.0%**

Table 4-4. Total area (acres) and percent of total area for habitat types covered by submerged aquatic vegetation (SAV) and mapped using sonar imagery within Hooksett Pool during 16 September through 25 October 2010.

Habitat Type	SAV Area (acres)	% of Total
sand/silt/clay	17.2	80.8%
gravel/cobble	1.6	7.5%
boulder	0.7	3.3%
woody debris	1.8	8.5%
TOTAL	**21.3**	**100.0%**

Table 4-5. Total area (acres) and percent of total area for six habitat types mapped using sonar imagery within Amoskeag Pool during 22 September through 2 November 2010.

Habitat Type	Area (acres)	% of Total
sand/silt/clay	424.4	81.5%
gravel/cobble	13.6	2.6%
boulder	68.5	13.1%
rip-rap	2.2	0.4%
ledge	3.1	0.6%
woody debris	8.8	1.7%
TOTAL	**520.6**	**100.0%**

Table 4-6. Total area (acres) and percent of total area for habitat types covered by submerged aquatic vegetation (SAV) and mapped using sonar imagery within Amoskeag Pool during 22 September through 2 November 2010.

Habitat Type	SAV Area (acres)	% of Total
sand/silt/clay	14.3	83.6%
gravel/cobble	0.4	2.3%
boulder	2.0	11.7%
rip-rap	0.1	0.6%
woody debris	0.3	1.8%
TOTAL	**17.1**	**100.0%**

Table 4-7. Discharge in cubic feet per second (cfs) observed on the Merrimack River (as measured at Goff's Falls USGS Gauge Station) during the time of the surveys.

Garvins Pool			Hooksett Pool			Amoskeag Pool		
Survey Date	Discharge (cfs)	Pool Elevation (ft)	Survey Date	Discharge (cfs)	Pool Elevation (ft)	Survey Date	Discharge (cfs)	Pool Elevation (ft)
09/24/10	919	223.18	**09/16/10**	649	191.60	**09/22/10**	969	181.04
10/20/10	4,970	222.88	**10/12/10**	1,890	191.30	**10/26/10**	2,800	181.14
10/25/10	2,730	222.96	**10/25/10**	2,730	191.53	**11/02/10**	3,060	181.11

FIGURES

Figure 2-1. Garvins, Hooksett, and Amoskeag Pools of the Merrimack River surveyed during 16 September through 2 November 2010.

Figure 3-1. Side scan sonar configuration used for Merrimack River surveys during 16 September through 2 November 2010.

Figure 3-2. Example of sonar imagery acquired along shoreline habitat using a single side beam for the habitat survey of the Merrimack River, 16 September through 2 November 2010. This technique resulted in imagery with 2 inches of accuracy.

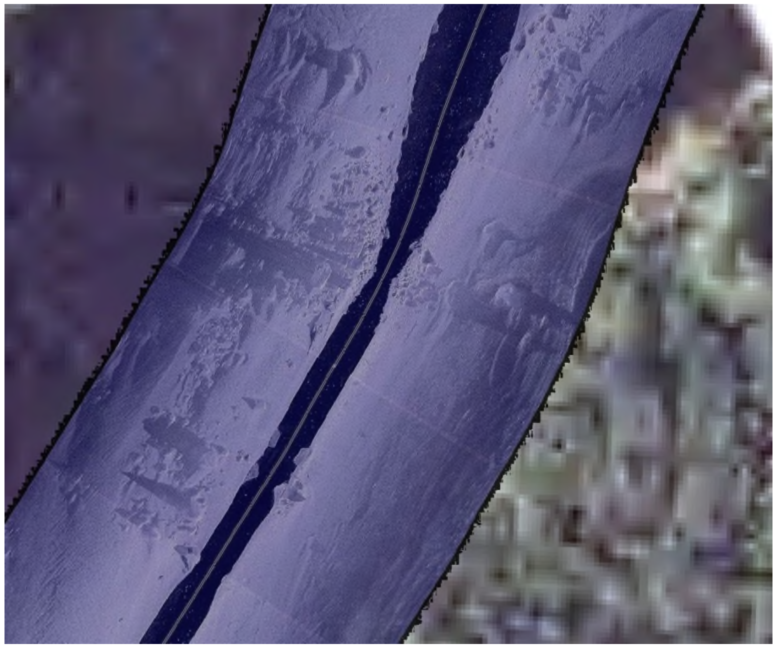

Figure 3-3. Example of sonar imagery acquired along mid-pool habitat using a beam set to record on each side during the habitat survey of the Merrimack River, 16 September through 2 November 2010.

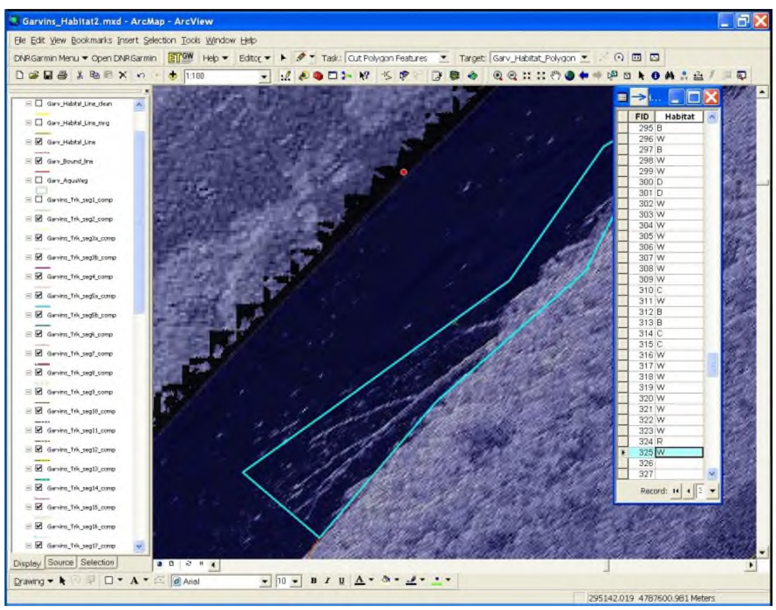

Figure 3-4. Example screenshot showing the creation of polygon units as borders around unique habitat types for the habitat survey of the Merrimack River, 16 September through 2 November 2010.

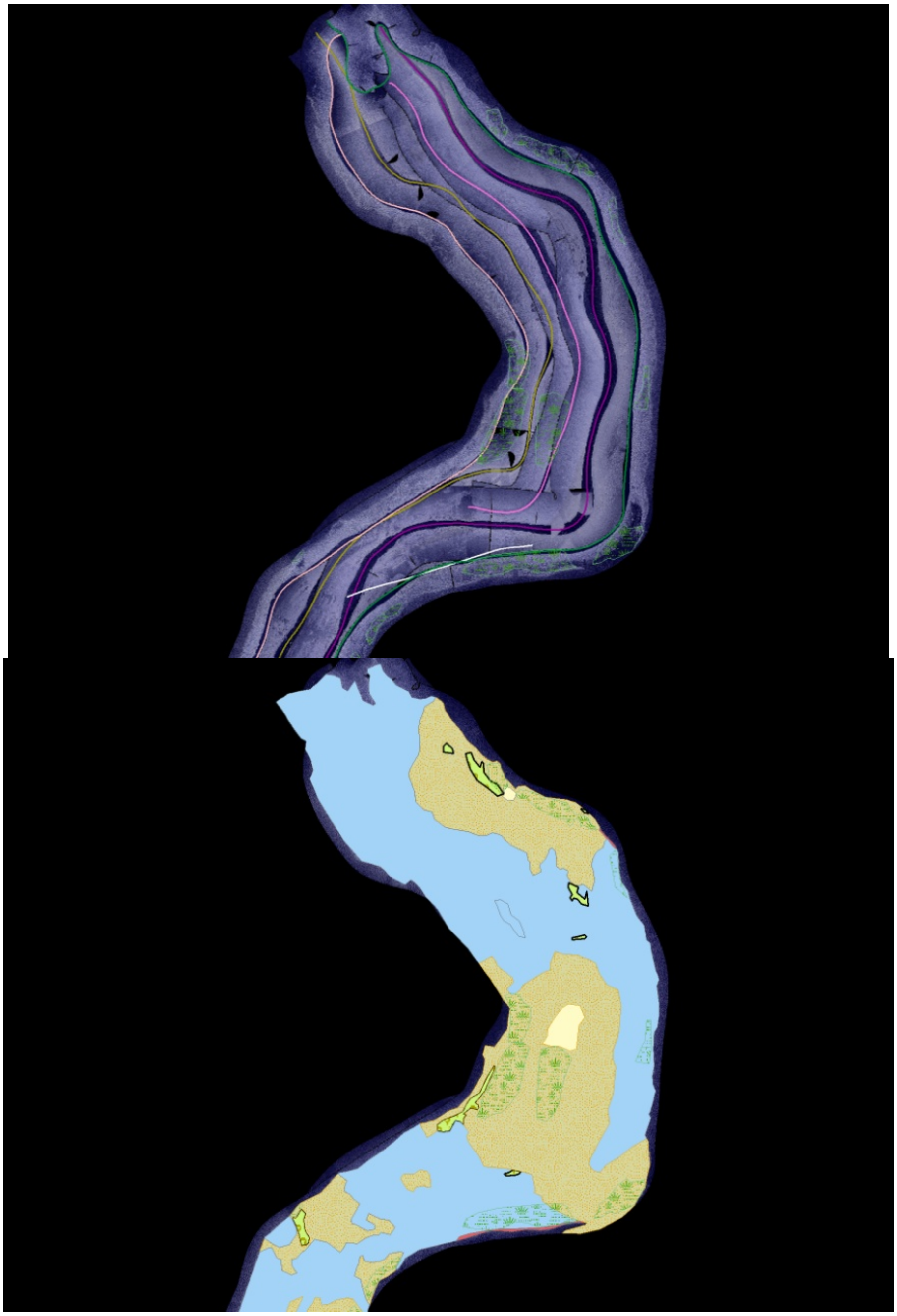

Figure 3-5. Example screenshot showing the polygon creation process as well as the corresponding final GIS habitat layer for the habitat survey of the Merrimack River, 16 September through 2 November 2010. The sidescan data layers are shown above, the lines are track lines representing the survey path, the images that follow along with these are the side scan image layers, and the polygons filled in with drawings of green plants represent identified SAV. Not all of the layers can be seen in this image as they are below other layer(s) in this display. The substrates determined from the images are shown in the lower image.

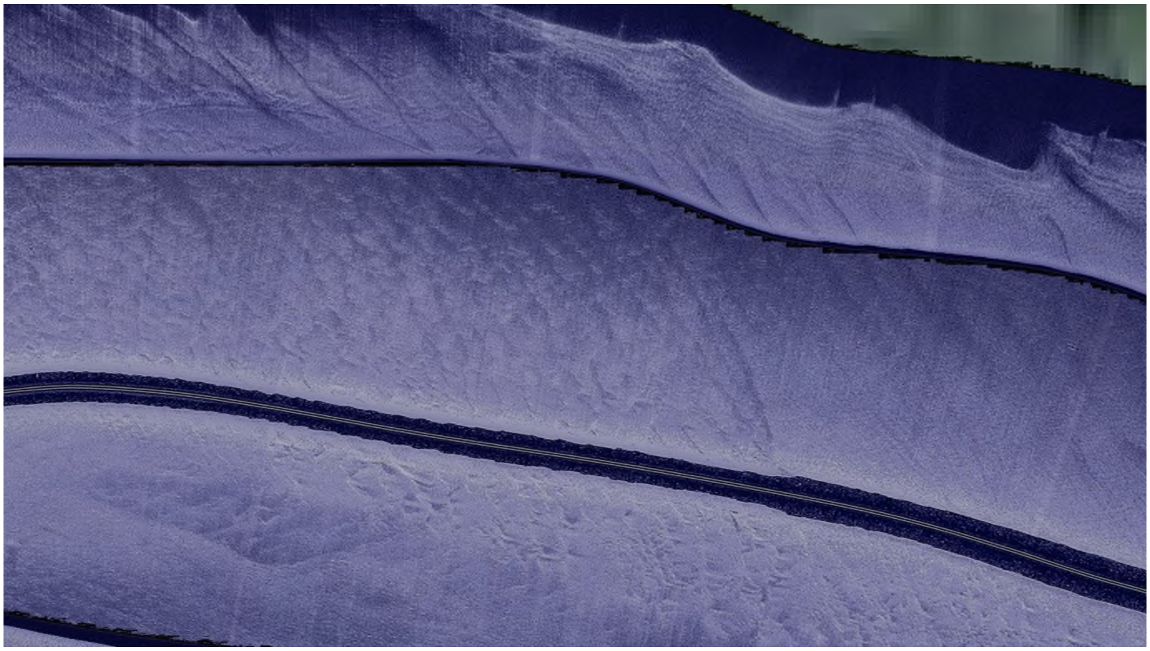

Figure 3-6. Example of sand/silt/clay habitat type as classified from sonar imagery for the habitat survey of the Merrimack River, 16 September through 2 November 2010.

Figure 3-7. Example of gravel/cobble habitat type as classified from sonar imagery for the habitat survey of the Merrimack River, 16 September through 2 November 2010. (Note: gravel/cobble habitat is located within the bounds of the red polygon in the center of the figure).

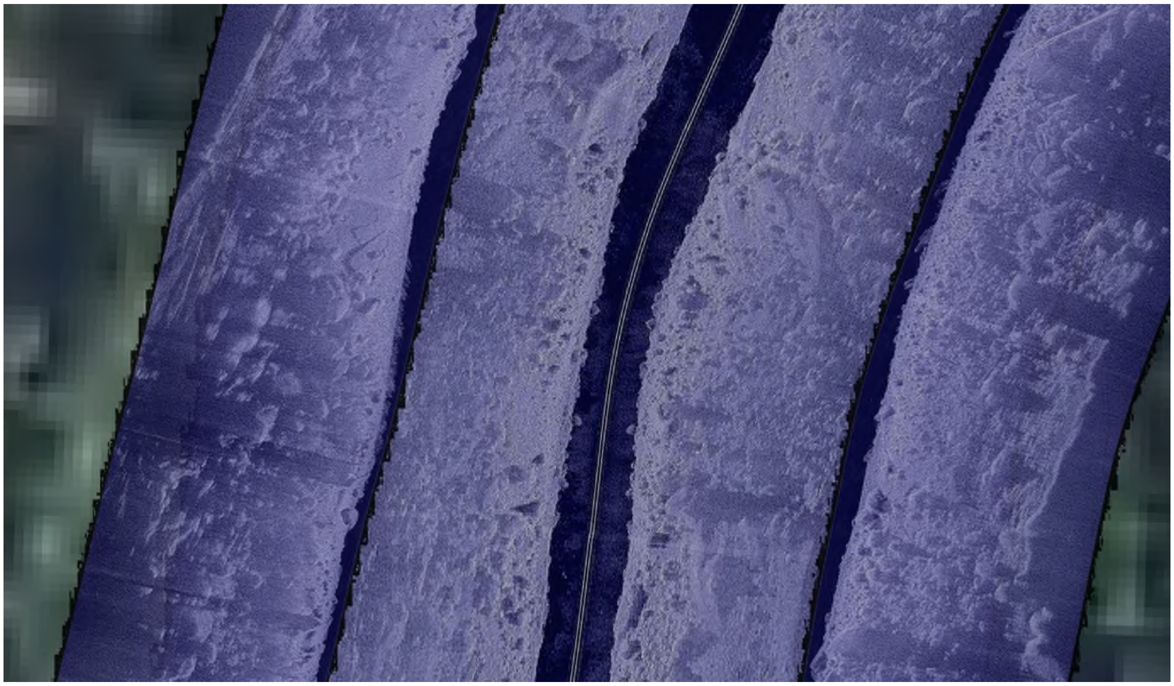

Figure 3-8. Example of boulder habitat type as classified from sonar imagery for the habitat survey of the Merrimack River, 16 September through 2 November 2010.

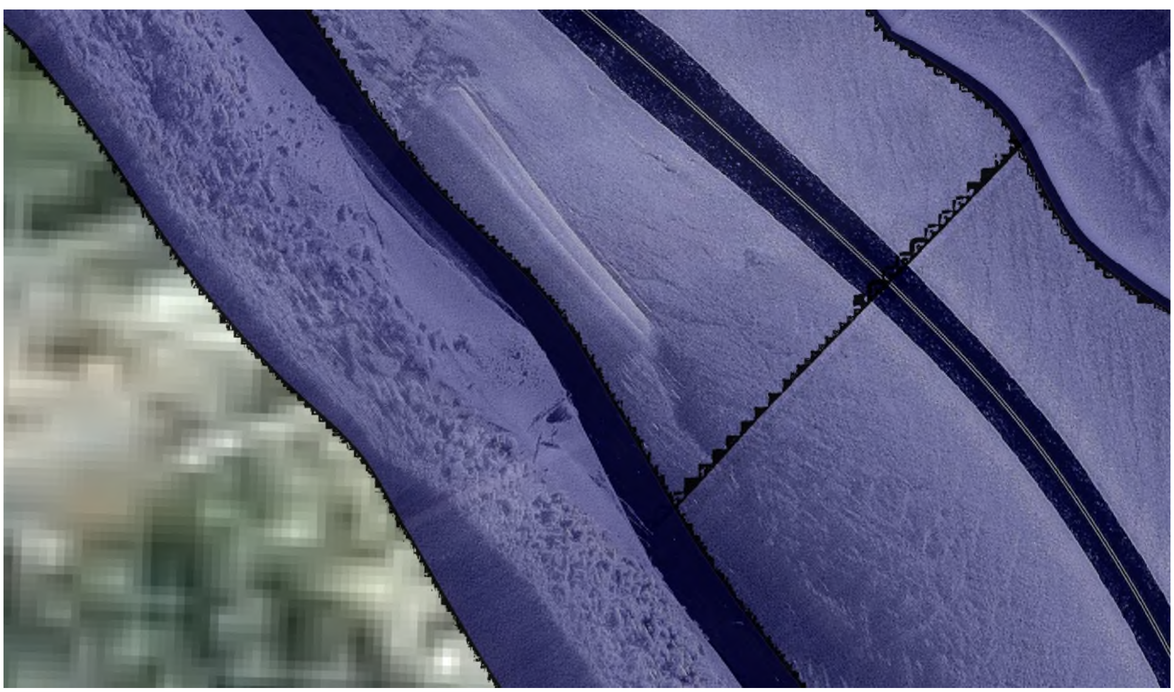

Figure 3-9. Example of rip-rap habitat type as classified from sonar imagery for the habitat survey of the Merrimack River, 16 September through 2 November 2010.

Figure 3-10. Example of ledge habitat type as classified from sonar imagery for the habitat survey of the Merrimack River, 16 September through 2 November 2010. (note: ledge habitat is located within the bounds of the polygon in the center).

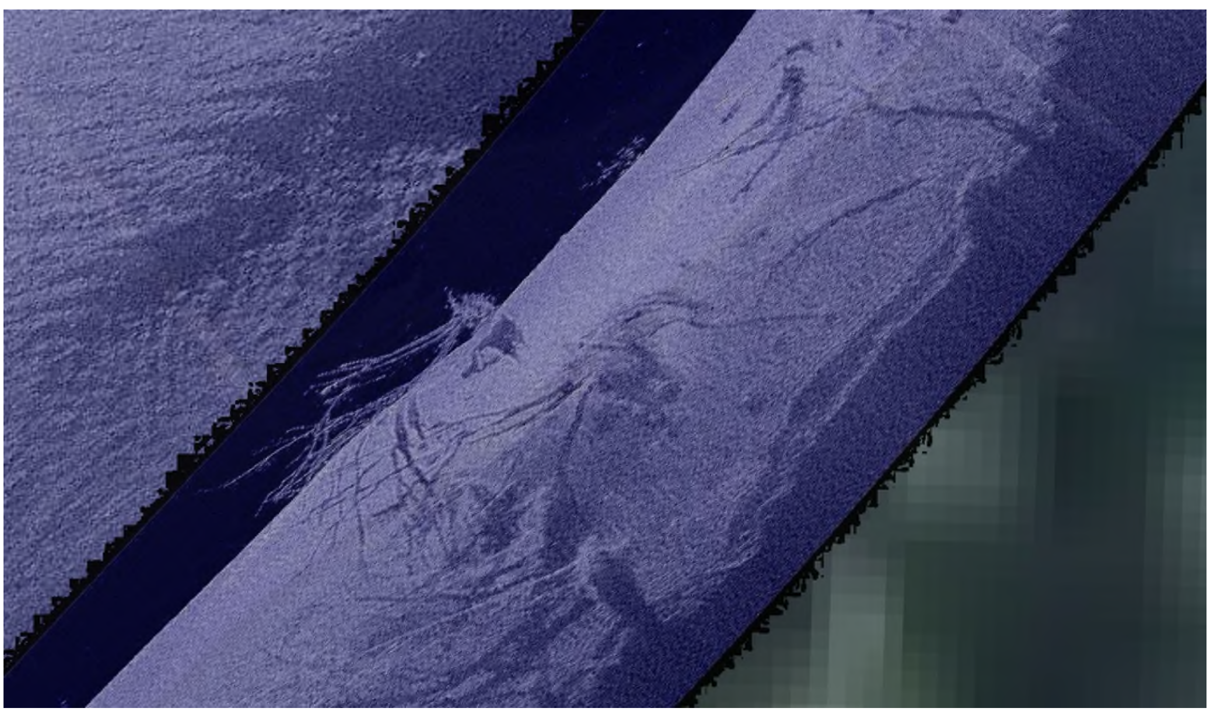

Figure 3-11. Example of woody debris habitat type as classified from sonar imagery for the habitat survey of the Merrimack River, 16 September through 2 November 2010.

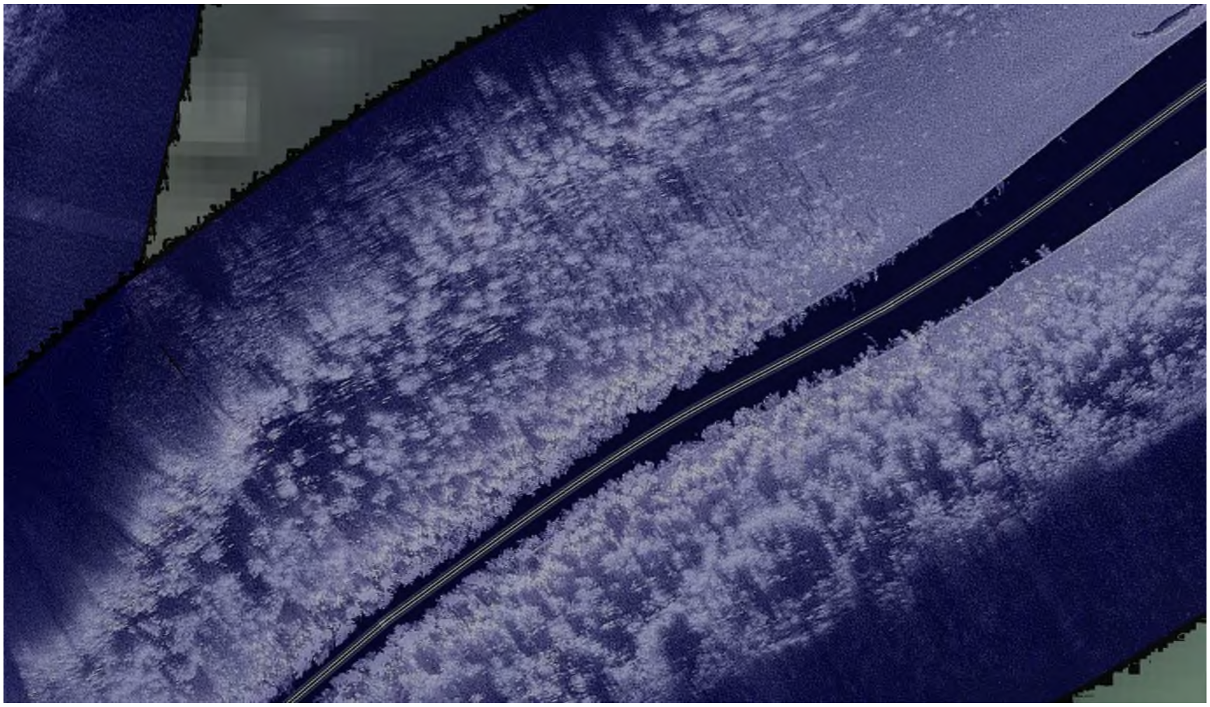

Figure 3-12. Example of submerged aquatic vegetation as classified from sonar imagery for the habitat survey of the Merrimack River, 16 September through 2 November 2010.

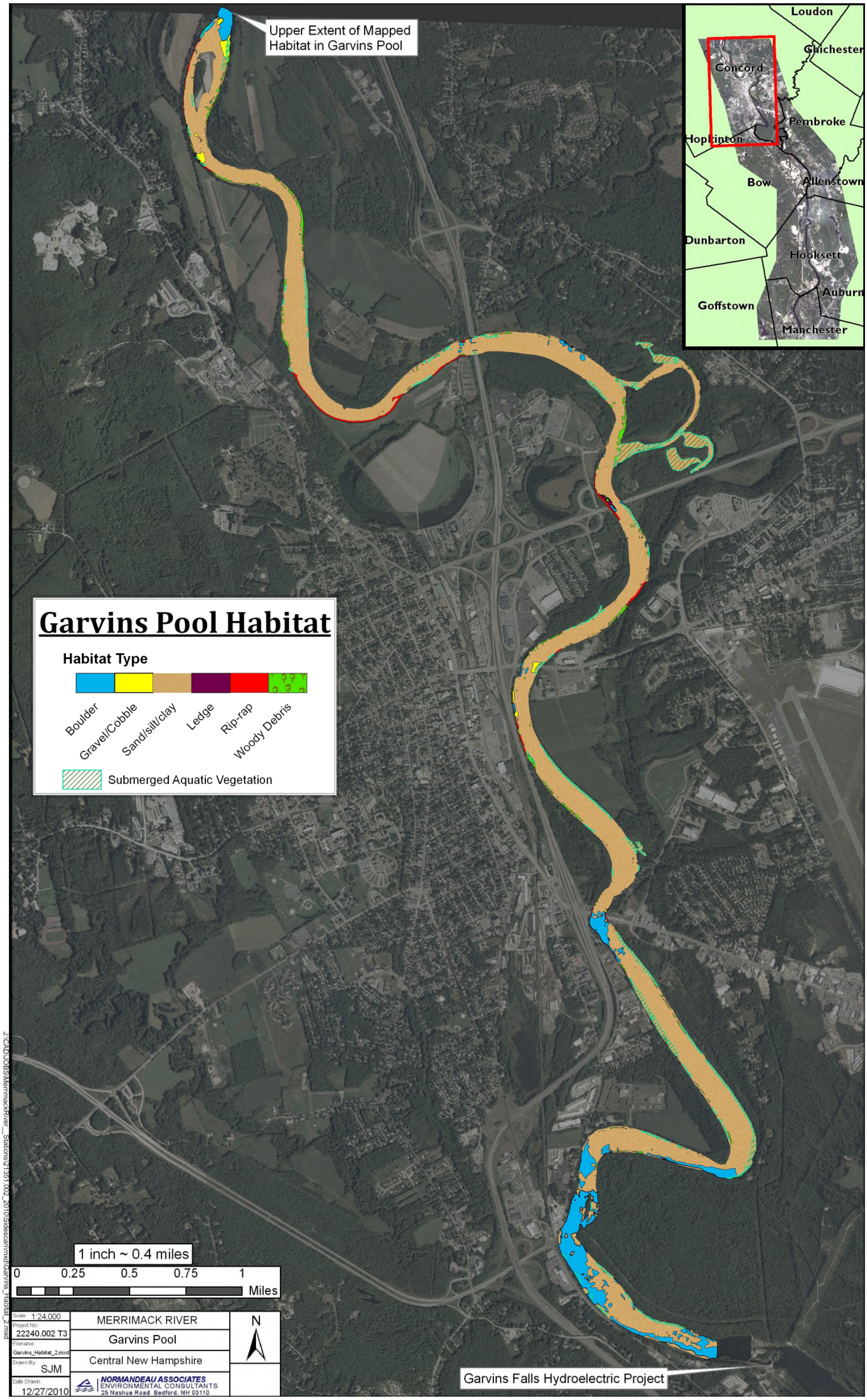

Figure 4-1. Garvins Pool and habitat classified by side scan sonar. Surveyed from 24 September to 25 October 2010.

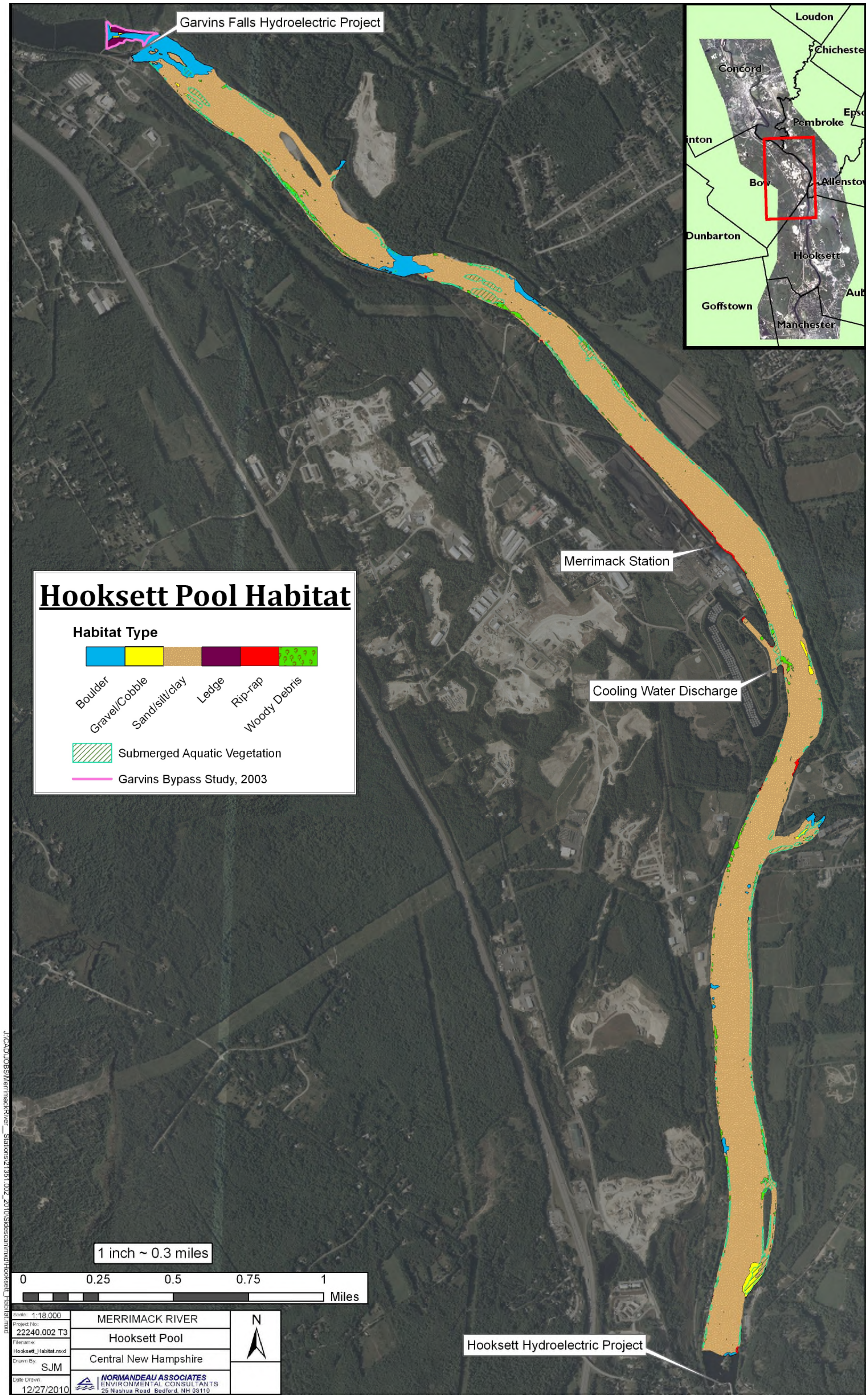

Figure 4-2. Hooksett Pool and habitat classified by side scan sonar. Surveyed from 16 September to 25 October 2010.

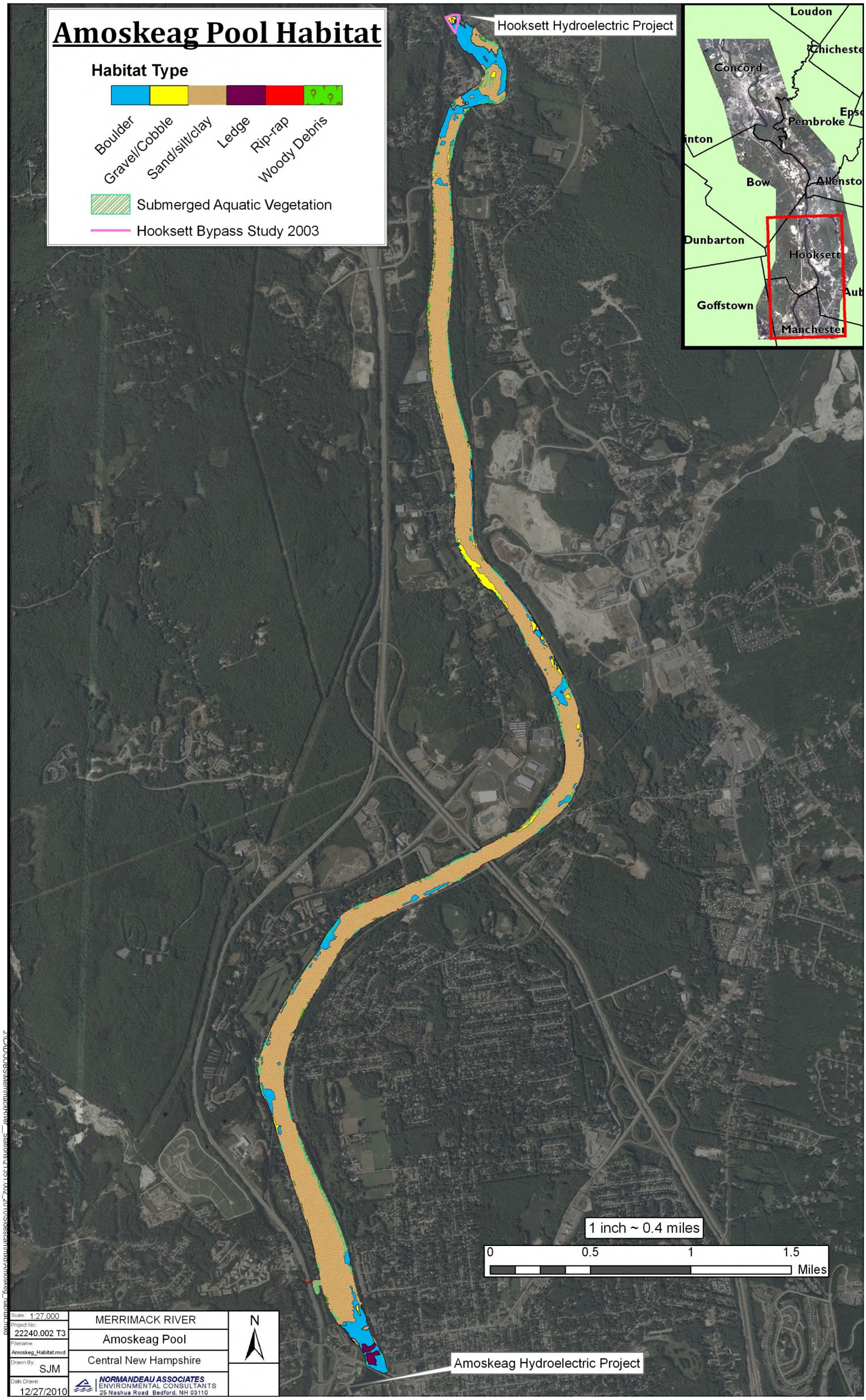

Figure 4-3. Amoskeag Pool and habitat classified by side scan sonar. Surveyed from 22 September to 2 November 2010.