Peninsula Harbour Submerged Aquatic Vegetation (SAV) and Cap Movement Study: 5 Years Post-cap Survey

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Abstract

Approximately 23 ha of Jellicoe Cove in the Peninsula Harbour Area of Concern was capped during the summer of 2012 with approximately 15 to 20 cm of medium to coarse sand to enhance natural recovery and reduce exposure of organisms to contaminated sediments. Year 5 post-capping monitoring of submerged aquatic vegetation and potential sediment movement was conducted September 18-21, 2017 by Northern Bioscience, as follow-up to Year 0 and Year 1 monitoring in 2012 and 2013 respectively. Underwater video was collected using a boat-mounted SeaViewer "Sea Drop 950" color video camera along approximately 21 km of transects at roughly 50 m spacing between transects. In addition, 31 grabs were taken with a petite ponar grab to confirm substrate composition at selected locations in and adjacent to the cap. Approximately 5400 georeferenced video images were extracted and interpreted at approximately 4-5 m intervals along the transects, of which approximately half were in the capped area. No mobilization of cap material beyond the cap or the adjacent 3 m transition zone was detected using underwater video and ponar grabs. A thin layer of silt has accumulated over much of the coarse and medium sand material in the cap. Interpretation of underwater video also showed that there are sparse patches of stonewort and other submerged aquatic vegetation in the capped zone five years post-capping, with approximately 5% of images within the cap with submergents compared to about 2% in 2013 (Year 1). However, submergents within the cap remain sparse compared to levels prior to capping and to more widespread and denser patches of stonewort, pondweeds, and other submergents outside the cap zone. Continued monitoring of longer-term substrate movement and vegetation recovery is recommended in Year 10 (2022).

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1 Introduction

1.1 General

Peninsula Harbour, a large embayment adjacent to the town of Marathon on Lake Superior, was identified as an Area of Concern in 1985 (Figure 1). Recent remedial actions have focused on the accessible water areas of the harbour, where sediments have high concentrations of mercury and PCBs. Remediation of the deeper areas will be achieved through natural sedimentation processes. The selected strategy involved placing a thin layer cap of clean sand over the area in Jellicoe Cove with the highest levels of contamination. Jellicoe Cove encompasses approximately 97 ha of Peninsula Harbour south of Skin Island (Figure 1). Capping of the contaminated sediment with a layer of clean sand was proposed with the following objectives:

- To reduce the risk to biota from contaminated sediment in Jellicoe Cove, thus reducing bioaccumulation into the food chain;
- To reduce the spread of contaminated sediment from Jellicoe Cove to the rest of Peninsula Harbour;
- To expedite the natural recovery of Jellicoe Cove; and
- To facilitate ecosystem recovery in Peninsula Harbour which will contribute to “delisting” as an Areas of Concern (AOC) identified in the *Great Lakes Water Quality Agreement between Canada and the United States*).

Figure 1. Map of Peninsula Harbour Area of Concern near town of Marathon (Environment Canada 2010).

1.2 Capping Operation

A total of 216,402 m^3 of cap material was placed in 2012 on the 20.3 ha of Area 1 and associated transition zones, with approximately 62% medium sand by volume, and 38% coarse sand (AECOM 2012)(Figure 2). Cap material was placed in a 3-m wide transition zone surrounding Area 1 to slope the new cap to the surrounding substrate or sediment, except for areas less than 1.5 m water depth along the rocky shoreline where no capping was to be applied. A piston core sampler was used to obtain core samples for sand placement thickness verification during project test and production phases (Appendix 2); core sampling was conducted in each cell to ensure the minimum cap thickness was achieved (AECOM 2012).

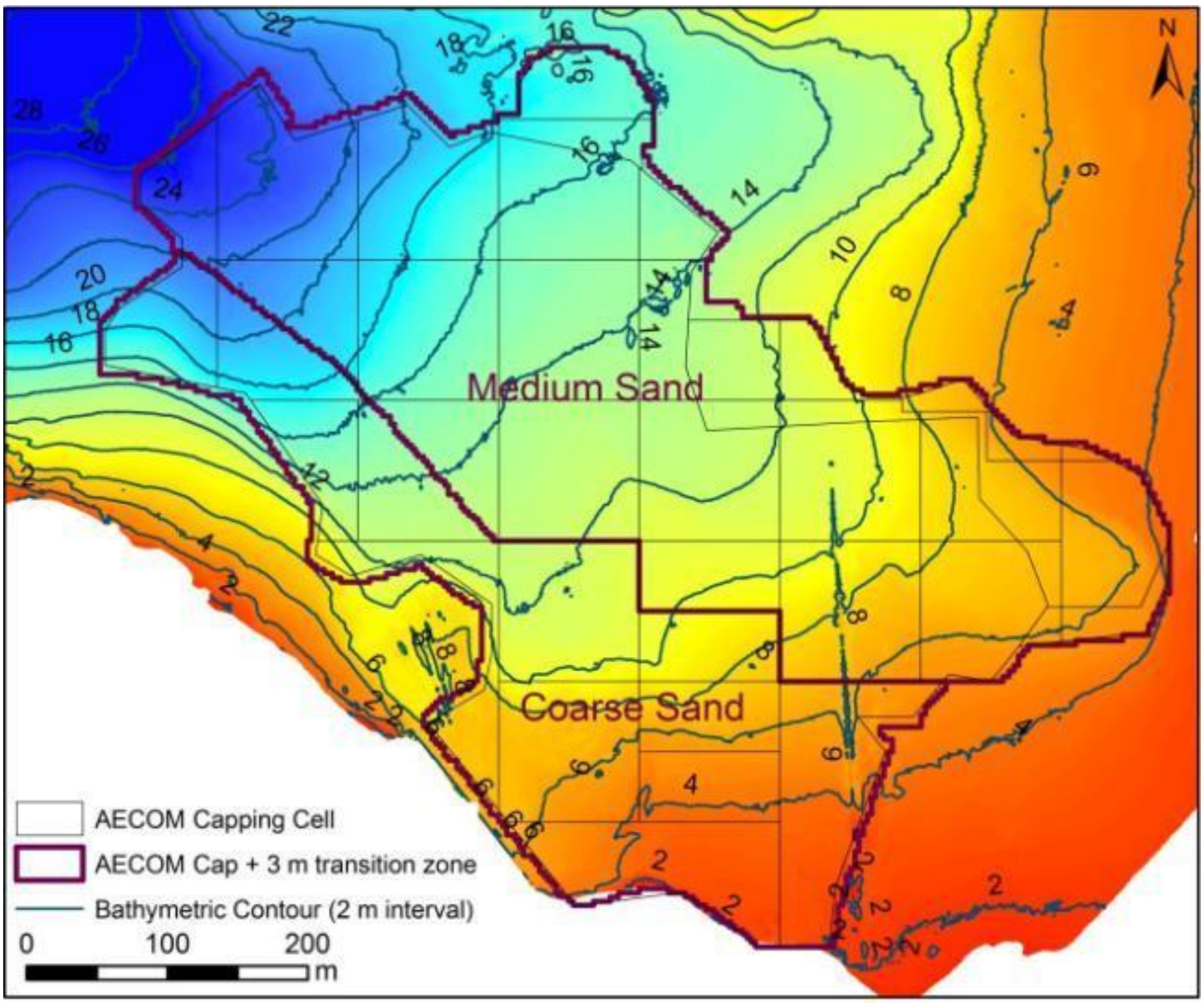

Figure 2. Cap area in Jellicoe Cove showing location of coarse and medium sand capping (AECOM 2012) overlain on bathymetry (provided by Environment Canada).

The methodology for confirmation of performance (thickness and spatial coverage) of capping consisted of measurement of cores taken at selected locations, supported by review and oversight of information provided by the contractor on the quantity and location of sand placed (AECOM 2012). In addition to coring to verify sand thickness and coverage at selected locations, sand quantity placed was also estimated from records of sand displacement measurements on the barge from which the sand was placed. According to AECOM (2012), capping activities across multiple cells in the same day and uncertainty in use of barge displacement measurements (influenced by weather, load balancing, etc.) generated challenges in confirming quantities placed in individual cells.

1.3 Study Purpose

The cap materials were specified based on calculations affirming stability, and although there remains potential for cap material to shift over time, movement is not anticipated to be substantial or widespread (AECOM 2012).

This current study was designed to compared conditions 5-year post-capping to baseline condition and 1-year post-capping. It includes monitoring:

- the distribution and potential movement of the sand cap; and
- the recovery of submerged aquatic vegetation (SAV) in the cap and adjacent areas.

2 Methods

Fieldwork for the Peninsula Harbour Sediment Movement and Submerged Aquatic Vegetation Monitoring Protocol was conducted September 19-21, 2017 using the same protocol employed in during Year 0 and Year 1 monitoring in 2012 and 2013 respectively (Foster and Ratcliff 2013, 2014). Field personnel included Dr. Rob Foster and Dr. Steve Hart. Harbour conditions were relatively calm with good weather during the survey.

2.1 Underwater Video

Video was collected using a boat-mounted SeaViewer “Sea Drop 950” color video camera (with LED lighting), the “Sea Trak” GPS video overlay unit, and a video capture unit (DVR-SD) for storing the video to SD cards (Figure 3). This system allows for GPS coordinates and time/date to be overlain on the video as it is recorded, which allowed for precise georeferencing of all images. The camera unit was suspended by hand over the side of the boat using the Kevlar-reinforced video cable (Figure 3). This deployment method allowed the greatest precision in maintaining the desired depth of the video camera above the bottom substrate.

Figure 3. SeaViewer console (left) and SeaViewer camera unit deployed (right).

A 2.27 kg (5 lb) downrigger ball attached to the camera helped maintain depth of the camera as the boat cruised along predetermined transects at approximately 1-2 km/hr. A handheld GPS (Garmin GPSMap 60CSx) was used to maintain position along transects and record locations of features (e.g., vegetation beds, ponar grabs). A grid of transects spaced approximately 50 m apart was surveyed over the cap and adjacent areas (Figure 4). Approximately 21.3 km of underwater video was collected, approximately 11.1 km with a southwest-northeast orientation and 10.2 km with a perpendicular, northwest-southeast orientation (Figure 6).

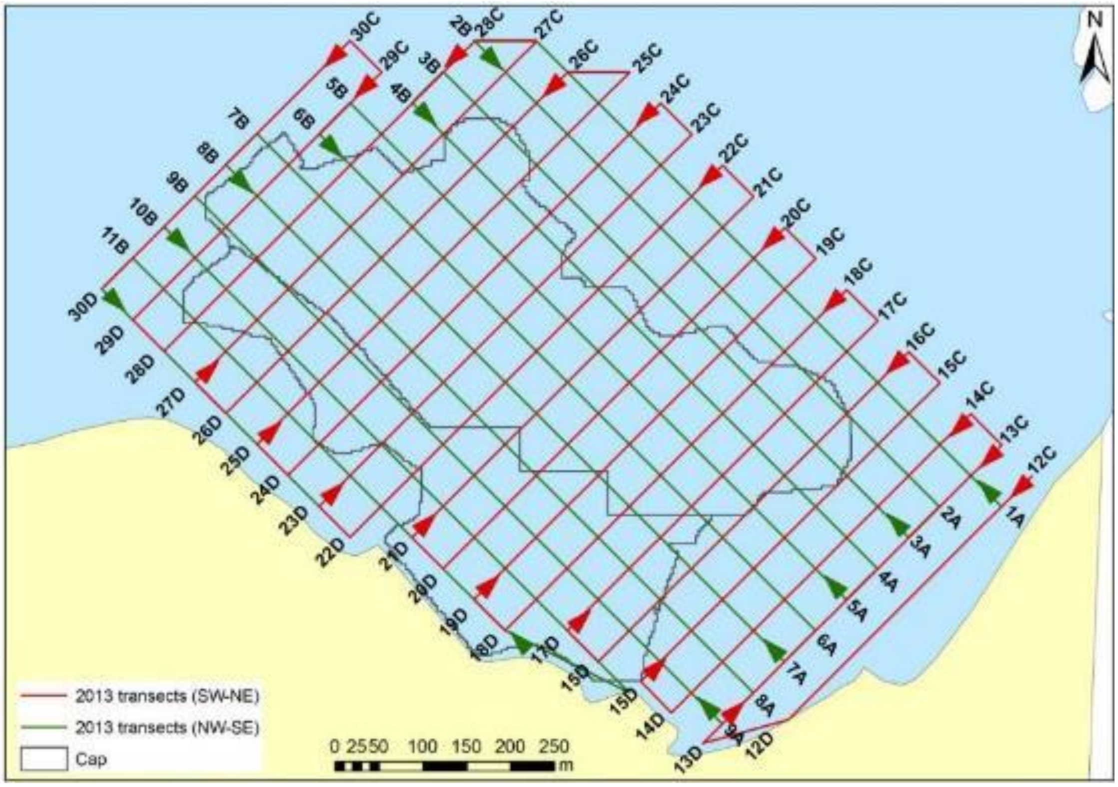

Figure 4. Planned transects (50 m spacing) and direction of travel during 2017 video monitoring.

Figure 5. GPS track taken during video transects in September 2017.

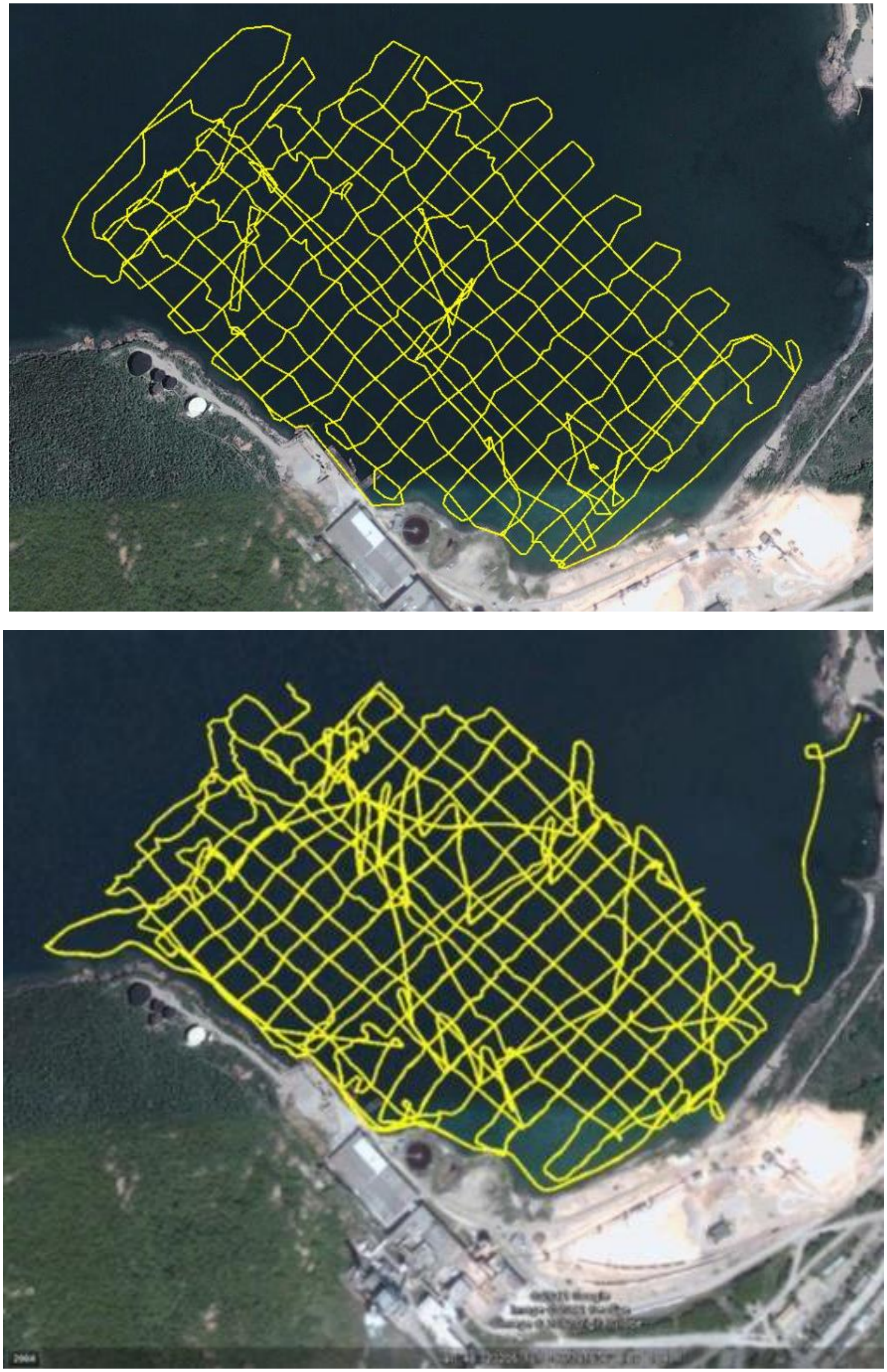

Figure 6. GPS track taken during video transects in 2013 (upper) and 2012 (lower).

2.2 Sediment Sampling

A total of 31 grabs were taken with a petite ponar grab to confirm substrate composition at selected locations in and adjacent to the cap. Grab locations in 2017 were similar to most of the 2012-2013 ponar grabs (Figure 7). Video was recorded of the substrate where the grabs were taken, and digital photographs of the material were also taken once the grab was retrieved (Figure 8). A visual assessment of particle size was conducted in the field; no laboratory analyses were conducted.

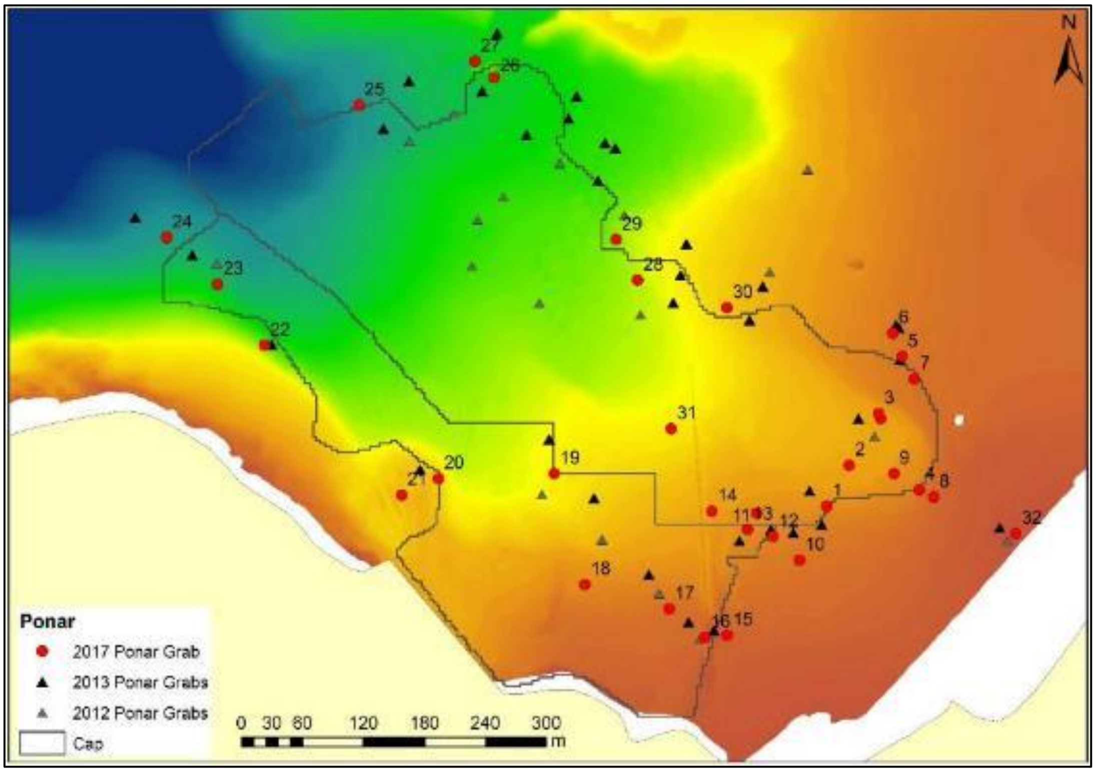

Figure 7. Year 5 (2017), Year 1 (2013) and Year 0 (2012) ponar grab locations in relation to the cap. Bathymetry provided by Environment Canada.

Figure 8. Petite ponar grab being lowered (left) and in action (right).

2.3 Video Interpretation and Analysis

Video data were interpreted by Northern Bioscience personnel involved with the field survey. Videos were downloaded and viewed on-screen using custom software provided by SeaView as well as Windows Live Movie Maker. Georeferenced sample points were extracted approximately every 4-5 m along the survey tracks and attribute data were entered into a spreadsheet, which was then brought into ArcGIS for mapping and analysis. See Appendix 3 for a summary of transects and associated video files and Figure 4 for location of transects.

The 4-5 m sampling interval of interpreted video frames was used for analysis to be consistent with pre-capping (2005, 2007) video by Environment Canada as well as Year 0 (2012) and Year 1 (2013) post-capping video. The entire video footage was viewed during the analysis, and representative still images (jpeg) were extracted from the video at 6 second intervals (which represents approximately 45 m distance based on the boat speed). A total of 5727 video points was extracted in 2017, 5424 with an interpretable image (2561 were in the actual cap area), compared to 5200 interpretable images in 2013 (2560 within the cap), and fewer in 2012 (approx. 3700 total images).

At each sample point the following was recorded/ interpreted:

- Submerged aquatic vegetation (SAV) abundance in the following cover classes: 1-25%, 26-75%, >75% (these can be pooled to approximate the sparse, moderate, and dense classes used in the Environment Canada videos);
- SAV species composition (ponar grabs were taken at select locations in the field to confirm species identifications);
- Other habitat features (e.g., coarse woody debris);
- Substrate type (e.g., silt, fine sand, medium sand cap, coarse sand cap, cobble, rock, bedrock, bark, and logs.
- Photo number (for selected points).

Water depth was interpolated from existing bathymetric data (provided by Environment Canada) in conjunction with the GPS coordinates. Video analysis of substrate types has some inherent limitations that must be recognized. Different classes of fine sediments are impossible to discriminate, therefore clays (<.002 mm), silts (0.002 - 0.05 mm), and very fine sands (0.002 - 0.25mm) were pooled as silt.

Appendix 3 shows the spatial extent of each video file from 2017 video footage. Appendix 5 has representative georeferenced images extracted from the 2017 video.

3 Results and Discussion

3.1 Substrate

3.1.1 Substrate Types

As in 2012-2013, angular coarse sand derived from crushed Manitoulin Island limestone could be easily distinguished from more rounded, multi-coloured medium sand derived from local granite (Marathon area sources) in samples taken by ponar grabs (Figure 9). See Table 1 for a summary of the 32 ponar grabs taken in 2017 and Appendix 4 for map and photos of ponar grab samples. Ponar grab samples taken outside the cap zone, had easily distinguished fine-textured sediments, with silt present in deeper water and fine sand in shallow water east of the cap zone (Figure 10). Several ponar grab samples within the cap zone had a range of particles sizes with some silts mixed in with medium or coarse sand (Appendix 4).

Figure 9. Coarse (Ponar # 18, left) and medium (Ponar # 19, right) sand capping material.

Figure 10. Silty (Ponar #15, left) and fine sandy sediment (Ponar #32, right) from outside the cap zone.

Table 1. Summary of 34 ponar grabs taken in September 19-20, 2017. See Figure 7 for locations.

2017 Ponar #	Easting*	Northing	Water Depth (m)	Substrate Notes	Location
1	5396718	544769	5.5	silty fine sand; very silty with a bit of organic	at edge of cap
2	5396758	544791	6.5	could see cap material on video; none in grab; very silty with a bit of organic	inside cap
3	5396809	544820	6	medium sand cap with silt	inside cap
4	5396734	544860	7.2	silty sand with some coarse sand cap and a bit of bark and fine woody debris	at edge of cap
5	5396865	544843	7.2	medium sand cap	just outside cap
6	5396888	544834	7.2	very hard packed sand	approx. 25 m off edge of cap
7	5396843	544855	7.2	medium sand cap	just inside cap
8	5396727	544874	7.2	hard-packed sand	10 m outside cap
9	5396750	544835	15	silty medium sand cap	within cap
10	5396665	544742	4.5	silty fine sand with some medium cap; cohesive and sticky so likely some clay as well; stonewort as well	approx. 40 m outside cap
11	5396711	544700	5.5	silty medium sand cap	within cap
12	5396688	544716	5.3	silty sand	approximately 5 m from cap edge
13	5396695	544691	5.3	coarse sand cap	within cap
14	5396713	544656	6.5	medium sand cap	within cap
15	5396591	544671	2.5	silty sand at edge of cobble	approx. 15 from edge of cap
16	5396589	544649	3	coarse sand cap	within cap, approx. 5 m from edge
17	5396617	544614	4	coarse sand cap with a bit of silt	within cap
18	5396641	544531	5	coarse sand cap with a bit of silt	within cap
19	5396750	544501	10.5	medium and coarse sand	on edge between medium and coarse sand cap
20	5396745	544387	10	coarse sand cap with not much silt	edge of cap
21	5396729	544351	8	silty clay with stonewort	off cap
22	5396876	544216	14	fine sand with not much silt	just outside cap
23	5396936	544170	16	coarse sand cap	inside cap
24	5396982	544120	18	mainly silty sand with a little bit of coarse cap	approx. 12 m outside cap
25	5397112	544309	21	silty sand with medium sand cap	at edge of cap
26	5397139	544442	16	medium sand capping with silty clay	approximately 15 m from cap edge

2017 Ponar #	Easting*	Northing	Water Depth (m)	Substrate Notes	Location
27	5397155	544423	17	mainly silty clay with some medium sand cap	approximately 5 m from cap edge
28	5396940	544583	12	medium sand cap with moderate amounts of silt and some fine woody debris	within cap
29	5396980	544562	13	silty clay with some fine woody debris	just outside cap
30	5396913	544671	9	fine silty sand with some clay and fine woody debris	just outside cap
31	5396794	544616	10	medium sand cap with some sand	middle of cap
32	5396691	544955	1.5	fine sand	outside cap along beach

*Universe Transverse Mercator Project (UTM) Zone 16, NAD83

3.1.2 Constraints

As in 2012-13, underwater video was generally capable of differentiating between capped and uncapped areas (Figure 11, Figure 12), but with some limitations. It was often difficult to differentiate between coarse and medium sand in the cap when overlain with silt. The ability to differentiate substrates in the underwater video varied with water depth, video speed, and homogeneity of substrate. Water clarity was generally very good in Peninsula Harbour and colour video was shot with ambient light. At water depths greater than about 15 m, supplemental LED lighting and infra-red video was required (it automatically changes modes), although this varied with time of day and degree of cloud cover. Sediment type was often more difficult to differentiate at these greater depths, and approximately 22% of the cap was greater than 16 m deep. Survey speed was generally kept to below 2 km/hr, and reduced where necessary to ensure that the video was interpretable. Video could also be paused post-hoc in the viewing software to examine individual frames in more detail where necessary.

Figure 11. Coarse sand cap with overlaying silt (left) and medium sand cap (Image #509c)(right).

Figure 12. Uncapped silt (left) and uncapped fine sand (right).

As in 2012-2013, the greatest constraint in determining substrate type using underwater video was that for much of cap area there was a thin layer (typically several mm) of silt over the medium and coarse sand cap material. This appeared to be more extensive and thicker in 2017 than previously. Substrate type was particularly difficult to discern at depths where infra-red lighting was required, although this was confirmed at a small number of locations using ponar grabs. Underlying substrate was routinely exposed by disturbing the upper layer of sediment with the downrigger ball attached to the camera during surveying. The resulting plume of sediment also helped confirm the silty texture of the upper sediment (Figure 13). Representative ponar grabs confirmed that the substrate types were consistent with interpretation based on the video imagery (e.g., Figure 14)

The layer of silt overlaying the coarse and medium cap is mainly from natural sedimentation, which is estimated to occur at a rate of approximately 2 mm per year (AECOM 2009b; ENVIRON 2008). At this rate, approximately 10 mm of silt would expect to have been deposited over top of the cap since 2012. Video footage of exposed cap substrate in 2017 indicates, that naturally occurring rates of silt deposition are either lower than previous estimates, or that the spatial distribution is unequal, perhaps due to currents or wave energy.

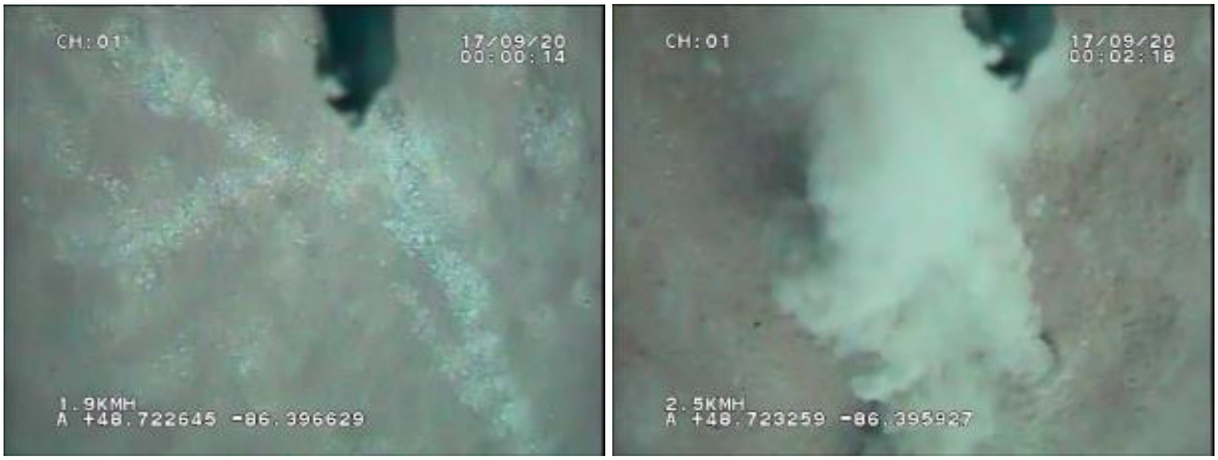

Figure 13. 2017 Cap material with silt (left) and silt plume disturbed by camera (right).

Figure 14. Video image (left) at 18 m and Ponar #31 grab sample (right) with medium sand cap and silt.

3.1.3 Comparison with Year 0 (2012) and Year 1 (2013)

Based on video interpretation of substrate, upper layers of the cap area are still covered by the medium or coarse sand cap (Figure 15) that are often overlain by a silt of varying thickness, especially in deeper areas. Cap material is presumed to be present below the silt, which was confirmed in the locations where ponar grabs were taken or where the upper silt was disturbed by the video camera. This was somewhat difficult to confirm directly by video interpretation of substrates in deep water. However, it generally appeared that most of the medium and coarse sand deposited in the cap area had remained in situ.

Figure 15. Substrate at margin of medium sand cap in approximately 2 m water depth (Image 719), with cap material at bottom of photo and non-cap scalloped sand outside cap (upper portion of photo).

There was little evidence of cap mobilization in shallow waters to the southeast of the cap along the gently sloping southeast sand shore. Underwater video showed a fairly clear demarcation along most of cap margin with no cap material apparent beyond the 3-m transition zone at the edge of the cap and submergent growth outside the cap (Figure 16, Figure 17). Overall, the distribution of sediments types observed in 2017 (Figure 21), did not appear to differ significantly from 2013 (Figure 22).

Figure 16. Coarse sand capping material within cap (Image 4084), approximately 5 m away just outside cap (Image 4085 lower left) and 5 m further outside cap (Image 4086, lower right).

Figure 17. Substrate with medium sand cap at southeast cap margin (left) and approximately 5 m outside cap (right).

Dense submergent growth along at least some of the outer margin of the cap provided strong evidence for a lack of mobilization of cap material along the southeast and southern portion of the cap where submergents are the most abundant outside the cap (Figure 18).

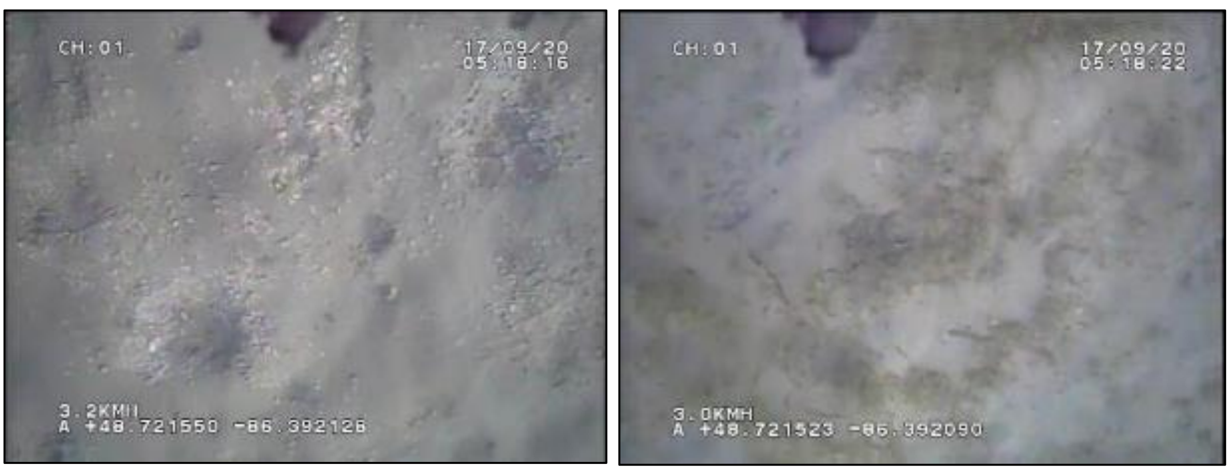

Figure 18. Coarse sand cap material and silt near southeast margin of the cap (left) and submergent growth within 5 m of edge of cap in 2017.

There did not appear to be much, if any cap movement along the southwest edge of the cap along the bedrock, cobble, and sheet piling shore. There were intermittent patches of coarse sand cap material mixed with submergent vegetation visible in 2013 underwater video transects between the cap and the shore (Figure 19). Re-examination of the 2012 video for this area indicates that there was some coarse sand capping present in late September 2012 which suggests that it may have been deposited during the capping process rather than mobilization.

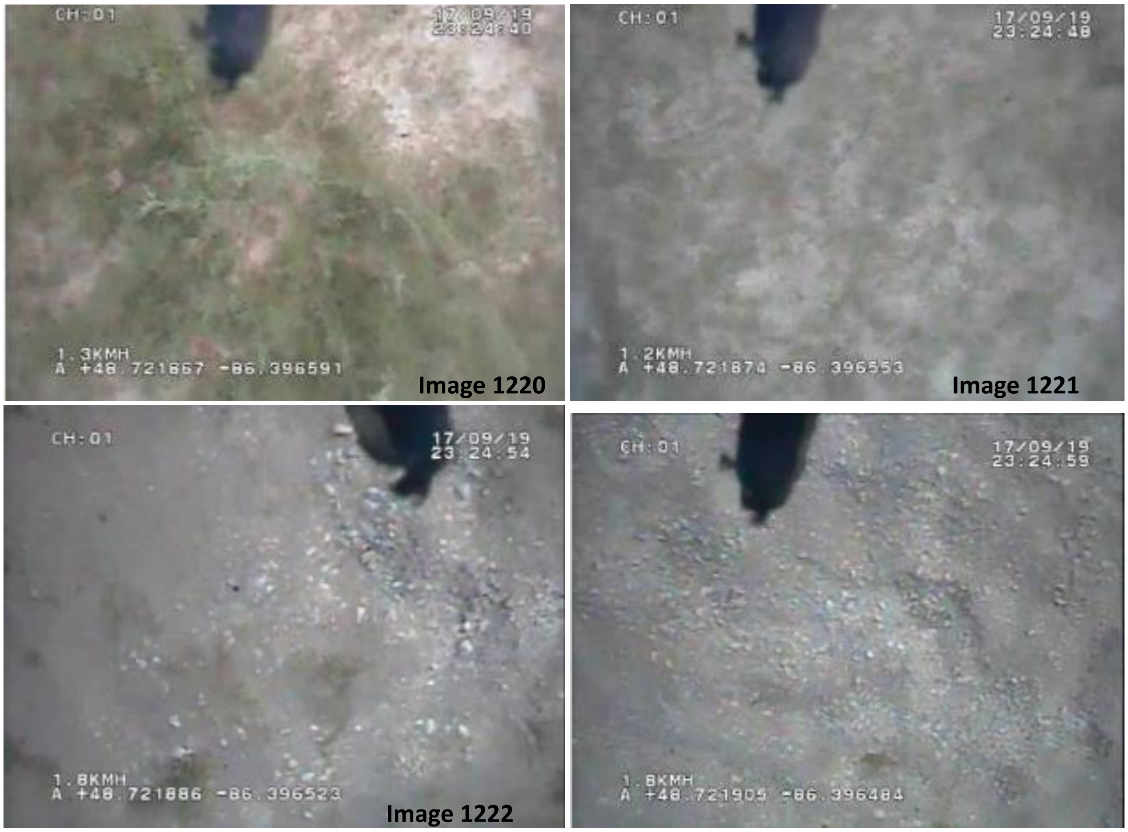

Figure 19. Dense stonewort approximately 5 m from southwest cap edge in 2017 (Image 1220, upper left) grading to coarse sand cap with no submergents (lower right).

There may have been some limited movement along deeper edge of cap area, but it is difficult to compare pre-capping conditions in deeper adjacent waters with post-capping conditions due to limited video and unreliable substrate data from acoustic mapping prior to the capping operation (AECOM 2009a; Foster and Harris 2011). Ponar grabs taken along the edge of the cap in deeper water (24, 27) had minimal amounts of cap material in them compared to grabs taken at the cap's edge or within the cap in deep water e.g., grabs 25, 26 (Appendix 4; Table 1, Figure 20).

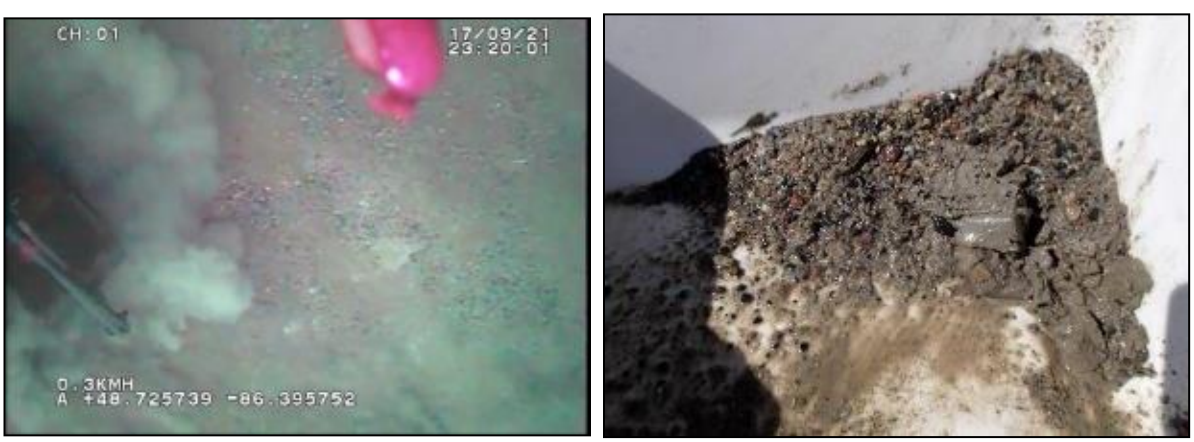

Figure 20. Video image (left) at 18 m and Ponar #26 grab sample (right) with medium sand cap and silt.

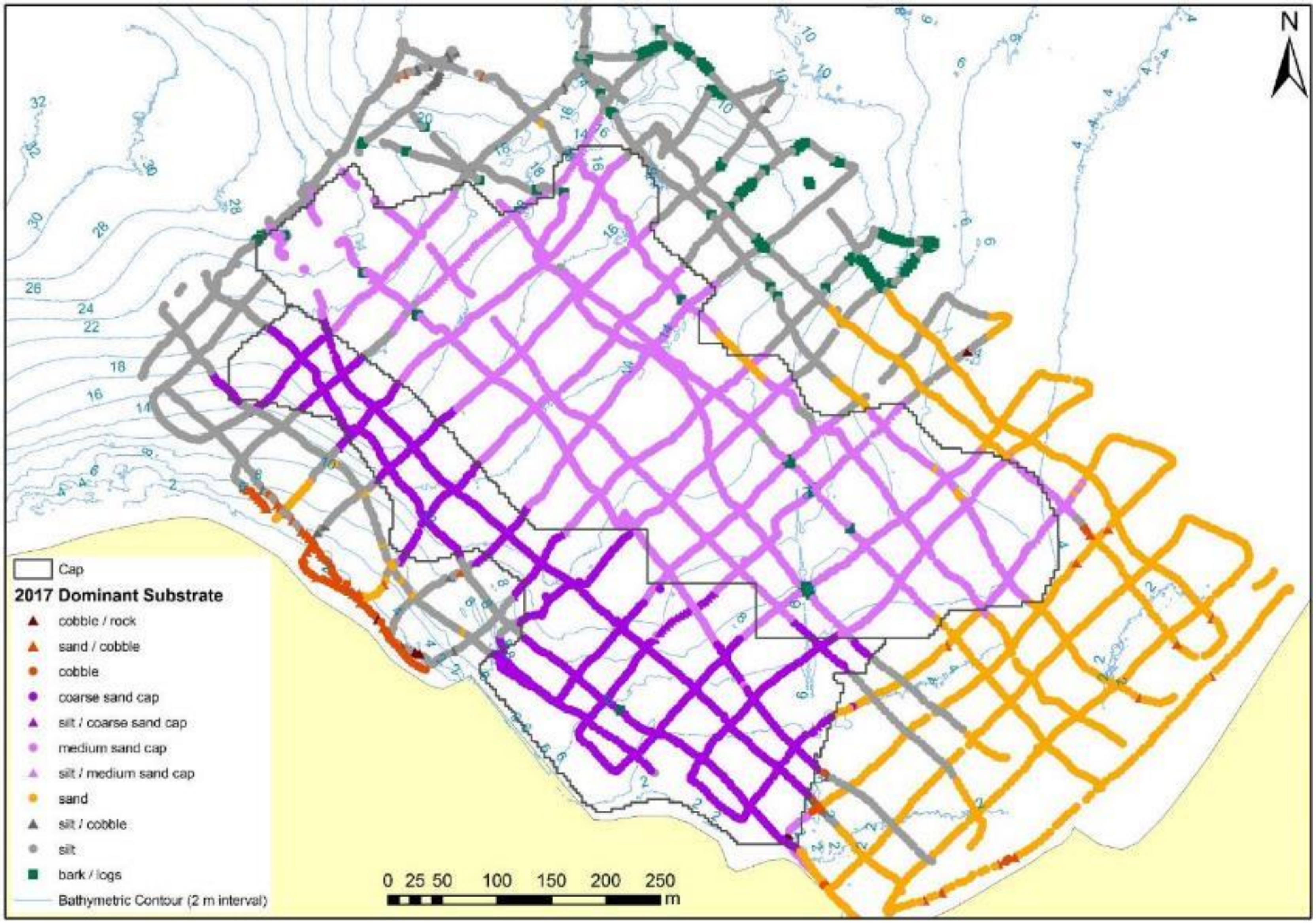

Figure 21. Sediment type interpreted from underwater video taken Year 5 post-capping, September 2017. Bathymetry provided by Environment Canada.

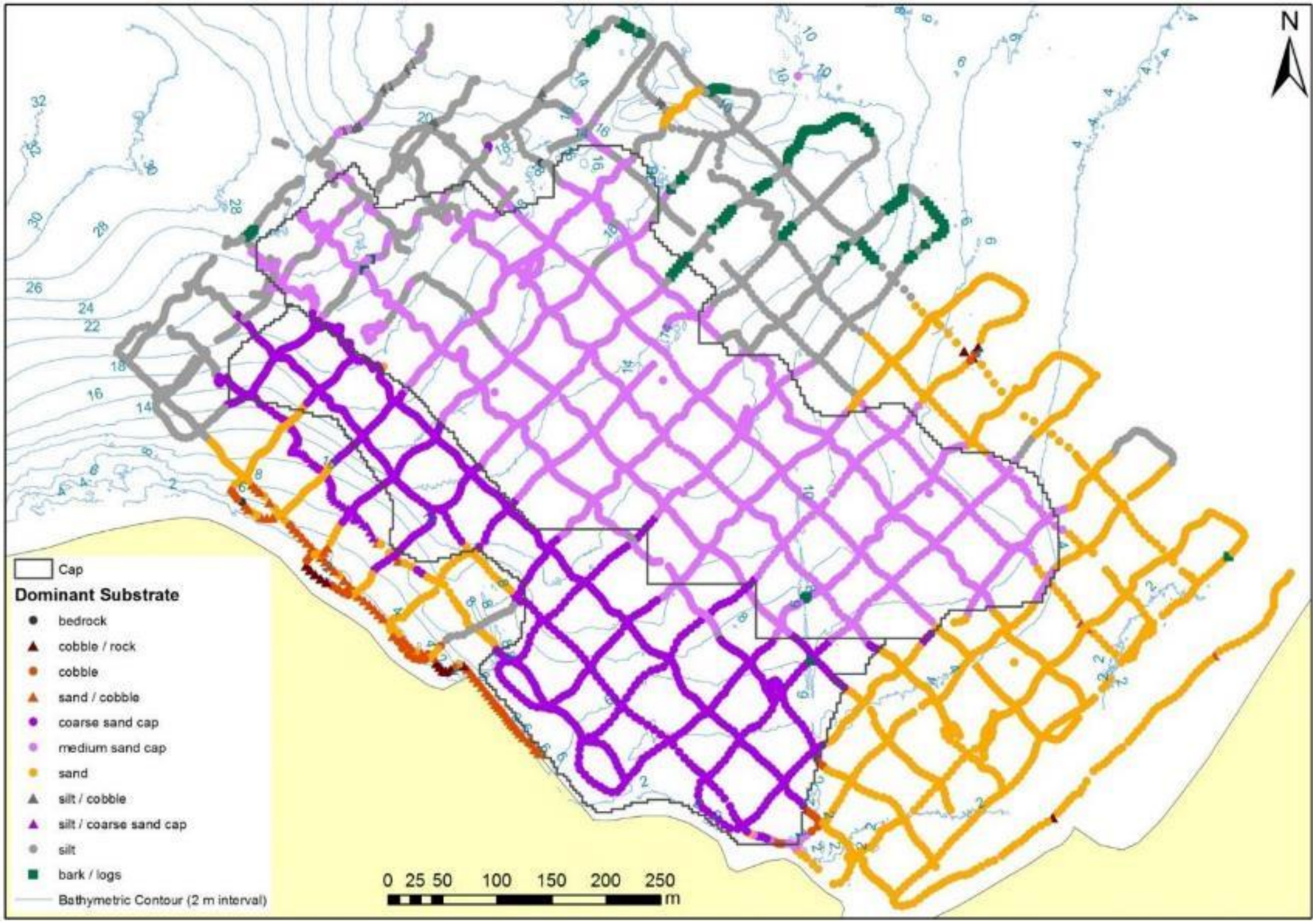

Figure 22. Sediment type interpreted from underwater video taken Year 1 post-capping, September 2013. Bathymetry provided by Environment Canada.

3.2 Submerged Aquatic Vegetation

3.2.1 Species

Submergents were easily detectable on the video, although species determination was often difficult. Within the cap area, stonewort or muskgrass (*Chara vulgaris*), was the most abundant species based on video interpretation and confirmed by ponar grabs (Figure 23). Stonewort is a jointed, filamentous macroalgae that resembles vascular plants (Newmaster et al. 1997). Several species of pondweeds could be also distinguished in the 2017 videos including Richardson's pondweed (*Potamogeton richardsonii*)(Figure 24) and an unknown species linear-leaved pondweed (Figure 25). Although less abundant, Canada smartweed (*Elodea canadensis*) is also present and it appears that water milfoil (*Myriophyllum* sp.) is also be present at low abundance (Figure 26). These species are difficult to tell from pondweeds and stonewort on the video however, and may have been overlooked in moderate to dense patches of other submergents. Pondweeds, stonewort, and Canada waterweed were observed pre-development in 2000 (Eakins and Fitchko in 2000) and were present on the 2005-2007 Environment Canada underwater videos.

Figure 23. Stonewort (*Chara vulgaris*) post-capping.

Figure 24. Richardson's Pondweed (*Potamogeton richardsonii*) observed post-capping during 2017.

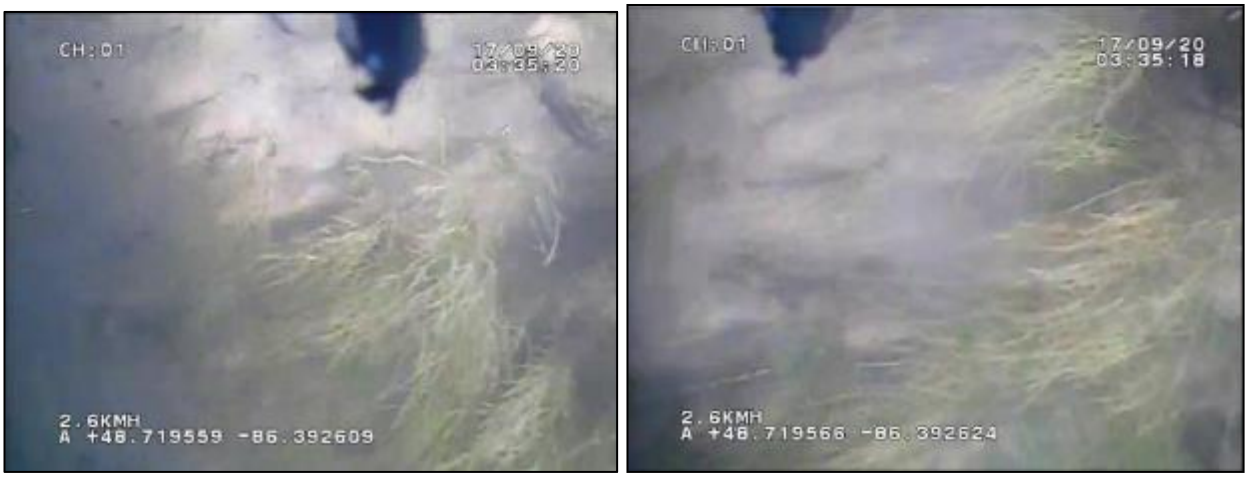

Figure 25. Unknown species of linear-leaved pondweed (*Potamogeton* sp.) observed post-capping during 2017.

Figure 26. Apparent Canada waterweed (*Elodea canadensis*) in the cap (left, Image #4062) and water milfoil (*Myriophyllum* sp.) observed post-capping during 2017.

The continued presence of curly-leaved pondweed (*Potamogeton crispus*) in shallow water southeast of the cap was confirmed in 2017 and it appears well-established (Figure 27). Curly-leaved pondweed was also visible on videos from shallow water east of the cap in 2012-2013. This invasive, non-native species (Catling and Dobson 1985; MN Sea Grant 2013) was first observed on the north shore of Lake Superior in 2012 (Foster and Ratcliff 2013). Although non-native, it may provide suitable habitat (e.g., cover) for fish and other aquatic life in the study area. Scattered clumps of what appears to be a filamentous alga were also observed in and outside the cap zone in a range of water depths (Figure 28). It is difficult to determine from the video imagery if the algae are attached to the stonewort or the substrate, or are free-floating.

Figure 27. Curly-leaved pondweed (*Potamogeton crispus*) with distinctive leaves.

Figure 28. Clumps of apparent algae in cap.

3.2.2 Abundance and Distribution

The overall pattern of abundance of submergents in Jellico Cove were generally similar from 2012 to 2017 (Figure 32 to Figure 34), with some variability due to the location of transects and interpreted video images. Submergents remained sparse within the cap. Although much of the submergent vegetation outside the cap was sparse, there were also moderate to dense patches of pondweed, and to a lesser extent, stonewort (Figure 35). On an absolute and proportional basis, there were more areas with moderate and dense abundance of stonewort and pondweed outside the cap area, than within.

Although relatively limited, there has been an increase in the amount of submergents in the cap from 2013 to 2017 (Figure 29). In 2017, approximately 4.5% (n=117) of the 2561 images interpreted from the cap area (61 in coarse sand cap, 56 in medium sand cap) showed evidence of submerged aquatic vegetation (Table 2). In comparison, only 1.8% (n=45) of the 2560 images interpreted from the cap area in 2013 (31 in coarse sand cap, 14 in medium sand cap) showed evidence of submerged aquatic vegetation (Foster and Ratcliff 2014). In 2012, 53 of 1826 (2.9%) images interpreted from the cap showed evidence of submerged aquatic vegetation (Foster and Ratcliff 2013).

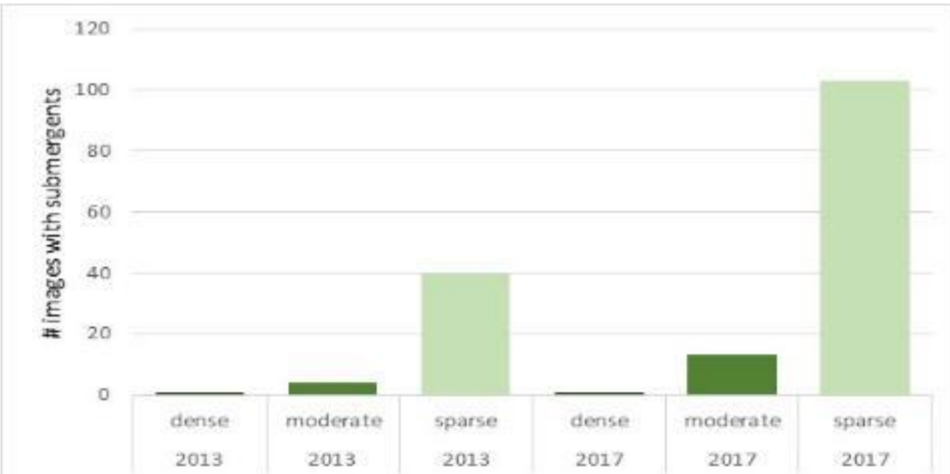

Figure 29. Number of images within the Peninsula Harbour cap with dense, moderate, or sparse submergent vegetation in 2013 and 2017.

Most of the submergents observed in the cap were stonewort, with just a few Canada smartweed, pondweeds, or algae (Figure 35). Most of the increase in the cap was from sparse clumps of stonewort, although there were some patches of moderately abundant stonewort as well (Figure 30, Figure 29, Figure 35). Stonewort was denser near the docks, which may be due in part to possible nutrient enrichment there. Increased light penetration due to shallower water depth, and shelter from the retaining wall may also play a role. Stonewort was also found along the southeastern margin of the cap intermixed with pondweeds, and in 6-14 m of water to the north of the cap. Pondweeds were most widespread and densest in the silty-sandy waters to the southeast of the cap in 1-5 m of water, although there were a few scattered individuals in the cap (Figure 34).

Figure 30. Moderate abundance of stonewort from the medium sand cap (left, Image # 1124) and moderate (right, Image #580), September 2017.

Table 2. Number of video images with submergents by abundance class inside and outside the cap area, September 2017.

	Coarse Sand Cap	Medium Sand Cap	Outside Cap	Total
Dense Subtotal	**1**		**98**	**99**
Pondweed			52	52
Stonewort	1		46	47
Moderate Subtotal	**5**	**8**	**372**	**385**
Other	1		4	5
Pondweed	1		224	225
Stonewort	3	8	144	155
Sparse Subtotal	**55**	**48**	**499**	**602**
Other	9	20	11	40
Pondweed	3	2	196	201
Stonewort	43	26	292	361
Submergent Total	**61**	**56**	**969**	**1086**
No Submergents	**860**	**1584**	**1894**	**4338**
TOTAL Interpretable Images	**921**	**1640**	**2863**	**5424**

In comparison, underwater video transects in 2005 and 2007 showed a much more extensive distribution and abundance of aquatic macrophytes within the cap area, including approximately 10 ha of the southern portion of the cap (Figure 36). The areas where submerged macrophytes were found ranged from shallow water to approximately 12 m deep, with the greatest density in 4-10 m of water. Density ranged from sparse to very dense beds up to 30-50 cm in height (Figure 31). Most of these beds have now been capped with medium to coarse sand, with only a few submergents having recolonized (Figure 31).

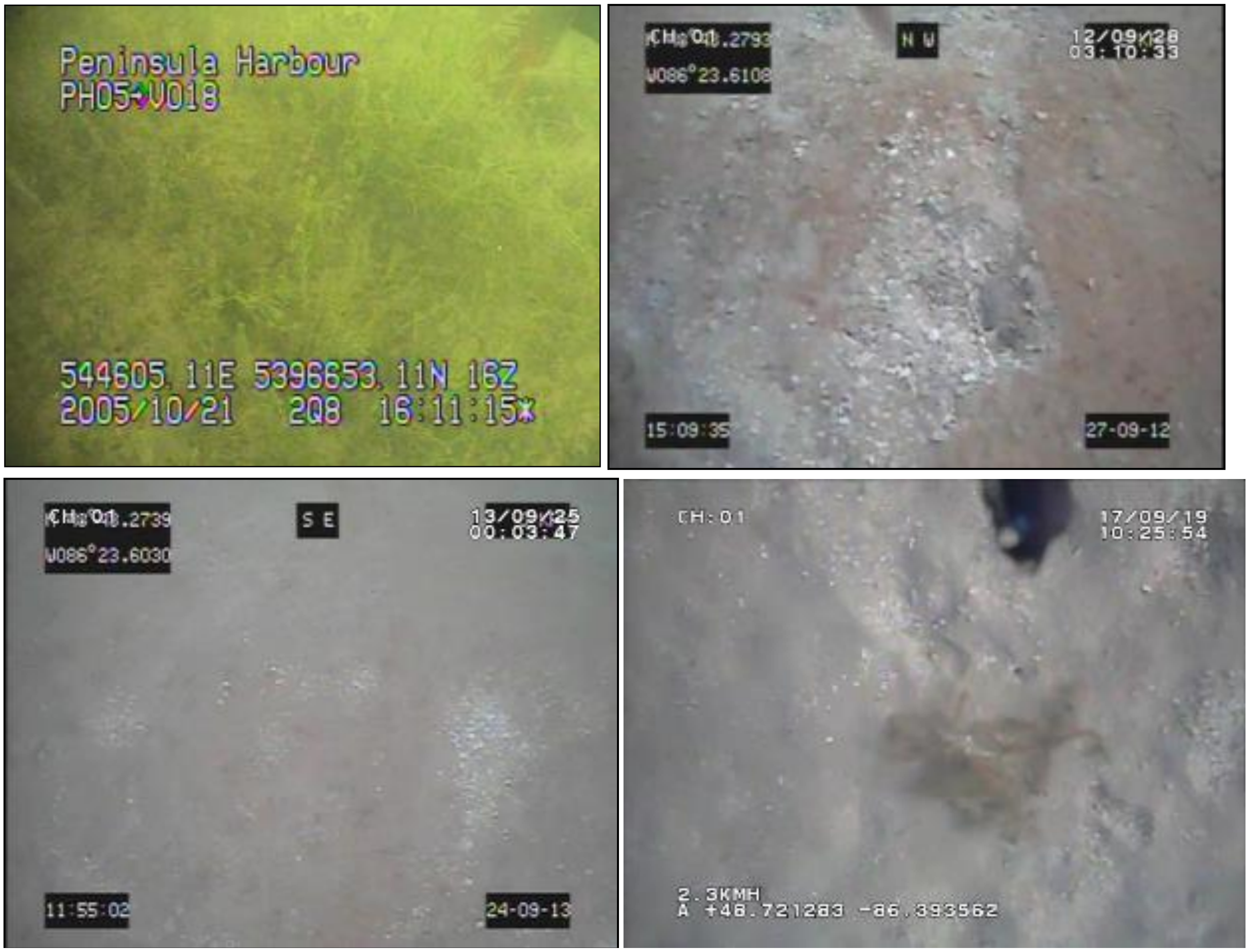

Figure 31. Dense stonewort along southern edge of cap zone in 2005 and at the same location (±4 m) in 2012 (upper right) and 2013 (lower left), and 2017 (lower right).

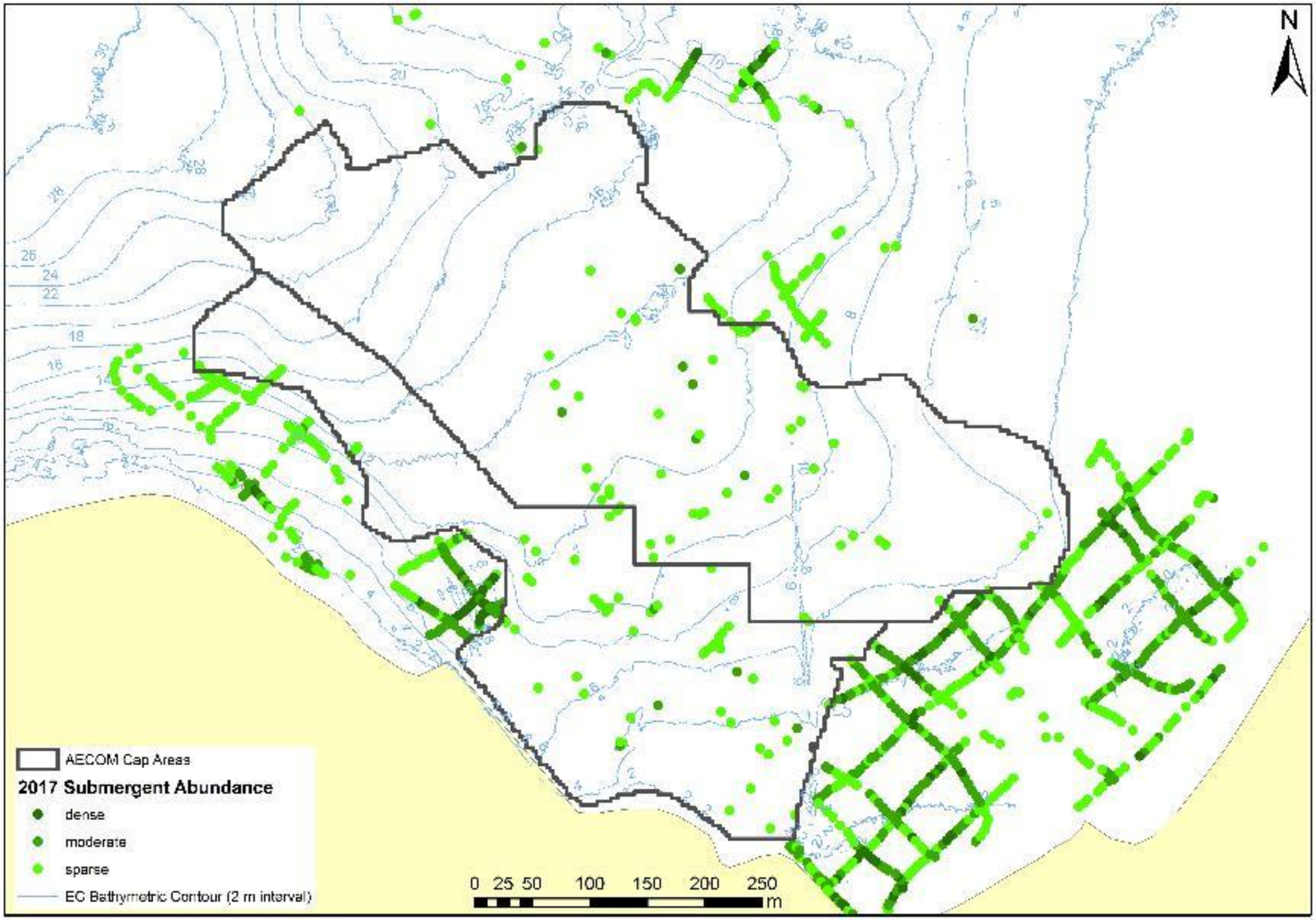

Figure 32. Distribution of submerged aquatic vegetation Year 5 post-capping, September 2017.

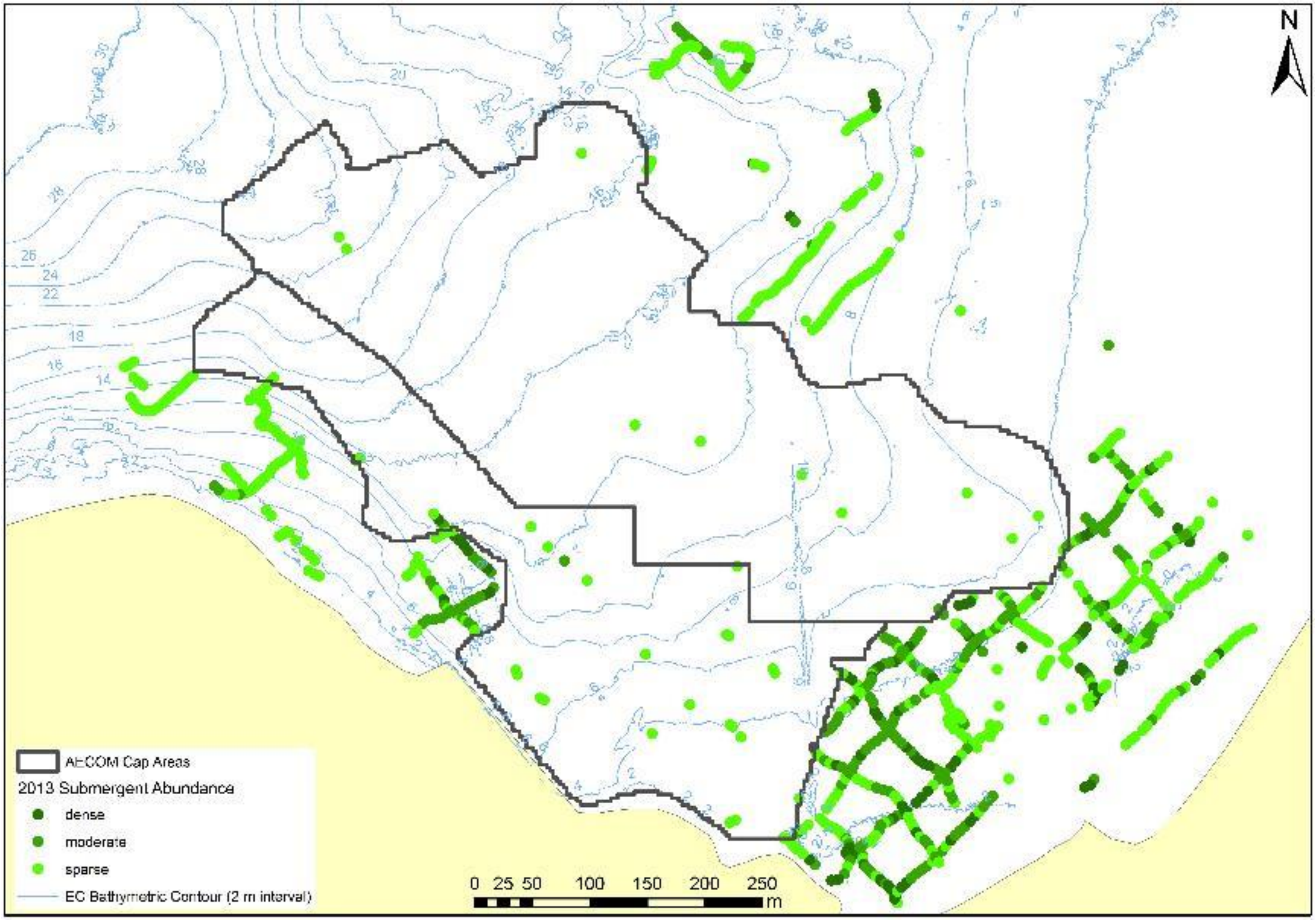

Figure 33. Distribution of submerged aquatic vegetation Year 1 post-capping, September 2013.

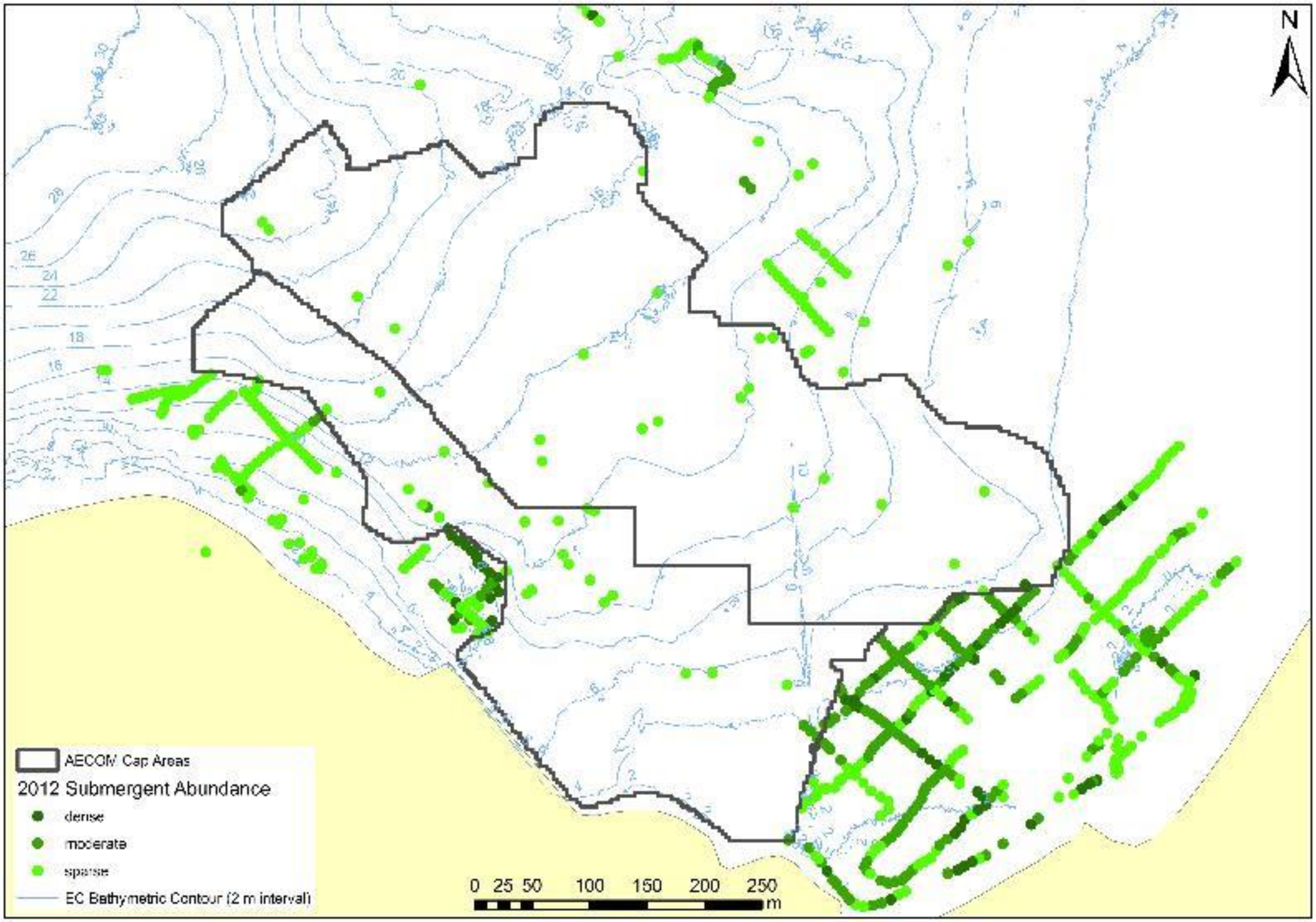

Figure 34. Distribution of submerged aquatic vegetation post-capping, September 2012.

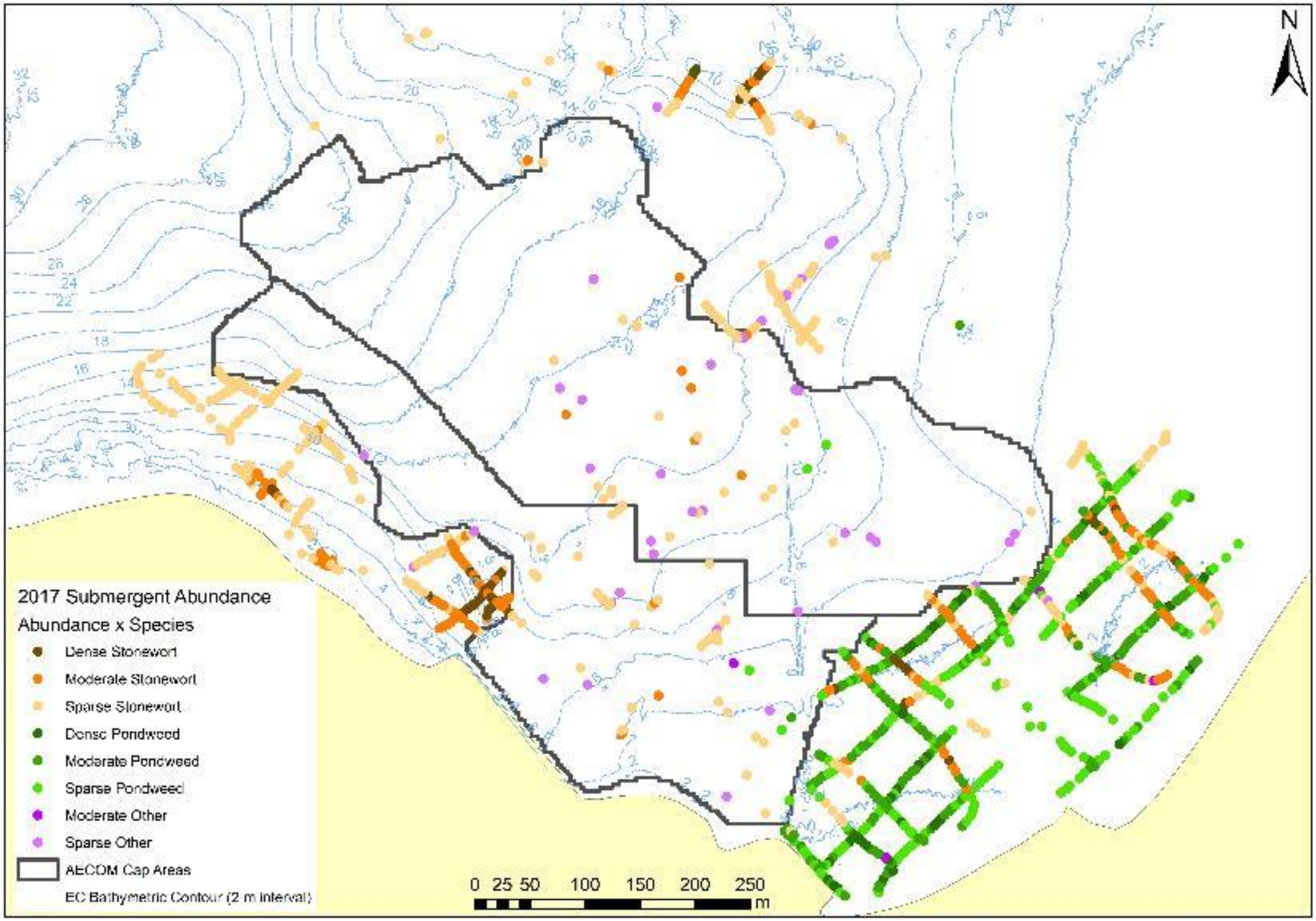

Figure 35. Distribution of 2017 submerged aquatic vegetation by species and abundance.

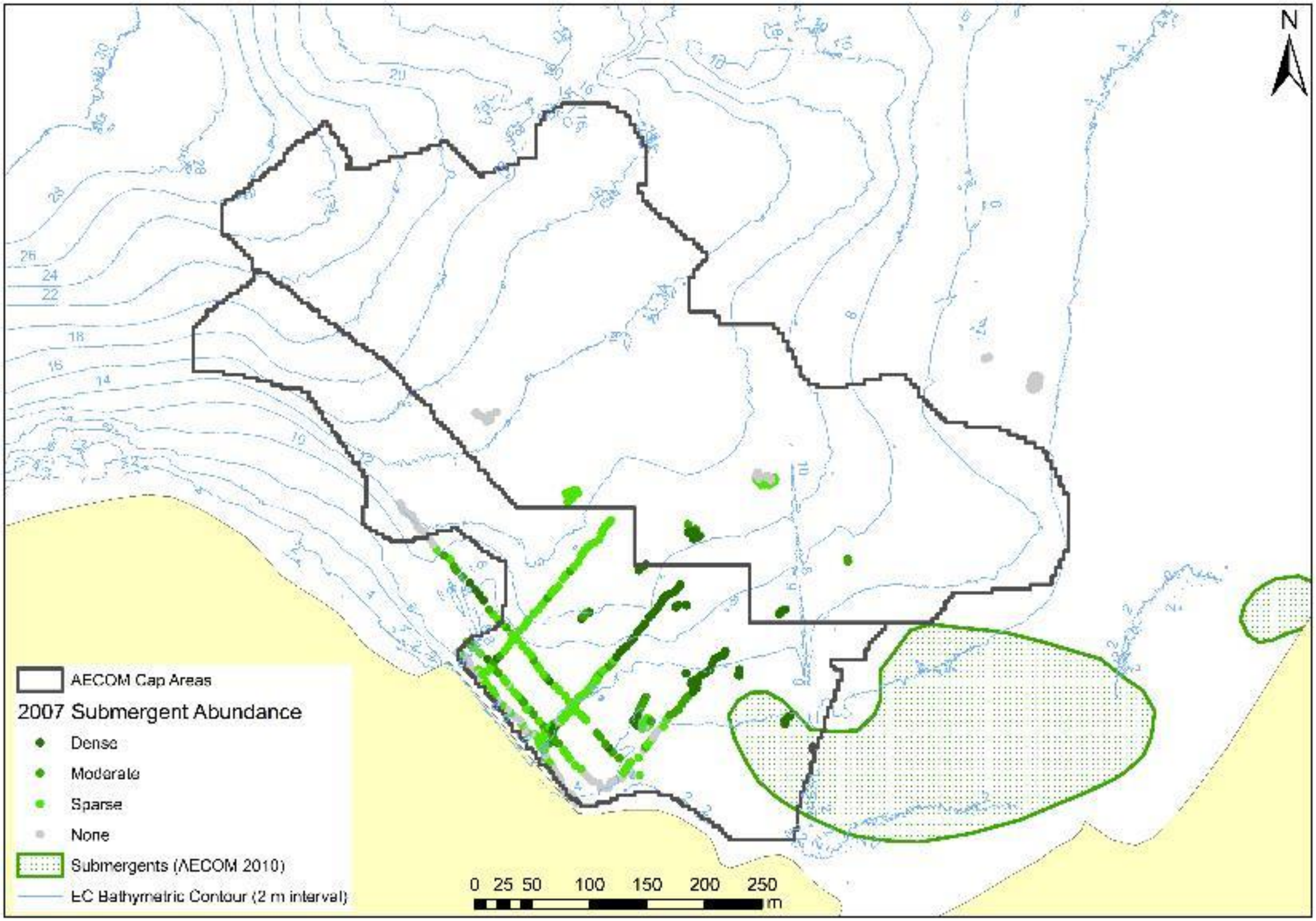

Figure 36. Distribution of 2007 submerged aquatic vegetation prior to capping based on Environment Canada underwater video (Foster and Harris 2011).

3.3 Other Features

No live fish were observed on the 2017 underwater video, although what appears to be a small, dead fish (unknown species) was observed (Figure 37). No other animals were observed in 2017 video. Several live amphipods were observed in ponar grab #4 just inside the cap in approximately 7 m of water.

Figure 37. Small dead fish observed outside the cap zone.

Underwater video showed extensive amounts of pulpwood and bark on the bottom of Jellicoe Cove in and near the cap (Figure 38, Figure 39,) from log booming in Peninsula up until 1987 (AECOM 2012). In 2017, logs were observed in 4.8% (n=124) of the 2561 interpretable images in the cap. This is approximately half the abundance of logs within the cap that were observed in 2013 (8.4% of 2560 images)(Figure 43). Much of the difference is from fewer logs observed in 2017 in deeper water (>20 m) in the northwest part of the cap, where visibility was poor in 2017. Frequency of logs in video from outside the cap remained similar in 2017 compared to 2013. In 2017, 9.5% of the 2863 images from outside the cap had visible logs compared to 9% of the 2482 images from outside the cap in 2013. Occurrences of logs within the cap were generally sparse; most of the large concentrations of logs were found outside of the cap to the northeast (Figure 42).

Figure 38. Abundant pulp logs in deep water outside cap zone (Image #1693, left) and bark deposits associated with pulpwood logs (Image 1305, right).

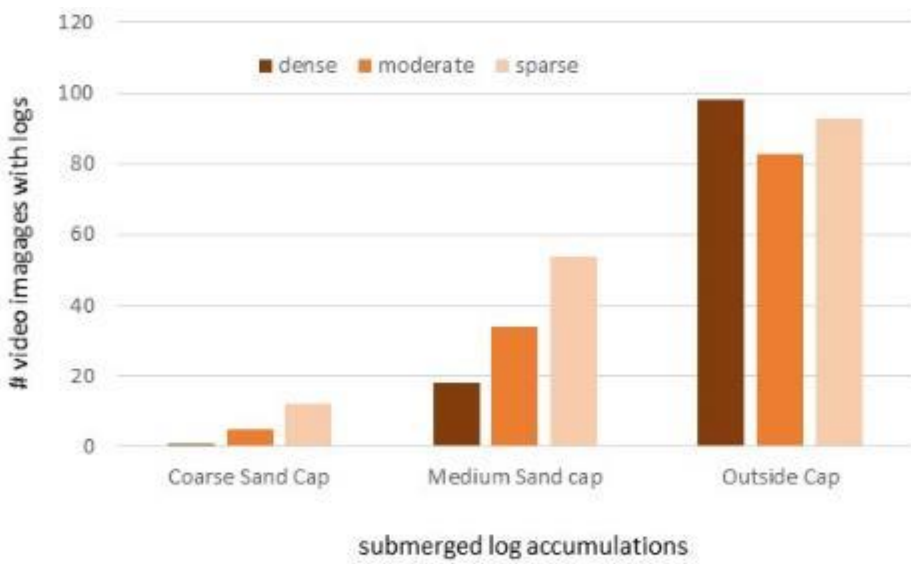

Figure 39. Abundance of submerged pulp logs in and outside the Jellicoe Cove cap.

In 2017, bark was observed in 5% (132/2561) of the cap images, compared to 9% (267/2863) images outside the cap. Bark was typically associated with pulpwood logs, often accumulating in sheltered depressions amongst or immediately adjacent to logs (Figure 42). Bark was also observed on firmer, sandy substrates; it may have been present on siltier substrates in deeper water where it had been covered over with a flocculent layer of silt. In 2013, bark was observed only in about 1% of the cap images and 5% of images from 4.8% outside the cap (Figure 43), despite a similar number of images. Small woody debris was rare throughout the cove, with sticks visible in only one image in 2017; sticks were rare in video images from 2013 as well. The cause of this apparent increase is unknown, since there have been no recent inputs of bark to Jellico Cove. Most of the apparent increase in bark in interpreted images was in the southeast corner of the cap in approximately 6-8 m of water, and it is possible that bark from sources near logs outside the cap has been displaced on to the cap by wave action during storms.

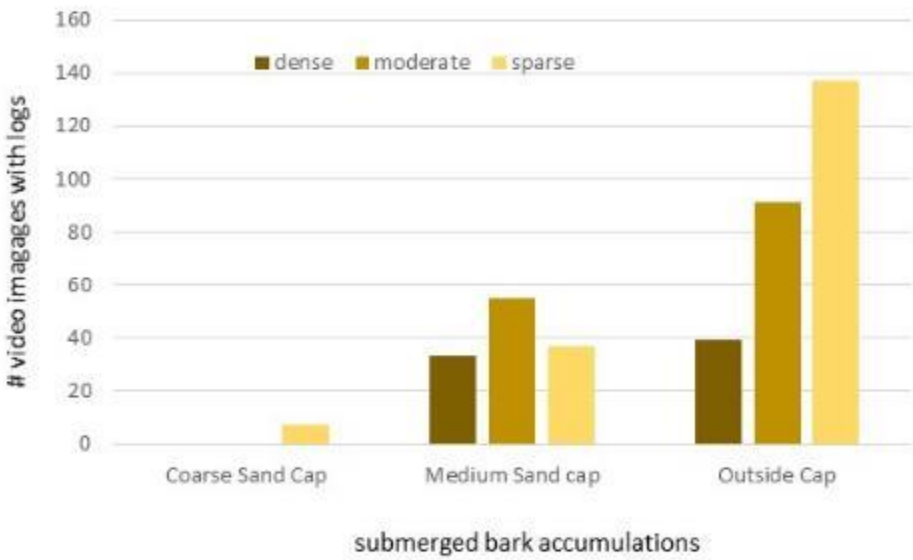

Figure 40. Abundance of submerged bark in and outside the Jellicoe Cove cap.

In 2017, approximately 25 images had identifiable industrial objects or debris, including the large diameter pipe, and cribbing that was a former intake or outtake for the mill (Figure 41, Figure 42). In 2013, approximately 50 images (mainly outside the cap) had image with manmade debris – the difference can be attributed to slight different positioning of transects in the field and possibly from some being buried by silt in the intervening time.

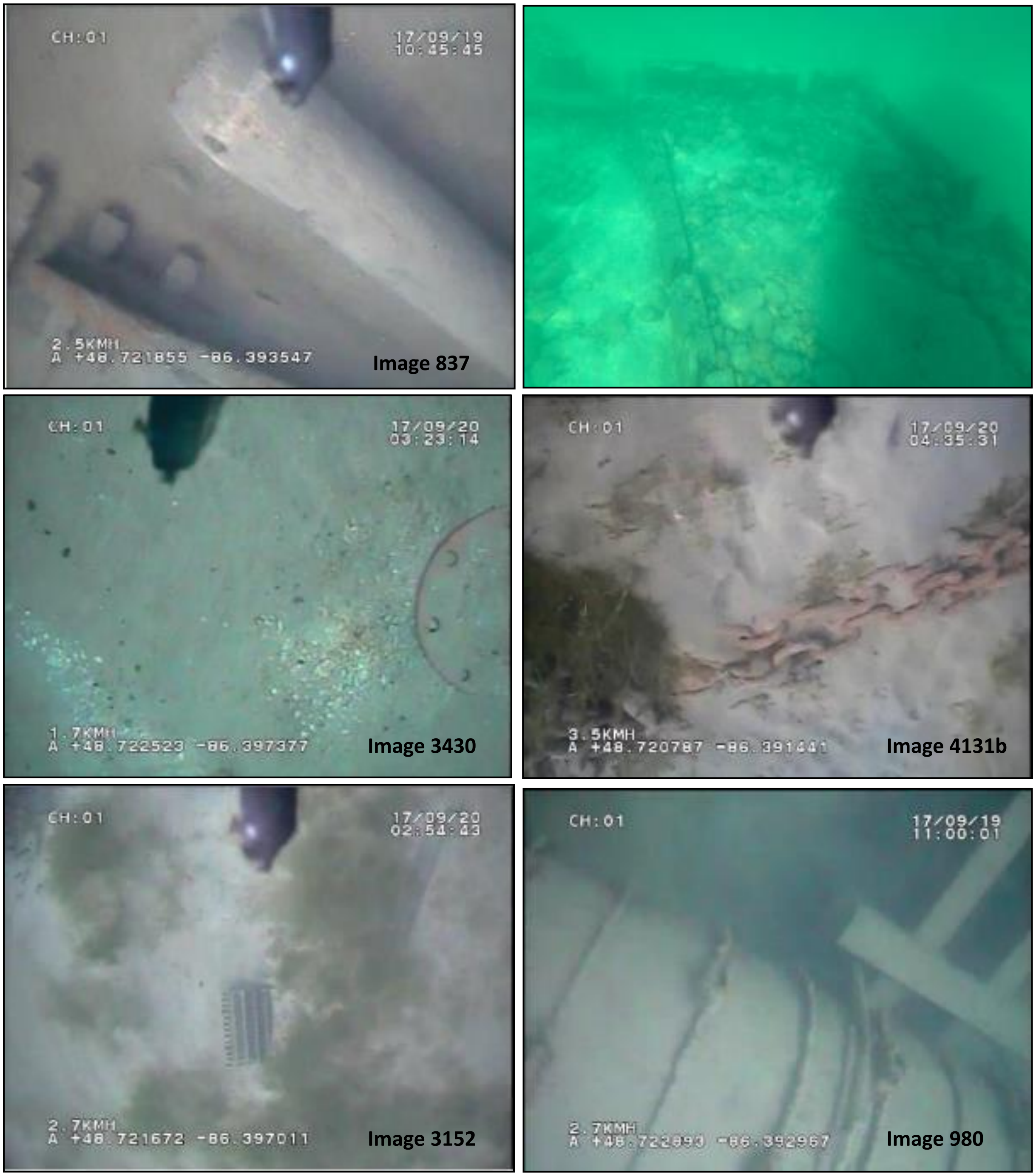

Figure 41. Industrial debris southeast of cap and large water intake pipe observed in cap zone.

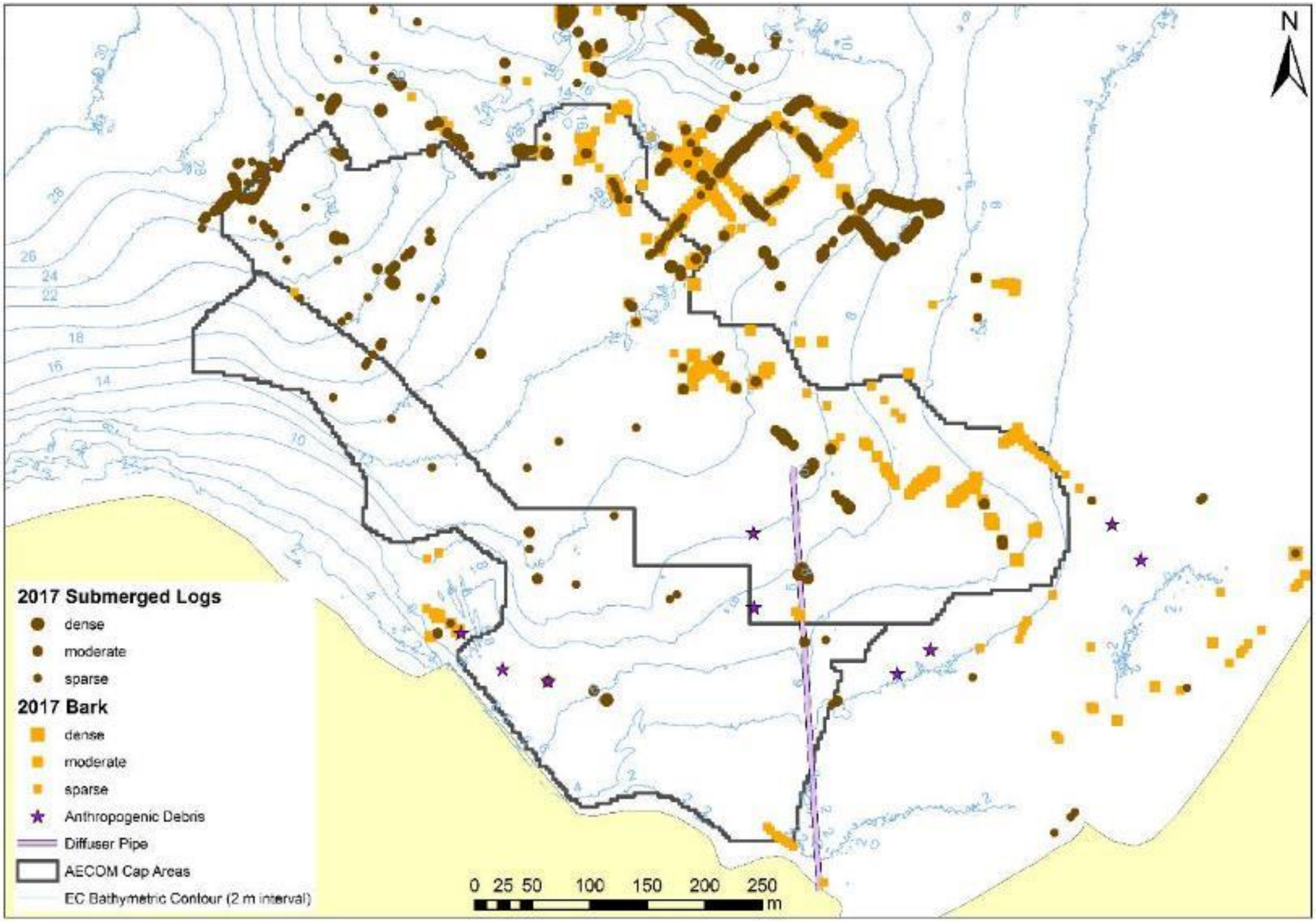

Figure 42. Distribution of coarse woody and anthropogenic debris in and near the Jellicoe Cove cap based on interpretation of Year 5 2017 underwater video.

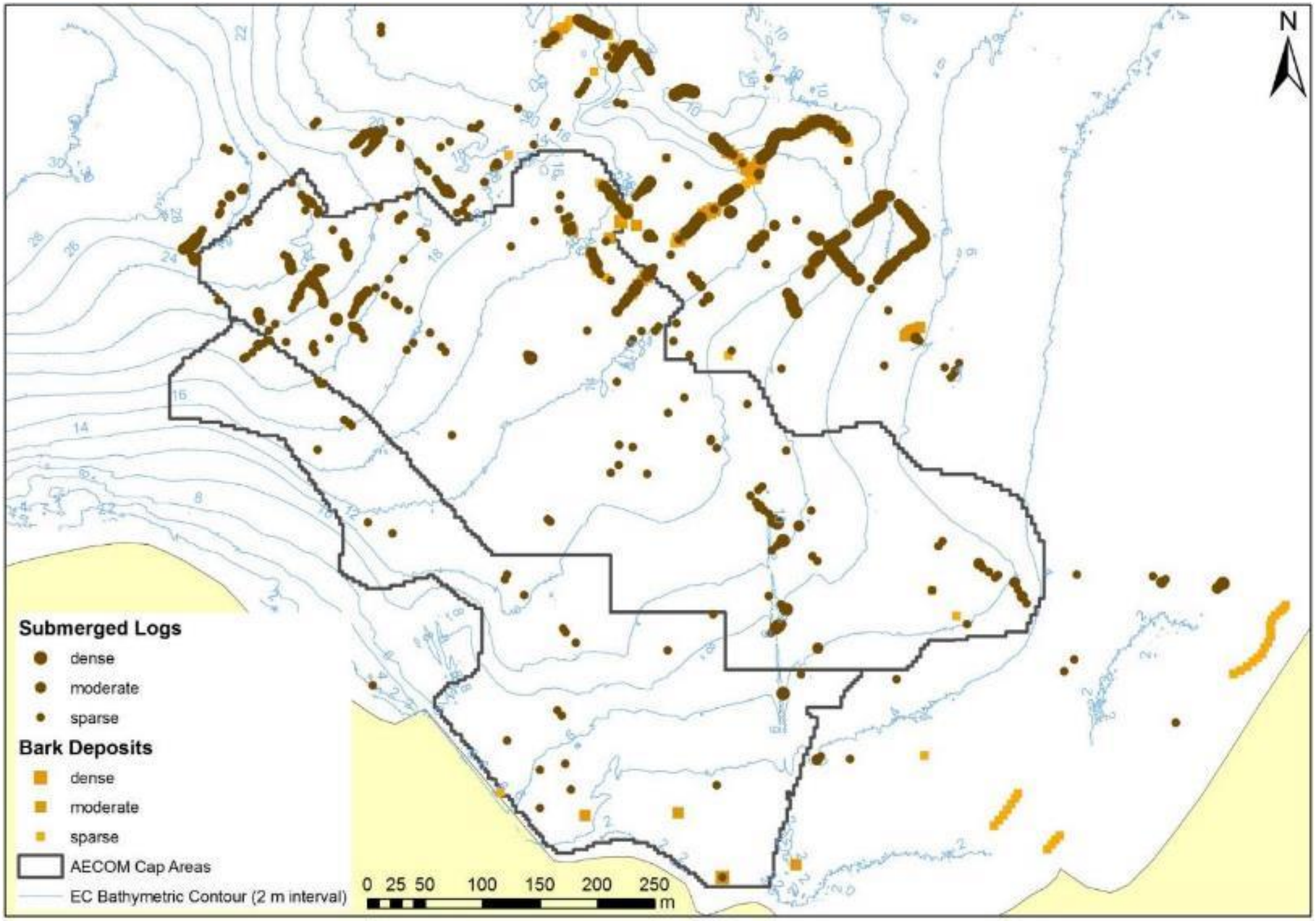

Figure 43. Distribution of coarse woody debris in and near the Jellicoe Cove cap based on interpretation of 2013 underwater video.

4 Summary and Conclusions

Monitoring in 2017 indicate that there has very little cap mobilization in in the five years post-capping and a fine layer of silt has accumulated over the coarse and medium sand cap material in much of the cap, reducing the risk of contaminants being biologically active. The initial capping in 2012 greatly reduced aquatic macrophyte abundance in the proposed cap area, which was the most significant negative impact due to reduced habitat suitability for fish (Foster and Harris 2011). Immediately post-capping, there was very little of the original submergent vegetation remaining in the cap, and one year later there was little regeneration of submergents. However, monitoring in 2017, five years post-capping has shown increased distribution and abundance of submergents within the cap. Although submergents are still limited compared to pre-capping abundance, continued natural silt deposition will likely improve substrate conditions for submergents and the recovery trend is expected to continue. Continued monitoring (e.g. Year 10 in 2022) will be required to track submergent recovery over the medium term.

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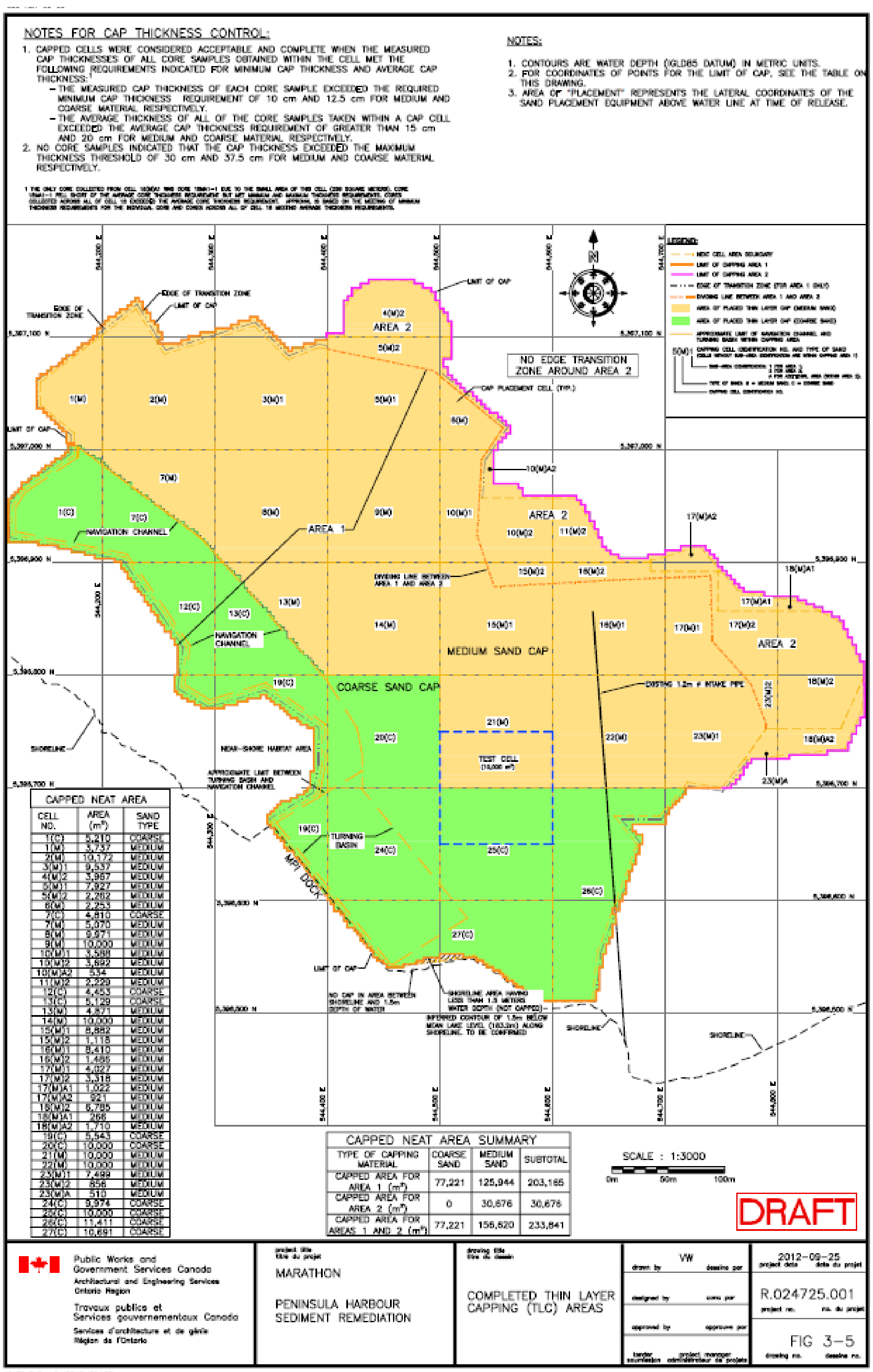
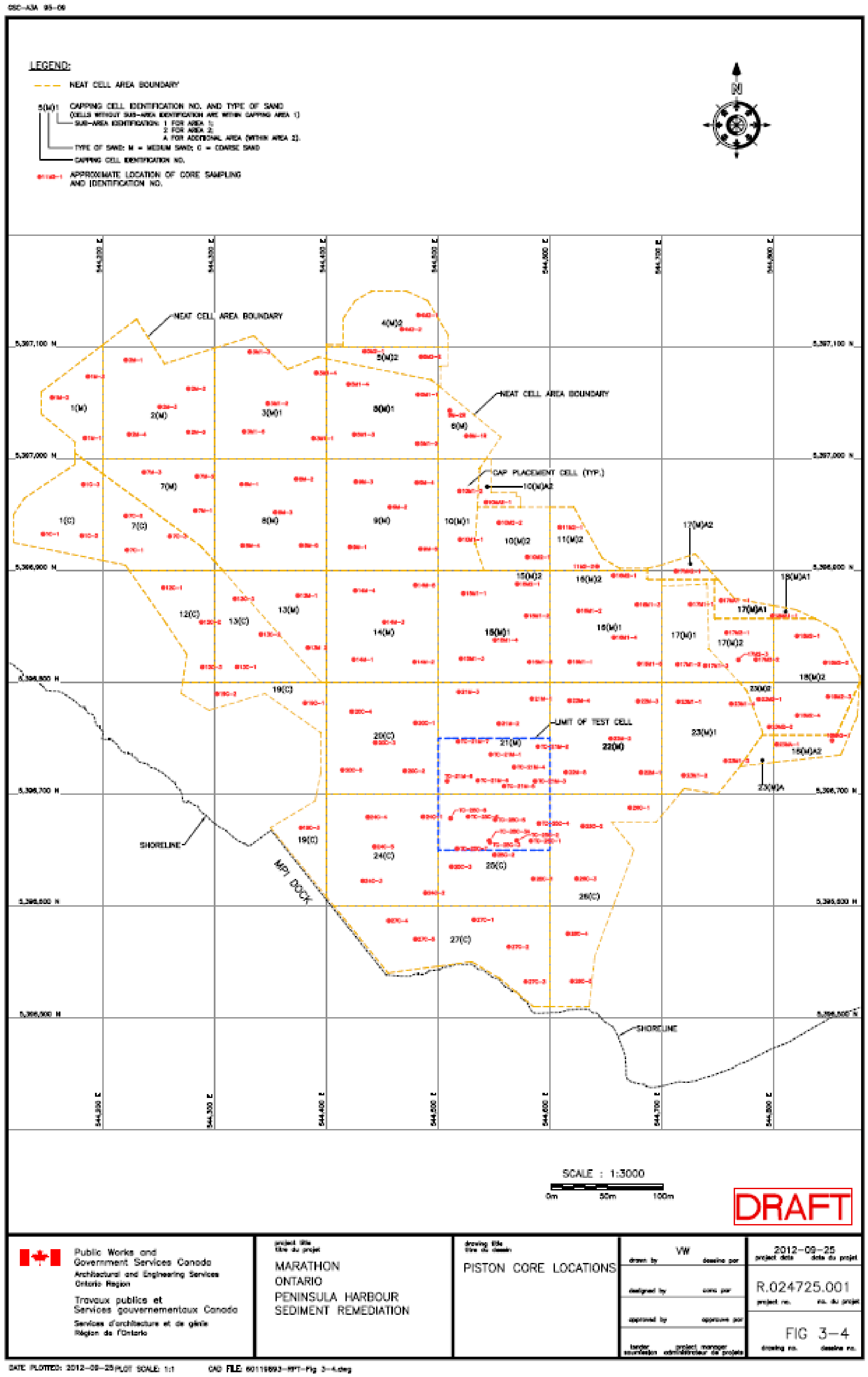
Appendix 1. Completed Thin Layer Capping (AECOM 2012).



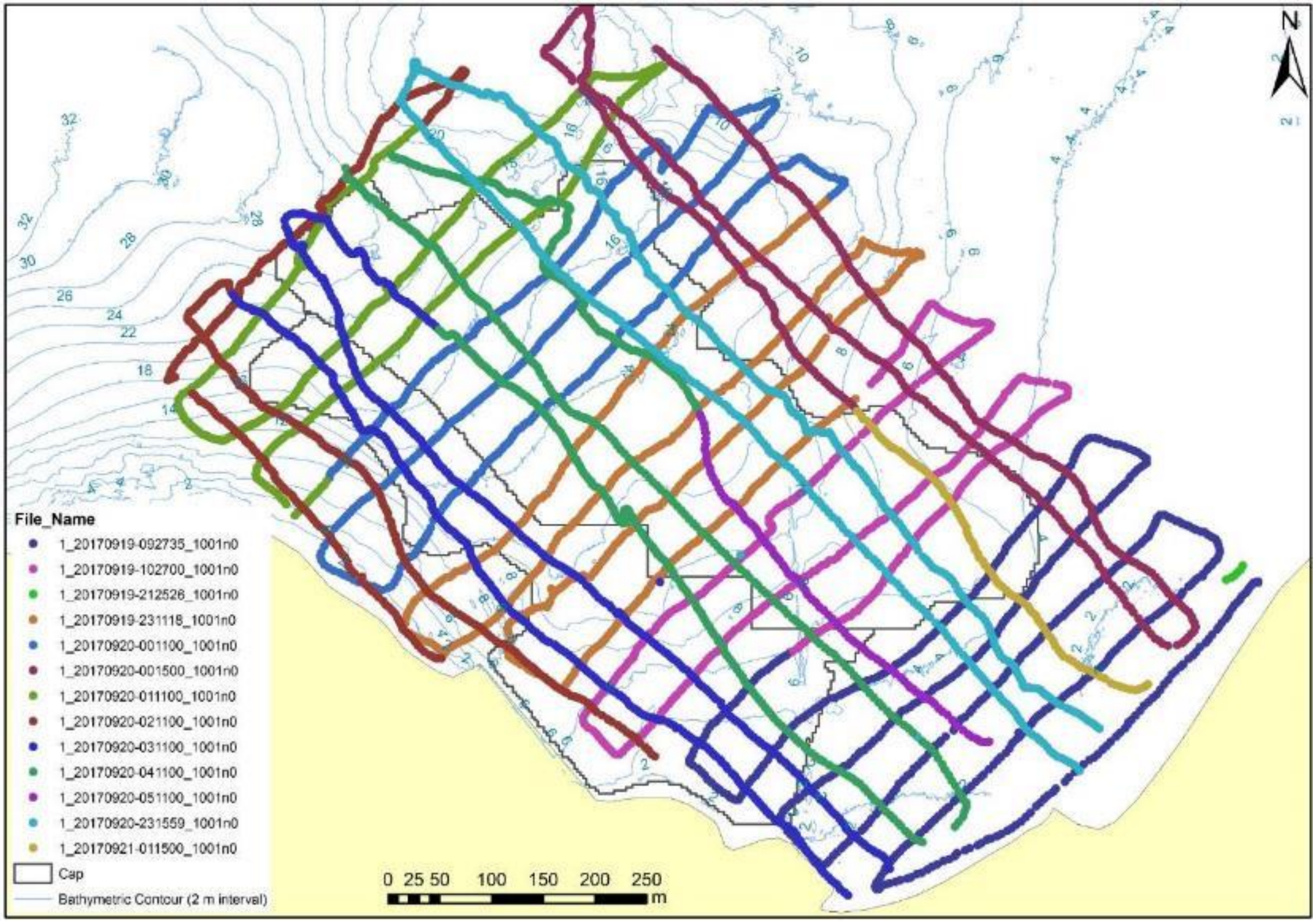
CAPPED NEAT AREA		
CELL NO.	AREA (m^2)	SAND TYPE
1(C)	5,210	COARSE
1(M)	3,737	MEDIUM
2(M)	10,172	MEDIUM
3(M)1	9,537	MEDIUM
4(M)2	3,967	MEDIUM
5(M)1	7,927	MEDIUM
5(M)2	2,262	MEDIUM
6(M)	2,253	MEDIUM
7(C)	4,810	COARSE
7(M)	5,070	MEDIUM
8(M)	9,971	MEDIUM
9(M)	10,000	MEDIUM
10(M)1	3,588	MEDIUM
10(M)2	3,892	MEDIUM
10(M)A2	534	MEDIUM
11(M)2	2,229	MEDIUM
12(C)	4,453	COARSE
13(C)	5,129	COARSE
13(M)	4,871	MEDIUM
14(M)	10,000	MEDIUM
15(M)1	8,882	MEDIUM
15(M)2	1,118	MEDIUM
16(M)1	8,410	MEDIUM
16(M)2	1,486	MEDIUM
17(M)1	4,027	MEDIUM
17(M)2	3,318	MEDIUM
17(M)A1	1,022	MEDIUM
17(M)A2	921	MEDIUM
18(M)2	6,785	MEDIUM
18(M)A1	266	MEDIUM
18(M)A2	1,710	MEDIUM
19(C)	5,543	COARSE
20(C)	10,000	COARSE
21(M)	10,000	MEDIUM
22(M)	10,000	MEDIUM
23(M)1	7,499	MEDIUM
23(M)2	858	MEDIUM
23(M)A	510	MEDIUM
24(C)	9,974	COARSE
25(C)	10,000	COARSE
26(C)	11,411	COARSE
27(C)	10,691	COARSE

CAPPED NEAT AREA SUMMARY			
TYPE OF CAPPING MATERIAL	COARSE SAND	MEDIUM SAND	SUBTOTAL
CAPPED AREA FOR AREA 1 (m^2)	77,221	125,944	203,165
CAPPED AREA FOR AREA 2 (m^2)	0	30,676	30,676
CAPPED AREA FOR AREAS 1 AND 2 (m^2)	77,221	156,620	233,841

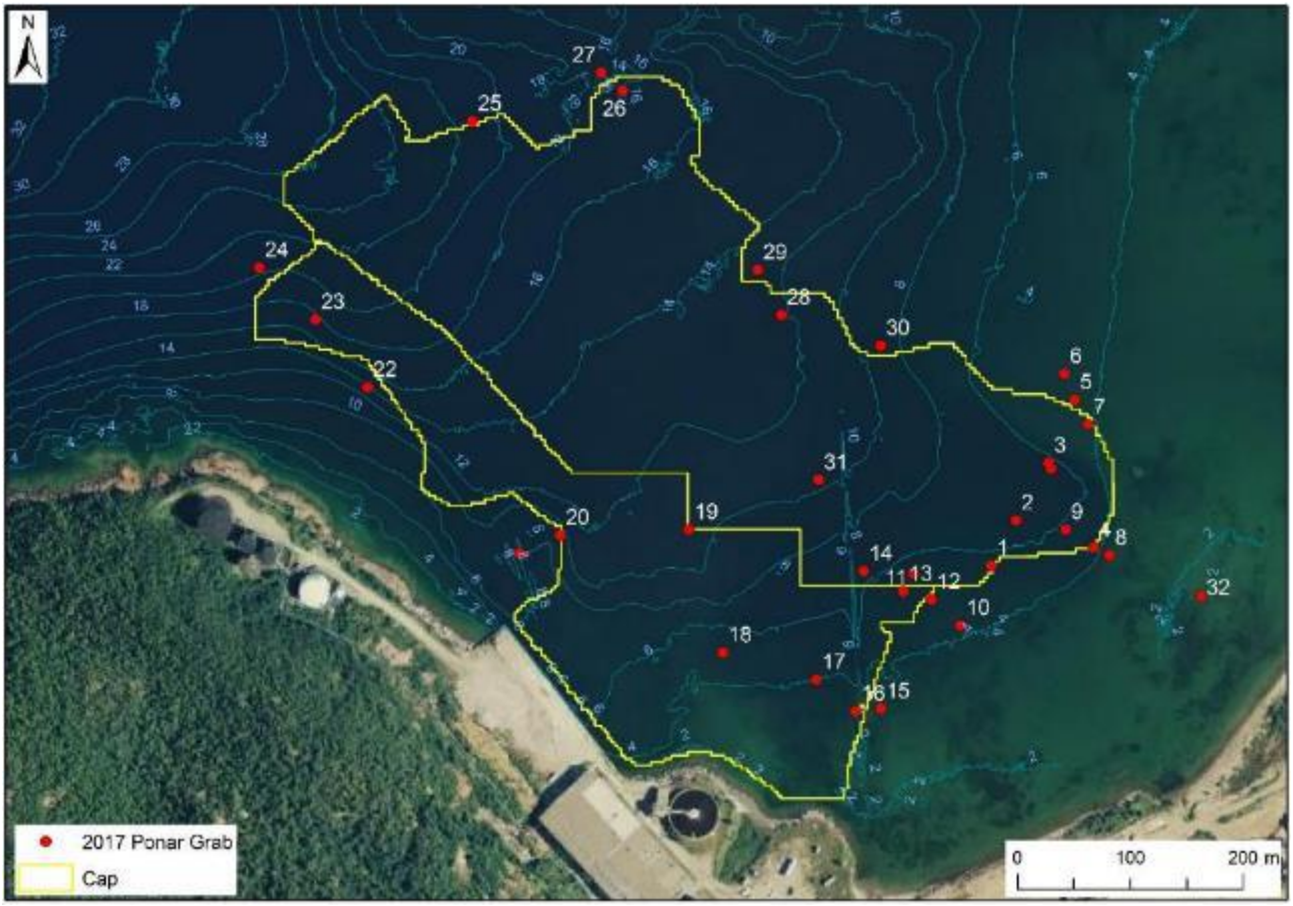
Appendix 2. Approximate location of piston core sampling to verify cap thickness (AECOM 2012).



Appendix 3. Location of 2017 video image footage by file name.



Appendix 4. Location (overlain with DFO bathymetry) and photographs of 2012 ponar grabs.




Ponar Grab #1


Ponar Grab #2

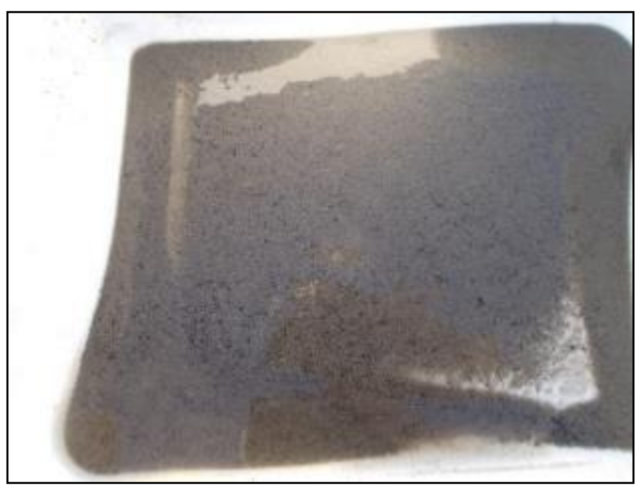

Ponar Grab #3


Ponar Grab #4


Ponar Grab #5


Ponar Grab #6


Ponar Grab #7


Ponar Grab #8

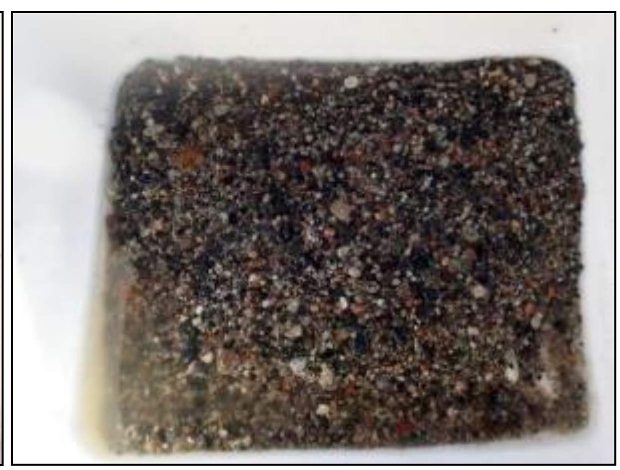

Ponar Grab #9


Ponar Grab #10


Ponar Grab #11


Ponar Grab #12

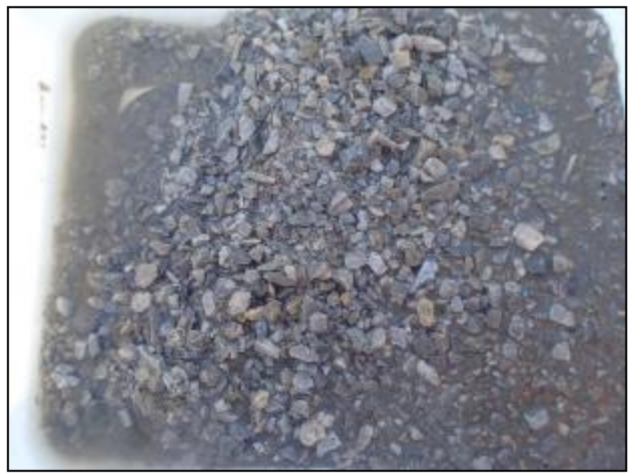

Ponar Grab #13

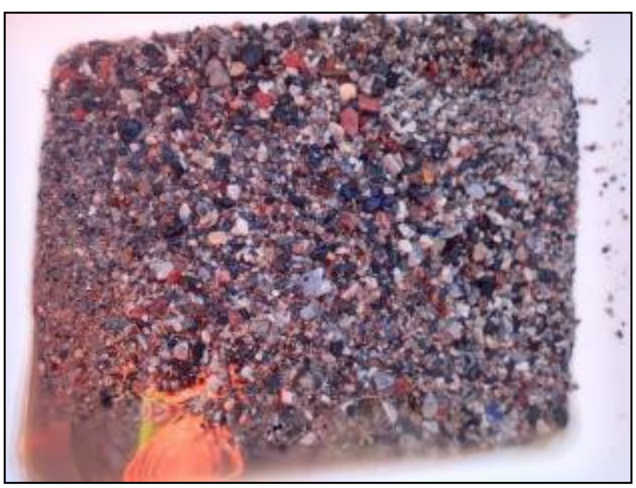

Ponar Grab #14


Ponar Grab #15


Ponar Grab #16


Ponar Grab #17


Ponar Grab #18

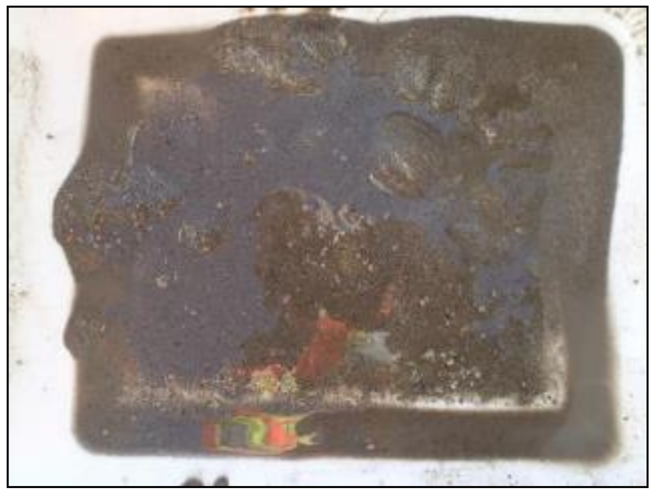

Ponar Grab #19


Ponar Grab #20

Ponar Grab #21

Ponar Grab #22

Ponar Grab #23



Ponar Grab #24

Ponar Grab #25

Ponar Grab #26


Ponar Grab #27


Ponar Grab #28


Ponar Grab #29


Ponar Grab #30


Ponar Grab #31


Ponar Grab #32

Appendix 5. Extracted 2017 video images for Peninsula Harbour.

Labels refer to unique video sample points in attached Excel spreadsheet and following photos.

#34.

#66

#103.

#106

#107

#345

#350

#352

#352B

#362

#365

#421

#430

#444

#475

#498

#509

#509b

#512

#514

#517

#571

#571b

#575

#579

#580

#716

#719

#720

#814

#837

#837b

#844

#847

#848

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#1600

#1600b

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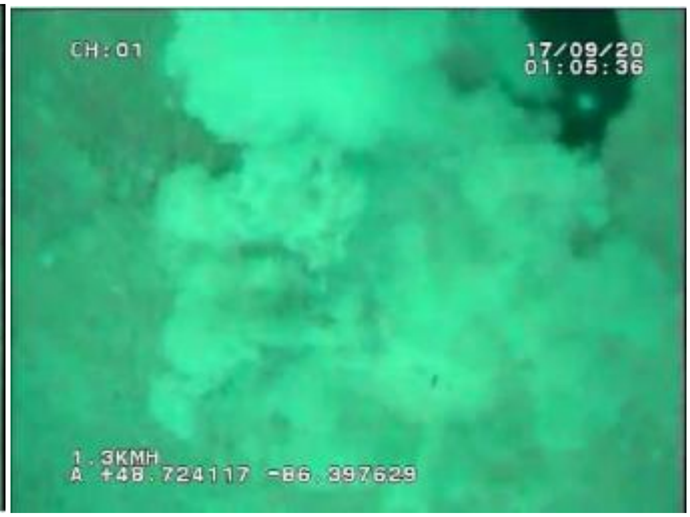

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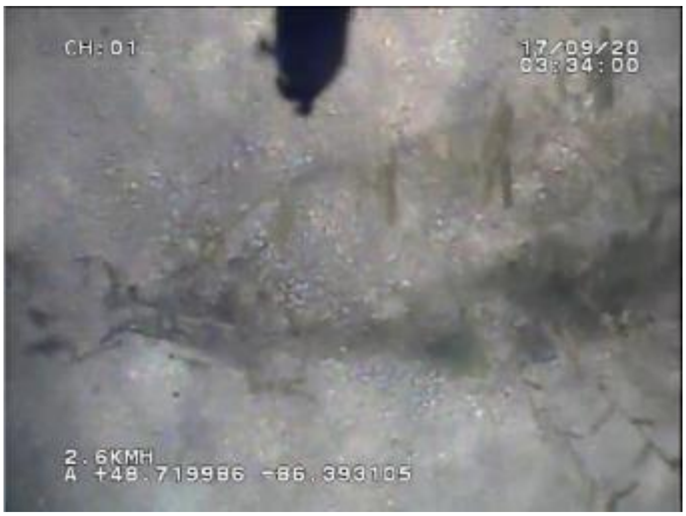
#3466



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