Appendix BB
Aquatic Environments Assessment Documentation

Appendix BB
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Marine Environment Baseline

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BOAT HARBOUR REMEDIATION PLANNING AND DESIGN PROJECT

BASELINE CONDITIONS REPORT - BENTHIC COMMUNITY - PIPELINE MARINE CORRIDOR

NOVA SCOTIA LANDS INC.

PROJECT NO.: 171-10478-00
DATE: MARCH 22, 2018

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1 CONTEXT

The Boat Harbour Effluent Treatment Facility (BHETF) became operational in 1967 and has been the primary processing system for effluent from the Kraft Pulp Mill.

The main components of the BHETF include: the wastewater effluent pipeline (over 3 km in length) that runs from the Kraft Pulp Mill and extends eastward, below the East River of Pictou (East River), to the BHETF property; twin settling basins and an Aeration Stabilization Basin (ASB) west-southwest of Boat Harbour; and the stabilization lagoon (Boat Harbour). Effluent from Boat Harbour discharges through a dam (northeast of Boat Harbour) into an estuary before being released to the Northumberland Strait. Prior to the construction of the twin settling basins and ASB, effluent was routed by open ditch from the pipeline on the east side of Highway 348 to a natural wetland area (Former Ponds 1, 2, and 3) before being discharged into the stabilization lagoon.

Over the operational period of the mill, many concerns have arisen for human and environmental safety. As a result of these concerns, remedial plans have been initiated. Prior to the treatment planned for the remediation, baseline conditions of the BHETF and the surrounding area, including habitat (substrate, presence/absence of aquatic vegetation) as well as macrobenthos and fish presence, are required to assess how remedial activities could impact the surrounding population and natural environment.

In this context, GHD retained WSP Canada Inc. (WSP) to conduct the key marine studies and assessments required as a complement to the Boat Harbour Rehabilitation Project (BHRP or Project).

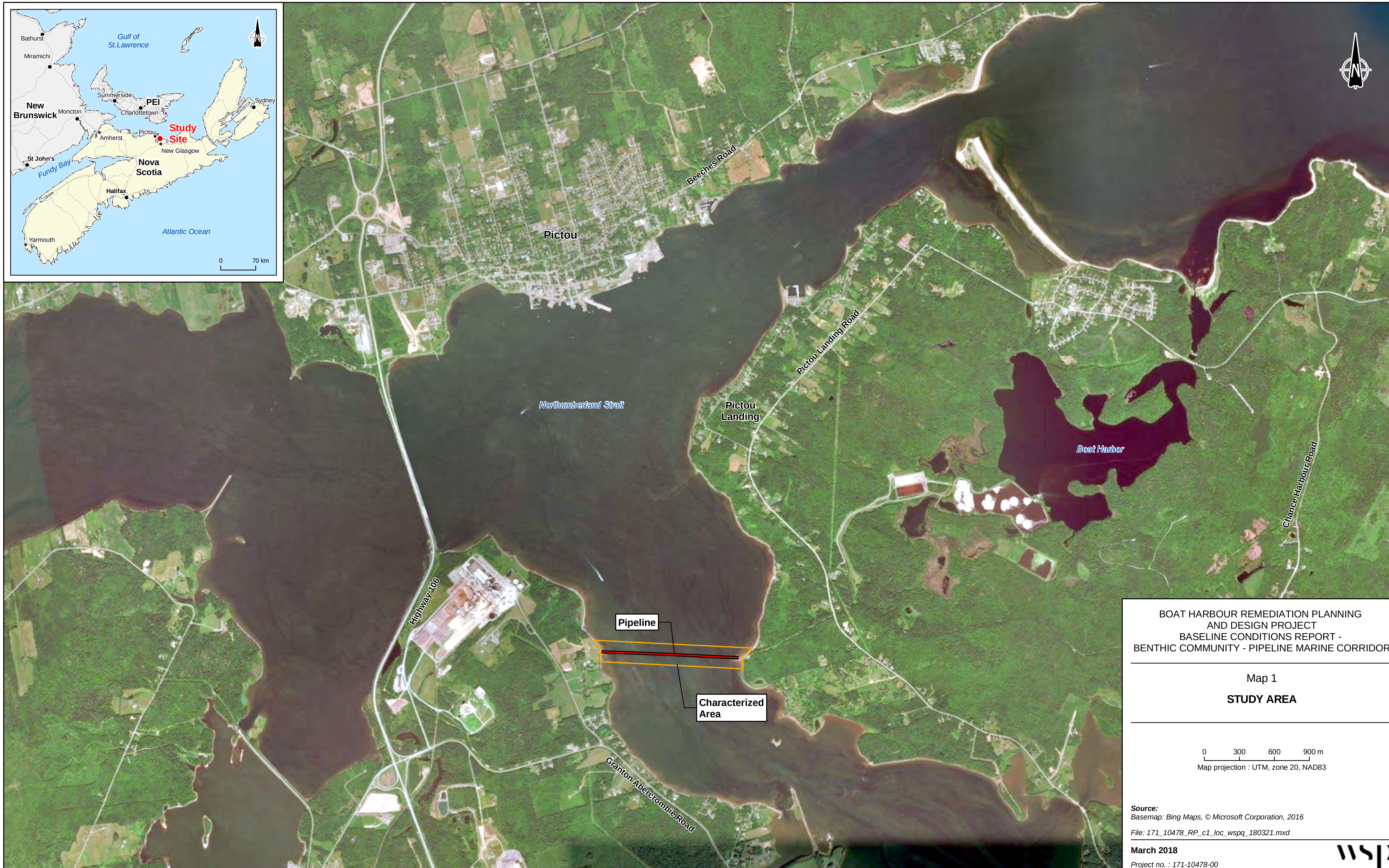
This report presents a first assessment, to define an overall picture of benthic habitat characterization before any work intervention on the pipeline.

1.1 OBJECTIVE

The main objective of this characterization is to describe marine habitats as well as the benthic community structure, density, diversity and species richness. Data collected during the 2017 field survey was used as a baseline to assess habitat recolonization following any intervention.

2 STUDY AREA

For the present project, the study area was limited to the pipeline section, which is about 1200 m long in the Northumberland Strait and oriented on an east-west axis. The surveys covered about 100 m on both sides of the pipeline. The study area is presented on Map 1.



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Map 1

STUDY AREA

0 300 600 900 m

Map projection : UTM, zone 20, NAD83

Source:
Basemap: Bing Maps, © Microsoft Corporation, 2016

File: 171_10478_RP_c1_loc_wspq_180321.mxd

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3 METHODS

3.1 BATHYMETRIC SURVEY

A bathymetric survey was performed on November 8, 2017, by a technician and a coastal engineer using a GPS-RTK, and, since the water depth on the site was generally shallow, a singlebeam echo sounder (5 cm precision). The data were georeferenced with a benchmark installed at the Boat Harbour prior to WSP's field campaign. All elevations are relative to the geodetic datum (CGVD2013). The area covered for this survey is about 100 m wide on each side of the pipeline axis. Bathymetric sampling has been completed following a 20 m spacing between survey lines (Map 2).

3.2 HABITAT CHARACTERIZATION

In order to get a complete description of the marine habitat present on the pipeline area, underwater video surveys were conducted on November 8, 2017, by a biologist and a professional diver. Two different techniques were used, which are transects and quadrats over the pipeline axis. The images were recorded on about 100 m wide on each side of the pipeline axis using an Axsub camera (model AxSee 57) fitted on a telescopic pole.

The video sequences were viewed by a specialist skilled for the identification of benthic invertebrates. For each sequence (transect or quadrat), the number of organisms (macrofauna and macroflora) was determined and a percentage cover was attributed to each class of substrate present (according to the grain size description table presented at Appendix A).

In addition to the underwater surveys, conductivity, temperature, and turbidity (CTD-Tu) profiling was conducted using a CTD-Tu probe (model RBR concerto). These profiles provide salinity, temperature and turbidity relative to depth through the water column. CTD cast were performed at two stations, at low and high tide (Map 2).

3.2.1 QUADRAT SAMPLING

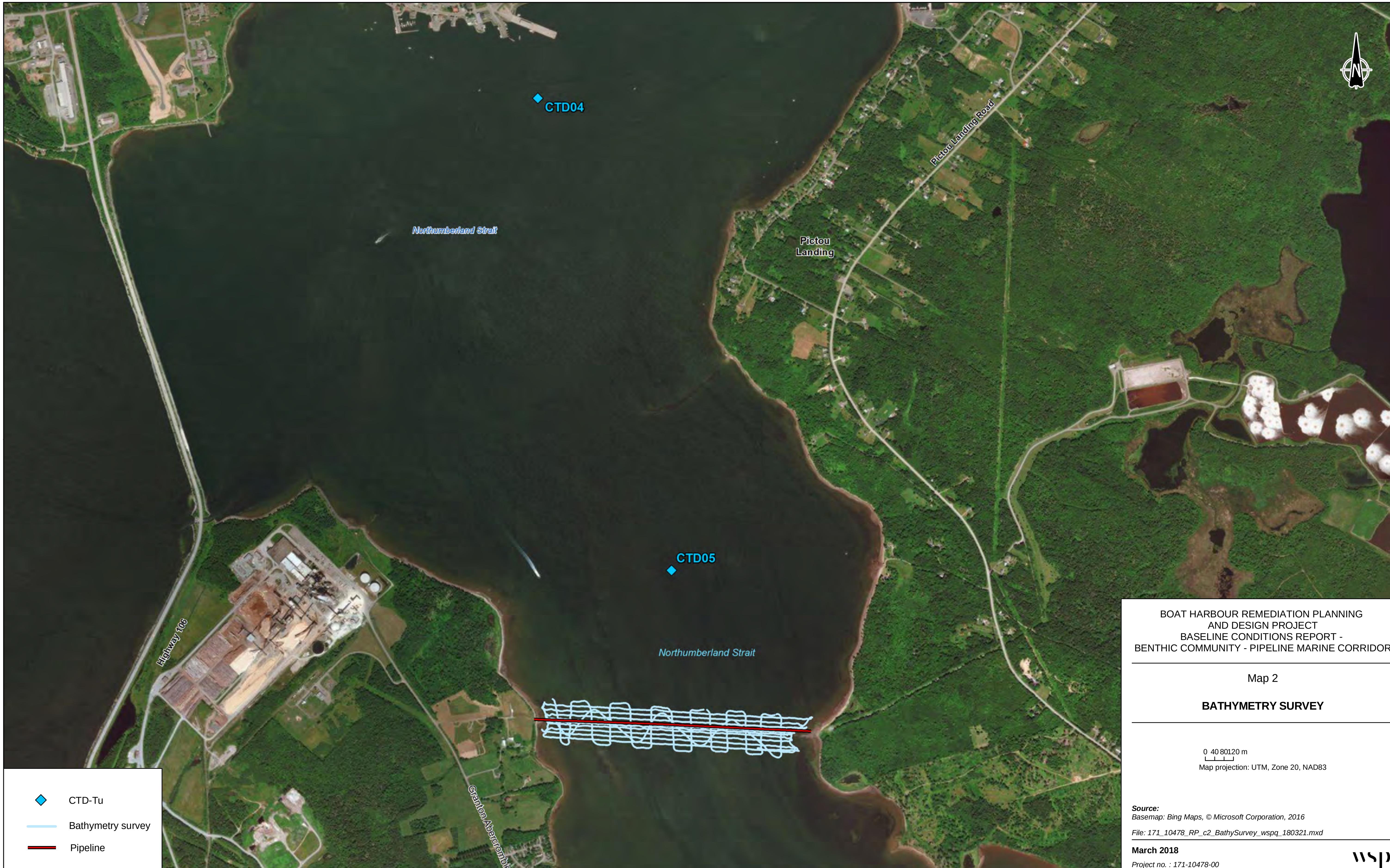
Prior to the field campaign, nine stations were positioned on the pipeline section (B1 to B9, Map 3). A handheld GPS (Garmin 78S) was used to position the boat on these locations, which was then anchored to allow the capture of still images. A 50 x 50 cm metal quadrat was dropped on the sea bottom and a video sequence was recorded.

Since the field surveys were done at high tide, the intertidal zone was only accessible by boat. Therefore, this area was characterized using the same technique on four more quadrats that were added closer to the shore (Q1 to Q4). Their geographic locations were acquired with a GPS and are presented on Map 3.

3.2.2 TRANSECTS

The first transects were recorded over the course of the pipeline from the eastern shore towards the west. However, on the day of sampling strong winds were blowing towards an opposite direction, making it difficult to maintain a straight trajectory at a speed slow enough to allow the identification of organisms on the images. Therefore, for the areas that were more exposed to the wind, transects were filmed over each of the quadrats on a perpendicular trajectory of the pipeline. During each sequence, a GPS was used to track the course of the boat and of the recorded area.

Approximately 1900 m of video (14 transects, length at Table 2) was recorded to characterize the seabed. Transects 1 to 7 were completed along the pipeline axis, whereas transects 8 to 14 were localized perpendicularly to the structure to ensure a good coverage of the habitat.



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Map 2

BATHYMETRY SURVEY

Source:
Basemap: Bing Maps, © Microsoft Corporation, 2016

File: 171_10478_RP_c2_BathySurvey_wspq_180321.mxd

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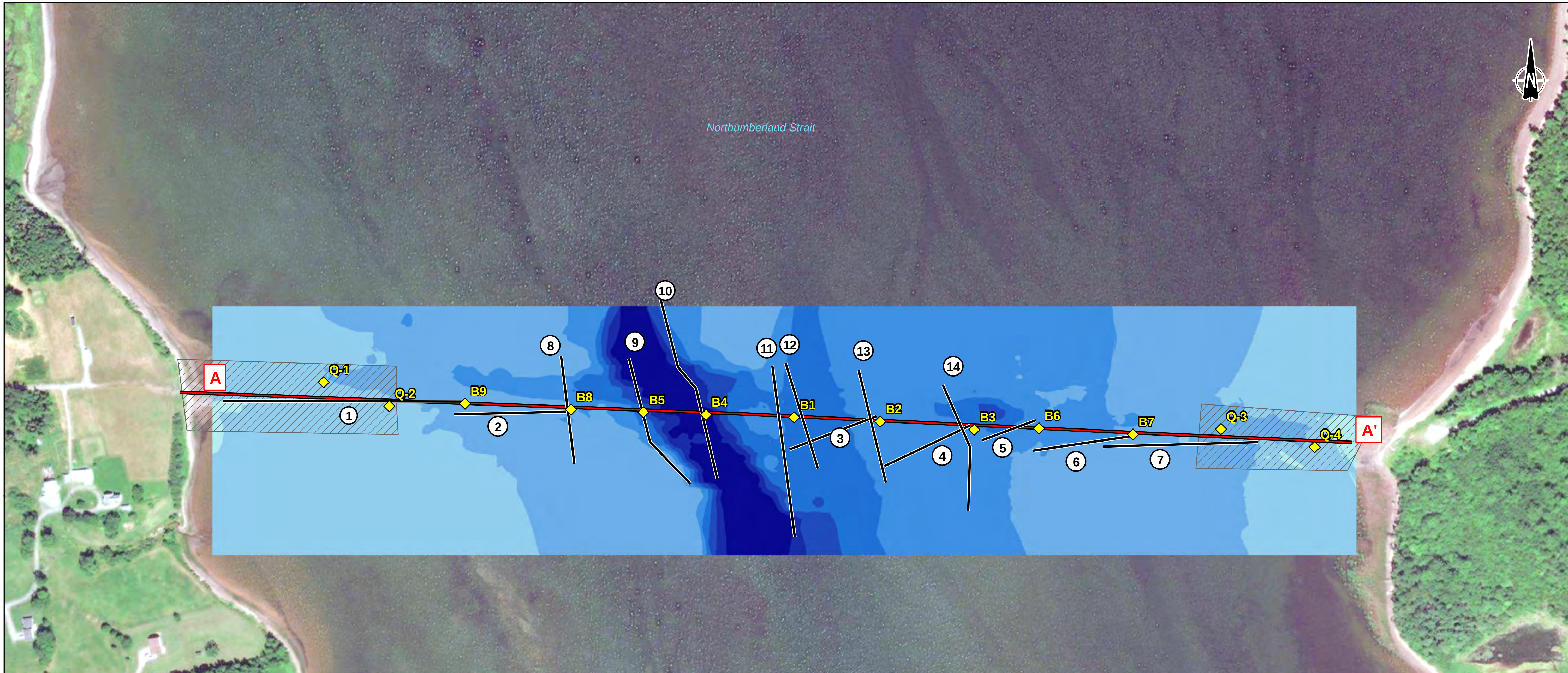


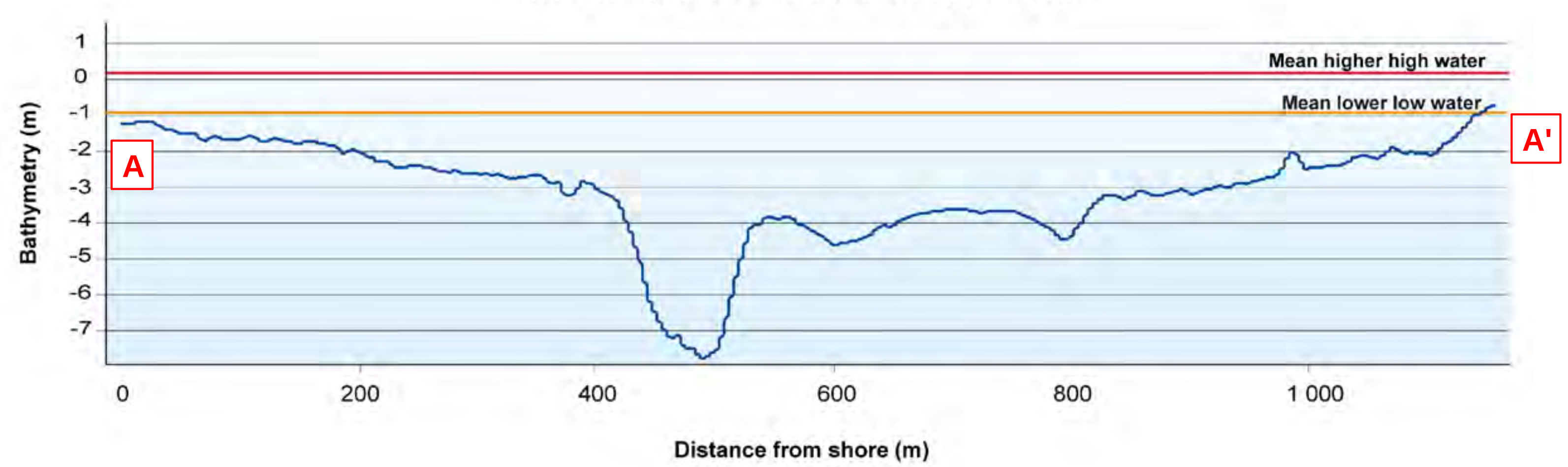
Project components

- B5 Quadrat
- 13 Transect number
- Transect
- Pipeline
- Intertidal zone

Bathymetry (meters)

- -8 to -7
- -7 to -6
- -6 to -5
- -5 to -4
- -4 to -3
- -3 to -2
- -2 to -1
- -1 to 0

Cross section of the water depth on the pipeline axis



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Map 3

TRANSECTS AND QUADRATS SAMPLED OVER THE PIPELINE SECTION

0 40 80 120 m

Map projection: UTM, Zone 20, NAD83

Source:
Basemap: Bing Maps, © Microsoft Corporation, 2016

File: 171_10478_RP_c3_pipeline_wspq_180321.mxd

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3.3 BENTHIC SAMPLING

Sediments were collected using a Ponar grab sampler (231.04 cm^2) for three composite samples at each of the nine stations (B01 to B09). The samples were sieved to obtain a 1 mm mesh size and preserved in formaldehyde until their analysis and the identification of the organisms at the genus level. Identification were performed by Laboratoire SAB inc. Identification was done to the lowest taxonomic level possible and an electronic database was then provided by the laboratory. Data were converted into density (abundance per m^2) for subsequent analyses.

3.4 DATA ANALYSIS

Diversity indices were calculated for the purpose of comparing the diversity between the different stations. The values obtained for each sample are presented in Table 3. The lab results were treated with Primer-E7 software (Clarkes and Gorley, 2015) to calculate indices using the following formulas:

Simpson's Diversity Index:

$$D = 1 - \sum_{i=1}^{S} (p_i)^2$$

Where: D = Simpson's Diversity Index

S = Total number of taxa at the station

pi = Proportion of a given taxon at the station

The values of this index are between 0 and 1, where 1 indicates the maximum diversity.

Pielou's evenness index, which is a measure of the relative abundance of the different taxa:

$$J' = -\sum (p_i * (Log)p_i)/LogS$$

Where: J' = Pielou's Evenness Index

S = Total number of taxa at the station

pi = Proportion of a given taxon at the station

The values of this index are between 0 and 1, where 0 indicates that a single taxon is present for a given sample and 1 indicates that all taxa in a sample are equally abundant.

3.5 SUBSTRATE PARTICLE SIZE

As for sampling done for the benthic organism analysis, sediment was collected with the Ponar grab at each of the nine stations along the pipeline axis for a particle size analysis. The sediments collected were analyzed at the Laboratoire de Géomorphologie et de Sédimentologie of Laval University. The material was first dried in a heat chamber for more than 12 hours and then dry weighed. The samples were sieved for a period of 10 minutes to ensure that all the aggregates were separated. A visual verification was then made using a binocular magnifier to confirm that the coarser particles were not aggregates. The fine fraction was finally measured using a Horiba laser granulometer.

4 RESULTS

4.1 BATHYMETRIC SURVEY

The data recorded during the bathymetric surveys allowed the production of the isobaths presented on Map 3 (elevation relative to CGVD2013 datum). The water depth is generally shallow and the slope from the shore towards the middle of the channel is moderate. The deepest section of the pipeline axis reaches about 8 m and is located slightly to the west of its center; it corresponds to the navigation channel of the East River of Pictou.

4.2 HABITAT CHARACTERIZATION

The description of the marine habitat of the pipeline section was based on the analysis of the type of substrate present. A first qualitative substrate characterization was done by image analysis. The images recorded on the quadrats and transects showed that the habitat is overall quite similar for the whole site and seems to generally consists of sand/silt with lesser amount of gravel, cobble and pebble.

Four quadrats located on the shallow area near the shore (B6, B7, Q1 and Q3) also had an important cover of seaweed debris, while quadrat Q2 was covered at 90% with shell debris. Gravel was found in low abundance on six transects located mostly closer to the shore while coarser substrate (cobble and boulder) was scarcely seen on transects 1, 3 and 6.

Table 1 Type of Substrate Present on Quadrats and Transects Characterized along the Pipeline Axis (Qualitative Characterization (Cover %))

Stations			Algae	Silt/Sand	Gravel	Pebble	Cobble	Boulder	Shells
Quadrats		B1		100					
		B2	20	80					
		B3	20	80					
		B4	10	80					10
		B5		100					
		B6	60	40					
		B7	60	40					
		B8	20	80					
		B9	20	70					10
		Q1	80	20					
		Q2	10						90
		Q3	90	10					
		Q4	20	10	30	20	10		10
Transects	East-west	1	15	30	10	5	10		30
		2	10	70	10				10
		3	10	80				1	9
		4	10	80					10
		5	20	70					10
		6	10	60	10			1	19
		7	10	60	20				10
	North-south	8	10	50	20				20
		9	10	70					20
		10	10	70	10				10
		11	10	80					10
		12	10	80					10
		13	20	70					10
		14	20	70					10

Water Depth (m)

0 - 3	
4 - 6	
7 - 8	

More precisely, granulometric analysis was completed on seven stations (B1 to B7) to define substrate type among the habitat.

The results of the particle size analysis show that sediments are mainly composed of silt (3.9 – 62.5 µm) with an average proportion of 85.2%. Since no clay was found, the remaining fraction, which accounts for 14.8%, represents coarser substrate. For most of the samples, this fraction only counts very fine and fine sand. While, the medium sand to the very fine gravel accounts for 20.3% for sample B7, the medium gravel that was found in sample B6 accounts for 6%. Those two facts explain the distance between samples B6 and B7 from the rest of the samples on Figure 1. Results details (analysis certificates) are present in Appendix B.

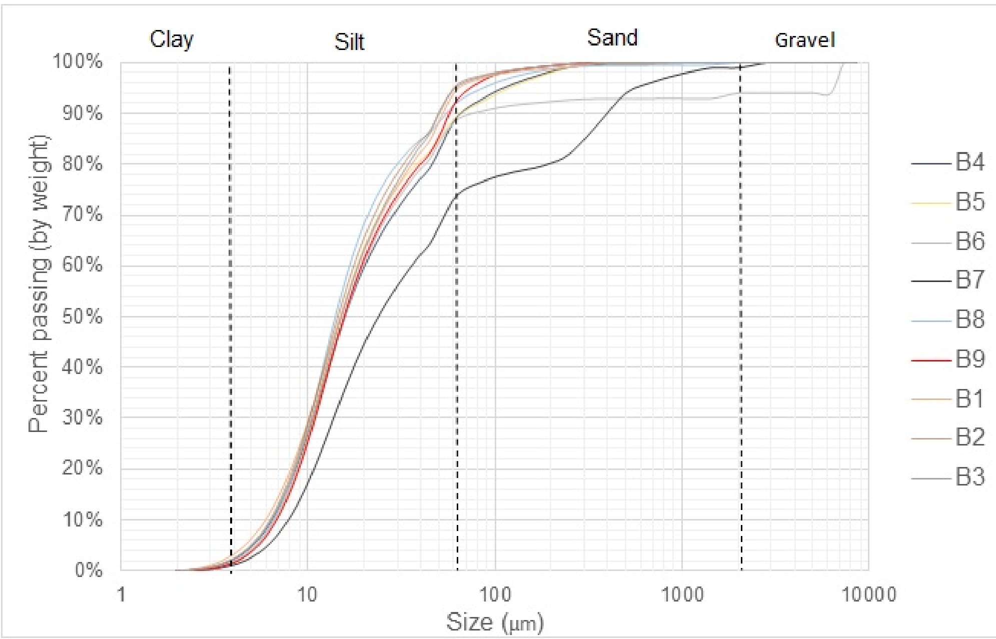


Figure 1 Cumulative Percentage of the Particle Size for WSP Samples Collected on the Pipeline

Also, CTD profiling was completed near the pipeline to characterize the water masses dynamic (Figure 2). At station CTD-05, close to the pipeline, the water depth was 3.5 m, whereas station CTD-04 was deeper with 9 m. The data logged with the probe produced very similar profiles for both stations at a same tidal stage. A slight thermocline is seen at around 1 m deep at low tide only. For data collected at high tide, the temperature is very stable and ranges between 10.5 and 11.5 ºC. At the time when the profiles were recorded, the salinity was relatively high (between 23 and 28 PSU). The effect of the fresh water intake of the surrounding rivers was more important for station CTD 05 but was still mild. Therefore, the habitat present on the pipeline area seems to remain with unaltered marine conditions at every tidal stages for this period of the year.

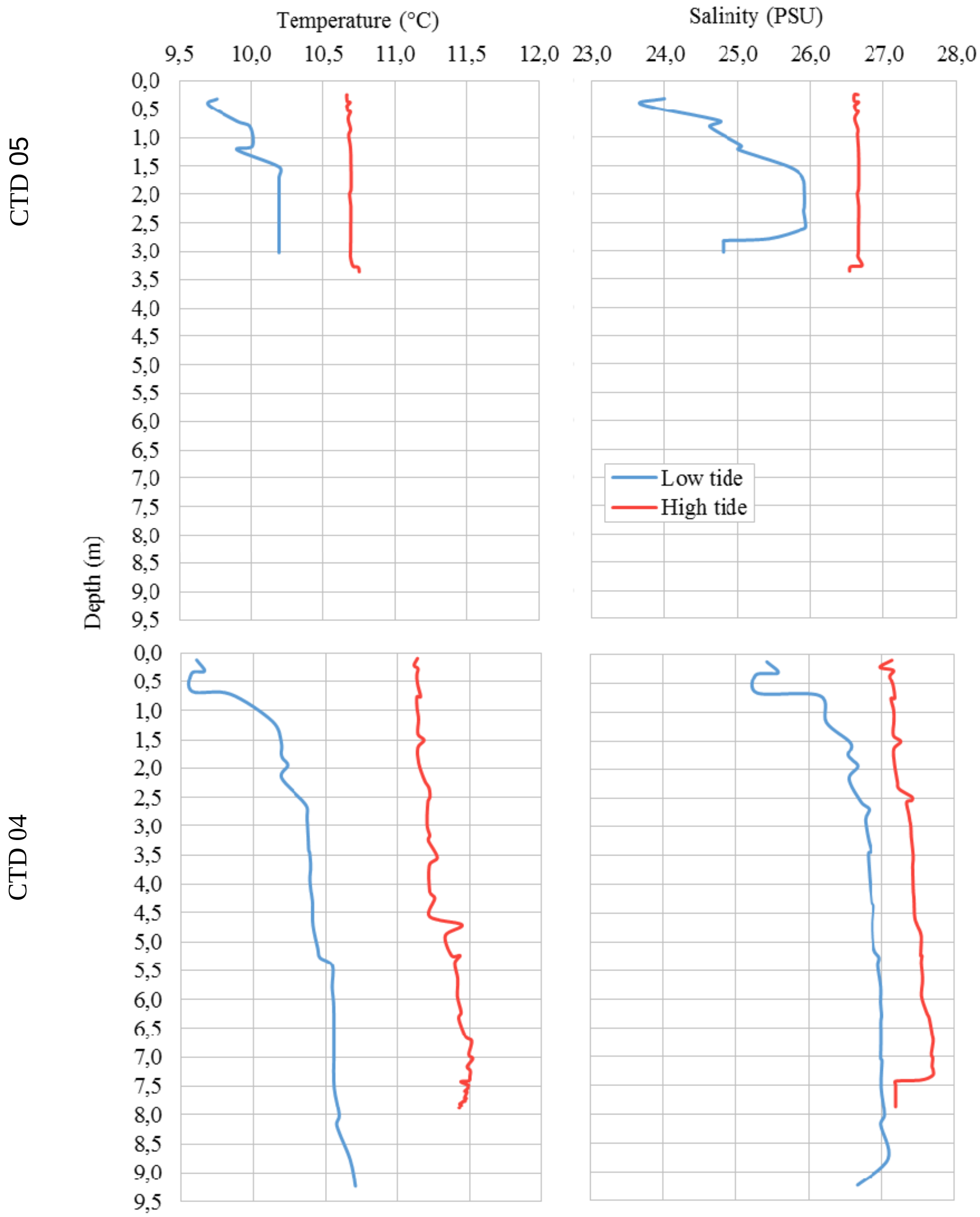


Figure 2 CTD Profiles at Stations CTD 04 and CTD 05

4.3 EPIBENTHIC COMMUNITY SURVEY

4.3.1 FLORA

The algae seen on the images recorded are part of the Fucus genus and could not be identified at the species level. They represented 10 to 20% of the cover for most of the transects and were more abundant on the sections where the substrate was coarser (pebbles and cobbles).

4.3.2 FAUNA

For the 13 quadrats characterized, no benthic organisms were observed on the images recorded.

For the 14 video transects, only six species have been identified (Table 2). The mussels were the most common taxon but could not be identified on the images to a more precise level than the family. Clams were also observed at several sites but were less common than mussels. For the two arthropods species seen, the *Cancer irroratus* (Atlantic rock crab) was present on all transects while the *Pagurus sp.* (hermit crab) was seen on 6 out of the 14 transects. Overall, around 90 specimens were counted along the whole area analyzed. Finally, two other species of benthic invertebrates were inventoried on the transects, namely *Metridium dianthus* (plumose anemone) with a total of 24 specimens and *Asterias rubens* (common starfish) with 19 specimens.

The distribution of the listed benthic organisms, which are all invertebrates, does not show any relation with the different depths and positioning on the pipeline axis. The type of substrate was not significantly different from one transects to another, so the communities found were similar. Only the presence of substrate such as boulders justifies the distribution of the plumose anemone. This kind of substrate provided a firm surface for attachment of those sessile organisms (Appendix C).

Neither of the identified species is designated as a threatened or endangered species within the federal and provincial authorities lists. Finally, no fish were observed during the surveys.

Table 2 Benthic Invertebrate Species Identified on the Images Acquired on the Transects

Taxa						Transect													
Class	**Order**	**Family**	**Genus**	**Species**	**Vernacular Name**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**
Malacostraca	Decapoda	Cancridae	*Cancer*	*C. irroratus*	Atlantic rock crab	15	5	1	5	5	8	4	7	4	5	8	2	9	5
		Paguridae	*Pagurus*	*Pagurus* sp.	Hermit crab	2	1		1		7				1			2	
Bivalvia	Mytilida	Mytilidae		sp.	Mussel	X		X	X	X	X	X	X	X	X	X		X	X
	Imparidentia	Mactridae		sp.	Clam	X							X	X		X		X	X
Anthozoa	Actiniaria	Metridiidae	*Metridium*	*M. dianthus*	Plumose anemone			12			10			2					
Asteroidea	Forcipulatida	Asteriidae	*Asterias*	*A. rubens*	Common starfish	3		1						1	12	2			

X: More than 20 specimens

4.4 ENDOBENTHIC COMMUNITY SURVEY

The analysis of the results provided by Laboratoire SAB inc. shows that for most of the stations, the *Mollusca* represents the most important phylum (1817 specimens: 64% of relative abundance, Figures 3 and 4) followed by the *Annelida* (1018 specimens; 36% of relative abundance) (Figure 4). From 2856 organisms counted, only 20 were crustaceans (Table 3). Soft bottom sediments are home of many burrowing organisms such as those two taxa (*Mollusca* and *Annelida*).

For the nine stations sampled, the higher densities of organisms were found at stations B1, B5 and B7 with respectively 896.6, 655.2 and 652.3 organisms/m^2 (Table 3 and Figure 3). The lower densities were found at stations B9 and B4 with respectively 112.1 and 237.1 organisms/m^2. There is no apparent relation between endobenthic densities organisms with the different depths and positioning along the pipeline axis (Map 3). The limited depth range (2-8 m) and similar substrate along the whole pipeline axis may not create habitat variations important enough to influence the type of organisms present and densities in the collected sediments.

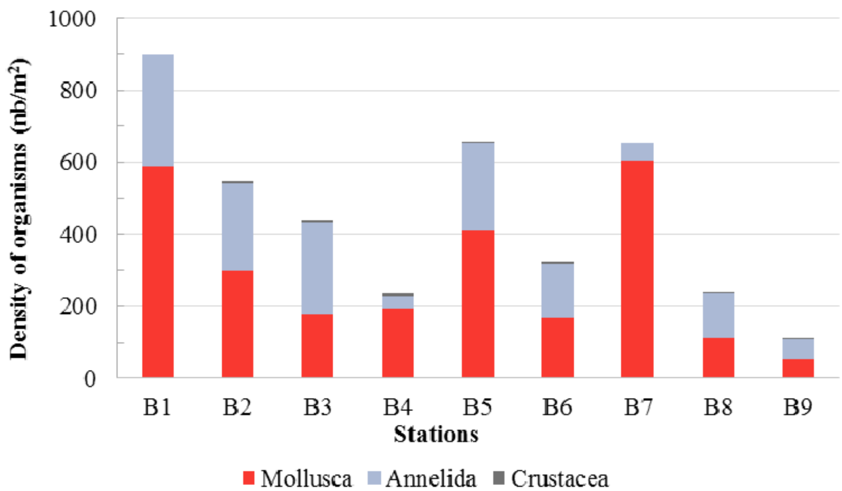


Figure 3 Density of Organisms Presented for the Three Principal Phylums Identified at the Nine Stations Sampled

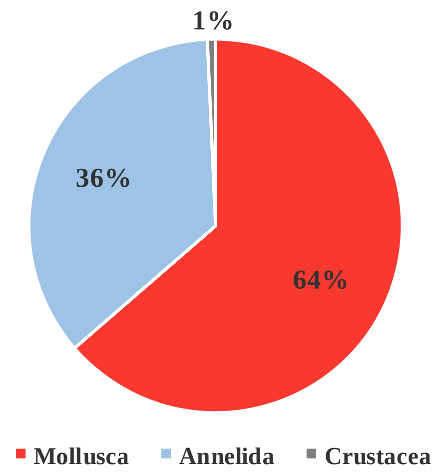


Figure 4 **Relative Abundance Of The Phylums Identified Within The Endobenthic Organisms Found In The Sediment Collected On The Pipeline Axis**

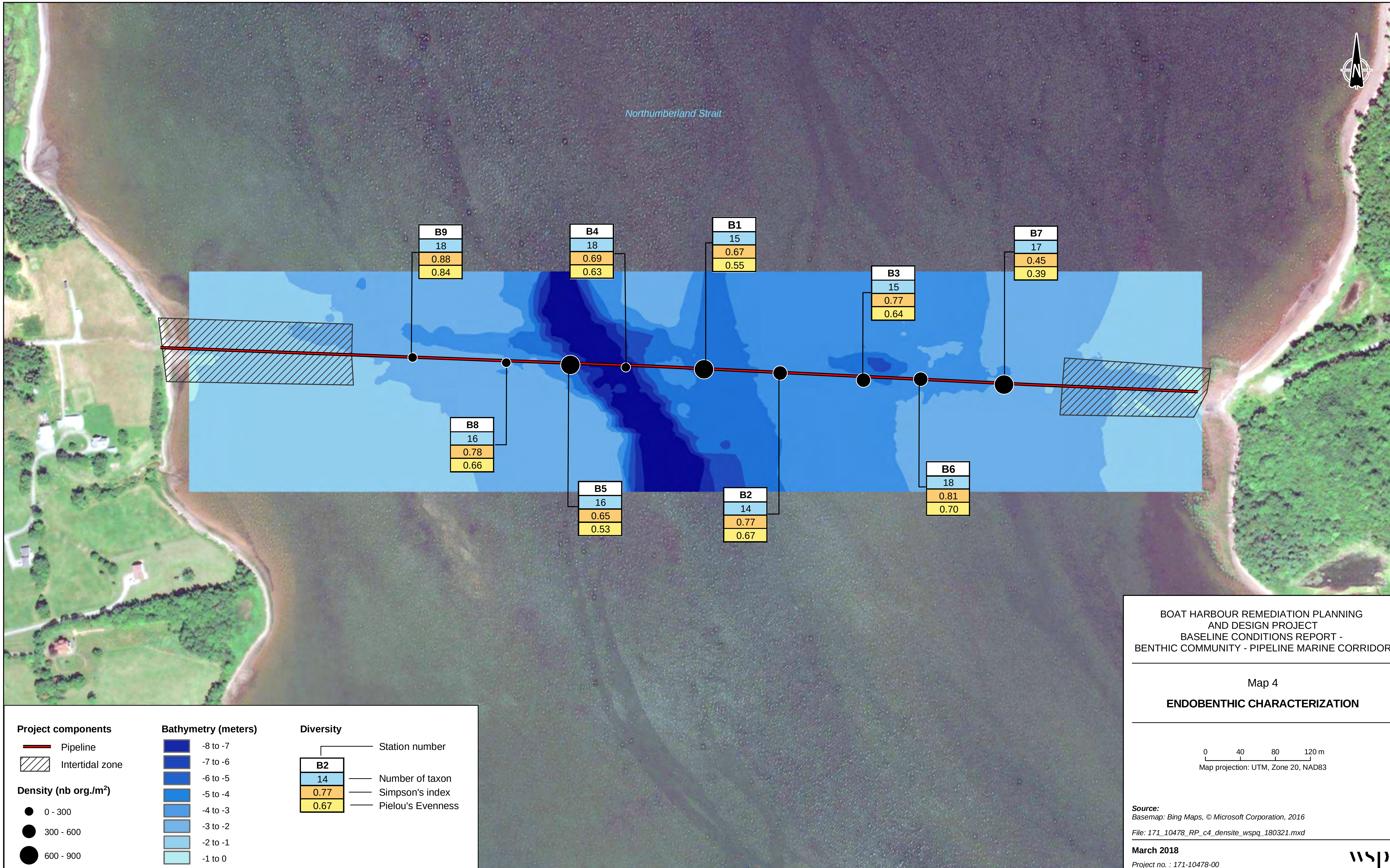
4.4.1 DIVERSITY INDICES

The total number of taxa identified is similar for each station and varies from 14 to 18. The highest values for the Simpsons diversity index were obtained at stations B9 and B6 and the lowest at B7 and B5 (Table 3). The results obtained for Pielou's index were similar with highest values found at station B9, and lower values at stations B7 and B5.

The analysis of the results shows that the samples with a high density are often composed of one predominant taxon. This finding is showed for station B7, which has the third highest density (652.3 organisms/m^2) and the lowest diversity indexes values (Pielou: 0.39, Simpson: 0.45). For this station, 74% of the identified organisms are within only one species, namely *Gemma gemma*. On the other hand, the station B9, which has the lowest density (112.1 organisms/m^2), obtained the highest values for both diversity indexes (Pielou: 0.84, Simpson: 0.88). The fact that a number of only 7 taxa represents 91% of the total count of organisms also shows the non-equal distribution of the different taxa found and the low average value obtained for Pielou's evenness index (0.62) (Map 4).

Table 3 Endobenthic Invertebrate Organisms Identified on the Pipeline Stations

Phylum	Class	Order	Family	Genus/Species	Number of organisms Station B1	B2	B3	B4	B5	B6	B7	B8	B9	Total
Porifera					C	C		C	C	C				-
Nemertea	Heteronemertea												1	**1**
Mollusca	Gastropoda	Neogastropoda	Buccinidae	*Buccinum undatum*		1		10	15	2	5	1		**34**
			Calyptraeidae	*Crepidula fornicata*									2	**2**
		Cephalaspidea	Calyptraeidae	*Retusa obtusa*	73	153	77	89	20	26	35	43	15	**531**
			Columbellidae	*Astyris lunata*				8						**8**
			Hydrobiidae	*Hydrobia acuta*				1						**1**
				Hydrobia truncata	1					2		1	6	**10**
			Naticidae	*Euspira heros*							1			**1**
	Bivalvia	Venerida	Arcticidae	*Arctica islandica*					1					**1**
			Hiatellidae	*Hiatella arctica*					1			1		**2**
			Mactridae	*Mulinia lateralis*	326	51	36	11	240	79	31	25	10	**809**
			Myacidae	*Mya arenaria*					1		2	3	1	**7**
			Nuculanidae (abîmé)					1						**1**
			Pharidae	*Ensis directus*							1			**1**
			Tellinidae	*Macoma calcarea*			1				1			**2**
				Tellina agilis	7	2	10	10	6	7	12	3	4	**61**
			Veneridae	*Gemma gemma*	2			4		2	334	1		**343**
			Yoldiidae	*Yoldia limatula*	1			2						**3**
Annelida	Polychaeta	Terrebilida	Ampharetidae	*Sabellides borealis*	1									**1**
			Capitellidae	Capitellidae (abîmé)	2									**2**
				Capitella jonesi		6				2				**8**
				Heteromastus filiformis									1	**1**
				Mediomastus ambiseta	6	1			2	2				**11**
			Cirratulidae	*Tharyx acutus*	23	65	26		9		3	4	4	**134**
			Flabelligeridae	*Pherusa affinis*				1						**1**
			Nephtyidae		1									**1**
				Nephtys ciliata				2	2			2		**6**
				Nephtys neotena	129	54	114	5	113	41	1	57	16	**530**
				Nephtys caeca					1					**1**
			Nereidae	*Hediste diversicolor*									2	**2**
				Neanthes virens			1							**1**
			Orbiniidae	*Leitoscoloplos fragilis*	19	21	31	1	12	28	20	21	5	**158**
			Pectinaridae	*Pectinaria granulata*									1	**1**
			Pholoidae	*Pholoe minuta*				1						**1**
			Phyllodocidae	*Eteone flava/longa*		5	1			2				**8**
				Eteone lactea			2			10	1			**13**
				Eteone sp.							2			**2**
				Eumida sanguinea									1	**1**
			Spionidae	Laonice cirrata	32	2	1	13	31	14	3	2	4	**102**
				Polydora websteri	1	16				3	1		1	**22**
				Polydora aggregata							1			**1**
				Scolelepis squamata					1					**1**
				Strblospio benedicti		1	2			2		1	3	**9**
Crustacea	Amphipoda		Ampeliscidae	Ampelisca vadorum		2	1	4		1				**8**
		Cumacea	Diastylidae	*Diastylis sculpta*			2		1	1		1	1	**6**
		Mysida	Mysidae	*Neomysis americana*			1	1						**2**
	Decapoda		Crangonidae	*Crangon septemspinosa*				1		1		2		**4**
Total					**624**	**380**	**306**	**165**	**456**	**225**	**454**	**168**	**78**	**2856**
N taxons					**15**	**14**	**15**	**18**	**16**	**18**	**17**	**16**	**18**	-
Density (nb org./m²)					**896,6**	**546,0**	**439,7**	**237,1**	**655,2**	**323,3**	**652,3**	**241,4**	**112,1**	-
Mean density ± standard deviation					**455,9 ± 252,6**									
Simpsons Diversity Index					**0,67**	**0,77**	**0,77**	**0,69**	**0,65**	**0,81**	**0,45**	**0,78**	**0,88**	-
Pielou's Evenness					**0,55**	**0,67**	**0,64**	**0,63**	**0,53**	**0,70**	**0,39**	**0,66**	**0,84**	-



BOAT HARBOUR REMEDIATION PLANNING AND DESIGN PROJECT
BASELINE CONDITIONS REPORT -
BENTHIC COMMUNITY - PIPELINE MARINE CORRIDOR

Map 4

ENDOBENTHIC CHARACTERIZATION

Source:
Basemap: Bing Maps, © Microsoft Corporation, 2016

File: 171_10478_RP_c4_densite_wspq_180321.mxd

March 2018

Project no. : 171-10478-00

wsp

5 CONCLUSION

Characterization of the habitat in the pipeline area was made using a combination of underwater video and endofauna sampling campaign. Visual observations of the substrate type from the video sequences and the analysis of the samples collected indicated a predominance of silt and fine sand with lesser amounts of gravel, cobble and pebble. The presence of algae (*Fucus sp*.) is scarce and limited to areas with coarser substrate.

Given the absence of bottom structure, due to the predominance of fine sediment, species that thrive in this habitat are mostly burrowed into the soft sediments. This kind of habitat supports a variety of endofauna that constructs permanent burrows, such as polychaetes and bivalvia. Most organisms living in this type of habitat are deposit feeders, feeding on the organic material. Benthic sampling results indicate that the endobenthic community observed along the pipeline is composed of 48 different taxa of which the most abundant are *Mulinia lateralis*, *Retusa obtuse* and *Nephtys neotena*, which are respectively within the bivalves, gastropods and polychaetes classes.

Underwater video surveys provided additional information on the epibenthic community. While mussels were the most common taxon, Atlantic rock crabs were found on every transect and clams on almost half of them.

Cobble and pebble patches observed within the habitat explains the occurrence of sessile organisms (ex.: plumose anemone) that use hard substrate to fix themselves on the bottom. This kind of habitat was scarce along the pipeline axis but could represent important protection for fishe or crab species.

None of the identified species are designated as a threatened or endangered within the federal and provincial authorities' lists.

6 BIBLIOGRAPHICAL REFERENCES

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APPENDIX

A GRAIN SIZE CLASSES DESCRIPTION

Grain Size Classes used for the Description of the Substrate

Grain Size Classes	Diametre (mm)
Rock	Bedrock
Large block	> 1000
Block	250 to 1000
Cobble	80 to 250
Pebble	40 to 80
Gravel	5 to 40
Sand	0.125 to 5
Silt	0.125 to 0.039
Clay	<0.0039
Organic matter	n/a

APPENDIX

B ANALYSIS CERTIFICATES

		Pic1	Pic2	Pic3	Pic4	Pic5	Pic6	Pic7	Pic8	Pic9
	ANALYST AND DATE:	,	,	,	,	,	,	,	,	,
	SIEVING ERROR:									
	SAMPLE TYPE:	Bimodal, Poorly Sorted	Bimodal, Poorly Sorted	Bimodal, Poorly Sorted	Bimodal, Poorly Sorted	Unimodal, Poorly Sorted	Trimodal, Very Poorly Sorted	Trimodal, Very Poorly Sorted	Unimodal, Poorly Sorted	Bimodal, Poorly Sorted
	TEXTURAL GROUP:	Sandy Mud	Mud	Mud	Sandy Mud	Sandy Mud	Gravelly Mud	Slightly Gravelly Sandy Mud	Slightly Gravelly Sandy Mud	Sandy Mud
	SEDIMENT NAME:	Very Fine Sandy Medium Silt	Medium Silt	Medium Silt	Very Fine Sandy Medium Silt	Very Fine Sandy Medium Silt	Medium Gravelly Medium Silt	Slightly Very Fine Gravelly Very Fine Sandy Coarse Silt	Slightly Very Fine Gravelly Very Fine Sandy Medium Silt	Very Fine Sandy Medium Silt
METHOD OF MOMENTS Arithmetic (μm)	MEAN ($\bar{x}_a$):	32.20	29.10	30.59	42.67	40.66	878.5	189.6	42.79	33.43
	SORTING (σ_a):	51.49	41.05	52.70	80.89	71.39	3264.3	442.1	167.6	44.68
	SKEWNESS (Sk_a):	5.816	5.268	11.96	8.645	5.519	3.672	4.814	12.62	4.653
	KURTOSIS (K_a):	48.60	40.70	234.7	130.6	55.85	14.56	32.01	174.5	36.64
METHOD OF MOMENTS Geometric (μm)	MEAN ($\bar{x}_g$):	19.40	18.79	19.43	22.36	21.47	29.61	44.71	19.41	21.08
	SORTING (σ_g):	2.466	2.319	2.338	2.739	2.659	6.115	4.782	2.536	2.409
	SKEWNESS (Sk_g):	0.645	0.678	0.648	0.769	0.979	2.383	0.826	1.413	0.634
	KURTOSIS (K_g):	3.577	3.591	3.731	3.359	3.717	8.401	2.672	6.402	3.106
METHOD OF MOMENTS Logarithmic (ϕ)	MEAN ($\bar{x}_\phi$):	5.688	5.734	5.685	5.483	5.541	5.078	4.483	5.687	5.568
	SORTING (σ_ϕ):	1.302	1.214	1.225	1.453	1.411	2.612	2.258	1.343	1.268
	SKEWNESS (Sk_ϕ):	-0.645	-0.678	-0.648	-0.769	-0.979	-2.383	-0.826	-1.413	-0.634
	KURTOSIS (K_ϕ):	3.577	3.591	3.731	3.359	3.717	8.401	2.672	6.402	3.106
FOLK AND WARD METHOD (μm)	MEAN (M_G):	19.15	18.53	19.18	21.85	20.78	21.42	49.33	18.35	21.05
	SORTING (σ_G):	2.411	2.273	2.293	2.718	2.618	5.085	5.064	2.333	2.417
	SKEWNESS (Sk_G):	0.185	0.206	0.188	0.303	0.347	0.494	0.462	0.300	0.265
	KURTOSIS (K_G):	1.003	1.053	1.015	1.033	1.234	2.586	0.992	1.275	1.012
FOLK AND WARD METHOD (ϕ)	MEAN (M_Z):	5.706	5.754	5.704	5.516	5.589	5.545	4.341	5.768	5.570
	SORTING (σ_I):	1.269	1.185	1.197	1.443	1.388	2.346	2.340	1.222	1.273
	SKEWNESS (Sk_I):	-0.185	-0.206	-0.188	-0.303	-0.347	-0.494	-0.462	-0.300	-0.265
	KURTOSIS (K_G):	1.003	1.053	1.015	1.033	1.234	2.586	0.992	1.275	1.012
FOLK AND WARD METHOD (Description)	MEAN:	Coarse Silt	Coarse Silt	Coarse Silt	Coarse Silt	Coarse Silt	Coarse Silt	Very Coarse Silt	Coarse Silt	Coarse Silt
	SORTING:	Poorly Sorted	Poorly Sorted	Poorly Sorted	Poorly Sorted	Poorly Sorted	Very Poorly Sorted	Very Poorly Sorted	Poorly Sorted	Poorly Sorted
	SKEWNESS:	Coarse Skewed	Coarse Skewed	Coarse Skewed	Very Coarse Skewed	Very Coarse Skewed	Very Coarse Skewed	Very Coarse Skewed	Coarse Skewed	Coarse Skewed
	KURTOSIS:	Mesokurtic	Mesokurtic	Mesokurtic	Mesokurtic	Leptokurtic	Very Leptokurtic	Mesokurtic	Leptokurtic	Mesokurtic
	MODE 1 (μm):	14.21	14.21	14.21	14.21	14.21	14.21	16.27	14.21	14.21
	MODE 2 (μm):	57.24	57.24	57.24	57.24		57.24	57.24		57.24
	MODE 3 (μm):						13760.0	430.0		
	MODE 1 (ϕ):	6.140	6.140	6.140	6.140	6.140	6.140	5.945	6.140	6.140
	MODE 2 (ϕ):	4.134	4.134	4.134	4.134		4.134	4.134		4.134
	MODE 3 (ϕ):						-3.763	1.237		
	D_{10} (μm):	6.792	7.155	7.238	7.337	7.700	7.559	8.988	7.525	7.785
	D_{50} (μm):	17.06	16.56	17.26	18.02	17.17	17.99	27.26	16.07	17.86
	D_{90} (μm):	66.14	60.90	60.32	94.25	93.76	110.6	561.4	71.69	77.26
	(D_{90} / D_{10}) (μm):	9.737	8.511	8.333	12.85	12.18	14.63	62.46	9.527	9.924
	(D_{90} - D_{10}) (μm):	59.34	53.75	53.08	86.91	86.06	103.0	552.4	64.17	69.47
	(D_{75} / D_{25}) (μm):	3.216	2.874	3.005	3.725	3.017	3.345	7.206	2.614	3.173
	(D_{75} - D_{25}) (μm):	23.10	19.83	21.73	29.97	22.42	26.29	86.54	17.29	24.68
	D_{10} (ϕ):	3.918	4.037	4.051	3.407	3.415	3.177	0.833	3.802	3.694
	D_{50} (ϕ):	5.873	5.916	5.857	5.794	5.864	5.797	5.197	5.959	5.807
	D_{90} (ϕ):	7.202	7.127	7.110	7.091	7.021	7.048	6.798	7.054	7.005
	(D_{90} / D_{10}) (ϕ):	1.838	1.765	1.755	2.081	2.056	2.218	8.161	1.855	1.896
	(D_{90} - D_{10}) (ϕ):	3.283	3.089	3.059	3.683	3.606	3.871	5.965	3.252	3.311
	(D_{75} / D_{25}) (ϕ):	1.344	1.302	1.321	1.412	1.325	1.368	1.859	1.269	1.347
	(D_{75} - D_{25}) (ϕ):	1.685	1.523	1.587	1.897	1.593	1.742	2.849	1.386	1.666
	% GRAVEL:	0.0%	0.0%	0.0%	0.0%	0.0%	7.0%	1.0%	0.4%	0.0%
	% SAND:	10.9%	9.5%	9.1%	16.7%	14.7%	8.2%	30.7%	11.0%	13.9%
	% MUD:	89.1%	90.5%	90.9%	83.3%	85.3%	84.7%	68.3%	88.6%	86.1%
	% V COARSE GRAVEL:	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
	% COARSE GRAVEL:	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
	% MEDIUM GRAVEL:	0.0%	0.0%	0.0%	0.0%	0.0%	6.0%	0.0%	0.0%	0.0%
	% FINE GRAVEL:	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
	% V FINE GRAVEL:	0.0%	0.0%	0.0%	0.0%	0.0%	1.0%	1.0%	0.4%	0.0%
	% V COARSE SAND:	0.0%	0.0%	0.1%	0.1%	0.0%	0.0%	2.6%	0.1%	0.0%
	% COARSE SAND:	0.0%	0.0%	0.0%	0.1%	0.1%	0.0%	8.2%	0.1%	0.0%
	% MEDIUM SAND:	1.2%	0.8%	0.7%	2.0%	2.4%	0.7%	8.4%	1.0%	0.7%
	% FINE SAND:	1.6%	1.5%	1.7%	4.4%	4.7%	1.5%	2.8%	3.1%	2.3%
	% V FINE SAND:	8.1%	7.2%	6.7%	10.1%	7.5%	5.9%	8.6%	6.7%	10.8%
	% V COARSE SILT:	16.0%	14.8%	17.0%	14.4%	12.0%	14.2%	14.6%	10.7%	14.7%
	% COARSE SILT:	27.6%	29.0%	29.2%	25.9%	28.7%	27.9%	23.9%	29.6%	28.7%
	% MEDIUM SILT:	31.6%	34.2%	32.5%	31.3%	34.1%	31.7%	22.9%	37.1%	32.6%
	% FINE SILT:	12.1%	11.3%	10.8%	10.6%	9.7%	10.0%	6.3%	10.4%	9.4%
	% V FINE SILT:	1.8%	1.2%	1.2%	1.1%	0.8%	0.9%	0.6%	0.8%	0.8%
	% CLAY:	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%

APPENDIX

C

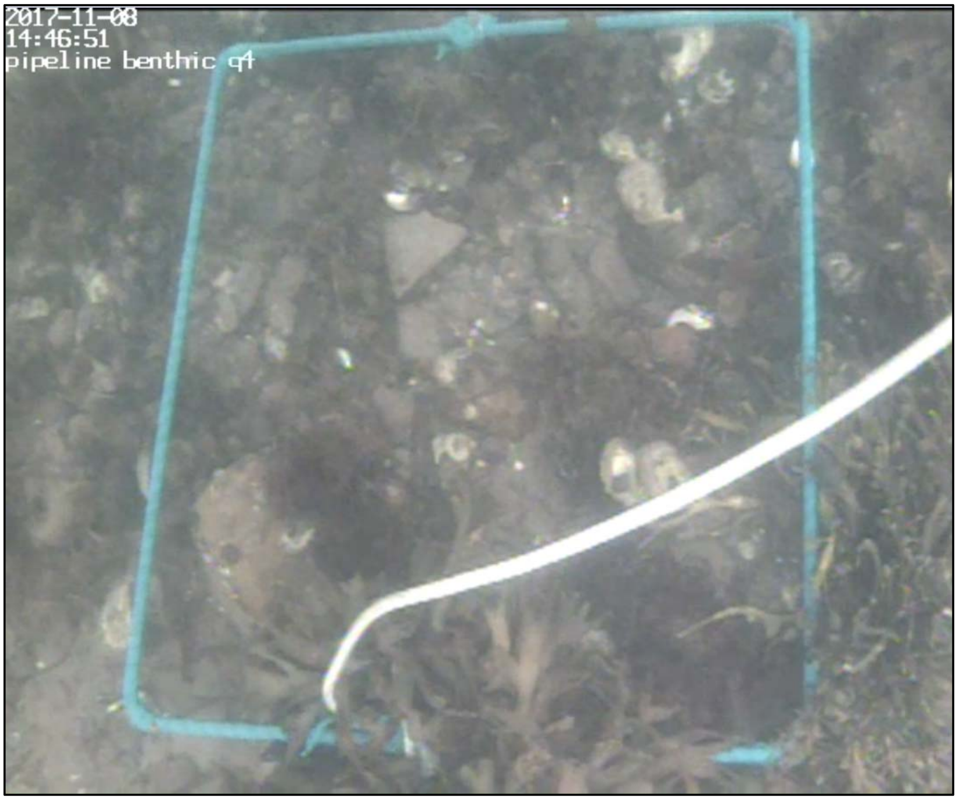
PHOTOGRAPHIC REPORT

Picture 1 Three *Pagurus sp.* – Hermit crab (video screenshot on transect 6).

Picture 2 Asterias rubens – Common starfish (video screenshot on transect 10).

Picture 3 Cancer irroratus – Atlantic rock crab (video screenshot on transect 4).

Picture 4 Metridium dianthus – Plumose anemone (video screenshot on transect 3).



Picture 5 Quadrat Q4 – Substrate of gravel pebbles and cobbles.

Picture 6 Eastern section of Transect 1 – Substrate of shells, pebbles and gravel.

Picture 7 Sediment sample for endobenthic organisms analysis.

Picture 8 "No anchor" sign on the east shore (view from B7).

Picture 9 “No anchor” sign on the west shore (view from B9).

Picture 10 Global view of all the stations on the pipeline (view from east to west).

NOVA SCOTIA LANDS INC.
PROJECT NO.: 171-10478-00

BOAT HARBOUR REMEDIATION PLANNING AND DESIGN PROJECT

DESKTOP STUDY: AQUATIC SPECIES AT RISK MARINE MAMMALS SEA TURTLES

DECEMBER 2019

BOAT HARBOUR REMEDIATION PLANNING AND DESIGN PROJECT

DESKTOP STUDY: AQUATIC SPECIES AT RISK MARINE MAMMALS SEA TURTLES

NOVA SCOTIA LANDS INC.

PROJECT NO.: 171-10478-00
DATE: DECEMBER 2019

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Reference to be cited :

WSP. 2019. *BOAT HARBOUR REMEDIATION PLANNING AND DESIGN PROJECT. DESKTOP STUDY: AQUATIC SPECIES AT RISK MARINE MAMMALS SEA TURTLES.* REPORT PRODUCED FOR NOVA SCOTIA LANDS INC. 24 PAGES AND APPENDICES.

TABLE OF CONTENTS

TABLES

APPENDIX

1 CONTEXT

The Boat Harbour Effluent Treatment Facility (BHETF) is located in north central Nova Scotia on the Northumberland Strait. The BHETF became operational in 1967 and has been the primary processing system for effluent from the Kraft Pulp Mill. Boat Harbour, known as A'se'k in Mi'kmaq, was originally a tidal estuary connected to the Northumberland Strait. The Harbour is currently a closed effluent stabilization basin, operating under a lease agreement with the Province by the Kraft Pulp Mill owner. The use of the BHETF for the reception and treatment of effluent from the Kraft Pulp Mill must cease no later than January 31, 2020, in accordance with the Boat Harbour Act. Once operations have ceased, the Province will remediate Boat Harbour, and lands associated with the BHETF, and restore Boat Harbour to a tidal estuary.

The main components of the BHETF include: the wastewater effluent pipeline (over 3 km in length) that runs from the Kraft Pulp Mill and extends eastward of the East River of Pictou (East River) to the BHETF property; twin settling basins and an Aeration Stabilization Basin (ASB) west-southwest of Boat Harbour; and the stabilization lagoon (Boat Harbour). Effluent from Boat Harbour discharges through a dam (northeast of Boat Harbour) into an estuary before being released to the Northumberland Strait. Prior to the construction of the twin settling basins and ASB, effluent was routed by open ditch from the pipeline on the east side of Highway 348 to a natural wetland area (Former Ponds 1, 2, and 3) before being discharged into the stabilization lagoon.

The BHETF contains approximately 1,149,000 m^3 of unconsolidated contaminated sludge/sediment including approximately 577,000 m^3 unconsolidated sludge/sediment within Boat Harbour, 263,000 m^3 in the wetlands, 180,000 m^3 in the containment cell, and 129,000 m^3 in the ASB. Once consolidated through dewatering, the total dewatered sludge/sediment volume to be managed is estimated to be between 312,500 and 517,700 m^3. The sludge is impacted with metals, polycyclic aromatic hydrocarbons (PAHs), and dioxins and furans. In addition to management of sludge/sediment, the anticipated volume of waste water to be generated through remediation of the BHETF is an estimated 5,700,000 m^3. This volume includes bulk water (wastewater in BHSL and the ASB) and sludge/sediment dewatering effluent. In addition to bulk water and dewatering effluent, combined groundwater and surface water contributions to BHSL is estimated at 28,000 m^3 per day, which will also need to be managed during remediation of the BHETF.

Over the operational period of the mill, many concerns have arisen for human and environmental safety. As a result of these concerns, remedial plans have been initiated. Prior to the treatment planned for the remediation, knowledge on habitat and aquatic species present in the BHETF and the surrounding area is needed to assess how remedial activities could impact the surrounding population and natural environment.

As part of the environmental impact assessment of the Boat Harbour Remediation Project (BHRP or Project), WSP Canada Inc. (WSP) was mandated to conduct a database and literature review to identify aquatic species at risk, marine mammals and sea turtles that could be encountered in the area.

1.1 OBJECTIVE

The main objective of this review is to describe and estimate the potential of presence of aquatic species at risk, marine mammals and sea turtles that could be encountered in the Northumberland Strait. Fish species that are not "at-risk" are covered in a separate document and are not included in the current review.

1.2 METHODS

1.2.1 STUDY AREA

The study area includes part of the Northumberland Strait, from the East side of the Confederation bridge to the Eastern coast of the Prince Edward Island to identify marine species that could potentially be present in the surrounding of Boat Harbour (Map 1-1). This area is characterized by average water depths ranging from 10 to 20 m but can reach values up to 50 m (Kranck, 1972). Water temperatures vary from -1.6ºC in winter to over 20ºC in summer (Dufour et al. 2010).

The eastern part of the study area encompasses the Ecologically and Biologically Significant Area (EBSA) 1-Western Cape Breton determined by Fisheries and Oceans Canada (DFO) and is surrounded by two other EBSA: 2-St. Georges Bay and 3-Western Northumberland Strait (Map 1-1; DFO, 2013). EBSA don't have any special protection status but have been identified for facilitating the evaluation of risk assessment when managing human activities and are significant for the ecosystem based on their uniqueness, the prevalence of a given biological component in the area and the function of the area for the biological component in question (DFO, 2013). The presence of the species found in the study area will be discussed in sections 2.1, 2.2. and 2.3.

The eastern tip of Prince Edward Island is also designated as a Marine Protected Area (Basin Head MPA), belonging to the Gulf of St. Lawrence Integrated Management Area (Map 1-1). This area is especially significant for its ecological importance for the Irish moss, an endemic specie to this MPA (DFO, 2019).

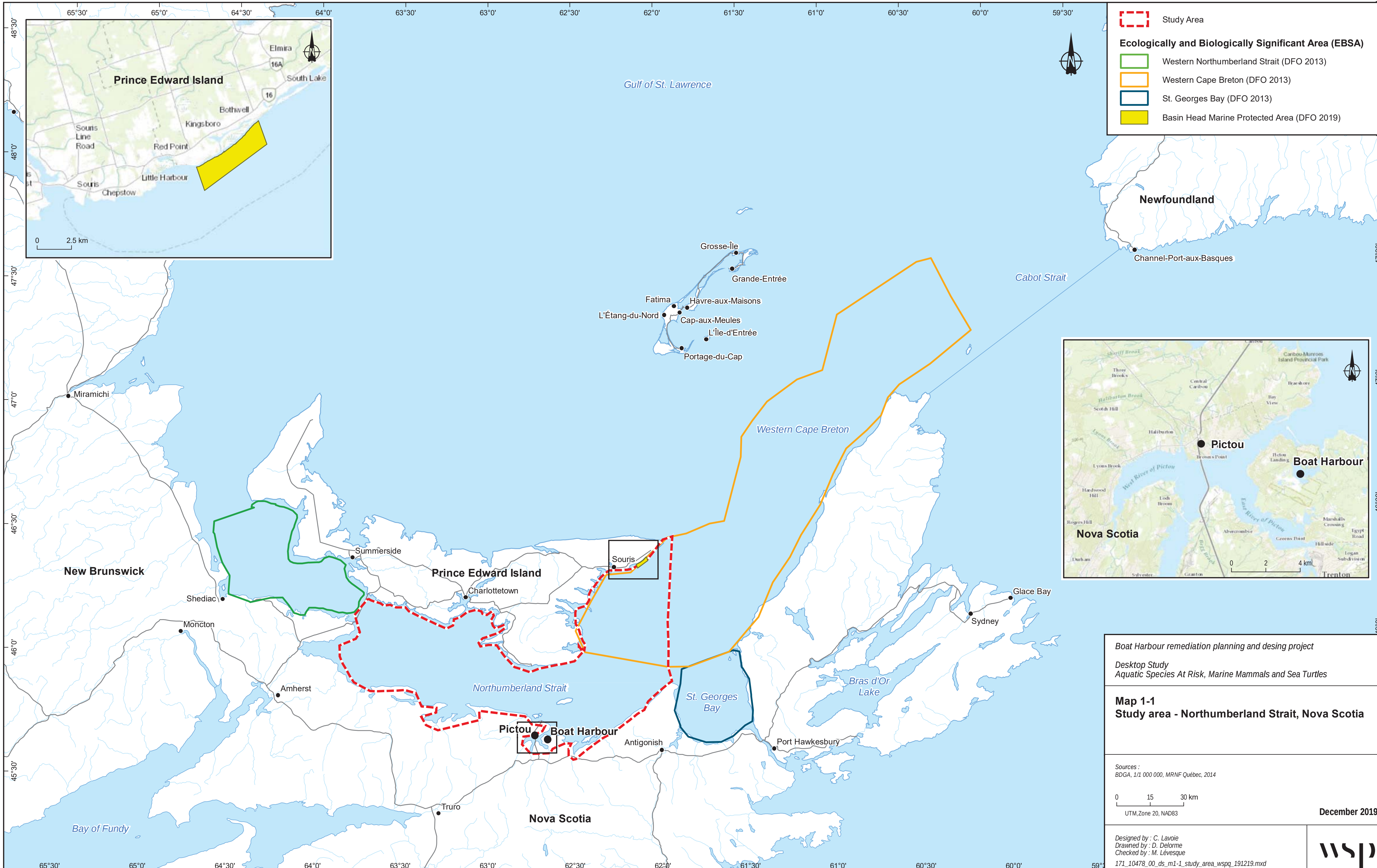
1.2.2 LITTERATURE AND DATABASES CONSULTATION

The main source for determining potential presence of aquatic species at risk, marine mammals and sea turtles in the study area was OBIS 2019, a database compiling the observations of aquatic species encountered in the area from which the data from 1979 to 2019 were analyzed. Complementary observations from other sources (DFO website and reports, Whalemap, COSEWIC reports and published literature) were also used.

For the aquatic species at risk, marine mammals and sea turtles, presence potential was assessed from all sources consulted and were based on the following criteria:

- **High**: Frequent sightings in the study area;
- **Moderate**: Infrequent but regular observations in the study area;
- **Low**: Sporadic sightings in the study area, punctual but annual observations outside the study area;
- **Rare**: No recent observations outside the range but possible presence.

It is important to note that the observations and sightings that are reported in the consulted sources should not be translated into the distribution range of a specie, but rather as a representation of their presence potential in the area. The observations can be biased by the sampling effort that is not homogeneous among the study area, nor across time, thus should be interpreted with caution. In addition, the study limited its search on species with a designated status, marine mammals and sea turtle. As such, fish species that are not "at-risk" are not covered in the review.



Study Area
Ecologically and Biologically Significant Area (EBSA)
Western Northumberland Strait (DFO 2013)
Western Cape Breton (DFO 2013)
St. Georges Bay (DFO 2013)
Basin Head Marine Protected Area (DFO 2019)
Prince Edward Island
Elmira
South Lake
Bothwell
Kingsboro
Souris Line Road
Red Point
Little Harbour
Souris
Chepstow
0
2.5 km
Gulf of St. Lawrence
Newfoundland
Channel-Port-aux-Basques
Cabot Strait
Grosse-Île
Grande-Entrée
Fatima
Havre-aux-Maisons
L'Étang-du-Nord
Cap-aux-Meules
L'Île-d'Entrée
Portage-du-Cap
Miramichi
Western Cape Breton
New Brunswick
Summerside
Prince Edward Island
Souris
Charlottetown
Shediac
Moncton
Amherst
Northumberland Strait
Pictou
Boat Harbour
Antigonish
St. Georges Bay
Port Hawkesbury
Bras d'Or Lake
Sydney
Glace Bay
Truro
Nova Scotia
Bay of Fundy
Pictou
Boat Harbour
Nova Scotia
0
2
4 km
Boat Harbour remediation planning and desing project
Desktop Study
Aquatic Species At Risk, Marine Mammals and Sea Turtles
Map 1-1
Study area - Northumberland Strait, Nova Scotia
Sources :
BDGA, 1/1 000 000, MRNF Québec, 2014
0
15
30 km
UTM,Zone 20, NAD83
December 2019
Designed by : C. Lavoie
Drawned by : D. Delorme
Checked by : M. Lévesque
171_10478_00_ds_m1-1_study_area_wspq_191219.mxd

2 RESULTS

2.1 AQUATIC SPECIES AT RISK

Aquatic species listed as at risk under the Species at Risk Act (SARA) or recommended by the Committee on the Status of Endangered Wildlife in Canada (COSEWIC) that could be encountered in the study area are presented in Table 2-1. A total of 11 species were identified and belong to the group of mysticetes and odontocetes cetaceans (whales), *Elasmobranchii* (skate and shark), *Actinopterygii* (fishes) and Reptilians (sea turtle). Sightings of the species at risk in the area are presented in Map 2-1. The periods of the year when the species have a potential to be encountered are presented in Table 2-2, while the date of every observation events for all the species are listed in Appendix A.

Table 2-1 Aquatic species at risk that could be encountered in the study area

Group	Specie	Common Name	Status[1]	Confirmed presence	Presence potential[3]
Mysticetes cetaceans	*Balaenoptera musculus*[2]	Blue whale	Endangered	DFO, 2019	Low
	Balaenoptera physalus	Fin whale	Special Concern	OBIS, 2019	Low
	Eubalaena glacialis	North Atlantic Right whale	Endangered	COSEWIC, 2013; Daoust *et al.,* 2017 OBIS, 2019	Low
Odontocete cetaceans	*Phocoena phocoena*	Harbour porpoise	Special Concern	Lesage et al., 2007; OBIS 2019	Moderate to High
Elasmobranchii	*Malacoraja senta*	Smooth skate	Special Concern	OBIS, 2019	Moderate
	Leucoraja ocellata	Winter skate	Endangered	COSEWIC 2015; OBIS, 2019	Moderate to High
	Amblyraja radiata	Thorny skate	Special concern	COSEWIC, 2005; OBIS, 2019	Moderate
	Carcharodon carcharias	White shark	Endangered	COSEWIC 2006;	Rare to nul
Actinopterygii	*Cyclopterus lumpus*	Lumpfish	Threatened	OBIS, 2019	Moderate
	Anarhichas lupus	Atlantic wolffish	Special Concern	OBIS, 2019	Low to Moderate
	Salmo salar	Atlantic salmon	Special Concern (Gaspé-Southern Gulf of St. Lawrence population)	DFO, 1997; DFO, 2014; OBIS, 2019	High
Reptilians	*Dermochelys coriaceae*	Leatherback Sea Turtle	Endangered	James *et al*., 2005; James *et al*., 2006	Low to Moderate

1 Status confered by the Species at Risk Act (SARA) or by the Comittee on the Status of Endengered Wildlife in Canada (COSEWIC)
2 The species in grey are suspected to be encountered in the study area according to Fisheries and Oceans, Canada (DFO), but no sightings were reported in this area by other sources.
3 The evaluated presence potential in the study area is based on all consulted sources; High: Frequent sightings in the study area; Moderate: Infrequent, but regular observations in the study area; Low: Sporadic sightings in the study area, punctual but annual observations outside the study area; Rare: No recent observation outside the range but possible presence.

Sources: DFO; OBIS 2019; COSEWIC; James et al., 2005; James et al., 2006; Lesage et al., 2007; Johnson 2018 (Whalemap)

MARINE MAMMALS

Among the marine mammals with an at-risk status, cetaceans from the mysticete and the odontocete groups can be encountered in the study area.

The mysticete cetaceans are migratory whales that feed on zooplankton using their baleen plates and benefit from the cold waters productivity of the Gulf of St. Lawrence (Lesage *et al*., 2007), while the odontocete are toothed cetaceans that feed mostly on pelagic, demersal and benthic fishes, cephalopods, and small aquatic species (Fontaine, 1998). Their distribution therefore follows the prey concentration, according to the time of the year (Table 2-2).

MYSTICETES CETACEANS

Overall, three species at risk of mysticetes cetaceans might be encountered in the study area: Blue whale, Fin whale and North Atlantic Right whale (Table 2-1; Map 2-1).

Blue Whale

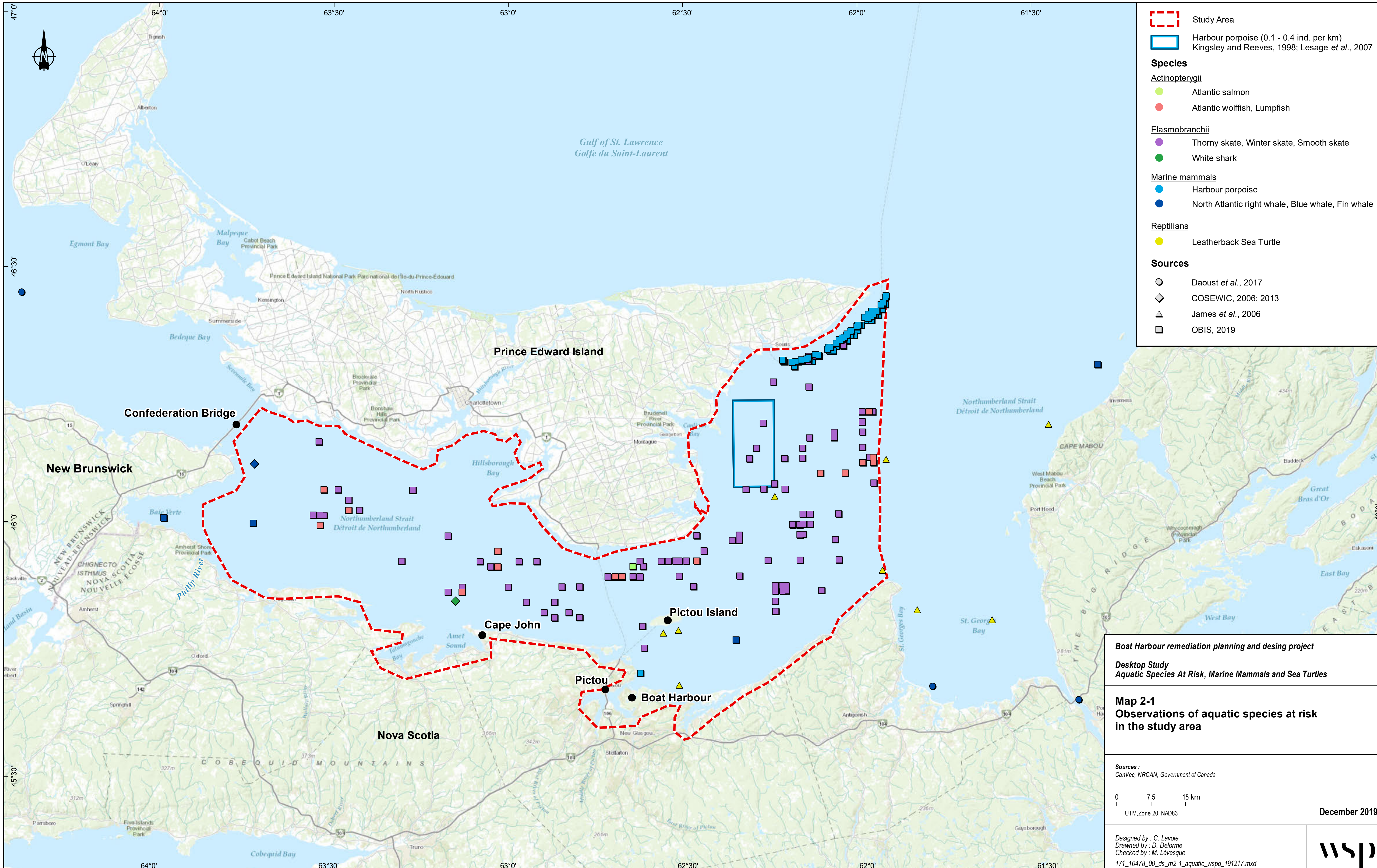
Even though the population size of the Blue whale (*Balaenoptera musculus*) is not known, its presence in Canada is estimated below 250 mature individuals, thus conferring the status “endangered” of this specie by the COSEWIC (COSEWIC, 2002). The Blue whale can be seen in the Gulf of St. Lawrence from April to December, both in coastal and pelagic waters. They are often found at the continental shelf edge, where upwelling produces high concentrations of krill (COSEWIC, 2002). Previous reports have been made during summer months especially on the Nova Scotian Banks, the Gulf and Estuary of St. Lawrence, the Belle Isle Strait and Grand Bank (Leatherwood *et al*., 1976). According to Fisheries and Oceans Canada (DFO, 2019), the Blue whale could be encountered in the study area but no recent observations of this specie have been reported by other sources (Johnson 2018, Lesage *et al.,* 2007; OBIS, 2019). Its presence potential in the study area is therefore determined low, but an encounter with a Blue whale is still possible since it has been reported in shallow inshore zones (Leatherwood *et al*., 1976).

The limiting factors and threats to this species include ship strikes and entanglement in fishing gear. They may also be vulnerable to human-generated underwater noise, chemical pollution and climate change but these have not been clearly specified or validated (COSEWIC, 2005).

Fin whale

During the summer, the Fin whale (*Balaenoptera physalus*) follows preys (mostly euphausiids) that are concentrating in regions characterized by shallow areas with topographic relief and low surface temperatures (COSEWIC 2005; Lesage *et al*., 2007). In the Southern Gulf, the presence of the Fin whale is rather scarce, but it can still be encountered on a regular basis along the Northwest coast of Cape Breton Island (Lesage *et al*., 2007). Its potential presence in the Northumberland Strait has been confirmed by previous sightings: two in 1964, east from the confederation bridge and one in 1967, between the Pictou Island and the shore (Map 2-1; OBIS, 2019). Nevertheless, no observation of Fin Whale was reported in the study area for at least the last five years by other sources (Johnson, 2018; Lesage *et al*., 2007). According to Fisheries and Oceans Canada (DFO, 2019), it is still suspected to be encountered in the area, thus supporting a low presence potential. Finally, the lack of knowledge about this specie has led to the designation of the status “special concern” by the COSEWIC in 2005.

The limiting factors and threats to this species include ship strikes and entanglement in fishing gear. They may also be vulnerable to human-generated underwater noise, chemical pollution and climate change but these have not been clearly specified or validated (COSEWIC, 2005).



Study Area
Harbour porpoise (0.1 - 0.4 ind. per km)
Kingsley and Reeves, 1998; Lesage et al., 2007
Species
Actinopterygii
Atlantic salmon
Atlantic wolffish, Lumpfish
Elasmobranchii
Thorny skate, Winter skate, Smooth skate
White shark
Marine mammals
Harbour porpoise
North Atlantic right whale, Blue whale, Fin whale
Reptilians
Leatherback Sea Turtle
Sources
Daoust et al., 2017
COSEWIC, 2006; 2013
James et al., 2006
OBIS, 2019
Gulf of St. Lawrence
Golfe du Saint-Laurent
Prince Edward Island
Confederation Bridge
New Brunswick
Northumberland Strait
Détroit de Northumberland
Pictou Island
Cape John
Pictou
Boat Harbour
Nova Scotia
Boat Harbour remediation planning and desing project
Desktop Study
Aquatic Species At Risk, Marine Mammals and Sea Turtles
Map 2-1
Observations of aquatic species at risk in the study area
Sources :
CanVec, NRCAN, Government of Canada
0 7.5 15 km
UTM,Zone 20, NAD83
December 2019
Designed by : C. Lavoie
Drawned by : D. Delorme
Checked by : M. Lévesque
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North Atlantic Right Whale

The North Atlantic Right Whale (*Eubalaena glacialis*) could also be encountered in the study area (DFO, 2019), especially between July and September, where this specie visits the shallow coastal waters of the St. Lawrence (Baleines en direct, 2019; Lesage *et al*., 2007). The number of individuals was estimated to 468 in 2010 and 409 in 2019. The relatively low recovery rate of this specie despite the end of the hunting since the 1930s led to the designation of the "endangered status" by the COSEWIC (COSEWIC, 2013; Baleines en direct 2019). The potential presence in the study area is supported by a few observations, including one observation in the study area in the Western part of the Northumberland Strait (east of the confederation bridge) between the period of 1849-2010 (Map 2-1; COSEWIC 2013). Outside the study area, one observation was recorded between 2010 and 2016 in the Western part of the Northumberland Strait (Map 2-1; Daoust *et al*., 2017), one along the West coast of Cape Breton in 2013 (map 2-1; OBIS, 2019) and two were observed in the St-George's Bay (Map 2-1; Daoust *et al*., 2017). Overall, fewer than a dozen of North Atlantic Right whale has been reported each year in the Gulf of St-Lawrence over the last four decades, but the additional efforts for documenting this specie since 2015 has led to the documentation of over 100 individuals in the Gulf (Daoust *et al*., 2017). Those observations, however, can not confirm that the North Atlantic Right whale has increased its use of the Gulf of St. Lawrence since the last decade, but are in concordance with Lesage *et al.* (2007) and Johnson (2018) observations. Nonetheless, the presence potential of the North Atlantic Right whale in the study area was estimated to be "low" because observations were reported in near vicinity of the study area but no observation confirmed that North Atlantic Right Whale are entering regularly the shallower waters of the Northumberland Strait.

The limiting factors and threats to this species include ship traffic and entanglement in fishing gear. Other potential limiting factors are possible but poorly understood (COSEWIC, 2013).

ODONTOCETE CETACEANS

Harbour porpoise

The only at-risk specie of odontocete cetacean that is encountered in the study area is the Harbour porpoise (*Phocoena phocoena*). Its distribution in the Gulf of St. Lawrence is ubiquitous but it can be encountered between the end of June to the end of September (Table 2-2; Lesage *et al*., 2007). The Harbour porpoise mostly feed on small fishes and cephalopods. Most of its prey are demersal and live on or near the sea floor. This specie is often encountered in bays and harbours where architectural features help to concentrate its prey. The reproduction period of this specie occurs early in summer, followed by a gestation period of 10 to 11 months, corresponding to its presence in the Gulf (COSEWIC, 2006a). Observations of Harbour porpoise in the study area were confirmed by numerous sources (Kingsley and Reeves, 1998; Lesage *et al*., 2007; OBIS, 2019) and its presence potential was evaluated to be moderate to high. Most observations were reported at the Eastern tip and coast of the Prince Edward Island in recent years (Map 2-1). The Northumberland Strait has been identified as an important migratory corridor for this specie (Jacques Whitford Environment Limited, 2001), thus can also be encountered during summer months. Despite the decline in the fishing industry and the reduction of incidental catches (Baleines en direct, 2019), COSEWIC attributed the status of "special concern" to this species in 2016 principally because of the lack of knowledge on this specie (COSEWIC, 2016).

Although the population remains abundant, harbour porpoises can be vulnerable to fisheries bycatch and represents its principal limiting factors and threats (COSEWIC, 2016).

ELASMOBRANCHII

A total of four at-risk species of *Elasmobranchii* have a potential to be encountered in the study area. Among them, three belong to the skate family (Smooth skate, Winter skate and Thorny skate) and one to the shark family (White shark). Those species are notably of interest, as skate and shark have been recognized particularly vulnerable to overfishing and to play a vital role in maintaining the ecosystem by occupying a distinct place in the food chain (WWF, 2012).

Smooth skate

The Laurentian-Scotian population of Smooth skate (*Malacoraja senta*) has been determined of "special concern" by the COSEWIC in 2012, as the number remain low since its steeply decline that occurred in the 1970s, even though there are no directed fisheries for this specie and that bycatches have been low for the past decade for this Designable Unit (DU – COSEWIC 2012d). This specie is found at various depth ranges, although its abundance is more important at depths between 150 m and 550 m. It prefers temperatures between 3 and 10 °C and lies on soft mud and clay substrate (COSEWIC 2012d). Nonetheless, the possible presence of this specie in the Northumberland Strait is confirmed by three observations noted in OBIS (2019) along the strait, but the latest occurrence was reported in 1992 (Map 2-1). However, the smooth skate is encountered periodically outside the study area, thus could be encountered in the study site with a low presence potential.

Although fisheries bycatch declined since mid-1990s and are relatively low, bycatch remains a limiting factors and threats to this species. Most individuals in the bycatches are released but their subsequent survival is unknown. Increased natural mortality may also be a limiting factor in some areas (COSEWIC, 2012d).

Winter skate

The Winter skate (*Leucoraja ocellata*) from the Gulf of St. Lawrence population can be observed at notable densities along the Northumberland Strait (Map 2-1). In opposition to the Smooth skate, the Winter skate prefers sandy or gravelly substrate and is more likely to be found in depths less than 150 m. It can be found in very shallow inshore areas in late summer and early autumn in the Southern Gulf and prefers temperatures around 8.7°C. The latest observations in OBIS dates from 2009 and the observations recorded by the COSEWIC (2015) include observations from 1970-2013. Its presence potential in the area is still estimated as "high", since reports in the area were constant through the last four decades. Because the number of mature individuals is estimated to have declined 99% since the early 1980s and because of the slow growth rate of this specie, the COSEWIC conferred the status "endangered" in 2015 to this specie.

The limiting factors and threats to this species include fisheries bycatch, notably in the flatfish fisheries (COSEWIC, 2015).

Thorny skate

Severe population declines of Thorny skate (*Amblyraja radiata*) have been observed in the southern part of their distribution while increases have been observed in the northern part of their range. Because the specie, as a whole, does not meet the criteria for a threatened status, the Thorny skate (*Amblyraja radiata*) status was designated "special concern" by the COSEWIC in 2012. However, the continuing southern decline of its range despite a reduction in fishing mortality is still of concern. In the Gulf of St. Lawrence, the Thorny skate can be encountered in temperatures ranging from 0 to 5 °C and in depths less than 100 m, but it has more recently occupied warmer and deeper waters (COSEWIC, 2012e). In the study area, the Thorny skate is mostly found in the Eastern part of the Northumberland Strait (Map 2-1). Even though its distribution has declined in the study area between 2001 and 2010 compared to 1994 (COSEWIC, 2012e), this specie is still suspected to be encountered in the study area nowadays, with a presence potential estimated to be moderate.

The limiting factors and threats to this species include fisheries bycatch and predation mortality but these factors have not been directly associated to the declines (COSEWIC, 2012e).

White shark

Since the Gulf of St. Lawrence is included in the Northern range limit of this specie and that it can wander into bays and harbours (WWF, 2012), the White shark (*Carcharodon carcharias*) could be encountered in the study area (DFO, 2019). It can be found just below the surface as well as in depths of 1280 m and in various environment such as sandy beaches, off rocky shores, enclosed bays, lagoons, harbours and estuaries. Two sightings of this specie have already been reported in the Northumberland Strait near Cape John during the months of July and August 1962 (Map 2-1; COSEWIC, 2006b), but no observation was reported in the area in the OBIS database. Even though the White shark is rare in most of its range (COSEWIC, 2006b), sightings of this specie have increased in canadian waters. As such, 22 sightings were confirmed between 2009 and 2018 among the 57 that are confirmed since the 1800s (DFO, 2019. However, its presence potential in the study area is more likely rare to nul, as observations of this specie in the study area are very limited. In less than one generation (approximately 14 years), its abundance has encountered a reduction of 80 % in areas of the Northwest Atlantic Ocean. Since this specie is very mobile, Canadian individuals are likely belonging to the same population, which is declared "endangered" by the COSEWIC (2006b).

The limiting factors and threats to this species include sport fishery, commercial bycatch, international trade and entanglement in fishing gears (COSEWIC, 2006b).

ACTINOPTERYGII

The Lumpfish, the Atlantic Wolffish and the Atlantic salmon are the three actinopterygians species at risk that are present in the study area (Map 2-1).

Lumpfish

Even though the distribution of the Lumpfish (*Cyclopterus lumpus*) is broadly distributed across the Northwest Atlantic, this marine fish specie status is designated "endangered" mainly because of the decline of approximately 58 % of its abundance in the last two decades. The Lumpfish inhabits both pelagic and benthic habitats, depending of their requirement for different life cycle stages (COSEWIC, 2017). For nesting, the Lumpfish is found in rocky areas with crevices, while young of the year are rather observed at the surface, usually hanging on seaweeds. Adults remain pelagic and gradually switch to a demersal lifestyle for spring spawning and reproduction (COSEWIC, 2017). In the Northumberland Strait, it was reported at nine occasions between 1980-1993 (Appendix A; Map 2-1). In the study area, its presence potential is higher for juveniles than adults, as few adults were reported in the last decades (COSEWIC, 2017). Thus, the presence potential is estimated to be moderate in the Northumberland Strait.

Atlantic Wolffish

The most recent observation reported in OBIS for the Atlantic Wolffish (*Anarhichas lupus*) goes to 1994 (Appendix A; Map 2-1), but according to DFO (2019), its current presence in the study area is expected. Depending on its life stage, the Atlantic Wolffish can be found in near-shore water, under shelters, on the continental shelf on rocky or sandy bottoms and near boulder or caves – which they use for spawning – and at depths around 150 m in the Gulf of St. Lawrence.

Overall, the specie is mostly located below the thermocline and under the influence of tidal and coastal currents. In the study area, six observations are reported in OBIS (2019), mostly in the eastern part. Because no recent reports of this specie were recorded in the area but is suspected to be encountered, its presence potential was evaluated to “low” to “moderate”. Its status of “special concern” designated by the COSEWIC is explained by the remaining low abundance of the specie compared to the early 1980s regardless of its increasing abundance over the last decade (COSEWIC 2012a).

The limiting factors and threats to this species include commercial fishing (directed and bycatch) particularly in the 1970s but declined considerably in the 1990s following the closure of several groundfish fisheries. Climate change and its effects on water temperatures may also affect the distribution and abundance of this species.

Atlantic salmon

For the Atlantic salmon (*Salmo salar*), the study area acts as a migratory zone since this specie migrates from fifteen rivers in the Northumberland shore to the ocean and vice versa (DFO, 1997; Jacques Whitford Environment Limited, 2001). As such, juveniles smolts and returning adults are expected to swim through the Northumberland Strait during the smolt run in late spring and spawning migration of the adults in late autumn. Only one observation of Atlantic salmon has been reported in the Strait in 1990 (Map 2-1). Even though few reports have been made in the study area, those results more likely reflect a lack of capture associated with fishing nets that are not targeting this pelagic species. Its presence in the area is therefore suspected to be high during migratory periods. In the study area, COSEWIC (2010) has designated this population of “special concern” (Gaspé-southern Gulf of St. Lawrence population), based on its poor marine survival that can be related to changes in marine ecosystems.

The limiting factors and threats to this species include climate change, changes to ocean ecosystems, fishing (commercial, subsistence, recreational, and illegal), dams and obstructions in freshwater, agriculture, urbanization, acidification, aquaculture, and invasive species (COSEWIC, 2010).

Reptilians

The only reptilian specie that present a status at risk in the study area is the Leatherback sea turtle (*Dermochelys coriaceae*), a migratory specie that use the cold waters of the Northern Atlantic to feed on organisms such as Cnidaria, Ctenophora and Urochordata (Tunicata). It is present in Canadian waters, including the Gulf of St. Lawrence, to feed from the months of April to December – more abundant between June to October – and inhabits both shelf and offshore waters. During the other time of the year, it inhabits warmer tropical waters, where nesting areas are aggregated mostly in Mexico, Costa Rica, Indonesia, Solomon Island and Papua New Guinea. Then, majority of sightings are from the continental shelf, inside the 200 m isobath and its median depth of sightings is 113 m (COSEWIC, 2012c). However, young sea turtles are found in warmer waters (James *et al*., 2006a). The Leatherback sea turtle, when foraging, spend most of its time near the surface. The presence of Leatherback sea turtle in the Northumberland Strait has been confirmed by James *et al*. (2005 and 2006b), where it was reported at few occurrences in the Eastern Northumberland Strait (Map 2-1). However, its presence is rather scarce in the Strait itself (six observations were reported from 1998 to 2005) and is mostly seen in the Laurentian Channel and the Inner Gulf (James *et al*., 2005; 2006a; 2006b), thus suggesting a presence potential in the study area from low to moderate. Even though the demographic status of the specie seems stable since the last generation, the Leatherback sea turtle have seen its abundance decline by 70 % and no significant increase is observed, thus conferring to this specie the status “endangered” (COSEWIC 2012c).

The limiting factors and threats to this species include fisheries bycatch, coastal and offshore resource development, marine pollution, poaching of eggs, changes to nesting beaches and climate change. There turtles are migrating into Canadian waters for feeding during the summer months, where they are threatened by entanglement in longline and fixed fishing gear (COSEWIC, 2012c).

Table 2-2 Occupation periods of aquatic species at risk in the study area

Species	Jan.	Feb.	March	April	May	June	July	August	Sept.	Oct.	Nov.	Dec.
Mysticetes cetaceans												
Blue whale (Gulf of St. Lawrence)												
Fin whale												
North Atlantic Right whale												
Odontocete cetaceans												
Harbour Porpoise												
Elasmobranchii												
Smooth skate												
Winter skate[1]												
Thorny skate[2]												
White Shark[3]												
Actinopterygii												
Lumpfish[4]												
Atlantic Wolffish[5]												
Atlantic salmon												
Reptilians												
Leatherback Sea turtle[5]												

Sources : Baleines en direct; COSEWIC; Leatherwood et al., 1976; Lesage et al., 2007

1 Occurs primarily in shallow and warm waters during late summer and early autumn and disperse throughout the Magdalen Shallows in winter.

2 Follows depths with a temperatures ranging from 0 °C to 5 °C.

3 Based on observations made in Northern Atlantic.

4 Spends a greater portion of their time near the bottom during winter months. Remains offshore late summer to early spring.

5 Dark green zones represent months were the specie is present at greater abundance.

2.2 MARINE MAMMALS

Overall, 10 species of marine mammals are encountered in the study area. Among them, four species have been designated as aquatic species at risk, such as the Blue whale, the Fin whale, the North-Atlantic Right whale and the Harbour porpoise. The description of the repartition of those species, as well as their presence potential in the area and their potential threats are described in section 2.1. Six other species of marine mammals, whose do not present a status at risk, are reported in the Northumberland Strait. As such, one mysticete cetacean (Minke whale), an odontocete cetacean from the *Delphinidae* family and four pinnipeds (Grey Seal, Harbour seal, Harp seal and Hooded seal) can be present in the study area, depending on the time of the year (Map 2-2; Table 2-4). The date of every observation events for all the species are listed in appendix A.

Table 2-3 Marine mammals encountered in the study area

Group	Specie[1]	Common Name	Status	Confirmed presence	Presence potential[3]
Mysticetes cetaceans	*Balaenoptera musculus*[2]	Blue whale	Endangered	DFO, 2019	Low
	Balaenoptera physalus	Fin whale	Special Concern	OBIS, 2019	Low
	Eubalaena glacialis	North Atlantic Right whale	Endangered	COSEWIC, 2013; Daoust *et al.,* 2017 OBIS, 2019	Low
	Balaenoptera acutorostrata	Minke Whale	Not at risk	Lesage *et al.,*2007; OBIS 2019	Moderate
Odontocete cetaceans	*Phocoena phocoena*	Harbour porpoise	Special Concern	Lesage et al., 2007; OBIS 2019	Moderate to High
	Delphiniade family	-	Not at risk	OBIS 2019	Rare
Pinnipedia	*Halichoerus grypus*	Grey Seal	Not at risk	OBIS 2019; Lesage *et al.,*2007; Robillard *et al*., 2005	High
	Phoca vitulina	Harbour Seal	Not at risk	OBIS, 2019; Robillard *et al*., 2005	Moderate
	Pagophilus groenlandicus	Harp seal	Not at risk	-	Low to Moderate
	Cystophora cristata	Hooded seal	Not at risk	-	Low

Sources: DFO 2019; OBIS 2019; COSEWIC; Lesage et al., 2007; Robillard et al., 2005

1 Species in pink present an "at-risk" status and are discussed in section 2.1.

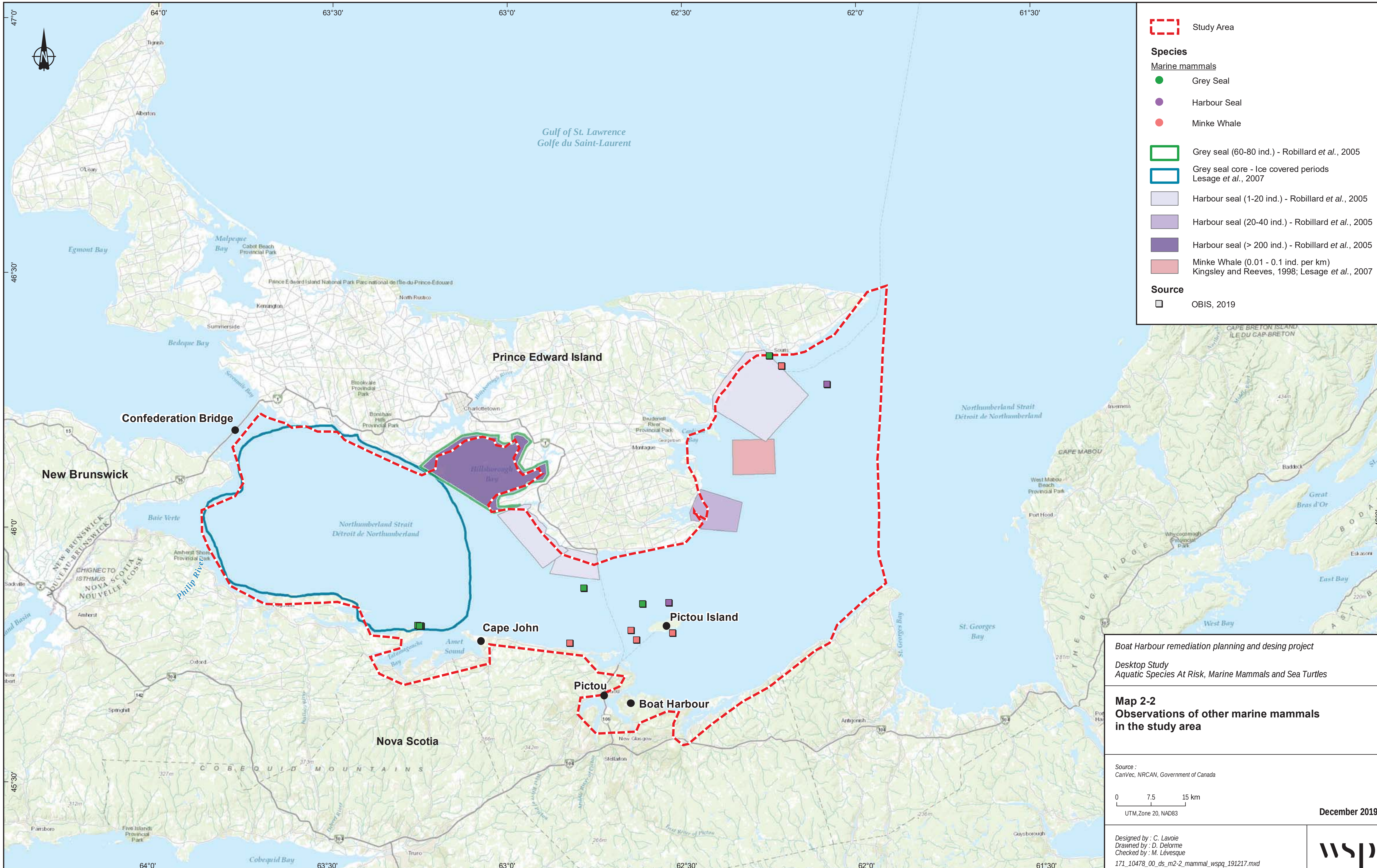
2 The species in grey are suspected to be encountered in the study area according to Fisheries and Oceans, Canada (DFO), but no sightings were reported in this area by other sources.

3 The evaluated presence potential in the study area is based on all consulted sources; High: Frequent sightings in the study area; Moderate: Infrequent, but regular observations in the study area; Low: Sporadic sightings in the study area, punctual but annual observations outside the study area; Rare: No recent observation outside the range but possible presence.

MYSTICETES CETACEANS

Minke whale

In a survey performed by Kingsley and Reeves in 1995-1996 over the Estuary and Gulf of St. Lawrence, the Minke whale (*Balaenoptera acutorostrata*) was observed in higher density along the north shelf of the Gulf and widely distributed, but patchily, elsewhere in the Gulf. The Minke whale appeared to converge where capelin schools were located, especially off eastern Newfoundland and in the Laurentian Channel, as well as in areas of high concentrations of cod and herring (Kingsley and Reeves, 1998; Leatherwood *et al*., 1976). It is found in Canadian waters, including the Golf of St. Lawrence, from late May to November (Table 2-4, Leatherwood *et al*., 1976), and prefer sector of sandy bottoms with no particular association to thermal fronts, as opposed to other rorquals (Doniol-Valcroze *et al*., 2007). From May to October, Minke whale can be observed more than 50 % of days in the Southern Gulf of St. Lawrence, thus indicating that this area (including the study area) is used on a regular basis by this specie (Lesage *et al*., 2007). The presence of the Minke whale is therefore estimated to be at least moderate in the study area, since its presence was confirmed with numerous sightings from 1995 to 2014 (Map 2-1). In the Gulf of St. Lawrence, the abundance of the Minke whale was estimated to 1 000 individuals (Kingsley and Reeves, 1998) and its population status is considered stable throughout its entire range, making this specie the most abundant rorqual in the world (NOAA, 2019).



Study Area
Species
Marine mammals
Grey Seal
Harbour Seal
Minke Whale
Grey seal (60-80 ind.) - Robillard et al., 2005
Grey seal core - Ice covered periods
Lesage et al., 2007
Harbour seal (1-20 ind.) - Robillard et al., 2005
Harbour seal (20-40 ind.) - Robillard et al., 2005
Harbour seal (> 200 ind.) - Robillard et al., 2005
Minke Whale (0.01 - 0.1 ind. per km)
Kingsley and Reeves, 1998; Lesage et al., 2007
Source
OBIS, 2019
Gulf of St. Lawrence
Golfe du Saint-Laurent
Prince Edward Island
Confederation Bridge
New Brunswick
Nova Scotia
Cape John
Pictou Island
Pictou
Boat Harbour
Northumberland Strait
Détroit de Northumberland
Hillsborough Bay
Charlottetown
Summerside
Malpeque Bay
Egmont Bay
Bedeque Bay
Baie Verte
Philip River
Cobequid Bay
St. Georges Bay
West Bay
East Bay
Antigonish
New Glasgow
Stellarton
Truro
Amherst
Souris
Montague
Inverness
COBEQUID MOUNTAINS
64°0'
63°30'
63°0'
62°30'
62°0'
61°30'
47°0'
46°30'
46°0'
45°30'
Boat Harbour remediation planning and desing project
Desktop Study
Aquatic Species At Risk, Marine Mammals and Sea Turtles
Map 2-2
Observations of other marine mammals
in the study area
Source :
CanVec, NRCAN, Government of Canada
0 7.5 15 km
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Checked by : M. Lévesque
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ODONTOCETES CETACEANS

Dolphins

One odontocete cetacean from the *Delphinidae* family has been reported in 1971 in the Northumberland Strait (OBIS, 2019; Map 2-2). Even though it is not possible to assess which specie was observed, three species of Dolphins can be encountered in the Gulf; the Atlantic White-Sided dolphin (*Lagenorhynchus acutus*), the White-Beaked dolphin (*Lagenorhynchus albirostris*) and the Short-Beaked Common dolphin (*Delphinus delphis*), all of which being present especially between spring and autumn (Baleines en direct, 2019; Lesage *et al.*, 2007). COSEWIC determined that none of these species were at risk since no significant threats were identified (COSEWIC, 2001). The presence of White-Sided dolphin is predominant between Gaspé and Anticosti as well as the West coast of Newfoundland, but their incursion into the Gulf greatly vary over time. As for the Short-Beaked Common Dolphin, its repartition in the Gulf is rather scarce and is mostly encountered within Newfoundland waters. However, a survey performed in 2002 showed evidences of Short-Beaked Common dolphin in the Gulf, especially in the Belle Isle Strait, the Esquiman Channel and the Laurentian Channel (Lesage *et al*., 2007). The White-Beaked dolphin can, in addition, be encountered in the Gulf during winter, but reports of its presence in the Gulf are scarce, as it is mostly encountered in the Northeastern part of the Gulf of St. Lawrence. Based on those observations, the presence potential of dolphins in the Northumberland Strait is rather low, as no other observation were reported in the area since 1971.

PINNIPEDS

Four pinniped species are encountered in the Gulf of St. Lawrence and all of them have a potential to be encountered in the study area. Among them, two are migratory species (Harp seals and Hooded) and two are permanent residents of the Gulf (Grey seal and Harbour seal). Grey seal, Harp seal and Hooded seals whelp on the packs of ice during winter, as Harbour seal whelp in various areas in the Gulf in late spring (Lesage *et al*., 2007). Because the populations trends of all the four species have significantly increased since the late 1960s – corresponding to the period following hunting closure – and that they are present at great abundance within their range, their status was assessed “not-at-risk” (DFO, 2019d), excepted for the Harp seal, whose the COSEWIC did not confer a status.

Grey seal

The Grey seal (*Halichoerus grypus*) is the most abundant pinniped in the Northumberland Strait. In this region, the Grey seal especially feed on Sand lance (*Ammodytes americanus*), Atlantic cod (*Gadus morhua*) and Atlantic Herring (*Clupea harengus*), all of which encountered in great abundance in the study area (Hammill and Stenson, 2000). It can often be observed in large packs on small isolated islet, sandbars, reefs and rocks exposed at low tide to haul-out and is often seen in the same areas as the Harbour seal (Robillard *et al*., 2005). Between the months of December to June, the Grey seal visits the southern Gulf of St. Lawrence (including the Northumberland Strait), as well as the Scotian Shelf, Maine and Massachusetts to breed. In addition, a significant area has been recognized for the reproduction period of grey seal during the ice-covered periods in the Northumberland Strait (Lesage *et al*., 2007), where numerous whelping zones on small island have been identified (Map 2-2). The numerous observations that have been reported throughout recent years therefore makes this specie more likely to be encountered in the study area (OBIS, 2019; Robillard *et al*., 2005), assessing its presence potential to “high”.

Harbour seal

The Harbour seal (*Phoca vitulina*) feeds mostly on Atlantic cod, Atlantic herring and Capelin (*Malotus villosus*) in the Southern Gulf of St. Lawrence and is present almost all year long in areas where ice conditions are light to intermediate during winter. Even though records of Harbour seal were more important in the Estuary of the Gulf, or around Anticosti Island (Lesage *et al*., 2007), it can also be found in the study area around the Prince Edward Island (Map 2-2). Harbour seal inhabits areas where ice is less important during winter. However, its diving patterns during both ice-free and ice-covered periods indicate that its movements are generally limited within a few kilometers from their haul-out sites (Lesage *et al*., 2004). Therefore, the likelihood of its presence in the study area during winter months is also expected. Moreover, hauling sites were identified in the study area by Robillard *et al*. (2005) and two observations were recorded in OBIS (2019), indicating that this specie has at least a moderate presence potential in the area. The specie's status was previously assessed "at-risk" by the COSEWIC, but its great adaptive ability and the lack of serious immediate threats over any substantial part of its range led the re-examination of its status to "not-at-risk" in November 2007 (COSEWIC, 2007).

Harp seal

Even though the Harp seal is the most abundant marine mammal predator in the Northwest Atlantic (Shelton *et al.,*1996), no observations of Harp seal (*Phagophilus groenlandicus*) in the study area were recorded in OBIS (2019). However, this area is included in its range (DFO, 2019c; Prescott and Richard, 2013) and Lesage *et al* (2007) writes that Harp seal can be encountered in higher concentrations in the Southern Gulf of St. Lawrence, notably into the Eastern Northumberland Strait throughout January to May. The evaluation of its presence potential is therefore estimated "low to moderate".

Hooded seal

Similarly to the Harp seal, the Hooded seal (*Cystophora cristata*) is a seasonal visitor of the Gulf of St. Lawrence and occurs from December to May. However, the repartition of this specie reported by Lesage (2007) should be interpreted with caution because the satellite telemetry data covered only a small portion of the annual cycle of the specie, thus no areas used by the hooded seal during late fall and early winter were recorded. Even though no observation is recorded in OBIS (2019), the Northumberland Strait has been identified as a significant area for this specie during their ice-covered periods, but to a lesser extent than the Harp seal (Lesage *et al*., 2007). Because the lack of data confirming the presence of the specie in the study area, although it may occur in the area during winter, its presence potential is determined to be low.

Table 2-4 Occupation period of marine mammals in the Gulf of St. Lawrence that could be encountered in the study area

Species[1]	Jan.	Feb.	March	April	May	June	July	August	Sept.	Oct.	Nov.	Dec.
Mysticetes cetaceans												
Blue whale (Gulf of St. Lawrence)												
Fin whale												
North Atlantic Right whale												
Minke Whale												
Odontocete cetaceans												
Harbour Porpoise												
Dolphins												

Pinnipeds												
Grey seals[2]												
Harbour seals[3]												
Harp seals												
Hooded seals												

Sources : COSEWIC; Leatherwood et al., 1976; Lesage et al., 2007

1 Species in pink present an "at-risk" status and are discussed in section 2.1.

2 Dark green zones represent months were the specie is present at greater abundance.

3 Harbour seal remain in the vicinity of their haul-out sites during summer and is believed to be relatively sedentary through the year

2.3 REPTILIANS

Leatherback sea turtle

Marine reptilians that are encountered in Northern Atlantic and Nova Scotian waters belong to three species of sea turtles: The Leatherback sea turtle, Kemp's Ridley sea turtle and Loggerhead turtle. Those species visit the cold waters of the Northern Atlantic each year, but the Leatherback sea turtle is the only reptilian that wanders into the Gulf of St. Lawrence and the study area during summer months. A description of the specie, including its presence potential in the study area as well as the period of the year where it can be encountered, is presented in the section 2.1 of the present document.

3 CONCLUSION

The objective of this review was to assess the presence potential of aquatic species at risk, marine mammals and sea turtles in the BHETF and the surrounding. The study area, that is included in the Northumberland Strait, encompasses the EBSA 1-Western Cape Breton determined by the DFO and is surrounded by two other EBSA: 2-St. Georges Bay and 3-Western Northumberland Strait (DFO, 2013). Several species listed at risk under the Species at Risk Act (SARA) or recommended by the Committee on the Status of Endangered Wildlife in Canada (COSEWIC) can be encountered in study area. These at-risk species include several **1)** marine mammals (Blue whale, Fin whale, North Atlantic Right Whale, Harbour porpoise); **2)** elasmobranch (Smooth skate, Winter skate, Thorny skate and White shark); **3)** ray-finned fishes (Lumpfish, Atlantic Wolffish and Atlantic salmon) and **4)** one reptilian (Leatherback sea turtle). Several other marine mammals without an at-risk status can also be present in the study area, including Minke whale, Dolphins (species not identified), Grey seal, Harbour seal, Harp seal, Hooded seal. In addition, several of these species are candidate or have been identified as ecologically significant species by DFO, meaning that they are having a leading role for defining the structure and/or function of the ecosystem or influencing the biodiversity and/or productivity. As such, the Fin whale, Minke whale, Harbour porpoise, Grey seal, Harp seal, Harbour seal, Thorny skate, White Shark are candidate of ecologically significant species and communities, while the Atlantic salmon and the Wolffish are ecologically significant species designated by DFO partners (DFO, 2013).

In this review, the potential presence of aquatic species with an at-risk status was evaluated to “high” for the Atlantic salmon, while it was evaluated “moderate to high” for the Harbour porpoise and the Winter Skate and “moderate” for the Smooth skate, the Thorny skate and the Lumpfish. Species with a “low to moderate” presence potential were the Atlantic Wolffish and the Leatherback Sea turtle. Species with a low potential all belonged to mysticete cetaceans, such as the Blue whale, the Fin whale and the North Atlantic Right Whale. Concerning the White shark, its presence potential was “rare to nul”. The occupation period of aquatic species at risk in the study area is somewhat variable, as it depends on the biology of the species. Overall, cetaceans (mysticete and odontocete included) are mostly presents during summer months, during ice-free covered periods, as well as White shark, Winter skate, Lumpfish and Leatherback sea turtle. Atlantic salmon is also a seasonal visitor of the study area, with a higher potential to be encountered in late spring and early autumn, while the Wolffish, the Smooth skate and the Thorny skate can be present all year long.

The potential presence of marine mammals not at risk was evaluated to “high” for Grey Seal, “moderate” for Minke Whale and Harbour Seal and “low” for Hooded seal. Dolphins and Harp seal are the least likely to be encountered. Grey seals and Harbour seals can be encountered all year in the study area, while Harp seals and Hooded seals are suspected to be encountered mostly during the ice-covered areas and the Minke whale during summer months, i.e. ice-free periods.

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APPENDIX

A

DATE OF SIGHTINGS REPORTED IN THE STUDY AREA

Group	Specie	Common Name	Confirmed presence	Date of event
Mysticetes cetaceans	*Balaenoptera musculus*	Blue whale	DFO, 2019	N/A
	Balaenoptera physalus	Fin whale	OBIS, 2019	1964
	Balaenoptera physalus	Fin whale	OBIS, 2019	1964
	Balaenoptera physalus	Fin whale	OBIS, 2019	1967-10-08
	Eubalaena glacialis	North Atlantic Right whale	COSEWIC, 2013	1849-2010
	Eubalaena glacialis	North Atlantic Right whale	Daoust et al., 2017	2010-2016
	Eubalaena glacialis	North Atlantic Right whale	Daoust et al., 2017	2010-2016
	Eubalaena glacialis	North Atlantic Right whale	Daoust et al., 2017	2010-2016
	Eubalaena glacialis	North Atlantic Right whale	OBIS, 2019	2013
	Balaenoptera acutorostrata	Minke Whale	OBIS 2019	2007-07-11
	Balaenoptera acutorostrata	Minke Whale	OBIS 2019	2013-09-12
	Balaenoptera acutorostrata	Minke Whale	OBIS 2020	2013-09-12
	Balaenoptera acutorostrata	Minke Whale	OBIS 2021	2013-09-16
	Balaenoptera acutorostrata	Minke Whale	OBIS 2022	2014-02-06
	Balaenoptera acutorostrata	Minke Whale	OBIS 2023	2014-09-17
	Balaenoptera acutorostrata	Minke Whale	OBIS 2024	n.d.
	Balaenoptera acutorostrata	Minke Whale	Kingsley and Reeves, 1998	1995-1996
Odontocete cetaceans	*Phocoena phocoena*	Harbour porpoise	Lesage et al., 2007;	1995-1996 and 2002
	Phocoena phocoena	Harbour porpoise	OBIS 2019	2007-07-09
	Phocoena phocoena	Harbour porpoise	OBIS 2019	2007-07-09
	Phocoena phocoena	Harbour porpoise	OBIS 2019	2007-07-09
	Phocoena phocoena	Harbour porpoise	OBIS 2019	2007-07-11
	Phocoena phocoena	Harbour porpoise	OBIS 2019	2007-07-11
	Phocoena phocoena	Harbour porpoise	OBIS 2019	2007-07-11
	Phocoena phocoena	Harbour porpoise	OBIS 2019	2007-07-11
	Phocoena phocoena	Harbour porpoise	OBIS 2019	2007-07-11
	Phocoena phocoena	Harbour porpoise	OBIS 2019	2007-08-13
	Phocoena phocoena	Harbour porpoise	OBIS 2019	2007-08-13
	Phocoena phocoena	Harbour porpoise	OBIS 2019	2007-08-14
	Phocoena phocoena	Harbour porpoise	OBIS 2019	2007-08-14
	Phocoena phocoena	Harbour porpoise	OBIS 2019	2007-08-14
	Phocoena phocoena	Harbour porpoise	OBIS 2019	2007-08-14
	Phocoena phocoena	Harbour porpoise	OBIS 2019	2007-08-14
	Phocoena phocoena	Harbour porpoise	OBIS 2019	2007-08-14
	Phocoena phocoena	Harbour porpoise	OBIS 2019	2007-08-14
	Phocoena phocoena	Harbour porpoise	OBIS 2019	2007-08-14
	Phocoena phocoena	Harbour porpoise	OBIS 2019	2007-08-14
	Phocoena phocoena	Harbour porpoise	OBIS 2019	2007-08-14
	Phocoena phocoena	Harbour porpoise	OBIS 2019	2007-08-14
	Phocoena phocoena	Harbour porpoise	OBIS 2019	2007-08-14
	Phocoena phocoena	Harbour porpoise	OBIS 2019	2007-08-14
	Phocoena phocoena	Harbour porpoise	OBIS 2019	2007-08-16
	Phocoena phocoena	Harbour porpoise	OBIS 2019	2007-08-16
	Phocoena phocoena	Harbour porpoise	OBIS 2019	2007-08-16
	Phocoena phocoena	Harbour porpoise	OBIS 2019	2007-08-16
	Phocoena phocoena	Harbour porpoise	OBIS 2019	2007-08-16
	Phocoena phocoena	Harbour porpoise	OBIS 2019	2007-08-16
	Phocoena phocoena	Harbour porpoise	OBIS 2019	2007-08-16
	Phocoena phocoena	Harbour porpoise	OBIS 2019	2007-08-17
	Phocoena phocoena	Harbour porpoise	OBIS 2019	2007-08-17
	Phocoena phocoena	Harbour porpoise	OBIS 2019	2007-08-17

Group	Specie	Common Name	Confirmed presence	Date of event
	Phocoena phocoena	Harbour porpoise	OBIS 2019	2007-08-17
	Phocoena phocoena	Harbour porpoise	OBIS 2019	2007-08-17
	Phocoena phocoena	Harbour porpoise	OBIS 2019	2007-08-18
	Phocoena phocoena	Harbour porpoise	OBIS 2019	2007-08-18
	Phocoena phocoena	Harbour porpoise	OBIS 2019	2014-11-07
	Delphiniade family	-	OBIS 2019	1971
Pinnipedia	*Phoca vitulina*	Harbour Seal	OBIS 2019	2007
	Phoca vitulina	Harbour Seal	OBIS 2019	2007
	Phoca vitulina	Harbour Seal	Robillard *et al*., 2005	1996 and 2001
	Phoca vitulina	Harbour Seal	Robillard *et al*., 2005	1996 and 2001
	Phoca vitulina	Harbour Seal	Robillard *et al*., 2005	1996 and 2001
	Phoca vitulina	Harbour Seal	Robillard *et al*., 2005	1996 and 2001
	Halichoerus grypus	Grey Seal	Robillard et al., 2005	1996 and 2001
	Halichoerus grypus	Grey Seal	Robillard et al., 2005	1996 and 2001
	Halichoerus grypus	Grey Seal	OBIS, 2019	(913 x) 2015-01-30
	Halichoerus grypus	Grey Seal	OBIS, 2019	2009-09-09
	Halichoerus grypus	Grey Seal	OBIS, 2019	2009-09-09
	Halichoerus grypus	Grey Seal	Lesage *et al.*,2007	2002
Elasmobranchii	*Malacoraja senta*	Smooth skate	OBIS, 2019	1985-09-25
	Malacoraja senta	Smooth skate	OBIS, 2019	1988-09-19
	Malacoraja senta	Smooth skate	OBIS, 2019	1992-09-25
	Leucoraja ocellata	Winter skate	OBIS, 2019	1971-09-30
	Leucoraja ocellata	Winter skate	OBIS, 2019	1971-09-30
	Leucoraja ocellata	Winter skate	OBIS, 2019	1972-09-06
	Leucoraja ocellata	Winter skate	OBIS, 2019	1973-08-05
	Leucoraja ocellata	Winter skate	OBIS, 2019	1973-09-05
	Leucoraja ocellata	Winter skate	OBIS, 2019	1974-09-04
	Leucoraja ocellata	Winter skate	OBIS, 2019	1974-09-04
	Leucoraja ocellata	Winter skate	OBIS, 2019	1974-09-06
	Leucoraja ocellata	Winter skate	OBIS, 2019	1975-09-03
	Leucoraja ocellata	Winter skate	OBIS, 2019	1975-09-03
	Leucoraja ocellata	Winter skate	OBIS, 2019	1978-09-09
	Leucoraja ocellata	Winter skate	OBIS, 2019	1978-09-09
	Leucoraja ocellata	Winter skate	OBIS, 2019	1979-09-14
	Leucoraja ocellata	Winter skate	OBIS, 2019	1979-09-14
	Leucoraja ocellata	Winter skate	OBIS, 2019	1980-09-04
	Leucoraja ocellata	Winter skate	OBIS, 2019	1980-09-04
	Leucoraja ocellata	Winter skate	OBIS, 2019	1980-09-04
	Leucoraja ocellata	Winter skate	OBIS, 2019	1981-09-02
	Leucoraja ocellata	Winter skate	OBIS, 2019	1981-09-02
	Leucoraja ocellata	Winter skate	OBIS, 2019	1981-09-02
	Leucoraja ocellata	Winter skate	OBIS, 2019	1982-09-09
	Leucoraja ocellata	Winter skate	OBIS, 2019	1982-09-09
	Leucoraja ocellata	Winter skate	OBIS, 2019	1983-09-17
	Leucoraja ocellata	Winter skate	OBIS, 2019	1983-09-17
	Leucoraja ocellata	Winter skate	OBIS, 2019	1984-08-29
	Leucoraja ocellata	Winter skate	OBIS, 2019	1984-08-30
	Leucoraja ocellata	Winter skate	OBIS, 2019	1984-08-30
	Leucoraja ocellata	Winter skate	OBIS, 2019	1984-09-05
	Leucoraja ocellata	Winter skate	OBIS, 2019	1984-09-17
	Leucoraja ocellata	Winter skate	OBIS, 2019	1984-09-21
	Leucoraja ocellata	Winter skate	OBIS, 2019	1985-09-17

Group	Specie	Common Name	Confirmed presence	Date of event
	Leucoraja ocellata	Winter skate	OBIS, 2019	1985-09-17
	Leucoraja ocellata	Winter skate	OBIS, 2019	1985-09-17
	Leucoraja ocellata	Winter skate	OBIS, 2019	1985-09-17
	Leucoraja ocellata	Winter skate	OBIS, 2019	1985-09-25
	Leucoraja ocellata	Winter skate	OBIS, 2019	1985-09-25
	Leucoraja ocellata	Winter skate	OBIS, 2019	1985-09-25
	Leucoraja ocellata	Winter skate	OBIS, 2019	1985-09-25
	Leucoraja ocellata	Winter skate	OBIS, 2019	1985-09-25
	Leucoraja ocellata	Winter skate	OBIS, 2019	1985-09-25
	Leucoraja ocellata	Winter skate	OBIS, 2019	1985-09-25
	Leucoraja ocellata	Winter skate	OBIS, 2019	1985-09-25
	Leucoraja ocellata	Winter skate	OBIS, 2019	1985-09-25
	Leucoraja ocellata	Winter skate	OBIS, 2019	1985-09-25
	Leucoraja ocellata	Winter skate	OBIS, 2019	1986-09-03
	Leucoraja ocellata	Winter skate	OBIS, 2019	1986-09-12
	Leucoraja ocellata	Winter skate	OBIS, 2019	1986-09-12
	Leucoraja ocellata	Winter skate	OBIS, 2019	1986-09-12
	Leucoraja ocellata	Winter skate	OBIS, 2019	1986-09-12
	Leucoraja ocellata	Winter skate	OBIS, 2019	1986-09-15
	Leucoraja ocellata	Winter skate	OBIS, 2019	1986-09-15
	Leucoraja ocellata	Winter skate	OBIS, 2019	1986-09-23
	Leucoraja ocellata	Winter skate	OBIS, 2019	1986-09-23
	Leucoraja ocellata	Winter skate	OBIS, 2019	1986-09-23
	Leucoraja ocellata	Winter skate	OBIS, 2019	1986-09-23
	Leucoraja ocellata	Winter skate	OBIS, 2019	1986-09-23
	Leucoraja ocellata	Winter skate	OBIS, 2019	1986-09-23
	Leucoraja ocellata	Winter skate	OBIS, 2019	1986-09-23
	Leucoraja ocellata	Winter skate	OBIS, 2019	1986-09-24
	Leucoraja ocellata	Winter skate	OBIS, 2019	1986-09-24
	Leucoraja ocellata	Winter skate	OBIS, 2019	1986-09-24
	Leucoraja ocellata	Winter skate	OBIS, 2019	1986-09-24
	Leucoraja ocellata	Winter skate	OBIS, 2019	1986-09-24
	Leucoraja ocellata	Winter skate	OBIS, 2019	1986-09-24
	Leucoraja ocellata	Winter skate	OBIS, 2019	1986-09-24
	Leucoraja ocellata	Winter skate	OBIS, 2019	1986-09-24
	Leucoraja ocellata	Winter skate	OBIS, 2019	1986-09-24
	Leucoraja ocellata	Winter skate	OBIS, 2019	1986-09-25
	Leucoraja ocellata	Winter skate	OBIS, 2019	1986-09-25
	Leucoraja ocellata	Winter skate	OBIS, 2019	1986-09-25
	Leucoraja ocellata	Winter skate	OBIS, 2019	1986-09-25
	Leucoraja ocellata	Winter skate	OBIS, 2019	1986-09-25
	Leucoraja ocellata	Winter skate	OBIS, 2019	1987-08-31
	Leucoraja ocellata	Winter skate	OBIS, 2019	1987-08-31
	Leucoraja ocellata	Winter skate	OBIS, 2019	1987-09-01
	Leucoraja ocellata	Winter skate	OBIS, 2019	1987-09-01
	Leucoraja ocellata	Winter skate	OBIS, 2019	1987-09-01
	Leucoraja ocellata	Winter skate	OBIS, 2019	1987-09-01
	Leucoraja ocellata	Winter skate	OBIS, 2019	1988-09-15
	Leucoraja ocellata	Winter skate	OBIS, 2019	1988-09-15
	Leucoraja ocellata	Winter skate	OBIS, 2019	1988-09-15
	Leucoraja ocellata	Winter skate	OBIS, 2019	1988-09-15
	Leucoraja ocellata	Winter skate	OBIS, 2019	1988-09-15

Group	Specie	Common Name	Confirmed presence	Date of event
	Leucoraja ocellata	Winter skate	OBIS, 2019	1988-09-15
	Leucoraja ocellata	Winter skate	OBIS, 2019	1988-09-16
	Leucoraja ocellata	Winter skate	OBIS, 2019	1989-09-15
	Leucoraja ocellata	Winter skate	OBIS, 2019	1989-09-15
	Leucoraja ocellata	Winter skate	OBIS, 2019	1989-09-23
	Leucoraja ocellata	Winter skate	OBIS, 2019	1990-09-03
	Leucoraja ocellata	Winter skate	OBIS, 2019	1990-09-19
	Leucoraja ocellata	Winter skate	OBIS, 2019	1990-09-19
	Leucoraja ocellata	Winter skate	OBIS, 2019	1990-09-19
	Leucoraja ocellata	Winter skate	OBIS, 2019	1990-09-20
	Leucoraja ocellata	Winter skate	OBIS, 2019	1991-09-21
	Leucoraja ocellata	Winter skate	OBIS, 2019	1991-09-22
	Leucoraja ocellata	Winter skate	OBIS, 2019	1991-09-22
	Leucoraja ocellata	Winter skate	OBIS, 2019	1992-09-15
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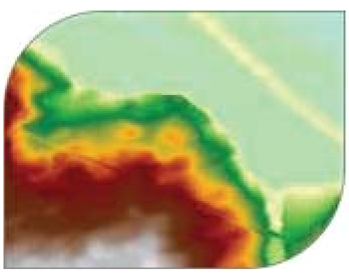
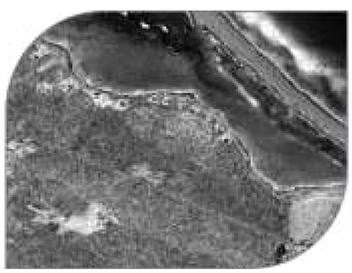
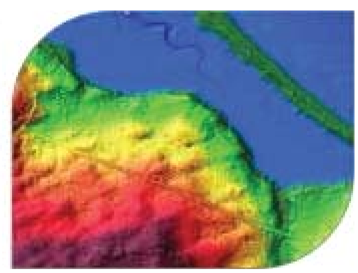
	Leucoraja ocellata	Winter skate	OBIS, 2019	1992-09-15
	Leucoraja ocellata	Winter skate	OBIS, 2019	1992-09-24
	Leucoraja ocellata	Winter skate	OBIS, 2019	1992-09-24
	Leucoraja ocellata	Winter skate	OBIS, 2019	1992-09-25
	Leucoraja ocellata	Winter skate	OBIS, 2019	1992-09-25
	Leucoraja ocellata	Winter skate	OBIS, 2019	1993-09-11
	Leucoraja ocellata	Winter skate	OBIS, 2019	1993-09-20
	Leucoraja ocellata	Winter skate	OBIS, 2019	1993-09-21
	Leucoraja ocellata	Winter skate	OBIS, 2019	1993-09-21
	Leucoraja ocellata	Winter skate	OBIS, 2019	1994-09-20
	Leucoraja ocellata	Winter skate	OBIS, 2019	1994-09-20
	Leucoraja ocellata	Winter skate	OBIS, 2019	1994-09-21
	Leucoraja ocellata	Winter skate	OBIS, 2019	1994-09-21
	Leucoraja ocellata	Winter skate	OBIS, 2019	1994-09-21
	Leucoraja ocellata	Winter skate	OBIS, 2019	2009-08-02
	Leucoraja ocellata	Winter skate	OBIS, 2019	2009-08-08
	Leucoraja ocellata	Winter skate	OBIS, 2019	2009-08-13
	Amblyraja radiata	Thorny skate	OBIS, 2019	1973-09-05
	Amblyraja radiata	Thorny skate	OBIS, 2019	1976-09-08
	Amblyraja radiata	Thorny skate	OBIS, 2019	1977-09-20
	Amblyraja radiata	Thorny skate	OBIS, 2019	1981-09-02
	Amblyraja radiata	Thorny skate	OBIS, 2019	1984-09-17
	Amblyraja radiata	Thorny skate	OBIS, 2019	1985-09-17
	Amblyraja radiata	Thorny skate	OBIS, 2019	1985-09-17
	Amblyraja radiata	Thorny skate	OBIS, 2019	1985-09-17
	Amblyraja radiata	Thorny skate	OBIS, 2019	1985-09-25
	Amblyraja radiata	Thorny skate	OBIS, 2019	1986-09-03
	Amblyraja radiata	Thorny skate	OBIS, 2019	1986-09-12
	Amblyraja radiata	Thorny skate	OBIS, 2019	1986-09-23
	Amblyraja radiata	Thorny skate	OBIS, 2019	1986-09-24
	Amblyraja radiata	Thorny skate	OBIS, 2019	1986-09-24
	Amblyraja radiata	Thorny skate	OBIS, 2019	1987-09-01
	Amblyraja radiata	Thorny skate	OBIS, 2019	1987-09-01
	Amblyraja radiata	Thorny skate	OBIS, 2019	1987-09-01
	Amblyraja radiata	Thorny skate	OBIS, 2019	1988-09-06
	Amblyraja radiata	Thorny skate	OBIS, 2019	1989-09-23
	Amblyraja radiata	Thorny skate	OBIS, 2019	1990-09-03

Group	Specie	Common Name	Confirmed presence	Date of event
	Amblyraja radiata	Thorny skate	OBIS, 2019	1990-09-03
	Amblyraja radiata	Thorny skate	OBIS, 2019	1991-09-12
	Amblyraja radiata	Thorny skate	OBIS, 2019	1991-09-21
	Amblyraja radiata	Thorny skate	OBIS, 2019	1992-09-05
	Amblyraja radiata	Thorny skate	OBIS, 2019	1992-09-15
	Amblyraja radiata	Thorny skate	OBIS, 2019	1992-09-25
	Amblyraja radiata	Thorny skate	OBIS, 2019	1993-09-10
	Amblyraja radiata	Thorny skate	OBIS, 2019	1993-09-11
	Amblyraja radiata	Thorny skate	OBIS, 2019	1993-09-21
	Amblyraja radiata	Thorny skate	OBIS, 2019	1993-09-21
	Amblyraja radiata	Thorny skate	OBIS, 2019	1994-09-10
	Amblyraja radiata	Thorny skate	OBIS, 2019	1994-09-21
	Amblyraja radiata	Thorny skate	OBIS, 2019	1994-09-21
	Amblyraja radiata	Thorny skate	OBIS, 2019	1994-09-21
	Amblyraja radiata	Thorny skate	OBIS, 2019	1994-09-21
	Carcharodon carcharias	White shark	COSEWIC 2006;	1962
	Carcharodon carcharias	White shark	COSEWIC 2006;	1962
Actinopterygii	*Cyclopterus lumpus*	Lumpfish	OBIS, 2019	1980-09-04
	Cyclopterus lumpus	Lumpfish	OBIS, 2019	1987-08-31
	Cyclopterus lumpus	Lumpfish	OBIS, 2019	1987-08-31
	Cyclopterus lumpus	Lumpfish	OBIS, 2019	1987-08-31
	Cyclopterus lumpus	Lumpfish	OBIS, 2019	1988-09-16
	Cyclopterus lumpus	Lumpfish	OBIS, 2019	1990-09-03
	Cyclopterus lumpus	Lumpfish	OBIS, 2019	1992-09-24
	Cyclopterus lumpus	Lumpfish	OBIS, 2019	1992-09-24
	Cyclopterus lumpus	Lumpfish	OBIS, 2019	1993-09-29
	Anarhichas lupus	Atlantic wolffish	OBIS, 2019	1991-09-13
	Anarhichas lupus	Atlantic wolffish	OBIS, 2019	1987-09-22
	Anarhichas lupus	Atlantic wolffish	OBIS, 2019	1988-09-07
	Anarhichas lupus	Atlantic wolffish	OBIS, 2019	1992-09-16
	Anarhichas lupus	Atlantic wolffish	OBIS, 2019	1985-09-15
	Anarhichas lupus	Atlantic wolffish	OBIS, 2019	1987-09-01
	Salmo salar	Atlantic salmon	OBIS, 2019	1990
Reptilians	*Dermochelys coriaceae*	Leatherback Sea Turtle	James *et al*., 2005/2006	1998-2005
	Dermochelys coriaceae	Leatherback Sea Turtle	James *et al*., 2005/2006	1998-2005
	Dermochelys coriaceae	Leatherback Sea Turtle	James *et al*., 2005/2006	1998-2005
	Dermochelys coriaceae	Leatherback Sea Turtle	James *et al*., 2005/2006	1998-2005
	Dermochelys coriaceae	Leatherback Sea Turtle	James *et al*., 2005/2006	1998-2005
	Dermochelys coriaceae	Leatherback Sea Turtle	James *et al*., 2005/2006	1998-2005
	Dermochelys coriaceae	Leatherback Sea Turtle	James *et al*., 2005/2006	1998-2005
	Dermochelys coriaceae	Leatherback Sea Turtle	James *et al*., 2005/2006	1998-2005
	Dermochelys coriaceae	Leatherback Sea Turtle	James *et al*., 2005/2006	1998-2005

Topo-bathymetric Lidar Research to support Remediation of Boat Harbour



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Executive Summary

The Applied Geomatics Research Group (AGRG) surveyed outer Pictou Harbour using airborne topo-bathymetric lidar in September 2016 to collect high-resolution elevation data and imagery. The sensor used was AGRG's Chiroptera II integrated topo-bathymetric lidar system, equipped with a 60 megapixel (MPIX) multispectral camera.

Boat Harbour is currently acting as a holding facility for effluent from the nearby Abercrombie Point Pulp Mill, but there is a plan to remediate this area back to its original state, as a tidal inlet. One of the objectives of this project was to develop a hydrodynamic model to simulate baseline current flow, water level variations and water circulation within outer Pictou Harbour. The hydrodynamic model was validated by comparing modelled surface elevation, and current speed and direction to observations from an Acoustic Doppler Current Profiler, which was deployed for 35 days to measure the water level and current speeds throughout a tidal cycle. The modelled surface elevation agreed very well with the observed surface elevation. The modelled east-west currents agreed well with the phase of the observations, but the model did not consistently simulate the observed variation in amplitude between tides. The model captured the large-scale nature of the north-south currents, predicting the amplitude of the flood tide well but predicting the phase wrong, and modelling some of the finer signals of the southern ebb tide well in phase but under-predicting amplitude. Current speed was highest in and near the Pictou Harbour channel, reaching 0.5 m/s along the axis of the channel, and currents near the outlet of Boat Harbour were slower, approximately 0.01 m/s during maximum ebb and flood flow.

In addition to the HD model, baseline information on the geomorphology and ecology of Pictou Harbour was also an objective of the study. The topo-bathymetric data and derived products (hydrodynamic model, imagery, digital elevation and surface models, lidar seabed reflectance, bottom type map) provide a detailed reference of the coastal environment and ecology, as part of the deliverables for this project. The plume discharging out of Boat Harbour was clearly visible on the imagery and the lidar did not penetrate through this dark mass of water. The bottom type classification depicting eelgrass distribution along with other cover types was produced from the data collected during the lidar survey is in very good agreement with the ground truth points collected. These data will help to determine if Pictou Harbour changes when Boat Harbour is converted back to its natural setting as a tidal inlet. One should consider a mapping program to measure the natural variability of the physical and biological system before Boat Harbour is altered, then a systematic mapping program to measure change once it is altered. AGRG researchers collected survey grade GPS points, water clarity, depth and underwater photos of the seabed conditions and bottom type. A bottom type classification map was produced from the lidar and photo products that separated bottom type into eelgrass, focus, mud, and sand. Fucus and sand were identified correctly by the classification 100% of the time, eelgrass 87.5% of the time, and mud 25% of the time.

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1 Introduction

1.1 Project Background

With the construction of a pulp mill at Abercrombie Point in 1967, Boat Harbour was transformed from a tidal inlet to a holding facility for effluent from the mill. A plan is in place to remediate Boat Harbour in an attempt to return it back to its original state. With the change back to a tidal inlet, the surrounding coastline in Pictou Harbour may change because of the changes in water circulation. It is important to capture a baseline of the current state of the coastal environment and the ecological distribution of materials.

The Applied Geomatics Research Group (AGRG) of the Nova Scotia Community College (NSCC) has many years of experience with lidar technology and coastal mapping. Recently the NSCC has acquired a topo-bathymetric lidar sensor and high-resolution aerial camera that is capable of surveying both the land topography and the submerged coastal topography, or bathymetry. This new topo-bathymetric lidar sensor offers a unique method to survey the shoreline in more detail than present, map and characterize environmentally sensitive areas, use the nearshore bathymetry to model the local tidal currents, and chart nearshore hazards to navigation.

In the summer of 2016, AGRG used the lidar system to survey Pictou Harbour. This report will highlight the results of the lidar survey and the derived data products, including the digital elevation model (DEM), digital surface model (DSM), and lidar intensity model, all derived from the lidar point cloud. Additionally, this report will present the high-resolution RCD30 60 MPIX imagery, processed using the aircraft trajectory and direct georeferencing. Ground truth maps, included in this report will highlight the results of the ground truth survey such as bottom type, seagrass percentage and water clarity. For the intertidal and subtidal areas this level of information has never been surveyed before with such sophisticated equipment and provides a rich series of GIS-ready data layers for capturing the baseline information for this study. The bathymetry from the survey was used to construct a hydrodynamic model of the circulation within outer Pictou Harbour based on present day conditions.

In addition to the deliverables stated above, the data collected from a nearby location, Little Harbour, surveyed and studied by AGRG in 2014 will be delivered. The DEM, airphoto mosaic, and eelgrass map can be used by NS Lands as a reference area, to provide a picture of what Boat Harbour may look like when converted back to its natural setting.

1.2 Study Area

Boat Harbour is located on the Nova Scotia shoreline of the Northumberland Strait, in Pictou County (Figure 1-1). The study area is east of Pictou Harbour and the Abercrombie Point Pulp Mill, and encompasses the community of Pictou Landing. The geography of this study area renders it a tidal inlet; however, it is currently acting as a holding facility for effluent from the pulp mill.

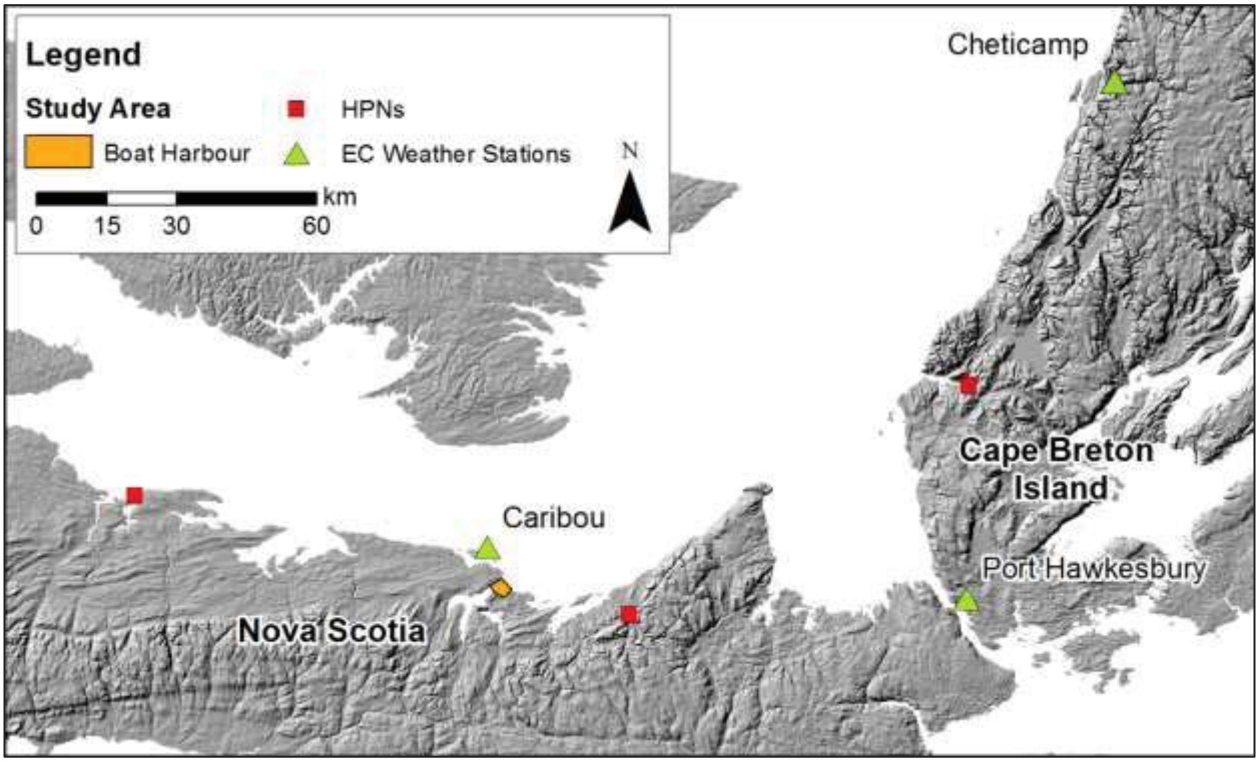

Figure 1-1: The topographic-bathymetric lidar study area in the Southern Gulf of St. Lawrence. Shown is the Boat Harbour study area (gold polygon), NS High Precision Network (HPN) stations (orange squares) and Environment Canada (EC) Weather Stations (green triangles).

2 Methods

2.1 Sensor Specifications

The AGRG utilized the Chiroptera II integrated topographic-bathymetric lidar sensor equipped with a 60 MPIX multispectral camera for this study. The system incorporates a 1064 nm near-infrared laser for ground returns and sea surface and a green 515 nm laser for bathymetric returns (Figure 2-1, Figure 2-2d). The lasers scan in an elliptical pattern, which enables coverage from many different angles on vertical faces, causes less shadow effects in the data, and is less sensitive to wave interaction. The bathymetric laser is limited by depth and clarity, and has a depth penetration rating of roughly 1.5 x the Secchi depth (a measure of turbidity or water clarity using a black and white disk). The Leica RCD30 camera (Figure 2-2d) collects co-aligned RGB+NIR motion compensated photographs which can be mosaicked into a single image in post-processing, or analyzed frame by frame for maximum information extraction. For the purposes of this report, the topographic laser will be referred to as the “topo” laser, and the bathymetric laser will be referred to as the ”bathy” laser.

The calibration of the lidar sensor and camera have been documented in an external report which will be included as part of the deliverables for this project.

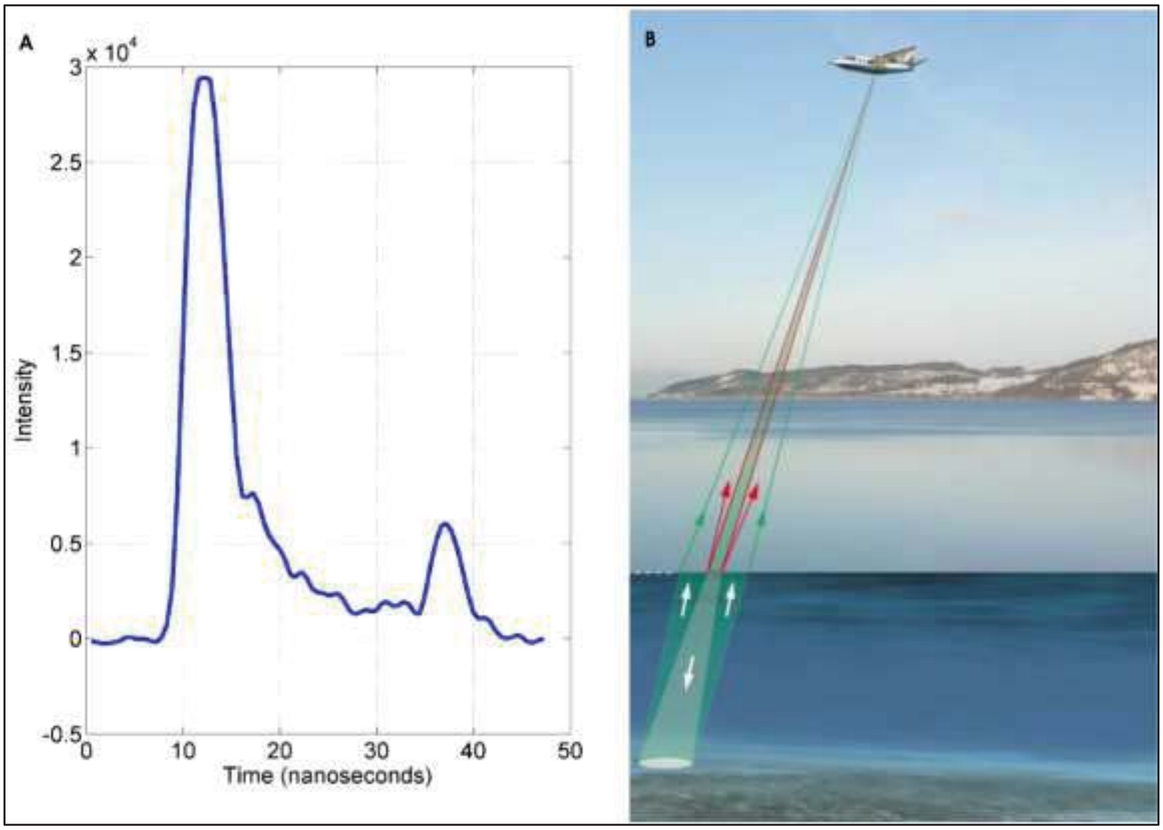

Figure 2-1: (A) Example of the Chiroptera II green laser waveform showing the large return from the sea surface and smaller return from the seabed. (B) Schematic of the Chiroptera II green and NIR lasers interaction with the sea surface and seabed (adapted from Leica Geosystems).

Figure 2-2: (a) Aircraft used for 2016 lidar survey; (b) display seen by lidar operator in-flight; (c) main body of sensor (right) and the data rack(left); (d) large red circles are the lasers; the RCD30 lens (right) and low resolution camera quality control(left).

2.2 Lidar Survey Details

The lidar survey was conducted in Sept 2016 (Table 1). The surveys were planned using Mission Pro software. The 19 planned flight lines for Boat Harbour are shown in Figure 2-3. The aircraft required ground-based high precision GPS data to be collected during the lidar survey in order to provide accurate positional data for the aircraft trajectory. Our Leica GS14 RTK GPS system was used to set up a base station set to log observations at 1-second intervals over a Nova Scotia High Precision Network (HPN) (Figure 1-1).

Survey Date	Survey Time (UTC)	Survey Duration	Number of Flight Lines
Sept 7	13:15 – 14:50	1 hour 35 mins	19

Table 1: 2016 NS Lands lidar survey dates, durations, areas, and flight lines.

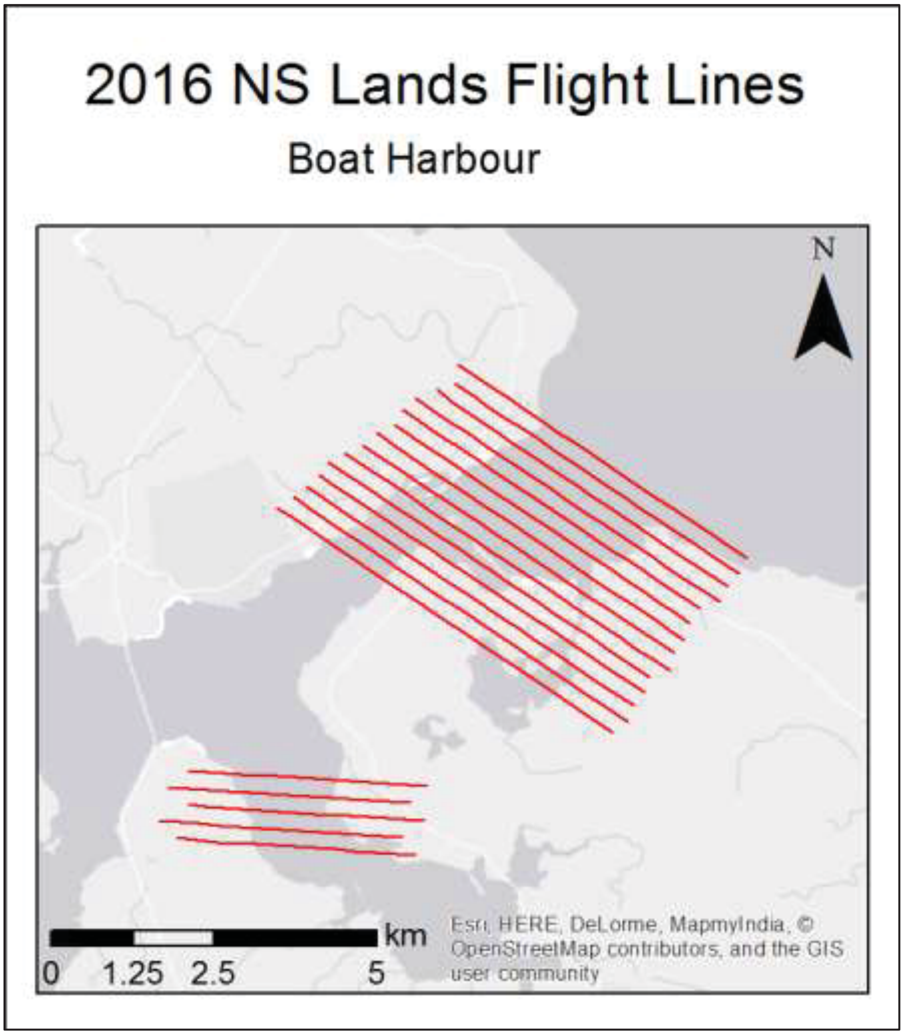

Figure 2-3: Flight lines for 2016 lidar survey in Boat Harbour.

2.3 Ground Truth Data Collection

Ground truth data collection is a crucial aspect of topo-bathymetric lidar surveys. In August 2016, AGRG researchers conducted traditional ground truth data collection including hard surface validation and depth measurements to validate the lidar, Secchi depth measurements for information on water clarity, and underwater photographs to obtain information on bottom type and vegetation. (Figure 2-5) The seabed elevation was measured directly using a large pole onto which the RTK GPS was threaded, in addition to manual measurements using a depth mate consisting of a lead ball on a graduated rope, in addition to a commercial-grade single beam echo sounder. By threading the RTK GPS antenna on the pole and measuring the elevation of the seabed directly we eliminated errors introduced into depth measurements obtained from a boat such as those caused by wave action, tidal variation, and angle of rope for lead ball drop measurements. Table 2 summarizes the ground truth measurements undertaken for the Boat Harbour study area in 2016, and Figure 2-4 shows a map of the distribution of ground truth measurements. Figure 2-5 illustrates some of the ground truth collection and results at Boat Harbour.

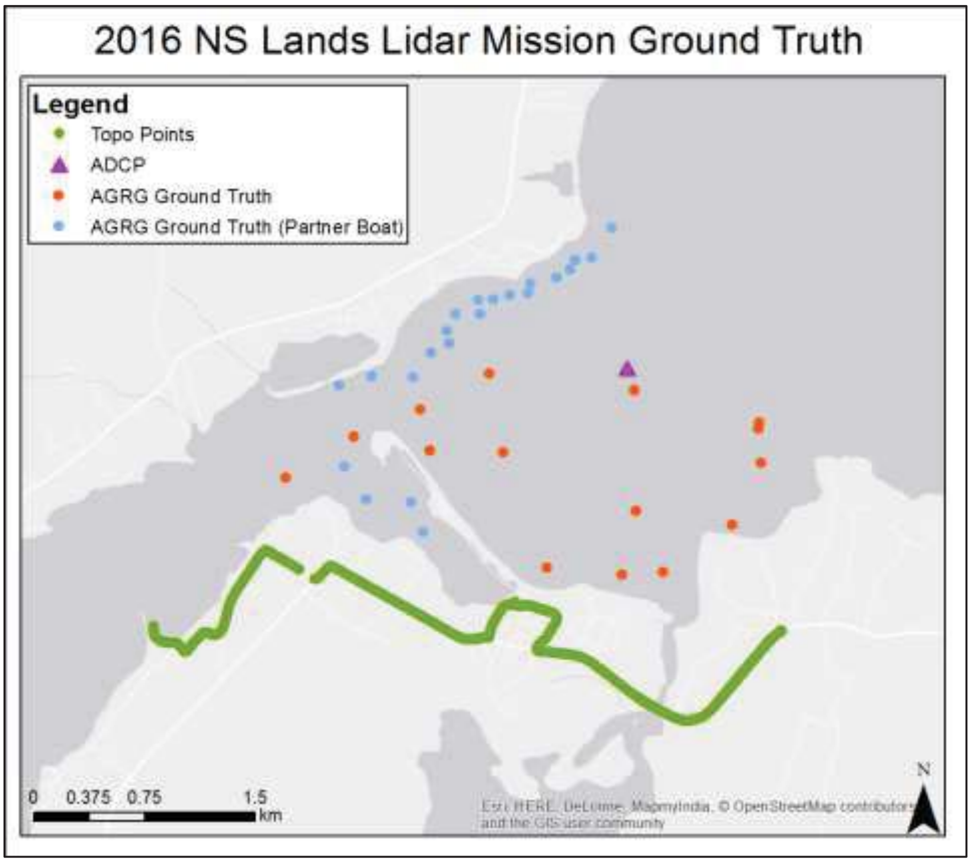

Figure 2-4: Location of hard surface GPS validation points, AGRG and partner boat-based ground truth points, and ADCP deployment at Boat Harbour.

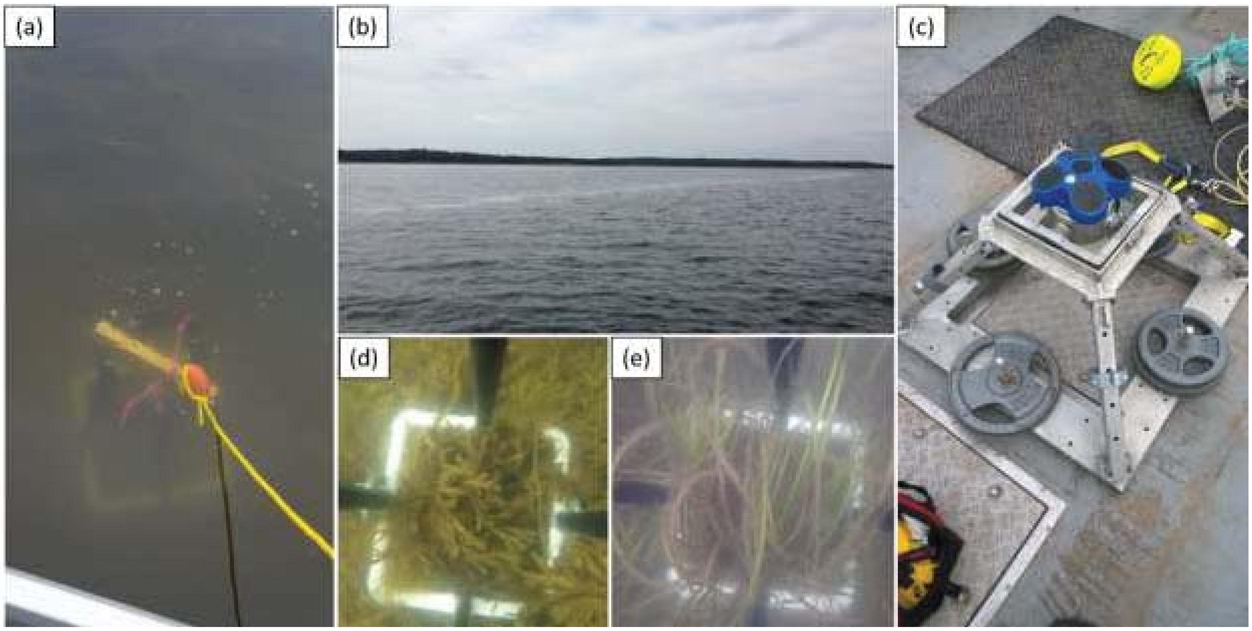

Figure 2-5: Ground truth collection at Boat Harbour. (a) Submerged quadrat collecting ground truth imagery, (b) Plume in Boat Harbour, (c) ADCP deployment, (d) and (e) Ground truth imagery results from quadrat.

Date	Base station (id)	GPS System (GS14 or 530/1200)	Secchi (Y or -)	Depth (see caption for options)	ADCP (Deployed, -, or Retrieved)	Underwater Photos (see caption for options)	Hard Surface GPS (Y or -)	CTD (Y or -)	Turbidity Buoy (deployed and recovered)	Cube (deployed and recovered)	River Ray (Y or -)
Aug 11	206392	GS14, 1200	Y	P, M, DM	Deployed	Q_{50}	Y	-	-	-	-
Aug 30	-	GS14	-	-	-	-	-	-	-	-	Y
Sept 13	-	-	-	-	Recovered	-	-	-	-	-	-

Table 2: Ground truth data summary. GPS Column: Two Leica GPS systems were used, the GS14 and the 1200. Depth Column: P=GPS antenna threaded onto the large pole for direct bottom elevation measurement; M=manual depth measurement using lead ball or weighted Secchi disk; DM=handheld single beam DepthMate echo sounder. Underwater Photos: Q_{50}=0.25 m^2 quadrat with downward-looking GoPro camera.

2.4 Time of Flight Conditions: Weather, Tide and Turbidity

Meteorological conditions during and prior to topo-bathy lidar data collection are an important factor in successful data collection. As the lidar sensor is limited by water clarity, windy conditions have the potential to stir up any fine sediment in the water and prevent laser penetration. Rain is not suitable for lidar collection, and the glare of the sun must also be factored in for the collection of aerial photography. Before each lidar survey we primarily monitored weather forecasts using four tools: the Environment Canada (EC) public forecast (http://weather.gc.ca/) (Figure 1-1); EC's Marine Forecast (https://weather.gc.ca/marine/index_e.html); SpotWx (www.spotwx.com), which allows the user to enter a precise location and choose from several forecasting models of varying model resolution and forecast length; and a customized EC forecast for the lidar study area provided to AGRG every eight hours. Each of these tools had strengths and weaknesses and it was through monitoring all four that a successful lidar mission was achieved. For example, the customized EC forecast was the only tool that provided a fog prediction, on an hourly basis. However, the SpotWx graphical interface proved superior for wind monitoring. Only the EC public forecast alerted us to Weather Warnings that were broadcast in real-time, such as thunderstorms, and the marine forecast provided the only information for offshore conditions.

Although the summer of 2016 was particularly hot and dry, a suitable window for the Pictou Harbour lidar survey was not available until Sept. 7. The survey followed three days of <20 km/h winds blowing mainly from the south; there were no major rainfall events in the week before the survey, which could have caused the water clarity to be reduced, and the survey started following low tide and ended at mid-tide (Figure 2-6).

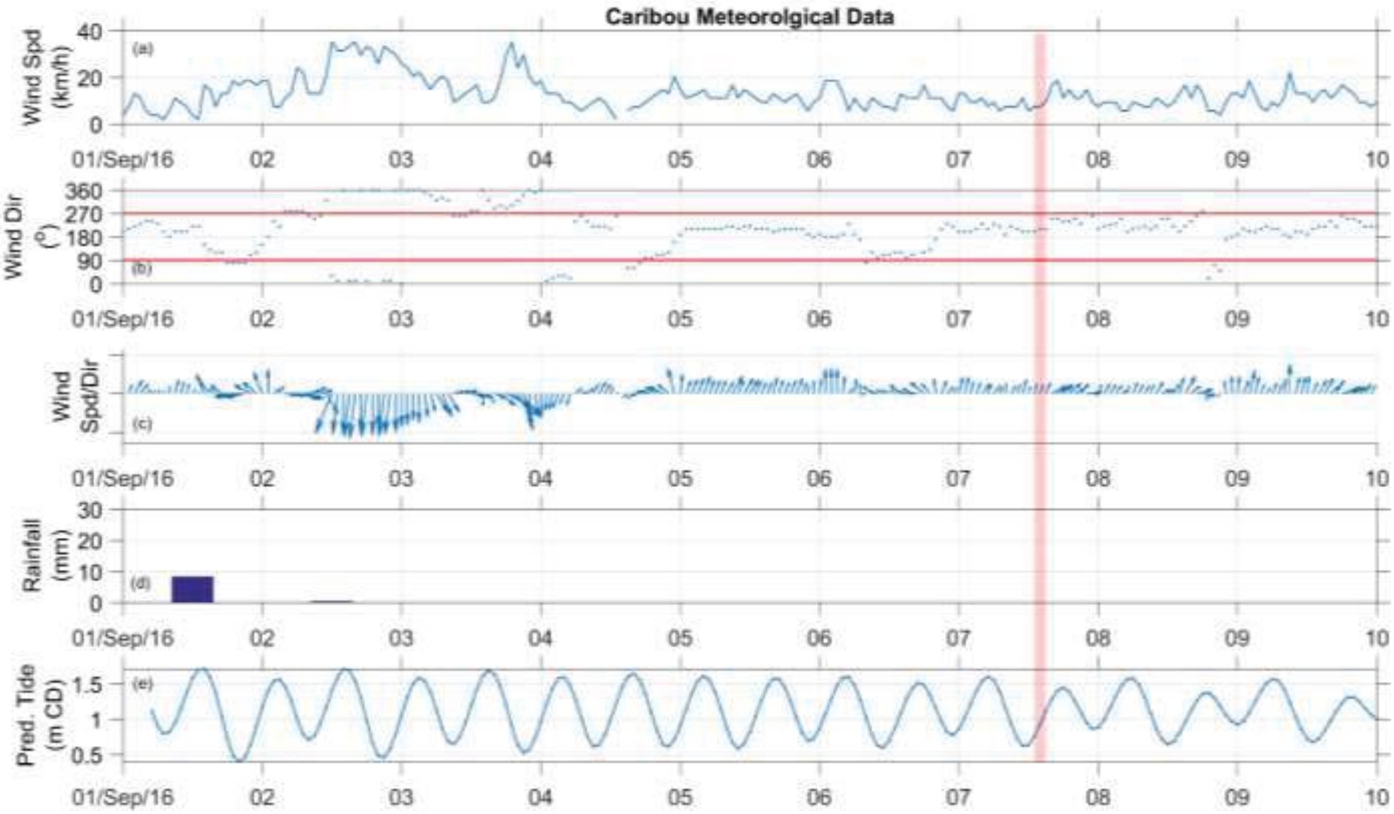

Figure 2-6: (a) Wind speed and (b) direction collected at the EC weather station at Caribou between Sept. 1 and 10, 2016, at 1 hour intervals. Panel (c) shows a vector plot of the wind, where the arrows point in the direction the wind is blowing, and the red box indicates the lidar survey duration. Panel (d) shows daily rainfall and (e) shows predicted tide at Pictou Harbour.

2.5 Acoustic Doppler Current Profiler (ADCP)

A Teledyne RDI Sentinel V20 1000 kHz Acoustic Doppler Current Profiler (ADCP) was deployed at Boat Harbour on August 11th to measure current speed and direction for minimum 35 days. The ADCP was recovered on September 13th. The current data were obtained for hydrodynamic model validation. Surface elevation of the ADCP compared well to CHS predicted tides and tidal range was 1.7 m (Figure 2-7). The current at the ADCP was dominated by tidal circulation and ranged from -0.24 m/s to 0.28 m/s in the east-west direction, and from -0.33 m/s to 0.06 m/s in the north-south direction (Figure 2-8). The vertical structure and magnitude of the currents varied throughout the tidal cycle, with the strongest currents occurring during the middle of the deployment when the tide was semidiurnal, near the water surface (Figure 2-9). When the tide was mixed, semidiurnal the currents were weaker during the lower tidal range and stronger during the higher tidal range (Figure 2-10).

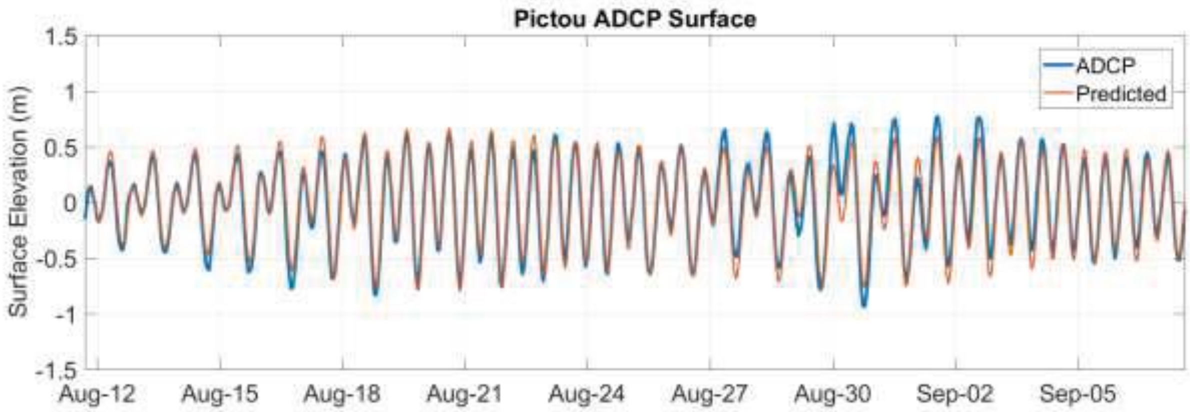

Figure 2-7: ADCP and CHS predicted surface elevation during the ADCP deployment.

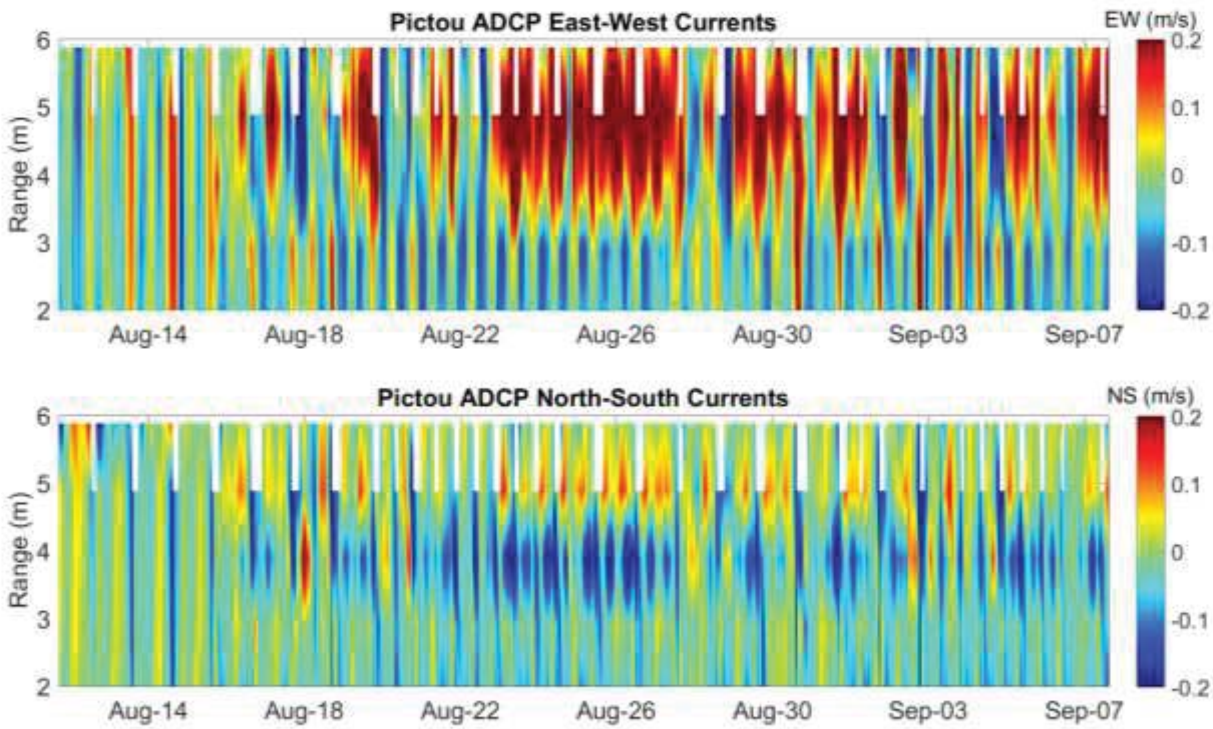

Figure 2-8: Current speeds over time (x axis) and depth (y axis, measured as range from the ADCP) for East-West currents (top panel) and North-South currents (bottom panel). Colours indicate current magnitude and direction.

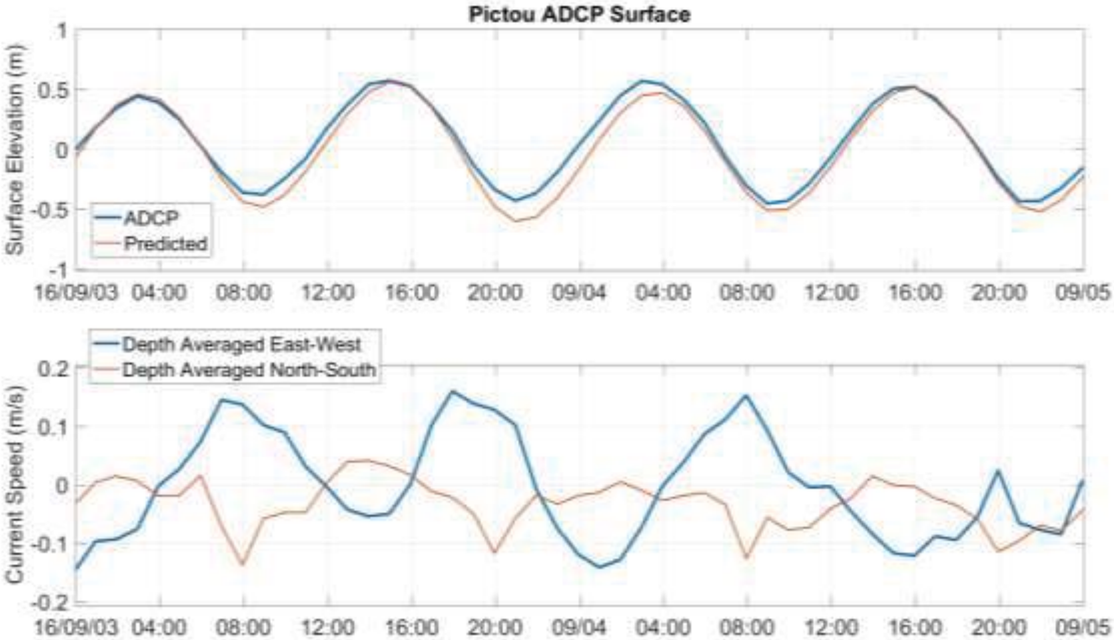

Figure 2-9: Observed and predicted surface elevation (top panel) and depth averaged currents (lower panel) between Sept. 3 and 5 during a semidiurnal tidal phase.

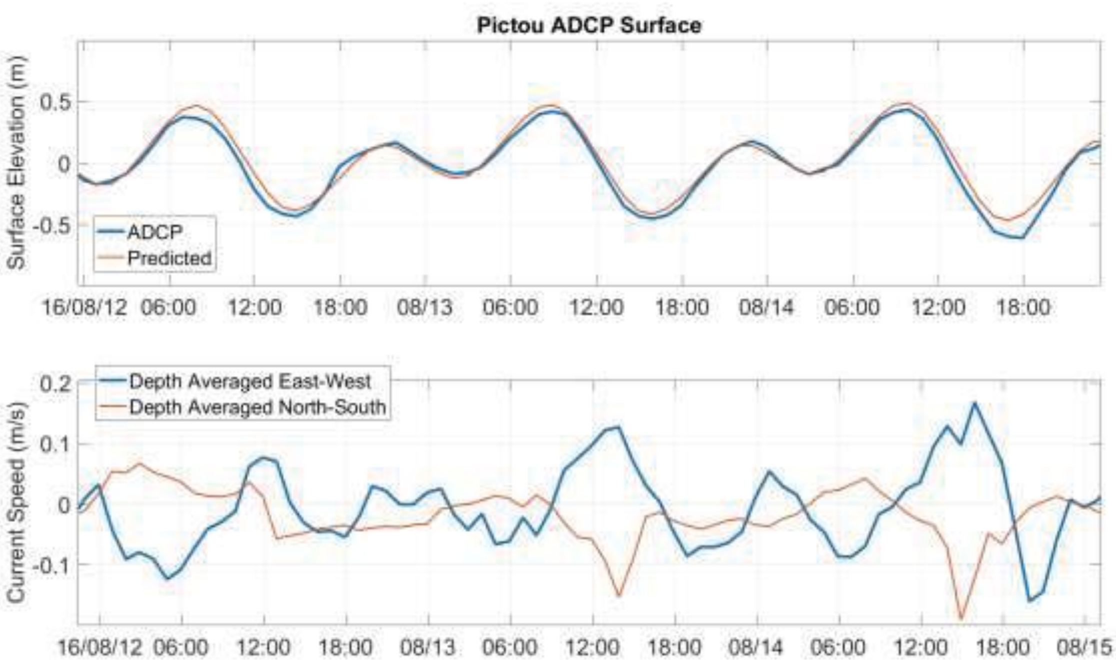

Figure 2-10: Observed and predicted surface elevation (top panel) and depth averaged currents (lower panel) between Aug. 12 - 15 during a mixed semidiurnal tidal phase.

2.6 Elevation Data Processing

2.6.1 Lidar processing

2.6.1.1 Point Cloud Processing

Once the GPS trajectory was processed for the aircraft, GPS observations were combined with the inertial measurement unit and the navigation data was linked to the laser returns and georeferenced. Lidar Survey Studio (LSS) software accompanies the Chiroptera II sensor and is used to process the lidar waveforms into discrete points. These data can then be inspected to ensure sufficient overlap between flight lines (30%) and that no gaps existed in the lidar coverage.

Integral to the processing of bathymetric lidar is the ability to map the water surface. The defined water surface is critical for two components of georeferencing the final target or targets that the reflected laser pulse recorded: the refraction of the light when it passes from the medium of air to water and the change in the speed of light from air to water. The LSS software computes the water surface from the lidar returns of both the topo and bathy lasers. In addition to classifying points as land, water surface or bathymetry, the system also computes a water surface that ensures the entire area of water surface is covered regardless of the original lidar point density. As previously mentioned, part of the processing involves converting the raw waveform lidar return time series into discrete classified points using LSS signal processing. Waveform processing may include algorithms specific to classifying the seabed. The points were examined in LSS both in planimetric and cross-section views. The waveforms for each point can be queried so that the location of the waveform peak can be identified and the type of point defined, for example water surface and bathymetry.

The LAS files, the file type output from LSS, were then read into TerraScan™ with the laser returns grouped by laser type so they could be easily separated, analyzed and further refined. Because of the differences in the lidar footprint between the topo and bathy lasers, the bathy point returns would be used to represent the water surface and both bathy and topo points would be used to represent targets on the land. See Table 3 and the attached Data Dictionary report for the classification codes for the delivered LAS 1.2 files. The refined classified LAS files were read into ArcGIS™ and a variety of raster surfaces at a 1 m spatial resolution were produced.

Class number	Description
0	Water model
1	Bathymetry (Bathy)
2	Bathy Vegetation
3	N/A
4	Topo laser Ground
5	Topo laser non-ground (vegetation & buildings)
6	Hydro laser Ground
7	Bathy laser non-ground
8	Water
9	Noise

10	Overlap Water Model
11	Overlap Bathy
12	Overlap Bathy Veg
13	N/A
14	Overlap Topo Laser Ground
15	Overlap Topo Laser Veg
16	Overlap Bathy Laser Ground
17	Overlap Bathy Laser Veg
18	Overlap Water
19	Overlap Noise

Table 3. Lidar point classification Codes and descriptions. Note that 'overlap' is determined for points which are within a desired footprint of points from a separate flight line; the latter of which having less absolute range to the laser sensor.

2.6.1.2 Gridded Surface Models

There are three main data products derived from the lidar point cloud. The first two are based on the elevation and include the Digital Surface Model (DSM), which incorporates valid lidar returns from vegetation, buildings, ground and bathymetry returns, and the Digital Elevation Model (DEM) which incorporates ground returns above and below the water line. The third data product is the intensity of the lidar returns, or the reflectance of the bathy laser. The lidar reflectance, or the amplitude of the returning signal from the bathy laser, is influenced by several factors including water depth, the local angle of incidence with the target, the natural reflectivity of the target material, the transmission power of the laser and the sensitivity of the receiver.

2.6.1.3 Depth Normalization of the Green Laser

The amplitude of the returning signal from the bathy laser provides a means of visualizing the seabed cover, and is influenced by several factors including water depth and clarity, the local angle of incidence with the target, the natural reflectivity of the target material, and the voltage or gain of the transmitted lidar pulse. The raw amplitude data are difficult to interpret because of variances as a result of signal loss due to the attenuation of the laser pulse through the water column at different scan angles. Gridding the amplitude value from the bathy laser results in an image with a wide range of values that are not compensated for depth and have significant differences for the same target depending on the local angle of incidence from flight line to flight line. As a result, these data are not suitable for quantitative analysis and are difficult to interpret for qualitative analysis. A process has been developed to normalize the amplitude data for signal loss in a recent publication (Webster et al., 2016). The process involved sampling the amplitude data from a location with homogeneous seabed cover (e.g., sand or eelgrass) over a range of depths. These data were used to establish a relationship between depth and the logarithm of the amplitude value. The inverse of this relationship was used with the depth map to adjust the amplitude data so that they could be interpreted without the bias of depth. A depth normalized amplitude/intensity image (DNI) was created for the study site using this technique that can be more consistently interpreted for the seabed cover material. Note that this analysis considers only bathymetric lidar values and ignores any topographic elevation points.

2.6.1.4 Aerial Photo Processing

The RCD30 60 MPIX imagery was processed using the aircraft trajectory and direct georeferencing. The low altitude and high resolution of the imagery required that the lidar data be processed first to produce bare-earth digital elevation models (DEMs) that were used in the orthorectification process. The aircraft trajectory, which combines the GPS position and the IMU attitude information into a best estimate of the overall position and orientation of the aircraft during the survey is required for this process. This trajectory, which is linked to the laser shots and photo events by GPS based time tags, is used to define the Exterior Orientation (EO) for each of the RCD30 aerial photos acquired. The EO, which has traditionally been calculated by selecting ground control point (x, y, and z) locations relative to the air photo frame and calculating a bundle adjustment, was calculated using direct georeferencing and exploiting the high precision of the navigation system. The EO file defines the camera position (x, y, z) for every exposure as well as the various rotation angles about the x, y and z axis known as omega, phi and kappa. The EO file along with a DEM was used with the aerial photo to produce a digital orthophoto. After the lidar data were processed and classified into ground points, the lidar-derived DEM (above and below the water line) was used in the orthorectification process in Erdas Imagine software and satisfactory results were produced.

2.6.2 Ellipsoidal to Orthometric Height Conversion

The original elevation of any lidar product are referenced to the same elevation model as the GPS they were collected with. This model is a theoretical Earth surface known as the ellipsoid, and elevations referenced to this surface are in ellipsoidal height (GRS80). To convert them to orthometric height (OHt), which is height relative to the Canadian Geodetic Vertical Datum of 1928 (CGVD28), an offset must be applied. The conversions are calculated based on the geoid-ellipsoid separation model, HT2, from Natural Resources Canada.

2.7 Bottom Type Classification

The eelgrass map was derived from the lidar and orthophotos and included the water depth raster, derived from the DEM, lidar bottom reflectance intensity, and the true-color aerial photograph orthomosaic. The approach uses the red and green imagery bands, which were extracted from the true-color aerial photograph orthomosaic. Ratios of their differences and of their sums were added together and weighted by the interlaced lidar intensity data. The result is then normalized by the effects of depth. The resulting raster represents vegetation presence index, and was subject to a threshold procedure to result in a final shapefile of vegetation presence or absence. The procedure to produce the final SAV map involved manual editing the shapefile using the RGB photos for interpretation, and included removing shadows created by overlapping trees in the imagery and clipping of the dataset to the relevant area.

2.8 Lidar Validation

Ground elevation measurements obtained using the RTK GPS system were used to validate the topographic lidar returns on areas of hard, flat surfaces. The GPS antenna was mounted on a vehicle and data were collected along roads within the study area, and points were collected manually along any wharves (green lines on Figure 2-4) present in the study area.

Boat-based ground truth data were used to validate the bathymetric lidar returns (blue and orange dots on Figure 2-4). Although various methods were used to measure depth during fieldwork, for this report only points measured using the large pole fitted with the RTK GPS antenna to directly measure the seabed elevation were used for the accuracy assessment; points that measured depth using sonar or a weighted rope were not considered at this time.

For both hard surface and boat-based GPS points, the differences in the GPS elevation and the lidar elevation (ΔZ) were calculated by extracting the lidar elevation from the DEM at the checkpoint and subtracting the lidar elevation from the GPS elevation. GPS points were subject to a quality control assessment such that the standard deviation of the elevation was required to be < 0.05 m.

3 Results

3.1 Lidar Validation

3.1.1 Topographic Validation

There were 635 data points collected along the roads with a calculated mean ΔZ of -0.14 m ± 0.04 m (Figure 3-1).

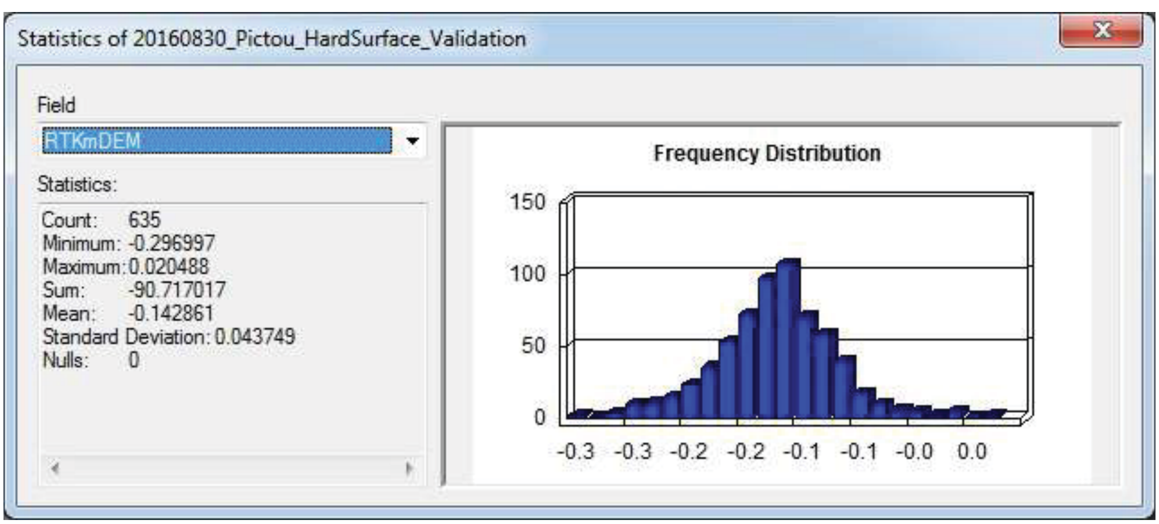

Figure 3.1: Topographic lidar validation for Boat Harbour.

3.1.2 Bathymetric Validation

Mean ΔZ was negative, indicating that the DEM elevation is less (shallower) than the observed GPS point. There were 28 points (direct seabed elevation measurements) with mean ΔZ -0.17 m ± 0.25 m (Figure 3-2).

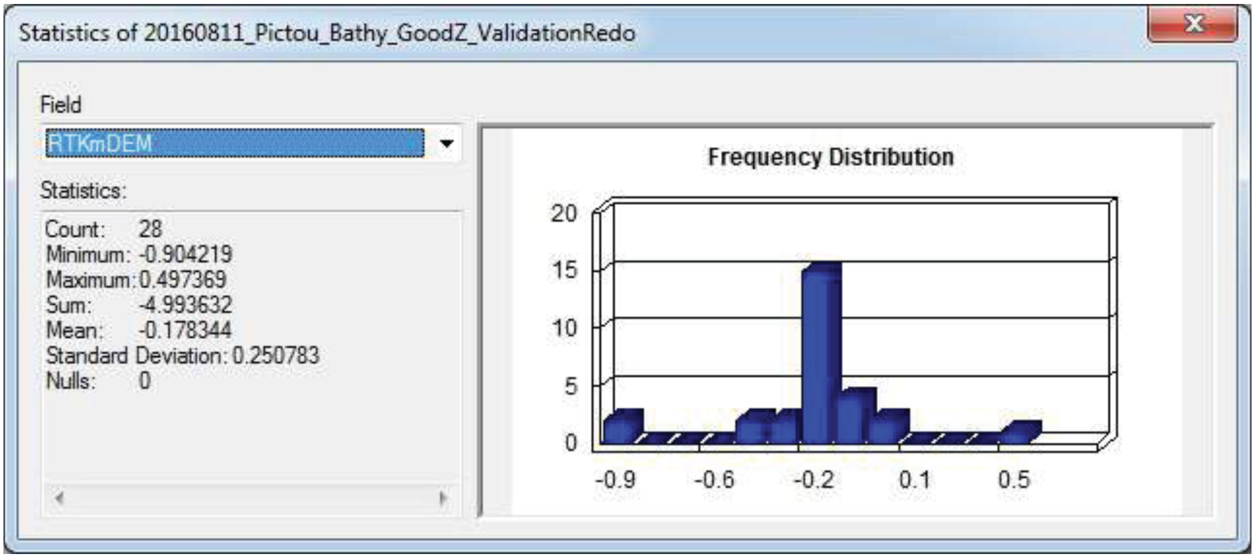

Figure 3.2: Bathymetric lidar validation for Boat Harbour.

3.1.3 Comparison between Multibeam and Lidar

AGRG acquired CHS 5 m multibeam data for Boat Harbour, which provided depth values for the channel and surrounding study area where the lidar sensor did not penetrate. There were areas of overlap between the multibeam data and the lidar, making it possible to compare the data (Figure 3-1) The multibeam data represented depth relative to chart datum, (lowest astronomical tide) however, these data needed to be converted to mean sea level (CGVD28) in order to accurately compare the values to the lidar, which is relative to CGVD28.

To convert the multibeam data to the correct datum, 0.92 m was subtracted from the data using a raster calculator in ArcGIS™ . 0.92 m is the difference between chart datum and mean sea level. With both data sets now relative to the same datum, the data were compared in ArcMap. Raster Calculator was used again to subtract the 'known' data (multibeam) from the lidar. The resulting data was a raster highlighting the areas of overlap between data sets as well as the difference. This dataset was then converted to points in order to interpret the summary statistics for further comparison (Figure 3-2).

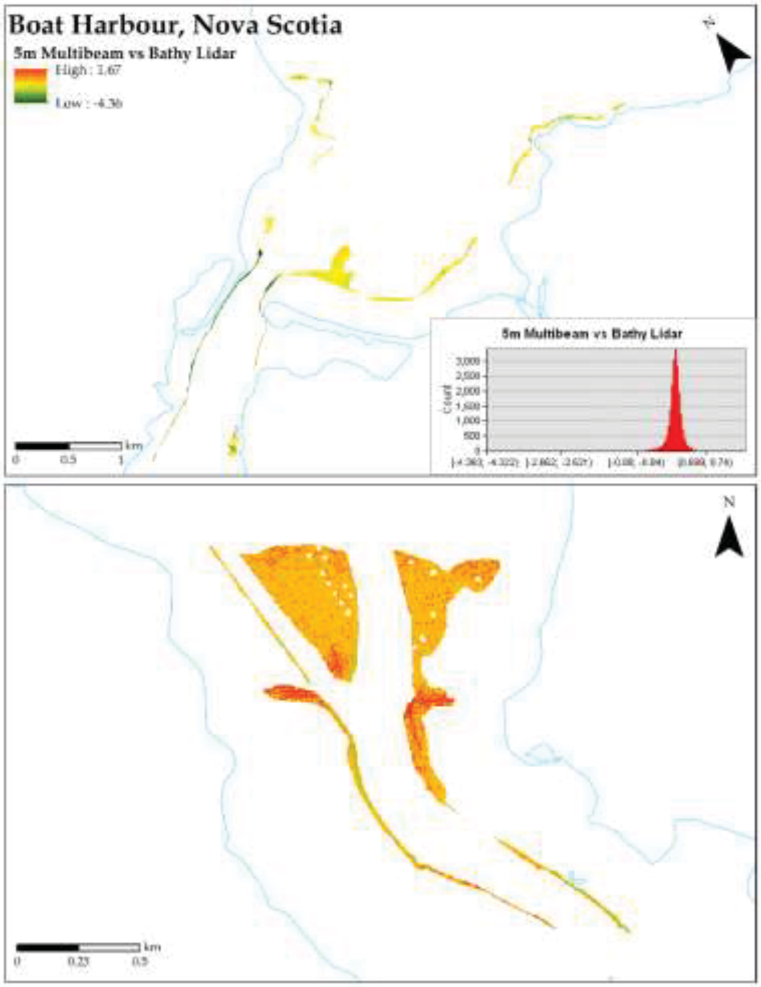

Figure 3-1: Map comparing the CHS 5m multibeam data in Boat Harbour to the lidar acquired by AGRG. The top panel shows the Northern section of study area (data frame rotated 36° to the north), the bottom panel shows the Southern section of the study area. Histogram illustrates a calculated mean ΔZ of -0.03 m ± 0.3 m.

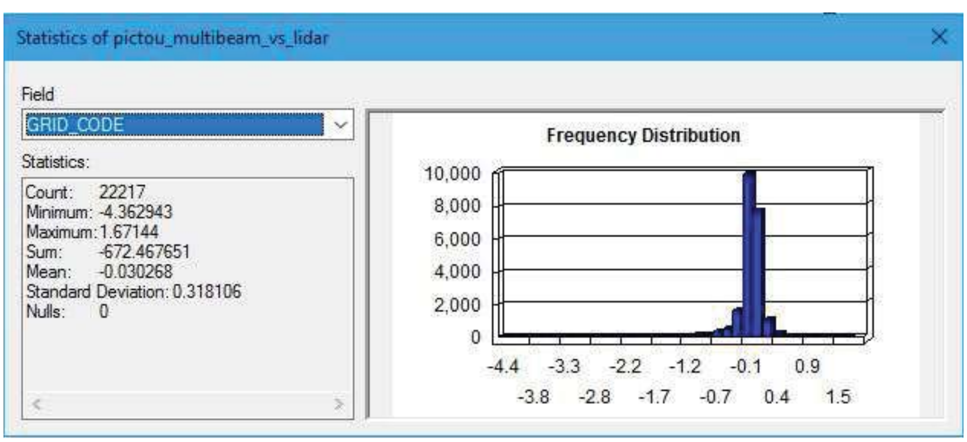

Figure 3-2: Histogram of resulting difference between multibeam and lidar shows a calculated mean ΔZ of -0.03 m ± 0.3 m.

3.2 Surface Models and Air Photos

3.2.1 Digital Elevation Model

Lidar penetration at Pictou Harbour was successful in the nearshore areas of the study area, penetrating to a maximum of -4.8 m CGVD28 (which roughly corresponds to an equivalent depth), located near the northwestern portion of Pictou Harbour (Figure 3-3). The lidar revealed sandbars, channels amidst flat, shallow coves, and complex nearshore topography. In the southern study area, near the submerged pipe, the lidar penetrated to -3 m CGVD28 (Figure 3-4). The lidar did not penetrate an area approximately 1 km long, and 400 m at its widest area, located at the mouth of Boat Harbour (Figure 3-3 shown as missing data, Figure 3-5). Poor water clarity resulted in the bathymetric laser reflecting off the surface of the water and not penetrating through the cloudy water.

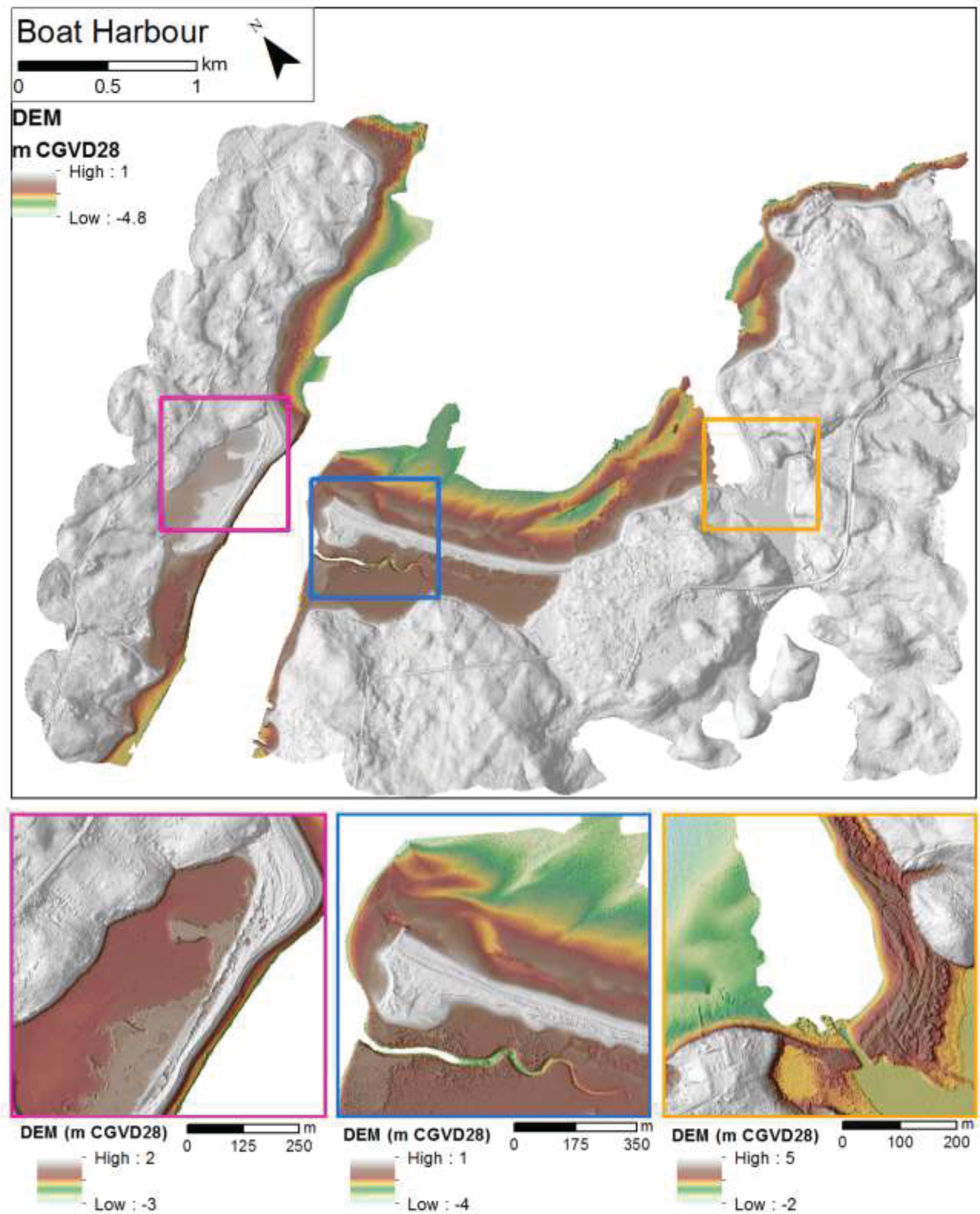

Figure 3-3: Digital Elevation Model for Boat Harbour, draped on a 5x hillshade, scaled to show bathymetry relief for the Northern section of study area (rotated 36° to the north), and with insets showing smaller features. Insets are matched to the larger figure by border colour.

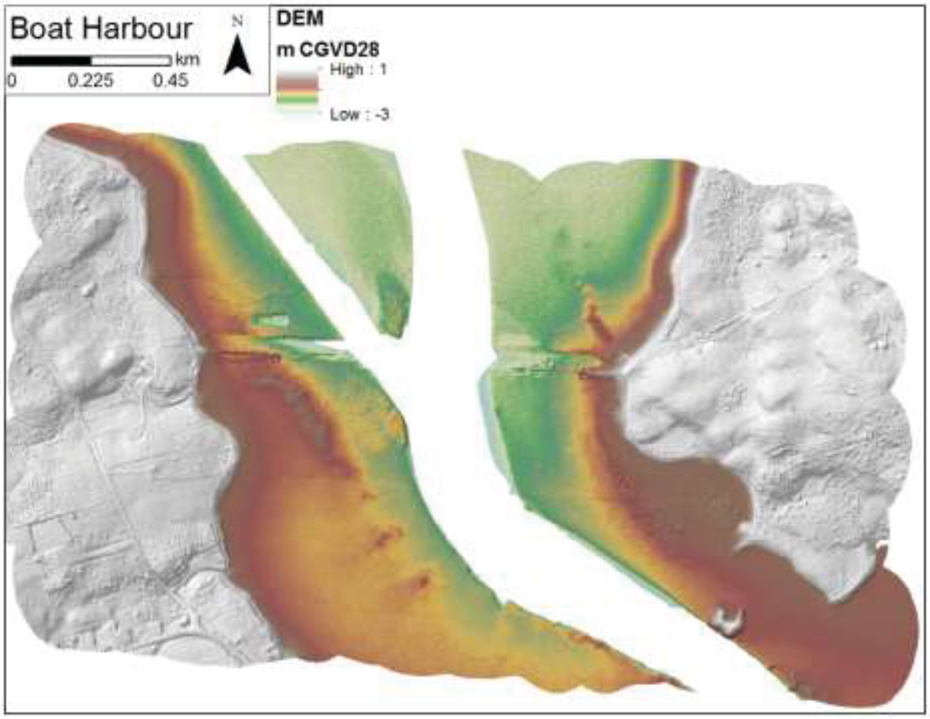

Figure 3-4: Digital Elevation Model for Boat Harbour draped on a 5x hillshade, rotated and scaled to show bathymetry relief for the Southern section of study area.

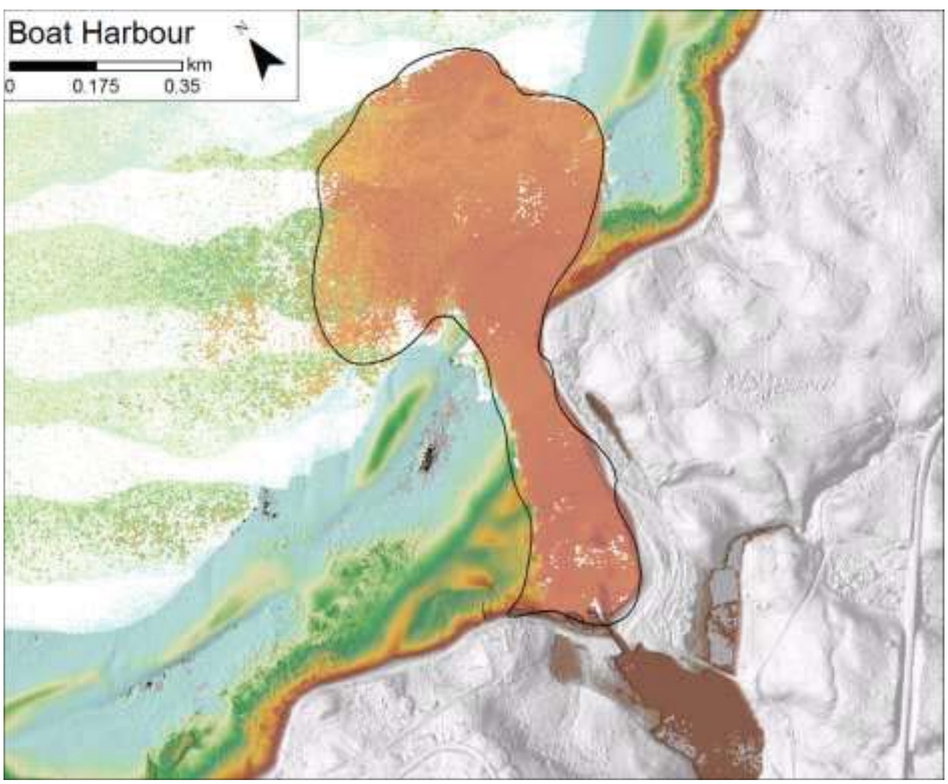

Figure 3-5: The raw (uncleaned) lidar DEM showing how the laser reflected off the opaque plume (outlined) located at the mouth of Boat Harbour.

3.2.2 Colour Shaded Relief Model

The Colour Shaded Relief (CSR) models show the topographic relief in shades of green-red-yellow, and the bathymetry relief in shades of blue where darker blue represents deeper water. CSRs provide an exaggeration of the DEMs and DSM's (5x actual height) and include artificial shading to accentuate topographic and bathymetric features. These maps are especially useful for identifying where the land ends and the water begins; for example, in Figure 3-6 the pink panel clearly identifies the nearshore area.

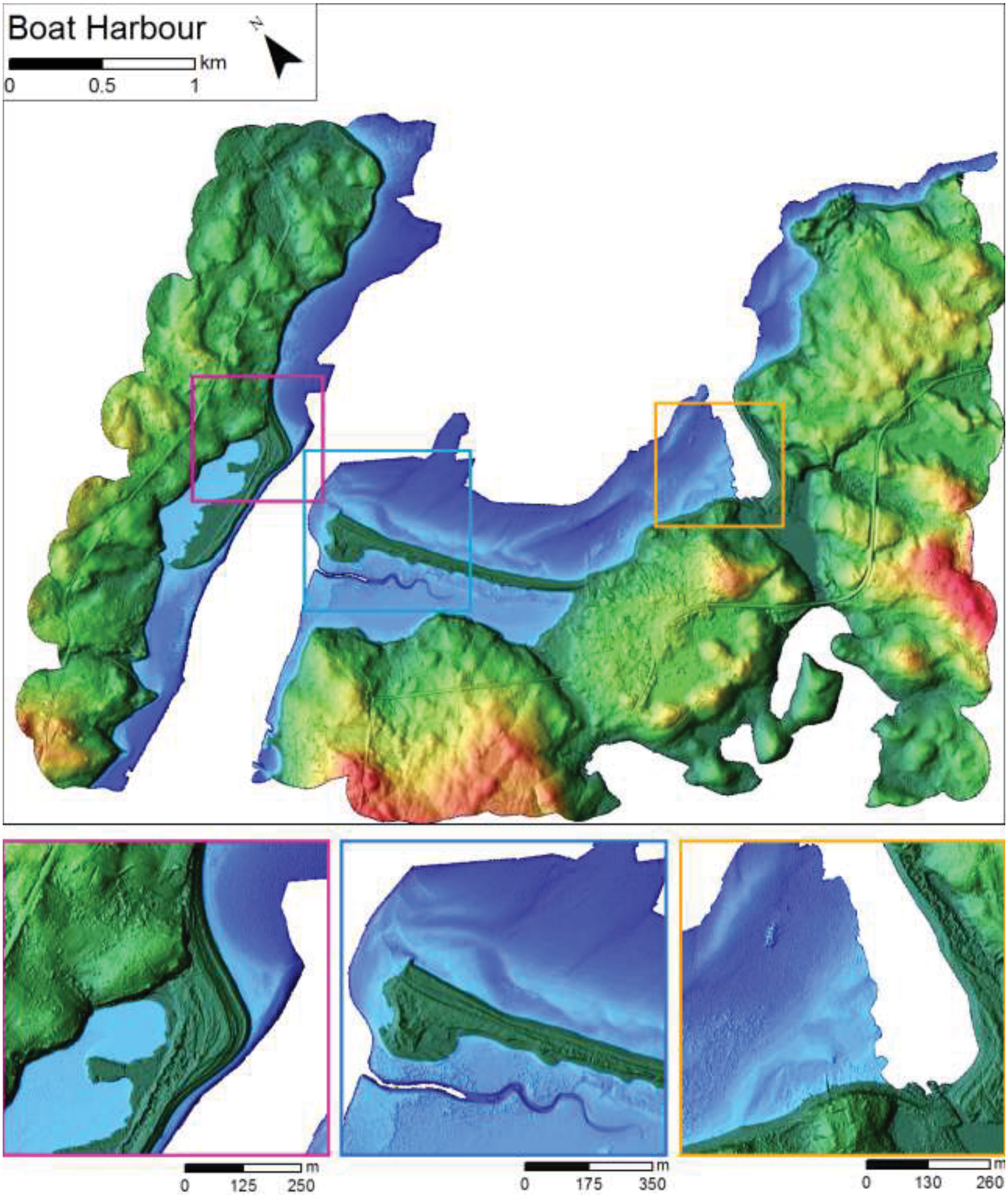

Figure 3-6: Colour Shaded Relief for Boat Harbour, scaled to show bathymetry relief for the Northern section of study area (rotated 36 ° to the north), and with insets showing smaller features. Insets are matched to the larger figure by border colour.

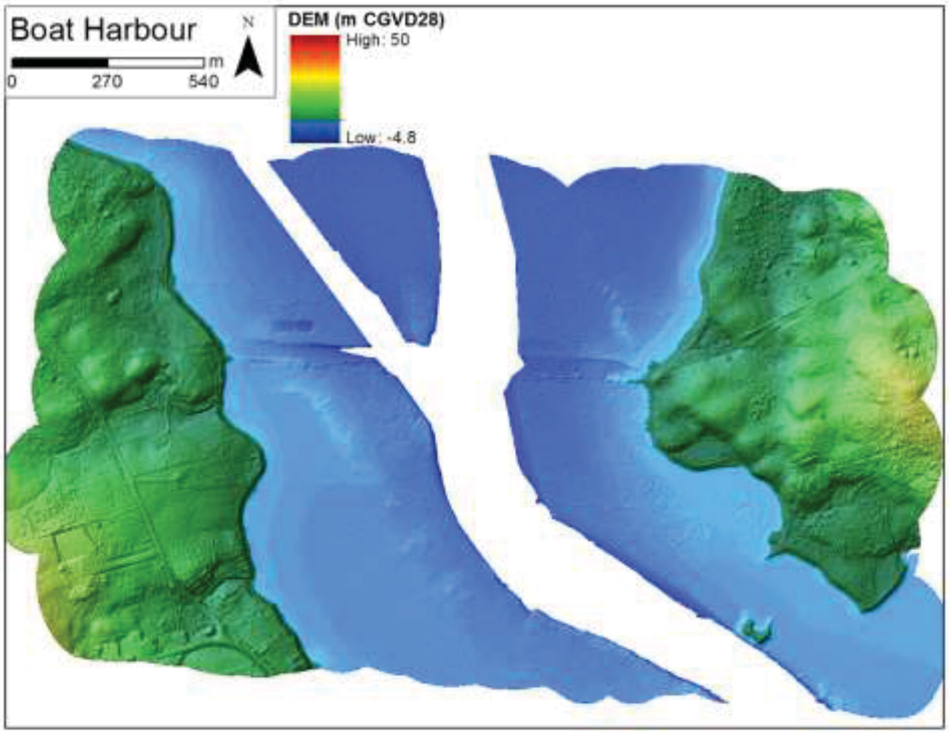

Figure 3-7: Colour Shaded Relief for Boat Harbour, scaled to show bathymetry relief for the Southern section of study area.

3.2.3 Depth Normalized Intensity

The Depth Normalized Intensity models (DNIs) can be a powerful tool to reveal submerged features and bottom type information that the air photos and DEM may not depict. The intensity data show the contrast between brightly coloured seabed and the dark colour of eelgrass or other submerged vegetation. The DNI maps suggests the presence of vegetation in the shallowest areas and south of the harbour mouth, and suggests that the seabed is mainly composed of sand north of the harbour mouth, with bands of darker vegetation in the nearshore (Figure 3-8, Figure 3-9).

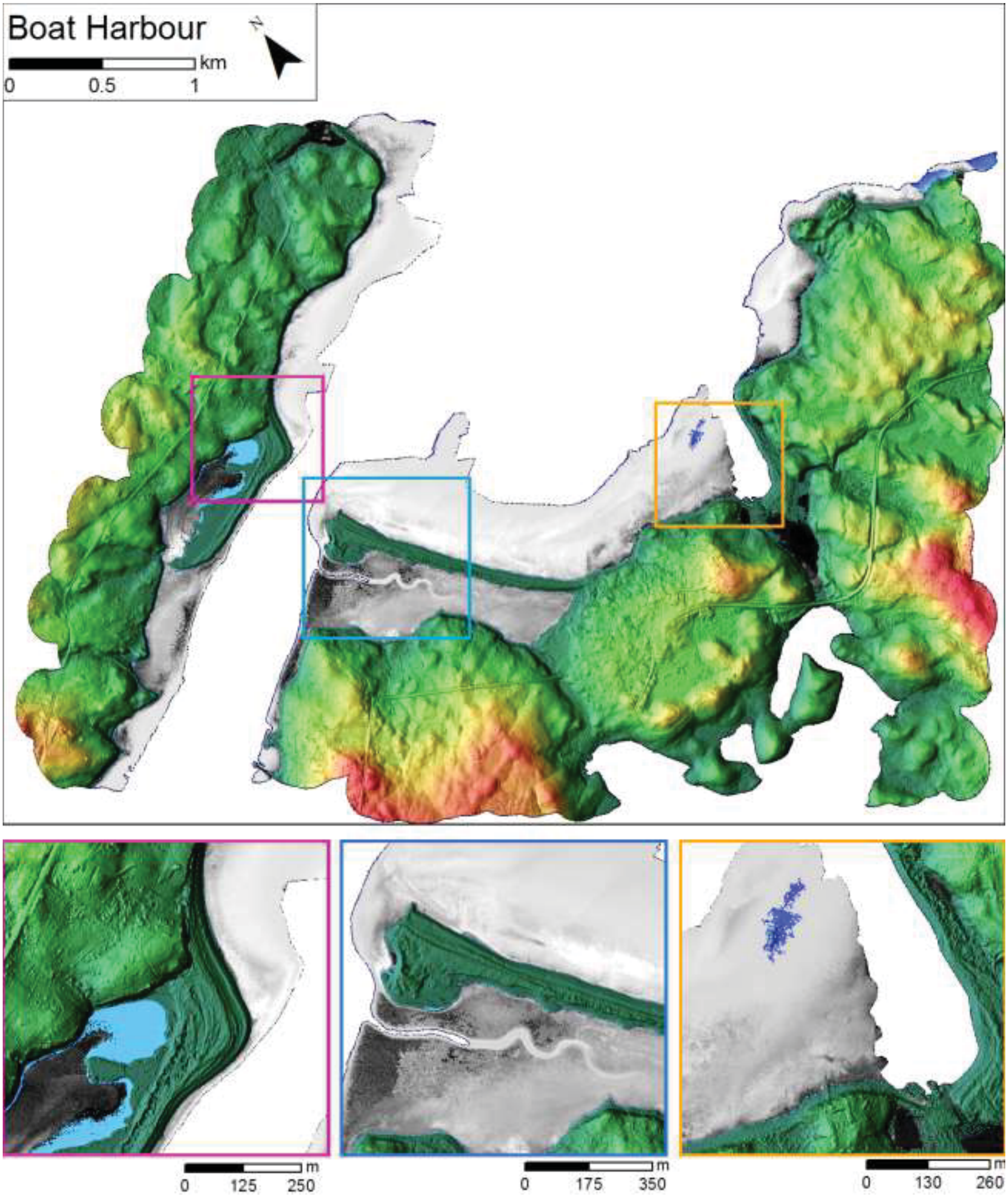

Figure 3-8: Depth-normalized intensity model (for bathymetry only) draped over the CSR, rotated 36° to the north. Typically, darker areas represent submerged vegetation, while brighter areas represent sand. Insets are matched to the larger figure by border colour.

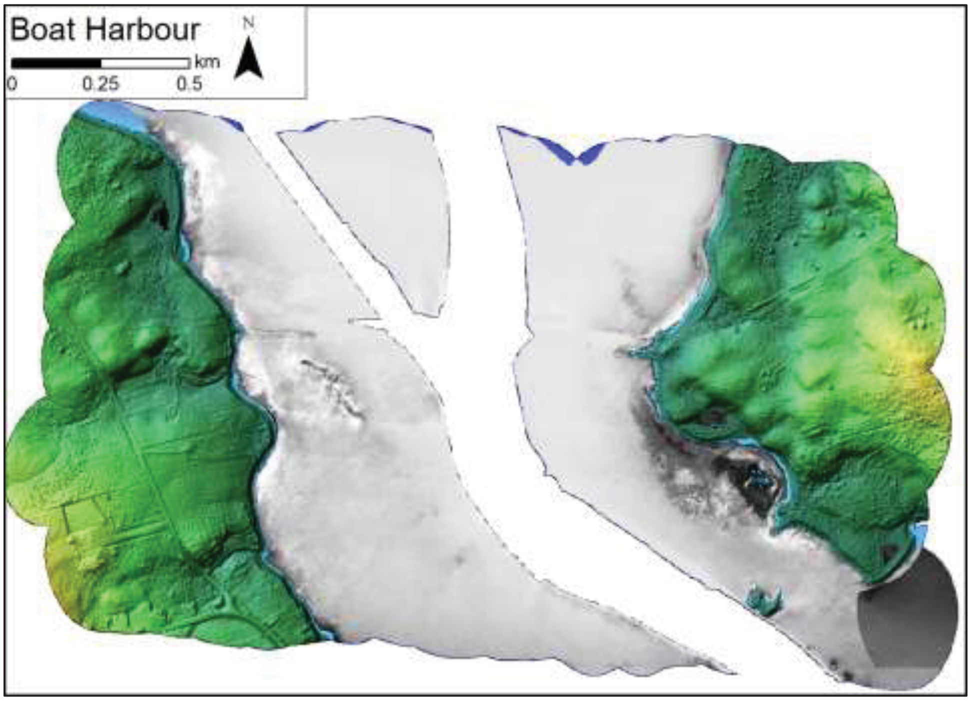

Figure 3-9: Depth-normalized intensity model (for bathymetry only) draped over the CSR. Typically, darker areas represent submerged vegetation, while brighter areas represent sand.

3.2.4 Air Photos

The aerial orthophoto mosaics provide insight into land use, water clarity, bottom type, wave action, and river morphology. The orthophoto panels show the different levels of water clarity throughout the study area (Figure 3-10, Figure 3-11). At Boat Harbour, submerged features such as sediment and sand ripples can be seen in both the blue and orange panels; additionally, a deep channel is visible in the blue panel.

Figure 3-10: Orthophoto Mosasic for Boat Harbour (rotated 36° to the north), and with insets showing smaller features. Insets are matched to the larger figure by border colour.

Figure 3-11: Orthophoto Mosaic for Boat Harbour, scaled to show bathymetry relief for the Southern section of study area.

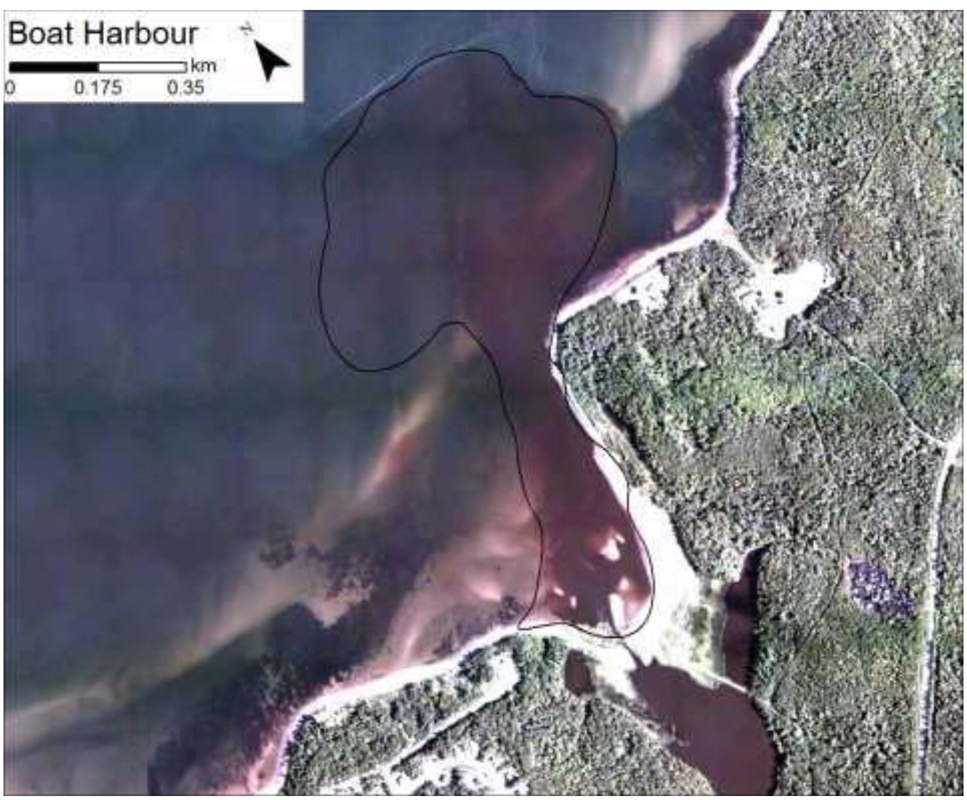

Figure 3-12: Orthophoto mosaic showing the plume of dark water near the mouth of Boat Harbour, outlined in black.

3.3 Ground Truth Maps

The underwater photographs taken using a GoPro camera mounted to a quadrat are useful indicators of bottom type throughout the study area. The following sections present some of the images obtained during the field season displayed on the RCD30 5 cm resolution orthophoto mosaics.

3.3.1 Boat Harbour

The bottom type at Boat Harbour was a combination of sand, mud, fucus and eelgrass. The water appears mainly clear in the inner bay, North West of Pictou (Figures 3.9 – 3.12). Towards Pictou Landing, on the Eastern side of the study area, the water is darker and the bottom appears to be composed mainly of mud and sand with a small amount of fucus present. (Figure 3.12)

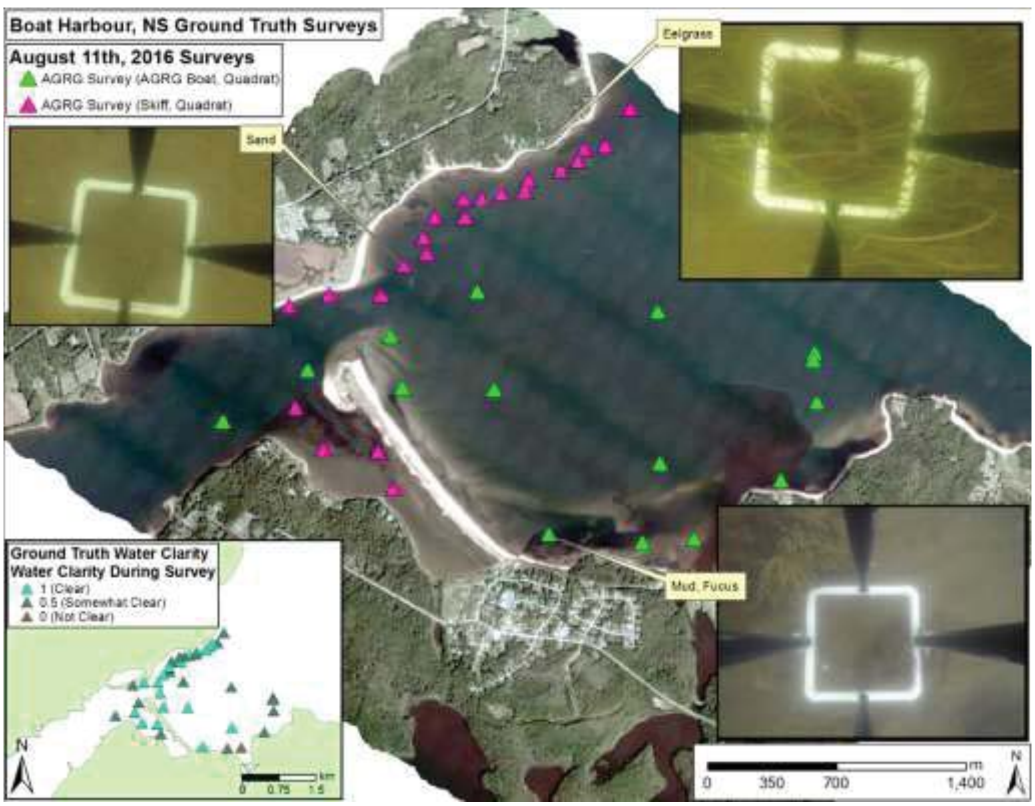

Figure 3-13: Boat Harbour underwater photo ground truth for both surveys (AGRG and partner boats). Background image is RCD30 orthophoto RGB mosaic.

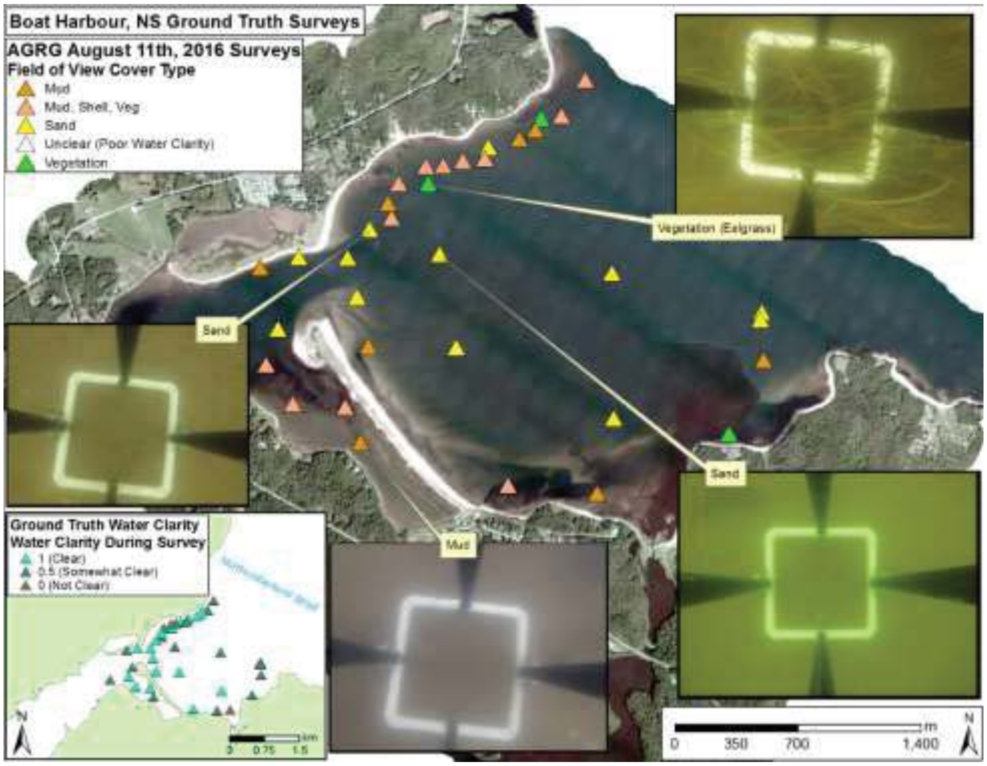

Figure 3-14: Boat Harbour underwater photo ground truth for both surveys (AGRG and partner boats) symbolized to show the field of view cover type. Background image is RCD30 orthophoto RGB mosaic.

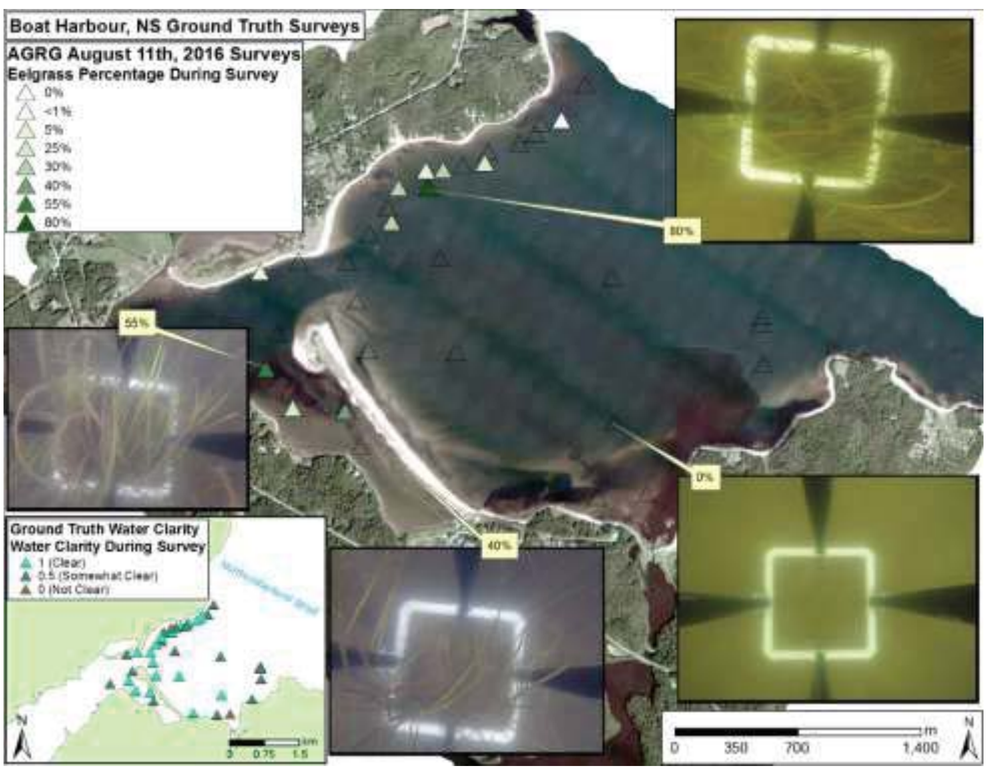

Figure 3-15: Boat Harbour underwater photo ground truth for both surveys (AGRG and partner boats) symbolized to show the eelgrass percentage. Background image is RCD30 orthphoto RGB mosaic.

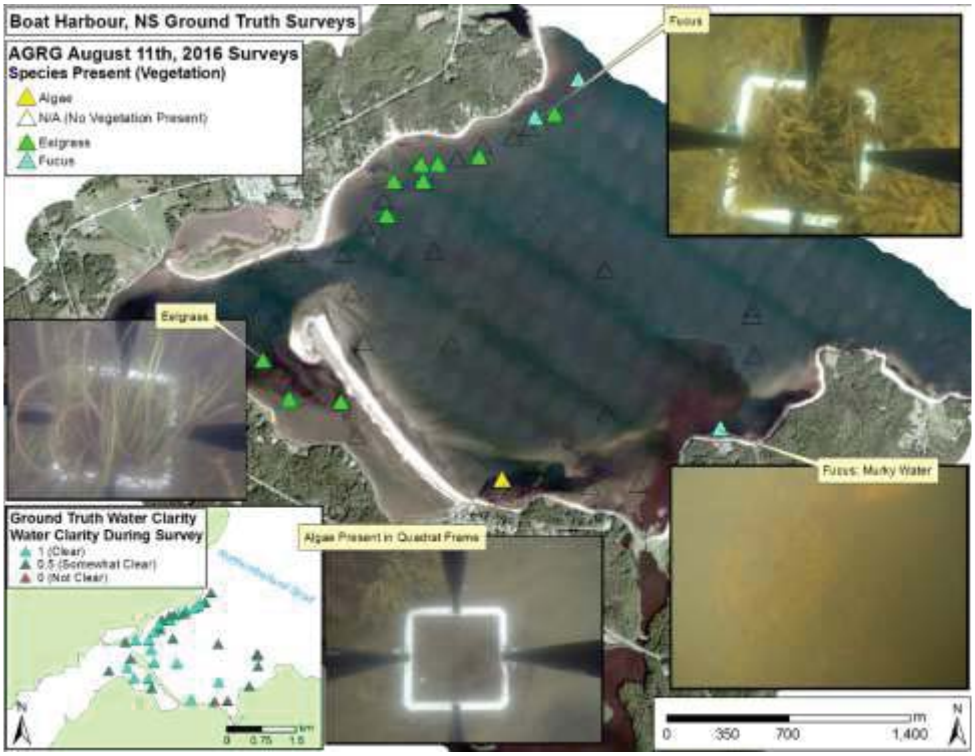

Figure 3-16: Boat Harbour underwater photo ground truth for both surveys (AGRG and partner boats) symbolized to show the species type of vegetation present. Background image is RCD30 orthophoto RGB mosaic.

3.4 Bottom Type Maps

Figures 3-17 to 3-21 depict the bottom type classification and eelgrass distribution produced by the methodology described in section 2.7. Both ground based and boat based ground truth points were compared to the bottom type classification produced and the overall agreement of the classification of eelgrass was 87.5% (Table 4).

Class	Number of Ground Truth Points	Points in Agreement with Classification	Percent Agreement (%)
Eelgrass	8	7	87.5
Fucus	4	4	100
Mud	8	2	25
Sand	3	3	100

Table 4 – Percent agreement between bottom type classification and ground truth points.

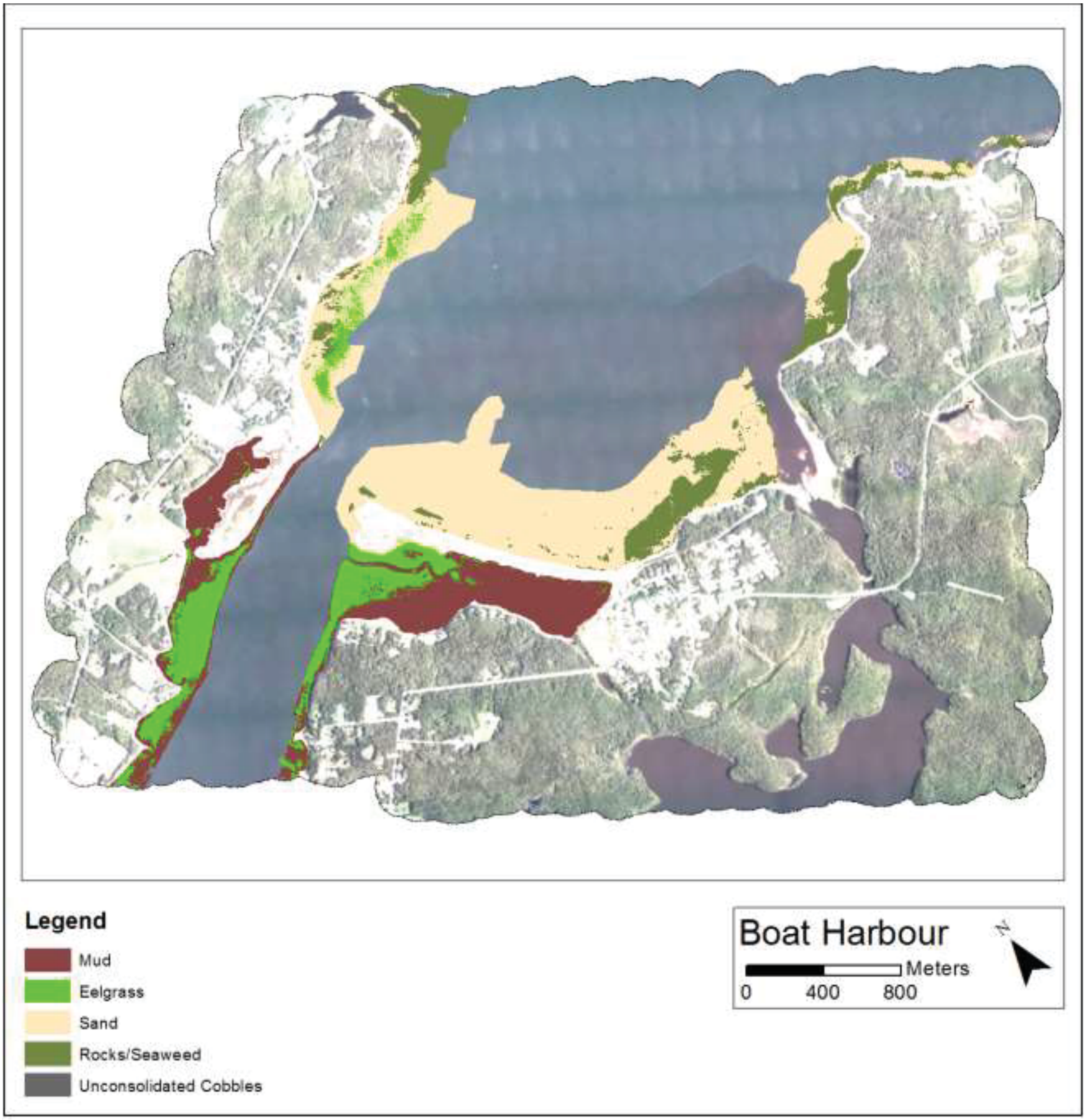

Figure 3-17 – Bottom type classification for Boat Harbour (rotated 36° to the north).

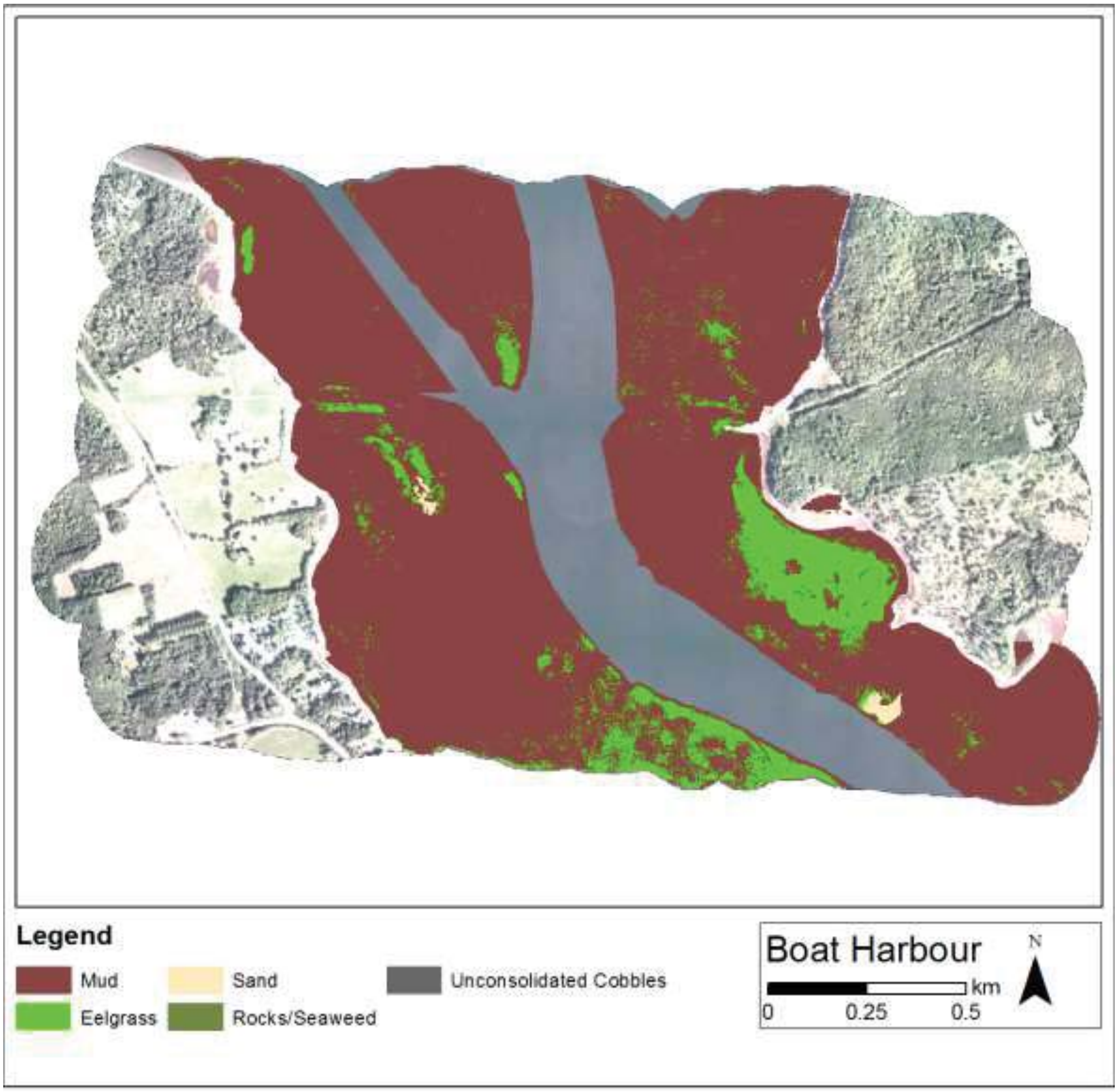

Figure 3-18 – Bottom type classification for the southern portion of the Boat Harbour study area.

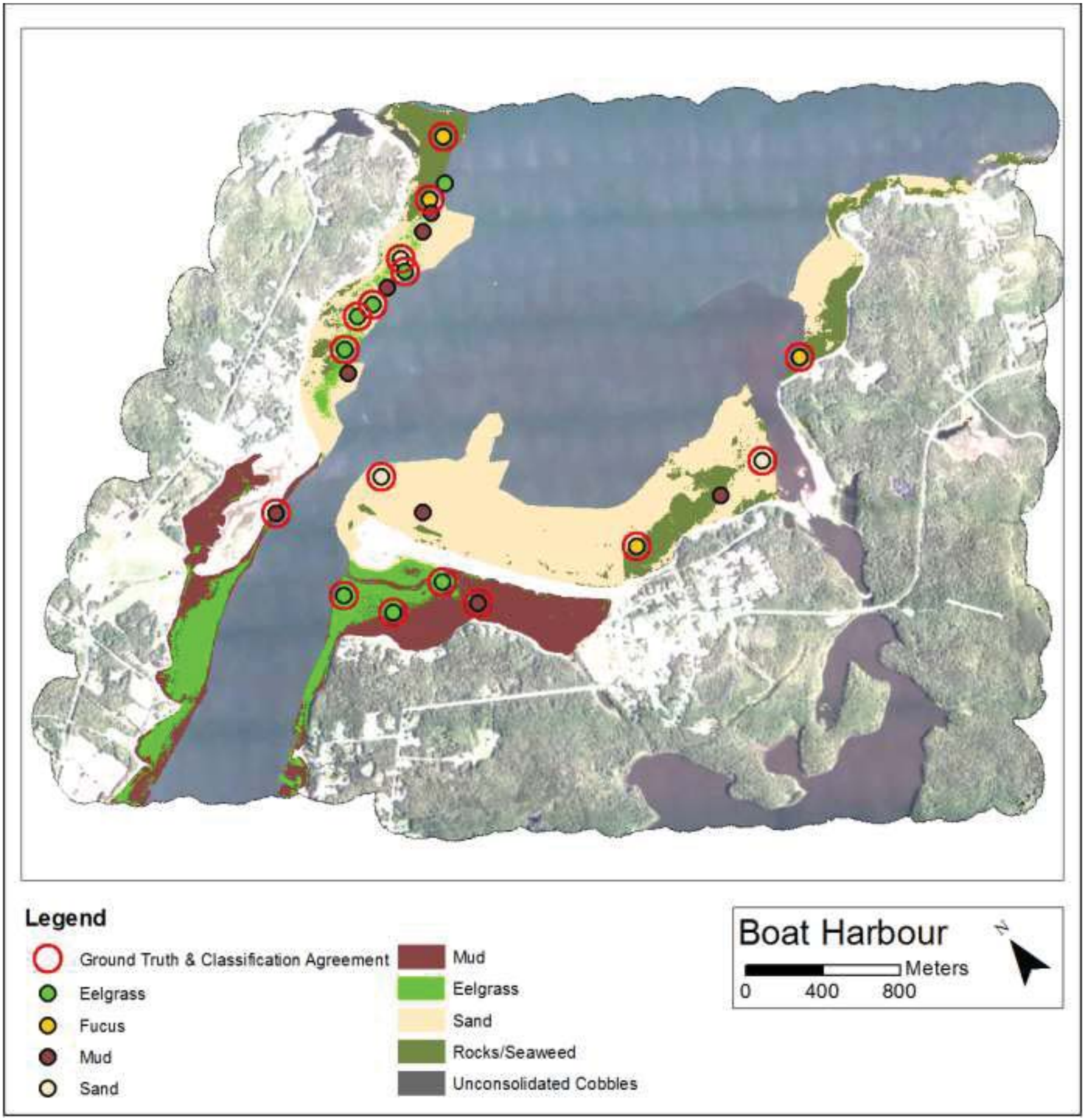

Figure 3-19 – Ground truth and classification agreement based on a sample size of 23 ground truth points. Red circles indicate agreement between the produced classification and ground truth points collected.

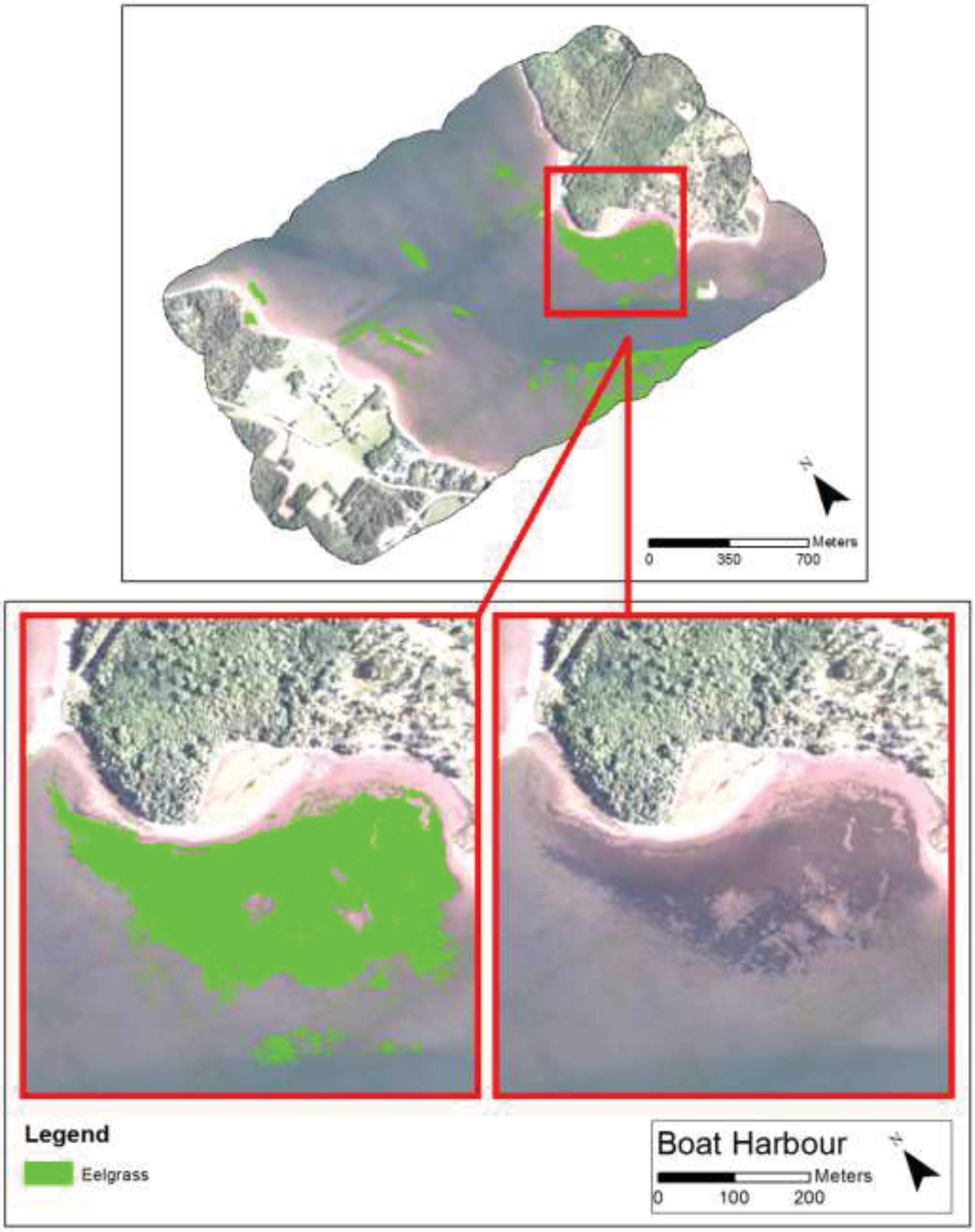

Figure 3-20 – Comparison of bottom type classification of eelgrass to the aerial photograph for the southern portion of the Boat Harbour study area.

Although no ground truth points were collected in the southern portion of the study area, eelgrass is visible on the aerial photograph and appears to be in very good agreement (Figure 31).

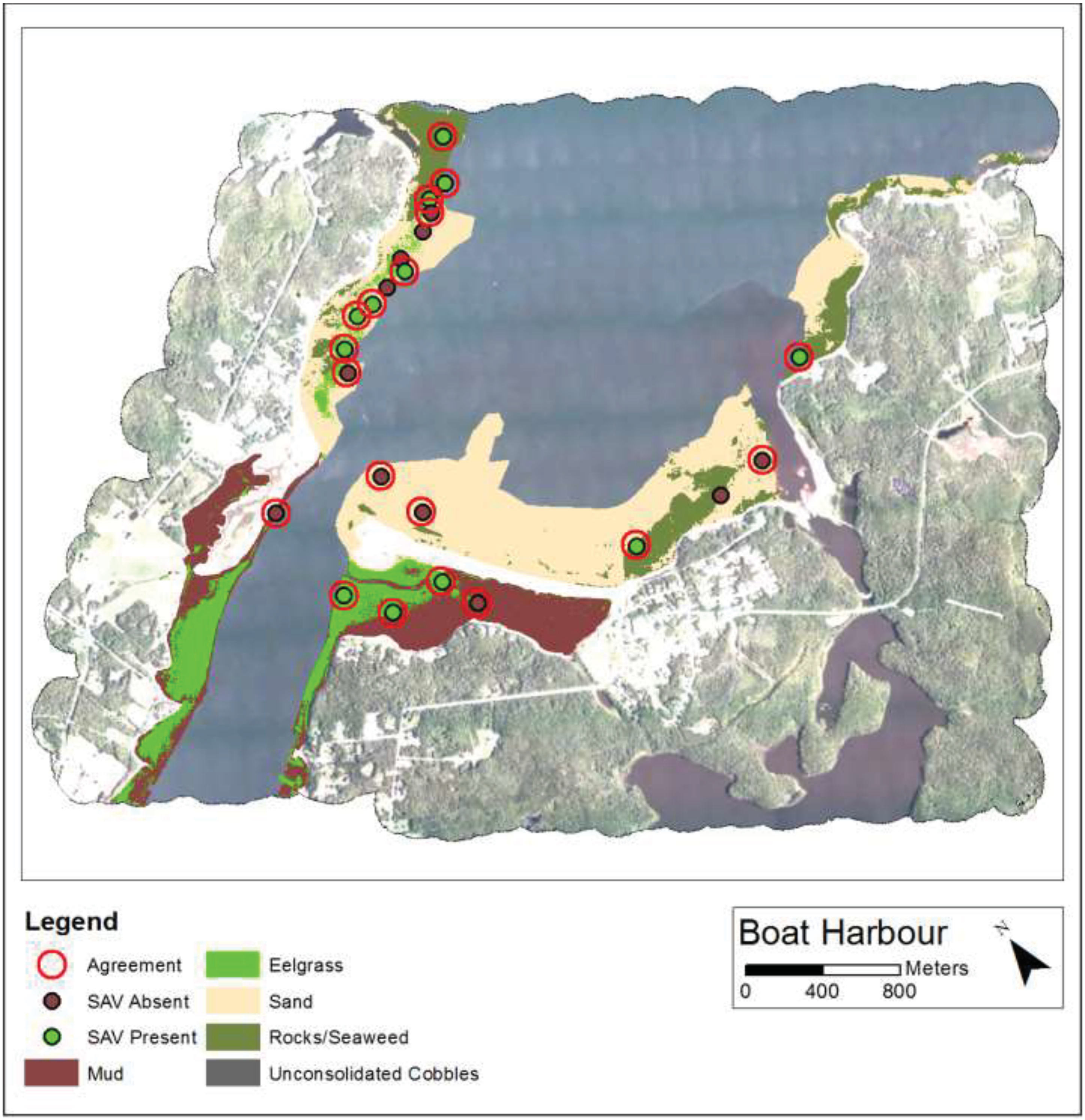

Figure 3-21 – Submerged aquatic vegetation (SAV) presence and absence. The red circles represent ground truth points which agree with the classification.

Figure 3-21 depicts the agreement between the presence and absence between the classification and ground truth data collected. The classification and ground truth points collected agreed very well with each other.

4 Hydrodynamic Model

A high-resolution 2-D hydrodynamic (HD) model was developed using the DHI Mike-21™ software module to simulate current flow and water level variations within the Pictou Harbour study area. The model domain was designed to be much larger than the lidar study area in order to properly model the circulation in the region through the Northumberland Strait into Pictou Harbour. Model inputs included bathymetry and boundaries, described in the following sections.

4.1 Modelling Methods

4.1.1 Grid Preparation

A variety of sources and resolutions of topography and bathymetry were required in order to complete the model depth grid (Table 5, Figure 4-1). Topo-bathymetric lidar data from 2014 (Little Harbour) and 2016 (Merigomish Harbour and Pictou Harbour) were down-sampled from 1 m to 9 m for computational efficiency. Other bathymetric data included a digital compilation of bathymetry data from various sources (e.g. multibeam, single beam, seismic, etc.) aggregated by CHS (Varma et al., 2008) between 5 and 20 m resolution, and 5 m multibeam data for Pictou Harbour and approach. A 20 m resolution database from the Nova Scotia Dept. of Natural Resources was used for the NS topography not included in the lidar dataset, and topographic lidar data collected by AGRG for PEI was used for the PEI coastline.

Provider	Source	Native Resolution	Domain
AGRG	Lidar: Pictou Harbour, Merigomish Harbour, Little Harbour	2 m	Topo/Bathy
CHS	Multibeam: Pictou Harbour and approach	5 m	Bathy
CHS	Chart soundings, echo sounding data, etc.	Variable	Bathy
AGRG	Lidar: PEI	2 m	Topo
NSDNR	Rasterized 1:10 000 Contour Data	20 m	Topo

Table 5: HD model bathymetric data sources, resolution, domain and number of observations. NSDNR: Nova Scotia Department of Natural Resources.

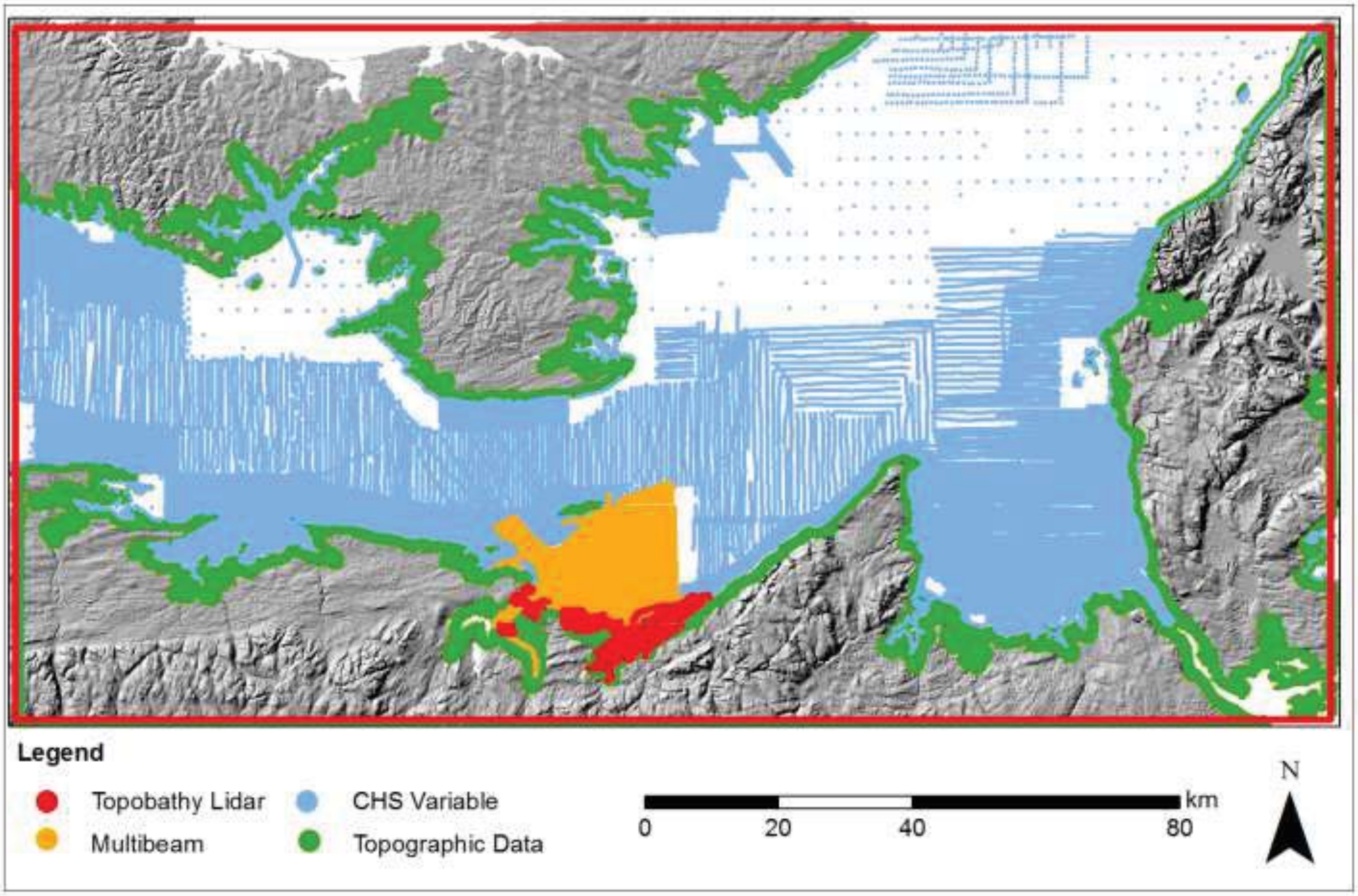

Figure 4-1: Sources of model topographic and bathymetric data.

A nested grid model approach was used to reduce the calculations required by the model. Five different model domains were developed using a 3:1 resolution step (Table 6, Figure 4-2). To generate the grids, the bathymetric and topographic datasets were subject to rigorous quality control procedures to ensure continuity between the various data sources. These datasets were then clipped to remove overlapping data points, giving preference to the higher resolution dataset, and topographic datasets were clipped to the coastline to reduce dataset size. The lowest resolution grids (Domains 4 and 5) were generated using only the coastal topographic data points and the CHS database bathymetry points, and were interpolated into rasters at their required resolutions (243 m and 729 m) using the ArcMap *Topo to Raster* tool to fill gaps in the different resolution datasets. The interpolation technique ensured a smooth elevation surface despite the coarse and irregular point spacing of the different datasets. All of the datasets (lidar, multibeam, topo points, etc.) were used to generate a 9 m resolution dataset to fit Domain 3; this was resampled and clipped to make the remaining model domains (Figure 4-3).

Domain	Resolution (m)
1	9
2	27
3	81
4	243
5	729

Table 6: Nested model domains as shown in Figure 4-2.

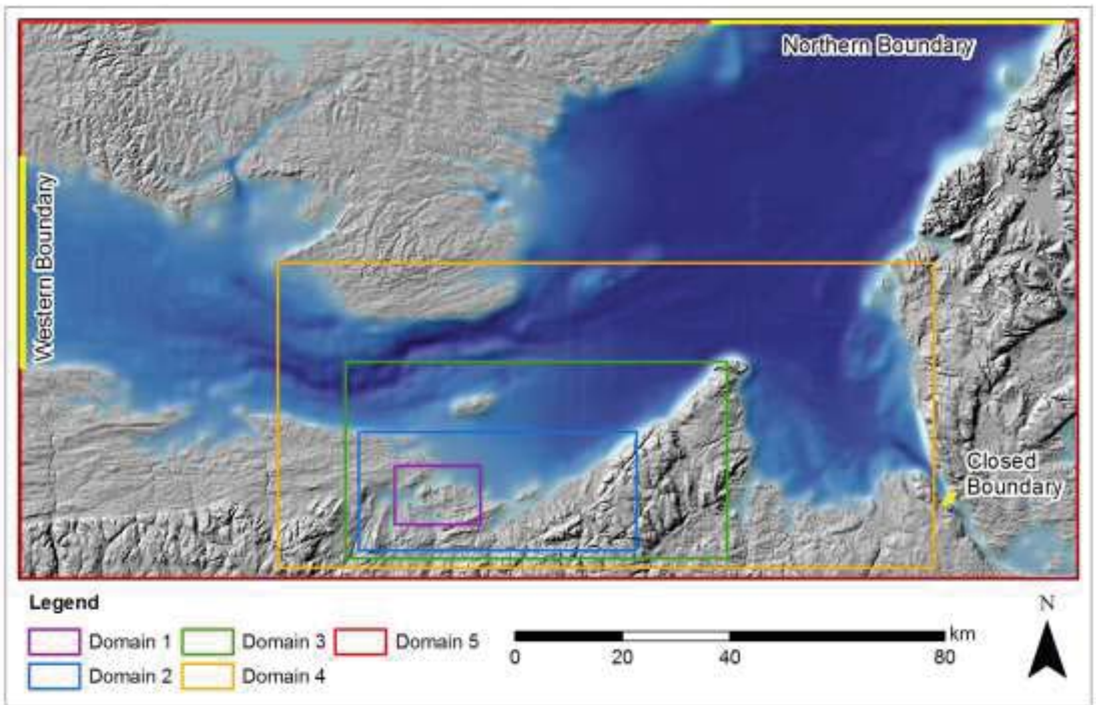

Figure 4-2: Mike 21 hydrodynamic model domain extents, boundaries, and Domain 5 grid draped over a 5x hillshade.

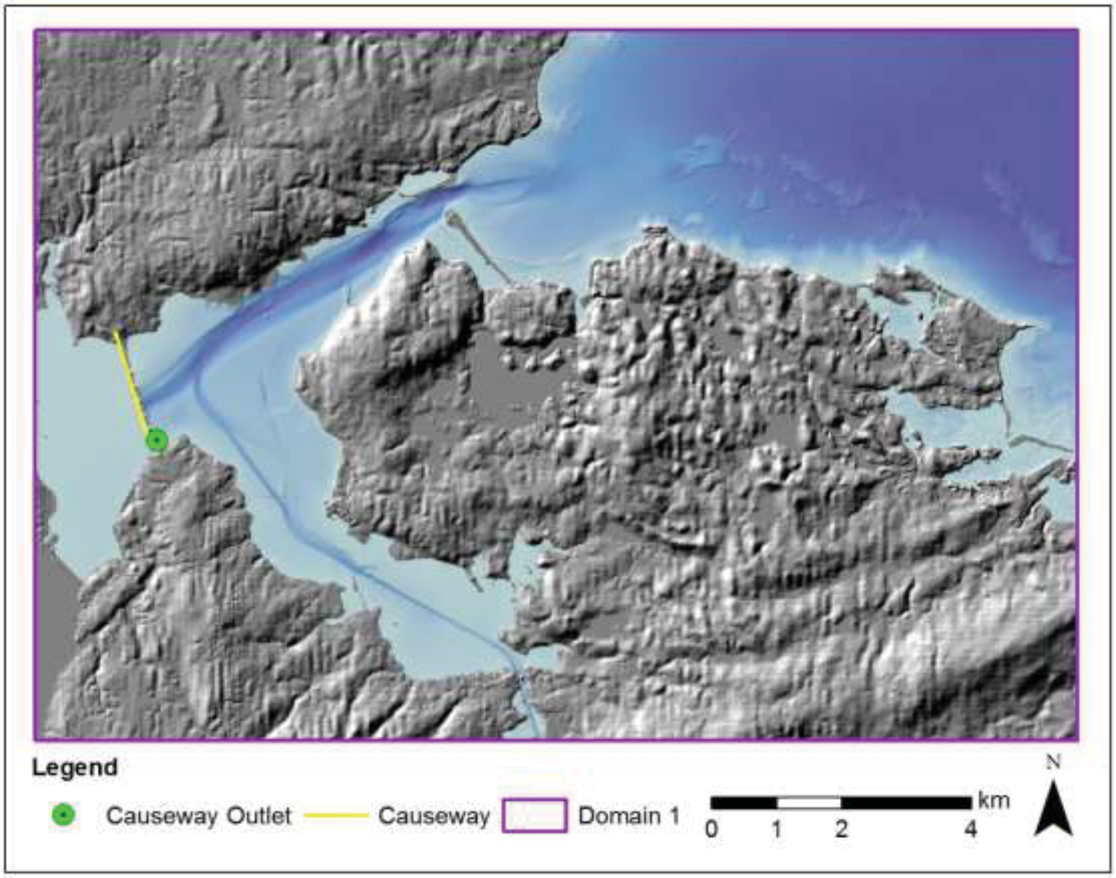

Figure 4-3: Domain 1: 9 m model grid draped over a 5x hillshade; Domain 2: 27 m model grid draped over a 5x hillshade. The Pictou Causeway is represented as a closed boundary with a point source discharge shown on the map by a green symbol.

4.1.2 Boundaries

The model simulated water level variations over the interpolated bathymetric surface in response to a forcing tidal boundary condition at two different locations. The Western Boundary extended from near Pugwash to PEI, and the Northern Boundary extended from Cape Breton to PEI (Figure 4-2). Both boundaries were forced with predicted tidal elevations at 5-minute resolution extracted from WebTide (Dupont et al., 2005). Tidal elevations across the Western Boundary varied between 0.01 m and 0.05 m and at the Northern boundary elevations across the boundary varied by as much as 0.15 m. The Canso Causeway represented a closed boundary; data south of the causeway were not included in the model domain. The Pictou Causeway was also represented by a closed boundary, as no bathymetric data were available to model the circulation in the harbour west of the causeway. Flow into Pictou Harbour through the causeway was represented by a positive discharge source. The values used to model flow under the causeway were somewhat arbitrary (flow = 2.0 m^3/s, velocity = 0.5 m/s). The values were varied during model calibration, but ideally actual measurements of flow and velocity over several tidal cycles would be used to provide more accurate model input.

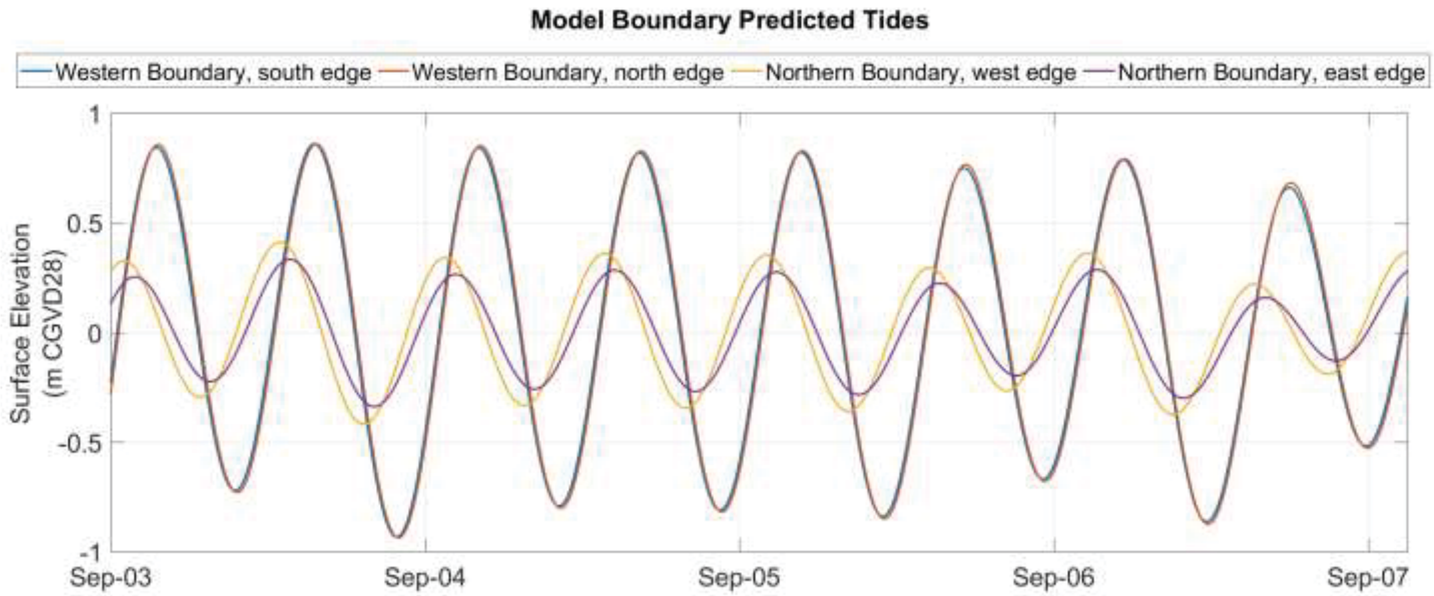

Figure 4-4: Tidal elevations predicted for the duration of the model simulation across the boundaries.

4.1.3 Model Parameters and Calibration

Parameters used in the model simulation are reported in Table 7. The model simulation start time (Sept. 3, 2016, 2:00) was chosen to overlap with observed currents and surface elevation, and to coincide with a high tide, for model stability. The calibration simulation lasted for two days, and model parameters were optimized by comparing model results to observations. The timestep (Δt) was chosen in order to minimize the Courant number, *C*, which was calculated based on

$$C = \sqrt{g \times z_{max}} \times \frac{\Delta t}{\Delta x}$$

where z_{max} is the maximum depth for each model grid, g is gravity, and Δx is the model resolution. A grid-dependent, velocity-based eddy viscosity scheme produced the best results. A constant eddy viscosity value, *E*, was calculated for each model domain as such

$$E = 0.02 \frac{\Delta x^2}{\Delta t}$$

following guidelines in a Mike 21 manual (DHI Water & Environment, 2008). The bed resistance value was varied between a Manning's M of 32 $m^{1/3}/2$ and 48 $m^{1/3}/2$; a value of 44 $m^{1/3}/2$ produced the most stable results. Effects of wind and waves were not modelled at this time.

Domain	Resolution (m) Δx	Courant Number	Eddy Viscosity (m^2/s)	Resistance ($m^{1/3}/2$ Manning's M)	Initial surface elevation (m)	Timestep (s) Δt	Drying Depth (m)	Flooding Depth (m)
1	9	5.70	0.32	44	0.5	4	0.01	0.02
2	27	2.51	2.92					
3	81	1.17	26.2					
4	243	0.43	236					
5	729	0.15	2126					

Table 7: Model Parameters.

4.1.4 Validation

The model was validated by simulating flow between Sept. 3, 2016 at 2:00 and Sept. 7 at 2:00 and comparing results to surface elevation and currents measured by the ADCP, and assessing the two-dimensional circulation of flow throughout Pictou Harbour.

The modelled surface elevation agreed well with the observed surface elevation, and exhibited an R^2 value of 0.92, Pearson coefficient of 0.96, and homogeneous distribution of residuals (Figure 4-5). The modelled east-west currents agreed well with the phase of the observations, but the model did not consistently simulate the observed variation in amplitude between tides (Figure 4-6). This resulted in a moderate error analysis (R^2 =- 0.33, Pearson = 0.57, somewhat homogeneous distribution of residuals). The model captured the large-scale nature of the north-south currents, predicting the amplitude of the flood tide but predicting the phase wrong, and modelling some of the finer signals of the southern ebb tide well in phase but under-predicting amplitude (Figure 4-7). The error analysis reflected these imperfections (R2 = 0.12, Pearson = 0.34). Assessment of current speed and direction show a different perspective on the modelled flow. The model simulates a consistent pattern from tidal cycle to tidal cycle, showing strong eastward current speeds on each ebb tide, followed by slower westward current speeds on the flood tide (Figure 4-8). The observations, in contrast, show a greater deal of variability between tidal cycles, although the general nature of the current speed and direction is represented.

Analysis of the depth-averaged ADCP current compared to the currents measured at all depths reveals that the water column at the site of the ADCP exhibited a great deal of variability, often showing eastward flow at one depth, and simultaneous westward flow at another depth (Figure 4-9). This type of flow structure is difficult to model accurately using a depth-averaged, two-dimensional model; however, Figure 4-9 shows that when the flow was well-mixed, or homogeneous throughout the water column and the depth-averaged flow was similar to the flow at each depth (e.g. Sept. 3, 9 PM– Sept. 4, 11 AM), the model simulated the observations well. When there was greater variability in flow between the surface and the seabed and the depth averaged ADCP was not a good representation of average flow (e.g. Sept. 4, 11 APM– Sept. 5, 11 PM), the model did not simulate that depth-averaged flow well.

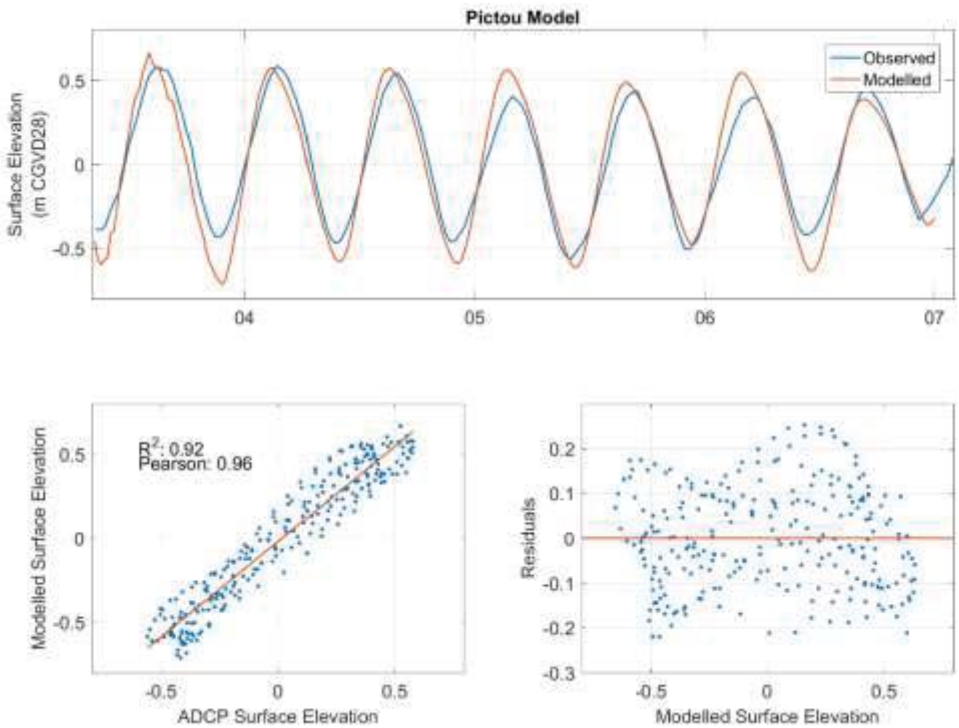

Figure 4-5: Modelled and observed surface elevation (upper panel), and error analysis (lower panels).

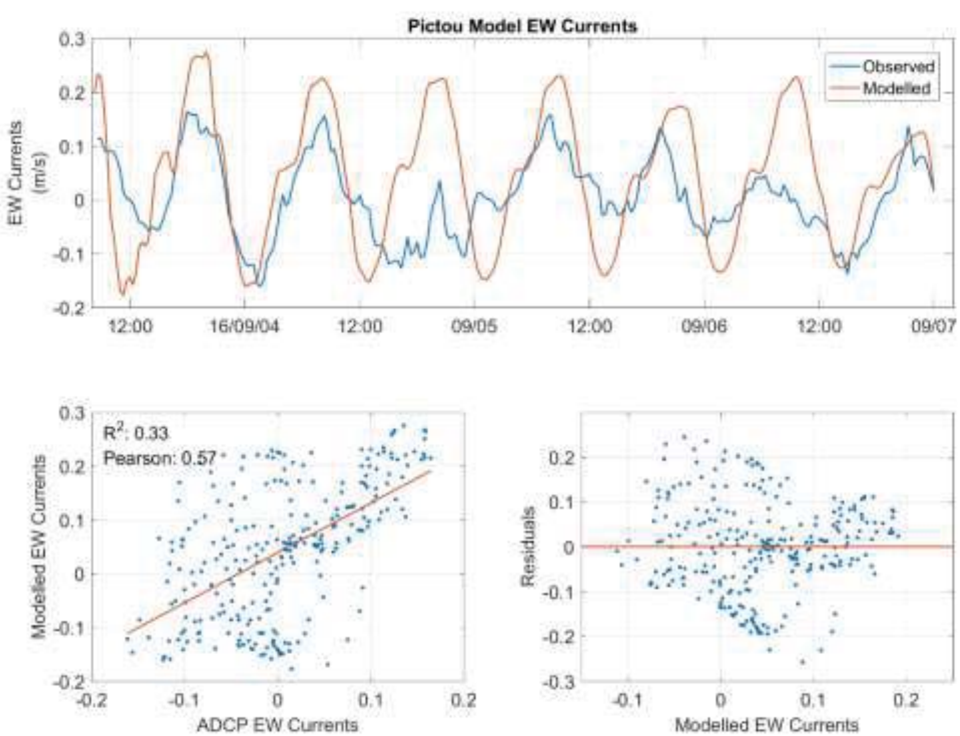

Figure 4-6: Modelled and observed EW current (upper panel), and error analysis (lower panels).

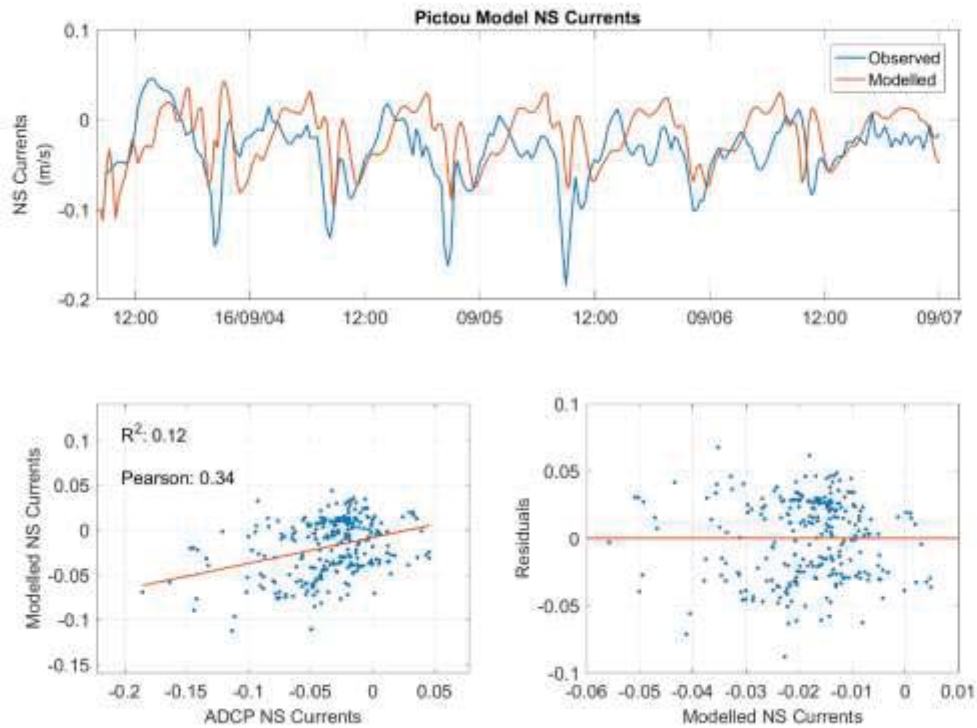

Figure 4-7: Modelled and observed NS current (upper panel), and error analysis (lower panels).

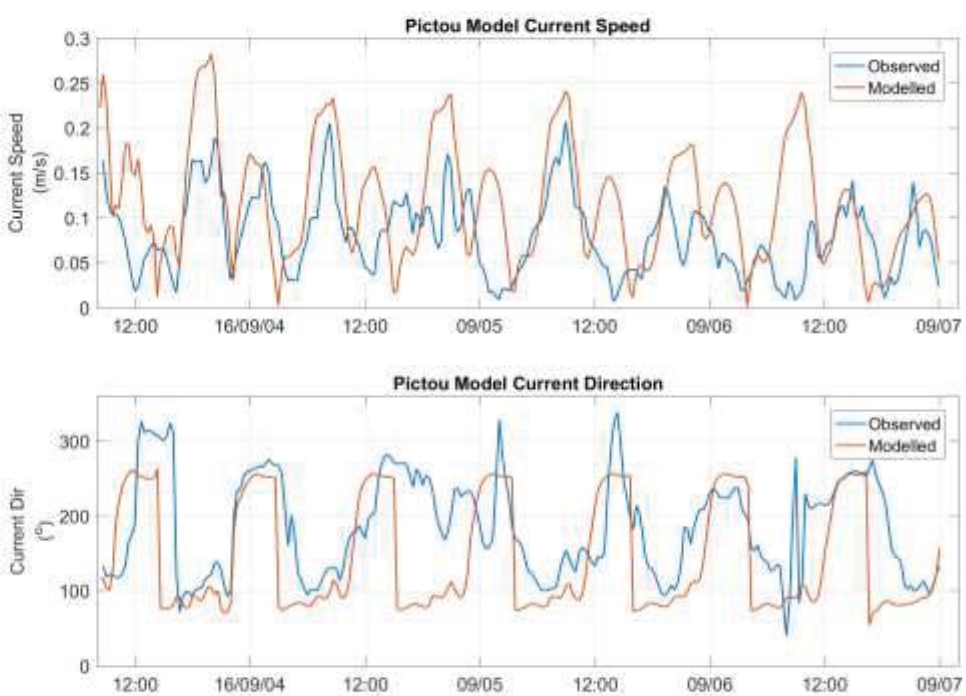

Figure 4-8: Modelled and observed current speed (upper panel) and direction (lower panel).

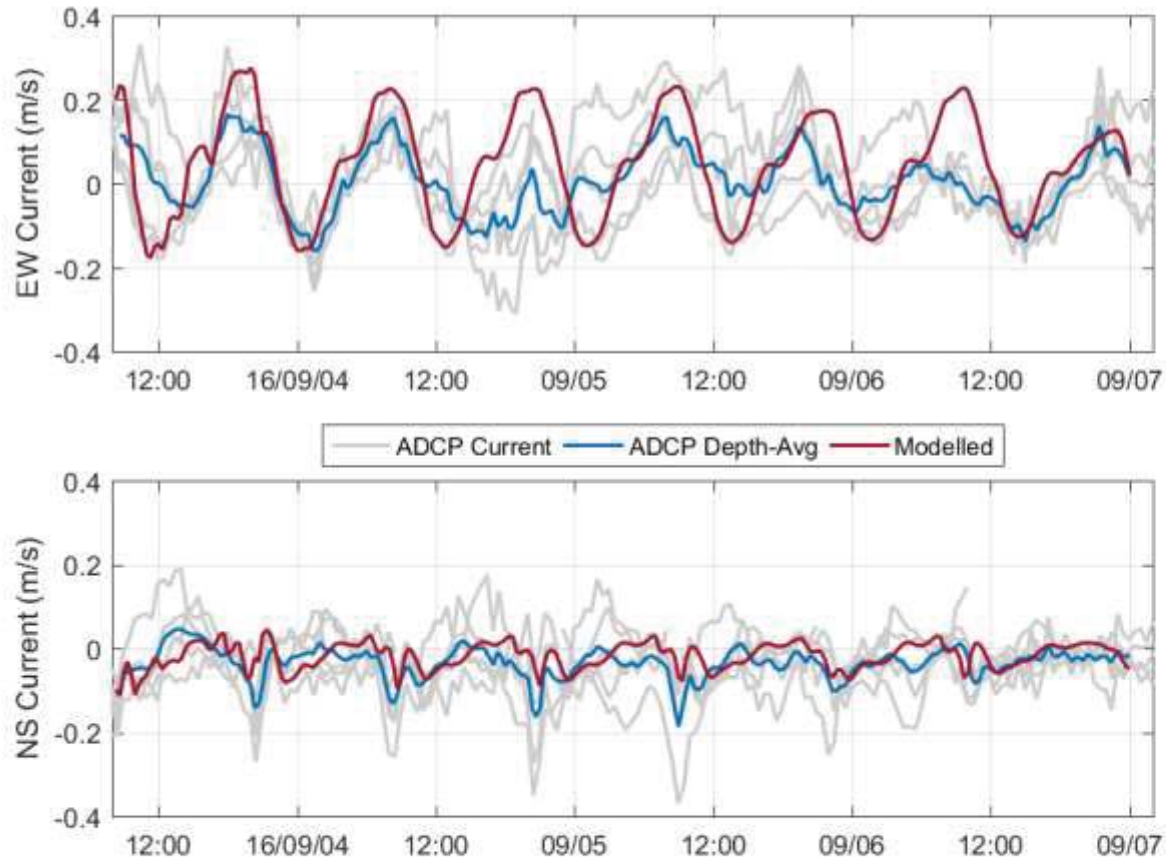

Figure 4-9: Modelled depth averaged current, observed depth averaged current, and currents for each depth as observed by the ADCP. EW currents shown on upper panel, NS currents shown on lower panel.

4.2 Modelling Results

The hydrodynamic model was successful in simulating tidal flow in Pictou Harbour (Figure 4-10 - Figure 4-12). During ebb tide the flow of water outside Pictou Harbour is from north to southeast, following the bathymetry contours; water in the back harbour flows northwest to exit the harbour, flowing faster in the deep channel (Figure 4-10a). Water flowing out of the main harbour channel flows to the east and southeast (Figure 4-10b), and water near the outlet of Boat Harbour flows north and then east, following the shoreline and joining the general flow pattern (Figure 4-10c). During flood tide, water enters Pictou Harbour flowing north and west from the southeast, increases in speed in the deep, narrow channel, and enters the back harbour (Figure 4-11a). The incoming tide near the outlet of Boat Harbour follows the 2 m depth contour closely, eventually flowing north to enter Pictou Harbour (Figure 4-11b). Closer to the shore near Boat Harbour water flows south towards the outlet at <0.05 m/s (Figure 4-11c).

Current speeds were highest in and near the channel, reaching 0.5 m/s along the axis of the channel; currents near the outlet of Boat Harbour were slower, approximately 0.01 m/s during maximum ebb and flood flow (Figure 4-12).

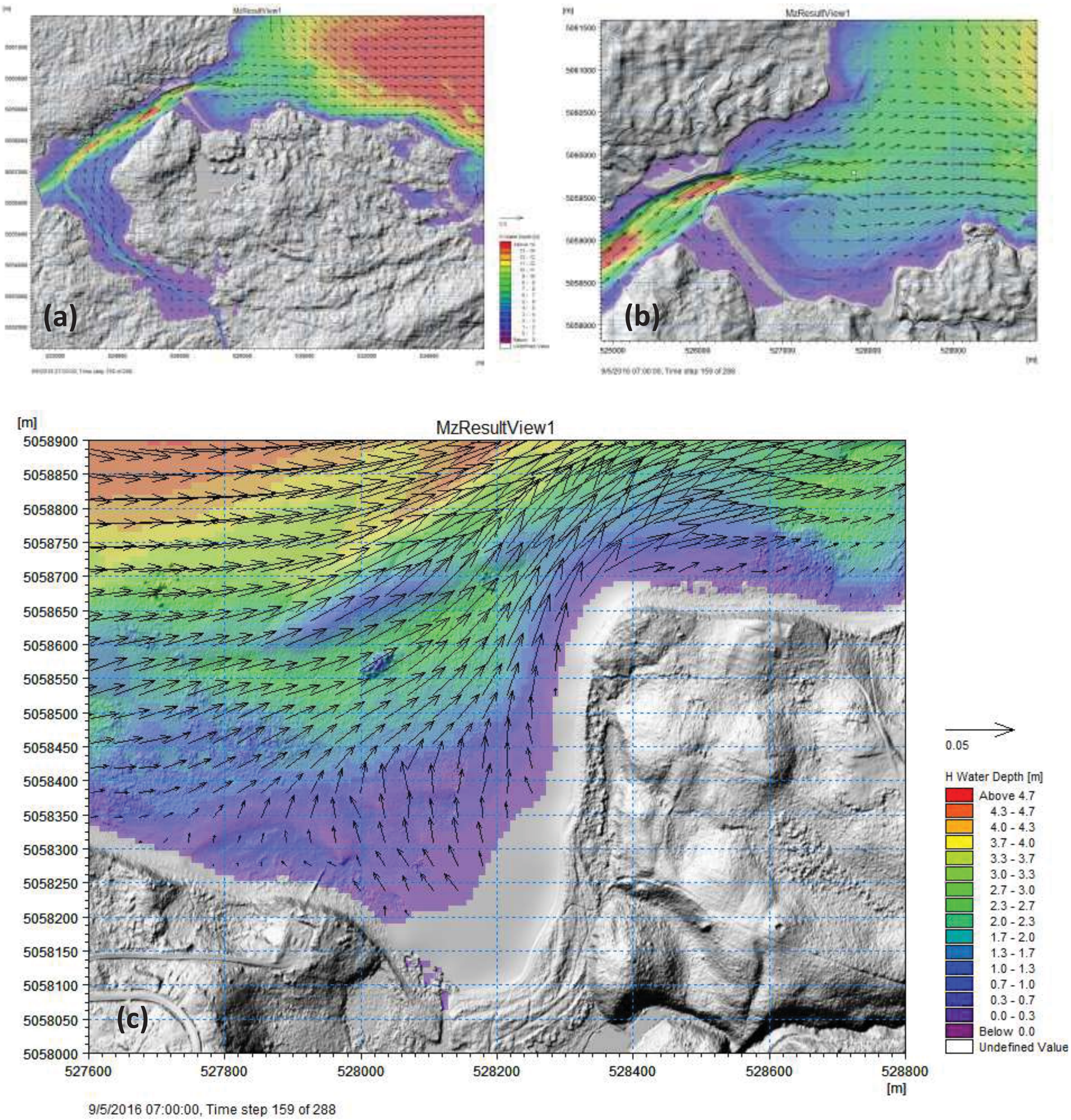

Figure 4-10: Water depth (represented by coloured contours) and velocity vectors (representing current direction and speed) during a typical flood tide (Sept. 5, 7:00). Model grid shown is (a) Domain 1, the 9 m grid, with every 35th vector plotted; (b) 9 m grid cropped to the northern lidar study area, with every 20th vector plotted; (c) 9 m grid cropped to Boat Harbour outlet, with every 4th vector plotted. Note the different vector scale for each plot, and the different colour scale for (c).

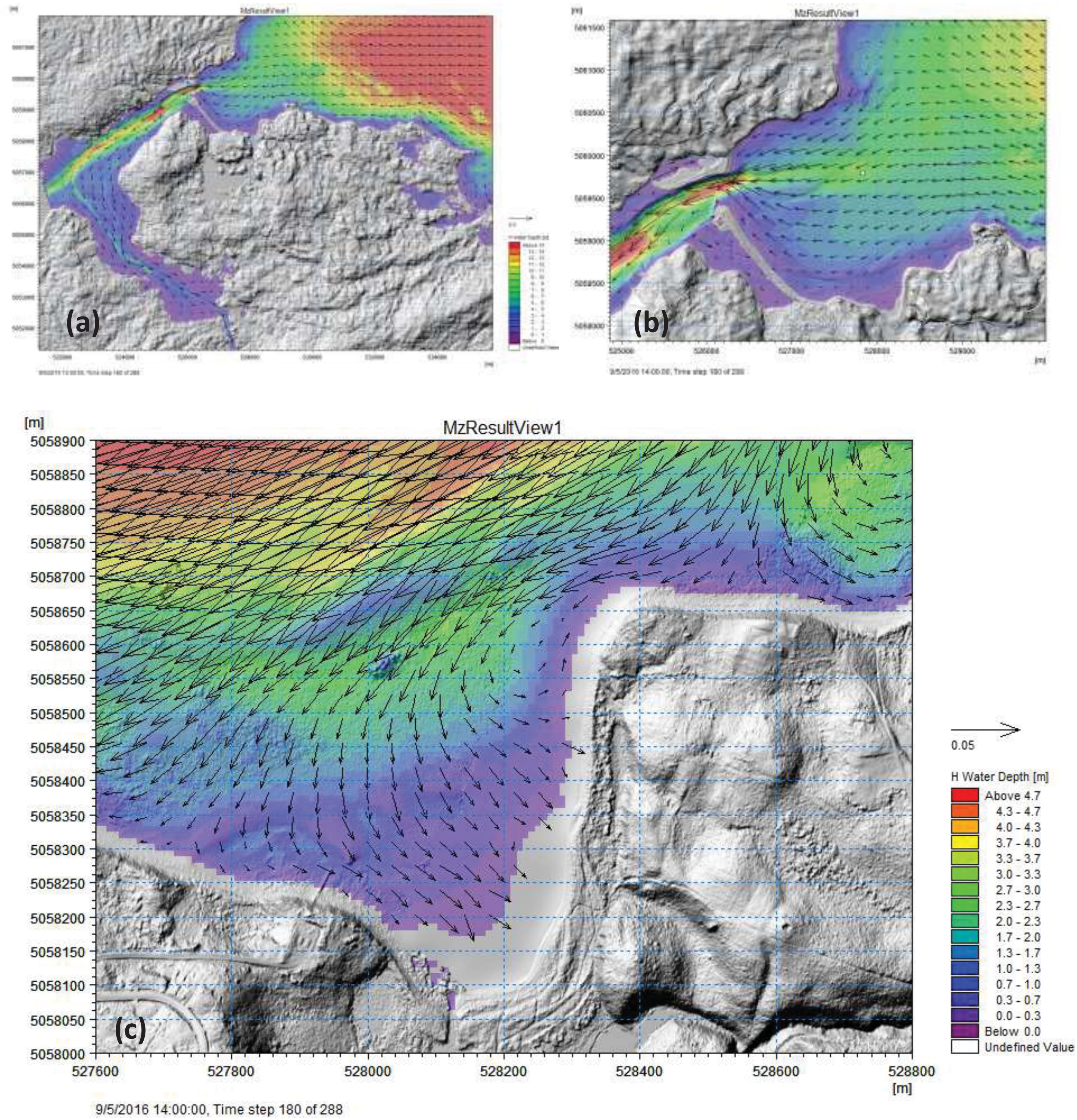

Figure 4-11: Water depth (represented by coloured contours) and velocity vectors (representing current direction and speed) during a typical ebb tide (Sept. 5, 14:00). Model grid shown is (a) Domain 1, the 9 m grid, with every 35th vector plotted; (b) 9 m grid cropped to the northern lidar study area, with every 20th vector plotted; (c) 9 m grid cropped to Boat Harbour outlet, with every 4th vector plotted. Note the different vector scale for each plot, and the different colour scale for (c).

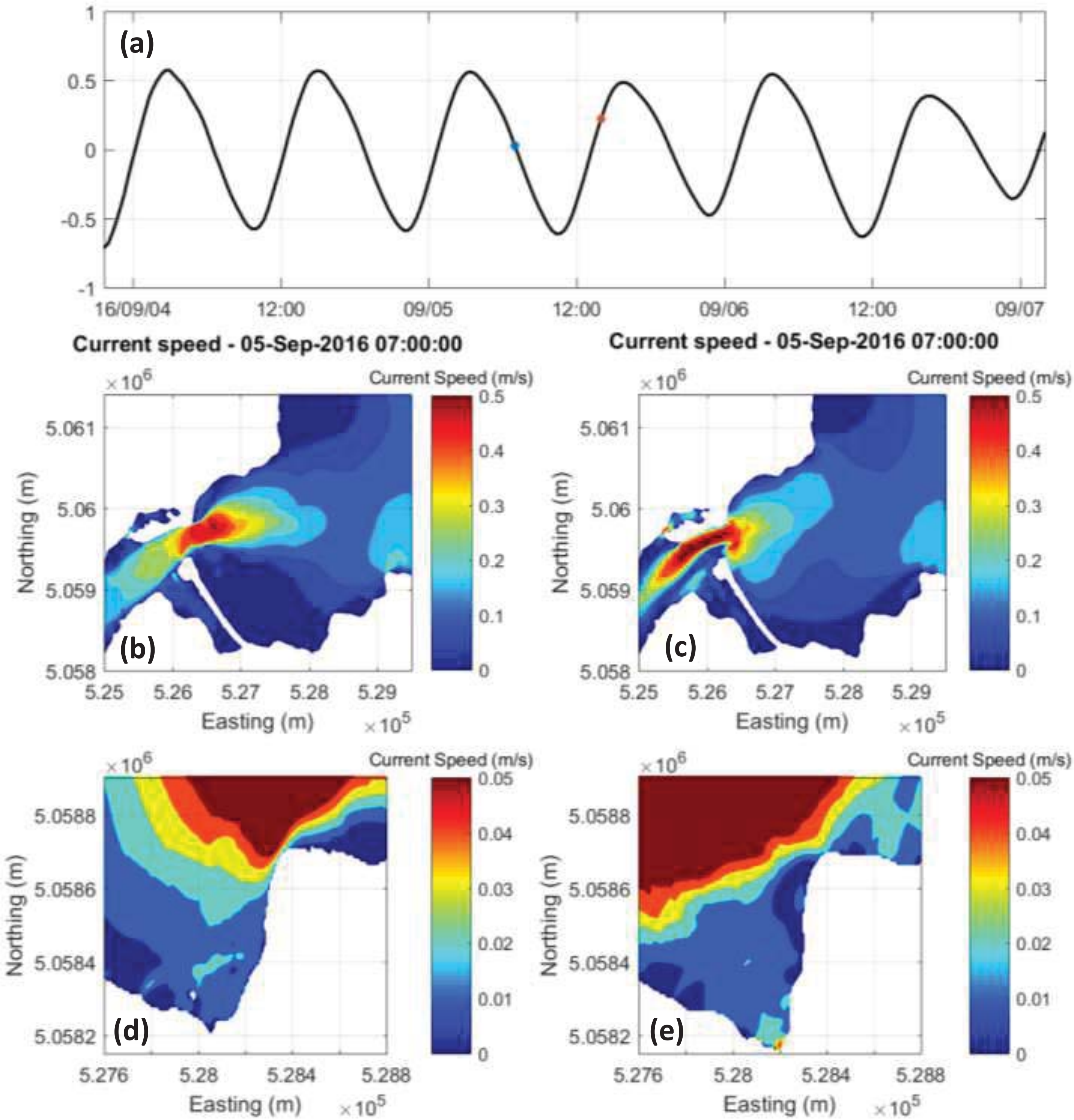

Figure 4-12: (a) Surface elevation, with markers representing the time of the lower figures. Current speeds during ebb tide (b,d) and flood tide (c,e) for the Pictou Harbour channel (b,c) and for the Boat Harbour outlet (d,e).

5 Discussion and Conclusions

A topo-bathymetric lidar survey of Pictou Harbour conducted on September 7, 2016 was successful in penetrating the seabed in the the study area, reaching a minimum elevation value of -4.8 m CGVD28. A data set from CHS consisting of 5 m multibeam data allowed the entire harbour to be covered in the study area, in particular, the channel where the lidar did not penetrate. The multibeam data were compared to the lidar in areas of overlap, along with the RTK GPS, which was validated as part of standard AGRG analysis. RTK GPS validation taken on land resulted in -0.14 m mean accuracy with a standard deviation of 0.04m, bathymetric validation resulted in -0.17 m mean accuracy with a standard deviation of 0.25 m. CHS 5m multibeam validation resulted in a -0.03 m mean with a standard deviation of 0.3 m.

Ground truth data collected by AGRG with the help of Pictou Landing First Nation in August 2016 resulted in a thorough collection throughout the study area, and were helpful in determining water clarity, bottom type and distribution of vegetation throughout the area at the time of the ground truth survey. This dataset was presented on a series of maps overlaid with the orthophoto mosaic. A seabed cover map was constructed from the aerial photos and the lidar derivatives and validated using the ground truth data.

An ADCP was deployed for 35 days to measure water level and current speeds throughout a tidal cycle. A hydrodynamic model was developed using topo-bathymetric lidar merged with the CHS multibeam data. The model was successful in simulating the current flow, water level variations and water circulation within outer Pictou Harbour and near Boat Harbour. A spatially varying bed resistance map could potentially improve model results, however, this can be implemented for future model development. Flow measurements for Pictou causeway would provide more accurate information to be used to model the flow through the causeway. The addition of wind to the model would likely not affect the overall circulation, but in future models the wind speed should be added for completeness. Ground control points for the southern portion of the study area would be useful for validating eelgrass distribution and the bottom type map for this area. The model, combined with the other data derived from this project help determine a base line condition so that in the future it can be compared when Boat Harbour is converted back to its natural setting as a tidal inlet.

6 References

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7 Acknowledgements

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Fish and Aquatic Habitat Baseline

- Fish and Fish Habitat Assessment (WSP 2018b)
- Boat Harbour Fish Population and Contaminant Assessment, Final Report (Cape Breton University, 2020)
- Literature Review Fish Species in Boat Harbour: Historical to Present (Cape Breton University, 2020)

BOAT HARBOUR REMEDIATION PLANNING AND DESIGN

FISH AND FISH HABITAT BASELINE REVIEW

SEPTEMBER 14, 2018

CONFIDENTIAL

BOAT HARBOUR REMEDIATION PLANNING AND DESIGN

FISH AND FISH HABITAT BASELINE REVIEW

GHD LIMITED

CONFIDENTIAL

WSP PROJECT NO.: 171-10478-00
DATE: SEPTEMBER 14, 2018

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September 14, 2018

CONFIDENTIAL

Attention: Peter Oram, P.Geo.
GHD LIMITED
45 Akerley Boulevard
Dartmouth, NS B3B 1J7

Dear Mr. Oram:

Subject: Boat Harbour Remediation Planning and Design– Fish and Fish Habitat Baseline Review

WSP Canada Inc. was retained to complete an assessment of the freshwater and marine fish and fish habitat for the Boat Harbour Effluent Treatment Facility located in Pictou County, Nova Scotia, to gain an understanding of the current conditions in Boat Harbour. It is understood that GHD Limited is planning remedial action for Boat Harbour and requires a baseline condition report.

This report summarizes the findings of the background freshwater and marine environment assessment of the surrounding area on the proposed site.

Sincerely,

Brady Leights, B.Et., Dip.R.M., E.Pt.
Environmental Technician

Christina Laflamme, M.Sc., EP
Senior Biologist

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APPENDICES

1 FRESHWATER ENVIRONMENT

1.1 INTRODUCTION

This report summarizes the methods and results used to evaluate fish and fish habitat within the Boat Harbour Effluent Treatment Facility (BHETF) study area freshwater environment by WSP biologists. Linear watercourses, waterbodies and wetlands were identified and evaluated for the presence of fish habitat and potential ability to support fish species. Field assessments were completed between August and November 2017.

1.2 DESKTOP REVIEW

Several studies have taken place previously at the BHETF located in Pictou Landing, Nova Scotia. Upon review of the previous studies a data gap regarding the state of watercourses was identified. While some reports had remarked on the state of the aquatic habitat of the Boat Harbour Stabilization Lagoon itself, the watercourses entering the harbour remained largely un-assessed. The goal of the assessment was to map the geographical position of all linear watercourses, waterbodies and wetlands, assess fish habitat of these identified features, and assess suitability for salmonid species.

1.3 BASELINE PROGRAM METHODOLOGY

1.3.1 AQUATIC HABITAT ASSESSMENT

A desktop review and site reconnaissance was conducted at the start of the Project to identify the presence of fish habitat within the Study Area. During the fish and fish habitat field program, each water feature (i.e., linear watercourse, waterbody and wetland) previously identified was followed until it reached the Project boundary or dissipated. If a watercourse became ephemeral in a section, effort was put forward to identify if and where the watercourse reappeared above ground. In the case that a watercourse flowed through a wetland, identifying the inflow and outflow was a priority, as well as characterizing the quality of the aquatic habitat in the wetland.

Once the total length of the watercourse located within the Study Area was established, assessors chose a representative reach 150 metres (m) in length to complete the in-depth assessment. The aquatic habitat assessment consisted of using a fish and fish habitat form developed from the guidelines and parameters outlined by Department of Fisheries and Oceans (DFO) and the United States Department of the Interior in association with the United States Fish and Wildlife Service pertaining to Atlantic Salmon (*Salmo salar*) (Marshall et al, DFO, 2014) and Brook Trout (*Salvelinus fontinalis*) (Raleigh et.al, USFWS, 1982). The various habitat components included in the fish and fish habitat form consist of:

- Stream morphology (i.e., sinuous, regular meandering, irregular meanders, tortuous meanders, braided, or straight)
- Watercourse type (i.e., large permanent, small permanent, intermittent, ephemeral, or a combination of these)
- Riparian vegetation identification
- Habitat types encountered (i.e. riffle, run, pool, flat, rapid, snye)
- Bank type (i.e., vertical, sloped, undercut, man-made, eroded)

- Substrate size: Fines (<0.0625 mm), Sand and small gravel (0.065-3.0 cm), Large gravel (3.1-6.4 cm), Cobble (6.5-25.6 cm), Boulder (>25.6 cm), & Bedrock. These size classes generalized from the Wentworth scale of rock particulate sizes. Substrate matter is measured on its rolling edge.
- In-Stream cover (i.e., small woody debris, large woody debris, undercut banks, overhanging vegetation, unembedded boulder and cobble, and aquatic vegetation)
- Barrier observations: full, partial, temporary, or none
- Water quality parameters: pH, water temperature, dissolved oxygen (mg/L and percentage), total dissolved solids, salinity, and specific conductivity.
- Percent pools and pool quality
- Water velocity (m/sec)
- Transect measurements: Bank-full and wetted widths, wetted depth, bank height, and percent embeddedness.
- GPS information about where transect measurements were taken (UTM coordinates zone 20T)
- Weather information for the date assessed, and remarks on previous precipitation which may influence wetted widths & depths.
- Habitat suitability rationale based on the aforementioned parameters and general site information pertaining to spawning, rearing, overwintering, and overall habitat quality.
- Additional notes about the site.

Compounded with the in-field assessment, a qualitative description of fish habitat modified from the Standard Methods Guide for Freshwater Fish and Fish Habitat Surveys (Sooley et al. 1998) was completed and tailored to be more compatible with conditions at the BHETF site, as the main salmonid species that has potential for occurrence at the site is Brook Trout, which is the most adaptable of the salmonid species. The habitat parameters outlined by Sooley (1998) are tailored more towards Atlantic Salmon, however conditions on site relate more to Brook Trout habitat, and are not likely preferred by Atlantic Salmon for most of the year, and some parameters relating to Atlantic Salmon or other salmonid species are included where they are specific to those species. Table 1 details the different types of fish habitat encountered at the BHETF.

Table 1: Fish Habitat Descriptions

TYPE	FISH HABITAT DESCRIPTIONS
I	Good salmonid spawning and rearing habitat, often with some large pools and abundant riffle sections. Substrate is made up of mostly small and large gravels with some cobble interspersed. Dominant habitat types are riffle and pool, as these features are important for Salmonid spawning and rearing.
II	Good salmonid rearing habitat with limited spawning habitat. Pockets of gravel, with adequate foraging areas for adult and juvenile salmonids. Habitat types may include run, riffle, pool, snye or step pool.
III	Poor rearing habitat with no spawning capabilities. Fast flowing and turbulent water often categorized by cascades, chutes, small waterfalls, substrate often consists of cobble, boulder, and bedrock. Lack of pools.
IV	Poor juvenile salmonid rearing habitat with no spawning capability. May provide shelter and foraging areas for larger, adult salmonids. Sluggish or shallow flows, and substrate usually consists mostly of fine materials. Poor pool development.
V	Poor habitat for salmonids of all sizes and age. Shallow, narrow streams with sluggish flow and possibly dry sections. These watercourses usually don't have significant habitat upstream to create cause for salmonid migration. Poor foraging areas, with substrate containing mostly fine materials. Inadequate for salmonid spawning.

1.3.2 WATER QUALITY

Water quality has a significant impact on the presence/absence of fish species. In general there are seven (7) parameters that are analyzed: pH, dissolved oxygen, total dissolved solids, specific conductivity, salinity and water velocity.

- **pH:** This measures the amount of acidity or alkalinity found in a substance, a completely neutral pH is measured at 7.0, any value less than 7.0 is considered acidic, and any value above 7.0 is considered basic (alkaline). The optimal pH range for Atlantic Salmon in Nova Scotia is considered to be between 5.6 and 8.0. The Optimal pH range for Brook Trout is between 4.5 and 8.0. The type of acids found in a watercourse (natural or inorganic) may alter the level of pH each species can tolerate.

- **Dissolved Oxygen:** This parameter measures the amount of oxygen dissolved in the water, and can identify areas where salmonid species may prefer or avoid. Dissolved oxygen levels for salmonid species are considered adequate when levels of at least 9.5 mg/L are achieved for early life stage salmonids and levels of at least 6.5 mg/L are achieved for all other life stage salmonids. Adult salmonid species can withstand lower levels of dissolved oxygen for brief periods, but excessive exposure to dissolved oxygen levels less than 5.0 mg/L is considered detrimental to their health.

- **Total Dissolved Solids:** This is the calculation of the amount of solids found flowing in water. Readings of 150-500 mg/L are considered acceptable for salmonid species, as levels lower than this may reflect poor productivity of benthic macro invertebrates, and levels higher than this are often linked to silt-loading or significant local erosion.

- **Conductivity:** This is the measurement of how easily electricity will pass through a substance, when referring to water, this parameter is often measured in micro-Siemens per centimetre (µS/cm). When taken in-field, this measurement can be used to determine the approximate quantitative amount of metals found in an area. Further laboratory testing should be completed to fully understand the individual conductive elements present in the substance. High conductivity readings may be an indicator of high total dissolved solids in the water. Generally, conductivity readings of between 150 and 500 µS/cm are considered acceptable for salmonid species. Measurements at BHETF were taken using Specific Conductivity, which is a calculated parameter using conductivity and temperature. Specific conductivity was used because it is easily comparable with data recorded in other parts of the world, or with reference streams. Specific conductance is calibrated using both ambient temperature, and a conductance calibration solution. In regards to the unit used to by the assessors (YSI 650 MDS), the temperature constant is set by manufacturers at 25ºC.

- **Salinity:** This is the measurement of dissolved salts in a substance. The field unit used at BHETF does not read true salinity, but uses an algorithm which includes conductivity and water temperature to calculate an expected salinity level. Brook Trout can thrive in areas with salinity levels in water of 10 ppm, and can acclimate themselves to water with 33 ppm salinity (sea water). This parameter was used mainly to identify if areas of salt water intrusion were apparent in watercourses on site.

- **Water Velocity:** This is the measurement of the speed of water flowing through an area. This parameter is commonly measured in metres/second (m/sec), and is a significant factor of dissolved oxygen levels. Areas with high velocity often have turbulent water, which creates higher levels of dissolved oxygen. Conversely, areas with little to no water velocity often have low levels of dissolved oxygen and higher amounts of settled out fine material in the substrate. An accepted resting water velocity for Brook Trout is <0.15 m/s, however Brook Trout can be found in areas above or below this range. Areas of extreme water velocity (>12 m/sec) may cause a barrier to all fish passage, and can increase habitat fragmentation. Areas with little to no water velocity may have depleted levels of dissolved oxygen, which can be detrimental to aquatic species. Velocity can effect species living in a watercourse to a heightened or lessened extent depending on the amount of in-stream cover (typically boulder) found in the area.

- **Water Temperature:** This is the measure of heat found in a watercourse, and is crucial for determining the suitability of a watercourse for aquatic species. Most salmonid species prefer cold, clear water, with areas of upwelling groundwater for spawning activities. Optimal temperature range for overall well-being of

Brook Trout is believed to be between 11 ºC and 16ºC. The recognized maximum tolerable temperature limit for Brook Trout is measured at roughly 24ºC, although Brook Trout will likely begin to seek out new habitat once water temperature hits 20ºC.

WSP conducted the water quality assessment during the aquatic habitat assessments, and benthic macro-invertebrate assessments. A field meter (YSI 650-MDS Multi-parameter) was used to measure dissolved oxygen (mg/L and percent), pH, specific conductivity, salinity, total dissolved solids, and water temperature at each sampling location. Care was taken by WSP's field technicians to ensure the instrument was properly calibrated, and that representative areas were chosen for water sampling (i.e. no samples were taken in white water riffles, or stagnant pools, as levels of dissolved oxygen and conductivity may not be representative of the watercourse.). Run-type habitat was used for testing when available with sufficient depth. At each sample station the YSI was left in the watercourse for three to five minutes to ensure the instrument had adequate time to settle on all parameters.

1.3.3 AQUATIC ECOSYSTEM CONDITION

Many species or groups of species of macroinvertebrates are diagnostic of certain kinds of aquatic habitats and their water quality. They are known as indicator organisms. Indicator organisms become numerically dominant under a specific set of environmental conditions. Stream organisms that exhibit adaptations to life in flowing waters are indicators of healthy stream environments. These organisms exhibit clues that they are from erosional substrates in stream environments. In contrast, organisms that live in depositional substrates (e.g. pools of streams, sediments of lakes) have features characteristic of lentic environments, i.e. poor stream environments.

The Order *Diptera* is made up of a diverse array of aquatic insects collectively known as the true flies. Mosquitoes (*Culicidae*), phantom crane flies (*Ptychopteridae*), crane flies (*Tipulidae*), black flies (*Simuliidae*), and non-biting midges (*Chironomidae*) are among the more well-known families in this order. Not unlike other aquatic insects, this Order has at least one aquatic based juvenile stage who emerge as adults to breed and lay eggs. This Order is related to slower moving, warmer water even though some families have adaptations for fast water. In a general sense, an aquatic stream habitat dominated by *Diptera* may not be ideal for fish, and is likely not in a reference condition. Heavily silted streams, with large amounts of organic matter, similar to conditions found in lakes and ponds, are known for high abundance of Dipterans.

The Orders *Ephemeroptera* (mayflies), *Plecoptera* (stoneflies), and *Trichoptera* (caddis flies) are collectively known as EPT taxa. As a group they show high adaptation for aquatic stream environments. These taxa are largely intolerant of pollution and poor water quality. They are primary fish food and are heavily adapted for clear running, non-silted stream habitats. In general, dominance of this group is indicative of high quality aquatic habitat, both in terms of water quality, low disturbance, and as potential fish habitat.

Benthic sampling locations were chosen due to substrate composition, and the watercourses location on the site. Watercourses were chosen in each section of the site, with preference given to watercourses with high percentages of sand, gravel, and cobble in the substrate. Watercourses with excess amounts fine materials were avoided for sampling due to preservation concerns and additional time finding and identifying individuals in these sediment rich samples. Samples were collected using a timed-kick method with a net and stopwatch, assessors kicked up substrate in a zig-zag pattern across the reach of the stream for 3:00 minute intervals at each location. Samples were preserved in 10% ethanol and shipped to the Canadian River Institute's CABIN certified lab in Saint John, New Brunswick.

Samples will help to create a baseline data for benthic community health in the watercourses at the BHETF site, and the EPT ratio may help to identify areas of either good or bad water quality as these taxa are indicators of stream health. Total abundance of all taxa may also help to indicate watercourses suitability for fish, as benthic macroinvertebrates are often preyed upon by freshwater fish species. This information is easily comparable to any additional benthic sampling carried out in the future to compare and contrast with present conditions and identify trends after remediation of the site is completed. Water velocities in the assessed watercourses were all similar in swiftness, with sluggish flow, less than 0.3 m/sec.

1.4 BASELINE CONDITIONS

1.4.1 AQUATIC HABITAT ASSESSMENT

A total of nineteen (19) watercourses were identified by technicians during both the desktop review and initial site reconnaissance. Watercourses identified included two (2) ephemeral channels, thirteen (13) intermittent channels, three (3) small permanent channels, and one (1) large permanent channel. Three (3) small drainage corridors were also identified on site (see Figure 1, Appendix A). Fish species were visually observed in two (2) of the watercourses on site, but only one of the two encounters resulted in a positive species identification.

The following is a description of each watercourse assessed at the BHETF. Watercourse field sheets are located in Appendix B. Figure 2 (Appendix A) illustrates the fish habitat classification for each watercourse surveyed. Limiting factors are described in each watercourse description to further explain how each assessment classification was determined using factors that are known to be integral for salmonid habitat requirements. Criteria considered "poor" are likely unfit for salmonids, while moderate and good scores are considered adequate, or optimal parameters for salmonid species. Photos of each watercourse are provided in Appendix C.

WC-1: A small permanent watercourse found in the southwest section of the Project area with an average bank-full width of 2.63 m. The assessed area is found between two wetlands, with a continuous defined channel. Fish were observed in this watercourse, but not identified (likely stickleback species). A partial barrier was observed in the reach, identified as an older inactive beaver structure. Substrate was dominated by small and large gravels as well as cobble. Spawning potential in this watercourse was moderate due to the presence of constant flow, and high amounts of gravels found in the substrate. Average depth was measured at 0.11 m, and the mix of habitat types encountered was conducive to aquatic life. In-stream cover was available in various forms, with undercut banks providing the most cover. Water quality parameters in this watercourse were considered adequate for young Brook Trout, and possibly adult Brook Trout in times of higher flow, however none were observed. An ATV bridge constructed of metal planks runs over the watercourse, but has no immediate impact on the aquatic habitat. This watercourse was classified as Type II.

Limiting factors:

- Water Temperature: 9.37^{o}C, (Good)
- pH: 6.94 (Good)
- Dissolved Oxygen: 12.21 mg/L (Good)
- Pool availability: Low-Moderate
- In-Stream cover: Trace-moderate
- Fines in substrate: 25% (Moderate)

WC-2: This watercourse was classed as an intermittent channel, and water was mostly absent at time of assessment. This watercourse runs in a mostly straight pattern for several metres before meeting a large wetted pool, then dissipating into a wetland area before re-consolidating to a defined channel and flowing into another large pool that is flow controlled by beavers. Beaver activity was apparent in various locations along the lower reach of the watercourse. As such, water depths were greater in the lower section, with an average depth of 0.26 m. The channel runs into a large wetland at the downstream end of the assessed area. Cover was readily available in various forms throughout the reach, with undercut banks, woody debris, and overhanging vegetation as the dominant cover types. Habitat in the lower section of this watercourse may be useable for young Brook Trout as rearing habitat, and possibly adult Brook Trout habitat in peak flow seasons, however no fish were observed at time of assessment. This watercourse was classified as Type V.

Limiting factors:

- Water Temperature: 12.59^{o}C (Good)
- pH: 6.83 (Good)
- Dissolved Oxygen: 2.17 mg/L (Poor)

- Pool availability: Low/ Moderate (habitat fragmentation)
- In-Stream cover: Trace
- Fines in substrate: 100% (Poor)

WC-2A: Found in the South section of the Project area, this area is an extension of WC-2 after an unconsolidated section running through a wetland area. This watercourse was classified as an intermittent stream, with an average bank-full width of 0.84 m. Fines were the dominant media in the substrate, with low amounts of gravels and cobble noted as well. Water depth was considered fairly deep compared to most of the watercourses in the Project area, with an average depth of 0.26 m, and a maximum depth of 0.63 m. Water quality parameters were all within range for salmonid species with the exception of dissolved oxygen which was low (3.65 mg/L). Beaver activity was apparent in various sections throughout the reach, but appeared to be inactive. This stream is bordered by mature forest on both sides, before entering a large wetland. A culvert was noted on a road passing over WC-2A, and was mostly full of beaver sticks, creating a large pool upstream of the culvert. No fish were observed at time of assessment. This watercourse is between Type II and Type III, as rearing habitat is available for young and adult Brook Trout if dissolved oxygen levels were more substantial.

Limiting factors:

- Water Temperature: 15.71^{o}C (Good)
- pH: 6.99 (Good)
- Dissolved Oxygen: 3.65 mg/L (Poor)
- Pool availability: Moderate-high
- In-Stream cover: Abundant
- Fines in substrate: 100% (Poor)

WC-3: Found in the southern section of the Project area, this watercourse was classified as an intermittent stream running in a sinuous pattern. The average bank-full width of the channel was measured as 0.77 m, with an average wetted depth of 0.08 m, and dry sections were encountered by the assessors in several sections. Substrate in this channel was a good mix of gravels and cobble, with some fines (20%) encountered. This channel runs above ground for roughly 120 m before becoming ephemeral. Water quality parameters taken were considered adequate for salmonid species, however access to this area is likely compromised due to dry sections and ephemeral sections. Undercut banks were the most abundant form of instream cover, but the lack of wetted width rendered them useless to fish at time of assessment. Habitat in this watercourse may be useable for early life stage Brook Trout at times of peak flow throughout the year, but unlikely habitat most of the year, as access to the most substantial areas of fish habitat are not easily accessible. No fish were noted at time of assessment. This watercourse is classified as Type V.

Limiting factors:

- Water Temperature: 13.42^{o}C (Good)
- pH: 7.12 (Good)
- Dissolved Oxygen: 6.62 mg/L (Moderate)
- Pool availability: Low (poor depth)
- In-Stream cover: Moderate
- Fines in substrate: 20% (Moderate)

WC-4: Found bordering a large wetland in the southern section of the Project area is this small, mostly ephemeral stream. The areas of channel apparent at the surface were found at the bottom of a hill, and the channel was mostly dry, save for 0.03 m of water found at one transect. This watercourse ran in a mostly straight pattern, and the channel lost definition entirely when it met an ATV trail. Substrate in the channel was mostly fines, with some small gravels interspersed. Average bank-full width was measured at 0.97 m, without substantial banks to keep water consolidated in the channel. Water quality parameters weren't possible to assess due to lack of depth in the channel, and no fish were noted at time of assessment. Not likely substantial habitat for adult Brook Trout, although young Brook Trout could potentially use this area as rearing habitat in times of higher flow if they could traverse the unconsolidated channel sections. This watercourse is classified as Type V.

Limiting factors:

- Water Temperature: Dry (Poor)
- pH: Dry (Poor)
- Dissolved Oxygen: Dry (Poor)
- Pool availability: Low - None
- In-Stream cover: Trace
- Fines in substrate: 75% (Poor)

WC-5: An intermittent watercourse flowing from the south side of the site in a northern direction. This watercourse runs from the Buck road, and empties into a pond. Gradient was considered quite steep for the first 30-40 m before the watercourse flattens and hits a pond with a flow control built by beavers. After this pond, the channel becomes very narrow (bank-full width of 0.54 m) and runs through a hillside wetland area. Water was absent in the upstream high gradient area, and average depth downstream was quite poor (0.03 m). The flow controlled beaver pond found halfway through the assessed reach appeared to be the most suitable fish habitat in the reach, but access to this pond is questionable. Several braids were noted in the channel after it has left the beaver pond, increasing the difficulty for fish trying to traverse the area. No fish were observed at time of assessment. This watercourse was classified as Type V.

Limiting factors:

- Water Temperature: Lack of depth for reading
- pH: Lack of depth for reading
- Dissolved Oxygen: Lack of depth for reading
- Pool availability: Low-Moderate (some pool areas, but inaccessible for fish at time of assessment)
- In-Stream cover: Trace-Moderate
- Fines in substrate: 40% (Poor)

WC-6: An intermittent watercourse which flows in a sinuous pattern before reaching a confluence with WC-7. Beaver activity was apparent in various sites form the headwater pond and continued through most of the reach. Dry section barriers were observed in several locations, and the watercourse's substrate consisted mostly of fine materials, which are not favourable for salmonid spawning. Average bank-full width of this watercourse was measured at 1.93 m, but the average depth was extremely shallow (0.04 m) and in mainly run with no pools. Water quality parameters in this watercourse were considered adequate for salmonids, and young Brook Trout could potentially rear in this area if they could access it, however there are several fragmentation features between this channel, and the Boat Harbour Stabilization Lagoon. No fish were observed at time of assessment. This watercourse was classified as Type IV.

Limiting factors:

- Water Temperature: 15.23^{o}C (Good)
- pH: 7.00 (Good)
- Dissolved Oxygen: 8.86 mg/L (Good)
- Pool availability: Low (poor depth)
- In-Stream cover: Trace-Moderate
- Fines in substrate: 75% (Poor)

WC-7: An intermittent watercourse which follows an irregular meandering pattern. WC-7 had an average bank-full of 1.16 m, and an average depth of 0.04 m. This watercourse likely sees times of much higher flow during spring thaw, and runs through a very well defined trench. WC-7 originates near the bottom of a steep hill, then flattens almost entirely. Substrate consisted mostly of fine materials, which are not ideal for salmonid spawning. The watercourse lacks substantial foraging areas for fish, and dry section barriers were identified numerous times during the initial assessment. Water quality parameters appeared to be adequate for salmonids at time of assessment, however no fish were observed due to the large amount of fragmentation encountered throughout the reach, in times of higher flow, this area may be suitable for young Brook Trout. Some in-stream cover was noted in the channel, with overhanging vegetation being the dominant cover type. This watercourse is between Type III and Type IV. WC-7 was identified as a former raw effluent discharge ditch, which may provide evidence of degraded sediment in this watercourse's substrate, and could have potentially deposited chemicals which are detrimental to aquatic species or water quality.

Limiting factors:

- Water Temperature: 14.01°C (Good)
- pH: 7.22 (Good)
- Dissolved Oxygen: 10.92 mg/L (Good)
- Pool availability: Low
- In-Stream cover: Moderate
- Fines in substrate: 80% (Poor)

WC-8: Found in the western section of the Project area, this watercourse is classified as an intermittent stream, with an average bank-full width of 0.74 m, and an average wetted depth of 0.05 m. This watercourse experiences severe silt-loading from an up-gradient clear cut found just above the channel, and was witnessed firsthand by the assessors. Substrate in this watercourse was dominated by fine materials, with small amounts of gravels interspersed. Small and large woody debris, undercut banks, and overhanging vegetation were the apparent forms on in-stream cover at this site. Water quality parameters were considered adequate for salmonid species, but access to this site may be compromised by a large wetland found downstream. Wetted width of this watercourse was quite narrow (0.45 m), and it is unlikely that adult or juvenile salmonids could or would utilize this habitat. This watercourse is classified as Type V.

Limiting factors:

- Water Temperature: 13.6°C (Good)
- pH: 7.08 (Good)
- Dissolved Oxygen: 7.01 mg/L (Moderate)
- Pool availability: None
- In-Stream cover: Moderate
- Fines in substrate: 85% (Poor)

WC-9: Found in the western portion of the Project area, this watercourse is classified as a large permanent stream, with an average bank-full width of 4.99 m, and runs in a straight pattern before emptying into the Boat Harbour Stabilization Lagoon. The wetland area upstream was once used as a settling pond for the BHETF, and banks of this stream appear to have been modified from their natural form. A significant beaver structure holds water levels approximately 0.75 m higher near the edge of the upstream wetland, restricting flow in the assessed area. Substrate in this watercourse consisted of mostly of cobble and boulder sized rock, with fines interspersed as well. Average depth in this watercourse was measured at 0.33 m, and a Three-spined Stickleback (*Gasterosteus aculeatus*) fish was observed. Water quality parameters taken at this site were considered fair, with the exception of dissolved oxygen which was low (3.98 mg/L). Juvenile and adult Brook Trout could likely utilize this watercourse if dissolved oxygen levels were higher. This watercourse is classified as Type II.

Limiting factors:

- Water Temperature: 18.57°C (Moderate)
- pH: 6.75 (Good)
- Dissolved Oxygen: 3.98 mg/L (Poor)

- Pool availability: Low-Moderate (possibly fragmented habitat)
- In-Stream cover: Trace-Moderate
- Fines in substrate: 40% (Poor-Moderate)

WC-10: Found in the western section of the Project area, this watercourse was classified as an intermittent watercourse, with an average bank-full width of 0.83 m. The channel runs from a large hilltop wetland, and into a small fringe wetland at the edge of the Boat Harbour Stabilization Lagoon. No significant salmonid habitat was observed at time of assessment, and this channel likely goes dry at various times throughout the year. Some riffle habitat was observed, but access to this habitat is questionable. Wetted width and depth were considered too small (0.43 m, and 0.04 m respectively) for adult fish. The area with defined channel runs for roughly 100 m before entering a fringe wetland on the edge of the former settling pond in the western section of the project area. No fish were noted during the assessment, and access may be compromised for fish during times of normal and low flow. This watercourse is classified as Type V.

Limiting factors:

- Water Temperature: Lack of depth for reading
- pH: Lack of depth for reading
- Dissolved Oxygen: Lack of depth for reading
- Pool availability: None
- In-Stream cover: Trace-Moderate
- Fines in substrate: 60% (Poor)

WC-11: Found in the west-northwestern section of the Project area, this watercourse has a poorly defined channel and is characterised as an ephemeral stream. Substrate in WC-11 was dominated by fine materials, with very little potential for fish. Average bank-full width of the channel was measured as 1.53 m with no wetted width or depth at time of assessment (dry channel). The day-lighted section of this watercourse ran in a straight pattern, before dissipating and reaching the Boat Harbour Stabilization Lagoon. No water quality parameters were taken at this watercourse due to the lack of water. Habitat connectivity is poor in this channel, which lessens the potential for fish even further. No fish were noted during the assessment. This watercourse is classified as Type V.

Limiting factors:

- Water Temperature: Dry
- pH: Dry
- Dissolved Oxygen: Dry
- Pool availability: Low (Dry Channel)
- In-Stream cover: Trace
- Fines in substrate: 100% (Poor)

WC-12: Found in the north-eastern section of the Project area, this watercourse is classified as an intermittent stream that runs in an irregular meandering pattern. Average bank-full width of this watercourse was measured at 2.25 m, and no wetted width or depth was detected at time of assessment. Substrate in the channel was distributed fairly evenly between fines, gravels and cobble. This watercourse runs through an area with a steep gradient, which contributes to the lack of water found in the channel. Undercut banks and large woody debris were the most apparent forms of in-stream cover in the channel, and this watercourse may be useable habitat for juvenile Brook Trout in times of peak flow throughout the year. No fish were observed at time of assessment, as the channel was dry in its entirety. This watercourse is between Type IV and V, as the channel was mostly dry at time of assessment.

Limiting factors:

- Water Temperature: Dry

- pH: Dry
- Dissolved Oxygen: Dry
- Pool availability: Low (Dry Channel)
- In-Stream cover: Trace-Moderate
- Fines in substrate: 40% (Poor-Moderate)

WC-13: Found in the north-western corner of the Project area, this watercourse is classified as intermittent, but has some small permanent characteristics (it likely goes dry only once or twice per year). Substrate in this watercourse is dominated by fine materials, but small and large gravels were also found in patches throughout the reach. This watercourse flows in a sinuous pattern, with an average bank-full width of 1.58 m. The upstream most section of the assessed reach is found on a hillside with a steep gradient and sudden elevation changes. Once off the hill, the watercourse gradient flattens significantly before entering the Boat Harbour Stabilization Lagoon, and the average wetted depth was measured at 0.09 m. The dominant riparian vegetation was speckled alder (*Alnus incana*). Foraging areas were identified for salmonid species, but no fish were observed at time of assessment. Potential for fish is high compared to most watercourses in the Study Area. This watercourse is classified as Type II.

Limiting factors:

- Water Temperature: 8.53°C (Good)
- pH: 7.77 (Good)
- Dissolved Oxygen: 13.26 mg/L (Good)
- Pool availability: Low
- In-Stream cover: Moderate-Abundant
- Fines in substrate: 60% (Moderate- hard clay with gravel over top)

WC-14: A small ephemeral stream with a day-lighted section running approximately 5 m before disappearing underground once more. Substrate in the day-lighted section was dominated by fine materials, and very little cover for fish species was observed. Average water depth in the assessed section was measured at 0.015 m, and field water quality analysis could not be completed due to lack of depth. Bank-full width in this section was measured as 0.43 m and the channel ran straight in the area that could be assessed. Not likely fish habitat, and no fish were noted during the assessment. This watercourse is classified as Type V.

Limiting factors:

- Water Temperature: Lack of depth for reading
- pH: Lack of depth for reading
- Dissolved Oxygen: Lack of depth for reading
- Pool availability: None
- In-Stream cover: None-Trace
- Fines in substrate: 100% (Poor)

WC-15: Found in the northeastern section of the Project area, this watercourse runs for a short time (~80 m) from the Project edge before entering the Boat Harbour Stabilization Lagoon. This watercourse was classified as intermittent, with an average bank-full width of 1.01 m. Fine materials were the most abundant substrate media, but small and large gravel as well as cobble were found in smaller amounts throughout the assessed reach. No pools were found in the assessment area, and habitat types were mostly run and riffle. Overhanging vegetation was the most abundant form of instream cover, but various other cover types were identified in smaller amounts. Average water depth was measured at 0.04 m at time of assessment, with a wetted-width of 0.38 m. A hung culvert found at the upstream end of the assessed area, and may be a partial barrier to fish passage depending on the amount of flow when traversing is attempted. This watercourse has some potentially useable spawning substrate, but is such a small stream that it is unlikely salmonids may spawn there. The abundance of riffle habitat in this watercourse may indicate possible forage areas for juvenile Brook Trout at times of higher flow. No fish were noted during the assessment. This watercourse falls is classified as Type IV.

Limiting factors:

- Water Temperature: Lack of depth for reading
- pH: Lack of depth for reading
- Dissolved Oxygen: Lack of depth for reading
- Pool availability: Low (poor depth)
- In-Stream cover: Trace- Moderate
- Fines in substrate: 55% (Poor- Moderate)

WC-16: Found in the eastern section of the Project area, this watercourse is classified as an intermittent stream, with an average bank-full width of 0.12 m. This watercourse runs in an irregular meandering pattern, and only passes through the Project area for a short time before entering the Boat Harbour Stabilization Lagoon. Field water quality parameters were considered good for salmonid species, and substrate media was an appropriate mix of fines, gravels, cobble and boulder. Undercut banks were the most abundant form of cover, with various other cover types available in smaller amounts. Surrounding this watercourse is a mature forest made up mostly of white and red pine. A culvert identified at the top of the assessed reach was considered a partial barrier, as the plunge pool may not be adequate for fish in times of low flow. No fish were noted during the assessment, although this habitat may be useable for juvenile and adult Brook Trout in times of higher flow. This watercourse is classified as Type II.

Limiting factors:

- Water Temperature: 13.42^{o}C (Good)
- pH: 7.12 (Good)
- Dissolved Oxygen: 6.62 mg/L (Moderate)
- Pool availability: Low (poor depth, few pool areas noted)
- In-Stream cover: Moderate
- Fines in substrate: 20% (Moderate)

WC-17: Found in the eastern section of the Project area, this watercourse is classified as a small permanent stream, with an average bank-full width of 1.54 m. This watercourse has a well-defined, deep channel that runs mostly through a wetland in the Project area. Average water depth was measured at 0.33 m. The channel experiences braiding and standing water in the wetland section near the entrance to the Boat Harbour Stabilization Lagoon. Substrate in this watercourse was mostly fine materials, which are not ideal for salmonid spawning, but this watercourse may be useful rearing habitat for young fish. Water quality parameters were considered fairly good with the exception of dissolved oxygen, which was considered low (4.44 mg/L). While this watercourse may not be ideal for Atlantic Salmon, it could potentially host species such as Brook Trout, Brown Bullhead (*Ameiurus nebulosus*), American Eel (*Anguilla rostrata*), or White Sucker (*Catostomus commersonii*). No fish were noted during the assessment. This watercourse is classified as Type IV.

Limiting factors:

- Water Temperature: 17.09^{o}C (Moderate)
- pH: 6.84 (Good)
- Dissolved Oxygen: 4.44 mg/L (Poor)
- Pool availability: Moderate-High
- In-Stream cover: Moderate
- Fines in substrate: 100% (Poor)

WC-18: Found in the eastern portion of the Project area, this watercourse is classified as an intermittent stream running in an irregular meandering pattern with an average bank-full width of 0.98 m. Water quality parameters were considered adequate for salmonid species with the exception of dissolved oxygen which was low at time of assessment (3.52 mg/L). In-stream cover was available in various forms along the assessed reach with the most abundant form of cover identified as undercut banks. Average water depth in the assessed area was calculated as 0.13 m. No velocity was detected during the assessment, which may be a contributing factor to the low dissolved oxygen encountered. Temporary barriers were noted in the form of dry sections in various areas throughout the assessed reach. Woody debris jams were also observed, and no fish were identified at time of assessment. Brook Trout may use this stream at peak times throughout the year, but Atlantic Salmon would likely search out habitat elsewhere. This watercourse is classified as Type IV.

Limiting factors:

- Water Temperature: 14.87°C (Good)
- pH: 6.59 (Good)
- Dissolved Oxygen: 3.52 mg/L (Poor)
- Pool availability: Moderate (Mostly run habitat)
- In-Stream cover: Moderate-Abundant
- Fines in substrate: 80% (Poor)

WC-19: Found in the south-eastern section of the Project area, this watercourse is classified as an intermittent stream, with an average bank-full width of 1.52 m. This watercourse runs in an irregular meandering pattern before entering a small wetland at the edge of the Boat Harbour Stabilization Lagoon. The watercourse is made up of a series of step-pools, as the gradient in the area is considered fairly steep. Water quality parameters taken at time of assessment were considered adequate for salmonid species, and cover was readily available in various forms for fish species. Average depth in the assessed area was measured at 0.17 m. This watercourse was bordered by mature forest on both sides, and a good mix of aquatic habitat types were noted during the assessment. A gentle constant flow (0.05 m/sec) was observed, and various potential foraging and spawning areas were noted for juvenile and adult Brook Trout. No fish were observed at time of assessment. This watercourse is classified as Type II.

Limiting factors:

- Water Temperature: 10.95°C (Good)
- pH: 5.64 (Moderate-Good)
- Dissolved Oxygen: 6.61 mg/L (Moderate)
- Pool availability: Moderate-High
- In-Stream cover: Moderate-Abundant
- Fines in substrate: 35% (Moderate)

1.4.2 WATER QUALITY

A total of thirteen (13) watercourses were assessed, as six (6) of the identified watercourses were dry. The results of the water quality assessment is shown in Table 2. Water temperatures at the BHETF site were within range for salmonid species, with an overall average temperature of 13.6°C, and extremes of 8.5°C at WC-13, and 18.5°C at WC-9 respectively. Total dissolved solids were measured in grams per liter (g/L), with an overall average of 0.0779 g/L, and extremes of 0.049 g/L at WC-3, and 0.128 g/L at WC-7. pH readings are considered to be fairly neutral throughout the site, as the calculated average pH of the combined watercourses was measured at 6.94, and the lowest pH reading identified as 5.64 at WC-19, which is still within the accepted tolerance range for Brook Trout (4.0 to 9.5), but outside of the optimal pH range (6.5 to 8.0). Specific conductance readings remained relatively stable throughout the assessed watercourses, with a combined average of 119.385 µS/cm, and extremes of 75 µS/cm at WC-3, and 196 µS/cm at WC-7 respectively which is considered good for salmonids.

Dissolved oxygen varied wildly from stream to stream at BHETF sites, this is in part due to the varied topography and canopy cover that exists on site. Watercourses in flat, open sections of the site may not have as high a sustained velocity as some watercourses found on hillslopes. Exposure to sunlight can influence the growth of aquatic vegetation and algae, which can in turn reduce the levels of dissolved oxygen in watercourses, or increase the probability of eutrophication. The reduced levels of dissolved oxgen are most likely caused by a high biological oxygen demand (BOD) due to decaying vegetation in slow moving water.

Stream morphology and habitat types play a role in dissolved oxygen as well. Watercourses with a high percentage of run habitat with low velocity tended to have lower levels of dissolved oxygen, while watercourses with high percentages of riffle habitat, rocky substrate, and swift, constant velocity tended to have higher levels of dissolved oxygen when measured in-field. While habitat features such as lakes or ponds can have high levels of dissolved oxygen without significant constant velocity, the sheer lack of deep water at the watercourses within the Study Area may have aided in the lack of dissolved oxygen found on site, as there is less water in these channels to draw oxygen from during biological processes before it becomes an issue. The YSI field unit used by the assessors is set up for in-stream readings, therefore pH and dissolved oxygen readings may show slightly different results when readings are taken in water with less than roughly 0.3 m/sec.

Table 2: Water Quality Results

	PARAMETER				
SITE CODE	**WATER TEMP (°C)**	**TDS (g/L)**	**pH**	**SPECIFIC CONDUCTIVITY (µS/cm)**	**DISSOLVED OXYGEN (mg/L)**
CEQG[1]	<24.0*	0.15-0.5*	6.5-9.0	150-500*	9.5 early life stages, 6.5 other life stages
WC-1	9.37	0.099	6.94	153	12.21
WC-2	12.59	0.051	6.83	78	2.17
WC-2A	15.71	0.065	6.99	100	3.65
WC-3	13.42	0.049	7.12	75	6.62
WC-6	15.23	0.099	7.00	153	8.86
WC-7	14.01	0.128	7.22	196	10.92
WC-8	13.60	0.091	7.08	138	7.00
WC-9	18.57	0.103	6.75	156	3.98
WC-13	8.53	0.058	7.77	89	13.26
WC-16	13.22	0.057	7.52	88	11.29
WC-17	17.09	0.093	6.84	142	4.44
WC-18	14.87	0.054	6.59	83	3.52
WC-19	10.95	0.066	5.64	101	6.61
Average	**13.628**	**0.0779**	**6.945**	**119.385**	**7.272**

Notes:
CEQG[1] – Canadian Environmental Quality Guidelines
*- Not CEQG, but accepted range for salmonid species (Raleigh, 1982)
n/a – not applicable

1.4.3 AQUATIC ECOSYSTEM CONDITION

A total of six (6) watercourses were included in the benthic macro-invertebrate assessment due to their substrate makeup, channel accessability, and flow (see Figure 3, Appendix A). The order *Diptera* was far and away the most abundant found at the BHETF sampling sites, this order made up 68.3% of all organisms collected between all samples. *Chronomidae* was by far the most abundant family of species across all samples, and this family made up 81.5 % of the order *Diptera*. The *Chironomidae* family of organisms thrives in areas with poor, moderate, or good water quality. The low levels of EPT family organisms may be an indicator of poor water quality throughout the watercourses on site.

The following is a quick synopsis of each benthic invertebrate sample taken at the Boat Harbour Effluent Treatment Facility.

WC-1: 323 individuals were identified across 23 taxa. The most abundant group of organisms found at sample site WC-1 was the order *Diptera*, which consisted of 164 individuals (50.4% of total organisms) across 4 families. This site had the highest percentage of EPT species of all sites sampled at boat harbour, with 29.4%.

WC-7: 317 individuals were identified across 26 taxa. The most abundant group of organisms found at sample site WC-7 was the order *Diptera*, which consisted of 266 individuals (83.9% of total organisms) across 7 families. This site had the second-lowest percentage of EPT species of all sites sampled at Boat Harbour, with 5.3%.

WC-9: 310 individuals were identified across 19 taxa. The most abundant group of organisms found at sample site WC-9 was the order *Diptera*, which consisted of 187 individuals (60.3% of total organisms) across 4 families. This site had the third lowest percentage of EPT species of all sites sampled, with 9.67%.

WC-13: 329 individuals were identified across 16 taxa. The most abundant group of organisms found at sample site WC-13 was the order *Diptera*, which consisted of 296 individuals (89.9% of total organisms) across 5 families. This site had the lowest percentage of EPT species of all sites sampled at boat harbour, with 3.3%.

WC-15: 317 individuals were identified across 23 taxa. The most abundant group of organisms found at sample site WC-15 was the order *Diptera*, which consisted of 150 individuals (47.3% of total organisms) across 6 families. This site had the second highest percentage of EPT species of all sites sampled, with 17.03%.

WC-16: 319 individuals were identified across 21 taxa. The most abundant group of organisms found at sample site WC-16 was the order *Diptera*, which consisted of 246 individuals (77.1% of total organisms) across 8 families. This site had the third highest percentage of EPT species of all sites sampled, with 10.3%.

Order and Family Identification, Total Abundance and Taxon Richness as well as the genus level identification results for sample site WC-9 are presented in Appendix D. The EPT Ratio measures are presented in Table 3.

Table 3: EPT Ratio Measures and Benthic Sampling Locations

BENTHIC RESULTS	WC-1	WC-7	WC-13	WC-15	WC-16	WC-9
Total individuals	323	317	329	317	319	310
EPHEMEROPTERA	54	3	0	3	1	2
PLECOPTERA	14	1	5	20	17	0
TRICHOPTERA	27	13	6	31	15	28
EPT TOTAL	95	17	11	54	33	30
% EPT	**29.4%**	**5.3%**	**3.3%**	**17.03%**	**10.3%**	**9.7%**

2 MARINE ENVIRONMENT

2.1 DESKTOP REVIEW

Previous reports have outlined several attributes pertaining to the physical marine environment found near the BHETF. A brief description compiled from previous reports of the Northumberland Strait and Pictou Road are detailed below. Note that "Pictou Road" in the context of this report refers to a section of marine environment found in the Northumberland Strait directly adjacent the BHETF, and not a road.

The environmental conditions of the Easter River of Pictou are described in the "Boat Harbour Remediation Planning and Design Project – Baseline Conditions Report – Benthic Community – Pipeline Marine Corridor" report (WSP, 2018).

2.2 HABITAT DESCRIPTIONS

2.2.1 THE NORTHUMBERLAND STRAIT

The Northumberland Strait separates Prince Edward Island from Nova Scotia and New Brunswick (see Figure 4, Appendix A). The Strait is an arm of the larger Gulf of St. Lawrence, and the minimum width across the strait is approximated at roughly 12 kilometres (km). Maximum depth of the strait is approximated at roughly 50 m. The Northumberland Strait is considered relatively sheltered with funnel shaped openings on both the New Brunswick and Nova Scotia ends. The length of the strait is approximated at 330 km from end to end and the tidal range for the strait is roughly 3.0 m. Temperatures fluctuate from winter to summer, as surface waters tend to freeze in the winter months, but it is not uncommon to measure a 20°C water temperature in summer months (Calder, 2003). Substrate composition in the Northumberland Strait varies depending on where samples are taken. Some general descriptions of the different substrates encountered in the Northumberland Strait as outlined in the Calder, 2003 report include:

- Boulders and sand in the North Western section of the strait
- Gravel, sand and shells in the West-Central section of the strait
- Mud in the East-Central section of the strait
- Mud or boulder in the Northeastern section of the strait

Table 4 lists several fish and shellfish species are believed to inhabit the Northumberland Strait.

Table 4: List of Potential Fish and Shellfilsh Species in Northumberland Strait

COMMON NAME	SCIENTIFIC NAME
Atlantic Salmon	*Salmo salar*
Brook Trout	*Salvelinus fontinalis*
Atlantic Herring	*Clupea harengus*
Winter Flounder	*Pseudopleuronectes americanus*
Capelin	*Mallotus villosus*
Shortfin Squid	*Illex spp.*
Atlantic Mackerel	*Scomber scombrus*
Rainbow Smelt	*Osmerus mordax*
Atlantic tomcod	*Microgadus tomcod*

COMMON NAME	SCIENTIFIC NAME
Cunner	*Tautogolabrus adspersus*
Atlantic Cod	*Gadus morhua*
American Eel	*Anguilla rostrata*
Striped Bass	*Morone saxatilis*
Spiny Dogfish	*Squalus acanthias*
Winter Skate	*Leucoraja ocellata*
Haddock	*Melanogrammus aeglefinus*
Atlantic Pollock	*Pollachius virens*
Mink Whale	*Balaenoptera acutorostrata*
Pilot Whale	*Globicephala melas*
Yellowtail Flounder	*Pleuronectes ferruginea*
American Plaice	*Hippoglossoides platessoides*
Atlantic Halibut	*Hippoglossus hippoglossus*
Witch Flounder	*Glyptocephalus cynoglossus*
Atlantic Butterfish	*Peprilus triacanthus*
Atlantic Bluefin Tuna	*Thunnus thynnus*
American Shad	*Alosa sapidissima*
Blueback Herring	*Alosa aestivalis*
Alewife	*Alosa pseudoharengus*
Longhorn Sculpin	*Myoxocephalus octodecemspinosus*
Atlantic Saury	*Scomberesox saurus*
Windowpane flounder	*Scophthalmus aquosus*
Lumpfish	*Cyclopterus lumpus*
Ocean Pout	*Zoarces americanus*
Sea Raven	*Hemitripterus americanus*
Fourbeard Rockling	*Enchelyopus cimbrius*
Snakeblenny	*Lumpenus lampretaeformis*
Three-spined Stickleback	*Gasterosteus aculeatus*
Wrymouth	*Cryptacanthodes maculatus*

Several endangered species are believed to inhabit the Northumberland Strait, in some cases this is year round, and in others, a stop in their migratory journey. The Lady Crab (*Ovalipes ocellatus*) for instance, is believed to live only in the Northumberland Strait, with the exception of a small population found in the Minas Basin (Rondeau 2016). While this species of crab is considered endangered by the DFO, COSEWIC has never assessed the species (Rondeau 2016). The white hake (*Urophycis tenuis*) is a fish species listed as "endangered" by COSEWIC in November, 2013, is known to spawn in the eastern portion of the Northumberland Strait (Rondeau, 2016). Table 5 identifies several species assessed by COSEWIC that are believed to inhabit the Northumberland Strait.

Table 5: COSEWIC Assessed Species

COMMON NAME	SCIENTIFIC NAME	STATUS	ASSESSMENT YEAR
American Eel	*Anguilla Rostrata*	Threatened	2012
American Plaice	*Hippoglossoides platessoides*	Threatened	2009

COMMON NAME	SCIENTIFIC NAME	STATUS	ASSESSMENT YEAR
Atlantic Cod	*Gadus morhua*	Endangered	2010
Atlantic Salmon	*Salmo salar*	Special Concern	2010
Bluefin Tuna	*Thunnus thynnus*	Endangered	2011
Spiny Dogfish	*Squalus acanthias*	Special Concern	2010
Striped Bass	*Morone saxatilis*	Special Concern	2012
Thorny Skate	*Amblyraja radiata*	Special Concern	2012
White Hake	*Urophycis tenuis*	Endangered	2013
White Shark*	*Carcharodon carcharias*	SARA-Endangered Atlantic population	2006
Winter Skate	*Leucoraja ocellata*	Endangered	2005
*White Shark have been recorded in Northumberland Strait, but no resident populations exist.			

The Northumberland Strait is considered an important feeding and foraging area for several fish, invertebrate, and marine mammal species. Table 6 lists the invertebrate species commonly found in the Northumberland Strait.

Table 6: List of Invertebrate Species in Northumberland Strait

COMMON NAME	SCIENTIFIC NAME
Snow Crab	*Chionoecetes opilio*
Sea Scallop	*Placopecten magellanicus*
Atlantic Rock Crab	*Cancer irroratus*
Lady Crab	*Ovalipes ocellatus*
Atlantic Lobster	*Homarus americanus*
Toad Crab	*Hyas araneus*
Mud Crab	*Dyspanopeus sayi*
Polar Sea Star	*Leptasterias polaris*
Brittle Star	*Ophiuroidea*
Blood Star	*Henricia sp.*
Asterias sp.	*Asterias sp.*
Mussels	*Mytilus edulis, Musculus niger, Modiolus modiolus*
Ocean Quahaug	*Arctica islandica*
Purple Sunstar	*Solaster endeca*
Sand Dollars	*Echinarachnius parma*

2.2.2 PICTOU ROAD

Pictou Road is a smaller sub-section of the Northumberland Strait, and is near the Boat Harbour Project (see Figure 4). Substrate in this area is sand, and extensive kelp beds do not form due to extreme fluctuations of water temperature, the erosion caused by sea ice, and generally turbid water (JWEL, 2005). Some sheltered areas and small coves were assessed for biodiversity, and seaweed species such as Rockweed (*Fucus serratus*), and Red Seaweed (*Furcellaria fastigiata*) were noted (JWEL, 2005).

Surveys at the mouth of Boat Harbour showed presence of Softshell Clam (*Mya arenaria*), Oysters (*Crassostrea virginica*), Blue Mussels (*Mytilus edilus*), Razor Clams (*Ensis directus*), Periwinkles (*Littorina littorea*), Sand Dollar (*Echinariachaius parma*), as well as seaweed species such as Water Gut (*Entermorpha intestinalis*) and Sea Lettuce (*Ulva lactuca*) (JWEL, 2005). Visual surveys of the substrate found near the mouth of Boat Harbour showed no significant buildup of sediment caused by effluent discharge, and that wavy sand covered the bottom.

Commercial fisheries in the Pictou Road area of the Northumberland Strait consist mostly of Atlantic Lobster, Atlantic Herring, Rock Crab, and American Eel. Historically, Atlantic Cod, and Redfish were fished in this area, but less so in recent years.

A comprehensive list of species identified in the Pictou Road area of the Northumberland Strait was compiled by Stantec in 2004 and is provided below (Table 7).

Table 7: List of Fish and Shellfish Species in Pictou Road (Northumberland Strait)

COMMON NAME	SCIENTIFIC NAME
Atlantic Tomcod	*Microgadus tomcod*
White Hake	*Urophycis tenuis*
American Eel	*Anguilla rostrata*
Alewife	*Alosa pseudoharengus*
Atlantic Herring	*Clupea harengus*
Winter Flounder	*Pseudopleuronectes americanus*
(Rainbow) Smelt	*Osmerus mordax*
Barndoor Skate	*Raja laevis*
American Little Skate	*Raja erinacea*
Smooth Skate	*Raja senta*
Thorny Skate	*Raja radiata*
Winter Skate	*Raja ocellata*
Atlantic Salmon	*Salmo salar*
Atlantic Mackerel	*Scomber scombrus*
Brook Trout	*Salvelinus fontinalis*
Atlantic Sea Raven	*Hemitriterus americanus*
Eelpout	*Lycodes* sp.
Blackspotted Stickleback	*Gasterosteus wheatlandi*
Ocean Pout	*Macrozoarces americanus*
Three-spined Stickleback	*Gasterosteus aculeatus*
Windowpane	*Scophthalmus aquosus*
Four-spine Stickleback	*Apeltes quadracus*
Longhorn Sculpin	*Myoxocephalus octodecemspinosus*
Nine-spine Stickleback	*Pungitius pungitius*
Striped Bass	*Morone saxatilis*
Atlantic Silverside	*Menidia menidia*
Cunner	*Tautogolabrus adspersus*
Mummichog	*Fundulus heteroclitus*

3 SUMMARY OF FINDINGS

The majority of watercourses at the BHETF site lack the appropriate physical habitat features to sustain populations of adult Brook Trout. A select few streams may have adequate spawning or rearing habitat for portions of the year, but no stream on site appeared adequate for year-round adult Brook Trout habitat. Most watercourses on site had a substrate that was dominated by fine materials, which is not preferred for Brook Trout spawning habitat, as fine materials may settle on top of eggs, depriving them of oxygen. Juvenile Brook Trout may be able to thrive in some of the watercourses found at the BHETF site, however none have been observed over the course of this assessment or previous assessments since commissioning of the site. Overwintering and low flow habitat was mostly absent, with very few large accessible pools noted, and the lack of depth in most of the assessed watercourses. It is hypothesized that adult salmonids could potentially use the stabilization lagoon as overwintering habitat, however the poor quality of water in this area may deter species from utilizing this habitat. It is difficult to picture salmonid species succeeding in winter conditions throughout the small tributary streams of the Study Area, as most were extremely shallow and quite narrow at time of assessment. Atlantic Salmon require even more stringent water quality and watercourse morphology attributes than that of Brook Trout, and spawning habitat relies heavier on substrate makeup, and a lack of fine materials which is not consistent with the aquatic habitat found within the Study Area.

With respect to the benthic macro-invertebrate assessment, data concludes that watercourses located within the Study Area have relatively low EPT ratios. Watercourses with the highest EPT ratios (WC-1, WC-15, and WC-16) were also the watercourses with the lowest levels of fine materials in the substrate. The *Chironomidae* family of organisms were the most abundant throughout entirety of the samples, which is to be expected as this family thrives in areas with poor, moderate, or good water quality. The low levels of EPT family organisms may be an indicator of poor water quality throughout the watercourses on site.

Within the marine environment, various marine species, including fish and shellfish, depend on the diverse habitat the Northumberland Strait provides. The Northumberland Strait is considered to be an important feeding and foraging area within the Atlantic Ocean. Of particular note, is the sandy substrate of the Pictou Road section of the Northumberland Strait which provides significant foraging habitat for some marine species with at least eight species at risk having been identified in that portion of the strait. Due to the high productivity of the area, several commercial fisheries have developed. The Pictou Road section of the Northumberland Strait is considered to be a vital part of the local commercial fishing community, with several species holding commercial or intrinsic value.

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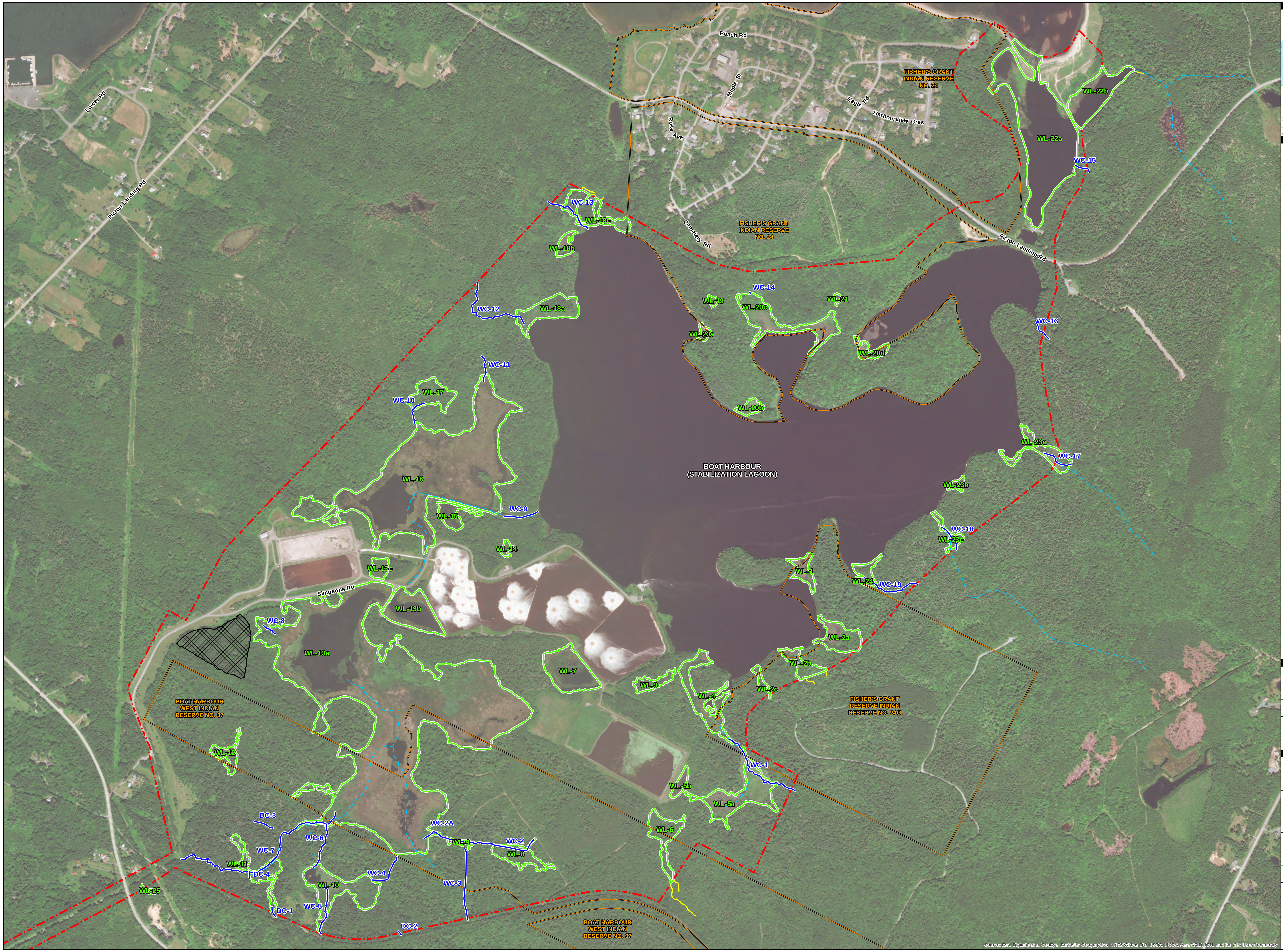
APPENDIX

A FIGURES



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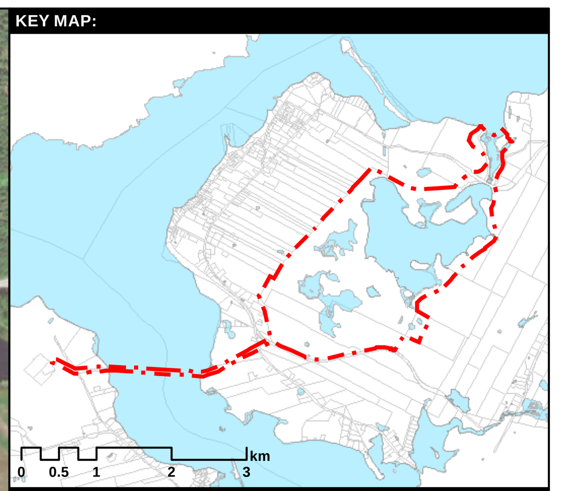


LEGEND:

- FIELD DELINEATED WATERCOURSE (WSP, 2017) (WC - watercourse; DC - drainage channel)
- WATERCOURSE (GHD)
- FIELD DELINEATED WETLAND BOUNDARY (WSP, 2017)
- FIRST NATIONS TERRITORY BOUNDARY
- FIELD DELINEATED WETLAND BOUNDARY (WSP, 2017) (Delineation extends beyond Study Area Boundary)
- APPROXIMATE LOCATION OF CLEARED AREA
- BOAT HARBOUR STUDY AREA BOUNDARY

N W E S

PROJECT:

PROJECT:

BOAT HARBOUR REMEDIATION, PLANNING AND DESIGN

PROJECT NO.: **171-10478**

CLIENT: GHD

FIGURE:

TITLE:

DELINEATED WATERCOURSES & WETLANDS

FIGURE NO.:	REVISION NO.:
1	1

SCALE: 0 50 100 200 300 400 Metres

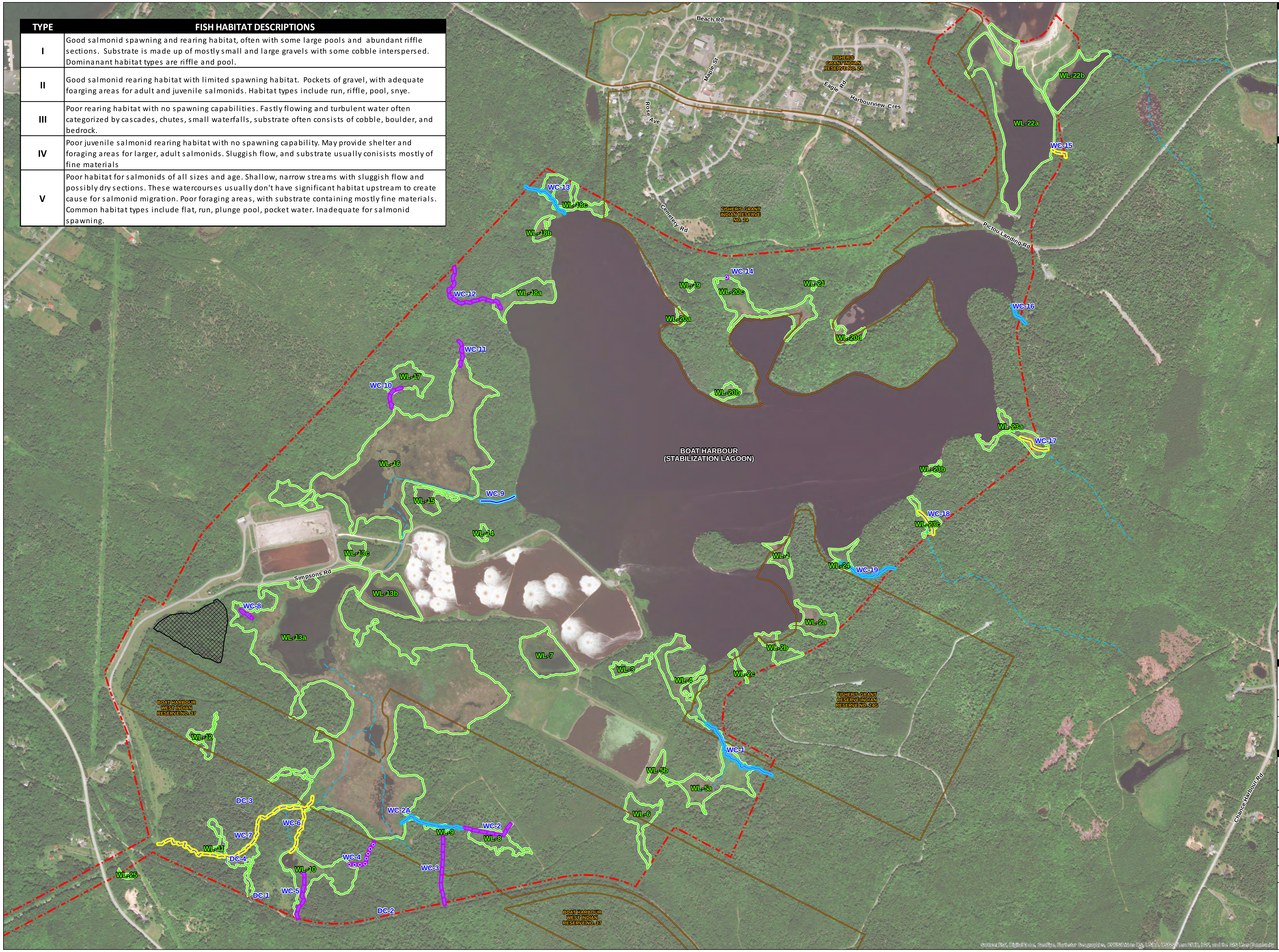
1:5,700

DATUM:	PROJECTION:
NAD 83 CSRS	UTM ZONE 20 NORTH
DRAWN BY: T. MOREHOUSE	CHECKED BY: C. LAFLAMME
CREATED DATE: (YYYY-MM-DD) 2018-02-09	REVISION DATE: (YYYY-MM-DD) 2018/09/13

WSP Canada Inc.
1 Spectacle Lake Drive,
Dartmouth, Nova Scotia
www.wsp.com

Path: S:\GIS\2_PROJECTS\2017\171_10478_GHD_BoatHarbour_NS_\8_MXD\20180913_171_10478_FIG1_Wetland_Watercourse_FISHrpt_R1.mxd

TYPE	FISH HABITAT DESCRIPTIONS
I	Good salmonid spawning and rearing habitat, often with some large pools and abundant riffle sections. Substrate is made up of mostly small and large gravels with some cobble interspersed. Dominanant habitat types are riffle and pool.
II	Good salmonid rearing habitat with limited spawning habitat. Pockets of gravel, with adequate foarging areas for adult and juvenile salmonids. Habitat types include run, riffle, pool, snye.
III	Poor rearing habitat with no spawning capabilities. Fastly flowing and turbulent water often categorized by cascades, chutes, small waterfalls, substrate often consists of cobble, boulder, and bedrock.
IV	Poor juvenile salmonid rearing habitat with no spawning capability. May provide shelter and foraging areas for larger, adult salmonids. Sluggish flow, and substrate usually conisists mostly of fine materials
V	Poor habitat for salmonids of all sizes and age. Shallow, narrow streams with sluggish flow and possibly dry sections. These watercourses usually don't have significant habitat upstream to create cause for salmonid migration. Poor foraging areas, with substrate containing mostly fine materials. Common habitat types include flat, run, plunge pool, pocket water. Inadequate for salmonid spawning.



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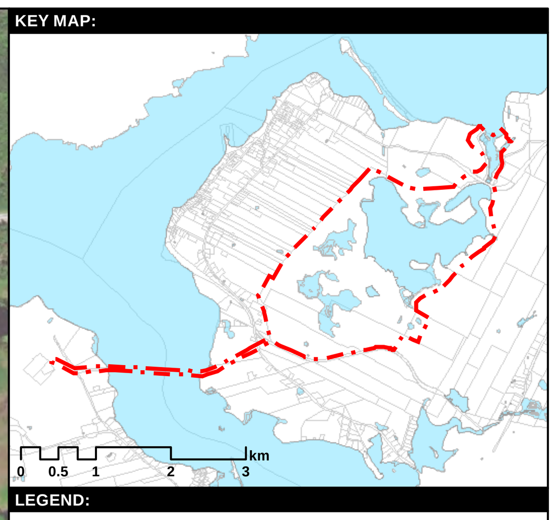

LEGEND:

WATERCOURSE CLASSIFICATION

- Large Permanent
- Small Permanent
- Intermittent
- Ephemeral
- Drainage Channel

FIELD DELINEATED WATERCOURSE LOCATIONS (WSP, 2017) (WC - watercourse; DC - drainage channel)

FISH HABITAT TYPE

- II
- IV
- V

- WATERCOURSE (GHD)
- FIELD DELINEATED WETLAND BOUNDARY (WSP, 2017)
- FIRST NATIONS TERRITORY BOUNDARY
- APPROXIMATE LOCATION OF CLEARED AREA
- BOAT HARBOUR STUDY AREA BOUNDARY

N
W E
S

PROJECT:

PROJECT:

BOAT HARBOUR REMEDIATION, PLANNING AND DESIGN

PROJECT NO.: **171-10478**

CLIENT: GHD

FIGURE:

TITLE:

WATERCOURSE POTENTIAL FOR FISH HABITAT

FIGURE NO.: 2	REVISION NO.: 1
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DRAWN BY: T. MOREHOUSE	CHECKED BY: C. LAFLAMME
CREATED DATE: (YYYY-MM-DD) 2018-02-09	REVISION DATE: (YYYY-MM-DD) 2018/09/14

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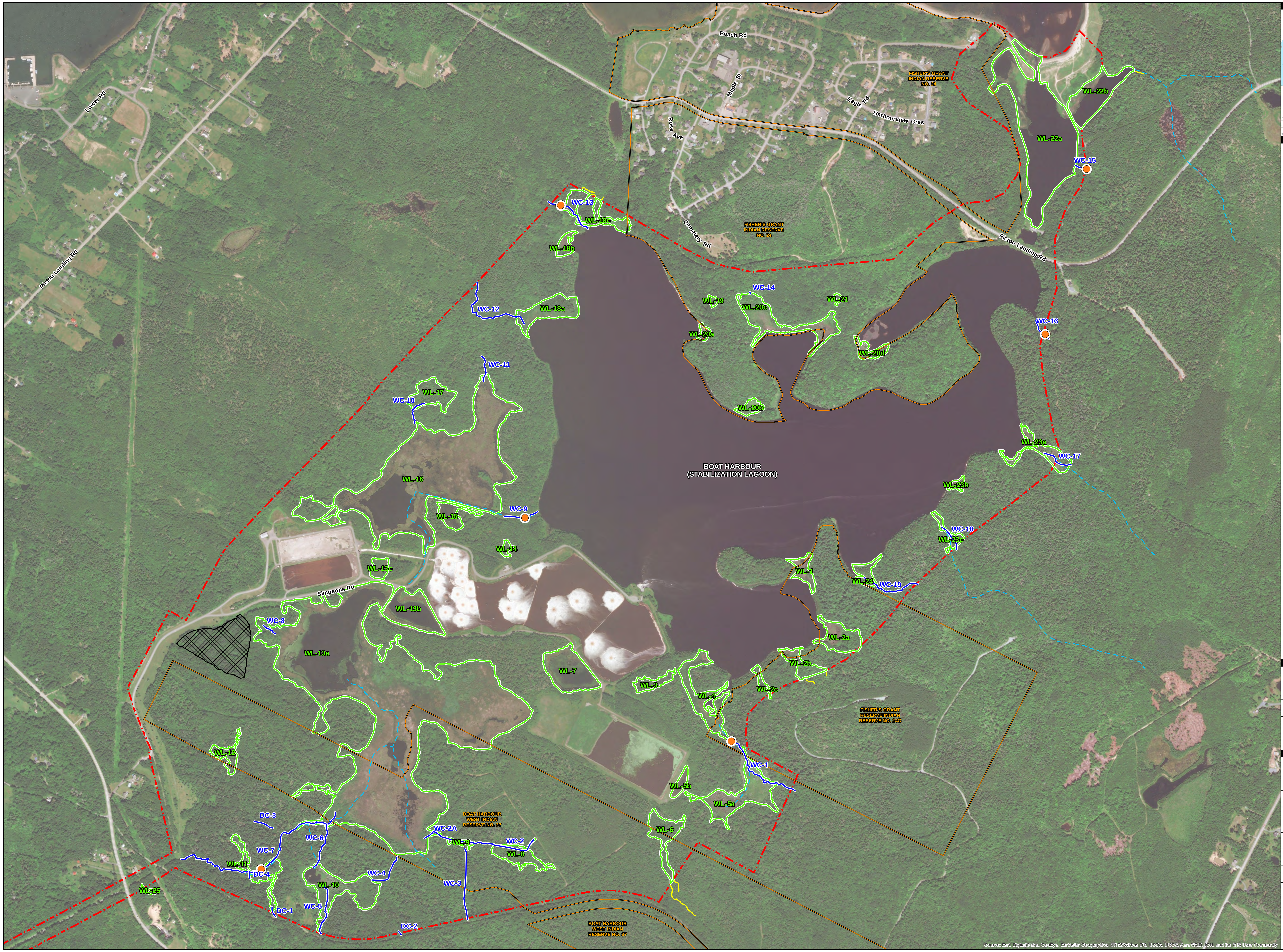
Path: S:\GIS\2_PROJECTS\2017\171_10478_GHD_BoatHarbour_NS_\8_MXD\20180913_171_10478_FIG2_FishHabitatType_FISHrpt_R1.mxd



KEY MAP:

LEGEND:

- BENTHICS SAMPLING LOCATIONS
- FIELD DELINEATED WATERCOURSE (WSP, 2017) (WC - watercourse; DC - drainage channel)
- WATERCOURSE (GHD)
- FIELD DELINEATED WETLAND BOUNDARY (WSP, 2017)
- FIRST NATIONS TERRITORY BOUNDARY
- FIELD DELINEATED WETLAND BOUNDARY (WSP, 2017) (Delineation extends beyond Study Area Boundary)
- APPROXIMATE LOCATION OF CLEARED AREA
- BOAT HARBOUR STUDY AREA BOUNDARY

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PROJECT:

PROJECT: **BOAT HARBOUR REMEDIATION, PLANNING AND DESIGN**

PROJECT NO.: **171-10478**

CLIENT: GHD

FIGURE:

TITLE: **BENTHIC SAMPLING LOCATIONS**

FIGURE NO.: 3	REVISION NO.: 1
SCALE: 0 50 100 200 300 400 Metres 1:5,700	
DATUM: NAD 83 CSRS	PROJECTION: UTM ZONE 20 NORTH
DRAWN BY: T. MOREHOUSE	CHECKED BY: C. LAFLAMME
CREATED DATE: (YYYY-MM-DD) 2018-02-09	REVISION DATE: (YYYY-MM-DD) 2018/09/13

WSP Canada Inc.
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Dartmouth, Nova Scotia
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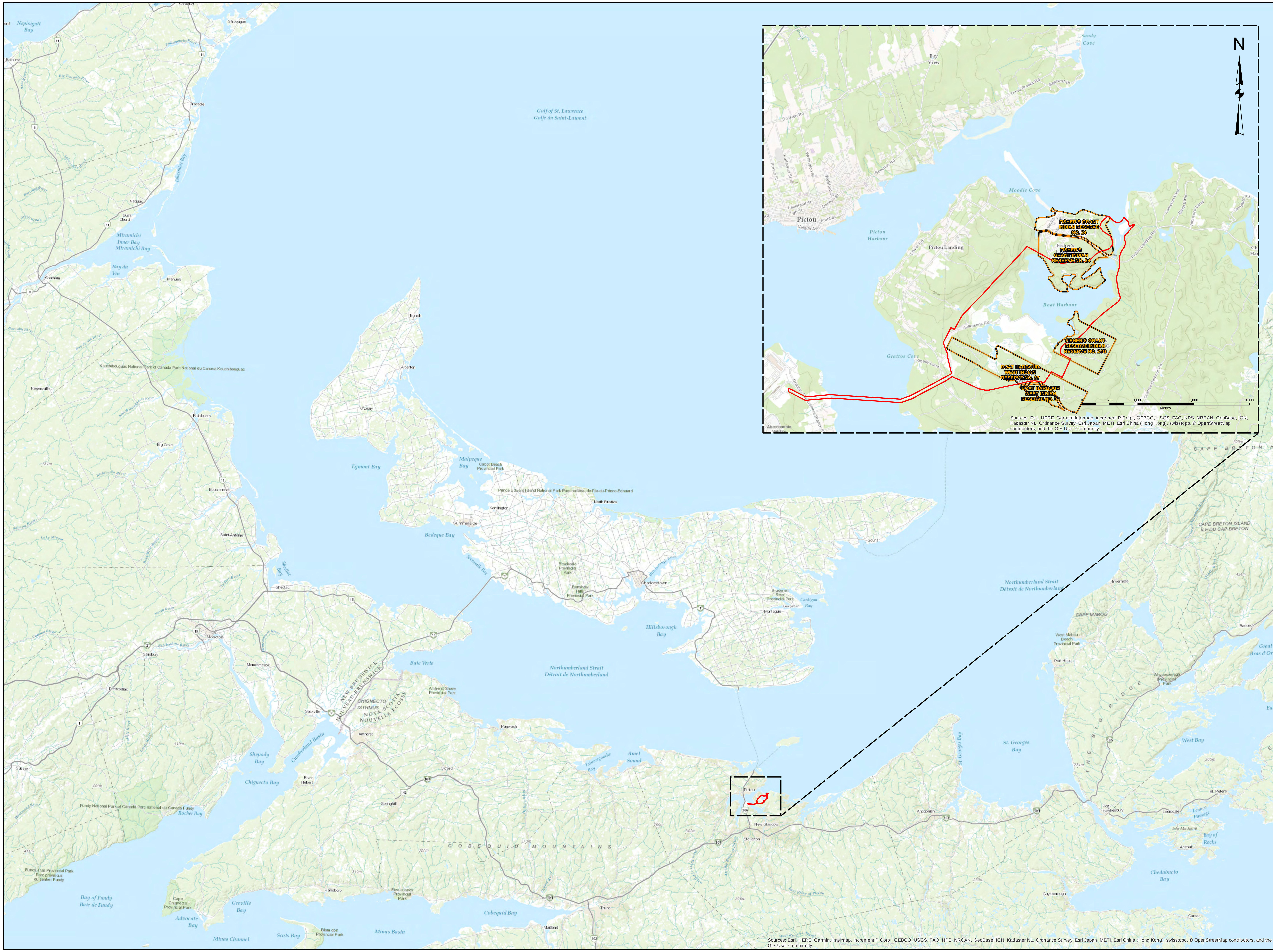
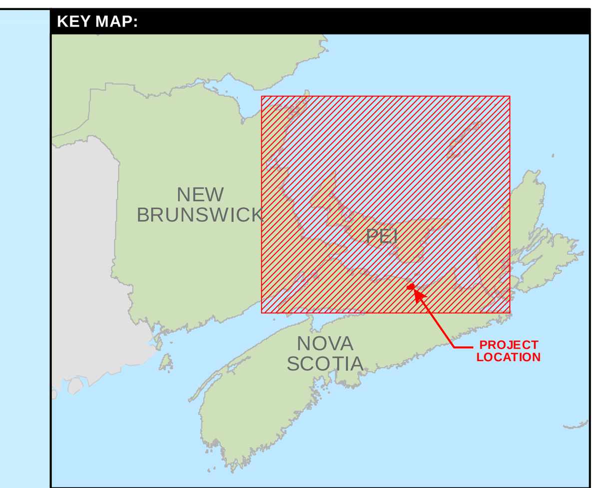
Path: S:\GIS\2_PROJECTS\2017\171_10478_GHD_BoatHarbour_NS_\8_MXD\20180913_171_10478_FIG3_Benthics_FISHrpt_R1.mxd



Path: S:\GIS\2_PROJECTS\2017\171_10478_GHD_BoatHarbour_NS_\8_MXD\20180913_171_10478_FIG4_MarineEnvironment_FISHtpt_R1.mxd

KEY MAP:



LEGEND:

FIRST NATIONS TERRITORY BOUNDARY

BOAT HARBOUR STUDY AREA BOUNDARY

N W E S

PROJECT:

PROJECT: BOAT HARBOUR REMEDIATION, PLANNING AND DESIGN

PROJECT NO.: 171-10478

CLIENT:

FIGURE:

TITLE: MARINE ENVIRONMENT

FIGURE NO.: 4	REVISION NO.: 1

SCALE: 0 5 10 20 30 Kilometres
1:500,000

DATUM: NAD 83 CSRS	PROJECTION: UTM ZONE 20 NORTH
DRAWN BY: T. MOREHOUSE	CHECKED BY: C. LAFLAMME
CREATED DATE: (YYYY-MM-DD) 2018-02-09	REVISION DATE: (YYYY-MM-DD) 2018/09/13

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APPENDIX

B

WATERCOURSE FIELD SHEETS

Site I.D.	WC-1
Assessors	BL, AF
Date (d/m/y)	30/08/2017
Coordinates (UTM)	5055281.02 N, 527079.19 E
Weather	Clear, 15°C
Recent precipitation?	No

Watercourse Type	
Small Permanent (2-5m)	
Stream Morphology	
Sinuous	
Left Bank Type	**Right Bank Type**
Sloped	Sloped
Undercut	Undercut

Transect Measurements							
Transect	Coordinates (UTM)	Feature Type	Bank-full Width (m)	Wetted Width (m)	Wetted Depth (m)	Embeddedness (%)	Bank Height (m)
T1	5055281.02 N, 527079.19 E	Riffle	2.27	0.78	0.05	25	0.30
T2	5055768.60 N, 527094.72 E	Run	1.93	1.50	0.12	25	0.29
T3	5055763.60 N, 527110.11 E	Riffle	2.95	2.21	0.09	0	0.29
T4	5055753.99 N, 527112.09 E	Pool	2.94	2.26	0.17	50	0.24
T5	5055730.15 N, 527129.79	Flat	3.08	1.45	0.16	100	0.16
Average:		**n/a**	**2.63**	**1.64**	**0.12**	**n/a**	**0.26**

Water Quality	
Temp °C	9.37
pH	6.94
D.O (mg/l)	12.21
D.O (%)	106.4
TDS	0.099
Sp. Cond (µS/cm)	153
Salinity	0.07
Velocity m/sec	0.07

Riparian Vegetation	
Left Bank	Right Bank
Shrub	Shrub
Mature Forest	Mature Forest
Barriers Observed?	
Yes, Partial	
Fish Observed?	
Yes, Species Unknown	

Habitat Suitability Rationale			
Spawning	Rearing	Overwintering	Overall
Poor-moderate: Watercourse has little riffle habitat, but had a good mix of media sizes in the substrate. Water velocity was quite low at time of assessment.	Poor-Moderate: some cover is available to juvenile fish, however much of this cover would not be usable for adult fish. Foraging areas were infrequent in the assessed area. Fish were observed but not identified.	Poor: lack of areas with presistent depth, it is assumed that most or all of this watercourse will freeze in winter months.	Poor: Some small fish were observed, but the assessed area runs between two large wetlands, with slow flow and an abundance of fine materials. Presistent sunlight entering the watercourse may influence water temperature.

Substrate (%)	(%)
Fines (<0.5cm)	25
Small Gravel (0.5-3cm)	15
Large Gravel (3.1-6.4cm)	25
Cobble (6.4-25.6cm)	30
Boulder (25.7+cm)	0
Bedrock	0

In-Stream Cover	
Small Woody Debris	Trace
Large Woody Debris	Trace
Undercut Banks	Trace-Moderate
Overhanging Vegetation	Trace
In-Stream Boulder	Trace
Aquatic Vegetation	Trace

Vegetation Identified

Impatiens Capensis, Carrex sp, Solidago Canadensis, Alnus Incana, Acer Rubrum, Picea Rubens, Abies Balsamea, Maianthemum Canadense, Tussilago Farfara

Notes

Beaver activity appears to be present in the south section of the assessed reach near transect 5. An Atv bridge is also present, however it doesn't seem to have a pronounced effect on the aquatic habitat in the area. A large wetland in the upstream section of the watercourse may influence water temperature as the watercourse in this section is exposed to full sunlight, with low water velocity.

Site I.D.	WC-2	Watercourse Type	
Assessors	BL, AF	Intermittent (<2m)	
Date (d/m/y)	30/08/2017	Stream Morphology	
Coordinates (UTM)	5055411.58 N, 526329.69 E	Irregular Meandering	
Weather	Cloud ~20c	Left Bank Type	Right Bank Type
Recent precipitation?	No	Sloped	Sloped
Water Quality		Sloped	Sloped

Transect Measurements							
Transect	Coordinates (UTM)	Feature Type	Bank-full Width (m)	Wetted Width (m)	Wetted Depth (m)	Embeddedness (%)	Bank Height (m)
T1	5055411.58 N, 526329.69 E	Flat/ dry	2.58	dry	dry	100	0.24
T2	5055402.10 N, 526379.07 E	Flat/ dry	2.08	dry	dry	100	0.28
T3	5055424.97 N, 526400.50 E	Flat/dry	1.89	dry	dry	100	0.36
T4	5055404.50 N, 526390.93 E	Pool	4.50	3.16	~0.35	100	0.31
T5	5055439.67 N, 526413.30 E	Flat/ dry	2.60	dry	dry	100	0.45
Average:		**n/a**	**2.73**	**dry**	**dry**	**100**	**0.33**

Water Quality	
Temp °C	12.59
pH	6.83
D.O (mg/l)	2.17
D.O (%)	20
TDS	0.051
Sp. Cond (µS/cm)	78
Salinity	0.04
Velocity m/sec	n/a

Riparian Vegetation	
Left Bank	Right Bank
Shrub	Shrub
Mature Forest	Mature Forest
Barriers Observed?	
Yes, Full	
Fish Observed?	
No	

Habitat Suitability Rationale			
Spawning	Rearing	Overwintering	Overall
Poor: Lack of suitable substrate, overloaded with fines, only one individual pool had water in it at time of assessment.	Poor: Habitat fragmentation is the largest issue on this watercourse, the reach appears to hold water only for short periods, and no fish were observed.	Poor: This channel is assumed to stay dry or freeze entirely during winter months, insufficient amounts of presistent deep areas for adequate overwintering habitat.	Poor: Not likely fish habitat for most of the year.

Substrate (%)	(%)
Fines (<0.5cm)	100
Small Gravel (0.5-3cm)	0
Large Gravel (3.1-6.4cm)	0
Cobble (6.4-25.6cm)	0
Boulder (25.7+cm)	0
Bedrock	0
In-Stream Cover	
Small Woody Debris	Trace
Large Woody Debris	None
Undercut Banks	None
Overhanging Vegetation	Abundant
In-Stream Boulder	None
Aquatic Vegetation	None

Vegetation Identified

Onoclea Sensibillis, Amelanchier spp., Acer Rubrum, Betula Alleghaniensis, Osmunda Cinnamomeum, Prunus Serotina, Picea Rubens, Aralia Nudicaulis, Thalictrum Pubescens, Maianthemum Canadense, Tsuga Canadensis, Aster sp. Impatiens Capensis.

Notes

This watercourse was dry, save for one pool. It is likely that the ditch from an upstream roadway is the main source of water for the channel, but is dry most of the time. The channel dissopates in the downstream end of the reach to many unconsolidated braids which further increases habitat fragmentation.

Site I.D.	WC-2A	Watercourse Type	
Assessors	BL, DB	Intermittent (<2m)	
Date (d/m/y)	27/09/2017	Stream Morphology	
Coordinates (UTM)	5055431.73, 526179.59	Sinuous	
Weather	Hot, Clear ~22c	Left Bank Type	Right Bank Type
Recent precipitation?	Minimal	Undercut	Undercut
Water Quality		Sloped	Sloped

Transect Measurements

Transect	Coordinates (UTM)	Feature Type	Bank-full Width (m)	Wetted Width (m)	Wetted Depth (m)	Embeddedness (%)	Bank Height (m)
T1	5055431.73, 526179.59	Dry Run	0.94	Dry	Dry	100	0.19
T2	5055439.27, 526132.52	Pool	11.51	9.42	0.57	100	0.30
T3	5055450.98, 526099.24	Run	0.58	0.56	0.08	100	0.31
T4	5055461.83, 526067.82	Flat	0.78	0.79	0.22	100	0.15
T5	5055444.80, 526042.11	Flat	1.06	0.89	0.17	100	0.06
Average:		**n/a**	**0.84**	**0.75**	**0.26**	**100**	**0.20**

Water Quality	
Temp °C	15.71
pH	6.99
D.O (mg/l)	3.65
D.O (%)	36
TDS	0.065
Sp. Cond (µS/cm)	100
Salinity	0.05
Velocity m/sec	n/a

Riparian Vegetation	
Left Bank	Right Bank
Shrub	Shrub
Young Forest	Young Forest
Barriers Observed?	
Yes, Full	
Fish Observed?	
No	

Habitat Suitability Rationale

Spawning	Rearing	Overwintering	Overall
Poor- Little diversity of habitat types, no variation in susbtrate type very little flowing water, and this watercourse appears to take a significant silt load fairly often.	Poor-Moderate: Cover was readily available at time of assessment, however habitat fragmentation is a large issue on this watercourse, beaver activity is apparent on various sections of the assessed reach.	Poor- Only pool observed on this watercourse was not readily accessible to fish species due to habitat fragmentation.	Poor- Connectivity issues due to beaver, as well as some ephemeral sections throughout the reach.

Substrate (%)	(%)
Fines (<0.5cm)	100
Small Gravel (0.5-3cm)	0
Large Gravel (3.1-6.4cm)	0
Cobble (6.4-25.6cm)	0
Boulder (25.7+cm)	0
Bedrock	0

In-Stream Cover	
Small Woody Debris	Moderate-Abundant
Large Woody Debris	Abundant
Undercut Banks	Abundant
Overhanging Vegetation	Moderate
In-Stream Boulder	None
Aquatic Vegetation	Trace-Moderate

Vegetation Identified

S. Alder, Eastern white hemlock, Red Maple, Yellow birch, Grey birch, Sensitive fern, Cattail sp., boneset, jewel weed, balsam fir, tall white aster, sarsaspirilla, carrex sp. Canada goldenrod, bedstraw.

Notes

Watercourse was dry in various sections, most of the area above the beaver pond (T2) was dry. Lots of older beaver activity in the area has created various debris jams throughout the reach. Watercourse dissopates into a large wetland area downstream.

Site I.D.	**WC-3**
Assessors	BL, DB
Date (d/m/y)	27/09/2017
Coordinates (UTM)	5055167.26, 526187.29
Weather	Overcast, 20c
Recent precipitation?	Yes, Minimal

Watercourse Type	
Intermittent (<2m)	
Stream Morphology	
Sinuous	
Left Bank Type	**Right Bank Type**
Sloped	Sloped
Undercut	Undercut

Transect Measurements

Transect	Coordinates (UTM)	Feature Type	Bank-full Width (m)	Wetted Width (m)	Wetted Depth (m)	Embeddedness (%)	Bank Height (m)
T1	5055167.26, 526187.29	"Pool"	1.25	1.15	0.10	50	0.40
T2	5055200.94, 526183.91	Dry Run	1.20	Dry	Dry	0	0.11
T3	5055237.34, 526173.91	Dry Riffle	0.66	Dry	Dry	0	0.08
T4	5055277.63, 526178.69	Flat	0.39	0.51	0.08	100	0.18
T5		Flat	0.36	0.38	0.06	50	0.32
Average:		**n/a**	**0.77**	**0.68**	**0.08**	**n/a**	**0.22**

Water Quality	
Temp °C	13.42
pH	7.12
D.O (mg/l)	6.62
D.O (%)	63.5
TDS	0.049
Sp. Cond (µS/cm)	75
Salinity	0.03
Velocity m/sec	n/a

Substrate (%)	(%)
Fines (<0.5cm)	20
Small Gravel (0.5-3cm)	30
Large Gravel (3.1-6.4cm)	25
Cobble (6.4-25.6cm)	25
Boulder (25.7+cm)	0
Bedrock	0

In-Stream Cover	
Small Woody Debris	Trace-Moderate
Large Woody Debris	Moderate
Undercut Banks	Abundant
Overhanging Vegetation	Trace
In-Stream Boulder	None
Aquatic Vegetation	None

Riparian Vegetation	
Left Bank	Right Bank
Mature Forest	Mature Forest
Mature Forest	Mature Forest
Barriers Observed?	
Yes, Temporary	
Fish Observed?	
No	

Vegetation Identified

Metteuccia Strutheriopteris, Aralia Nudicaulis, Tsuga Canadensis, Betula Alleghaniensis, Abies Balsamea, Onoclea Sensibillis, Picea Mariana, Pinus Strobus, Acer Rubrum, Hamamelis Virginiana, Betula Papyrifera.

Habitat Suitability Rationale

Spawning	Rearing	Overwintering	Overall
Poor-Moderate: Good substrate and water quality, many dry sections observed on the reach which impedes habitat connectivity.	Poor: Watercourse was dry in most areas of the reach, no fish were observed, however good cover was available.	Poor: No persistent deep sections noted in the reach, will freeze entirely or stay dry for most times of the year.	Poor: May have some useable habitat for short periods throughout the year, but not often.

Notes

Watercourse has a defined dry channel that runs for roughly 120 meters then dissopates into ephemeral section, may resurface in spots further downstream.

Site I.D.	WC-4
Assessors	BL, DB
Date (d/m/y)	27/09/2017
Coordinates (UTM)	5055321.36 525917.19
Weather	Clear ~20c
Recent precipitation?	Yes, Minimal

Watercourse Type	
Ephemeral	
Stream Morphology	
Straight	
Left Bank Type	**Right Bank Type**
Sloped	Sloped
Sloped	Sloped

Transect Measurements							
Transect	Coordinates (UTM)	Feature Type	Bank-full Width (m)	Wetted Width (m)	Wetted Depth (m)	Embeddedness (%)	Bank Height (m)
T1	5055321.36, 525917.19	Dry Run	0.80	Dry	Dry	100	0.12
T2	5055352.01, 525930.34	Dry Run	0.77	Dry	Dry	100	0.16
T3	5055370.79, 525948.30	Flat	1.34	0.52	0.03	100	0.10
T4							
T5							
Average:		**n/a**	**0.97**	**0.52**	**0.03**	**100**	**0.10**

Water Quality	
Temp °C	n/a
pH	n/a
D.O (mg/l)	n/a
D.O (%)	n/a
TDS	n/a
Sp. Cond (µS/cm)	n/a
Salinity	n/a
Velocity m/sec	n/a

Riparian Vegetation	
Left Bank	Right Bank
Mature Forest	Mature Forest
Mature Forest	Mature Forest
Barriers Observed?	
Yes, Full	
Fish Observed?	
No	

Substrate (%)	(%)
Fines (<0.5cm)	75
Small Gravel (0.5-3cm)	25
Large Gravel (3.1-6.4cm)	0
Cobble (6.4-25.6cm)	0
Boulder (25.7+cm)	0
Bedrock	0

In-Stream Cover	
Small Woody Debris	Trace
Large Woody Debris	Trace
Undercut Banks	Trace-Moderate
Overhanging Vegetation	Trace
In-Stream Boulder	None
Aquatic Vegetation	None

Vegetation Identified

Imptatiens Capensis, Aster Spp., Tussilago Farfara, Betula Alleghaniensis, Aralia Nudicaulis, Trientalis Borealis, Onoclea Sensibillis, Osmanthus Heterophyllus, Tsuga Canadensis, Picea Rubens, Betula Papyrifera, Acer Rubrum, Picea Mariana.

Habitat Suitability Rationale			
Spawning	Rearing	Overwintering	Overall
Poor: Channel dissopates into wetland, with little possibility of connectivity to downstream habitat.	Poor: Mostly drainage for nearby hill near wetland, some cover but lots of fragmentation noted.	Poor: Will freeze, no deep sections and very little flow.	Poor: Clearly drainage channel, no useful habitat features, no good for fish.

Notes

Not likely fish habitat, only drainage channel that runs for a short period. No significant habitat features. ATV trail runs through the downstream section of the watercourse, entire daylighted section is roughly ~60 meters.

Site I.D.	WC-5	Watercourse Type	
Assessors	BL, AF	Intermittent (<2m)	
Date (d/m/y)	30/08/2017	Stream Morphology	
Coordinates (UTM)	5055124.98 N, 525691.30 E	Sinuous	
Weather	Cloud, 21c	Left Bank Type	Right Bank Type
Recent precipitation?	No	Sloped	Sloped
Water Quality		Undercut	Undercut

Transect Measurements							
Transect	Coordinates (UTM)	Feature Type	Bank-full Width (m)	Wetted Width (m)	Wetted Depth (m)	Embeddedness (%)	Bank Height (m)
T1	5055124.98 N, 525691.30 E	Run/ dry	2.84	dry	dry	0	0.34
T2	5055134.93 N, 525685.91 E	Run	0.87	0.37	0.06	0	0.40
T3	5055153.26 N, 525692.60 E	Pond	~12	~10	~0.50	100	0.33
T4	5055177.30 N, 525706.20 E	Run	1.00	0.25	0.01	25	0.35
T5	5055197.54 N, 525703.87 E	Run	0.56	0.32	0.05	100	0.16
Average:		**n/a**	**1.32**	**0.24**	**0.16**	**n/a**	**0.32**

Water Quality		Riparian Vegetation	
Temp °C	n/a	Left Bank	Right Bank
pH	n/a	Mature Forest	Mature Forest
D.O (mg/l)	n/a	Shrub	Shrub
D.O (%)	n/a	Barriers Observed?	
TDS	n/a	Yes, Full	
Sp. Cond (µS/cm)	n/a	Fish Observed?	
Salinity	n/a	No	
Velocity m/sec	n/a		

Habitat Suitability Rationale			
Spawning	Rearing	Overwintering	Overall
Poor: Substrate was overloaded with fines, which can reduce available oxygen for fish eggs, possibly leading to suffocation. Dry sections and steep gradient were also observed.	Poor: Habitat fragmentation was observed on this watercourse in various forms, a culvert was identified with a large outflow drop, steep gradient sections may not hold substantial water, and the downstream section was severely braided.	Poor: There was one large pool identified in the watercourse however access to this pool is likely compromised due to low flow, channel braiding, and steep gradient. Beaver activity was also identified in the reach.	Poor: The one feature of this watercourse considered usable by fish may be inaccessable for most of the year.

Substrate (%)	(%)
Fines (<0.5cm)	40
Small Gravel (0.5-3cm)	20
Large Gravel (3.1-6.4cm)	20
Cobble (6.4-25.6cm)	20
Boulder (25.7+cm)	n/a
Bedrock	n/a

In-Stream Cover	
Small Woody Debris	Trace
Large Woody Debris	None
Undercut Banks	Trace
Overhanging Vegetation	Abundant
In-Stream Boulder	None
Aquatic Vegetation	None

Vegetation Identified

Onoclea Sensibillis, Maianthemum Canadense, Cornus Canadensis, Acer Rubrum, Abies Balsamea, Osmunda Cinnamomeum, Willow sp., Osmanthus Heterophyllus, Aster spp., Impatiens Capensis, Rubus Occidentalis, Cattail spp., Rosa spp., Tussilago Farfara, Betula Populifolia, Picea Rubrum, Trientalis Borealis.

Notes

Beaver activity was apparent in the outflow section of the large pool, it is unknown if these beavers are active presently at the site or if this activity was carried out in the past. Gradient from the pool to the culvert upstream was severe, and it is unlikely that adequate water depth would be present for fish species to traverse the area. Below the pool, the channel begins to braid and contiues to until dissopated completely.

Site I.D.	WC-6	Watercourse Type	
Assessors	BL, AF	Intermittent (<2m)	
Date (d/m/y)	30/08/2017	Stream Morphology	
Coordinates (UTM)	5055394.13 N, 525185.67 E	Sinuous	
Weather	Cloud ~23c	Left Bank Type	Right Bank Type
Recent precipitation?	No	Sloped	Sloped
		Sloped	Sloped

Transect Measurements

Transect	Coordinates (UTM)	Feature Type	Bank-full Width (m)	Wetted Width (m)	Wetted Depth (m)	Embeddedness (%)	Bank Height (m)
T1	5055394.13 N, 525185.67 E	Riffle	2.24	0.20	0.02	100	0.16
T2	5055412.49 N, 525688.23 E	Run	1.15	0.48	0.02	25	0.19
T3	5055458.05 N, 525710.55 E	Run	1.61	0.58	0.02	25	0.26
T4	5655494.0 N, 5255707.01 E	Run/ flat	2.72	1.59	0.09	100	0.15
T5	n/a	n/a	n/a	n/a	n/a	n/a	n/a
Average:		**n/a**	**1.93**	**0.71**	**0.04**	**n/a**	**0.19**

Water Quality

Temp °C	15.23
pH	7
D.O (mg/l)	8.86
D.O (%)	88.6
TDS	0.099
Sp. Cond (µS/cm)	153
Salinity	0.07
Velocity m/sec	0.05

Riparian Vegetation

Left Bank	Right Bank
Mature Forest	Mature Forest
Young Forest	Young Forest

Barriers Observed?
Yes, Partial

Fish Observed?
No

Substrate (%)	(%)
Fines (<0.5cm)	75
Small Gravel (0.5-3cm)	5
Large Gravel (3.1-6.4cm)	10
Cobble (6.4-25.6cm)	5
Boulder (25.7+cm)	5
Bedrock	n/a

In-Stream Cover

Small Woody Debris	Trace
Large Woody Debris	Trace
Undercut Banks	Trace
Overhanging Vegetation	Abundant
In-Stream Boulder	Trace
Aquatic Vegetation	Trace

Vegetation Identified

Abies Balsamea, Tsuga Canadensis, Tussilago Farfara, Impatiens Capensis, Eupatorium Perfoliatum, Picea Rubrum, Populus Tremuliodes, Cornus Canadensis, Polygonium Sagittatum, Burr reed spp., Quercus Rubra.

Habitat Suitability Rationale

Spawning	Rearing	Overwintering	Overall
Poor: Substrate has an abundance of fines, which could impede fish egg's ability to take in oxygen, no suitable gravel areas for salmonid spawning.	Poor: A series of beaver built structures were noted along the upstream end of the reachjust after it leaves the headwater pond. It is unlikely that fish species can traverse this area and gain access to the headwater pond.	Poor: The watercourse itself has very little depth, and was dry in various sections throughout the assessed reach. The large pool that could be used for overwintering is likely inaccessible.	Poor: Little variation of cover was identified, shallow water depth, and habitat fragmentation all contribute to the low quality habitat for aquatic fish species.

Notes

Habitat fragmentation was observed at various sections of the watercourse, these included dry sections, and beaver activity. The watercourse continues downstream for roughly 100 meters, until reaching a confluence with another watercourse coded as BH5. No fish were observed in this watercourse (BH4).

Site I.D.	**WC-7**
Assessors	BL, AF
Date (d/m/y)	30/08/2017
Coordinates (UTM)	5055500.51 N, 525645.01 E
Weather	Cloud, 22c
Recent precipitation?	No

Watercourse Type	
Intermittent (<2m)	
Stream Morphology	
Irregular Meandering	
Left Bank Type	**Right Bank Type**
Sloped	Sloped
Sloped	Sloped

Transect Measurements

Transect	Coordinates (UTM)	Feature Type	Bank-full Width (m)	Wetted Width (m)	Wetted Depth (m)	Embeddedness (%)	Bank Height (m)
T1	5055500.51 N, 525645.01 E	Flat	0.68	0.56	0.06	50	0.17
T2	5055483.01 N, 525610.02 E	Run	1.25	0.57	0.02	25	0.18
T3	5055445.21 N, 525554.34 E	Flat	1.26	0.38	0.02	75	0.17
T4	5055402.10 N, 525545.03	Run	1.41	0.88	0.10	50	0.12
T5	5055365.32 N, 525521.34 E	Riffle	1.19	0.96	0.01	25	0.14
Average:		**n/a**	**1.16**	**0.67**	**0.04**	**n/a**	**0.16**

Water Quality	
Temp °C	14.01
pH	7.22
D.O (mg/l)	10.92
D.O (%)	106
TDS	0.128
Sp. Cond (µS/cm)	196
Salinity	0.09
Velocity m/sec	0.07

Riparian Vegetation	
Left Bank	Right Bank
Shrub	Shrub
Mature Forest	Mature Forest
Barriers Observed?	
Yes, Temporary	
Fish Observed?	
No	

Substrate (%)	**(%)**
Fines (<0.5cm)	80
Small Gravel (0.5-3cm)	10
Large Gravel (3.1-6.4cm)	5
Cobble (6.4-25.6cm)	5
Boulder (25.7+cm)	0
Bedrock	0
In-Stream Cover	
Small Woody Debris	Trace-Moderate
Large Woody Debris	Trace-Moderate
Undercut Banks	None
Overhanging Vegetation	Moderate-Abundant
In-Stream Boulder	None
Aquatic Vegetation	None

Vegetation Identified

Solidago Canadensis, Cattail sp., Eupatorium Perfoliatum, Aster spp., Maianthemum Canadense, Polygonum Sagittatum, carrex sp, Onoclea Sensibillis, Picea Mariana, Abies Balsamea, Acre Rubrum, Betula alleghaniensis, Impatiens Capensis, Betula Papyrifera, Sorbus Americana, Apple sp.

Habitat Suitability Rationale

Spawning	Rearing	Overwintering	Overall
Poor-Moderate: Some suitable substrate was identified for spawning, however the water depth was extremely shallow at time of assessment, (max 10cm) but in times of higher flow, this may not be as much of an issue.	Poor: A lack of substantial foraging areas was identified as a potential issue for fish. Some dry sections and unconsolidated flow also caused habitat fragmentation	Poor: No substantial pool areas were identified (either wetted or dry) in the assessed reach. As such, this watercourse has high freeze potential.	Poor: Channel is small and shallow, the assessed reach runs though a steep section with high banks, likely scarred out during the spring thaw.

Notes

BH5 Runs off a steep hill and then flattens almost entirely with very low velocity and a large amount of silt deposited in the downstream section. This watercourse then runs through a series of wetlands before reaching open, navigable water. Unlikely fish habitat due to the emense amount of upstream, fragmented travel it would take before reaching the assessed area.

Site I.D.	WC-8	Watercourse Type	
Assessors	BL, DB	Intermittent (<2m)	
Date (d/m/y)	29/09/2017	Stream Morphology	
Coordinates (UTM)	5056166.75, 525492.28	Sinuous	
Weather	Clear, 15c	Left Bank Type	Right Bank Type
Recent precipitation?	Yes, ~60mm sept 28	Sloped	Sloped
Water Quality		Sloped	Sloped
Temp °C	13.6	Riparian Vegetation	
pH	7.08	Left Bank	Right Bank
D.O (mg/l)	7	Shrub	Shrub
D.O (%)	67.3	Shrub	Shrub
TDS	0.091	Barriers Observed?	
Cond (µS/cm)	0.11	Yes, Partial	
Salinity	0.07	Fish Observed?	
Velocity m/sec	n/a	No	

Substrate (%)	(%)	Vegetation Identified
Fines (<0.5cm)	85	Cattail sp. Spiraea Alba, Alnus incana, Vibernum Nudem, Betula Populifolia.
Small Gravel (0.5-3cm)	10	
Large Gravel (3.1-6.4cm)	5	
Cobble (6.4-25.6cm)	0	
Boulder (25.7+cm)	0	
Bedrock	0	
In-Stream Cover		
Small Woody Debris	Moderate	
Large Woody Debris	Trace-Moderate	
Undercut Banks	Moderate-Abundant	
Overhanging Vegetation	Trace-Moderate	
In-Stream Boulder	None	
Aquatic Vegetation	None	

Transect Measurements

Transect	Coordinates (UTM)	Feature Type	Bank-full Width (m)	Wetted Width (m)	Wetted Depth (m)	Embeddedness (%)	Bank Height (m)
T1	5056166.75, 525492.28	Run	0.28	0.16	0.04	50	0.14
T2	5056155.60, 525514.00	Run	0.32	0.23	0.06	75	0.10
T3	5056145.64, 525526.92	Run	0.85	0.59	0.06	100	0.12
T4	5056139.98, 525533.14	Run	1.50	0.83	0.04	100	0.07
T5							
Average:		**n/a**	**0.74**	**0.45**	**0.05**	**n/a**	**0.11**

Habitat Suitability Rationale

Spawning	Rearing	Overwintering	Overall
Poor: Very small channel, with much influence from an up-gradient clearcut. This watercourse likely experiences extreme silt influence during precipitation events due to the clear cut.	Poor: Shallow, narrow reachwhich dissopates into a large wetland. Not probable fish habitat, fragmentation and turbitdity are issues here.	Poor: Lack of presistent deep sections and swift flow, will freeze or stay dry during winter months.	Poor: Not likely fish habitat due to the minimal channel size and lack of constant adequate depth.

Notes

Channel runs for a short section before dissopating into the wetland downstream. Not likely fish habitat due to the small physical size and the amount of silt diposited into the watercourse during precipitation events.

Site I.D.	WC-9	Watercourse Type	
Assessors	BL, DB	Large Permanent (>5m)	
Date (d/m/y)	27/09/2017	Stream Morphology	
Coordinates (UTM)	5056556.28, 526427.78	Straight	
Weather	22c, Clear	Left Bank Type	Right Bank Type
Recent precipitation?	Yes, minimal	Sloped	Sloped
		Man-Made	Man-Made

Transect Measurements

Transect	Coordinates (UTM)	Feature Type	Bank-full Width (m)	Wetted Width (m)	Wetted Depth (m)	Embeddedness (%)	Bank Height (m)
T1	5056556.28, 526427.78	Run	6.15	5.85	0.52	100	0.30
T2	5056541.53, 526394.24	Run	4.60	3.10	0.20	50	>1m
T3	5056535.19, 526365.66	Riffle	4.40	2.01	0.09	25	>1m
T4	5056538.35 526343.56	Run	1.80	1.50	0.10	50	>1m
T5	5056538.48, 526312.37	Beaver pond	~8	~8	0.75	100	>1m
Average:		**n/a**	**4.99**	**4.09**	**0.33**	**n/a**	**>1m**

Water Quality

Temp °C	18.57
pH	6.75
D.O (mg/l)	3.98
D.O (%)	42.6
TDS	0.103
Sp. Cond (µS/cm)	156
Salinity	0.07
Velocity m/sec	0.04

Riparian Vegetation

Left Bank	Right Bank
Young Forest	Young Forest
Young Forest	Young Forest
Barriers Observed?	
No Barriers	
Fish Observed?	
No	

Habitat Suitability Rationale

Spawning	Rearing	Overwintering	Overall
Poor-moderate: Some riffle habitat but little gravels in substrate, abundant fines and large rock.	Moderate-Good: Good depth, good cover, some foraging areas, upstream habitat is fragmented by large beaver structure.	Moderate: Deep in lower section, shallow in upper section due to beaver activity. Deep section is near mouth of boat harbour, most fish would likely winter in the harbour itself.	Poor: Deep in the lower section, but stream only runs for ~100m before entering the wetland.

Substrate (%)	(%)
Fines (<0.5cm)	40
Small Gravel (0.5-3cm)	0
Large Gravel (3.1-6.4cm)	0
Cobble (6.4-25.6cm)	25
Boulder (25.7+cm)	25
Bedrock	10

In-Stream Cover

Small Woody Debris	Trace
Large Woody Debris	Trace
Undercut Banks	None
Overhanging Vegetation	Trace
In-Stream Boulder	Moderate
Aquatic Vegetation	Trace

Vegetation Identified

Betula Papyrifera, Acer Rubrum, Alnus Incana, Abies Balsamea, Acer Pensylvanicum, Picea Rubens.

Notes

Large beaver structure restricts flow from the upstream habitat, most of the assessed channel has low water depths. Banks were man-made, as this area used to be discharge channel for a former settling pond.

Site I.D.	**WC-10**
Assessors	BL, AF
Date (d/m/y)	06/10/2017
Coordinates (UTM)	
Weather	Clear, 18c
Recent precipitation?	Minimal

Water Quality	
Temp °C	n/a
pH	n/a
D.O (mg/l)	n/a
D.O (%)	n/a
TDS	n/a
Sp. Cond (µS/cm)	n/a
Salinity	n/a
Velocity m/sec	n/a

Substrate (%)	**(%)**
Fines (<0.5cm)	60
Small Gravel (0.5-3cm)	15
Large Gravel (3.1-6.4cm)	15
Cobble (6.4-25.6cm)	5
Boulder (25.7+cm)	5
Bedrock	0

In-Stream Cover	
Small Woody Debris	Moderate
Large Woody Debris	Moderate
Undercut Banks	Trace-Moderate
Overhanging Vegetation	Trace
In-Stream Boulder	Trace
Aquatic Vegetation	None

Watercourse Type	
Intermittent (<2m)	
Stream Morphology	
Sinuous	
Left Bank Type	**Right Bank Type**
Sloped	Sloped
Undercut	Undercut
Riparian Vegetation	
Left Bank	Right Bank
Mature Forest	Mature Forest
Shrub	Shrub
Barriers Observed?	
Yes, Partial	
Fish Observed?	
No	

Vegetation Identified

Betula Alleghansis, Acer Rubrum, Tsuga Canadensis, Alnus Incana, Onoclea Sensibillis, Maianthemum Canadense, Cornus Canadensis, Osmunda Cinnamomeum, Abies Balsamea, Picea Rubens. Aralia Nudicaulis, Acer Pensylvanicum.

Transect Measurements

Transect	Coordinates (UTM)	Feature Type	Bank-full Width (m)	Wetted Width (m)	Wetted Depth (m)	Embeddedness (%)	Bank Height (m)
T1		Riffle	0.85	0.45	0.03	75	0.31
T2		Riffle	0.90	0.44	0.04	75	0.28
T3		Riffle	0.80	0.37	0.02	100	0.36
T4		Riffle	0.82	0.51	0.06	75	0.22
T5		Riffle	0.82	0.40	0.05	50	0.31
Average:		**riffle**	**0.84**	**0.43**	**0.04**		

Habitat Suitability Rationale

Spawning	Rearing	Overwintering	Overall
Poor-moderate: Some good riffle habitat was identified, but dry section barriers encountered thorughout the reach are causing habitat fragmentation.	Poor: Shallow depth, little cover, no deep pools, some foraging areas, but access to these areas is questionable.	Poor: No persistent deep sections for overwintering were observed, and the channel will likely freeze entirely or go dry in the winter months.	Poor: Not likely fish habitat for most of the year.

Notes

The main action this channel performs is drainage for a hilltop wetland upstream. The channel dissopates after roughly 100 metres, and is not considered significant habitat for fish species.

Site I.D.	WC-11
Assessors	BL, AF
Date (d/m/y)	31/08/2017
Coordinates (UTM)	5057081.51 N, 526232.61 E
Weather	Cloud ~20c
Recent precipitation?	No

Watercourse Type	
Ephemeral	
Stream Morphology	
Straight	
Left Bank Type	**Right Bank Type**
Sloped	Sloped
Sloped	Sloped

Transect Measurements

Transect	Coordinates (UTM)	Feature Type	Bank-full Width (m)	Wetted Width (m)	Wetted Depth (m)	Embeddedness (%)	Bank Height (m)
T1	5057081.51 N, 526233.61 E	Dry Run	2.01	Dry	Dry	100	0.22
T2	5057068.18 N, 526250.01 E	Dry Run	1.05	Dry	Dry	100	0.15
T3							
T4							
T5							
Average:		**n/a**	**1.53**	**n/a**	**n/a**	**100**	**0.18**

Water Quality

Temp °C	dry
pH	dry
D.O (mg/l)	dry
D.O (%)	dry
TDS	dry
Sp. Cond (µS/cm)	dry
Salinity	dry
Velocity m/sec	dry

Riparian Vegetation

Left Bank	Right Bank
Young Forest	Young Forest
Young Forest	Young Forest

Barriers Observed?
Yes, Full

Fish Observed?
No

Habitat Suitability Rationale

Spawning	Rearing	Overwintering	Overall
Poor: Ephemeral channel that is daylighted for roughly ~10 meters before dissopating into a wetland area. No access up or downstream for fish species.	Poor: Lack of habitat variation, no water was noted in the small section of daylighted channel that was located. An ATV trail runs just upstream of the daylighted section and this is likely the source of most of this watercourses flow.	Poor: No persistent areas of deep water or constant flow to keep from freezing. This watercourse is likely influenced heavily by the nearby ATV trail.	Poor: Seems to be more of an opportunistic drainange corridor for overland flow from the ATV trail rather than a natural stream.

Substrate (%)	(%)
Fines (<0.5cm)	100
Small Gravel (0.5-3cm)	0
Large Gravel (3.1-6.4cm)	0
Cobble (6.4-25.6cm)	0
Boulder (25.7+cm)	0
Bedrock	0

In-Stream Cover

Small Woody Debris	Trace
Large Woody Debris	Trace
Undercut Banks	None
Overhanging Vegetation	None
In-Stream Boulder	None
Aquatic Vegetation	None

Vegetation Identified

Maianthemum Canadense, Alnus Incana, Acer Rubrum, Betula Alleghaniensis, Solidago Canadensis, Carrex sp. Cornus Canadensis.

Notes

This watercourse has very little potential for fish presence due to the lack of connectivity between the harbour below and the daylighted section located by the assessors. The area seems to be heavily influenced by a well used all-terrian vehicle trail found roughly ~2 meters from the daylighted section.

Site I.D.	WC-12	Watercourse Type	
Assessors	BL, DB	Intermittent (<2m)	
Date (d/m/y)	27/09/2017	Stream Morphology	
Coordinates (UTM)	5057213.54, 526297.99	Irregular Meandering	
Weather	Hot, clear	Left Bank Type	Right Bank Type
Recent precipitation?	yes, minimal	Sloped	Sloped
Water Quality		Undercut	Undercut
Temp °C	n/a	**Riparian Vegetation**	
pH	n/a	Left Bank	Right Bank
D.O (mg/l)	n/a	Mature Forest	Mature Forest
D.O (%)	n/a	Mature Forest	Mature Forest
TDS	n/a	Barriers Observed?	
Sp. Cond (µS/cm)	n/a	Yes, Full	
Salinity	n/a	Fish Observed?	
Velocity m/sec	n/a	No	
Substrate (%)	**(%)**	**Vegetation Identified**	
Fines (<0.5cm)	40	Acer Rubrum, Picea Rubens, Onoclea Sensibillis, Aralia Nudicaulis, Acer Penslyvanicum	
Small Gravel (0.5-3cm)	20		
Large Gravel (3.1-6.4cm)	20		
Cobble (6.4-25.6cm)	20		
Boulder (25.7+cm)	0		
Bedrock	0		
In-Stream Cover			
Small Woody Debris	Moderate		
Large Woody Debris	Moderate-Abundant		
Undercut Banks	Moderate		
Overhanging Vegetation	Trace		
In-Stream Boulder	None		
Aquatic Vegetation	None		

Transect Measurements

Transect	Coordinates (UTM)	Feature Type	Bank-full Width (m)	Wetted Width (m)	Wetted Depth (m)	Embeddedness (%)	Bank Height (m)
T1	5057213.54, 526297.99	Dry riffle	2.54	dry	dry	50	0.50
T2	5057218.38 526297.91	Dry flat	2.36	dry	dry	25	0.25
T3	5057226.68, 526318.68	Dry run	1.86	dry	dry	75	0.35
T4	5057220.52, 526333.27	Dry pool	2.23	dry	dry	50	>1m
T5							
Average:		**n/a**	**2.25**	**dry**	**dry**	**n/a**	**0.53**

Habitat Suitability Rationale

Spawning	Rearing	Overwintering	Overall
Poor: Channel is a dry scar that runs through a small valley. No water, some suitable substrate was observed.	Poor: No water, likely only runs during the spring thaw, as no water was noted even after a significant precipitation event.	Poor: lack of presistent deep sections to use as overwintering habitat.	Poor: likely only serves as overland flow drainage during spring thaw, not useable for fish most of the year.

Notes

Watercourse is a dry scar through a small valley in an area of extreme gradient. No water was observed in the channel at time of assessment, habitat is fragmented severely.

Site I.D.	WC-13	Watercourse Type	
Assessors	BL, AF	Intermittent (<2m)	
Date (d/m/y)	31/08/2017	Stream Morphology	
Coordinates (UTM)	5057543.44 N, 526546.81 E	Sinuous	
Weather	Cloud, 20c	Left Bank Type	Right Bank Type
Recent precipitation?	No	Sloped	Sloped
Water Quality		Undercut	Sloped
Temp °C	8.53	Riparian Vegetation	
pH	7.77	Left Bank	Right Bank
D.O (mg/l)	13.26	Shrub	Shrub
D.O (%)	113.4	Mature Forest	Mature Forest
TDS	0.058	Barriers Observed?	
Sp. Cond (µS/cm)	89	No Barriers	
Salinity	0.04	Fish Observed?	
Velocity m/sec	0.30	No	

Substrate (%)	(%)
Fines (<0.5cm)	60
Small Gravel (0.5-3cm)	30
Large Gravel (3.1-6.4cm)	10
Cobble (6.4-25.6cm)	0
Boulder (25.7+cm)	0
Bedrock	0

In-Stream Cover	
Small Woody Debris	Abundant
Large Woody Debris	Trace
Undercut Banks	Trace-Moderate
Overhanging Vegetation	Moderate-Abundant
In-Stream Boulder	None
Aquatic Vegetation	Moderate

Vegetation Identified

Alnus Incana, Impatiens Capensis, Aster spp., Equisetum Palustre, Onoclea Sensibillis, Acer Rubrum, Osmunda Cinnamomeum, Abies Balsamea, Populus Tremuliodes, Virbernum Nudum, Solidago Canadensis, Clintonia Borealis.

Transect Measurements

Transect	Coordinates (UTM)	Feature Type	Bank-full Width (m)	Wetted Width (m)	Wetted Depth (m)	Embeddedness (%)	Bank Height (m)
T1	5057543.44 N,526564.81 E	Riffle	1.38	0.97	0.06	0	0.13
T2	5057565.74 N, 526548.82 E	Riffle	1.63	1.32	0.07	0	0.28
T3	50557587 N, 526533.77 E	Run	1.48	0.89	0.20	50	0.15
T4	5057593.65 N, 526515.06 E	Run	1.51	0.77	0.08	50	0.25
T5	5057598.16 N, 526492.08 E	Run	1.88	1.36	0.05	25	0.50
Average:		**n/a**	**1.58**	**1.06**	**0.09**	**n/a**	**0.26**

Habitat Suitability Rationale

Spawning	Rearing	Overwintering	Overall
Poor: While some gravels were noted in the substrate, but no accumulation in potential spawning areas, with fines distributed in with the gravels, which lowers the watercoures' spawning potential.	Moderate: Cover was available in various forms, velocity was constant, and water quality was considered adequate for salmonids.	Poor: Lack of presistent deep sections to keep this watercourse from freezing entirely or going dry in winter months.	Poor: Shallow, narrow watercourse with an abundance of fine materials in the substrate.

Notes

Two makeshift bridges were found in the downstream section of this watercourse, with an ATV stream crossing found near transect 3. Potential for a substantial fish population is low in this watercourse.

Site I.D.	WC-14
Assessors	BL, AF
Date (d/m/y)	30/08/2017
Coordinates (UTM)	5057298.93 N, 527148.16 E
Weather	Cloud 22c
Recent precipitation?	No

Watercourse Type	
Ephemeral	
Stream Morphology	
Straight	
Left Bank Type	**Right Bank Type**
Sloped	Sloped
Sloped	Sloped

Water Quality	
Temp °C	n/a
pH	n/a
D.O (mg/l)	n/a
D.O (%)	n/a
TDS	n/a
Sp. Cond (µS/cm)	n/a
Salinity	n/a
Velocity m/sec	n/a

Riparian Vegetation	
Left Bank	Right Bank
Shrub	Shrub
Shrub	Shrub

Barriers Observed?
Yes, Full

Fish Observed?
No

Substrate (%)	(%)
Fines (<0.5cm)	100
Small Gravel (0.5-3cm)	0
Large Gravel (3.1-6.4cm)	0
Cobble (6.4-25.6cm)	0
Boulder (25.7+cm)	0
Bedrock	0

Vegetation Identified
Betula Alleghansis, Acer Pensylvanicum, Fraxinus Americana, Abies Balsamea, Pinus Strobus, Tsuga Canadensis, Osmunda Cinnamomeum, Maianthemum Canadense.

In-Stream Cover	
Small Woody Debris	Trace
Large Woody Debris	None
Undercut Banks	Trace
Overhanging Vegetation	None
In-Stream Boulder	None
Aquatic Vegetation	None

Transect Measurements

Transect	Coordinates (UTM)	Feature Type	Bank-full Width (m)	Wetted Width (m)	Wetted Depth (m)	Embeddedness (%)	Bank Height (m)
T1	5057298.93 N, 527148.46 E	Run	0.43	0.38	0.02	75	0.24
T2	n/a no channel	~	~	~	~	~	~
T3	n/a no channel	~	~	~	~	~	~
T4	n/a no channel	~	~	~	~	~	~
T5	n/a no channel	~	~	~	~	~	~
Average:		**n/a**	**0.43**	**0.38**	**0.02**	**n/a**	**0.24**

Habitat Suitability Rationale

Spawning	Rearing	Overwintering	Overall
Poor: Ephemeral channel that is only daylighted for roughly 5 meters before dissapearing underground. Very shallow, with no suitable spawning areas.	Poor: Very little cover, inadequate water depth, and likely unreachable by fish.	Poor: Will freeze.	Poor: This watercourse is more of groundwater drainage corridor for the adjacent hill, extremely unlikely fish habitat.

Notes

Ephemeral watercourse with a small daylighted section, this watercourse is not likely fish habitat and disperses into the wetland surrounding the daylighted section of channel.

Site I.D.	**WC-15**
Assessors	BL, AF
Date (d/m/y)	31/08/2017
Coordinates (UTM)	5057719.23 N, 528300.67 E
Weather	Cloud ~22c
Recent precipitation?	No

Watercourse Type	
Intermittent (<2m)	
Stream Morphology	
Sinuous	
Left Bank Type	**Right Bank Type**
Sloped	Sloped
Sloped	Sloped

Water Quality	
Temp °C	n/a
pH	n/a
D.O (mg/l)	n/a
D.O (%)	n/a
TDS	n/a
Sp. Cond (µS/cm)	n/a
Salinity	n/a
Velocity m/sec	n/a

Riparian Vegetation	
Left Bank	Right Bank
Mature Forest	Mature Forest
Shrub	Shrub
Barriers Observed?	
Yes, Partial	
Fish Observed?	
No	

Substrate (%)	**(%)**
Fines (<0.5cm)	55
Small Gravel (0.5-3cm)	20
Large Gravel (3.1-6.4cm)	15
Cobble (6.4-25.6cm)	10
Boulder (25.7+cm)	0
Bedrock	0

In-Stream Cover	
Small Woody Debris	Trace-Moderate
Large Woody Debris	Trace
Undercut Banks	Trace
Overhanging Vegetation	Moderate
In-Stream Boulder	None
Aquatic Vegetation	None

Vegetation Identified

Thalictrum Pubescens, Impatiens Capensis, Cattail sp, Aster spp., Alnus Incana, Tsuga Canadensis, Betula Populifolia, Betula Alleghanisis, Osmunda Cinnamomeum, Osmunda Claytoniana, Abies Balsamea, Solidago Canadensis, Onoclea Sensibillis, carrex sp, Spiraea Tomentosa, Taxus Canadensis, Onoclea Sensibillis, Trientalis Borealis, Cornus Canadensis, Polygonum sagittatum.

Transect Measurements

Transect	Coordinates (UTM)	Feature Type	Bank-full Width (m)	Wetted Width (m)	Wetted Depth (m)	Embeddedness (%)	Bank Height (m)
T1	5057719.23 N, 528300.01 N	Run	1.02	0.39	0.02	25	0.21
T2	5057722.63 N, 528285.51 E	Run	2.81	0.49	0.05	50	0.10
T3	5057725.93 N, 528281.51E	Run	0.87	0.39	0.05	25	0.19
T4	5057731.75 N, 528257.72	Run	0.35	0.26	0.03	75	0.04
T5	n/a	n/a	n/a	n/a	n/a	n/a	n/a
Average:		**n/a**	**1.01**	**0.38**	**0.04**	**n/a**	**0.11**

Habitat Suitability Rationale

Spawning	Rearing	Overwintering	Overall
Poor: Lack of adequate gravels in substrate for successful salmonid spawning.	Poor: Depth was extremely shallow at time of assessment, and connectivity between areas of the stream was poor. No fish were observed while on site.	Poor: Lack of persistent deep areas for fush to seek refuge in the winter months, areas my dry up or freeze entirely in winter conditions.	Poor: The reach was very short inside the project area, with little variation in habitat types, shallow depth, and low velocity. Not likely salmonid habitat.

Notes

Stream runs for < 80 meters from the project boundary before emptying into boat harbour. This watercourse is not likely salmonid habitat due to the lack of depth, substrate, habitat variation, and flow. A culvert found at the upstream end of the reach appears to be a barrier to fish passage at times of low flow and possibly mid-flow as well.

Site I.D.	WC-16	Watercourse Type	
Assessors	BL, AF	Intermittent (<2m)	
Date (d/m/y)	31/08/2017	Stream Morphology	
Coordinates (UTM)	5057164.22 N, 528145.91 E	Irregular Meandering	
Weather	Cloud, ~20c	Left Bank Type	Right Bank Type
Recent precipitation?	No	Undercut	Undercut
Water Quality		Sloped	Sloped
Temp °C	13.22	Riparian Vegetation	
pH	7.52	Left Bank	Right Bank
D.O (mg/l)	11.29	Mature Forest	Mature Forest
D.O (%)	107.7	Mature Forest	Mature Forest
TDS	0.057	Barriers Observed?	
Sp. Cond (µS/cm)	88	Yes, Temporary	
Salinity	0.04	Fish Observed?	
Velocity m/sec	0.07	Yes, Species Unknown	
Substrate (%)	(%)	Vegetation Identified	
Fines (<0.5cm)	30	Pinus Strobus, Pinus Resinosa, Carrex sp., Betula Populifolia, Populus Grandidentata, Picea Rubens, Acer Rubrum, Onoclea Sensibillis, Pteridium Aquilinum, Trientalis Borealis, Cornus Canadensis.	
Small Gravel (0.5-3cm)	30		
Large Gravel (3.1-6.4cm)	20		
Cobble (6.4-25.6cm)	15		
Boulder (25.7+cm)	5		
Bedrock	0		
In-Stream Cover			
Small Woody Debris	Trace		
Large Woody Debris	Trace		
Undercut Banks	Abundant		
Overhanging Vegetation	Moderate		
In-Stream Boulder	Trace		
Aquatic Vegetation	Trace-Moderate		

Transect Measurements							
Transect	Coordinates (UTM)	Feature Type	Bank-full Width (m)	Wetted Width (m)	Wetted Depth (m)	Embeddedness (%)	Bank Height (m)
T1	5057148.78 N, 528158.72 E	Riffle	0.86	0.53	0.03	0	0.18
T2	5057164.22 N, 528145.91 E	Pool	1.02	1.07	0.15	0	0.31
T3	5057175.58 N, 528129.14 E	Run	0.50	0.58	0.07	0	0.20
T4	5057184.56 N, 528129.00 E	Run	1.15	0.63	0.07	0	0.35
T5	5057205.26 N, 528120.32 E	Run	2.08	1.72	0.14	50	0.15
Average:		**n/a**	**1.12**	**0.91**	**0.09**	**n/a**	**0.24**

Habitat Suitability Rationale			
Spawning	Rearing	Overwintering	Overall
Poor-moderate: Some suitable spawning areas in the upstream end of the reach were identified, and small fish were observed but species was not identified.	Poor-moderate: Cover was available in various forms throughout the reach, small numbers of small fish observed, some flow was recorded, and no barriers were observed in the assessed area at time of assessment, however the upstream culvert may be at times of low flow.	Poor: Fish would likely overwinter in the large body of water that this watercourse empties into.	Poor-moderate: Some cover and good substrate in sections, but shallow, narrow watercourse overall.

Notes

Watercourse runs through the project area for a short time before entering boat harbour. The culvert observed in the upstream section had no apparent plunge pool and may be a possible barrier at times of extremely low flow.

Site I.D.	WC-17
Assessors	BL, AF
Date (d/m/y)	31/08/2017
Coordinates (UTM)	5056737.38 N, 528186.99 E
Weather	Clear, Sun
Recent precipitation?	No

Water Quality	
Temp °C	17.09
pH	6.84
D.O (mg/l)	4.44
D.O (%)	45.5
TDS	0.093
Sp. Cond (µS/cm)	142
Salinity	0.07
Velocity m/sec	n/a

Substrate (%)	(%)
Fines (<0.5cm)	100
Small Gravel (0.5-3cm)	0
Large Gravel (3.1-6.4cm)	0
Cobble (6.4-25.6cm)	0
Boulder (25.7+cm)	0
Bedrock	0

In-Stream Cover	
Small Woody Debris	None
Large Woody Debris	None
Undercut Banks	Moderate-Abundant
Overhanging Vegetation	Moderate
In-Stream Boulder	None
Aquatic Vegetation	Moderate

Watercourse Type	
Small Permanent (2-5m)	
Stream Morphology	
Irregular Meandering	
Left Bank Type	**Right Bank Type**
Sloped	Sloped
Sloped	Sloped
Riparian Vegetation	
Left Bank	Right Bank
Field	Field
Shrub	Shrub
Barriers Observed?	
No Barriers	
Fish Observed?	
No	

Vegetation Identified
Typha spp., Alnus Incana, Spiraea Tomintosa, Maianthemum Canadense

Transect Measurements

Transect	Coordinates (UTM)	Feature Type	Bank-full Width (m)	Wetted Width (m)	Wetted Depth (m)	Embeddedness (%)	Bank Height (m)
T1	5056737.38 N, 528186.99 E	Flat	1.43	1.20	0.20	100	0.04
T2	5056743.54 N, 528181.19 E	Flat	1.64	1.30	0.46	100	0.04
T3	~	~	~	~	~	~	~
T4	~	~	~	~	~	~	~
T5	~	~	~	~	~	~	~
Average:		**n/a**	**1.54**	**1.25**	**0.33**	**100**	**0.04**

Habitat Suitability Rationale

Spawning	Rearing	Overwintering	Overall
Poor: No velocity, overloaded with fines, no variation of habitat types.	Moderate: Deep turbid waters offer decent cover for young fish, may be useful habitat for american eel, white sucker, or brown bullhead.	Poor-Moderate: Some deep water but none flowing, this may lead to freeze over. Fish likely use the large harbour downstream for overwintering purposes.	Poor-Moderate: Not likely salmonid habitat, but could be fair habitat for brown bullhead, american eel, white sucker.

Notes

Watercourse runs through a shrubby wetland, access was compromised in the lower section as the banks had little definition and sure-footing was hard to find. Briading and standing water were abundant in the lower section.

Site I.D.	WC-18
Assessors	BL, AF
Date (d/m/y)	31/08/2017
Coordinates (UTM)	5055844.04 N, 527850.25 E
Weather	Cloud, ~25c
Recent precipitation?	No

Watercourse Type	
Intermittent (<2m)	
Stream Morphology	
Irregular Meandering	
Left Bank Type	**Right Bank Type**
Undercut	Undercut
Sloped	Sloped

Transect Measurements

Transect	Coordinates (UTM)	Feature Type	Bank-full Width (m)	Wetted Width (m)	Wetted Depth (m)	Embeddedness (%)	Bank Height (m)
T1	5058144.23 N, 527850.25 E	Pool	1.34	0.71	0.18	100	0.22
T2	5056463.04 N, 527836.76 E	Run	0.91	0.49	0.11	75	0.27
T3	5056481.14 N, 527825.22 E	Flat	0.35	0.46	0.10	75	0.31
T4	5056502.02 N, 527801.26 E	Flat	1.34	0.89	0.15	100	0.19
T5	~	~	~	~	~	~	~
Average:		**n/a**	**0.99**	**0.64**	**0.13**	**n/a**	**0.24**

Water Quality

Temp °C	14.87
pH	6.59
D.O (mg/l)	3.52
D.O (%)	34.5
TDS	0.054
Sp. Cond (µS/cm)	83
Salinity	0.04
Velocity m/sec	n/a

Riparian Vegetation

Left Bank	Right Bank
Mature Forest	Mature Forest
Mature Forest	Mature Forest
Barriers Observed?	
Yes, Temporary	
Fish Observed?	
No	

Habitat Suitability Rationale

Spawning	Rearing	Overwintering	Overall
Poor: Lack of suitable substrate and flow, overloaded with fine materials which could potentially smother salmonid eggs.	Poor-Moderate: Depth of flow and instream cover were adequate on this watercourse, however the low amounts of dissolved oxygen are not ideal for salmonids.	Poor: Will likely freeze due to lack of constant flow and areas deeper than 0.5m.	Poor: Watercourse may be suitable for brown bullhead or white sucker, but not for anadromous salmonid species.

Substrate (%)	(%)
Fines (<0.5cm)	80
Small Gravel (0.5-3cm)	10
Large Gravel (3.1-6.4cm)	5
Cobble (6.4-25.6cm)	5
Boulder (25.7+cm)	0
Bedrock	0
In-Stream Cover	
Small Woody Debris	Moderate
Large Woody Debris	Trace-Moderate
Undercut Banks	Abundant
Overhanging Vegetation	Trace
In-Stream Boulder	None
Aquatic Vegetation	Trace

Vegetation Identified

Thalictrum Pubescens, Chelone Glabra, Abies Balsamea, Typha spp. Polygonum Sagitattatum, Betula Populifolia, Alnus Incana, Equisetum Palustre, Aralia Nudicaulis, Acer Rubrum, Onoclea Sensibillis, Maianthemum Canadense, Impatiens Capensis, Spiraea Tomintosa.

Notes

Deep stream with mostly standing water. Debris jams were noted in various sections which hold the water level higher than normal, but also cause habitat fragmentation for fish species.

Site I.D.	**WC-19**
Assessors	BL, CP
Date (d/m/y)	12/10/2017
Coordinates (UTM)	5056305.65, 527681.20
Weather	Overcast, ~16c
Recent precipitation?	

Watercourse Type	
Intermittent (<2m)	
Stream Morphology	
Irregular Meandering	
Left Bank Type	**Right Bank Type**
Sloped	Sloped
Undercut	Undercut

Transect Measurements							
Transect	Coordinates (UTM)	Feature Type	Bank-full Width (m)	Wetted Width (m)	Wetted Depth (m)	Embeddedness (%)	Bank Height (m)
T1	5056305.65, 527681.20	Flat	1.30	0.97	0.22	75	0.25
T2	5056286.89, 527662.83	Pool	2.68	1.67	0.28	50	0.30
T3	5056283.64, 527622.71	Pool	1.53	1.40	0.19	75	0.50
T4	5056294.52, 527583.81	Riffle	1.10	0.80	0.05	0	0.24
T5	5056322.98, 527550.59	Run	0.49	0.34	0.13	30	0.11
Average:		**n/a**	**1.52**	**0.89**	**0.17**	**n/a**	**0.28**

Water Quality	
Temp °C	10.95
pH	5.64
D.O (mg/l)	6.61
D.O (%)	54.3
TDS	0.066
Cond (µS/cm)	0.074
Salinity	0.05
Velocity m/sec	0.05

Riparian Vegetation	
Left Bank	Right Bank
Mature Forest	Mature Forest
Mature Forest	Mature Forest
Barriers Observed?	
Yes, Partial	
Fish Observed?	
No	

Habitat Suitability Rationale			
Spawning	Rearing	Overwintering	Overall
Moderate-Good: Some gravel areas were found scattered throughout the reach, with a gentle constant flow. No fishes were observed at time of assessment however.	Moderate-Good: Cover is readily available in various forms, with some foraging areas noted along the assessed area. Depth, and water quality were both adequate for salmonid habitat.	Moderate-Good: Some deep pool -like sections may be adequate for overwintering, but is not confirmed.	Moderate-Good: Fairly nice stream, has wetlands above and below the defined reach. The habitat in between these sections is mostly step-pools.

Substrate (%)	**(%)**
Fines (<0.5cm)	35
Small Gravel (0.5-3cm)	25
Large Gravel (3.1-6.4cm)	20
Cobble (6.4-25.6cm)	15
Boulder (25.7+cm)	5
Bedrock	0

In-Stream Cover	
Small Woody Debris	Trace-Moderate
Large Woody Debris	Trace-Moderate
Undercut Banks	Moderate-Abundant
Overhanging Vegetation	Trace
In-Stream Boulder	Trace
Aquatic Vegetation	Trace

Vegetation Identified

Trientalis Borealis, Acer Rubrum, Acer Pensylvanicum, Tsuga Canadensis, Betula Alleghaniensis, Abies Balsamea, Picea Rubens, Tussilago Farfara, Impatiens Capensis, Osmunda Cinnamomeum, Onoclea Sensibillis.

Notes

Intermittent watercourse that runs from a small undifined wet area at the border of the project area, to a fringe wetland at the edge of boat harbour. The channel is well defined between these two wet-areas, and the habitat appears to be adequate for salmonid species. Some small barriers were noted in the form of elevation drops between pool areas, which may be diffficult for fish to traverse in times of low flow.

APPENDIX

C

PHOTO LOG

Photo 1: Watercourse 1, August 30, 2017

Photo 2: Watercourse 1, August 30, 2017

Photo 3: Watercourse 2, August 30, 2017

Photo 4: Watercourse 2, August 30, 2017

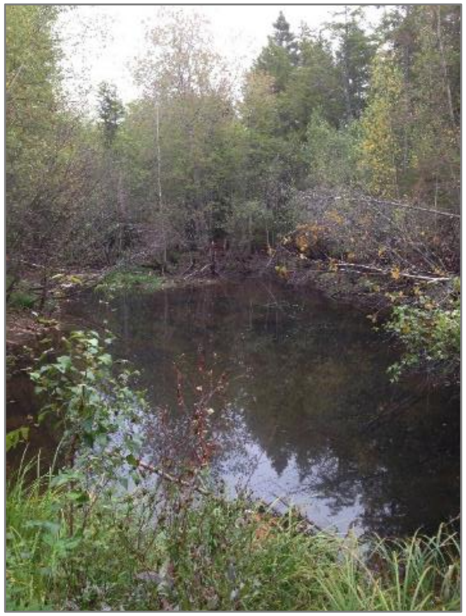

Photo 5: Watercourse 2A, September 29, 2017

Photo 6: Watercourse 2A, September 29, 2017

Photo 7: Watercourse 3, September 27, 2017

Photo 8: Watercourse 3, September 27, 2017

Photo 9: Watercourse 4, September 29, 2017

Photo 10: Watercourse 4, September 29, 2017

Photo 11: Watercourse 5, August 30, 2017

Photo 12: Watercourse 5, August 30, 2017

Photo 13: Watercourse 6, August 23, 2017

Photo 14: Watercourse 6, August 23, 2017

Photo 15: Watercourse 7, August 30, 2017

Photo 16: Watercourse 7, August 30, 2017

Photo 17: Watercourse 8, September 29, 2017

Photo 18: Watercourse 8, September 29, 2017

Photo 19: Watercourse 9, September 27, 2017

Photo 20: Watercourse 9, September 27, 2017

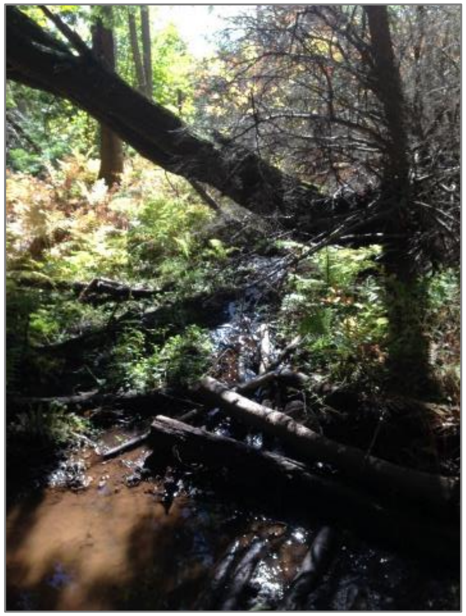
Photo 21: Watercourse 10, October 6, 2017


Photo 22: Watercourse 10, October 6, 2017


Photo 23: Watercourse 11, August 31, 2017


Photo 24: Watercourse 11, August 31, 2017

Photo 25: Watercourse 12, September 27, 2017

Photo 26: Watercourse 12, September 27, 2017

Photo 27: Watercourse 13, August 31, 2017

Photo 28: Watercourse 13, August 31, 2017

Photo 29: Watercourse 14, August 30, 2017

Photo 30: Watercourse 14, August 30, 2017

Photo 31: Watercourse 15, September 12, 2017

Photo 32: Watercourse 15, September 12, 2017

Photo 33: Watercourse 16, August 31, 2017

Photo 34: Watercourse 16, August 31, 2017

Photo 35: Watercourse 17, August 31, 2017

Photo 36: Watercourse 17, August 31, 2017

Photo 37: Watercourse 18, August 31, 2017

Photo 38: Watercourse 18, August 31, 2017

Photo 39: Watercourse 19, October 12, 2017

Photo 40: Watercourse 19, October 12, 2017

APPENDIX

D

BENTHIC MACRO INVERTEBRATE TABLES

Boat Harbour 2017
Benthic Invertebrate Diversity and Abundance*

TAXA		Number / Sub-sample						Number / Sample					
		WC-1	WC-7	WC-13	WC-15	WC-16	WC-9	WC-1	WC-7	WC-13	WC-15	WC-16	WC-9
COLLEMBOLA	*Entomobryidae*				1			0	0	0	6.67	0	0
EPHEMEROPTERA	*Baetidae*	42	2					525	13.34	0	0	0	0
	Caenidae						1	0	0	0	0	0	7.14
	Ephemerellidae	1			3	1	1	12.5	0	0	20.01	5.26	7.14
	Leptophlebiidae	11	1					137.5	6.67	0	0	0	0
ODONATA	*Gomphidae*	1						12.5	0	0	0	0	0
MEGALOPTERA	*Sialidae*		3					0	20.01	0	0	0	0
COLEOPTERA	*Crysomelidae*	6						75	0	0	0	0	0
	Haliplidae						1	0	0	0	0	0	7.14
	Elmidae	2	1					25	6.67	0	0	0	0
	immature	24	3					300	20.01	0	0	0	0
PLECOPTERA	*Capniidae*	10	1			1		125	6.67	0	0	5.26	0
	Leuctridae	2			19	15		25	0	0	126.73	78.9	0
	Nemouridae	1		4	1			12.5	0	133.32	6.67	0	0
	Perlodidae	1						12.5	0	0	0	0	0
	immature			1		1		0	0	33.33	0	5.26	0
TRICHOPTERA	*Hydropsychidae*	15		1			23	187.5	0	33.33	0	0	164.22
	Hydroptilidae	2						25	0	0	0	0	0
	Lepidostomatidae				20			0	0	0	133.4	0	0
	Leptoceridae		2		1		4	0	13.34	0	6.67	0	28.56
	Limnephilidae		1					0	6.67	0	0	0	0
	Odontoceridae		1					0	6.67	0	0	0	0
	Polycentropodidae		3					0	20.01	0	0	0	0
	Rhyacophilidae	9	2	1	6	7	1	112.5	13.34	33.33	40.02	36.82	7.14
	Uenoidae	1	3					12.5	20.01	0	0	0	0
	immature		1	4	4	8		0	6.67	133.32	26.68	42.08	0
DIPTERA	*Ceratopogonidae*	7	42		38	43	14	87.5	280.14	0	253.46	226.18	99.96
	Chironomidae	150	195	287	102	187	146	1875	1300.65	9565.71	680.34	983.62	1042.44
	Dixidae		2		3	4		0	13.34	0	20.01	21.04	0
	Empididae			3		3	26	0	0	99.99	0	15.78	185.64
	Ephydridae		4		3			0	26.68	0	20.01	0	0
	Psychodidae		8		2	1		0	53.36	0	13.34	5.26	0
	Ptychopteridae		11	1		2		0	73.37	33.33	0	10.52	0
	Simuliidae	1		1				12.5	0	33.33	0	0	0
	Tabanidae					1		0	0	0	0	5.26	0
	Tipulidae	6	4	4	2	5	1	75	26.68	133.32	13.34	26.3	7.14
OLIGOCHAETA	*Lumbriculidae*		1	1	12	2		0	6.67	33.33	80.04	10.52	0
	Naididae			1				0	0	33.33	0	0	0
HIRUDINEA	*Erpobdellidae*						5	0	0	0	0	0	35.7
GASTROPODA	*Lymnaeidae*				1			0	0	0	6.67	0	0
	Planorbidae						1	0	0	0	0	0	7.14
BIVALVIA	*Pisidiidae*		3		85	9	58	0	20.01	0	566.95	47.34	414.12
AMPHIPODA	*Gammaridae*	17	8					212.5	53.36	0	0	0	0
	Hyalellidae	1					10	12.5	0	0	0	0	71.4
ACARINA	*Arrenuridae*						4	0	0	0	0	0	28.56
	Aturidae			3				0	0	99.99	0	0	0
	Halacaridae						6	0	0	0	0	0	42.84
	Hygrobatidae				2	1		0	0	0	13.34	5.26	0
	Lebertiidae	3	1	1	3	3	4	37.5	6.67	33.33	20.01	15.78	28.56
	Mideopsidae				1	4		0	0	0	6.67	21.04	0
	Sperchontidae	10	4	4	3	3	3	125	26.68	133.32	20.01	15.78	21.42
	Sarcoptiformes		10	12	5	18	1	0	66.7	399.96	33.35	94.68	7.14
	Total # of individuals	323	317	329	317	319	310	4037.50	2114.39	10965.57	2114.39	1677.94	2213.40
	Number of taxa	23	26	16	23	21	19	23	26	16	23	21	19
% of sample		8	15	3	15	19	14	100	100	100	100	100	100

Taxa not included in count

PORIFERA						Present	0	0	0	0	0	Present
NEMATODA		3	1	3	2	48	0	20.01	33.3	20	10.5	342.9
COPEPODA		2	7	2	4	10	0	13.34	233.1	13.3	21.1	71.4
OSTRACODA	2		2			28	25	0	66.7	0	0	200

*NOTE: The samples were partially decomposed so the data may not be an accurate representation of diversity and abundance. The organisms of sample BH9 however are in good shape.

Method of subsampling used: Marchant box, following CABIN protocol
Sieve size used for rinsing sample: 400 µ
Taxonomist: Jo-Anne Monahan, Biotech Taxonomy

Number / Sub sample				Number / Sample
Order	Family	Genus	WC-9	WC-9
COLLEMBOLA	*Isotomatidae*		1	6.67
EPHEMEROPTERA	*Ephemerellidae*		1	6.67
		Eurylophella	2	13.34
PLECOPTERA	*Leuctridae*		6	40.02
		Leuctra	5	33.35
	Nemouridae		1	6.67
	immature/damaged		7	46.69
TRICHPTERA	*Lepidostomatidae*	*Lepidostoma*	17	113.39
	Leptoceridae		1	6.67
		Rhyacophila	6	40.02
	immature/damaged		5	33.35
DIPTERA	*Ceratopogonidae*		20	133.40
		Ceratopogon	5	33.35
		Probezzia	10	66.70
	Chironomidae	*Polypedilum*	8	53.36
		Constempellina	3	20.01
		Neostempellina	9	60.03
		Tribe Tanytarsini	20	133.40
		Diamesa	1	6.67
		Diplocladius	6	40.02
		Eukiefferiella	2	13.34
		Heleniella	17	113.39
		Parametriocnemus	5	33.35
		Tvetenia	1	6.67
		Subfamily Orthcladiinae	5	33.35
		Alanotanypus	2	13.34
		Subfamily Tanypodinae	4	26.68
		unidentifiable	19	126.73
	Dixidae	*Dixa*	3	20.01
	Ephydridae or Phoridae		3	20.01
	Psychodidae	*Pericoma*	2	13.34
	Tipulidae	*Tipula*	1	6.67
		Pseudolimnophila	1	6.67
OLIGOCHAETA	*Lumbriculidae*		12	80.04
GASTROPODA	*Lymnaeidae*		1	6.67
BIVALVIA	*Pisidiidae*		85	566.95
ACARINA	*Sarcoptiformes*		5	33.35
	Hygrobatidae		2	13.34
	Lebertiidae		3	20.01
	Mideopsidae		1	6.67
	Sperchontidae		3	20.01
	Total # individuals		311	2074.37
	% of sample		15	100

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Cape Breton University

Prepared for Nova Scotia Lands, June 11, 2020

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Cover Image: Dr. Ezilrani Panneerselvam and Adekolapo Adesida backpack electroshocking in a Boat Harbour tributary, Sept 2019. Image Credit Zach Hoover

Executive Summary

Boat Harbour, surrounding wetlands and tributary watercourses, and the downstream estuary were surveyed between September 23 and October 10, 2019 to identify, enumerate, and characterize the fish community. Active and passive approaches resulted in the capture of 522 fish: 16 in Boat Harbour, 104 in the wetlands and watercourses, and 402 in the estuary. In total, five species were captured, with only three species found in Boat Harbour. Captured fish were measured (to determine their overall condition) and released alive, with a subset retained for liver somatic index (LSI), gonadosomatic index (GSI), and tissue burden (metals and organics) analyses. Overall, fish were in good condition, with similar LSI and GSI values among most locations/groups—although small sample sizes for the subset of fish lethally sampled must be acknowledged as a constraint for some endpoints. Of the nine metals measured, most did not show significant differences among locations or when compared to reference fish. Organic analyses measured 17 dioxins and furans, and 9 PAHs. Nine dioxins and furans were found in fish tissues, but only one furan was found above the lower quantification limit. Five polycyclic aromatic hydrocarbons were found in fish tissues, with many well above reference fish and the *post-hoc* control tomcod (*Microgadus tomcod*) concentrations. Though no statistical tests were possible due to low sample size, our organic analyses data suggest organic tissue burdens may play a role in the impoverished fish community in Boat Harbour and associated habitats.

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1.0 Background

With the cessation of effluent addition to Boat Harbour in January 2020, an assessment of the fish community within Boat Harbour proper as well as tributary streams and adjacent wetlands was completed. The purpose of this survey was to help quantify current fish community abundance in Boat Harbour and to serve as a baseline for fish community conditions and contaminant burdens prior to remediation. As the current wetlands and tributary streams will persist as freshwater fish refugia after Boat Harbour is rehabilitated to a tidal estuary, Pictou Landing First Nation (PLFN) community members are interested in the recovery of these fish and their contaminant burdens as sentinels of surrounding ecosystem integrity. After the cessation of effluent addition, the wetland and tributary stream fish communities will continue to interact with and share trophic linkages with the new estuarine Boat Harbour fish community. Consequently, monitoring organic and inorganic contaminant burdens of fish resident in wetlands, Boat Harbour tributary streams, and Boat Harbour proper before, during, and post remediation has long-term value. This project also fulfills a request from Fisheries and Oceans Canada (DFO) to identify and enumerate the finfish community currently resident in Boat Harbour and surrounding tributaries and wetlands.

A previous survey utilized passive and active fish-sampling approaches in the former Cove C to establish the presence/absence of fish in the area identified for berm construction and pilot dredging (Figure 1). A total of 7 fish, 2 mummichog (*Fundulus heteroclitus*) and 5 ninespine stickleback (*Pungitius pungitius*), were collected, measured, and released during this survey with a Catch-Per Unit-Effort (CPUE) of 0.187 fish per minute. All captured fish were found along the littoral margins of Boat Harbour along the former Cove C (red line, Figure 1); none were captured by multi-panel experimental variable mesh gill net set partially across the approximate present day location of the berm across Cove C (blue line, Figure 1). In a subsequent survey (outside the former Cove C), additional mummichog and ninespine stickleback were collected, along with an additional species (tomcod, *Microgadus tomcod*) also identified (Jim Williams, St. Francis Xavier University, *pers. comm.*). The absence of large-bodied fish, despite sonar signals resembling large fish reported by other researchers (D. Burke, Nova Scotia Lands, *pers. comm.*) could be attributable to ineffectiveness of passive gear under the conditions deployed, but are more likely aberrations in density attributable to unconsolidated sediments mimicking the sonic signal reflected by fish tissues.

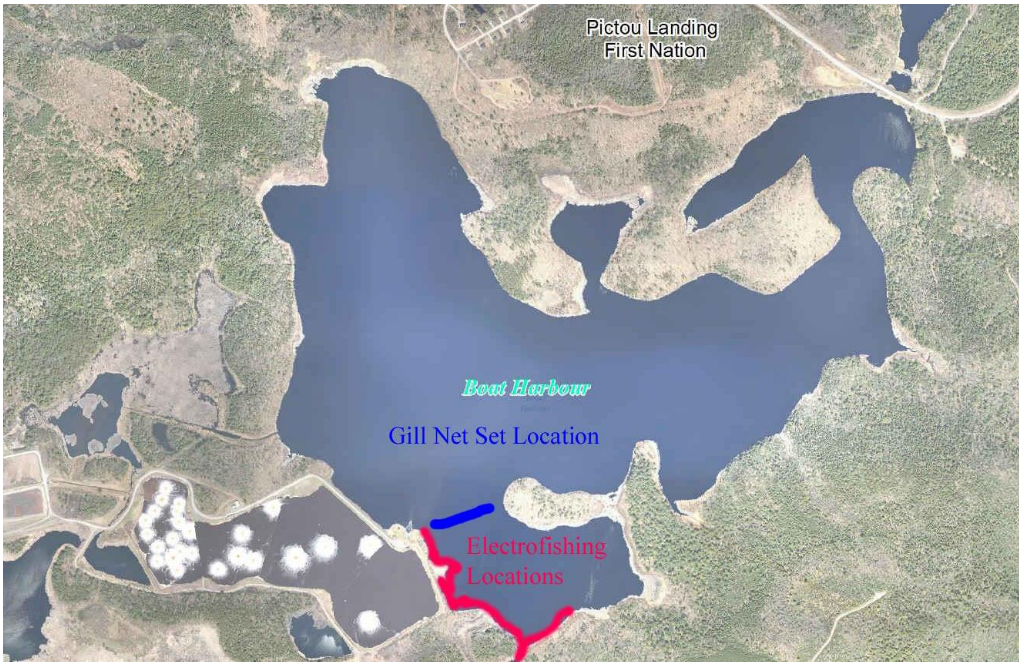

Figure 1. Map of Boat Harbour illustrating areas of previous fish survey in then identified Cove C, with gill net location in blue, and electrofishing areas marked in red (Oakes, 2016).

This project, three years later, surveyed fish species on a greatly expanded scale, within Boat Harbour proper, tributaries and wetlands of interest selected by Nova Scotia Lands, and the Boat Harbour estuary. This study incorporates fish capture data (species, location, and method) with metrics of fish health (liver somatic index (LSI), gonadosomatic index (GSI), and condition factor (K)), as well as generating whole body homogenates on a subset of the captured fish to determine accumulated inorganic and organic contaminant burdens.

2.0 Methods

2.1 Method Overview

All sampling took place between September 23 and October 10, 2019 (Figure 2). Fish were sampled using both active (electrofishing and seining) and passive (gill net, minnow trap, and Fyke net) methods in Boat Harbour, surrounding wetlands and watercourses, and the estuary downstream of Boat Harbour. Boat Harbour and the estuary were divided into pelagic cross-basin transects and shore transects (Figure 3).

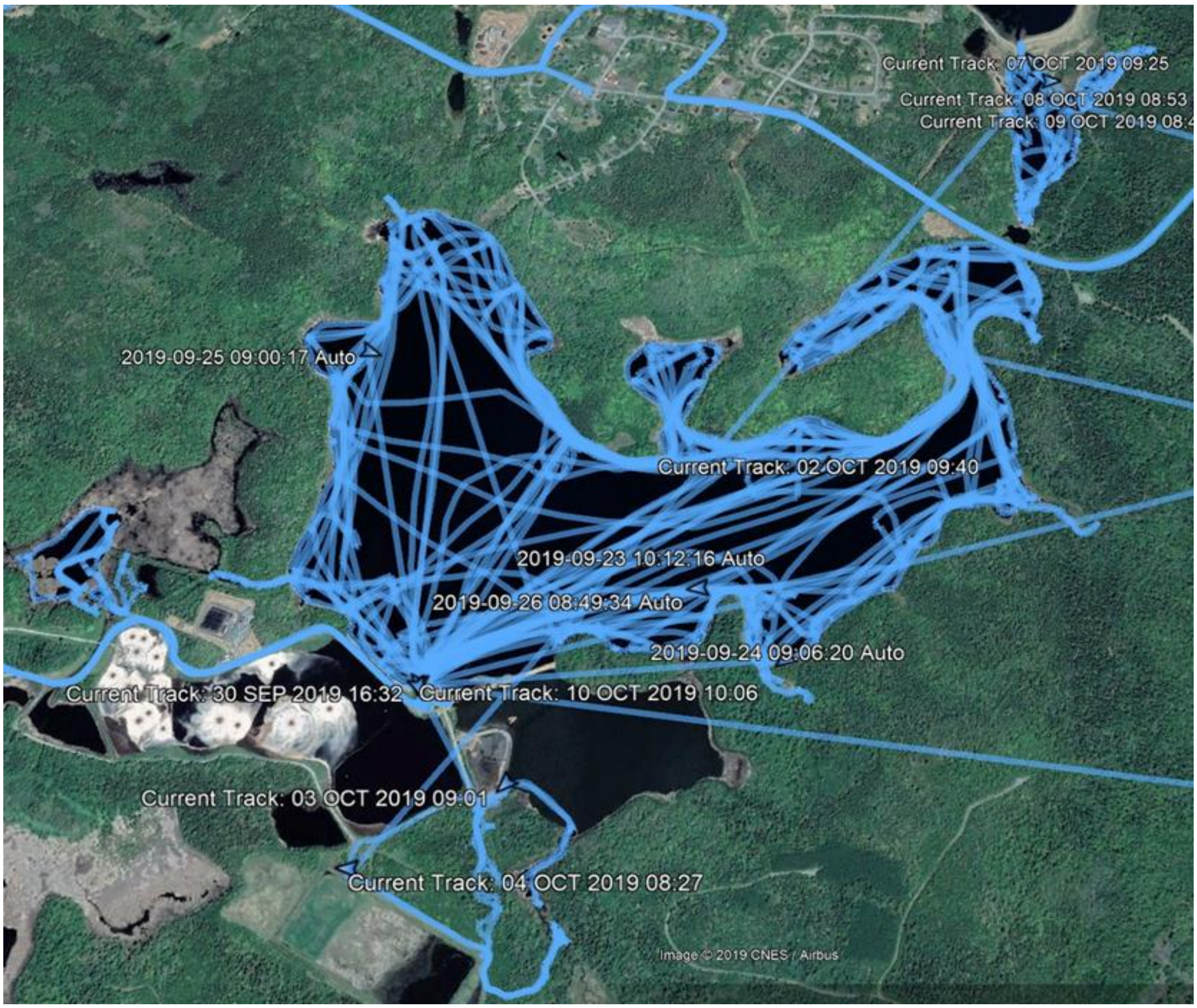

Figure 2. Sampling tracks recorded with GPS used to follow transects. Tracks were recorded between September 23 and October 10, 2019, with the device powered on approximately 70% of the time spent sampling.

Captured fish were identified, measured, and most were released adjacent to the transect of capture although a subset of each species were lethally sampled by a lethal overdose of tricaine methanesulfonate *aka* MS-222. LSI and GSI were calculated for these lethally sampled fish while condition factor data was collected for all captured fish. Lethally sampled fish tissues were tested for accumulated inorganic and organic contaminant burdens by inductively coupled plasma mass spectroscopy (ICP-MS) and gas chromatography (GC), respectively.

2.2 Site Delineation

Shore and cross-basin transects in Boat Harbour and the Boat Harbour estuary were demarcated in ArcGIS Pro 2.4.1 (Figure 3). Shore transects were 200 m long, with the following exceptions: ST62 = 89 m, E-ST12 = 92 m, E-ST14 = 148 m, and E-ST20 = 211 m. Boat Harbour was divided into 62 shore transects (Figure 3a), while the estuary was divided into 20 (Figure 3b). Cross-basin transects were generally at least 110 m long to accommodate the length of the gill nets, with transect boundaries located at the junction of two shore transects. When possible, cross-basin transects extended between visible points of land which could be used for easy navigation. Additionally, Boat Harbour and the estuary were initially divided into distinct zones for comparison, and similar numbers of cross-basin transects were assigned to each zone. Boat Harbour was divided into 30 cross-basin transects (a map labelling error omitted CB11) (Figure *3*c), while the estuary was divided into 21 cross-basin transects (Figure 3d). Boat Harbour wetlands and watercourses deemed important by Nova Scotia Lands were mapped and assigned identifiers (Figure 3c).

2.3 Fish Sampling

Sampling took place between September 23rd and October 10th, 2019. Active sampling was performed daily on weekdays between 9:00 AM and 5:00 PM (see 2.3.1). Passive sampling was performed over the same intervals, and gear was often left in place overnight (see 2.3.2).

Upon capture, fish were identified by species, weighed with a battery-powered scale (0.01 g resolution), measured for total length, and released. A subset of each species was lethally sampled for metals, and organics analyses. These fish were anesthetized with an overdose of MS-222, transferred to individual sample bags, and stored in an ice-filled cooler while the crew worked in the field. At the conclusion of daily sampling, fish were transferred from the cooler to a freezer held at -20°C. Upon completion of all sampling, fish were transferred to the Cape Breton University (CBU) campus via ice-filled cooler, and stored in a freezer held at -20°C.

Additionally, reference mummichog were captured by colleagues from St. Francis Xavier University. These fish were captured with minnow traps on October 11, 2019 near Pomquet Harbour, 45°38’27.4”N, 61°49’06.0”W.

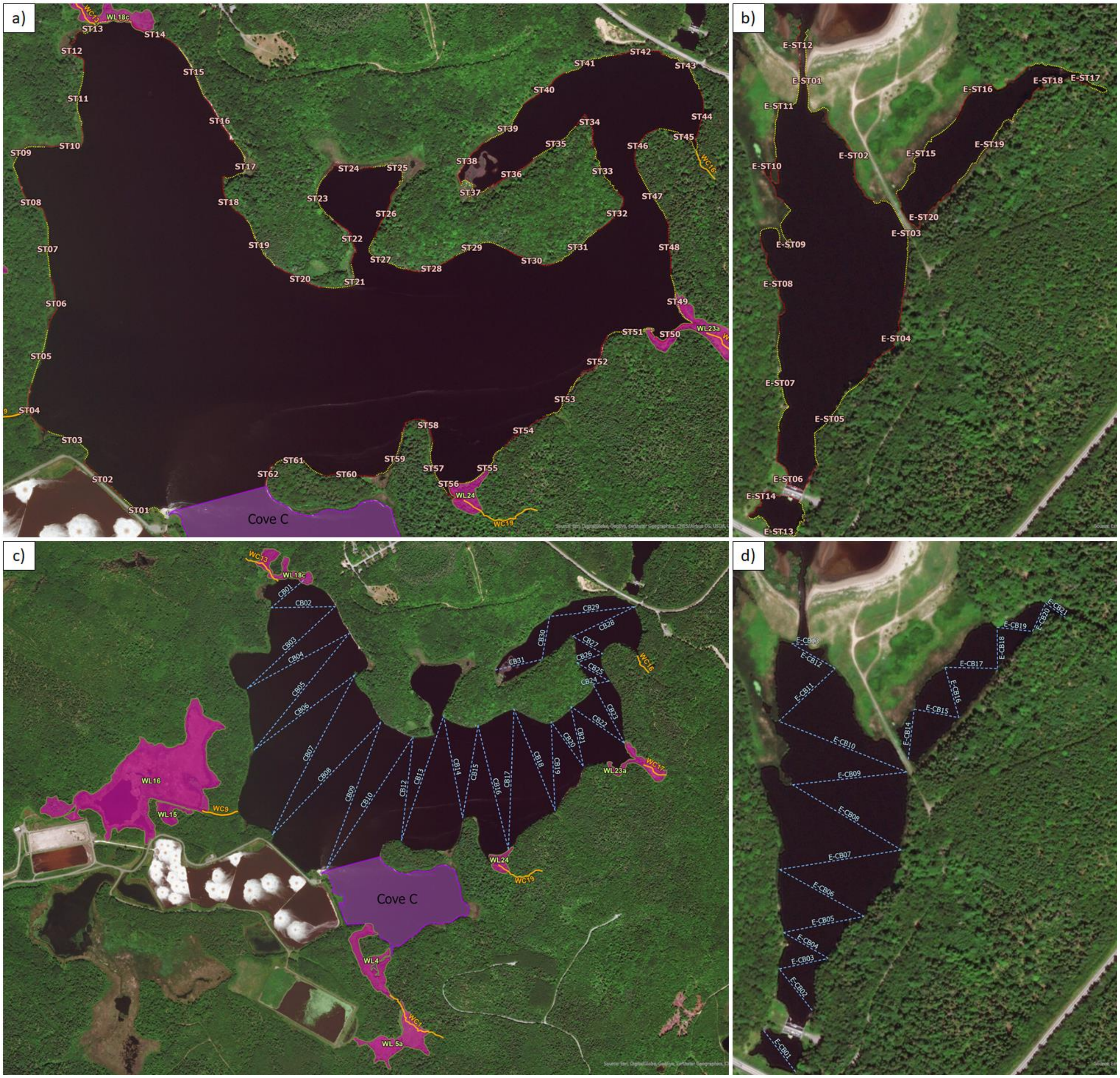

Figure 3. a) 62 Boat Harbour shore transects; b) 20 Boat Harbour estuary shore transects; c) 30 Boat Harbour cross-basin transects, including important wetlands and watercourses; d) 21 Boat Harbour estuary cross-basin transects.

2.3.1 Active Approaches

Electrofishing

As an active approach independent of fish movements or behaviours, electrofishing is very efficient and complements passive approaches such as gill nets and baited minnow traps. It is not without bias as the electrical potential which elicits involuntary muscle contractions resulting in movement of the fish toward the anode (galvanotaxis) and subsequent immobilization (galvanonarcosis) and netting are more pronounced in larger fish, their greater length resulting in a higher voltage gradient experienced from the tip of their snout to the caudal fin. Generally, if electroshocker settings are appropriate to capture small-bodied fish, larger-bodied fish will be readily captured, the latter being a body size not collected in Boat Harbour despite suggestive sonar traces. The absence of larger-bodied fish collected using active gear biased to their capture, in tandem with no larger-bodied fish collected by passive means suggests that, if present in Boat Harbour at all, larger-bodied fish are not abundant.

Fish sampling efforts in Boat Harbour were focused on three potential habitat types: 1) shoreline transects, where previous surveys identified small-bodied fish (Figure 3a), 2) cross-basin (open water) areas away from the shoreline where previous gillnetting was unable to capture any fish (Figure 3c), and 3) identified tributaries and wetlands (Figure 3c). Initially, the electrofishing efforts were split into multiple platforms: 1) a Smith-Root SR-18H electroshocking boat, which is ideal for deeper water conditions in non-wadeable portions of Boat Harbour, 2) backpack electroshocking using a Smith Root LR-24, which is suitable for tributaries and shallower margins of wetlands inaccessible by boat, and 3) small boat backpack electroshocking, which is a hybridized modification previously used in Boat Harbour where the unconsolidated sediments proved too dangerous to wade, but allowed access to regions too shallow for the draft of the heavy 18’ Smith-Root purpose built electrofishing boat.

Sampling began with the Smith-Root SR-18 purpose-built electrofishing boat operated by the University of New Brunswick, but the high organic content of Boat Harbour waters fouled the generator’s cooling impeller, inducing a water pump failure which required the boat to withdraw from the study. In one partial day of sampling, the SR-18 electrofishing boat covered one cross-basin transect and seven shore transects.

After withdrawal of the SR-18 electrofishing boat, electrofishing continued along Boat Harbour shore transects and the wetlands and watercourses. In Boat Harbour, the sediments made electrofishing while wading too hazardous, so electrofishing was performed with a Smith-Root LR-24 while aboard a 14’ aluminum boat. The boat was piloted along each shore transect using GPS guidance, while three crew members operated the electrofisher and captured fish. All 62 shore transects were sampled in this manner.

Wadeable portions of the wetlands and watercourses were sampled with the LR-24 on foot. Exceptions included WL4 (Wetland 4) and WL16, which were too deep and sampled by boat. WL05a, WL15, and WL18c contained no sampleable water, so were excluded from the survey. WC17 (Watercourse 17), WC19, WL23a, and WL24 were inaccessible by boat and were deemed too hazardous to wade, so were also excluded.

The Boat Harbour estuary salinities proved amenable for surveying with the LR-24 backpack electrofisher, and 16 shore transects were surveyed by boat. E-ST01 and E-ST12 were surveyed by foot, being too shallow for the boat. E-ST13 and E-ST14 were excluded, as they were deemed too hazardous for crew safety. All cross-basin transects were also surveyed with the LR-24 by boat, with the exception of E-CB01.

Seining

Beach seining was attempted in several locations of Boat Harbour by colleagues from St. Francis Xavier University. One end of the seine was held stationary on shore, while the other end was swept through the deepest accessible portion of the littoral zone in an arc. The sweeping end was then hauled to shore on a continuing arc, and the net was checked for fish. Poor wading conditions and heavy organic loads in Boat Harbour made this approach very difficult.

2.3.2 Passive Approaches

Gill nets

Experimental mesh gill nets are long straight nets anchored at both ends, with mesh openings that vary in size. These nets are made up of several panels, each panel having a specific mesh size. Gill nets entangle fish as they swim through, and because experimental nets have multiple size openings, they capture fish of various sizes. Fish mortality in gill nets can be relatively low if the nets are checked frequently. Nets were set starting from shore and extended 356’ (108.5 m) toward the pelagic zone. As in the previous Boat Harbor survey, gill nets consisted of 12 panels (stretch mesh size / length of the panel in feet): 1½”/31’ -- 2”/30’ -- 3”/30’ -- 4”/30’ -- 5”/29’ -- 6”/30’ -- 1½”/31’ -- 2”/29’ -- 6”/30’ -- 5”/29’ -- 4”/26’ -- 3”/31’. Gill nets were set for at least two hours, then checked for fish.

Gill nets were set on 14 randomly chosen cross-basin transects in Boat Harbour, with 5 left overnight. Cumulatively, gill nets were set for 114:00 (h:min) sampling hours in Boat Harbour. Water levels in most of the estuary were too low to fully vertically extend the gill nets, so nets were placed in the deepest parts of the estuary (E-CB02-04, E-CB14-18). Gill nets were set on 6 randomly chosen cross-basin transects, with 1 left overnight. Cumulatively, gill nets were set for 32:02 sampling hours in the estuary.

Baited minnow traps

Minnow traps are cylindrical tapered metal traps with concave funnel-shaped openings at each end. Fish swim into the opening but cannot easily find the way out. These traps can be used with or without bait, with baited traps being more appropriate for low-density and/or non-shoaling populations. Minnow traps generally have low mortality and escape rates if checked frequently. Minnow traps were placed at the midpoint of each shore transect in Boat Harbour (n = 62), baited with dry dog food, and left in place overnight.

Fyke nets

Fyke nets are anchored by a lead line adjacent to the shore and extend toward the pelagic (nearshore) zone, where they are also anchored near the pot, a mesh trap. These nets use mesh wings to guide moving fish into the unbaited pot, where they can be collected without lifting the entire net. Fyke nets are ideally suited to lentic or slow-moving environments, but the water must be deep enough to cover the tunnels and can be difficult to set in areas with dense macrophytes or other obstructions. Furthermore, unconsolidated sediments cannot be so deep as to cover the pot or fish could suffocate. Outside of these conditions, these nets generally have high rates of survival and cause relatively little stress to fish, assuming temperature and dissolved oxygen levels remain stable. They are, however, contingent upon fish movement and encounter. Fyke nets were set on three cross-basin transects in Boat Harbour by colleagues from St. Francis Xavier University. These nets were checked, reset, and modified over four days, but no fish were captured using this approach.

2.4 Water Quality

Basic water quality characteristics (pH, temperature, dissolved oxygen, conductivity, and redox) were recorded at the midpoint of each shore transect, excluding E-ST13 and E-ST14. Water quality characteristics were also measured at each wetland and watercourse, excluding those described in section 2.3.1. Dissolved oxygen was measured with a YSI dissolved oxygen probe, while all other parameters were measured with a Myron Ultrameter II 6PFC.

2.5 Indices of Fish and Community Health

2.5.1 Catch Per Unit Effort

Catch per unit effort (CPUE) is used to measure relative abundance in a given location, and may be useful for comparison with future studies. CPUE was calculated for each location by dividing the number of fish caught by the time spent sampling with each gear type. Electrofishing values were reported in fish / sampling minute, while passive gear types were reported in fish / sampling hour.

2.5.2 Condition Factor

K is commonly used as a measure of energy used for somatic growth, and therefore, a measure of overall fish health. K was calculated for every fish captured using measurements taken in the field, and was calculated with the following formula:

*K = weight (g) / total length ^ 3 (cm) * 100*

A literature review was performed for comparison with K values generated in this study. Published literature values were found for each species, and weighted means were calculated based on the available data (means were weighted by sample size for each study). For golden shiner (*Notemigonus crysoleucas)*, literature values were based on the work of Galloway (2005) and Graves *et al.,* (2017). For ninespine stickleback, literature values were based on the work of Golder Associates (2005), Golder Associates (2008), and Guderley & Foley (1990). For mummichog, literature values were based on the work of Blatchley (2013), EcoMetrix (2016), Finley *et al*. (2009), and Galloway (2005). Only control or reference site fish were used for calculations.

2.5.3 Liver Somatic Index

LSI is used to measure the weight of a fish's liver relative to body weight, as an indication of the energy investment for detoxification. LSI requires dissection, so only lethally sampled fish were used. LSI was calculated with the following formula:

*LSI = liver weight (g) / (body weight - liver weight) * 100*

LSI is often calculated and evaluated separately by sex, but small sample sizes in the current study required combining sexes. As in section 2.5.2, a literature value was performed for comparison of LSI. The same sources were used for LSI, with the exception of Golder (2008) which did not include LSI data.

2.5.4 Gonadosomatic Index

GSI is used to measure the weight of a fish's gonads relative to body weight, as an indication of the energy investment for reproduction. GSI requires dissection, so only lethally sampled adult fish were used. GSI was calculated with the following formula:

*GSI = gonad weight (g) / (body weight - gonad weight) * 100*

GSI is calculated and evaluated separately by sex, but small sample sizes in the current study required combining sexes. As in section 2.5.2, a literature value was performed for comparison of GSI. For golden shiner, literature values were based on the work of Galloway (2005) and Rowan & Stone (1996). For ninespine stickleback, literature values were based on the work of

Golder Associates (2005) and Guderley & Foley (1990). For mummichog, literature values were based on the work of EcoMetrix (2016) and Galloway (2005). Only literature values for fish captured/held in non-reproductive state were used to generate GSI values, as GSI changes during reproductive season. The present study began on September 23rd, which should be outside of reproductive season for all species examined.

2.5.5 Fish Tissue Heavy Metals

Lethally sampled fish (n = 70) were analyzed by inductively coupled plasma mass spectrometry (ICP-MS) for metal content. As most fish were small-bodied, their tissue masses were insufficient for contaminant analyses without pooling; consequently, fish were divided into 25 samples, 16 of these samples were composites of multiple fish while 9 represented fish of sufficient mass to constitute a single sample (Appendix 1). For each sample, whole fish were cut into small pieces and homogenized by mortar and pestle. After complete homogenization, samples were placed into labeled bags and stored in a freezer until digestion. For microwave digestion, 0.5 g of homogenized sample was placed in a digestion vessel with 10 ml of concentrated high purity nitric acid. This mixture was left for 15 min (pre-digestion) before being placed in a microwave for a 15-min digestion (the maximum temperature of digestion was 200°C). Samples were then cooled to ambient temperature. The contents of the digestion vessels were then added to 40 ml of nanopure water (18 MΩ cm) to give a total sample volume of 50 ml. Each digested sample was then analyzed by inductively coupled plasma–mass spectrometry (ICP-MS) at the CBU Verschuren Centre (Sydney, NS). ICP-MS is based on vaporization, dissociation, and ionization of chemical elements when introduced into hot plasma. These ions can be separated according to their mass/charge ratios by a high-resolution magnetic mass analyzer and detected, multiplied, and counted using fast digital electronics (Montaser, 1998). ICP-MS provides the lowest possible detection limits, and in typical quantitative analysis, the concentration of each metal is determined by comparing the counts measured for a selected isotope to an external calibration curve generated for that element (Appendix 2). Unknown samples are then run, and the signal intensities are compared to the calibration curve to determine their concentrations. For a sample calculation, taking dilution factors into account, see Appendix 3.

2.5.6 Fish Tissue Organics

Digested fish whole body homogenates were grouped into seven composite samples (Appendix 1) and sent to ALS Life Sciences (Burlington, ON) for organic analyses including Dioxins and Furans by EPA Method 1613B, and Polycyclic Aromatic Hydrocarbons (PAH) by CARB Method 429.

2.6 Statistical Analyses

Statistical analyses were performed with R version 3.6.1 (R Core Team, 2019). All data were checked for conformance to test assumptions (Homogeneity of Variance and Normal Distribution of residuals) using diagnostic plots and Levene's test or the Fligner-Killeen test when applicable. If data were heteroscedastic or non-normal, transformations were applied. If these transformations were not successful, non-parametric tests were used. Outliers were removed when justified, as noted below. For all parameters except water quality, three species (golden shiner, ninespine stickleback, and mummichog) were compared among three locations (Boat Harbour, Estuary, and Wetlands & Watercourses) assuming adequate sample sizes were captured. Additionally, mummichog from the Boat Harbour Treatment complex were compared to reference mummichog collected simultaneously from Pomquet Harbour, a known reference site. See Table 1 for a summary of sample sizes and statistical tests for each fish parameter.

2.6.1 Water Quality

Water quality parameters (temperature, dissolved oxygen, electrical conductivity, pH, and redox) were compared individually among locations. Initially, a 1-way MANOVA was planned, but the data did not meet test assumptions. All parameters were heteroscedastic, and the residuals were non-normal. No suitable transformation could be found, so parameters were evaluated with Welch's ANOVA, followed by Games-Howell *post-hoc*, where applicable. Welch's ANOVA does not assume homogeneity of variance, and like the classical ANOVA, is robust to departures from normality (Delacre *et al*., 2019).

2.6.2 Condition Factor

First, length and weight were compared within species among locations. Only a single ninespine stickleback was captured in Boat Harbour, so it was removed from subsequent analyses. Similarly, no golden shiner were found in the estuary. Five outliers were found and removed. When performing t-tests, R uses Welch's t-test by default, so comparisons between two locations within species did not require homogeneity of variance. Length and weight for golden shiner and ninespine stickleback were evaluated with t-tests, while length and weight for mummichog were evaluated with Welch's ANOVA followed by Games-Howell *post-hoc*.

K was also evaluated for golden shiner and ninespine stickleback by t-test. Welch's ANOVA with Games-Howell *post-hoc* was used for mummichog.

Table 1. Sample sizes and statistical tests for fish characteristics. Sample sizes are provided for each characteristic, species, and location, as well as the statistical test used for comparison, if applicable. Dashes (-) indicate no statistical test was performed.

		Boat Harbour		Wetlands and Watercourses		Estuary		Reference	
		n	Test	n	Test	n	Test	n	Test
Golden Shiner	Length (cm)	10	t-test	44	t-test	-	-	-	-
	Weight (g)	10	t-test	44	t-test	-	-	-	-
	Condition Factor (K)	10	t-test	44	t-test	-	-	-	-
	Liver Somatic Index (LSI)	5	Mann-Whitney U	4	Mann-Whitney U	-	-	-	-
	Gonadosomatic Index (GSI)	4	-	2	-	-	-	-	-
Ninespine Stickleback	Length (cm)	1	-	56	t-test	5	t-test	-	-
	Weight (g)	1	-	56	t-test	5	t-test	-	-
	Condition Factor (K)	1	-	56	t-test	5	t-test	-	-
	Liver Somatic Index (LSI)	1	-	27	t-test	5	t-test	-	-
	Gonadosomatic Index (GSI)	1	-	17	t-test	4	t-test	-	-
Mummichog	Length (cm)	5	Welch's ANOVA	3	Welch's ANOVA	391	Welch's ANOVA	20	Welch's ANOVA
	Weight (g)	5	Welch's ANOVA	3	Welch's ANOVA	391	Welch's ANOVA	20	Welch's ANOVA
	Condition Factor (K)	5	Welch's ANOVA	3	Welch's ANOVA	391	Welch's ANOVA	20	Welch's ANOVA
	Liver Somatic Index (LSI)	5	Welch's ANOVA	2	-	4	Welch's ANOVA	20	Welch's ANOVA
	Gonadosomatic Index (GSI)	2	-	2	-	4	Mann-Whitney U	18	Mann-Whitney U

2.6.3 Liver Somatic Index

Only one ninespine stickleback was captured in Boat Harbour, so it was removed from statistical analyses. Similarly, only two mummichog were captured in the wetlands and watercourses, so they were excluded from analyses. Golden shiner data were non-normal (with a small sample size, $n = 9$), so Mann-Whitney U test was used to compare Boat Harbour with wetlands and watercourses. Ninespine stickleback were evaluated with a t-test, and mummichog with Welch's ANOVA.

2.6.4 Gonadosomatic Index

Only adults were used for GSI analyses. Four adult golden shiner were captured in Boat Harbour, while only two were captured in the wetlands and watercourses. Therefore, golden shiner were removed from analyses. As with LSI, Boat Harbour ninespine stickleback and wetland and watercourse mummichog were removed from analyses. Five mummichog were captured in Boat Harbour, but only two were sufficiently recrudescent to be sexed, therefore this group was excluded from analyses. Ninespine stickleback data were evaluated with a t-test, while mummichog data were evaluated with a Mann-Whitney U test.

2.6.5 Fish Tissue Heavy Metals

Fish tissues were evaluated for nine metals (Cr-52, Mn-55, Ni-60, Cu-63, Zn-66, As-75, Cd-111, Pb-208, and Fe-KED-56). Negative values for replicates were changed to zero, and replicates for each sample were averaged to generate a sample mean. For Cd-111, two sample means were zero. For analyses, these zeros were changed to half the detection limit. One outlier was removed from the dataset. Initially, a 1-way MANOVA was planned, but data did not meet the assumptions. Therefore, individual ANOVAs were performed for each metal. To improve normality of the residuals, data were transformed in the following manner: Mn-55 - no transformation; Cr-52, Ni-60, Cu-63, Zn-66, As-75, Pb-208, and Fe-KED-56--log transformation; Cd-111--rank transformation. After transformation, 1-way ANOVAs were performed, followed by Tukey *post-hoc*, where applicable.

3.0 Results

Data for this study can be found online, at the Scholars Portal Dataverse (https://dataverse.scholarsportal.info/dataverse/bh).

3.1 Fish Sampling

In total, 522 fish were captured (Table 2). For a summary of capture numbers by transect, see Appendix 4. All three areas (Boat Harbour, wetlands and watercourses, and the estuary) contained mummichog and ninespine stickleback, with mummichog composing the majority of all fish captured (*n* = 393). Golden shiner were only found in Boat Harbour and the wetlands and watercourses, with juvenile golden shiner only found in the wetlands and watercourses. In the course of sampling, only two large-bodied fish were captured: one tomcod and one white perch (*Morone americana*). Both of these fish were captured in the estuary.

Table 2. Species and counts of fish caught in Boat Harbour and associated locations. In total, five species--522 fish were captured. Juvenile golden shiner is separated from adults, as they were only found in the wetlands and watercourses.

	Boat Harbour	Wetlands and Watercourses	Estuary
Total	**16**	**104**	**402**
Mummichog (*Fundulus heteroclitus)*	5	3	393
Ninespine stickleback (*Pungitius pungitius*)	1	55	7
Golden shiner (*Notemigonus crysoleucas*)	10	2	0
Juvenile golden shiner (*Notemigonus crysoleucas*)	0	44	0
Tomcod (*Microgadus tomcod*)	0	0	1
White perch (*Morone americana*)	0	0	1

In Boat Harbour, 12 fish were caught on shore transects with electrofishing gear (8 golden shiner and 4 mummichog). 4 fish were also caught on shore transects in baited minnow traps (2 golden shiner, 1 ninespine stickleback, and 1 mummichog). Beach seining of shore transects was unsuccessful. Similarly, no fish were caught on cross-basin transects with either gillnets or Fyke nets.

In the wetlands and watercourses, electrofishing was the sole method of survey. 3 mummichog were captured, as well as 55 ninespine stickleback, 2 adult golden shiner, and 44 juvenile golden shiner.

In the estuary, electrofishing on shore transects produced 389 mummichog and 7 ninespine stickleback. Electrofishing on cross-basin transects captured 4 mummichog, and gillnetting a subset of cross-basin transects caught 1 white perch and 1 tomcod. Additionally, in order to ensure the efficacy of baited minnow traps, one trap was placed on a shore transect for two hours and captured >30 mummichog. These fish were not added to the total catch numbers.

3.2 Water Quality

Water temperature was significantly different ($F_{(2,12.7)} = 99.7$, $p < 0.001$; Table 3), with all three locations significantly different from one another ($p < 0.05$, all). Dissolved oxygen followed the same pattern ($F_{(2,10.3)} = 69.8$, $p < 0.001$) *post-hoc* ($p < 0.05$, all), as did electrical conductivity ($F_{(2,17.20)} = 8609$, $p < 0.001$) *post-hoc* ($p < 0.001$, all). There was also a significant difference found for pH ($F_{(2,11.4)} = 39.2$, $p < 0.001$), with Boat Harbour significantly higher than the estuary ($p < 0.001$). A significant difference was found for redox ($F_{(2,12.2)} = 7.72$, $p = 0.007$), with Boat Harbour significantly lower than the wetlands and watercourses ($p = 0.026$).

Table 3. Mean (±SD) water quality parameters.

	Boat Harbour	Wetlands and Watercourses	Estuary
Temperature (^{o}C)	18.5 (2.0)	10.5 (2.3)	14.9 (0.4)
Dissolved oxygen (ppm)	0.84 (0.17)	9.29 (2.35)	4.21 (1.69)
Conductivity (µS/cm)	1514 (46)	108 (21)	3254 (1014)
pH	7.85 (0.13)	7.33 (0.42)	7.56 (0.13)
Redox (mV)	105 (32)	159 (32)	115 (62)

3.3 Indices of Fish and Community Health

3.3.1 Catch Per Unit Effort

Minnow traps were placed on all 62 Boat Harbour shore transects for a cumulative 1259.8 sampling hours and captured 4 fish, yielding a CPUE of 0.003 fish/h (Table 4). Electrofishing also took place on every Boat Harbour shore transect with a cumulative 265.95 minutes of shocking time and captured 12 fish, yielding a CPUE of 0.045 fish/min. The SR-18 electrofishing boat also spent 7.98 shocking minutes on one Boat Harbour cross-basin transect, but failed to capture any fish (CPUE = 0). Wetlands and watercourses were sampled for 115.87 shocking minutes capturing 104 fish, yielding a CPUE of 0.898 fish/min. Electrofishing in the estuary was the most successful of any gear type for any location. 18 estuary shore transects were surveyed with the LR-24 with a cumulative time of 39.10 shocking minutes catching 396 fish, yielding a CPUE of 10.128 fish/min. Similarly, 20 estuary cross-basin transects were sampled with the backpack electrofisher for 37.42 minutes catching 4 fish, yielding a CPUE of

0.107 fish/min. Gill nets were set in Boat Harbour and the estuary for 114 and 32.03 sampling hours, respectively. Gill nets in Boat Harbour captured 0 fish, while gill nets in the estuary captured 2 fish, yielding a CPUE of 0.062 fish/h. Beach seining and Fyke nets were unsuccessful in capturing any fish in Boat Harbour.

Table 4. Catch per unit effort. Dashes (-) indicate gear type not deployed in this location.

	Boat Harbour	Wetlands and Watercourses	Estuary
Minnow traps (fish/h)	0.003	-	-
Electrofishing shore transects (fish/min)	0.045	0.898	10.128
Electrofishing cross-basin transects (fish/min)	0	-	0.107
Gill nets (fish/h)	0	-	0.062

3.3.2 Condition Factor

Golden shiner in Boat Harbour were longer and heavier than those found in the wetlands and watercourses (length: $t_{(21.9)} = 17.3$, $p < 0.001$; weight: $t_{(10.0)} = 8.27$, $p < 0.001$; Table 5). This result is to be expected, given no juvenile golden shiner were found in Boat Harbour while only two adult golden shiner were found in the wetlands and watercourses. No significant difference in size was found between ninespine stickleback captured in the wetlands and watercourses, and those captured in the estuary (length: $t_{(4.5)} = -0.53$, $p = 0.622$; weight: $t_{(4.2)} = 0.70$, $p = 0.518$). Significant differences were found among locations for length and weight of mummichog. Length ($F_{(3,8.1)} = 140.0$, $p < 0.001$) was not different between Boat Harbour vs wetlands and watercourses ($p = 0.974$) or Boat Harbour vs reference ($p = 0.141$), but was different for mummichog in all other comparisons (Boat Harbour vs estuary, wetlands and watercourses vs estuary, wetlands and watercourses vs reference, estuary vs reference; $p \leq 0.017$ for all). Weight ($F_{(3,6.9)} = 41.2$, $p < 0.001$) of mummichog in the estuary was lower than all other locations ($p \leq 0.023$ for all comparisons), but not significantly different among the other locations ($p \geq 0.358$ for all comparisons).

Table 5. Physical characteristics. Number of fish captured, mean (±SD), and range are provided for each species captured. Asterisks denote groups which were not included in statistical analyses and dashes indicate no data.

		Boat Harbour			Wetlands and Watercourses			Estuary			Reference		
		n	Mean	Range	n	Mean	Range	n	Mean	Range	n	Mean	Range
Golden Shiner	Length (cm)	10	11.0 (1.0)	9.5-13.0	44	4.0 (1.7)	1.8-11.6	-	-	-	-	-	-
	Weight (g)	10	11.70 (3.71)	6.50-18.50	44	0.74 (1.84)	0.05-12.28	-	-	-	-	-	-
	Condition Factor (K)	10	0.85 (0.08)	0.74-0.95	44	0.70 (0.26)	0.30-1.52	-	-	-	-	-	-
	Liver Somatic Index (LSI)	5	2.02 (1.98)	0.13-4.28	4	0.36 (0.05)	0.30-0.39	-	-	-	-	-	-
	Gonadosomatic Index (GSI)	4*	2.30 (1.56)	0.85-3.88	2*	0.56 (0.13)	0.47-0.65	-	-	-	-	-	-
Ninespine Stickleback	Length (cm)	1*	4.8 (-)	-	56	4.8 (0.8)	2.9-6.5	5	4.6 (0.9)	3.0-5.2	-	-	-
	Weight (g)	1*	0.40 (-)	-	56	0.78 (0.37)	0.11-1.68	5	0.99 (0.66)	0.24-1.93	-	-	-
	Condition Factor (K)	1*	0.36 (-)	-	56	0.66 (0.16)	0.31-1.11	5	0.92 (0.32)	0.59-1.37	-	-	-
	Liver Somatic Index (LSI)	1*	3.00 (-)	-	27	2.49 (1.59)	0.18-6.70	5	2.61 (2.12)	0.92-6.14	-	-	-
	Gonadosomatic Index (GSI)	1*	1.18 (-)	-	17	1.34 (0.87)	0.14-3.01	4	2.32 (1.10)	1.14-3.76	-	-	-
Mummichog	Length (cm)	5	8.8 (0.7)	8.1-10.0	3	8.9 (0.3)	8.7-9.3	391	5.1 (1.8)	2.8-11.1	20	7.8 (0.8)	6.7-10.3
	Weight (g)	5	8.47 (1.86)	6.75-11.52	3	8.66 (1.12)	7.52-9.76	391	2.86 (3.17)	0.24-17.11	20	7.06 (2.79)	3.56-16.20
	Condition Factor (K)	5	1.24 (0.11)	1.15-1.41	3	1.21 (0.11)	1.10-1.32	391	1.65 (0.60)	0.70-4.74	20	1.40 (0.11)	1.18-1.65
	Liver Somatic Index (LSI)	5	1.82 (1.88)	0.24-4.65	2*	3.41 (0.65)	2.95-3.87	4	4.35 (1.86)	1.71-5.94	20	2.71 (0.66)	1.30-3.95
	Gonadosomatic Index (GSI)	2*	2.10 (0.30)	1.88-2.31	2*	0.69 (0.76)	0.15-1.22	4	3.27 (3.65)	0.51-8.37	18	0.41 (0.35)	0.03-1.34
Tomcod	Length (cm)	-	-	-	-	-	-	1*	27.0 (-)	-	-	-	-
	Weight (g)	-	-	-	-	-	-	1*	160.65 (-)	-	-	-	-
	Condition Factor (K)	-	-	-	-	-	-	1*	0.82 (-)	-	-	-	-
	Liver Somatic Index (LSI)	-	-	-	-	-	-	1*	4.68 (-)	-	-	-	-
	Gonadosomatic Index (GSI)	-	-	-	-	-	-	1*	2.63 (-)	-	-	-	-
White Perch	Length (cm)	-	-	-	-	-	-	1*	15.5 (-)	-	-	-	-
	Weight (g)	-	-	-	-	-	-	1*	41.02 (-)	-	-	-	-
	Condition Factor (K)	-	-	-	-	-	-	1*	1.10 (-)	-	-	-	-
	Liver Somatic Index (LSI)	-	-	-	-	-	-	1*	1.48 (-)	-	-	-	-
	Gonadosomatic Index (GSI)	-	-	-	-	-	-	1*	0.57 (-)	-	-	-	-

K for golden shiner in Boat Harbour was significantly higher than those in the wetlands and watercourses ($t_{(48.7)} = 3.12$, $p = 0.003$; Table 5; Figure 4a). However, there was no significant difference found between ninespine stickleback in the wetlands and watercourses and those found in the estuary ($t_{(4.2)} = 1.83$, $p = 0.139$; Figure 4b). K was significantly different among mummichog ($F_{(3,7.9)} = 23.0$, $p < 0.001$; Figure 4c), with fish in the estuary showing a significantly higher K than all other locations ($p \leq 0.024$, all). Comparisons among mummichog from Boat Harbour, wetlands and watercourses, and the reference site found no difference ($p \geq 0.085$ for all comparisons).

3.3.3 Liver Somatic Index

No significant LSI differences were found for golden shiner ($U = 16$, $p = 0.176$; Figure 4d), ninespine stickleback ($t_{(4.9)} = 0.12$, $p = 0.908$; Figure 4e), or mummichog ($F_{(2,4.8)} = 1.86$, $p = 0.252$; Figure 4f).

3.3.4 Gonadosomatic Index

No significant difference in GSI was found for ninespine stickleback from the wetlands and watercourses and the estuary ($t_{(3.9)} = 1.66$, $p = 0.173$; Figure 4h). However, mummichog in the estuary had significantly higher GSI than reference fish ($U = 62$, $p = 0.026$; Figure 4i).

3.3.5 Fish Tissue Heavy Metals

No significant differences among locations were found for 7 of the 9 metals tested. These included: Cr-52 ($F_{(3,19)} = 0.28$, $p = 0.843$; Figure 5a), Mn-55 ($F_{(3,19)} = 2.16$, $p = 0.126$; Figure 5b), Ni-60 ($F_{(3,19)} = 0.49$, $p = 0.693$; Figure 5c), Cu-63 ($F_{(3,19)} = 2.92$, $p = 0.061$; Figure 5d), Cd-111 ($F_{(3,19)} = 1.22$, $p = 0.331$; Figure 5g), Pb-208 ($F_{(3,19)} = 0.76$, $p = 0.528$; Figure 5h), and Fe-KED-56 ($F_{(3,19)} = 1.28$, $p = 0.311$; Figure 5i). Significant differences were found for Zn-66 and As-75. For zinc ($F_{(3,19)} = 3.63$, $p = 0.032$; Figure 5e), fish from the wetlands and watercourses had significantly higher concentrations than fish from the estuary ($p = 0.048$) and reference fish ($p = 0.044$). All other comparisons were non-significant ($p \geq 0.150$, all). For arsenic ($F_{(3,19)} = 6.78$, $p = 0.003$; Figure 5f), reference fish concentrations were higher than all other locations ($p \leq 0.043$, all). All other comparisons were non-significant ($p \geq 0.431$, all).

3.3.6 Fish Tissue Organics

Dioxins and Furans

17 dioxins and furan congeners were assessed in the seven homogenized samples (Appendix 5). Nine dioxins and furans were found above the estimated detection limit (EDL) (Figure 6), but eight of these were below the lower quantification limit (LQL). Only one furan, 2,3,7,8-TCDF was found above the LQL in all samples except EC (fish ID ECB18-01, a tomcod captured in the estuary).

Polycyclic Aromatic Hydrocarbons

Nine PAHs were assessed in the seven homogenized samples (Appendix 5). Five PAHs were found above the EDLs (Figure 7), with fluorene and phenanthrene found in all samples.

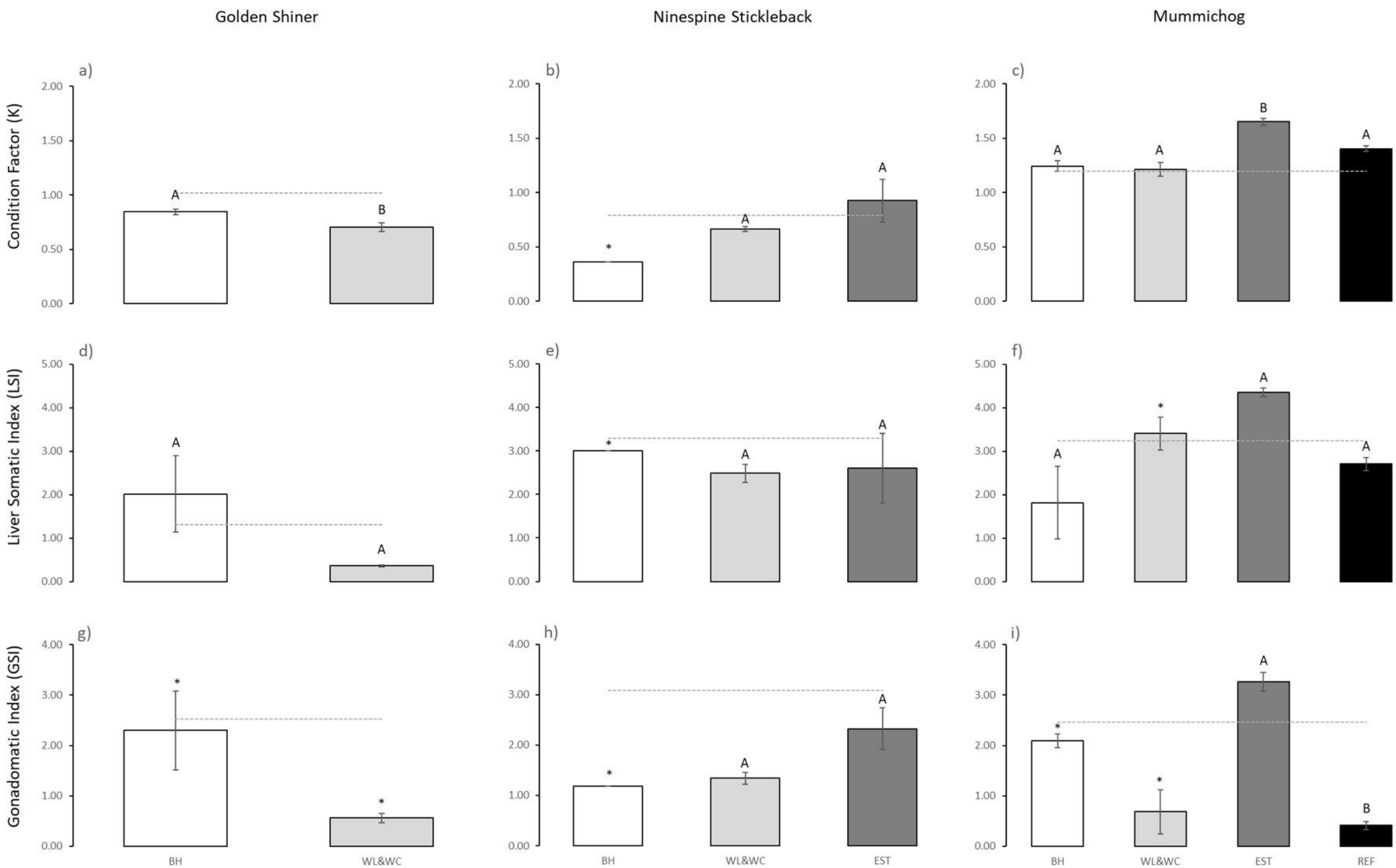

Figure 4. Mean (±SE) condition factor, liver somatic index, and gonadosomatic index. White bars = Boat Harbour, light grey = wetlands and watercourses, dark grey = estuary, and black = reference. Different capital letters above error bars indicate significant differences. Asterisks denote groups which were not included in statistical analyses. Dashed horizontal light grey lines indicate literature values for each parameter.

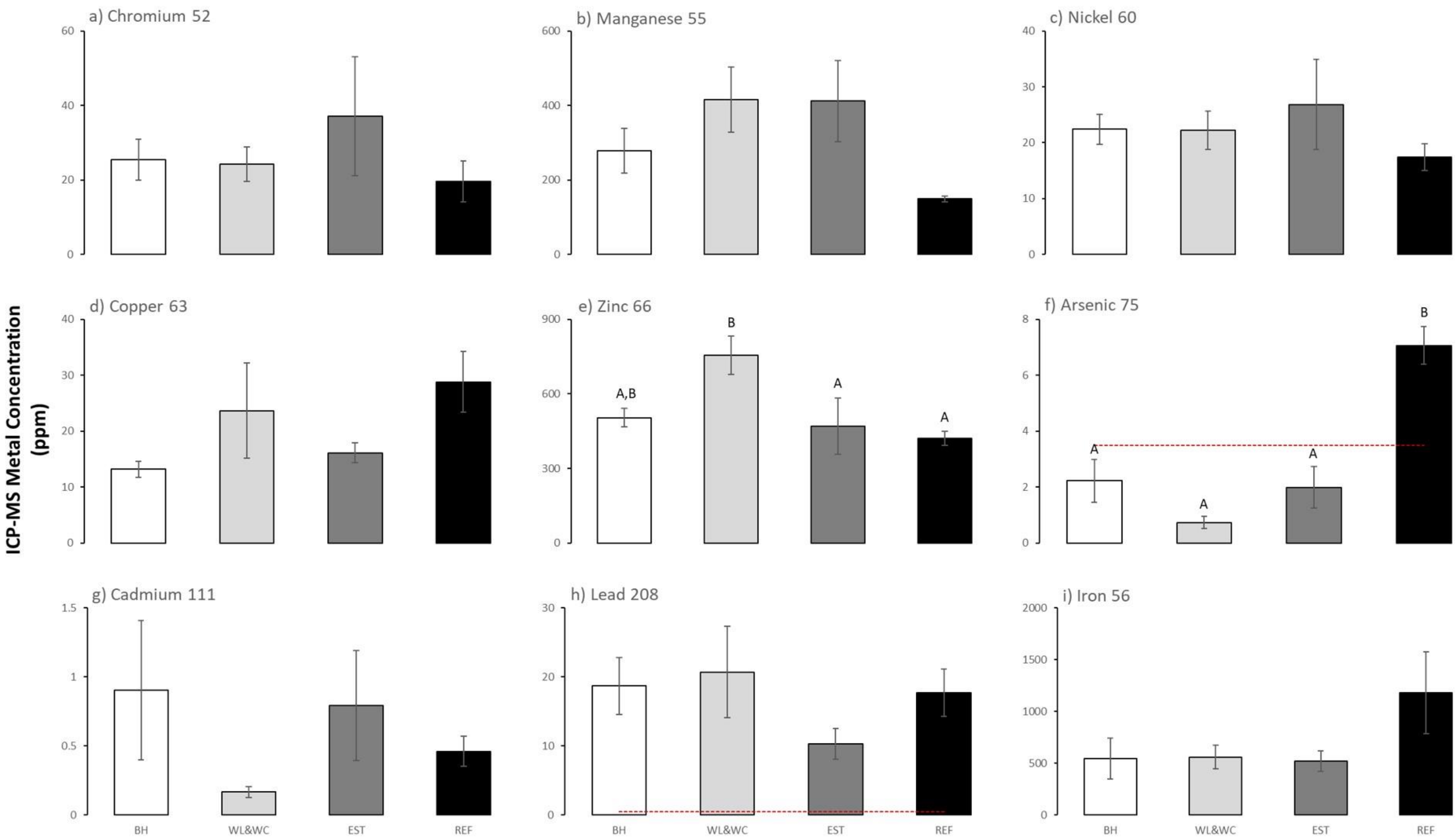

Figure 5. Mean (±SE) metal concentration in fish tissues. White bars = Boat Harbour, light grey = wetlands and watercourses, dark grey = estuary, and black = reference. Different capital letters above error bars indicate significant differences. Dashed horizontal red lines represent CFIA guidelines for fish tissue.

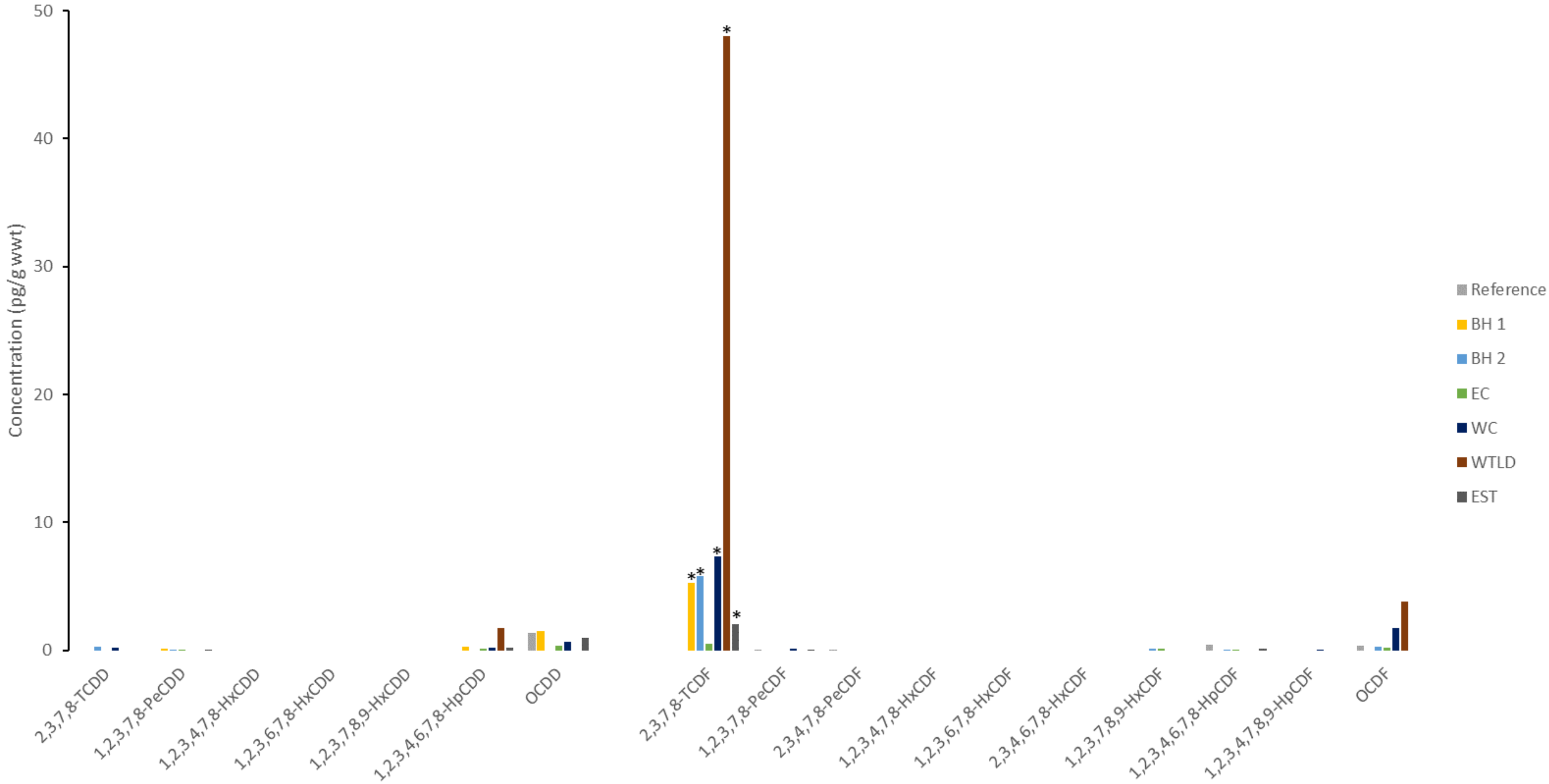

Figure 6. Dioxins and furans (pg/g wet weight) in fish tissue. Seven homogenized samples (Appendix 1) are shown--Reference, BH 1 = Boat Harbour 1, BH 2 = Boat Harbour 2, EC = ECB18-01, a tomcod captured in the estuary, WC = watercourses, WTLD = wetlands, EST = estuary. 9 of 17 dioxins and furans are shown, those which were not found in samples have been omitted. Asterisks represent concentrations which were greater than LQL, bars without asterisks were less than LQL, but greater than EDL.

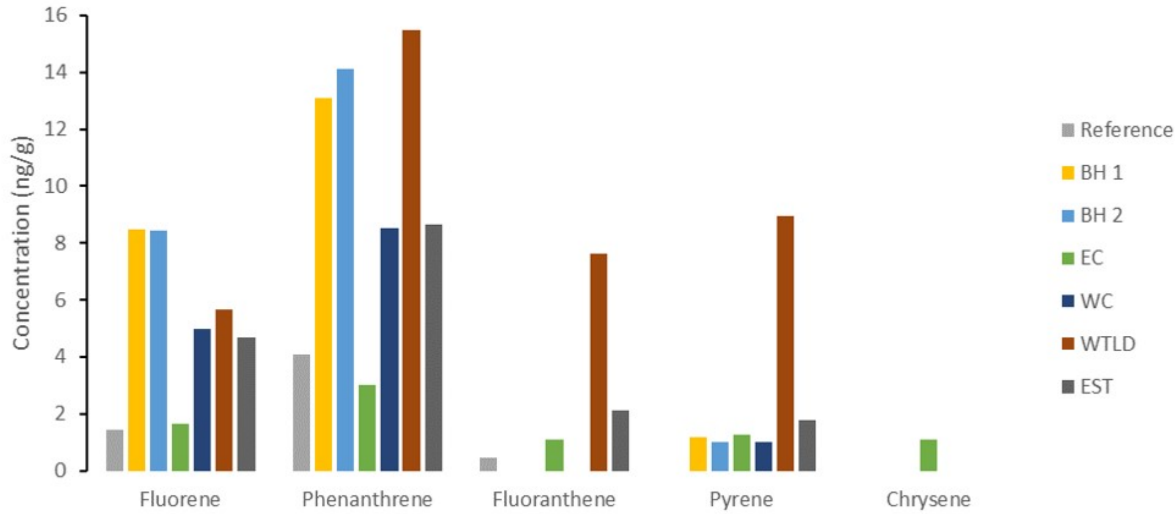

Figure 7. Polycyclic aromatic hydrocarbons (ng/g) in fish tissue. Seven homogenized samples (Appendix 1) are shown--Reference, BH 1 = Boat Harbour 1, BH 2 = Boat Harbour 2, EC = ECB18-01, a tomcod captured in the estuary, WC = watercourses, WTLD = wetlands, EST = estuary. Five of nine PAHs are shown, those which were not found in samples have been omitted.

4.0 Discussion

Individual species and community abundance, as well as inorganic and organic contaminant tissue burdens of fish, have long been utilized as metrics of fish community health in both relatively clean and contaminated aquatic environments (Dahmer *et al.,* 2015; Loomer *et al.,* 2015; Oakes *et al.,* 2003; Santos *et al.,* 2010; Serafin *et al.,* 2019; Tetreault *et al.,* 2011). Overall, fish population data collected in the fall of 2019 from Boat Harbour and adjacent habitats suggest an impoverished Boat Harbour proper fish community, with some evidence of tributary streams and wetlands serving as a source population for the adult fish found within Boat Harbour, while providing evidence the Boat Harbour Estuary supports a more abundant fish population. Organic contaminants (PAHs, dioxins, furans) accumulated in whole body fish tissue homogenates demonstrate the legacy of industrial contamination in Boat Harbour as well as its tributary streams and wetlands, all of which have also influenced the estuarine receiving environment. Metal analyses demonstrate elevated tissue burdens in fish communities relative to adjacent wetland macroinvertebrates (Meaghan Quanz, Dalhousie University *et al.,* unpublished data) reflecting decades of industrial contamination, but also the influence of local geology, particularly for As.

Of the 522 fish captured in Boat Harbour, surrounding wetlands and tributary streams and the Boat Harbour Estuary (hereafter Estuary), almost all (n = 520) were small-bodied fish; a single tomcod and white perch captured in the estuary were the only large-bodied fish which might be taken in a recreational fishery context, and therefore of some relevance for human consumption. However, fish of all sizes fill ecological niches, transferring both energy and nutrients, but also contaminants to fish, birds, and mammals of higher trophic levels. It is advantageous the majority of fish collected within and adjacent to Boat Harbour were small-bodied, as they tend to have smaller defined home ranges and are consequently better sentinel species reflecting the environmental conditions of the site of capture with greater fidelity than more mobile large-bodied fish species (Galloway *et al.,* 2003; Hicks & Servos, 2017; Tetreault *et al.,* 2011).

Gill and Fyke nets, both of which target large-bodied fish via mesh selectivity, were deployed in Boat Harbour for approximately 198 cumulative sampling hours. Given that no fish were caught in these nets, it is possible that there is currently no large-bodied fish community in Boat Harbour, that this community is very small in number, or possibly that hydraulically connected portions of the Boat Harbour water system facilitate significant seasonal movements of larger fish. The majority of small-bodied fish were found in the Estuary (n = 400), followed by the wetlands and tributary watercourses (n = 104), contrasting with a relatively impoverished Boat Harbour proper fish community (n = 16). The Estuary was dominated by mummichog (n = 393), which were comparatively rare in freshwater Boat Harbour (n = 5) and the wetlands and watercourses (n = 3), consistent with their preference for brackish environments, while their presence in freshwater demonstrates their reported broad salinity tolerances (Scott & Crossman, 1973). While mummichog are routinely used as estuarine sentinel species due to their relative abundance, recent evidence demonstrates they are less sensitive to endocrine-mediated disruptions than other teleosts, suggesting their dominant presence in the Estuary may be due to tolerance of chemical species and/or environmental conditions unfavourable to survival of other teleosts (Rutherford *et al.*, 2020). A second small-bodied fish species in Boat Harbour and adjacent water bodies that possesses wide salinity tolerances is the ninespine stickleback. Ninespine stickleback are often found in freshwater environments, although anadromous estuarine populations are fairly common (Page & Burr, 2011). In the present study, we found the greatest number of ninespine stickleback in the wetlands and watercourses, followed by the estuary, with only a single individual collected in fall 2019 from Boat Harbour proper, despite being the most abundant species in an earlier 2016 survey (Oakes, 2016). In the 2019 fish survey, golden shiner (n = 10) was the most abundant species found in Boat Harbour, a species not captured in the 2016 survey, suggesting some community plasticity (Oakes, 2016).

Adult golden shiner were found in all littoral regions of Boat Harbour where fish were captured with the exception of the western shore (ST01-ST12, Appendix 4), a habitat where only a single ninespine stickleback was captured. Interestingly, of the golden shiner captured in the wetlands and tributary watercourses (n = 46), only two were adults, the other 44 being immature fish. Specifically, golden shiner were found in WL16, WC09 (which flows out of WL16, into Boat Harbour), and WL04. Golden shiner is a hardy species typically found in lotic environments with dense macrophytes (Page & Burr, 2011), which certainly is the case in the *Typha*-dominated littoral regions of Boat Harbour and its tributaries and wetlands where these fish were collected. Golden shiner are tolerant of low dissolved oxygen and high water temperatures, approaching a 37°C critical thermal maximum (Smale & Rabeni, 1995), conditions consistent with those found in Boat Harbour. Adult golden shiner are also tolerant of moderate salinities, although fry are very sensitive, showing low survival rates in as little as 2,000 ppm (Murai & Andrews, 1977). The spatial segregation of the immature and adult golden shiner distributions found in this study may be attributable to a number (or combination) of factors. Adult, and larger fish in general, are typically less sensitive to elevated water temperatures and hypoxia than younger fish, and Boat Harbour had a higher average temperature and lower dissolved oxygen concentration than its wetlands and tributary watercourses. Boat Harbour also had a higher average electrical conductivity (a rough surrogate for salinity) than the wetlands and tributary watercourses; precluding the presence of young golden shiner which are particularly susceptible to elevated salinities. Population density and competition for food/prey availability may also play a role. Our CPUE results suggest the wetlands and watercourses have a much higher golden shiner population density than Boat Harbour. If young golden shiner are restricted to the wetlands and watercourses, and adults are better able to tolerate the conditions in Boat Harbour, it seems likely that adults would spread to the less densely-populated areas in Boat Harbour. As such, there is a good possibility the tributaries and wetlands serve as “source” populations for Boat Harbour, with Boat Harbour itself being a “sink” population, where conditions are such that successful golden shiner recruitment is not possible and golden shiner in this waterbody are entirely dependent on emigration from adjacent wetlands and tributary watercourses.

Condition Factor, the ratio of fish weight to length, was measured as an index of overall health and somatic fitness as K reflects changes in food intake, fat deposition, and muscle development (Galloway *et al.*, 2003; Goede and Barton, 1990). Although K is often expressed as a metric of "plumpness" alone, in reality K integrates a suite of physical and biological circumstances that fluctuate with physiological function, environmental contaminant detoxification and other significant expenditures of energy, relative energy/food availability, and parasitic infection intensity within a waterbody (Datta *et al.*, 2013; Galloway *et al.*, 2003; Oakes *et al.*, 2005). Based on calculated K values for all fish captured in this study, fish in Boat Harbour and associated water bodies generally were in overall good condition, consistent with an earlier study (Oakes, 2016). Condition factors for most species and groups were roughly equivalent to published literature values, although golden shiner were slightly lower. The difference in K between golden shiner in Boat Harbour and the wetlands and watercourses is most likely due to developmental stage as fish tend to grow in length before gaining mass.

Liver-somatic indices are frequently used to assess exposure to contaminants as liver size (as a fraction of total body mass) often increases in fish and mammals with elevated enzymatic detoxification activities for organisms inhabiting contaminated environments (Goede & Barton, 1990; Oakes *et al.*, 2005; Tête *et al.*, 2013). Enlarged livers, as indicated by LSI, are often a result of altered lipid concentrations (Oakes & Van Der Kraak, 2003), hyperplasia (increase in cell number) or hypertrophy (increase in cell size) as adaptive responses of the liver to foreign compounds (Goede & Barton, 1990; Munkittrick *et al.*, 1994; Oakes *et al.*, 2004). Similarly, gonadosomatic indices increase as fish gonadal tissues recrudesce approaching spawning, occupying a greater percentage of the body cavity as reproductive behaviours and physiological processes develop seasonally in response to changing photoperiod and water temperature (Galloway *et al.*, 2003; Munkittrick *et al.*, 1994). Comparisons among locations for LSI and GSI in the present study were hampered by low sample sizes (with the exception of ninespine stickleback from the wetlands and tributary watercourses and reference mummichog) as our Animal Care and Scientific Collection permits limited lethal sampling, a necessary condition to measure internal liver and gonadal tissues. The results of our statistical analyses should be interpreted within this context. When comparing LSI and GSI literature values, which almost invariably are gender-specific, our sample sizes afforded as conditions of permitting did not allow this, often requiring indices of both genders to be pooled. Specifically, sample sizes for LSI and GSI in this study were affected by: 1) low numbers of adult fish captured outside of the estuary, and 2) our Fisheries and Oceans Canada Scientific Collection Permit and Cape Breton University Animal Care Committee approval only allowed retention of enough fish to meet the mass requirements for metal and organic contaminant analyses. As in the present study, difficulties in ascribing GSI differences between sites, or comparing to reference literature, is demonstrated by the Bosker *et al.,* (2009) study where mummichog GSIs were reduced in response to a 28 d exposure to 3% New Brunswick pulp mill effluent, but the transitory nature of effluent constituents and process changes is reflected in these differences no longer being detectable in a follow up investigation.

From an environmental contaminants perspective, fish are an ideal model to evaluate the health of pulp and paper effluent receiving environments, and as such, are routinely employed for Environmental Effects Monitoring programmes (Environment Canada, 2010; Harrison, 1996; Lowell *et al.,* 2003; Oakes *et al.*, 2005). Evaluation of raw effluent discharges entering Boat Harbour were compared to Provincial or Federal surface water criteria, as well as Provincial or Federal human health criteria for drinking water. Results indicated both PCBs and dioxins and furans were below the applicable criteria. However, metals exceeded the marine criteria for barium, boron, cadmium, copper, lead, mercury, and zinc while metals parameters reported to exceed the Provincial human health criteria were sodium and vanadium (GHD, 2018). However, an important aspect of the regulation of organic chemicals in aquatic environments is establishing the quantitative link between pulp mill effluent loadings (e.g., kg/yr) and concentrations (e.g., µg/g or µg/L) in water, sediment, and biota (Environment Canada, 2010). Fugacity describes partitioning of inorganic and organic effluent constituents as a function of their chemical properties and those of the phases (or compartments) in which they can partition. Such partition coefficients between water, air, sediment, and biota are difficult to model and must be validated empirically (Mackay & Southwood, 1992). Prior to the present study, no investigations had been undertaken to measure how inorganic and organic pulp mill effluent constituents entering Boat Harbour partition to biota.

Environmental metals are well-studied due to their toxicity, persistence in the environment, and bioaccumulative nature (Ahmed *et al.*, 2019; Authman *et al.*, 2015; Tête *et al.*, 2013). In Boat Harbour and adjacent water bodies, metals occur naturally from weathering of metal-bearing rocks and direct atmospheric deposition, which augment those associated with legacy pulp mill discharges (GHD 2018; Hoffmann *et al.,* 2017). Notably, coal combustion is one of the most important anthropogenic emission sources of trace elements and an important source of a number of metals (Wagner & Boman, 2003), which depending on wind direction, may be an important influence on Boat Harbour metal deposition given its proximity to Nova Scotia Power's Trenton Generating Station. During coal combustion, Cd, Pb, and As are partially volatile, while Hg is fully volatile (Ali *et al.*, 2019). These metal species, coincidentally or otherwise, are all present in Boat Harbour and adjacent aquatic systems. Definitive atmospheric deposition has been linked to extensive coal combustion in China where 8 metals (Hg, As, Se, Pb, Cr, Cd, Ni, and Sb) are spatially correlated in environs adjacent coal combustion, each varying slightly with the source of the coal (Tian *et al.,* 2013).

Contamination of aquatic and terrestrial ecosystems with metals is of considerable local concern as accumulation in biota causes a potential health threat to higher level consumers such as fish-eating birds and mammals, including humans. The trophic transfer of these elements via aquatic and terrestrial food chains/webs has important implications for wildlife and human health (Authman *et al.,* 2015; Tête *et al.*, 2013). Of the nine metals measured in fish whole body homogenates by ICP-MS in the present study, most did not show significant differences among locations or when compared to reference Pomquet Harbour fish, suggesting a widespread rather than localized source apportionment. Interestingly, fish from Boat Harbour and surrounding areas had much lower body burdens of arsenic than reference fish, demonstrating the influence of As-bearing rock at the local level, rather than a point source industrial release as a primary contribution for this species. Arsenic tissue burdens in fish from Boat Harbour and surrounding areas were below the Canadian Food Inspection Agency (CFIA) Action Level of 3.5 ppm (Government of Canada, 2012). Lead concentrations however, were well above the CFIA level of 0.5 ppm (although not differing among locations, again suggestive of a diffuse, rather than point source of release). The present study also provided limited evidence of metal biomagnification relative to macroinvertebrate (Order Odonata) data collected the year previously by Meaghan Quanz (Dalhousie University, unpublished data) from Boat Harbour wetlands, where fish whole body homogenates (relative to macroinvertebrate whole body homogenates) were approximately 20x higher (range 6-40x) for the metals compared (Appendix 6).

The Boat Harbour remediation project was driven in part by concerns over organic contaminant burdens, including dioxins, furans, and PAHs; due not only to their relative concentrations, but also by public concern over their disproportionate toxicity (Achten & Hofmann, 2009; GHD, 2018; Gupta, 2018; Harrison, 1996, 2002; Hoffmann *et al.,* 2019). The disclosure in 1987 that dioxins were present in pulp mill effluents as well as fish and mussels inhabiting their receiving environments prompted governments throughout the world to revise their environmental standards for the pulp and paper industry (Harrison, 1996; Koistinen, 1992; Munkittrick *et al.*, 2013). One dioxin congener, 2,3,7,8-TCDD, is considered the most potent of the dioxins, and one capable of exerting toxicological effects at vanishingly low concentrations (Pohjanvirta and Tuomisto, 1994). Public concerns over the presence of dioxins and furans in particular are well founded as they are virtually insoluble in water but have a relatively high solubility in lipids so they rapidly bioaccumulate in fatty tissues of plankton, macroinvertebrates, and animal fat (including humans) where they are extremely stable and rapidly concentrate in higher trophic levels where their elimination is very slow (Arciszewski *et al.* 2015; Dahmer *et al.* 2015). These organic contaminants are very efficient at binding the aryl hydrocarbon receptor (AhR) where they induce a battery of detoxification enzymes that increase liver size (and hence LSI) while generating reactive oxygen species that damage tissues through lipid peroxidation, leading to endocrine disruption, cellular apoptosis, and cancers (Arciszewski *et al.* 2015; Dahmer *et al.*, 2015; Miller *et al.*, 2015; Oakes & Van Der Kraak, 2003; Oakes *et al*., 2004, 2005). Dioxins and furans are frequently elevated in fish exposed to pulp mill effluents, but decline in environmental matrices over time following mill closure and cessation of additional effluent inputs (Dahmer *et al.* 2015; Mackay & Southwood, 1992; Munkittrick et val., 1994). Even with cessation of chemical perturbations, subtle ecosystem disturbances can remain such as altered food web dynamics, even years after pulp mill closure, making complete ecosystem recovery difficult to predict (Arciszewski *et al.* 2015; Miller *et al.*, 2015). In the present study, one furan, 2,3,7,8-TCDF was found above the LQL in all samples except EC, a tomcod captured in the estuary, which, as a large-bodied fish, may have recently immigrated prior to capture, without sufficient residence time to acquire detectable tissue burdens. Atlantic tomcod typically spend spring and summer in deeper coastal waters, moving into estuaries or freshwater rivers to spawn in fall/winter (Cohen *et al.*, 1990), the time of capture in the present study. Though no statistical analyses were possible, EC may serve as a *post-hoc* control for the organic analyses (along with the reference mummichog), given the tomcod we captured was almost certainly not a permanent resident of the Boat Harbour estuary.

Polycyclic aromatic hydrocarbons are an important group of over 100 different organic compounds containing two or more benzene rings that are considered ubiquitous in the environment, present naturally in high concentrations in fossil fuels including coal, and critically produced by extreme heating or combustion of a variety of organic materials (Achten & Hofmann, 2009; Gupta, 2018; MacAskill *et al.*, 2016; Pirsaheb *et al.*, 2018). Due to their carcinogenic and mutagenic nature, PAHs can cause severe harm to living organisms (Okari *et al.*, 2002; Pacheco & Santos, 1997; Serafin *et al.*, 2019). The pulp and paper industry is also a source of PAHs, produced during processing of paper through the use of chemicals and excessive heat and pressure on wood fibre (Gupta, 2018; Okari *et al.*, 2002; Pacheco & Santos, 1997). The toxicity of PAHs to fish has been well studied, but recent work shows their toxicity is exacerbated by hypoxic conditions similar to those found at Boat Harbour in killifish (*Fundulus grandis*) a relative of the mummichog (Serafin *et al.*, 2019). PAH log K_{OW} (partition coefficients from water to lipids) vary with molecular weight with larger PAHs being increasingly insoluble in water, and instead readily partitioning into hydrophobic interstitial spaces of fine-grained sediments and lipid-rich tissues of fish and mammals, as is the case in Boat Harbour (Hoffman *et al.*, 2019; MacAskill *et al.*, 2016;Wartman *et al.*, 2009). Two and four ring PAHs also have some volatility, facilitating airborne transport, which is important for lower molecular weight PAHs such as naphthalene (Achten & Hofmann, 2009; MacAskill *et al.*, 2016; Serafin *et al.*, 2019). The fugacity, or partitioning behaviour of organic contaminants like PAHs as well as dioxins and furans depend on each congener’s specific chemical properties. Changes in partitioning coefficients dramatically modify the ability of organic contaminants to move from one compartment to another, including partitioning from pulp mill effluent into sediments or fish tissues. Most species of fish have detoxifying enzyme systems inducible with exposure to PAHs, dioxins, and furans known as the cytochrome P450 mixed function oxygenase (MFO) system. MFOs are primarily in hepatic tissues, where they can rapidly metabolize many bioaccumulated PAHs, followed by excretion of the now more hydrophilic metabolites into the bile (Wartman *et al.*, 2009). MFOs seem to be more efficient hydroxylating larger PAHs (Baussant *et al.* 2001), however, enzymatic hydroxylation of organic contaminants can also serve as a maladaptive response, taking a relatively benign PAH and bioactivating it into a more toxic compound (Uppstad *et al.*, 2010). Similarly, dioxins and furans, which like PAHs also bind the AhR strongly and induce MFOs, are interesting as having many congeners which resist hydroxylation, leading to reactive oxygen species generation resulting in cellular damage, endocrine dysfunction, and death (Dahmer *et al.*, 2015; Mackay & Southwood, 1992; Munkittrick *et al.*, 1994; Oakes *et al.* 2003, 2004, 2005; Wartman *et al.*, 2009). These toxicity mechanisms, well studied in fish exposed to pulp mill effluents, are also relevant to human health and underlie the concern organic contaminants generate in the lay community regarding their presence in Boat Harbour, while also potentially contributing to the impoverished fish community observed in the present study.

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Appendix 1: Samples for Fish Tissue Metal and Organic Analyses

Sample makeup for ICP-MS metal analysis. Each row represents an individual sample. Samples are grouped by location of capture. Fish ID number represents the location of capture and ordinal sequence in which it was captured at that location. For instance, ST05-01 was the first fish captured at shore transect 05 in Boat Harbour. ST = Boat Harbour shore transect, WC = watercourse, WL = wetland, ECB = estuary cross-basin transect, EST = estuary shore transect, REF = reference fish. Commas separate multiple fish composited in the same sample.

Fish ID number	Composite Sample?
ST05-01	N
ST19-01	N
ST36-01,02	Y
ST37-01	N
ST47-01	N
ST60-01	N
ST59-01, ST61-02	Y
ST61-01,03	Y
WC09-02,03	Y
WC09-05	N
WC16-01, 03,04,06	Y
WL04-01,02,03,04,05,06,07	Y

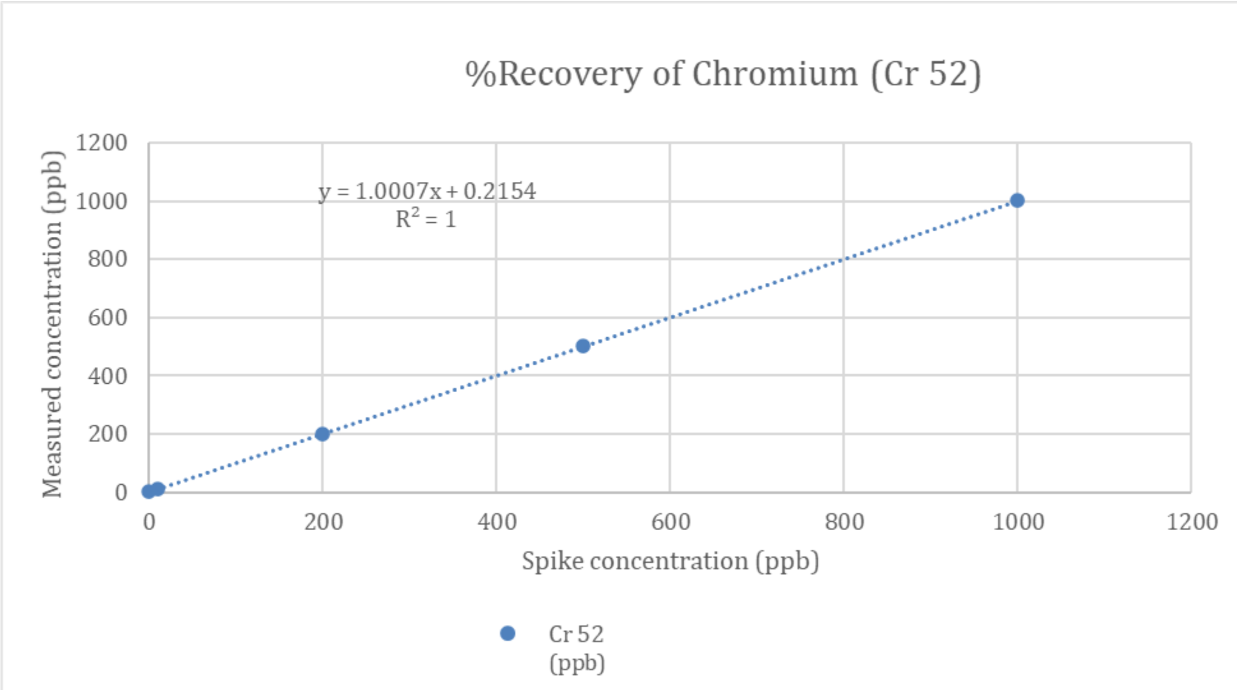
WL04-10,11,12,13,18,20	Y
WL04-08,09,14,16,19	Y
ECB03-01	N
ECB18-01	N
EST01-02,03, EST18-28	Y
EST01-01, EST02-02, EST03-14, EST04-08, EST07-38, EST18-31, EST07-56	Y
EST15-01,02	Y
REF 01,02,15,19	Y
REF 06,10,14,17	Y
REF 05,16,18	Y
REF 03,08,11,20	Y
REF 04,07,09,12,13	Y

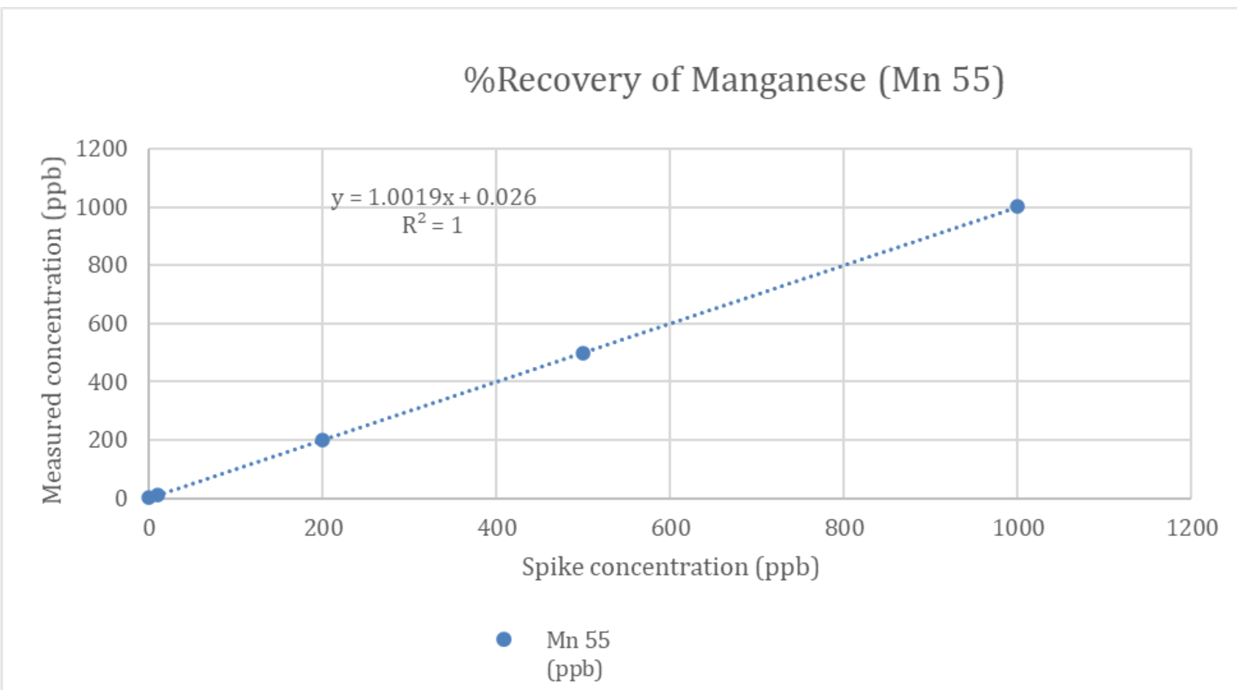
After microwave digestion, these composite samples were then combined into seven samples for organic analyses. Note, sample 3 (Boat Harbour Part 2) is partially made up of the same fish from sample 2 in order to meet sample mass requirements of the analyses.

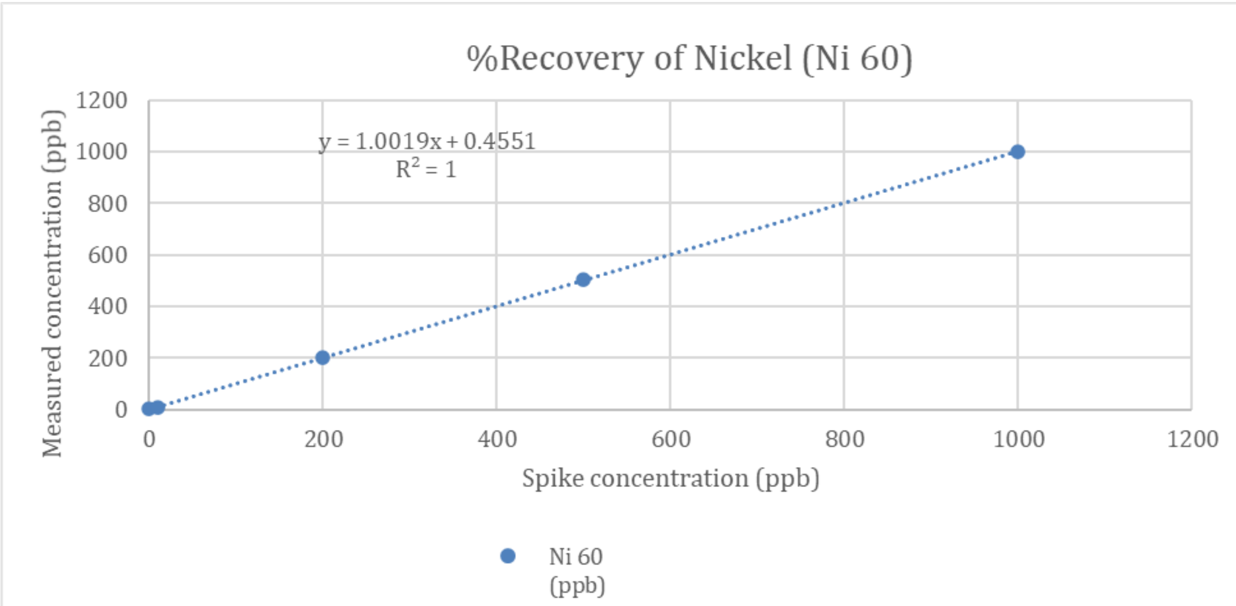
Sample number	Sample name	Fish ID numbers
1	Reference	REF-01-20
2	Boat Harbour Part 1	ST59-01, ST61-02 / ST61-01,03 / ST60-01 / ST47-01
3	Boat Harbour Part 2	ST19-01 / ST37-01 / ST36-01,02 / ST61-01,03 /

		ST60-01 / ST59-01, ST61-02 / ST47-01
4	EC	ECB18-01
5	Water Course	WC09-05 / WC09-02,03 / WC16-01,03,04,06
6	Wetland	WL04-01,02,03,04,05,06,07 / WL04-10,11,12,13,18,20 / WL04-08,09,14,16,19
7	EST	EST01-01, EST02-02, EST03-14, EST04-08, EST07-38, EST18-31, EST07-56 / EST15-01,02 / ECB03-01 / EST01-02,03, EST18-28

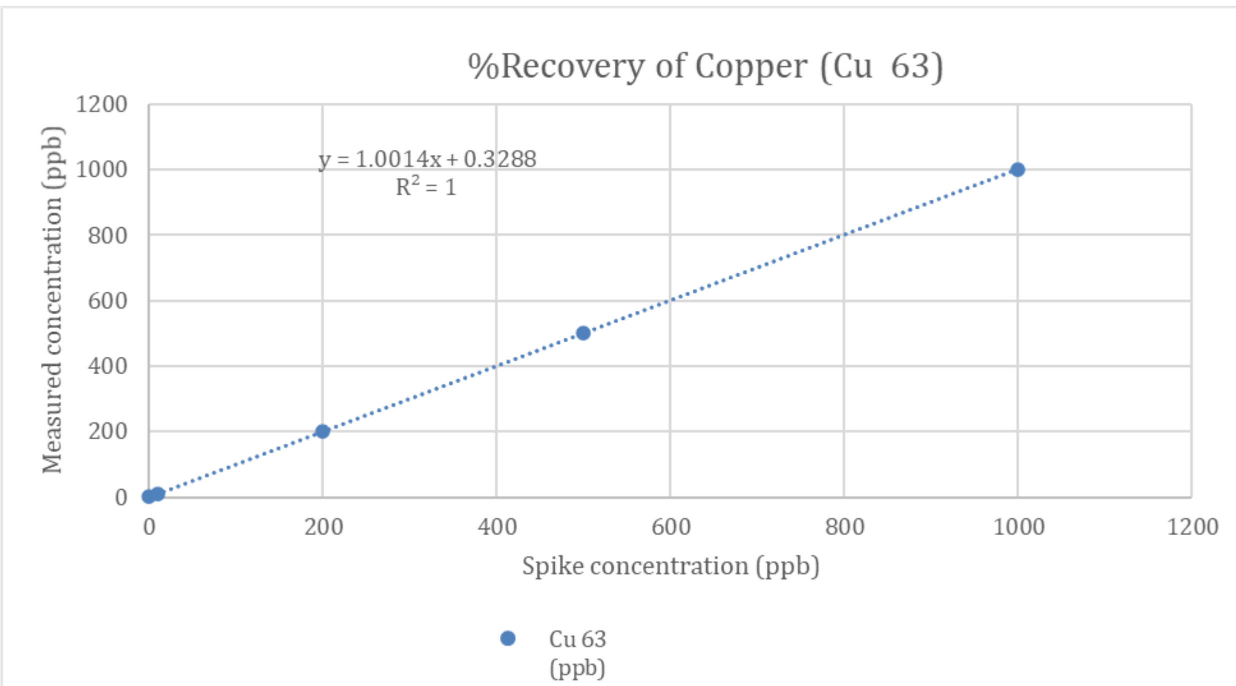
Appendix 2: The Recovery of Metals Analyzed by ICP-MS



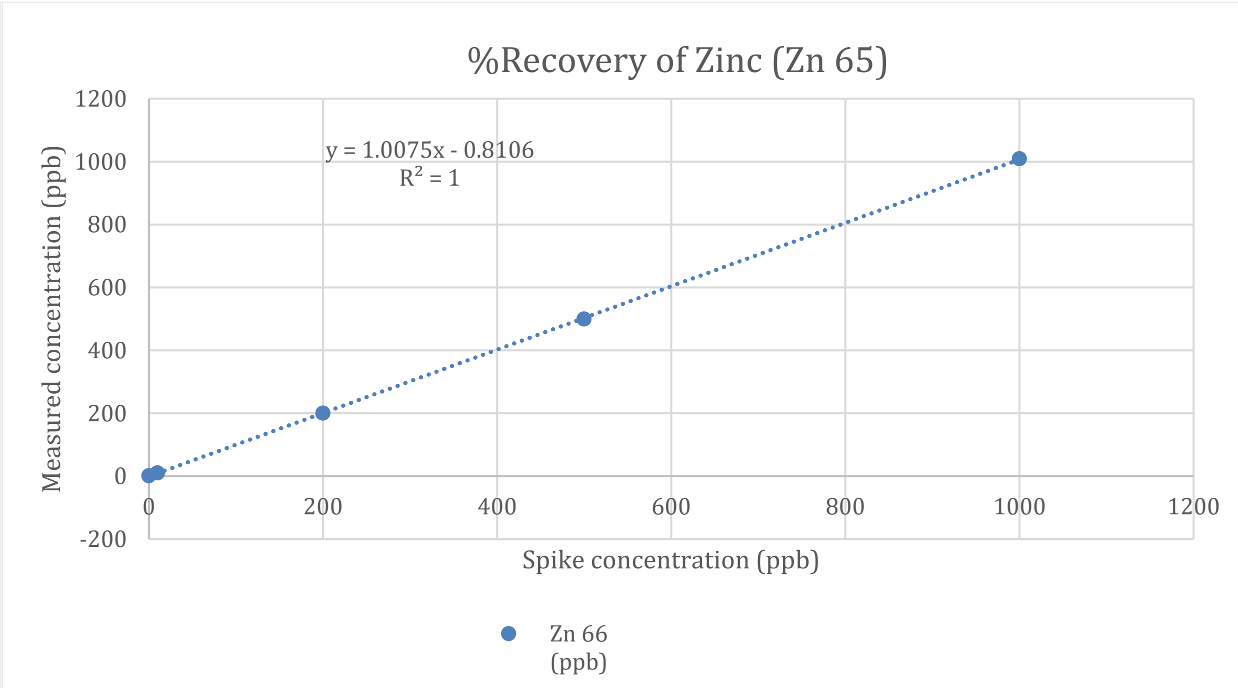




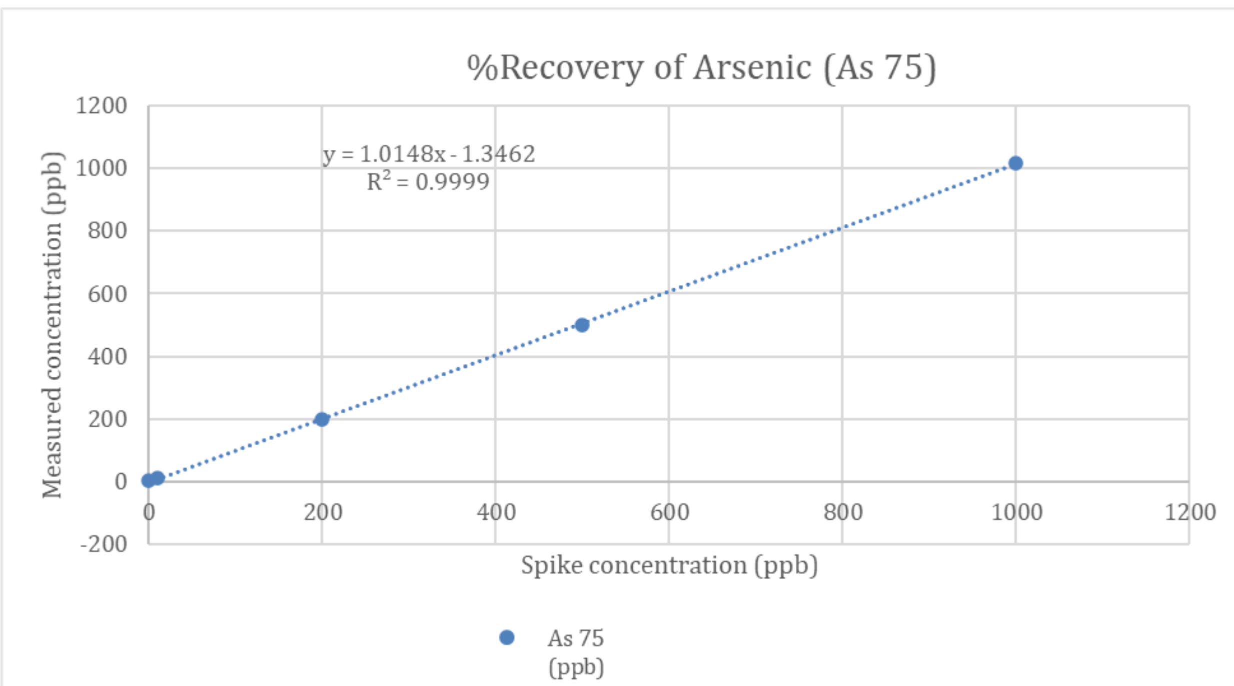
%Recovery of Nickel (Ni 60)
y = 1.0019x + 0.4551
R² = 1
Measured concentration (ppb)
1200
1000
800
600
400
200
0
0
200
400
600
800
1000
1200
Spike concentration (ppb)
Ni 60 (ppb)



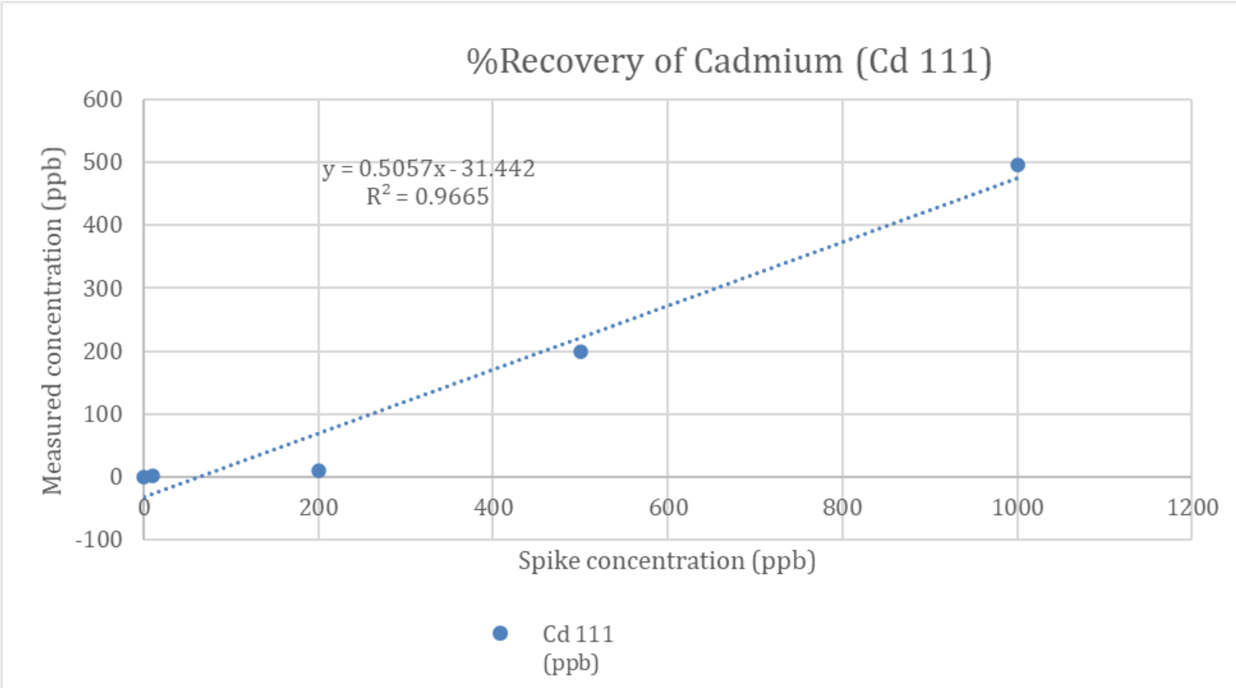
%Recovery of Copper (Cu 63)
y = 1.0014x + 0.3288
R² = 1
Measured concentration (ppb)
1200
1000
800
600
400
200
0
0
200
400
600
800
1000
1200
Spike concentration (ppb)
Cu 63 (ppb)



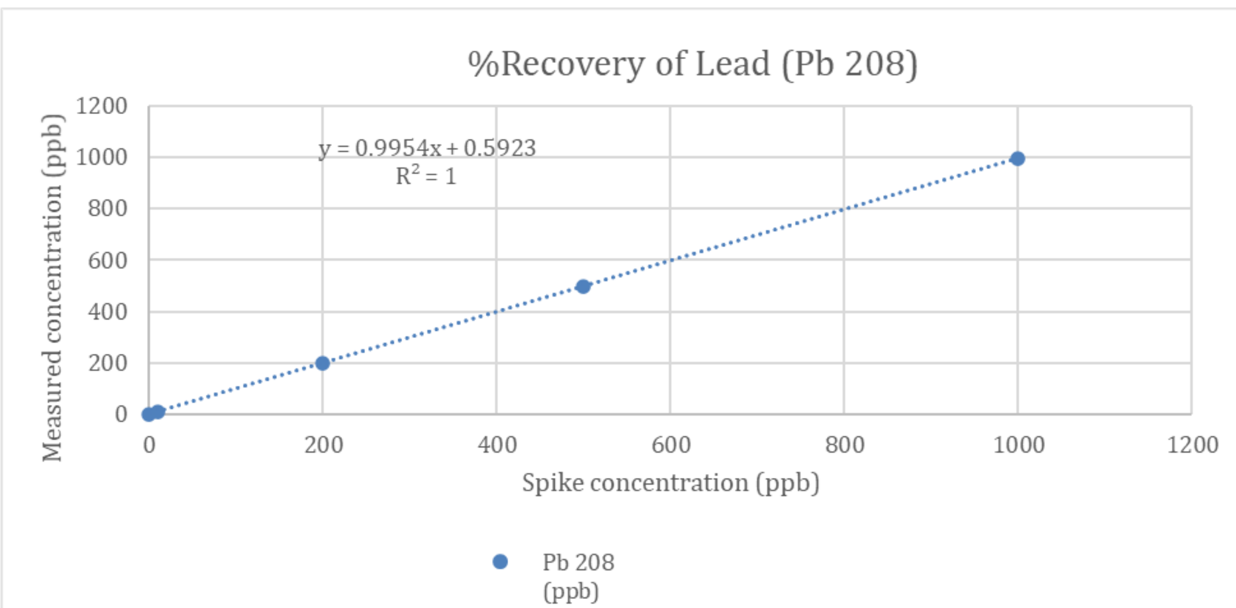
%Recovery of Zinc (Zn 65)
y = 1.0075x - 0.8106
R² = 1
Measured concentration (ppb)
Spike concentration (ppb)
1200
1000
800
600
400
200
0
-200
0
200
400
600
800
1000
1200
Zn 66 (ppb)



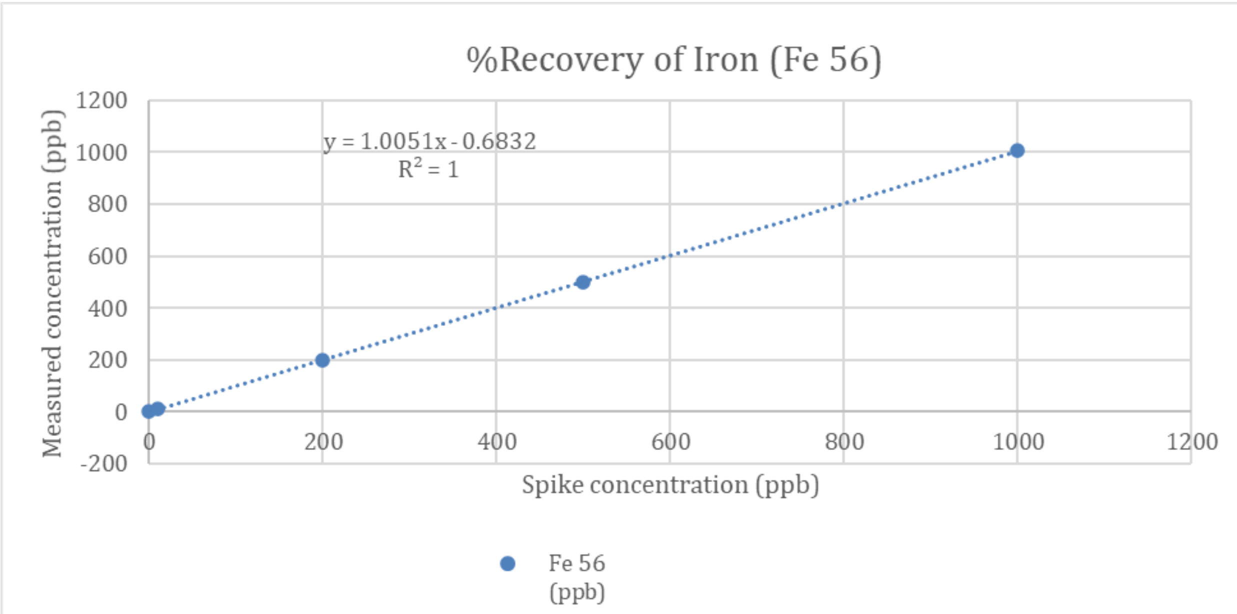
%Recovery of Arsenic (As 75)
y = 1.0148x - 1.3462
R² = 0.9999
Measured concentration (ppb)
Spike concentration (ppb)
1200
1000
800
600
400
200
0
-200
0
200
400
600
800
1000
1200
As 75 (ppb)



%Recovery of Cadmium (Cd 111)
y = 0.5057x - 31.442
R2 = 0.9665
Measured concentration (ppb)
600
500
400
300
200
100
0
-100
0
200
400
600
800
1000
1200
Spike concentration (ppb)
Cd 111 (ppb)



%Recovery of Lead (Pb 208)
y = 0.9954x + 0.5923
R2 = 1
Measured concentration (ppb)
1200
1000
800
600
400
200
0
0
200
400
600
800
1000
1200
Spike concentration (ppb)
Pb 208 (ppb)



%Recovery of Iron (Fe 56)
y = 1.0051x - 0.6832
R² = 1
Measured concentration (ppb)
1200
1000
800
600
400
200
0
-200
0
200
400
600
800
1000
1200
Spike concentration (ppb)
Fe 56 (ppb)

Appendix 3: Sample Calculation for Processing ICP-MS Data

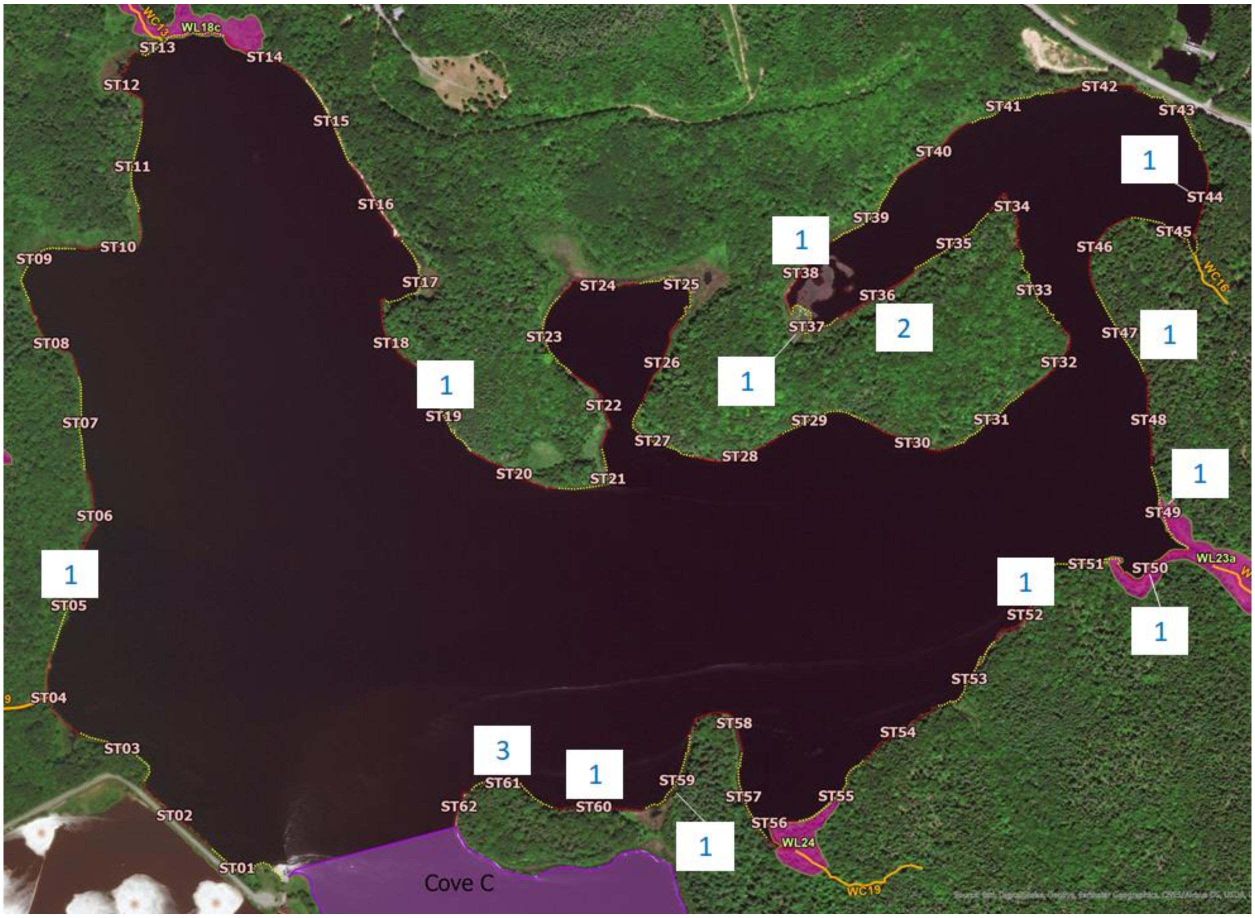
A sample fish tissue in Estuary cross basin has 22.96 ppb Chromium based on ICP-MS determination.

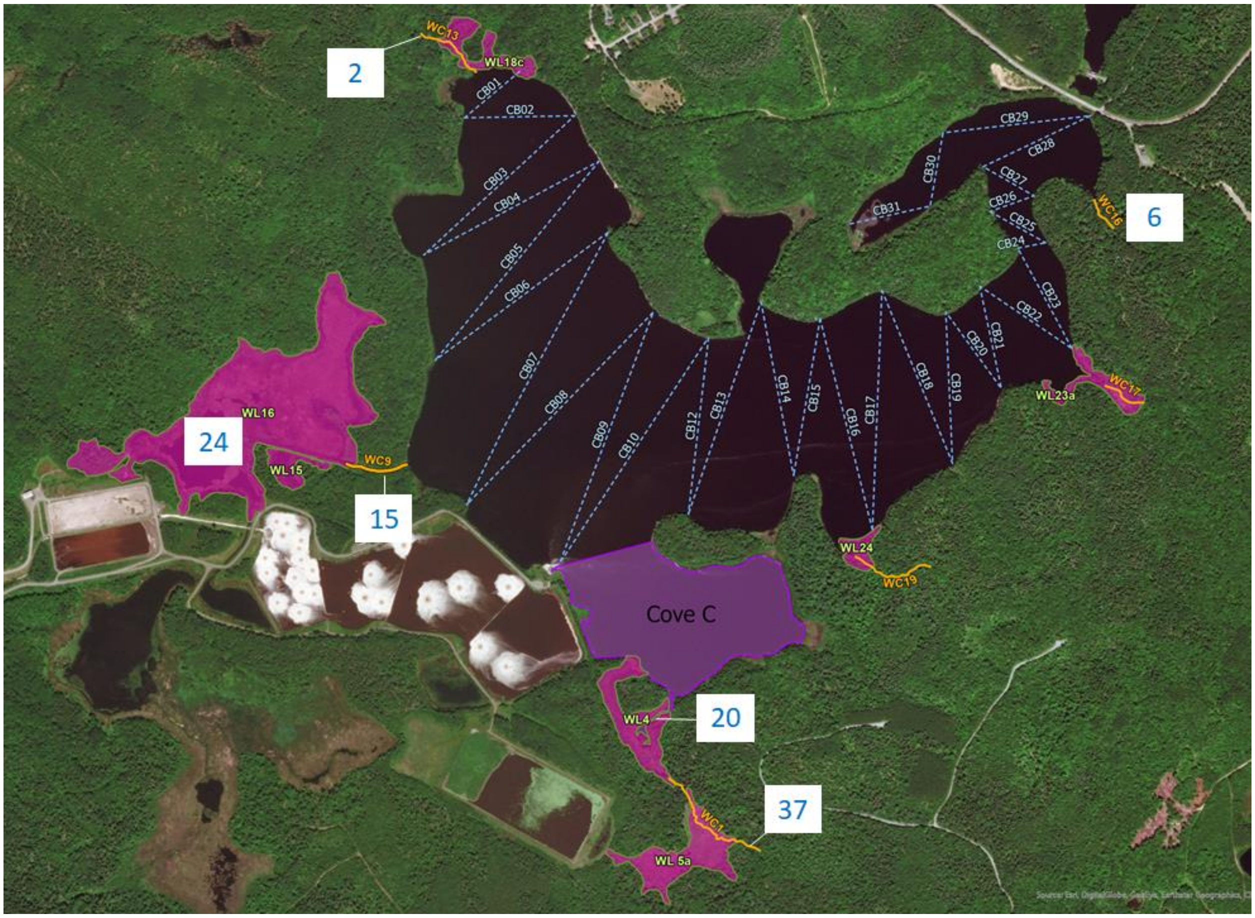
Taking in account the dilution factor of the digestion (0.5 g tissue in 10 ml of nitric acid) and 50X dilution:

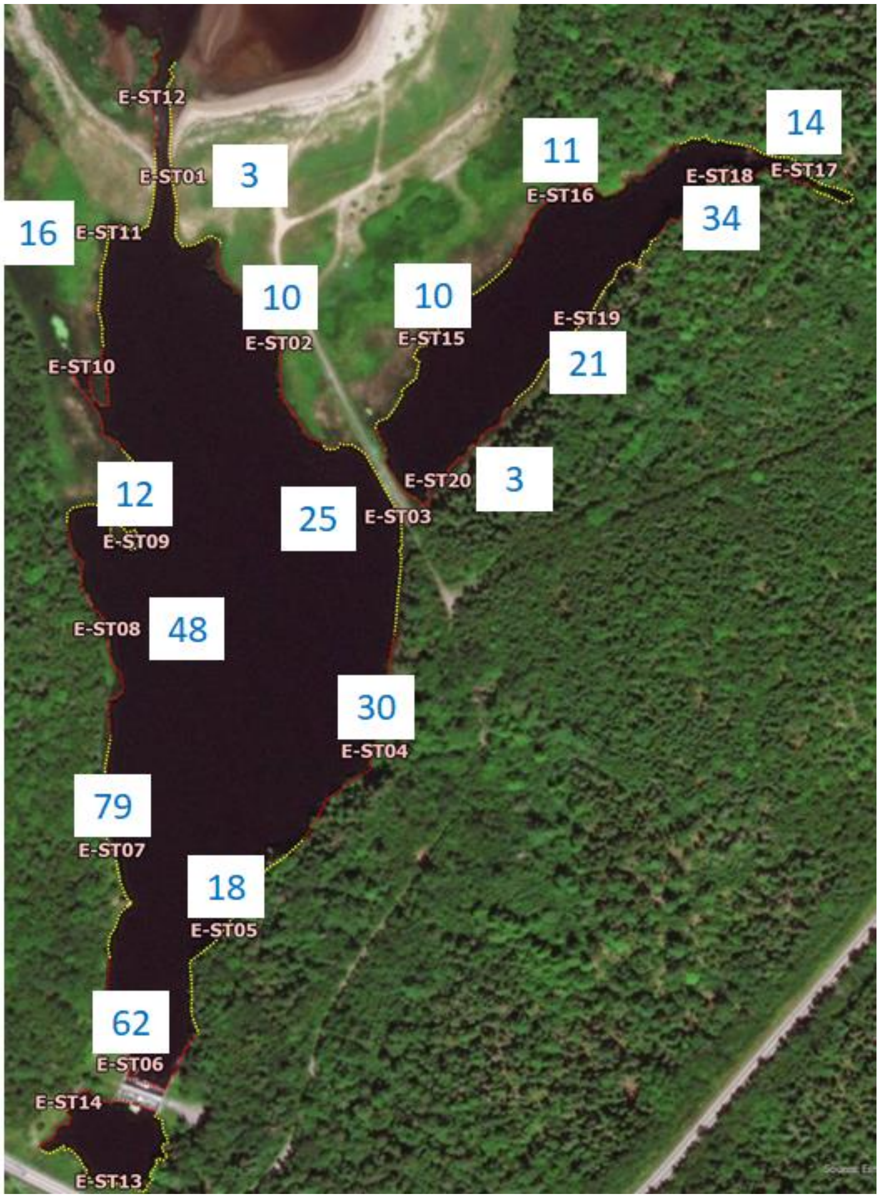
22.964326 ppb *20 *50= 22964.326 ppb= 22.964 ppm Chromium in 1g fish tissue

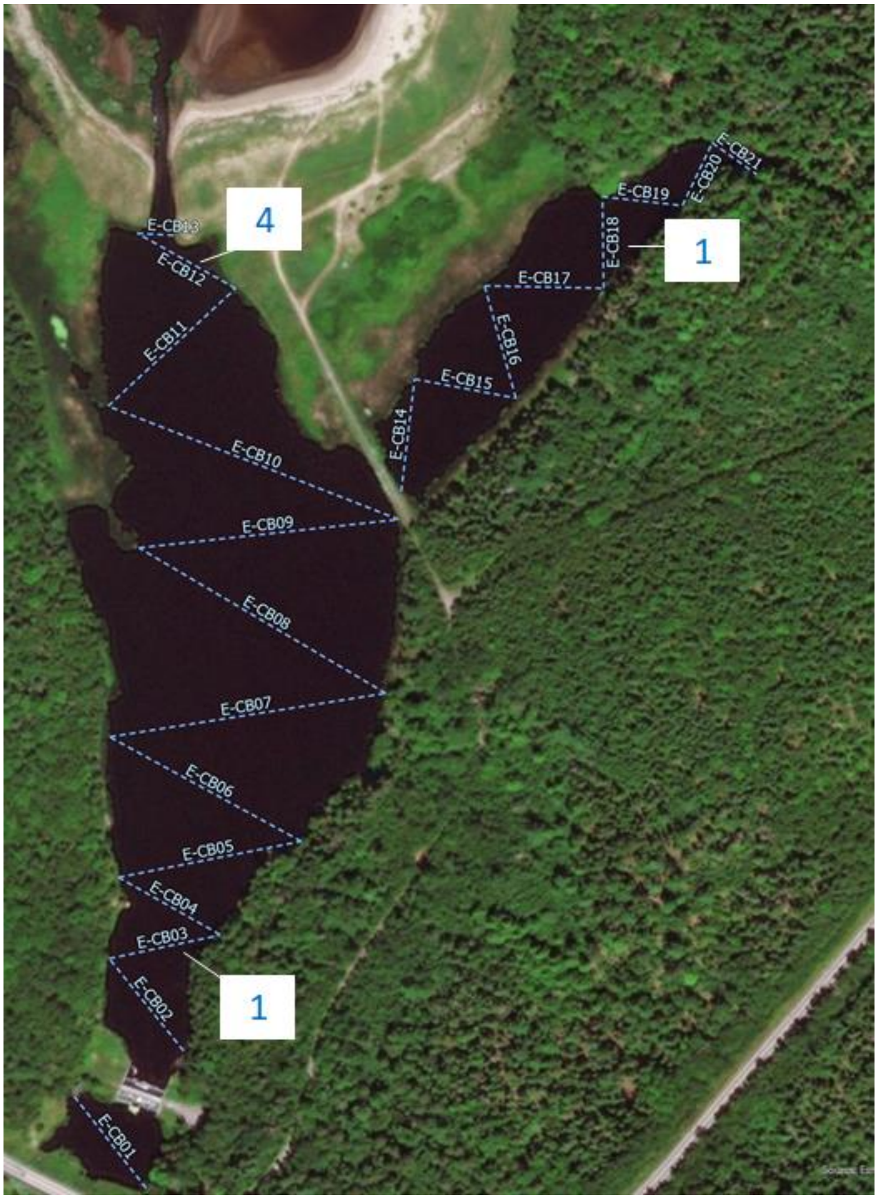
Appendix 4: Fish Capture Locations

Number of fish captured (blue numbers in white boxes) are shown for each transect/wetland and watercourse in Boat Harbour and surrounding areas.




2
WC13
WL18c
CB01
CB02
CB03
CB04
CB05
CB06
CB07
CB08
CB09
CB10
CB12
CB13
CB14
CB15
CB16
CB17
CB18
CB19
CB20
CB21
CB22
CB23
CB24
CB25
CB26
CB27
CB28
CB29
CB30
CB31
6
WC16
WC17
WL23a
WL16
24
WL15
WC9
15
WL24
WC19
Cove C
WL4
20
37
WC1
WL 5a


E-ST12
E-ST01
3
16
E-ST11
11
E-ST16
14
E-ST18
E-ST17
34
10
E-ST02
10
E-ST15
E-ST19
21
E-ST10
12
E-ST09
25
E-ST03
E-ST20
3
E-ST08
48
30
E-ST04
79
E-ST07
18
E-ST05
62
E-ST06
E-ST14
E-ST13


E-CB01
E-CB02
E-CB03
E-CB04
E-CB05
E-CB06
E-CB07
E-CB08
E-CB09
E-CB10
E-CB11
E-CB12
E-CB13
E-CB14
E-CB15
E-CB16
E-CB17
E-CB18
E-CB19
E-CB20
E-CB21
4
1
1

Appendix 5: Fish Tissue Organics Reports

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1435 Norjohn Court, Unit 1, Burlington, ON, Canada L7L 0E6
Phone: 905-331-3111, FAX: 905-331-4567

Certificate of Analysis

ALS Project Contact:	Claire Kocharakkal	**Client Name:**	Cape Breton University
ALS Project ID:	CBU100	**Client Address:**	1250 Grand Lake Road
ALS WO#:	L2419710		PO Box 5300
Date of Report	13-Mar-20		Sydney, NS B1P 6L2, Canada
Date of Sample Receipt	21-Feb-20	**Client Contact:**	Dr. Ken Oakes
		Client Project ID:	

COMMENTS: **PCDD/F by EPA 1613B via Isotope Dilution**

Certified by:

Ron McLeod, PhD, C.Chem.
Director, Air Toxics & Special Chemistries, Life Sciences

ALS Life Sciences

Sample Analysis Summary Report

Sample Name	REFERENCE SAMPLE #1	BOAT HARBOUR PART ONE #2	Duplicate	BOAT HARBOUR PART 2 #3	EC #4	WATER COURSE #5
ALS Sample ID	L2419710-1	L2419710-2	WG3280582-4	L2419710-3	L2419710-4	L2419710-5
Sample Size	10.30	6.82	6.38	10.27	10.09	7.23
Sample size units	g	g	g	g	g	g
Percent Moisture	n/a	n/a	n/a	n/a	n/a	n/a
Sample Matrix	Fish tissue	Fish tissue	QC	Fish tissue	Fish tissue	Fish tissue
Sampling Date	n/a	n/a	n/a	n/a	n/a	n/a
Extraction Date	27-Feb-20	27-Feb-20	27-Feb-20	27-Feb-20	27-Feb-20	27-Feb-20
Target Analytes	**pg/g wwt**	**pg/g wwt**	**pg/g wwt**	**pg/g wwt**	**pg/g wwt**	**pg/g wwt**
2,3,7,8-TCDD	<0.085	<0.21	<0.30	0.265	<0.10	0.237
1,2,3,7,8-PeCDD	<0.073	0.113	0.0972	0.0613	0.0624	<0.048
1,2,3,4,7,8-HxCDD	<0.055	<0.11	<0.071	<0.069	<0.040	<0.063
1,2,3,6,7,8-HxCDD	<0.052	<0.10	<0.071	<0.066	<0.058	<0.062
1,2,3,7,8,9-HxCDD	<0.053	<0.10	<0.070	<0.067	<0.047	<0.062
1,2,3,4,6,7,8-HpCDD	<0.18	0.257	0.257	<0.16	0.154	0.188
OCDD	1.37	1.51	0.922	<0.65	0.352	0.700
2,3,7,8-TCDF	<0.047	5.26	5.23	5.78	0.526	7.32
1,2,3,7,8-PeCDF	0.0806	<0.12	<0.13	<0.13	<0.054	0.120
2,3,4,7,8-PeCDF	0.0612	<0.091	<0.10	<0.095	0.0684	0.0705
1,2,3,4,7,8-HxCDF	<0.069	<0.070	<0.091	<0.039	<0.039	<0.041
1,2,3,6,7,8-HxCDF	<0.071	<0.071	<0.059	<0.043	<0.042	<0.041
2,3,4,6,7,8-HxCDF	<0.33	<0.069	<0.069	<0.038	<0.043	<0.039
1,2,3,7,8,9-HxCDF	<0.13	<0.091	<0.21	0.147	0.121	<0.18
1,2,3,4,6,7,8-HpCDF	0.414	<0.063	<0.11	0.0779	0.0793	<0.11
1,2,3,4,7,8,9-HpCDF	<0.045	<0.077	<0.048	<0.038	<0.034	0.0678
OCDF	0.358	<0.24	0.317	0.253	0.189	1.78
Extraction Standards	**% Rec**	**% Rec**	**% Rec**	**% Rec**	**% Rec**	**% Rec**
13C12-2,3,7,8-TCDD	80	74	79	69	68	78
13C12-1,2,3,7,8-PeCDD	114	103	110	99	88	101
13C12-1,2,3,4,7,8-HxCDD	87	84	82	71	71	78
13C12-1,2,3,6,7,8-HxCDD	80	79	74	73	65	79
13C12-1,2,3,4,6,7,8-HpCDD	103	88	86	82	70	81
13C12-OCDD	94	79	75	72	63	75
13C12-2,3,7,8-TCDF	94	84	93	79	80	91
13C12-1,2,3,7,8-PeCDF	123	101	114	102	90	105
13C12-2,3,4,7,8-PeCDF	124	106	119	107	91	108
13C12-1,2,3,4,7,8-HxCDF	103	89	91	83	75	89
13C12-1,2,3,6,7,8-HxCDF	100	86	88	79	71	85
13C12-2,3,4,6,7,8-HxCDF	89	89	90	83	74	88
13C12-1,2,3,7,8,9-HxCDF	88	84	85	79	74	84
13C12-1,2,3,4,6,7,8-HpCDF	110	100	96	91	80	95
13C12-1,2,3,4,7,8,9-HpCDF	124	102	100	94	82	94
Cleanup Standard						
37Cl4-2,3,7,8-TCDD (Cleanup)	82	69	76	71	71	77
Homologue Group Totals	**pg/g wwt**	**pg/g wwt**	**pg/g wwt**	**pg/g wwt**	**pg/g wwt**	**pg/g wwt**
Total-TCDD	<0.085	<0.21	<0.15	0.265	<0.10	0.237
Total-PeCDD	<0.045	0.113	0.0972	0.0613	0.0624	<0.048
Total-HxCDD	<0.055	<0.11	<0.071	<0.069	<0.040	<0.063
Total-HpCDD	0.158	0.257	0.428	<0.044	0.231	0.188
Total-TCDF	<0.047	5.55	5.41	5.78	0.526	7.32
Total-PeCDF	0.142	<0.12	<0.053	<0.061	0.0684	0.189
Total-HxCDF	0.146	<0.091	<0.063	0.147	0.121	<0.051
Total-HpCDF	0.414	<0.077	<0.048	0.0779	0.0793	0.0678
Toxic Equivalency - (WHO 2005)						
Lower Bound PCDD/F TEQ (WHO 2005)	0.0254	0.642	0.623	0.920	0.150	0.997
Mid Point PCDD/F TEQ (WHO 2005)	0.207	0.899	1.01	0.970	0.223	1.06
Upper Bound PCDD/F TEQ (WHO 2005)	0.266	0.945	1.02	0.987	0.279	1.09

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Sample Analysis Summary Report

Sample Name	WETLAND #6	ESTUARY #7
ALS Sample ID	L2419710-6	L2419710-7
Sample Size	1.11	10.07
Sample size units	g	g
Percent Moisture	n/a	n/a
Sample Matrix	Fish tissue	Fish tissue
Sampling Date	n/a	n/a
Extraction Date	27-Feb-20	27-Feb-20
Target Analytes	**pg/g wwt**	**pg/g wwt**
2,3,7,8-TCDD	<2.2	<0.14
1,2,3,7,8-PeCDD	<0.76	0.0725
1,2,3,4,7,8-HxCDD	<1.3	<0.082
1,2,3,6,7,8-HxCDD	<1.4	<0.082
1,2,3,7,8,9-HxCDD	<1.3	<0.081
1,2,3,4,6,7,8-HpCDD	1.71	0.214
OCDD	<4.2	0.975
2,3,7,8-TCDF	48.0	2.08
1,2,3,7,8-PeCDF	<0.69	0.0864
2,3,4,7,8-PeCDF	<0.52	<0.039
1,2,3,4,7,8-HxCDF	<0.53	<0.059
1,2,3,6,7,8-HxCDF	<0.60	<0.055
2,3,4,6,7,8-HxCDF	<0.56	<0.12
1,2,3,7,8,9-HxCDF	<1.5	<0.095
1,2,3,4,6,7,8-HpCDF	<0.69	0.127
1,2,3,4,7,8,9-HpCDF	<0.80	<0.056
OCDF	3.80	<0.46
Extraction Standards	**% Rec**	**% Rec**
13C12-2,3,7,8-TCDD	38	67
13C12-1,2,3,7,8-PeCDD	50	89
13C12-1,2,3,4,7,8-HxCDD	40	79
13C12-1,2,3,6,7,8-HxCDD	38	74
13C12-1,2,3,4,6,7,8-HpCDD	43	86
13C12-OCDD	38	80
13C12-2,3,7,8-TCDF	46	78
13C12-1,2,3,7,8-PeCDF	52	92
13C12-2,3,4,7,8-PeCDF	54	95
13C12-1,2,3,4,7,8-HxCDF	46	88
13C12-1,2,3,6,7,8-HxCDF	41	81
13C12-2,3,4,6,7,8-HxCDF	43	85
13C12-1,2,3,7,8,9-HxCDF	43	77
13C12-1,2,3,4,6,7,8-HpCDF	47	94
13C12-1,2,3,4,7,8,9-HpCDF	52	100
Cleanup Standard		
37Cl4-2,3,7,8-TCDD (Cleanup)	69	72
Homologue Group Totals	**pg/g wwt**	**pg/g wwt**
Total-TCDD	<2.2	<0.14
Total-PeCDD	<0.76	0.0725
Total-HxCDD	<1.4	<0.082
Total-HpCDD	1.71	0.214
Total-TCDF	48.0	2.08
Total-PeCDF	<0.69	0.0864
Total-HxCDF	<0.70	0.270
Total-HpCDF	<0.80	0.127
Toxic Equivalency - (WHO 2005)		
Lower Bound PCDD/F TEQ (WHO 2005)	4.82	0.287
Mid Point PCDD/F TEQ (WHO 2005)	6.83	0.408
Upper Bound PCDD/F TEQ (WHO 2005)	8.69	0.497

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Quality Control Summary Report

Sample Name	Method/Corn Oil Blank	Method/Reagent Blank	Laboratory Control Sample
ALS Sample ID	WG3280582-1	WG3280582-5	WG3280582-2
Sample Size	10.00	10.00	1
Sample size units	g	g	n/a
Percent Moisture	n/a	n/a	n/a
Sample Matrix	QC	QC	QC
Sampling Date	n/a	n/a	n/a
Extraction Date	27-Feb-20	27-Feb-20	27-Feb-20
Target Analytes	**pg/g wwt**	**pg/g wwt**	**% Rec**
2,3,7,8-TCDD	<0.10	<0.18	109
1,2,3,7,8-PeCDD	<0.047	<0.060	110
1,2,3,4,7,8-HxCDD	<0.059	<0.088	107
1,2,3,6,7,8-HxCDD	0.0780	0.0750	107
1,2,3,7,8,9-HxCDD	0.0650	<0.084	110
1,2,3,4,6,7,8-HpCDD	<0.092	0.115	109
OCDD	0.334	0.395	102
2,3,7,8-TCDF	<0.058	<0.095	107
1,2,3,7,8-PeCDF	<0.087	<0.088	110
2,3,4,7,8-PeCDF	0.0680	<0.054	101
1,2,3,4,7,8-HxCDF	<0.046	<0.061	108
1,2,3,6,7,8-HxCDF	<0.045	<0.046	110
2,3,4,6,7,8-HxCDF	<0.043	<0.051	107
1,2,3,7,8,9-HxCDF	0.126	<0.099	114
1,2,3,4,6,7,8-HpCDF	<0.068	<0.11	109
1,2,3,4,7,8,9-HpCDF	<0.060	<0.078	100
OCDF	<0.19	0.346	109
Extraction Standards	**% Rec**	**% Rec**	**% Rec**
13C12-2,3,7,8-TCDD	72	44	45
13C12-1,2,3,7,8-PeCDD	88	62	54
13C12-1,2,3,4,7,8-HxCDD	81	61	49
13C12-1,2,3,6,7,8-HxCDD	80	56	47
13C12-1,2,3,4,6,7,8-HpCDD	90	63	57
13C12-OCDD	72	54	46
13C12-2,3,7,8-TCDF	83	50	51
13C12-1,2,3,7,8-PeCDF	93	62	57
13C12-2,3,4,7,8-PeCDF	94	65	58
13C12-1,2,3,4,7,8-HxCDF	87	69	52
13C12-1,2,3,6,7,8-HxCDF	86	65	51
13C12-2,3,4,6,7,8-HxCDF	92	65	54
13C12-1,2,3,7,8,9-HxCDF	86	62	53
13C12-1,2,3,4,6,7,8-HpCDF	104	68	63
13C12-1,2,3,4,7,8,9-HpCDF	106	72	66
Cleanup Standard			
37Cl4-2,3,7,8-TCDD (Cleanup)	70	46	69
Homologue Group Totals	**pg/g wwt**	**pg/g wwt**	
Total-TCDD	<0.10	<0.18	
Total-PeCDD	<0.042	<0.060	
Total-HxCDD	0.143	0.0750	
Total-HpCDD	<0.032	0.115	
Total-TCDF	<0.058	<0.095	
Total-PeCDF	0.0680	<0.058	
Total-HxCDF	0.126	<0.051	
Total-HpCDF	<0.032	<0.078	
Toxic Equivalency - (WHO 2005)			
Lower Bound PCDD/F TEQ (WHO 2005)	0.0474	0.00887	
Mid Point PCDD/F TEQ (WHO 2005)	0.162	0.197	
Upper Bound PCDD/F TEQ (WHO 2005)	0.224	0.322	

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Sample Analysis Report

Sample Name	**REFERENCE SAMPLE #1**	Sampling Date	n/a
ALS Sample ID	L2419710-1	Extraction Date	27-Feb-20
Analysis Method	EPA 1613B	Sample Size	10.30 g
Analysis Type	Sample	Percent Moisture	n/a
Sample Matrix	Fish tissue	Split Ratio	2

Approved:
T.Patterson
--e-signature--
05-Mar-2020

Run Information	**Run 1**
Filename	7-200304A25
Run Date	04-Mar-20 23:33
Final Volume	20 uL
Dilution Factor	1
Analysis Units	pg/g wwt
Instrument - Column	HRMS-7 DB5MSUST780127H

Target Analytes	**TEF (WHO 2005)**	**Ret. Time**	**Conc. g/g wwt**	**EDL /g wwt**	**Flags**	**EMPC g wwt**	**LQL**
2,3,7,8-TCDD	1	NotFnd	<0.085	0.085	U		1.9
1,2,3,7,8-PeCDD	1	32.04	<0.073	0.045	M,J,R	0.073	9.7
1,2,3,4,7,8-HxCDD	0.1	NotFnd	<0.055	0.055	U		9.7
1,2,3,6,7,8-HxCDD	0.1	NotFnd	<0.052	0.052	U		9.7
1,2,3,7,8,9-HxCDD	0.1	NotFnd	<0.053	0.053	U		9.7
1,2,3,4,6,7,8-HpCDD	0.01	35.77	<0.18	0.052	M,J,R	0.18	9.7
OCDD	0.0003	37.26	1.37	0.051	J,B		19
2,3,7,8-TCDF	0.1	NotFnd	<0.047	0.047	U		1.9
1,2,3,7,8-PeCDF	0.03	31.08	0.0806	0.041	M,J		9.7
2,3,4,7,8-PeCDF	0.3	31.83	0.0612	0.032	M,J,B		9.7
1,2,3,4,7,8-HxCDF	0.1	NotFnd	<0.069	0.069	M,U		9.7
1,2,3,6,7,8-HxCDF	0.1	NotFnd	<0.071	0.071	U		9.7
2,3,4,6,7,8-HxCDF	0.1	34.02	<0.33	0.077	M,J,R	0.33	9.7
1,2,3,7,8,9-HxCDF	0.1	34.44	<0.13	0.094	M,J,R	0.13	9.7
1,2,3,4,6,7,8-HpCDF	0.01	35.24	0.414	0.040	M,J		9.7
1,2,3,4,7,8,9-HpCDF	0.01	36.02	<0.045	0.045	M,J,R	0.045	9.7
OCDF	0.0003	37.36	0.358	0.052	M,J		19

Extraction Standards	**pg**		**% Rec**	**Limits**
13C12-2,3,7,8-TCDD	4000	27.84	80	25-164
13C12-1,2,3,7,8-PeCDD	4000	32.02	114	25-181
13C12-1,2,3,4,7,8-HxCDD	4000	34.10	87	32-141
13C12-1,2,3,6,7,8-HxCDD	4000	34.15	80	28-130
13C12-1,2,3,4,6,7,8-HpCDD	4000	35.76	103	23-140
13C12-OCDD	8000	37.26	94	17-157
13C12-2,3,7,8-TCDF	4000	26.93	94	24-169
13C12-1,2,3,7,8-PeCDF	4000	31.07	123	24-185
13C12-2,3,4,7,8-PeCDF	4000	31.80	124	21-178
13C12-1,2,3,4,7,8-HxCDF	4000	33.60	103	26-152
13C12-1,2,3,6,7,8-HxCDF	4000	33.66	100	26-123
13C12-2,3,4,6,7,8-HxCDF	4000	34.00	89	29-147
13C12-1,2,3,7,8,9-HxCDF	4000	34.42	88	28-136
13C12-1,2,3,4,6,7,8-HpCDF	4000	35.20	110	28-143
13C12-1,2,3,4,7,8,9-HpCDF	4000	36.01	124	26-138
Cleanup Standard	**pg**			
37Cl4-2,3,7,8-TCDD (Cleanup)	80	27.87	82	35-197

Homologue Group Totals	**# peaks**	**Conc. g/g wwt**	**EDL /g wwt**		
Total-TCDD	0.00	<0.085	0.085	U	1.9
Total-PeCDD	0.00	<0.045	0.045	U	9.7
Total-HxCDD	0.00	<0.055	0.055	U	9.7
Total-HpCDD	1.00	0.158	0.052		9.7
Total-TCDF	0.00	<0.047	0.047	U	1.9
Total-PeCDF	2.00	0.142	0.041		9.7
Total-HxCDF	2.00	0.146	0.094		9.7
Total-HpCDF	1.00	0.414	0.045		9.7

Toxic Equivalency - (WHO 2005)	**pg/g wwt**
Lower Bound PCDD/F TEQ (WHO 2005)	0.0254
Mid Point PCDD/F TEQ (WHO 2005)	0.207
Upper Bound PCDD/F TEQ (WHO 2005)	0.266

EDL	Indicates the Estimated Detection Limit, based on the measured background noise for this target in this sample.
TEF	Indicates the Toxic Equivalency Factor
TEQ	Indicates the Toxic Equivalenc
M	Indicates that a peak has been manually integrated.
U	Indicates that this compound was not detected above the EDL.
J	Indicates that a target analyte was detected below the calibrated range.
R	Indicates that the ion abundance ratio for this compound did not meet the acceptance criterion.
B	Indicates that this target was detected in the blank at greater than 10% of the sample concentration.
LQL	Lower Quantification Limit, based on the lowest calibration level corrected for sample size, splits and dilutions.
EMPC	Estimated Maximum Possible Concentration – elevated detection limit due to interference or positive id criterion failure

ALS Life Sciences

Sample Analysis Report

Sample Name	**BOAT HARBOUR PART ONE #2**	Sampling Date	n/a		
ALS Sample ID	L2419710-2	Extraction Date	27-Feb-20		Approved:
Analysis Method	EPA 1613B	Sample Size	6.82	g	*T.Patterson*
Analysis Type	Sample	Percent Moisture	n/a		--e-signature--
Sample Matrix	Fish tissue	Split Ratio	2		05-Mar-2020

Run Information	**Run 1**
Filename	7-200304A27
Run Date	05-Mar-20 00:58
Final Volume	20 uL
Dilution Factor	1
Analysis Units	pg/g wwt
Instrument - Column	HRMS-7 DB5MSUST780127H

Target Analytes	**TEF (WHO 2005)**	**Ret. Time**	**Conc. g/g wwt**	**EDL /g wwt**	**Flags**	**EMPC g wwt**	**LQL**
2,3,7,8-TCDD	1	27.92	<0.21	0.21	M,J,R	0.21	2.9
1,2,3,7,8-PeCDD	1	32.03	0.113	0.067	M,J		15
1,2,3,4,7,8-HxCDD	0.1	NotFnd	<0.11	0.11	U		15
1,2,3,6,7,8-HxCDD	0.1	NotFnd	<0.10	0.10	U		15
1,2,3,7,8,9-HxCDD	0.1	NotFnd	<0.10	0.10	U		15
1,2,3,4,6,7,8-HpCDD	0.01	35.77	0.257	0.073	J		15
OCDD	0.0003	37.27	1.51	0.063	J,B		29
2,3,7,8-TCDF	0.1	26.98	5.26	0.14			2.9
1,2,3,7,8-PeCDF	0.03	NotFnd	<0.12	0.12	U		15
2,3,4,7,8-PeCDF	0.3	NotFnd	<0.091	0.091	U		15
1,2,3,4,7,8-HxCDF	0.1	33.60	<0.070	0.070	M,U		15
1,2,3,6,7,8-HxCDF	0.1	NotFnd	<0.071	0.071	U		15
2,3,4,6,7,8-HxCDF	0.1	NotFnd	<0.069	0.069	U		15
1,2,3,7,8,9-HxCDF	0.1	34.42	<0.091	0.091	M,U	0.084	15
1,2,3,4,6,7,8-HpCDF	0.01	NotFnd	<0.063	0.063	U		15
1,2,3,4,7,8,9-HpCDF	0.01	NotFnd	<0.077	0.077	U		15
OCDF	0.0003	37.36	<0.24	0.10	M,J,R	0.24	29

Extraction Standards	**pg**		**% Rec**	**Limits**
13C12-2,3,7,8-TCDD	4000	27.87	74	25-164
13C12-1,2,3,7,8-PeCDD	4000	32.03	103	25-181
13C12-1,2,3,4,7,8-HxCDD	4000	34.09	84	32-141
13C12-1,2,3,6,7,8-HxCDD	4000	34.15	79	28-130
13C12-1,2,3,4,6,7,8-HpCDD	4000	35.76	88	23-140
13C12-OCDD	8000	37.26	79	17-157
13C12-2,3,7,8-TCDF	4000	26.96	84	24-169
13C12-1,2,3,7,8-PeCDF	4000	31.08	101	24-185
13C12-2,3,4,7,8-PeCDF	4000	31.82	106	21-178
13C12-1,2,3,4,7,8-HxCDF	4000	33.60	89	26-152
13C12-1,2,3,6,7,8-HxCDF	4000	33.67	86	26-123
13C12-2,3,4,6,7,8-HxCDF	4000	34.00	89	29-147
13C12-1,2,3,7,8,9-HxCDF	4000	34.41	84	28-136
13C12-1,2,3,4,6,7,8-HpCDF	4000	35.20	100	28-143
13C12-1,2,3,4,7,8,9-HpCDF	4000	36.01	102	26-138
Cleanup Standard	**pg**			
37Cl4-2,3,7,8-TCDD (Cleanup)	80	27.90	69	35-197

Homologue Group Totals	**# peaks**	**Conc. g/g wwt**	**EDL /g wwt**		
Total-TCDD	0.00	<0.21	0.21	U	2.9
Total-PeCDD	1.00	0.113	0.067		15
Total-HxCDD	0.00	<0.11	0.11	U	15
Total-HpCDD	1.00	0.257	0.073		15
Total-TCDF	2.00	5.55	0.14		2.9
Total-PeCDF	0.00	<0.12	0.12	U	15
Total-HxCDF	0.00	<0.091	0.091	U	15
Total-HpCDF	0.00	<0.077	0.077	U	15

Toxic Equivalency - (WHO 2005)	**pg/g wwt**
Lower Bound PCDD/F TEQ (WHO 2005)	0.642
Mid Point PCDD/F TEQ (WHO 2005)	0.899
Upper Bound PCDD/F TEQ (WHO 2005)	0.945

EDL	Indicates the Estimated Detection Limit, based on the measured background noise for this target in this sample.
TEF	Indicates the Toxic Equivalency Factor TEQ Indicates the Toxic Equivalenc
M	Indicates that a peak has been manually integrated.
U	Indicates that this compound was not detected above the EDL.
J	Indicates that a target analyte was detected below the calibrated range.
R	Indicates that the ion abundance ratio for this compound did not meet the acceptance criterion.
B	Indicates that this target was detected in the blank at greater than 10% of the sample concentration.
LQL	Lower Quantification Limit, based on the lowest calibration level corrected for sample size, splits and dilutions.
EMPC	Estimated Maximum Possible Concentration – elevated detection limit due to interference or positive id criterion failure

ALS Life Sciences

Sample Analysis Report

Sample Name	**Duplicate**	Sampling Date	n/a
ALS Sample ID	WG3280582-4	Extraction Date	27-Feb-20
Analysis Method	EPA 1613B	Sample Size	6.38 g
Analysis Type	Sample	Percent Moisture	n/a
Sample Matrix	QC	Split Ratio	2

Approved:
T.Patterson
--e-signature--
05-Mar-2020

Run Information	**Run 1**
Filename	7-200304A26
Run Date	05-Mar-20 00:16
Final Volume	20 uL
Dilution Factor	1
Analysis Units	pg/g wwt
Instrument - Column	HRMS-7 DB5MSUST780127H

Target Analytes	**TEF (WHO 2005)**	**Ret. Time**	**Conc. g/g wwt**	**EDL /g wwt**	**Flags**	**EMPC g wwt**	**LQL**
2,3,7,8-TCDD	1	27.87	<0.30	0.15	M,J,R	0.30	3.1
1,2,3,7,8-PeCDD	1	32.04	0.0972	0.056	J		16
1,2,3,4,7,8-HxCDD	0.1	NotFnd	<0.071	0.071	U		16
1,2,3,6,7,8-HxCDD	0.1	NotFnd	<0.071	0.071	U		16
1,2,3,7,8,9-HxCDD	0.1	NotFnd	<0.070	0.070	U		16
1,2,3,4,6,7,8-HpCDD	0.01	35.76	0.257	0.057	M,J		16
OCDD	0.0003	37.26	0.922	0.058	J,B		31
2,3,7,8-TCDF	0.1	26.95	5.23	0.083			3.1
1,2,3,7,8-PeCDF	0.03	31.08	<0.13	0.053	M,J,R	0.13	16
2,3,4,7,8-PeCDF	0.3	31.80	<0.10	0.040	M,J,R	0.10	16
1,2,3,4,7,8-HxCDF	0.1	33.60	<0.091	0.049	M,J,R	0.091	16
1,2,3,6,7,8-HxCDF	0.1	33.66	<0.059	0.050	M,J,R	0.059	16
2,3,4,6,7,8-HxCDF	0.1	34.01	<0.069	0.048	M,J,R	0.069	16
1,2,3,7,8,9-HxCDF	0.1	34.43	<0.21	0.063	M,J,R	0.21	16
1,2,3,4,6,7,8-HpCDF	0.01	35.20	<0.11	0.041	M,J,R	0.11	16
1,2,3,4,7,8,9-HpCDF	0.01	NotFnd	<0.048	0.048	U		16
OCDF	0.0003	37.34	0.317	0.074	M,J		31

Extraction Standards	**pg**		**% Rec**	**Limits**
13C12-2,3,7,8-TCDD	4000	27.84	79	25-164
13C12-1,2,3,7,8-PeCDD	4000	32.02	110	25-181
13C12-1,2,3,4,7,8-HxCDD	4000	34.08	82	32-141
13C12-1,2,3,6,7,8-HxCDD	4000	34.13	74	28-130
13C12-1,2,3,4,6,7,8-HpCDD	4000	35.75	86	23-140
13C12-OCDD	8000	37.25	75	17-157
13C12-2,3,7,8-TCDF	4000	26.92	93	24-169
13C12-1,2,3,7,8-PeCDF	4000	31.07	114	24-185
13C12-2,3,4,7,8-PeCDF	4000	31.79	119	21-178
13C12-1,2,3,4,7,8-HxCDF	4000	33.59	91	26-152
13C12-1,2,3,6,7,8-HxCDF	4000	33.65	88	26-123
13C12-2,3,4,6,7,8-HxCDF	4000	33.98	90	29-147
13C12-1,2,3,7,8,9-HxCDF	4000	34.41	85	28-136
13C12-1,2,3,4,6,7,8-HpCDF	4000	35.19	96	28-143
13C12-1,2,3,4,7,8,9-HpCDF	4000	36.00	100	26-138
Cleanup Standard	**pg**			
37Cl4-2,3,7,8-TCDD (Cleanup)	80	27.86	76	35-197

Homologue Group Totals	**# peaks**	**Conc. g/g wwt**	**EDL /g wwt**		**LQL**
Total-TCDD	0.00	<0.15	0.15	U	3.1
Total-PeCDD	1.00	0.0972	0.056		16
Total-HxCDD	0.00	<0.071	0.071	U	16
Total-HpCDD	2.00	0.428	0.057		16
Total-TCDF	2.00	5.41	0.083		3.1
Total-PeCDF	0.00	<0.053	0.053	U	16
Total-HxCDF	0.00	<0.063	0.063	U	16
Total-HpCDF	0.00	<0.048	0.048	U	16

Toxic Equivalency - (WHO 2005)	**pg/g wwt**
Lower Bound PCDD/F TEQ (WHO 2005)	0.623
Mid Point PCDD/F TEQ (WHO 2005)	1.01
Upper Bound PCDD/F TEQ (WHO 2005)	1.02

EDL	Indicates the Estimated Detection Limit, based on the measured background noise for this target in this sample.
TEF	Indicates the Toxic Equivalency Factor — TEQ: Indicates the Toxic Equivalenc
M	Indicates that a peak has been manually integrated.
U	Indicates that this compound was not detected above the EDL.
J	Indicates that a target analyte was detected below the calibrated range.
R	Indicates that the ion abundance ratio for this compound did not meet the acceptance criterion.
B	Indicates that this target was detected in the blank at greater than 10% of the sample concentration.
LQL	Lower Quantification Limit, based on the lowest calibration level corrected for sample size, splits and dilutions.
EMPC	Estimated Maximum Possible Concentration – elevated detection limit due to interference or positive id criterion failure

ALS Life Sciences

Sample Analysis Report

Sample Name	**BOAT HARBOUR PART 2 #3**	Sampling Date	n/a		
ALS Sample ID	L2419710-3	Extraction Date	27-Feb-20		Approved:
Analysis Method	EPA 1613B	Sample Size	10.27	g	*T.Patterson*
Analysis Type	Sample	Percent Moisture	n/a		--e-signature--
Sample Matrix	Fish tissue	Split Ratio	2		05-Mar-2020

Run Information	**Run 1**
Filename	7-200304A28
Run Date	05-Mar-20 01:40
Final Volume	20 uL
Dilution Factor	1
Analysis Units	pg/g wwt
Instrument - Column	HRMS-7 DB5MSUST780127H

Target Analytes	**TEF (WHO 2005)**	**Ret. Time**	**Conc. g/g wwt**	**EDL /g wwt**	**Flags**	**EMPC g wwt**	**LQL**
2,3,7,8-TCDD	1	27.90	0.265	0.14	M,J		1.9
1,2,3,7,8-PeCDD	1	32.04	0.0613	0.053	M,J		9.7
1,2,3,4,7,8-HxCDD	0.1	NotFnd	<0.069	0.069	U		9.7
1,2,3,6,7,8-HxCDD	0.1	NotFnd	<0.066	0.066	U		9.7
1,2,3,7,8,9-HxCDD	0.1	NotFnd	<0.067	0.067	U		9.7
1,2,3,4,6,7,8-HpCDD	0.01	35.78	<0.16	0.044	M,J,R	0.16	9.7
OCDD	0.0003	37.27	<0.65	0.051	M,J,R	0.65	19
2,3,7,8-TCDF	0.1	26.99	5.78	0.084			1.9
1,2,3,7,8-PeCDF	0.03	31.10	<0.13	0.061	M,J,R	0.13	9.7
2,3,4,7,8-PeCDF	0.3	31.83	<0.095	0.047	M,J,R	0.095	9.7
1,2,3,4,7,8-HxCDF	0.1	NotFnd	<0.039	0.039	U		9.7
1,2,3,6,7,8-HxCDF	0.1	NotFnd	<0.043	0.043	U		9.7
2,3,4,6,7,8-HxCDF	0.1	NotFnd	<0.038	0.038	U		9.7
1,2,3,7,8,9-HxCDF	0.1	34.43	0.147	0.051	J,B		9.7
1,2,3,4,6,7,8-HpCDF	0.01	35.20	0.0779	0.030	M,J		9.7
1,2,3,4,7,8,9-HpCDF	0.01	NotFnd	<0.038	0.038	U		9.7
OCDF	0.0003	37.36	0.253	0.050	J		19

Extraction Standards	**pg**		**% Rec**	**Limits**
13C12-2,3,7,8-TCDD	4000	27.89	69	25-164
13C12-1,2,3,7,8-PeCDD	4000	32.04	99	25-181
13C12-1,2,3,4,7,8-HxCDD	4000	34.10	71	32-141
13C12-1,2,3,6,7,8-HxCDD	4000	34.15	73	28-130
13C12-1,2,3,4,6,7,8-HpCDD	4000	35.76	82	23-140
13C12-OCDD	8000	37.26	72	17-157
13C12-2,3,7,8-TCDF	4000	26.96	79	24-169
13C12-1,2,3,7,8-PeCDF	4000	31.09	102	24-185
13C12-2,3,4,7,8-PeCDF	4000	31.82	107	21-178
13C12-1,2,3,4,7,8-HxCDF	4000	33.60	83	26-152
13C12-1,2,3,6,7,8-HxCDF	4000	33.67	79	26-123
13C12-2,3,4,6,7,8-HxCDF	4000	34.00	83	29-147
13C12-1,2,3,7,8,9-HxCDF	4000	34.42	79	28-136
13C12-1,2,3,4,6,7,8-HpCDF	4000	35.20	91	28-143
13C12-1,2,3,4,7,8,9-HpCDF	4000	36.01	94	26-138
Cleanup Standard	**pg**			
37Cl4-2,3,7,8-TCDD (Cleanup)	80	27.90	71	35-197

Homologue Group Totals	**# peaks**	**Conc. g/g wwt**	**EDL /g wwt**		**LQL**
Total-TCDD	1.00	0.265	0.14		1.9
Total-PeCDD	1.00	0.0613	0.053		9.7
Total-HxCDD	0.00	<0.069	0.069	U	9.7
Total-HpCDD	0.00	<0.044	0.044	U	9.7
Total-TCDF	1.00	5.78	0.084		1.9
Total-PeCDF	0.00	<0.061	0.061	U	9.7
Total-HxCDF	1.00	0.147	0.051		9.7
Total-HpCDF	1.00	0.0779	0.038		9.7

Toxic Equivalency - (WHO 2005)	**pg/g wwt**
Lower Bound PCDD/F TEQ (WHO 2005)	0.920
Mid Point PCDD/F TEQ (WHO 2005)	0.970
Upper Bound PCDD/F TEQ (WHO 2005)	0.987

EDL	Indicates the Estimated Detection Limit, based on the measured background noise for this target in this sample.
TEF	Indicates the Toxic Equivalency Factor
TEQ	Indicates the Toxic Equivalenc
M	Indicates that a peak has been manually integrated.
U	Indicates that this compound was not detected above the EDL.
J	Indicates that a target analyte was detected below the calibrated range.
R	Indicates that the ion abundance ratio for this compound did not meet the acceptance criterion.
B	Indicates that this target was detected in the blank at greater than 10% of the sample concentration.
LQL	Lower Quantification Limit, based on the lowest calibration level corrected for sample size, splits and dilutions.
EMPC	Estimated Maximum Possible Concentration – elevated detection limit due to interference or positive id criterion failure

ALS Life Sciences

Sample Analysis Report

Sample Name	**EC #4**	Sampling Date	n/a		
ALS Sample ID	L2419710-4	Extraction Date	27-Feb-20		Approved:
Analysis Method	EPA 1613B	Sample Size	10.09	g	*T.Patterson*
Analysis Type	Sample	Percent Moisture	n/a		--e-signature--
Sample Matrix	Fish tissue	Split Ratio	2		05-Mar-2020

Run Information	**Run 1**
Filename	7-200304A29
Run Date	05-Mar-20 02:22
Final Volume	20 uL
Dilution Factor	1
Analysis Units	pg/g wwt
Instrument - Column	HRMS-7 DB5MSUST780127H

Target Analytes	**TEF (WHO 2005)**	**Ret. Time**	**Conc. g/g wwt**	**EDL /g wwt**	**Flags**	**EMPC g wwt**	**LQL**
2,3,7,8-TCDD	1	NotFnd	<0.10	0.10	U		2.0
1,2,3,7,8-PeCDD	1	32.03	0.0624	0.040	M,J		9.9
1,2,3,4,7,8-HxCDD	0.1	NotFnd	<0.040	0.040	U		9.9
1,2,3,6,7,8-HxCDD	0.1	34.13	<0.058	0.040	M,J,R	0.058	9.9
1,2,3,7,8,9-HxCDD	0.1	34.28	<0.047	0.039	M,J,R	0.047	9.9
1,2,3,4,6,7,8-HpCDD	0.01	35.76	0.154	0.031	M,J		9.9
OCDD	0.0003	37.27	0.352	0.035	J,B		20
2,3,7,8-TCDF	0.1	26.95	0.526	0.062	J		2.0
1,2,3,7,8-PeCDF	0.03	31.09	<0.054	0.044	M,J,R	0.054	9.9
2,3,4,7,8-PeCDF	0.3	31.82	0.0684	0.035	M,J,B		9.9
1,2,3,4,7,8-HxCDF	0.1	NotFnd	<0.039	0.039	M,U		9.9
1,2,3,6,7,8-HxCDF	0.1	33.66	<0.042	0.042	M,U	0.042	9.9
2,3,4,6,7,8-HxCDF	0.1	33.99	<0.043	0.039	M,J,R	0.043	9.9
1,2,3,7,8,9-HxCDF	0.1	34.42	0.121	0.048	M,J,B		9.9
1,2,3,4,6,7,8-HpCDF	0.01	35.20	0.0793	0.029	J		9.9
1,2,3,4,7,8,9-HpCDF	0.01	NotFnd	<0.034	0.034	U		9.9
OCDF	0.0003	37.37	0.189	0.042	M,J		20

Extraction Standards	**pg**		**% Rec**	**Limits**
13C12-2,3,7,8-TCDD	4000	27.84	68	25-164
13C12-1,2,3,7,8-PeCDD	4000	32.02	88	25-181
13C12-1,2,3,4,7,8-HxCDD	4000	34.09	71	32-141
13C12-1,2,3,6,7,8-HxCDD	4000	34.14	65	28-130
13C12-1,2,3,4,6,7,8-HpCDD	4000	35.76	70	23-140
13C12-OCDD	8000	37.26	63	17-157
13C12-2,3,7,8-TCDF	4000	26.93	80	24-169
13C12-1,2,3,7,8-PeCDF	4000	31.07	90	24-185
13C12-2,3,4,7,8-PeCDF	4000	31.80	91	21-178
13C12-1,2,3,4,7,8-HxCDF	4000	33.59	75	26-152
13C12-1,2,3,6,7,8-HxCDF	4000	33.66	71	26-123
13C12-2,3,4,6,7,8-HxCDF	4000	33.99	74	29-147
13C12-1,2,3,7,8,9-HxCDF	4000	34.41	74	28-136
13C12-1,2,3,4,6,7,8-HpCDF	4000	35.19	80	28-143
13C12-1,2,3,4,7,8,9-HpCDF	4000	36.01	82	26-138
Cleanup Standard	**pg**			
37Cl4-2,3,7,8-TCDD (Cleanup)	80	27.87	71	35-197

Homologue Group Totals	**# peaks**	**Conc. g/g wwt**	**EDL /g wwt**		**LQL**
Total-TCDD	0.00	<0.10	0.10	U	2.0
Total-PeCDD	1.00	0.0624	0.040		9.9
Total-HxCDD	0.00	<0.040	0.040	U	9.9
Total-HpCDD	2.00	0.231	0.031		9.9
Total-TCDF	1.00	0.526	0.062		2.0
Total-PeCDF	1.00	0.0684	0.044		9.9
Total-HxCDF	1.00	0.121	0.048		9.9
Total-HpCDF	1.00	0.0793	0.034		9.9

Toxic Equivalency - (WHO 2005)	**pg/g wwt**
Lower Bound PCDD/F TEQ (WHO 2005)	0.150
Mid Point PCDD/F TEQ (WHO 2005)	0.223
Upper Bound PCDD/F TEQ (WHO 2005)	0.279

EDL	Indicates the Estimated Detection Limit, based on the measured background noise for this target in this sample.
TEF	Indicates the Toxic Equivalency Factor — TEQ: Indicates the Toxic Equivalenc
M	Indicates that a peak has been manually integrated.
U	Indicates that this compound was not detected above the EDL.
J	Indicates that a target analyte was detected below the calibrated range.
R	Indicates that the ion abundance ratio for this compound did not meet the acceptance criterion.
B	Indicates that this target was detected in the blank at greater than 10% of the sample concentration.
LQL	Lower Quantification Limit, based on the lowest calibration level corrected for sample size, splits and dilutions.
EMPC	Estimated Maximum Possible Concentration – elevated detection limit due to interference or positive id criterion failure

ALS Life Sciences

Sample Analysis Report

Sample Name	**WATER COURSE #5**	Sampling Date	n/a	
ALS Sample ID	L2419710-5	Extraction Date	27-Feb-20	Approved:
Analysis Method	EPA 1613B	Sample Size	7.23 g	*T.Patterson*
Analysis Type	Sample	Percent Moisture	n/a	--e-signature--
Sample Matrix	Fish tissue	Split Ratio	2	05-Mar-2020

Run Information	**Run 1**
Filename	7-200304A30
Run Date	05-Mar-20 03:04
Final Volume	20 uL
Dilution Factor	1
Analysis Units	pg/g wwt
Instrument - Column	HRMS-7 DB5MSUST780127H

Target Analytes	**TEF (WHO 2005)**	**Ret. Time**	**Conc. g/g wwt**	**EDL /g wwt**	**Flags**	**EMPC g wwt**	**LQL**
2,3,7,8-TCDD	1	27.87	0.237	0.12	M,J		2.8
1,2,3,7,8-PeCDD	1	NotFnd	<0.048	0.048	U		14
1,2,3,4,7,8-HxCDD	0.1	NotFnd	<0.063	0.063	U		14
1,2,3,6,7,8-HxCDD	0.1	NotFnd	<0.062	0.062	U		14
1,2,3,7,8,9-HxCDD	0.1	NotFnd	<0.062	0.062	U		14
1,2,3,4,6,7,8-HpCDD	0.01	35.77	0.188	0.077	M,J		14
OCDD	0.0003	37.26	0.700	0.043	J,B		28
2,3,7,8-TCDF	0.1	26.95	7.32	0.076			2.8
1,2,3,7,8-PeCDF	0.03	31.08	0.120	0.047	M,J		14
2,3,4,7,8-PeCDF	0.3	31.82	0.0705	0.038	M,J,B		14
1,2,3,4,7,8-HxCDF	0.1	33.60	<0.041	0.041	M,U	0.028	14
1,2,3,6,7,8-HxCDF	0.1	NotFnd	<0.041	0.041	U		14
2,3,4,6,7,8-HxCDF	0.1	33.99	<0.039	0.039	M,U		14
1,2,3,7,8,9-HxCDF	0.1	34.41	<0.18	0.051	M,J,R	0.18	14
1,2,3,4,6,7,8-HpCDF	0.01	35.20	<0.11	0.025	J,R	0.11	14
1,2,3,4,7,8,9-HpCDF	0.01	36.00	0.0678	0.032	M,J		14
OCDF	0.0003	37.35	1.78	0.045	J		28

Extraction Standards	**pg**		**% Rec**	**Limits**
13C12-2,3,7,8-TCDD	4000	27.84	78	25-164
13C12-1,2,3,7,8-PeCDD	4000	32.02	101	25-181
13C12-1,2,3,4,7,8-HxCDD	4000	34.08	78	32-141
13C12-1,2,3,6,7,8-HxCDD	4000	34.13	79	28-130
13C12-1,2,3,4,6,7,8-HpCDD	4000	35.75	81	23-140
13C12-OCDD	8000	37.25	75	17-157
13C12-2,3,7,8-TCDF	4000	26.93	91	24-169
13C12-1,2,3,7,8-PeCDF	4000	31.07	105	24-185
13C12-2,3,4,7,8-PeCDF	4000	31.80	108	21-178
13C12-1,2,3,4,7,8-HxCDF	4000	33.59	89	26-152
13C12-1,2,3,6,7,8-HxCDF	4000	33.66	85	26-123
13C12-2,3,4,6,7,8-HxCDF	4000	33.99	88	29-147
13C12-1,2,3,7,8,9-HxCDF	4000	34.41	84	28-136
13C12-1,2,3,4,6,7,8-HpCDF	4000	35.19	95	28-143
13C12-1,2,3,4,7,8,9-HpCDF	4000	36.00	94	26-138
Cleanup Standard	**pg**			
37Cl4-2,3,7,8-TCDD (Cleanup)	80	27.86	77	35-197

Homologue Group Totals	**# peaks**	**Conc. g/g wwt**	**EDL /g wwt**	Flags	LQL
Total-TCDD	1.00	0.237	0.12		2.8
Total-PeCDD	0.00	<0.048	0.048	U	14
Total-HxCDD	0.00	<0.063	0.063	U	14
Total-HpCDD	1.00	0.188	0.077		14
Total-TCDF	1.00	7.32	0.076		2.8
Total-PeCDF	2.00	0.189	0.047		14
Total-HxCDF	0.00	<0.051	0.051	U	14
Total-HpCDF	1.00	0.0678	0.032		14

Toxic Equivalency - (WHO 2005)	**pg/g wwt**
Lower Bound PCDD/F TEQ (WHO 2005)	0.997
Mid Point PCDD/F TEQ (WHO 2005)	1.06
Upper Bound PCDD/F TEQ (WHO 2005)	1.09

EDL	Indicates the Estimated Detection Limit, based on the measured background noise for this target in this sample.
TEF	Indicates the Toxic Equivalency Factor TEQ Indicates the Toxic Equivalenc
M	Indicates that a peak has been manually integrated.
U	Indicates that this compound was not detected above the EDL.
J	Indicates that a target analyte was detected below the calibrated range.
R	Indicates that the ion abundance ratio for this compound did not meet the acceptance criterion.
B	Indicates that this target was detected in the blank at greater than 10% of the sample concentration.
LQL	Lower Quantification Limit, based on the lowest calibration level corrected for sample size, splits and dilutions.
EMPC	Estimated Maximum Possible Concentration - elevated detection limit due to interference or positive id criterion failure

ALS Life Sciences

Sample Analysis Report

Sample Name	**WETLAND #6**	Sampling Date	n/a
ALS Sample ID	L2419710-6	Extraction Date	27-Feb-20
Analysis Method	EPA 1613B	Sample Size	1.11 g
Analysis Type	Sample	Percent Moisture	n/a
Sample Matrix	Fish tissue	Split Ratio	2

Approved:
T.Patterson
--e-signature--
05-Mar-2020

Run Information	**Run 1**
Filename	7-200304A31
Run Date	05-Mar-20 03:46
Final Volume	20 uL
Dilution Factor	1
Analysis Units	pg/g wwt
Instrument - Column	HRMS-7 DB5MSUST780127H

Target Analytes	**TEF (WHO 2005)**	**Ret. Time**	**Conc. g/g wwt**	**EDL /g wwt**	**Flags**	**EMPC g wwt**	**LQL**
2,3,7,8-TCDD	1	NotFnd	<2.2	2.2	U		18
1,2,3,7,8-PeCDD	1	NotFnd	<0.76	0.76	U		90
1,2,3,4,7,8-HxCDD	0.1	NotFnd	<1.3	1.3	U		90
1,2,3,6,7,8-HxCDD	0.1	NotFnd	<1.4	1.4	U		90
1,2,3,7,8,9-HxCDD	0.1	NotFnd	<1.3	1.3	U		90
1,2,3,4,6,7,8-HpCDD	0.01	35.75	1.71	0.73	M,J		90
OCDD	0.0003	37.26	<4.2	0.78	M,J,R	4.2	180
2,3,7,8-TCDF	0.1	26.98	48.0	1.2	M		18
1,2,3,7,8-PeCDF	0.03	31.07	<0.69	0.69	M,U	0.59	90
2,3,4,7,8-PeCDF	0.3	NotFnd	<0.52	0.52	U		90
1,2,3,4,7,8-HxCDF	0.1	NotFnd	<0.53	0.53	U		90
1,2,3,6,7,8-HxCDF	0.1	NotFnd	<0.60	0.60	U		90
2,3,4,6,7,8-HxCDF	0.1	NotFnd	<0.56	0.56	U		90
1,2,3,7,8,9-HxCDF	0.1	34.43	<1.5	0.70	M,J,R	1.5	90
1,2,3,4,6,7,8-HpCDF	0.01	NotFnd	<0.69	0.69	U		90
1,2,3,4,7,8,9-HpCDF	0.01	NotFnd	<0.80	0.80	U		90
OCDF	0.0003	37.35	3.80	0.86	M,J		180

Extraction Standards	**pg**		**% Rec**	**Limits**
13C12-2,3,7,8-TCDD	4000	27.86	38	25-164
13C12-1,2,3,7,8-PeCDD	4000	32.02	50	25-181
13C12-1,2,3,4,7,8-HxCDD	4000	34.08	40	32-141
13C12-1,2,3,6,7,8-HxCDD	4000	34.13	38	28-130
13C12-1,2,3,4,6,7,8-HpCDD	4000	35.75	43	23-140
13C12-OCDD	8000	37.25	38	17-157
13C12-2,3,7,8-TCDF	4000	26.95	46	24-169
13C12-1,2,3,7,8-PeCDF	4000	31.07	52	24-185
13C12-2,3,4,7,8-PeCDF	4000	31.80	54	21-178
13C12-1,2,3,4,7,8-HxCDF	4000	33.59	46	26-152
13C12-1,2,3,6,7,8-HxCDF	4000	33.66	41	26-123
13C12-2,3,4,6,7,8-HxCDF	4000	33.99	43	29-147
13C12-1,2,3,7,8,9-HxCDF	4000	34.41	43	28-136
13C12-1,2,3,4,6,7,8-HpCDF	4000	35.19	47	28-143
13C12-1,2,3,4,7,8,9-HpCDF	4000	36.00	52	26-138
Cleanup Standard	**pg**			
37Cl4-2,3,7,8-TCDD (Cleanup)	80	27.89	69	35-197

Homologue Group Totals	**# peaks**	**Conc. g/g wwt**	**EDL /g wwt**		**LQL**
Total-TCDD	0.00	<2.2	2.2	U	18
Total-PeCDD	0.00	<0.76	0.76	U	90
Total-HxCDD	0.00	<1.4	1.4	U	90
Total-HpCDD	1.00	1.71	0.73		90
Total-TCDF	1.00	48.0	1.2		18
Total-PeCDF	0.00	<0.69	0.69	U	90
Total-HxCDF	0.00	<0.70	0.70	U	90
Total-HpCDF	0.00	<0.80	0.80	U	90

Toxic Equivalency - (WHO 2005)	**pg/g wwt**
Lower Bound PCDD/F TEQ (WHO 2005)	4.82
Mid Point PCDD/F TEQ (WHO 2005)	6.83
Upper Bound PCDD/F TEQ (WHO 2005)	8.69

EDL	Indicates the Estimated Detection Limit, based on the measured background noise for this target in this sample.
TEF	Indicates the Toxic Equivalency Factor TEQ Indicates the Toxic Equivalenc
M	Indicates that a peak has been manually integrated.
U	Indicates that this compound was not detected above the EDL.
J	Indicates that a target analyte was detected below the calibrated range.
R	Indicates that the ion abundance ratio for this compound did not meet the acceptance criterion.
LQL	Lower Quantification Limit, based on the lowest calibration level corrected for sample size, splits and dilutions.
EMPC	Estimated Maximum Possible Concentration – elevated detection limit due to interference or positive id criterion failure

ALS Life Sciences

Sample Analysis Report

Sample Name	**ESTUARY #7**	Sampling Date	n/a	
ALS Sample ID	L2419710-7	Extraction Date	27-Feb-20	Approved:
Analysis Method	EPA 1613B	Sample Size	10.07 g	*T.Patterson*
Analysis Type	Sample	Percent Moisture	n/a	--e-signature--
Sample Matrix	Fish tissue	Split Ratio	2	05-Mar-2020

Run Information	**Run 1**
Filename	7-200304A32
Run Date	05-Mar-20 04:28
Final Volume	20 uL
Dilution Factor	1
Analysis Units	pg/g wwt
Instrument - Column	HRMS-7 DB5MSUST780127H

Target Analytes	**TEF (WHO 2005)**	**Ret. Time**	**Conc. g/g wwt**	**EDL /g wwt**	**Flags**	**EMPC g wwt**	**LQL**
2,3,7,8-TCDD	1	NotFnd	<0.14	0.14	U		2.0
1,2,3,7,8-PeCDD	1	32.04	0.0725	0.058	M,J		9.9
1,2,3,4,7,8-HxCDD	0.1	NotFnd	<0.082	0.082	U		9.9
1,2,3,6,7,8-HxCDD	0.1	NotFnd	<0.082	0.082	U		9.9
1,2,3,7,8,9-HxCDD	0.1	NotFnd	<0.081	0.081	U		9.9
1,2,3,4,6,7,8-HpCDD	0.01	35.76	0.214	0.050	J		9.9
OCDD	0.0003	37.26	0.975	0.050	J,B		20
2,3,7,8-TCDF	0.1	26.98	2.08	0.087	M		2.0
1,2,3,7,8-PeCDF	0.03	31.09	0.0864	0.046	M,J		9.9
2,3,4,7,8-PeCDF	0.3	NotFnd	<0.039	0.039	U		9.9
1,2,3,4,7,8-HxCDF	0.1	33.60	<0.059	0.042	M,J,R	0.059	9.9
1,2,3,6,7,8-HxCDF	0.1	33.68	<0.055	0.044	M,J,R	0.055	9.9
2,3,4,6,7,8-HxCDF	0.1	34.00	<0.12	0.043	M,J,R	0.12	9.9
1,2,3,7,8,9-HxCDF	0.1	34.43	<0.095	0.060	M,J,R	0.095	9.9
1,2,3,4,6,7,8-HpCDF	0.01	35.20	0.127	0.036	M,J		9.9
1,2,3,4,7,8,9-HpCDF	0.01	36.02	<0.056	0.042	M,J,R	0.056	9.9
OCDF	0.0003	37.36	<0.46	0.059	J,R	0.46	20

Extraction Standards	**pg**		**% Rec**	**Limits**
13C12-2,3,7,8-TCDD	4000	27.87	67	25-164
13C12-1,2,3,7,8-PeCDD	4000	32.03	89	25-181
13C12-1,2,3,4,7,8-HxCDD	4000	34.09	79	32-141
13C12-1,2,3,6,7,8-HxCDD	4000	34.14	74	28-130
13C12-1,2,3,4,6,7,8-HpCDD	4000	35.76	86	23-140
13C12-OCDD	8000	37.26	80	17-157
13C12-2,3,7,8-TCDF	4000	26.95	78	24-169
13C12-1,2,3,7,8-PeCDF	4000	31.08	92	24-185
13C12-2,3,4,7,8-PeCDF	4000	31.82	95	21-178
13C12-1,2,3,4,7,8-HxCDF	4000	33.59	88	26-152
13C12-1,2,3,6,7,8-HxCDF	4000	33.66	81	26-123
13C12-2,3,4,6,7,8-HxCDF	4000	33.99	85	29-147
13C12-1,2,3,7,8,9-HxCDF	4000	34.41	77	28-136
13C12-1,2,3,4,6,7,8-HpCDF	4000	35.19	94	28-143
13C12-1,2,3,4,7,8,9-HpCDF	4000	36.01	100	26-138
Cleanup Standard	**pg**			
37Cl4-2,3,7,8-TCDD (Cleanup)	80	27.89	72	35-197

Homologue Group Totals	**# peaks**	**Conc. g/g wwt**	**EDL /g wwt**		**LQL**
Total-TCDD	0.00	<0.14	0.14	U	2.0
Total-PeCDD	1.00	0.0725	0.058		9.9
Total-HxCDD	0.00	<0.082	0.082	U	9.9
Total-HpCDD	1.00	0.214	0.050		9.9
Total-TCDF	1.00	2.08	0.087		2.0
Total-PeCDF	1.00	0.0864	0.046		9.9
Total-HxCDF	1.00	0.270	0.060		9.9
Total-HpCDF	1.00	0.127	0.042		9.9

Toxic Equivalency - (WHO 2005)	**pg/g wwt**
Lower Bound PCDD/F TEQ (WHO 2005)	0.287
Mid Point PCDD/F TEQ (WHO 2005)	0.408
Upper Bound PCDD/F TEQ (WHO 2005)	0.497

EDL	Indicates the Estimated Detection Limit, based on the measured background noise for this target in this sample.
TEF	Indicates the Toxic Equivalency Factor TEQ Indicates the Toxic Equivalenc
M	Indicates that a peak has been manually integrated.
U	Indicates that this compound was not detected above the EDL.
J	Indicates that a target analyte was detected below the calibrated range.
R	Indicates that the ion abundance ratio for this compound did not meet the acceptance criterion.
B	Indicates that this target was detected in the blank at greater than 10% of the sample concentration.
LQL	Lower Quantification Limit, based on the lowest calibration level corrected for sample size, splits and dilutions.
EMPC	Estimated Maximum Possible Concentration – elevated detection limit due to interference or positive id criterion failure

ALS Life Sciences

Laboratory Method Blank Analysis Report

Sample Name	**Method/Corn Oil Blank**	Sampling Date	n/a
ALS Sample ID	WG3280582-1	Extraction Date	27-Feb-20
Analysis Method	EPA 1613B	Sample Size	10.00 g
Analysis Type	Blank	Percent Moisture	n/a
Sample Matrix	QC	Split Ratio	2

Approved:
T.Patterson
--e-signature--
05-Mar-2020

Run Information	**Run 1**
Filename	7-200304A21
Run Date	04-Mar-20 20:45
Final Volume	20 uL
Dilution Factor	1
Analysis Units	pg/g wwt
Instrument - Column	HRMS-7 DB5MSUST780127H

Target Analytes	**TEF (WHO 2005)**	**Ret. Time**	**Conc. g/g wwt**	**EDL /g wwt**	**Flags**	**EMPC g wwt**	**LQL**
2,3,7,8-TCDD	1	NotFnd	<0.10	0.10	U		2.0
1,2,3,7,8-PeCDD	1	32.04	<0.047	0.042	M,J,R	0.047	10
1,2,3,4,7,8-HxCDD	0.1	NotFnd	<0.059	0.059	U		10
1,2,3,6,7,8-HxCDD	0.1	34.13	0.0780	0.061	M,J		10
1,2,3,7,8,9-HxCDD	0.1	34.26	0.0650	0.059	M,J		10
1,2,3,4,6,7,8-HpCDD	0.01	35.76	<0.092	0.032	M,J,R	0.092	10
OCDD	0.0003	37.26	0.334	0.030	J		20
2,3,7,8-TCDF	0.1	NotFnd	<0.058	0.058	U		2.0
1,2,3,7,8-PeCDF	0.03	31.07	<0.087	0.039	M,J,R	0.087	10
2,3,4,7,8-PeCDF	0.3	31.80	0.0680	0.030	M,J		10
1,2,3,4,7,8-HxCDF	0.1	33.59	<0.046	0.046	M,U	0.029	10
1,2,3,6,7,8-HxCDF	0.1	NotFnd	<0.045	0.045	U		10
2,3,4,6,7,8-HxCDF	0.1	33.99	<0.043	0.043	M,U	0.037	10
1,2,3,7,8,9-HxCDF	0.1	34.41	0.126	0.057	M,J		10
1,2,3,4,6,7,8-HpCDF	0.01	35.20	<0.068	0.025	M,J,R	0.068	10
1,2,3,4,7,8,9-HpCDF	0.01	36.01	<0.060	0.032	J,R	0.060	10
OCDF	0.0003	37.34	<0.19	0.044	M,J,R	0.19	20

Extraction Standards	**pg**		**% Rec**	**Limits**
13C12-2,3,7,8-TCDD	4000	27.83	72	25-164
13C12-1,2,3,7,8-PeCDD	4000	32.00	88	25-181
13C12-1,2,3,4,7,8-HxCDD	4000	34.08	81	32-141
13C12-1,2,3,6,7,8-HxCDD	4000	34.13	80	28-130
13C12-1,2,3,4,6,7,8-HpCDD	4000	35.76	90	23-140
13C12-OCDD	8000	37.25	72	17-157
13C12-2,3,7,8-TCDF	4000	26.92	83	24-169
13C12-1,2,3,7,8-PeCDF	4000	31.06	93	24-185
13C12-2,3,4,7,8-PeCDF	4000	31.79	94	21-178
13C12-1,2,3,4,7,8-HxCDF	4000	33.58	87	26-152
13C12-1,2,3,6,7,8-HxCDF	4000	33.65	86	26-123
13C12-2,3,4,6,7,8-HxCDF	4000	33.98	92	29-147
13C12-1,2,3,7,8,9-HxCDF	4000	34.40	86	28-136
13C12-1,2,3,4,6,7,8-HpCDF	4000	35.19	104	28-143
13C12-1,2,3,4,7,8,9-HpCDF	4000	36.01	106	26-138
Cleanup Standard	**pg**			
37Cl4-2,3,7,8-TCDD (Cleanup)	80	27.86	70	35-197

Homologue Group Totals	**# peaks**	**Conc. g/g wwt**	**EDL /g wwt**		
Total-TCDD	0.00	<0.10	0.10	U	2.0
Total-PeCDD	0.00	<0.042	0.042	U	10
Total-HxCDD	2.00	0.143	0.061		10
Total-HpCDD	0.00	<0.032	0.032	U	10
Total-TCDF	0.00	<0.058	0.058	U	2.0
Total-PeCDF	1.00	0.0680	0.039		10
Total-HxCDF	1.00	0.126	0.057		10
Total-HpCDF	0.00	<0.032	0.032	U	10

Toxic Equivalency - (WHO 2005)	**pg/g wwt**
Lower Bound PCDD/F TEQ (WHO 2005)	0.0474
Mid Point PCDD/F TEQ (WHO 2005)	0.162
Upper Bound PCDD/F TEQ (WHO 2005)	0.224

EDL	Indicates the Estimated Detection Limit, based on the measured background noise for this target in this sample.
TEF	Indicates the Toxic Equivalency Factor
TEQ	Indicates the Toxic Equivalenc
M	Indicates that a peak has been manually integrated.
U	Indicates that this compound was not detected above the EDL.
J	Indicates that a target analyte was detected below the calibrated range.
R	Indicates that the ion abundance ratio for this compound did not meet the acceptance criterion.
LQL	Lower Quantification Limit, based on the lowest calibration level corrected for sample size, splits and dilutions.
EMPC	Estimated Maximum Possible Concentration – elevated detection limit due to interference or positive id criterion failure

ALS Life Sciences

Laboratory Method Blank Analysis Report

Sample Name	**Method/Reagent Blank**	Sampling Date	n/a
ALS Sample ID	WG3280582-5	Extraction Date	27-Feb-20
Analysis Method	EPA 1613B	Sample Size	10.00 g
Analysis Type	Blank	Percent Moisture	n/a
Sample Matrix	QC	Split Ratio	2

Approved:
T.Patterson
--e-signature--
05-Mar-2020

Run Information	**Run 1**
Filename	7-200304A22
Run Date	04-Mar-20 21:27
Final Volume	20 uL
Dilution Factor	1
Analysis Units	pg/g wwt
Instrument - Column	HRMS-7 DB5MSUST780127H

Target Analytes	**TEF (WHO 2005)**	**Ret. Time**	**Conc. g/g wwt**	**EDL /g wwt**	**Flags**	**EMPC g wwt**	**LQL**
2,3,7,8-TCDD	1	NotFnd	<0.18	0.18	U		2.0
1,2,3,7,8-PeCDD	1	NotFnd	<0.060	0.060	U		10
1,2,3,4,7,8-HxCDD	0.1	34.07	<0.088	0.070	M,J,R	0.088	10
1,2,3,6,7,8-HxCDD	0.1	34.14	0.0750	0.070	M,J,B		10
1,2,3,7,8,9-HxCDD	0.1	34.26	<0.084	0.069	M,J,R	0.084	10
1,2,3,4,6,7,8-HpCDD	0.01	35.77	0.115	0.050	M,J		10
OCDD	0.0003	37.26	0.395	0.037	J,B		20
2,3,7,8-TCDF	0.1	NotFnd	<0.095	0.095	U		2.0
1,2,3,7,8-PeCDF	0.03	31.08	<0.088	0.058	M,J,R	0.088	10
2,3,4,7,8-PeCDF	0.3	31.80	<0.054	0.047	M,J,R	0.054	10
1,2,3,4,7,8-HxCDF	0.1	33.59	<0.061	0.038	M,J,R	0.061	10
1,2,3,6,7,8-HxCDF	0.1	33.65	<0.046	0.042	M,J,R	0.046	10
2,3,4,6,7,8-HxCDF	0.1	34.00	<0.051	0.040	M,J,R	0.051	10
1,2,3,7,8,9-HxCDF	0.1	34.42	<0.099	0.051	M,J,R	0.099	10
1,2,3,4,6,7,8-HpCDF	0.01	35.20	<0.11	0.067	J,R	0.11	10
1,2,3,4,7,8,9-HpCDF	0.01	NotFnd	<0.078	0.078	U		10
OCDF	0.0003	37.36	0.346	0.049	M,J		20

Extraction Standards	**pg**		**% Rec**	**Limits**
13C12-2,3,7,8-TCDD	4000	27.84	44	25-164
13C12-1,2,3,7,8-PeCDD	4000	32.02	62	25-181
13C12-1,2,3,4,7,8-HxCDD	4000	34.08	61	32-141
13C12-1,2,3,6,7,8-HxCDD	4000	34.13	56	28-130
13C12-1,2,3,4,6,7,8-HpCDD	4000	35.75	63	23-140
13C12-OCDD	8000	37.25	54	17-157
13C12-2,3,7,8-TCDF	4000	26.92	50	24-169
13C12-1,2,3,7,8-PeCDF	4000	31.07	62	24-185
13C12-2,3,4,7,8-PeCDF	4000	31.79	65	21-178
13C12-1,2,3,4,7,8-HxCDF	4000	33.59	69	26-152
13C12-1,2,3,6,7,8-HxCDF	4000	33.66	65	26-123
13C12-2,3,4,6,7,8-HxCDF	4000	33.99	65	29-147
13C12-1,2,3,7,8,9-HxCDF	4000	34.41	62	28-136
13C12-1,2,3,4,6,7,8-HpCDF	4000	35.19	68	28-143
13C12-1,2,3,4,7,8,9-HpCDF	4000	36.00	72	26-138
Cleanup Standard	**pg**			
37Cl4-2,3,7,8-TCDD (Cleanup)	80	27.86	46	35-197

Homologue Group Totals	**# peaks**	**Conc. g/g wwt**	**EDL /g wwt**		
Total-TCDD	0.00	<0.18	0.18	U	2.0
Total-PeCDD	0.00	<0.060	0.060	U	10
Total-HxCDD	1.00	0.0750	0.070		10
Total-HpCDD	1.00	0.115	0.050		10
Total-TCDF	0.00	<0.095	0.095	U	2.0
Total-PeCDF	0.00	<0.058	0.058	U	10
Total-HxCDF	0.00	<0.051	0.051	U	10
Total-HpCDF	0.00	<0.078	0.078	U	10

Toxic Equivalency - (WHO 2005)	**pg/g wwt**
Lower Bound PCDD/F TEQ (WHO 2005)	0.00887
Mid Point PCDD/F TEQ (WHO 2005)	0.197
Upper Bound PCDD/F TEQ (WHO 2005)	0.322

EDL	Indicates the Estimated Detection Limit, based on the measured background noise for this target in this sample.
TEF	Indicates the Toxic Equivalency Factor
TEQ	Indicates the Toxic Equivalenc
M	Indicates that a peak has been manually integrated.
U	Indicates that this compound was not detected above the EDL.
J	Indicates that a target analyte was detected below the calibrated range.
R	Indicates that the ion abundance ratio for this compound did not meet the acceptance criterion.
B	Indicates that this target was detected in the blank at greater than 10% of the sample concentration.
LQL	Lower Quantification Limit, based on the lowest calibration level corrected for sample size, splits and dilutions.
EMPC	Estimated Maximum Possible Concentration – elevated detection limit due to interference or positive id criterion failure

ALS Life Sciences

Laboratory Control Sample Analysis Report

Sample Name	**Laboratory Control Sample**	Sampling Date	n/a		
ALS Sample ID	WG3280582-2	Extraction Date	27-Feb-20		Approved:
Analysis Method	EPA 1613B	Sample Size	1	n/a	*T.Patterson*
Analysis Type	LCS	Percent Moisture	n/a		--e-signature--
Sample Matrix	QC	Split Ratio	2		05-Mar-2020

Run Information	**Run 1**
Filename	7-200304A18
Run Date	04-Mar-20 18:39
Final Volume	20 uL
Dilution Factor	1
Analysis Units	%
Instrument - Column	HRMS-7 DB5MSUST780127H

Target Analytes	**pg**	**Ret. Time**	**% Rec**	**Limits**	**Flags**
2,3,7,8-TCDD	400	27.89	109	67-158	
1,2,3,7,8-PeCDD	2000	32.04	110	70-142	
1,2,3,4,7,8-HxCDD	2000	34.10	107	70-164	
1,2,3,6,7,8-HxCDD	2000	34.15	107	76-134	
1,2,3,7,8,9-HxCDD	2000	34.27	110	64-162	
1,2,3,4,6,7,8-HpCDD	2000	35.77	109	70-140	
OCDD	4000	37.26	102	78-144	
2,3,7,8-TCDF	400	26.96	107	75-158	
1,2,3,7,8-PeCDF	2000	31.09	110	80-134	
2,3,4,7,8-PeCDF	2000	31.82	101	68-160	
1,2,3,4,7,8-HxCDF	2000	33.60	108	72-134	
1,2,3,6,7,8-HxCDF	2000	33.67	110	84-130	
2,3,4,6,7,8-HxCDF	2000	34.00	107	70-156	
1,2,3,7,8,9-HxCDF	2000	34.42	114	78-130	
1,2,3,4,6,7,8-HpCDF	2000	35.20	109	82-122	
1,2,3,4,7,8,9-HpCDF	2000	36.02	100	78-138	
OCDF	4000	37.36	109	63-170	
Extraction Standards	**pg**		**% Rec**	**Limits**	
13C12-2,3,7,8-TCDD	4000	27.86	45	20-175	
13C12-1,2,3,7,8-PeCDD	4000	32.03	54	21-227	
13C12-1,2,3,4,7,8-HxCDD	4000	34.09	49	21-193	
13C12-1,2,3,6,7,8-HxCDD	4000	34.14	47	25-163	
13C12-1,2,3,4,6,7,8-HpCDD	4000	35.76	57	26-166	
13C12-OCDD	8000	37.26	46	13-138	
13C12-2,3,7,8-TCDF	4000	26.95	51	22-152	
13C12-1,2,3,7,8-PeCDF	4000	31.08	57	21-192	
13C12-2,3,4,7,8-PeCDF	4000	31.80	58	13-328	
13C12-1,2,3,4,7,8-HxCDF	4000	33.59	52	19-202	
13C12-1,2,3,6,7,8-HxCDF	4000	33.66	51	21-159	
13C12-2,3,4,6,7,8-HxCDF	4000	33.99	54	17-205	
13C12-1,2,3,7,8,9-HxCDF	4000	34.41	53	22-176	
13C12-1,2,3,4,6,7,8-HpCDF	4000	35.20	63	21-158	
13C12-1,2,3,4,7,8,9-HpCDF	4000	36.01	66	20-186	
Cleanup Standard	**pg**				
37Cl4-2,3,7,8-TCDD (Cleanup)	80	27.89	69	31-191	

ALS Life Sciences
1435 Norjohn Court, Unit 1, Burlington ON, L7L 0E6
Phone: 905-331-3111, FAX: 905-331-4567

Certificate of Analysis

ALS Project Contact:	Claire Kocharakkal	**Client Name:**	Cape Breton University
ALS Project ID:	CBU100	**Client Address:**	1250 Grand Lake Road, PO Box 5300
ALS WO#:	L2419710		Sydney, NS B1P 6L2
Date of Report	13-Mar-20		Canada
Date of Sample Receipt	21-Feb-20	**Client Contact:**	Dr. Ken Oakes
		Client Project ID:	

COMMENTS: **PAH by CARB method 429 (LR option)- Isotope dilution**

Certified by: SKennedy

Steve Kennedy
Technical Supervisor

ALS Life Sciences

Sample Analysis Summary Report

Sample Name	Method Blank		Method Blank		REFERENCE SAMPLE #1		BOAT HARBOUR PART ONE #2		Duplicate		BOAT HARBOUR PART 2 #3	
ALS Sample ID	WG3280582-1		WG3280582-5		L2419710-1		L2419710-2		WG3280582-4		L2419710-3	
Sample Size	10.00		10.00		10.30		6.82		6.38		10.27	
Sample units	g		g		g		g		g		g	
Moisture Content	n/a		n/a		n/a		n/a		n/a		n/a	
Matrix	QC		QC		Fish Tissue		Fish Tissue		QC		Fish Tissue	
Sampling Date	n/a		n/a		n/a		n/a		n/a		n/a	
Extraction Date	27-Feb-20		27-Feb-20		27-Feb-20		27-Feb-20		27-Feb-20		27-Feb-20	
Target Analytes	**ng/g**		**ng/g**		**ng/g**		**ng/g**		**ng/g**		**ng/g**	
Fluorene	<0.40	U	<0.40	U	1.43		8.49		9.13		8.45	
Phenanthrene	0.888		0.776	M	4.07		13.1		15.1		14.1	
Anthracene	<0.40	U	<0.40	U	<0.39	U	1.21	R	1.42	R	1.31	R
Fluoranthene	0.488	M	1.14		0.462	M	2.26	R	2.96	R	2.07	M,R
Pyrene	0.622		1.04		0.616	R	1.16		1.61		1.02	
Benzo(a)Anthracene	<0.40	U	<0.40	U	<0.39	U	<0.59	U	<0.63	U	<0.39	U
Chrysene	<0.40	U	<0.40	U	<0.39	U	<0.59	U	<0.63	U	<0.39	U
Benzo(b)Fluoranthene	<0.40	U	<0.40	U	<0.39	U	<0.59	U	<0.63	U	<0.39	U
Benzo(a)Pyrene	<0.40	U	<0.40	U	<0.39	U	<0.59	U	<0.63	U	<0.39	U
Extraction Standards	**% Rec**		**% Rec**		**% Rec**		**% Rec**		**% Rec**		**% Rec**	
Phenanthrene D10	57.2		29.6		43.8		34.4		37.2		37.7	
Anthracene-D10	56.2		28		43.7		36.1		40		43.3	
Fluoranthene D10	65.2		48		59.8		54.9		60		61.9	
Benz(a)Anthracene-D12	68.8		59.5		36.4		33.1		35.5		35.8	
Chrysene D12	51.4		45.7		38.4	M	44.1	M	49.2	M	52.4	M
Benzo(b)Fluoranthene-D12	67		59.6	M	61.5		43.4		55		35.4	
Benzo(a)Pyrene D12	63.7		47.8		64.8		69.1		73.5		47.3	M

U Indicates that this compound was not detected above the LOD.
M Indicates that a peak has been manually integrated.

R Indicates that the ion abundance ratio for this compound did not meet the acceptance criterion.

ALS Life Sciences

Sample Analysis Summary Report

Sample Name	EC #4		WATER COURSE #5		WETLAND #6		ESTUARY #7		Laboratory Control Sample
ALS Sample ID	L2419710-4		L2419710-5		L2419710-6		L2419710-7		WG3280582-2
Sample Size	10.09		7.23		1.11		10.07		1
Sample units	g		g		g		g		n/a
Moisture Content	n/a		n/a		n/a		n/a		n/a
Matrix	Fish Tissue		Fish Tissue		Fish Tissue		Fish Tissue		QC
Sampling Date	n/a		n/a		n/a		n/a		n/a
Extraction Date	27-Feb-20		27-Feb-20		27-Feb-20		27-Feb-20		27-Feb-20
Target Analytes	**ng/g**		**ng/g**		**ng/g**		**ng/g**		**% Rec**
Fluorene	1.66		4.98		5.66		4.67		94.9
Phenanthrene	3.03		8.54		15.5		8.66		98.9
Anthracene	<0.40	U	0.609	R	<3.6	U	0.536	M,R	93.0
Fluoranthene	1.07		1.40	R	7.62		2.11		90.7
Pyrene	1.25		0.999		8.94		1.77		95.2
Benzo(a)Anthracene	<0.40	U	<0.55	U	<3.6	U	<0.40	U	83.9
Chrysene	1.11	M	<0.55	U	<3.6	U	<0.40	U	98.0
Benzo(b)Fluoranthene	<0.40	U	<0.55	U	<3.6	U	<0.40	U	86.6
Benzo(a)Pyrene	<0.40	U	<0.55	U	<3.6	U	<0.40	U	79.3
Extraction Standards	**% Rec**		**% Rec**		**% Rec**		**% Rec**		**% Rec**
Phenanthrene D10	40.2		41.9		23.7		36.6		34.9
Anthracene-D10	41.1		46		23.7		45.2		35.1
Fluoranthene D10	58.3		61.8		27.6		57.7		37.5
Benz(a)Anthracene-D12	37.9		38.2		19.1		36.4		42.1
Chrysene D12	50.3	M	41.9	M	21.7	M	43.8	M	31
Benzo(b)Fluoranthene-D12	47.5		36.3		27.5		33.6		48.1
Benzo(a)Pyrene D12	48.1	M	41.4	M	28	M	44	M	39.1

U Indicates that this compound was not detected above the LOD.
M Indicates that a peak has been manually integrated.

R Indicates that the ion abundance ratio for this compound did not meet the acceptance criterion.

ALS Life Sciences

Laboratory Method Blank Analysis Report

Sample Name	**Method Blank**	Sampling Date	n/a
ALS Sample ID	WG3280582-1	Extraction Date	27-Feb-20
Analysis Method	PAH by CARB 429		
Analysis Type	blank		
Sample Matrix	QC		
Sample Size	10.00 g		
Percent Moisture	n/a		
Split Ratio	2	Workgroup	WG3280582

Approved:
Santheep Mathew
--e-signature--
05-Mar-2020

Run Information	**Run 1**
Filename	20030407.D
Run Date	3/4/2020 15:39
Final Volume	1 mL
Dilution Factor	1
Analysis Units	ng/g
Instrument	MSD-5
Column	HP-5MS UST530312H

Target Analytes		**Ret. Time**	**Concentration ng/g**	**Flags**	
Fluorene		5.66	<0.40	U	
Phenanthrene		7.81	0.888		
Anthracene		7.92	<0.40	U	
Fluoranthene		11.16	0.488 M		
Pyrene		11.80	0.622		
Benzo(a)Anthracene		15.68	<0.40	U	
Chrysene		15.79	<0.40	U	
Benzo(b)Fluoranthene		19.00	<0.40	U	
Benzo(a)Pyrene		19.95	<0.40	U	
Extraction Standards			**% Rec**		**Limits**
Phenanthrene D10	200	7.75	57.2		50-150
Anthracene-D10	200	7.88	56.2		50-150
Fluoranthene D10	200	11.11	65.2		50-150
Benz(a)Anthracene-D12	200	15.62	68.8		50-150
Chrysene D12	200	15.72	51.4		50-150
Benzo(b)Fluoranthene-D12	200	18.94	67.0		50-150
Benzo(a)Pyrene D12	200	19.81	63.7		50-150

M Indicates that a peak has been manually integrated.
U Indicates that this compound was not detected above the MDL.

R Indicates that the ion abundance ratio for this compound did not meet the acceptance criterion.

ALS Life Sciences

Sample Analysis Report

Sample Name	**Method Blank**	Sampling Date	n/a
ALS Sample ID	WG3280582-5	Extraction Date	27-Feb-20
Analysis Method	PAH by CARB 429		
Analysis Type	sample		
Sample Matrix	QC		
Sample Size	10.00 g		
Percent Moisture	n/a		
Split Ratio	2	Workgroup	WG3280582

Approved:
Santheep Mathew
--e-signature--
05-Mar-2020

Run Information	**Run 1**
Filename	20030406.D
Run Date	3/4/2020 15:03
Final Volume	1 mL
Dilution Factor	1
Analysis Units	ng/g
Instrument	MSD-5
Column	HP-5MS UST530312H

Target Analytes		**Ret. Time**	**Concentration ng/g**	**Flags**
Fluorene		5.65	<0.40	U
Phenanthrene		7.81	0.776	M
Anthracene		7.91	<0.40	U
Fluoranthene		11.16	1.14	
Pyrene		11.80	1.04	
Benzo(a)Anthracene		15.67	<0.40	U
Chrysene		15.79	<0.40	U
Benzo(b)Fluoranthene		18.99	<0.40	U
Benzo(a)Pyrene		19.87	<0.40	U

Extraction Standards			**% Rec**	**Limits**
Phenanthrene D10	200	7.75	29.6	50-150
Anthracene-D10	200	7.88	28.0	50-150
Fluoranthene D10	200	11.11	48.0	50-150
Benz(a)Anthracene-D12	200	15.61	59.5	50-150
Chrysene D12	200	15.72	45.7	50-150
Benzo(b)Fluoranthene-D12	200	18.94	59.6 M	50-150
Benzo(a)Pyrene D12	200	19.81	47.8	50-150

M Indicates that a peak has been manually integrated.
U Indicates that this compound was not detected above the MDL.

R Indicates that the ion abundance ratio for this compound did not meet the acceptance criterion.

ALS Life Sciences

Sample Analysis Report

Sample Name	**REFERENCE SAMPLE #1**	Sampling Date	n/a
ALS Sample ID	L2419710-1	Extraction Date	27-Feb-20
Analysis Method	PAH by CARB 429		
Analysis Type	sample		
Sample Matrix	Fish Tissue		
Sample Size	10.30 g		
Percent Moisture	n/a		
Split Ratio	2	Workgroup	WG3280582

Approved:
Santheep Mathew
--e-signature--
05-Mar-2020

Run Information	**Run 1**
Filename	20030408.D
Run Date	3/4/2020 16:15
Final Volume	1 mL
Dilution Factor	1
Analysis Units	ng/g
Instrument	MSD-5
Column	HP-5MS UST530312H

Target Analytes		**Ret. Time**	**Concentration ng/g**	**Flags**
Fluorene		5.66	1.43	
Phenanthrene		7.81	4.07	
Anthracene		7.92	<0.39	U
Fluoranthene		11.16	0.462 M	
Pyrene		11.80	0.616	R
Benzo(a)Anthracene		15.71	<0.39	U
Chrysene		15.79	<0.39	U
Benzo(b)Fluoranthene		19.02	<0.39	U
Benzo(a)Pyrene		19.86	<0.39	U
Extraction Standards			**% Rec**	**Limits**
Phenanthrene D10	200	7.75	43.8	50-150
Anthracene-D10	200	7.88	43.7	50-150
Fluoranthene D10	200	11.11	59.8	50-150
Benz(a)Anthracene-D12	200	15.62	36.4	50-150
Chrysene D12	200	15.72	38.4 M	50-150
Benzo(b)Fluoranthene-D12	200	18.94	61.5	50-150
Benzo(a)Pyrene D12	200	19.81	64.8	50-150

M Indicates that a peak has been manually integrated.
U Indicates that this compound was not detected above the MDL.

R Indicates that the ion abundance ratio for this compound did not meet the acceptance criterion.

ALS Life Sciences

Sample Analysis Report

Sample Name	**BOAT HARBOUR PART ONE #2**	Sampling Date	n/a
ALS Sample ID	L2419710-2	Extraction Date	27-Feb-20
Analysis Method	PAH by CARB 429		
Analysis Type	sample		
Sample Matrix	Fish Tissue		
Sample Size	6.82 g		
Percent Moisture	n/a		
Split Ratio	2	Workgroup	WG3280582

Approved:
Santheep Mathew
--e-signature--
05-Mar-2020

Run Information	**Run 1**
Filename	20030409.D
Run Date	3/4/2020 16:51
Final Volume	1 mL
Dilution Factor	1
Analysis Units	ng/g
Instrument	MSD-5
Column	HP-5MS UST530312H

Target Analytes		**Ret. Time**	**Concentration ng/g**	**Flags**	
Fluorene		5.65	8.49		
Phenanthrene		7.81	13.1		
Anthracene		7.92	1.21	R	
Fluoranthene		11.16	2.26	R	
Pyrene		11.80	1.16		
Benzo(a)Anthracene		15.66	<0.59	U	
Chrysene		15.81	<0.59	U	
Benzo(b)Fluoranthene		19.00	<0.59	U	
Benzo(a)Pyrene		19.86	<0.59	U	
Extraction Standards			**% Rec**		**Limits**
Phenanthrene D10	200	7.75	34.4		50-150
Anthracene-D10	200	7.88	36.1		50-150
Fluoranthene D10	200	11.11	54.9		50-150
Benz(a)Anthracene-D12	200	15.62	33.1		50-150
Chrysene D12	200	15.72	44.1 M		50-150
Benzo(b)Fluoranthene-D12	200	18.94	43.4		50-150
Benzo(a)Pyrene D12	200	19.81	69.1		50-150

M Indicates that a peak has been manually integrated.
U Indicates that this compound was not detected above the MDL.

R Indicates that the ion abundance ratio for this compound did not meet the acceptance criterion.

ALS Life Sciences

Sample Analysis Report

Sample Name	**Duplicate**	Sampling Date	n/a
ALS Sample ID	WG3280582-4	Extraction Date	27-Feb-20
Analysis Method	PAH by CARB 429		
Analysis Type	sample		
Sample Matrix	QC		
Sample Size	6.38 g		
Percent Moisture	n/a		
Split Ratio	2	Workgroup	WG3280582

Approved:
Santheep Mathew
--e-signature--
05-Mar-2020

Run Information	**Run 1**
Filename	20030410.D
Run Date	3/4/2020 17:26
Final Volume	1 mL
Dilution Factor	1
Analysis Units	ng/g
Instrument	MSD-5
Column	HP-5MS UST530312H

Target Analytes	**Ret. Time**	**Concentration ng/g**	**Flags**
Fluorene	5.65	9.13	
Phenanthrene	7.81	15.1	
Anthracene	7.92	1.42	R
Fluoranthene	11.16	2.96	R
Pyrene	11.80	1.61	
Benzo(a)Anthracene	15.68	<0.63	U
Chrysene	15.80	<0.63	U
Benzo(b)Fluoranthene	19.00	<0.63	U
Benzo(a)Pyrene	19.90	<0.63	U

Extraction Standards			**% Rec**	**Limits**
Phenanthrene D10	200	7.75	37.2	50-150
Anthracene-D10	200	7.88	40.0	50-150
Fluoranthene D10	200	11.11	60.0	50-150
Benz(a)Anthracene-D12	200	15.62	35.5	50-150
Chrysene D12	200	15.72	49.2 M	50-150
Benzo(b)Fluoranthene-D12	200	18.94	55.0	50-150
Benzo(a)Pyrene D12	200	19.81	73.5	50-150

M Indicates that a peak has been manually integrated.
U Indicates that this compound was not detected above the MDL.

R Indicates that the ion abundance ratio for this compound did not meet the acceptance criterion.

ALS Life Sciences

Sample Analysis Report

Sample Name	**BOAT HARBOUR PART 2 #3**	Sampling Date	n/a
ALS Sample ID	L2419710-3	Extraction Date	27-Feb-20
Analysis Method	PAH by CARB 429		
Analysis Type	sample		
Sample Matrix	Fish Tissue		
Sample Size	10.27 g		
Percent Moisture	n/a		
Split Ratio	2	Workgroup	WG3280582

Approved:
Santheep Mathew
--e-signature--
05-Mar-2020

Run Information	**Run 1**
Filename	20030411.D
Run Date	3/4/2020 18:02
Final Volume	1 mL
Dilution Factor	1
Analysis Units	ng/g
Instrument	MSD-5
Column	HP-5MS UST530312H

Target Analytes		**Ret. Time**	**Concentration ng/g**	**Flags**	
Fluorene		5.65	8.45		
Phenanthrene		7.81	14.1		
Anthracene		7.92	1.31	R	
Fluoranthene		11.16	2.07 M	R	
Pyrene		11.80	1.02		
Benzo(a)Anthracene		15.69	<0.39	U	
Chrysene		15.79	<0.39	U	
Benzo(b)Fluoranthene		18.99	<0.39	U	
Benzo(a)Pyrene		NotFnd	<0.39	U	
Extraction Standards			**% Rec**		**Limits**
Phenanthrene D10	200	7.75	37.7		50-150
Anthracene-D10	200	7.88	43.3		50-150
Fluoranthene D10	200	11.11	61.9		50-150
Benz(a)Anthracene-D12	200	15.62	35.8		50-150
Chrysene D12	200	15.73	52.4 M		50-150
Benzo(b)Fluoranthene-D12	200	18.94	35.4		50-150
Benzo(a)Pyrene D12	200	19.81	47.3 M		50-150

M Indicates that a peak has been manually integrated.
U Indicates that this compound was not detected above the MDL.

R Indicates that the ion abundance ratio for this compound did not meet the acceptance criterion.

ALS Life Sciences

Laboratory Method Blank Analysis Report

Sample Name	**EC #4**	Sampling Date	n/a
ALS Sample ID	L2419710-4	Extraction Date	27-Feb-20
Analysis Method	PAH by CARB 429		
Analysis Type	Blank		
Sample Matrix	Fish Tissue		
Sample Size	10.09 g		
Percent Moisture	n/a		
Split Ratio	2	Workgroup	WG3280582

Approved:
Santheep Mathew
--e-signature--
05-Mar-2020

Run Information	**Run 1**
Filename	20030412.D
Run Date	3/4/2020 18:38
Final Volume	1 mL
Dilution Factor	1
Analysis Units	ng/g
Instrument	MSD-5
Column	HP-5MS UST530312H

Target Analytes		**Ret. Time**	**Concentration ng/g**	**Flags**	
Fluorene		5.65	1.66		
Phenanthrene		7.81	3.03		
Anthracene		7.93	<0.40	U	
Fluoranthene		11.16	1.07		
Pyrene		11.80	1.25		
Benzo(a)Anthracene		15.68	<0.40	U	
Chrysene		15.79	1.11	M	
Benzo(b)Fluoranthene		19.00	<0.40	U	
Benzo(a)Pyrene		19.88	<0.40	U	
Extraction Standards			**% Rec**		**Limits**
Phenanthrene D10	200	7.75	40.2		50-150
Anthracene-D10	200	7.88	41.1		50-150
Fluoranthene D10	200	11.11	58.3		50-150
Benz(a)Anthracene-D12	200	15.62	37.9		50-150
Chrysene D12	200	15.72	50.3	M	50-150
Benzo(b)Fluoranthene-D12	200	18.94	47.5		50-150
Benzo(a)Pyrene D12	200	19.81	48.1	M	50-150

M Indicates that a peak has been manually integrated.
U Indicates that this compound was not detected above the MDL.

R Indicates that the ion abundance ratio for this compound did not meet the acceptance criterion.

ALS Life Sciences

Sample Analysis Report

Sample Name	**WATER COURSE #5**	Sampling Date	n/a
ALS Sample ID	L2419710-5	Extraction Date	27-Feb-20
Analysis Method	PAH by CARB 429		
Analysis Type	sample		
Sample Matrix	Fish Tissue		
Sample Size	7.23 g		
Percent Moisture	n/a		
Split Ratio	2	Workgroup	WG3280582

Approved:
Santheep Mathew
--e-signature--
05-Mar-2020

Run Information	**Run 1**
Filename	20030413.D
Run Date	3/4/2020 19:14
Final Volume	1 mL
Dilution Factor	1
Analysis Units	ng/g
Instrument	MSD-5
Column	HP-5MS UST530312H

Target Analytes	**Ret. Time**	**Concentration ng/g**	**Flags**
Fluorene	5.65	4.98	
Phenanthrene	7.81	8.54	
Anthracene	7.92	0.609	R
Fluoranthene	11.16	1.40	R
Pyrene	11.80	0.999	
Benzo(a)Anthracene	15.67	<0.55	U
Chrysene	15.80	<0.55	U
Benzo(b)Fluoranthene	19.00	<0.55	U
Benzo(a)Pyrene	19.89	<0.55	U

Extraction Standards			**% Rec**	**Limits**
Phenanthrene D10	200	7.75	41.9	50-150
Anthracene-D10	200	7.88	46.0	50-150
Fluoranthene D10	200	11.11	61.8	50-150
Benz(a)Anthracene-D12	200	15.61	38.2	50-150
Chrysene D12	200	15.73	41.9 M	50-150
Benzo(b)Fluoranthene-D12	200	18.94	36.3	50-150
Benzo(a)Pyrene D12	200	19.82	41.4 M	50-150

M Indicates that a peak has been manually integrated.
U Indicates that this compound was not detected above the MDL.

R Indicates that the ion abundance ratio for this compound did not meet the acceptance criterion.

ALS Life Sciences

Sample Analysis Report

Sample Name	**WETLAND #6**	Sampling Date	n/a
ALS Sample ID	L2419710-6	Extraction Date	27-Feb-20
Analysis Method	PAH by CARB 429		
Analysis Type	sample		
Sample Matrix	Fish Tissue		
Sample Size	1.11 g		
Percent Moisture	n/a		
Split Ratio	2	Workgroup	WG3280582

Approved:
Santheep Mathew
--e-signature--
05-Mar-2020

Run Information	**Run 1**
Filename	20030414.D
Run Date	3/4/2020 19:49
Final Volume	1 mL
Dilution Factor	1
Analysis Units	ng/g
Instrument	MSD-5
Column	HP-5MS UST530312H

Target Analytes		**Ret. Time**	**Concentration ng/g**	**Flags**
Fluorene		5.66	5.66	
Phenanthrene		7.81	15.5	
Anthracene		7.92	<3.6	U
Fluoranthene		11.16	7.62	
Pyrene		11.80	8.94	
Benzo(a)Anthracene		15.69	<3.6	U
Chrysene		15.80	<3.6	U
Benzo(b)Fluoranthene		19.01	<3.6	U
Benzo(a)Pyrene		19.86	<3.6	U
Extraction Standards			**% Rec**	**Limits**
Phenanthrene D10	200	7.75	23.7	50-150
Anthracene-D10	200	7.88	23.7	50-150
Fluoranthene D10	200	11.11	27.6	50-150
Benz(a)Anthracene-D12	200	15.62	19.1	50-150
Chrysene D12	200	15.73	21.7 M	50-150
Benzo(b)Fluoranthene-D12	200	18.94	27.5	50-150
Benzo(a)Pyrene D12	200	19.81	28.0 M	50-150

M Indicates that a peak has been manually integrated.
U Indicates that this compound was not detected above the MDL.

R Indicates that the ion abundance ratio for this compound did not meet the acceptance criterion.

ALS Life Sciences

Sample Analysis Report

Sample Name	**ESTUARY #7**	Sampling Date	n/a
ALS Sample ID	L2419710-7	Extraction Date	27-Feb-20
Analysis Method	PAH by CARB 429		
Analysis Type	sample		
Sample Matrix	Fish Tissue		
Sample Size	10.07 g		
Percent Moisture	n/a		
Split Ratio	2	Workgroup	WG3280582

Approved:
Santheep Mathew
--e-signature--
05-Mar-2020

Run Information	**Run 1**
Filename	20030415.D
Run Date	3/4/2020 20:25
Final Volume	1 mL
Dilution Factor	1
Analysis Units	ng/g
Instrument	MSD-5
Column	HP-5MS UST530312H

Target Analytes		**Ret. Time**	**Concentration ng/g**	**Flags**
Fluorene		5.65	4.67	
Phenanthrene		7.81	8.66	
Anthracene		7.92	0.536 M	R
Fluoranthene		11.16	2.11	
Pyrene		11.80	1.77	
Benzo(a)Anthracene		15.68	<0.40	U
Chrysene		15.79	<0.40	U
Benzo(b)Fluoranthene		19.00	<0.40	U
Benzo(a)Pyrene		19.88	<0.40	U
Extraction Standards			**% Rec**	**Limits**
Phenanthrene D10	200	7.75	36.6	50-150
Anthracene-D10	200	7.88	45.2	50-150
Fluoranthene D10	200	11.11	57.7	50-150
Benz(a)Anthracene-D12	200	15.61	36.4	50-150
Chrysene D12	200	15.73	43.8 M	50-150
Benzo(b)Fluoranthene-D12	200	18.94	33.6	50-150
Benzo(a)Pyrene D12	200	19.82	44.0 M	50-150

M Indicates that a peak has been manually integrated.
U Indicates that this compound was not detected above the MDL.

R Indicates that the ion abundance ratio for this compound did not meet the acceptance criterion.

ALS Life Sciences

Sample Analysis Report

Sample Name	**Laboratory Control Sample**	Sampling Date	n/a
ALS Sample ID	WG3280582-2	Extraction Date	27-Feb-20
Analysis Method	PAH by CARB 429		
Analysis Type	sample		
Sample Matrix	QC		
Sample Size	1 n/a		
Percent Moisture	n/a		
Split Ratio	1	Workgroup	WG3280582

Approved:
Santheep Mathew
--e-signature--
05-Mar-2020

Run Information	**Run 1**
Filename	20030403.D
Run Date	3/4/2020 13:16
Final Volume	1 mL
Dilution Factor	10
Analysis Units	% Rec
Instrument	MSD-5
Column	HP-5MS UST530312H

Target Analytes		**Ret. Time**	**Concentration % Rec**	**Flags**
Fluorene		5.65	94.9	
Phenanthrene		7.81	98.9	
Anthracene		7.92	93.0	
Fluoranthene		11.16	90.7	
Pyrene		11.80	95.2	
Benzo(a)Anthracene		15.67	83.9	
Chrysene		15.80	98.0	
Benzo(b)Fluoranthene		19.00	86.6	
Benzo(a)Pyrene		19.88	79.3	
Extraction Standards			**% Rec**	**Limits**
Phenanthrene D10	100	7.75	34.9	50-150
Anthracene-D10	100	7.88	35.1	50-150
Fluoranthene D10	100	11.11	37.5	50-150
Benz(a)Anthracene-D12	100	15.61	42.1	50-150
Chrysene D12	100	15.72	31.0	50-150
Benzo(b)Fluoranthene-D12	100	18.94	48.1	50-150
Benzo(a)Pyrene D12	100	19.81	39.1	50-150

M Indicates that a peak has been manually integrated.
U Indicates that this compound was not detected above the MDL.

R Indicates that the ion abundance ratio for this compound did not meet the acceptance criterion.

Appendix 6: Approximate Biomagnification of Select Metals in Boat Harbour and Adjacent Waterbodies

Fish whole body homogenates (Summer/Fall 2019) (maximum values in study) relative to macroinvertebrates (Order Odonata) whole body homogenates (maximum values in study) collected by Meaghan Quanz in Spring, Summer and Fall of 2018 sampling intervals in wetlands adjacent Boat Harbour (Dalhousie University, M.E.S. Thesis, unpublished data, *personal communication*). Mean metal increase from invertebrate to fish trophic levels was a 20x increase for the metals examined. *Note*: Comparisons approximate as trophic levels were sampled in different years.

Metal	Macroinvertebrate	Fish	Approximate Biomagnification Factor (BCF)
As	1 mg/kg	6 mg/kg	6x
Cr	1 mg/kg	40 mg/kg	40x
Cd	0.15 mg/kg	1 mg/kg	6.6x
Cu	4 mg/kg	30 mg/kg	7.5x
Pb	1 mg/kg	20 mg/kg	20x
Zn	20 mg/kg	800 mg/kg	40x

Literature Review
Fish Species in Boat Harbour: Historical to Present

2020

Prepared for:
Nova Scotia Lands

Jasmine Hoover
Cape Breton University

Introduction

This review attempts to give a picture of what species, particularly fish, were present prior to 1967 before Boat Harbour was used as an effluent treatment facility. Pre-1967, A'se'k was a tidal estuary, used by Pictou Landing First Nations (PLFN) as a source of food, medicine and traditional activities. As no baseline environmental assessment was done on fish abundance and species composition prior to effluent addition, a literature review focusing on historical publications, scientific studies, and memories recounted in news and literature was used to gain insight into ecological aspects of A'se'k. Information was gathered using databases, online searching, archives and available government reports. Although focused on fish and shellfish, there is also mention of other flora and fauna reliant on Boat Harbour's unpolluted waters. The archival data is split into three sections: 1) early history, which focused on some of the earliest literature found mentioning fish species in the area; and 2) recent history, the time period directly before and after 1967, and 3) post-effluent, which examines species found in and around Boat Harbour from 1970 to present.

There are two appendices to this report. The first, Appendix A. is a list of species mentioned specifically within Boat Harbour, it's watercourses and tributaries, Pre vs Post effluent. The second, Appendix B, *select literature*, is a grouping of documents found during this review that are difficult to find, and may be useful for reference and future use.

Early History

Unfortunately, the history of Boat Harbour has been one with an underlying theme of tension. Even before Pictou Landing First Nation was designated as a reserve in the 1850's/60's, Boat Harbour was a traditional Mi'kmaq encampment. Maritime harbours in general, and Boat Harbour specifically, were an ideal location for the Mi'kmaq, who spent summers drawing from the marine wealth (and respite from biting insects) while encamped along the shorelines of Atlantic Canada, venturing further inland each fall and winter as seasonal abundance of food dictated. The land of the Mi'kmaw (NS, PEI, NB), had a short growing season, forcing primary dependence on fishing, gathering and hunting, rather than agriculture (Upton, 1979). With much local variation, in January Mi'kmaq caught smelt, tomcod, seals and walrus. February and March and fall months were primarily for hunting game,while April to October fish, shellfish, lobster, crab and eels were critically important in season. Diets, especially in autumn were greatly supplemented by berries, nuts and fruit (Upton, 1979).

In 1761 a Royal Proclamation was issued in Nova Scotia, acknowledging that PLFN had a claim to all land along the northeastern shore of Nova Scotia, including the area around A'se'k. Despite this, history books describe speculators taking up land around 1765, and settlers settling there shortly after, limiting the area available to the Pictou Mi'kmaq and forcing them to require licenses to hunt and fish in the area (Patterson, 1877; John Ashton, 2018; GHD, 2018). The Illustrated historical atlas of Pictou County shows the 50 acre parcel inside Moodie Cove as "Indian Land" along with 89 acres south of the parcel and another parcel giving access to Boat

Harbour (J.H.Meacham & Company, 1879). Ashton, a well known historian in Pictou, mentions that the Mi'kmaq requested access to, and land adjacent Boat Harbour, several times throughout history as settlers encroached on their territory (Ashton, *personal communication*, 2019). In 1877, Patterson's book, *A History of the County of Pictou,* there are mentions of several species of fish and shellfish found in the Pictou area. He includes information recorded by Monsieur Denys in 1672 where Denys describes huge oysters, *the size of a shoe* (Patterson, 1877. p. 25), at a large harbour past Pictou Harbour. Patterson's book also describes an abundance of clams, salmon, smelts, other shellfish and game. Patterson mentions Pictou as a favourable location for the Mi'kmaq. "The rivers swarmed with fish, and the woods in the rear were plentifully stocked with game " (Patterson, 1877 p. 27).

One early piece of documentation found with species information specifically mentioning Micmac people in Pictou Landing, was from 1922. In *Medicines used by the MicMac Indians*, Wallis travelled to, and interviewed local Micmac people living in Pictou Landing in the summers of 1911 and 1912. Specifically, this report mentions: bees, cod, eel, porcupine, raccoon, skunk and squirrel. People living in Pictou Landing utilized various parts of animals and plants for medicinal purposes, and relied on them for their health and sustenance. Eel skin was used as a bandage for sprains (Wallis, 1922). The codfish louse, a parasite found on the gills of the cod, is another cure for ailments. Fat from various animals including raccoon, turtle, porcupine, and skunk is mentioned often for medicinal use (Wallis, 1922). Today, we know that bioaccumulations of contaminants tend to store in the fat of these animals. There are also plants, from swampy areas mentioned, which would showcase the importance of clean water nearby. "The roots of ukskusaligAn, a plant growing in low swampy places, is beaten until soft, then tied around the waist…" (Wallis, 1922). The overall picture from the history books and recollections mentioned later in this review, are of an area rich in natural resources, which was relied on by the Mi'kmaq for health and sustenance.

During a community consultation in 2016, a story board was used to demonstrate Boat Harbour in 1936, this image is Figure 1, below and mentions shellfish as well as a map of the area at the time.

Figure 1. U'logku'way The Past, Boat Harbour in 1936 (Pictou Landing First Nation & Government of Nova Scotia, 2016b)

In and around 1967

No comprehensive study was done looking at species of fish and related wildlife in Boat Harbour immediately before and after the start of effluent flowing into it. When the pulp mill planning began, local people and groups began to write letters of concern. A 1966 letter to the Premier of Nova Scotia, from Dr's MacDonald and Hamm, warn that " Dr. Bates (who worked for the government) has now said that the damming of Boat Harbour will improve it. …. This is exactly like taking a man who has two good legs and removing one -- and then saying to him, 'you are much better off with one'"(MacDonald & Hamm, 1966). They go on to try and compel the Premier to not allow this to happen, and believe the project is going ahead without explanation, justification, or alternative options, simply because no one has demonstrated any legal right to stop it.

In another later letter, this time to the engineering company, Drs. MacDonald and Hamm write that 'effluent toilette' at the plant is inefficient and inadequate, and that the foul odor from the lagoons indicate that they are dead. He mentions the effluent having driven aquatic life further and further out to sea (MacDonald & Hamm, 1970).

Because of the importance of the lobster fishery in the Northumberland Strait, Scarratt did a baseline larvae study immediately before the effluent began to flow into Boat Harbour in 1966. Several of his testing stations were at the mouth of Boat Harbour; however he did not capture larvae until further away from the mouth of Boat Harbour in his study. He concluded that lobster larvae would not normally encounter undiluted effluent (Scarratt, 1968).

In 1969, Krauel's technical report looked at flushing characteristics pre- and post-effluent addition because of the importance of the local fishery. His research suggested that a new location for the effluent outfall should be found, as flushing capacity was inadequate at Boat Harbour. In fact, he suggests a pipeline out into the depths of the Northumberland Strait (Krauel, 1969).

In 1969, J.A. Delaney and Associates submitted a report on the Sea Pollution from Boat Harbour. They mention that local residents had previously carried out watersports, and fishing for smelt in the coves and inlets, however this is no longer possible because of the contamination (Delaney and Associates, 1969). They mention that the lack of tidal action has resulted in higher contamination, and has degraded biological organisms including fish and plant life. *"On visiting Boat Harbour, one is appalled by the utter desolation of the water, which is extremely dark brown in color and emanates a strong odor of septicity"* (Delaney and Associates, 1969). Lobster catches were also reported as having diminished by about 30% in the area. They also recommended the same as Krauel, that effluent should be released farther from shore, although mentioned that ideally, the waste would be treated more so that less waste would be released. The further recommended a lime treatment (Delaney and Associates, 1969).

A plankton survey was done as part of the Delaney report. Samples from the mouth of Boat Harbour at a depth of about 12 feet, contained dead or very sluggish cyclopoid copepods, *Oithona* sp. and *Oncaea sp.*; dead *Planktoniella sp.*, and a slow and feeble *Ceratium longipes* movements, which normally are quick and jerky in motion (MacLellan, 1969). Various samples were taken around the area, the more distant plankton were from the effluent, the healthier they were found to be. Only one fish was found between Mckenzie Head and Otter Pond, which died shortly after collection and was not identified. This report noted that larval and adult fish such as herring and mackerel, feed on cyclopoid copepods, and that pollution is impacting higher trophic levels through the food chain. They also expressed concern that they found dead soft-shelled clams in samples taken between McKenzie Head and Otter Pond (MacLellan, 1969). Researchers noted "Boat Harbour was visited. The magnitude of pollution was unbelievable. The effluent from the mill has completely ruined what must once have been a lovely wooded area. No life at all was detectable; it looks like a waste land, black, foamy, stinking of H_2S" (Axelsen, 1969).

A report from the Bedford Institute describes benthic samples from the outlet off of Boat Harbour before and after the start of effluent addition. The report noted "The 1967 series was done just prior to the start of effluent discharge from the holding pond of the 500 ton/day bleached kraft mill at Abercrombie Point, Pictou County" (Bedford Institute, 1969). Samples were taken from 0.2 miles off the outlet of Boat Harbour, 0.15 miles off MacKenzie Head and 0.5 miles off the outlet of Otter Pond. They found that for the first two locations, amphipods, maldanidae worms, and sand dollars were not found in 1969 samples, although abundant in the 1967 samples. The Polychaetes and Pelecypods tested decreased in biomass for the first two locations, while the 3rd was unchanged. They concluded that there have been significant changes in the benthic community since the start of effluent discharge (Bedford Institute, 1969).

There have been many publications done after 1970 that include local resident's knowledge of the area around 1967. According to local residents, they realized they had been deceived immediately after the effluent began to flow. Fish were killed on masse, and community members recalled watching the fish trying to escape from the water on to the shores of Boat Harbour (Pictou Landing First Nation, 2018). These are outlined further in the next section.

Community members memories of area around 1967

A MEKS (Mi'kmaq Ecological Knowledge Study) done by Membertou Geomatics Solutions in 2019, used interviews with Mi'kmaq individuals who resided in communities nearby the proposed (new) pipeline for the mill. The MEKS includes some useful background information. In 1966, the province decided to acquire the riparian rights associated with the Reserve parcels around Boat Harbour (Hodder, 2019). At a PLFN public meeting in 1965, community members were against the proposed project. They were upset by the loss of: clams, quahogs, eels, smelt, lobster and trout, feeding grounds for ducks and geese, anchorage for their boats, swimming and recreational sites and future building lots along the shoreline (Hodder, 2019).

Interviewees for this MEKS were asked to identify areas (around the proposed new pipeline, which includes parts of Boat Harbour) where they knew of traditional uses having taken place, or currently in use (Hodder, 2019). Species mentioned for fishing include: salmon, mackerel, trout, bass, lobster, smelt, eels, herring, crab, clams, gaspereau, quahog, flatfish, minnows, oysters, cod, mussels, perch, scallops and tuna (Hodder, 2019). Hunting species included: deer and rabbit, partridge, racoon, fox, beaver, coyote, muskrat, bobcat, porcupine, fisher, duck, lynx and moose. During these interviews there were several stories shared of dead fish floating on the water's surface not too long after Boat Harbour was being used by the pulp mill. They also expressed uneasiness regarding use of anything harvested in the area including fish, game and plants (Hodder, 2019).

The Pictou Landing Native Women's Group, together with researchers from several Canadian universities, have several reports and publications that outline A'se'k characteristics pre-effluent. They noted that very few reports contained information about game animals, fish and shellfish habits in the area (Castleden et al., 2016). They carried out interviews with elders using narrative inquiry, gathering valuable oral histories, and employed a two-eyed seeing approach to their work. Specific animals mentioned in their work include fish (salmon, smelt, eels), shellfish (clam), muskrat, beaver, moose, rabbits, deer, as well as plants (Castleden et al., 2017). Community members feel they no longer have access to the tidal estuary that was once known for its highly productive subsistence of fisheries and recreational and medicinal functions. Quotes from the research group's interviews are below:

"There was a time when most of our food was from there. Every family was hunting, fishing, trapping and gathering. We ate healthier then. The salmon ran in the streams, and so many smelts we would take home buckets and buckets of them. We would go down with our shovels and buckets and dig up clams, cooking them right there on the shore" (Castleden et al., 2017.p. 28).

"At first, there was nothing to it really, just a mill. But then we saw all the fish dying. The rabbits and the deer- they seemed to disappear. And if we did hunt one, they had strange lumps. All those swampy areas we used to get our cranberries, all that is under water now, and we do not even know if our medicines are good anymore" (Castleden et al., 2017. p. 28).

"So now nobody goes down there to hunt or trap, get eels or smelts, snare rabbits or fish…. Nothing grows there or lives there anymore, and if it did- we would not trust it" (Heather Castleden et al., 2017. p. 29).

Part of their work also included scientific investigation, with Dr. Ron Russel conducting ecotoxicology testing on species currently found in Boat Harbour including mummichog, muskrat, beavers and frogs. They noted a low biodiversity in the area when it comes to plankton, and the fish and mammals collected were species that can often tolerate polluted areas (Castleden et al., 2016).

The group also was involved in a web map project, that outlined areas where traditional medicines are collected, wild vegetation, fishing, swimming and more in and around Boat Harbour in the past, present and future. The map was created using responses to the group's survey as well as oral histories (Castleden et al., 2016). Quotes from community members are included in the Web application, including this one regarding fishing in Boat Harbour:

""Ya we used to go clamming there too. Summertime… we used to cook them out in the backyard. We'd have a big bucket of them and cook them… It was fun. (But) There's nuttin' living in the water… I mean how can they. How can they possibly live there!" (McCurdy, 2016).

Community members also mentioned catching smelt in the area pre-effluent. Several animals such as rabbits, deer and moose were also mentioned, with some community members still hunting in the area while others do not eat anything from around the area after the effluent started (McCurdy, 2016).

Recent History - 1970- present

In 1972 a dam was built, and in 1973 an upgraded treatment system was installed, including settling basins, aeration lagoon and stabilization lagoon, used to this day. A review of the system in 1974 mentioned that ducks are present in the lagoon, but mentioned that this may be because they are accustomed to resting there when the lagoon was in its natural state (Baker, 1974).

In 1992, new regulations required all pulp and paper mills in Canada to conduct aquatic environmental effects monitoring studies (St-Jean et al., 2003). Although too late for the initial effluent flow into Boat Harbour, there are Environmental Management requirements now in place that include scientific testing in the area. With new environmental regulations in place, Northern Pulp has completed a report to NS Environment respecting their proposed 2020 pipeline which would go directly out to the Northumberland Strait (full report: https://novascotia.ca/nse/ea/Replacement_Effluent_Treatment_Facility_Project/). This report includes data on fish habitat in the area surrounding the proposed pipeline. Although these studies are in neighbouring Caribou and Pictou Harbour, it is not unreasonable to assume similar species would have been present in and around Boat Harbour's watercourses and tributaries pre- effluent addition. Briefly, species found in this 2019 study include stickleback, brook trout, common white sucker, several dace species and shiners. Fish species which have potential to use tidally influenced areas in and around Pictou, include: brook trout, stickleback, striped bass, silversides, American eel, salmon, herring, smelt, and other estuarine fish (Dillon Consulting, 2019). The report to the Nova Scotia government also includes underwater surveys of nearby Caribou Harbour and Pictou Harbour, during which consultants found crab, mussels, clam, oysters, and scallop, as would be expected in those areas (Stantec Consulting Ltd., 2019). The Marine Environment Impact Assessment, by EcoMetrix surveyed local resource users who indicated the following species have been harvested in the past year: lobster, mussels, mackerel, oysters, surf clam, brook trout, brown trout, scallops, striped bass, atlantic salmon, lake trout, rainbow trout, soft clam, haddock, other clam, smelt , crab, other bass (EcoMetrix, 2019). Ecometrix also notes in their 2016 work in Boat Harbour that the residents of Fisher's Grant Reserve 24 harvested a variety of species from the Pictou Road Area in 2016, including lobster, rock crab, herring, and eels. They report that the First Nation fishery also included the collection of shellfish and eels from Boat Harbour area prior to it's conversion into a wastewater treatment facility (EcoMetrix, 2016).

In 2014, a First Nations Food, Nutrition and Environment Study (FNFNES) was done on several communities including Pictou Landing First Nation. This study looked at ingestion rates for traditional foods as well as sampling for chemical contaminant content (Chan et al., 2017). In 2019, a follow up survey was done by NS Lands, with assistance from GHD for PLFN, using a focus group to summarize and validate anticipated Harvested Traditional Food Consumption post-remediation from Boat Harbour. The foods identified in the latter survey were the top 10 traditional food items found in the 2014 FNFNES. The rate of anticipated traditional food consumption will be multiplied by contaminant concentrations in each food source to determine an estimate of ingested dose by contaminants that could be potentially transferred to humans. In general, the focus group data averages were within the range of consumption frequencies reported in the FNFNES for lobster, moose, Atlantic salmon, all fish, strawberries and deer. For blueberries, raspberries, blackberries and crab, the focus group averages were higher than in the FNFNES (GHD, 2019). Unfortunately, because this was post- effluent, we only learned about current traditional food consumption.

Recent studies within Boat Harbour show the dramatic effect the pulp mill has had on the ecosystem. In 2016 Dr. Ken Oakes performed a fish survey in Cove C of Boat Harbour. This is the area just past the settling ponds in the treatment facility seen in Figure 2 below.

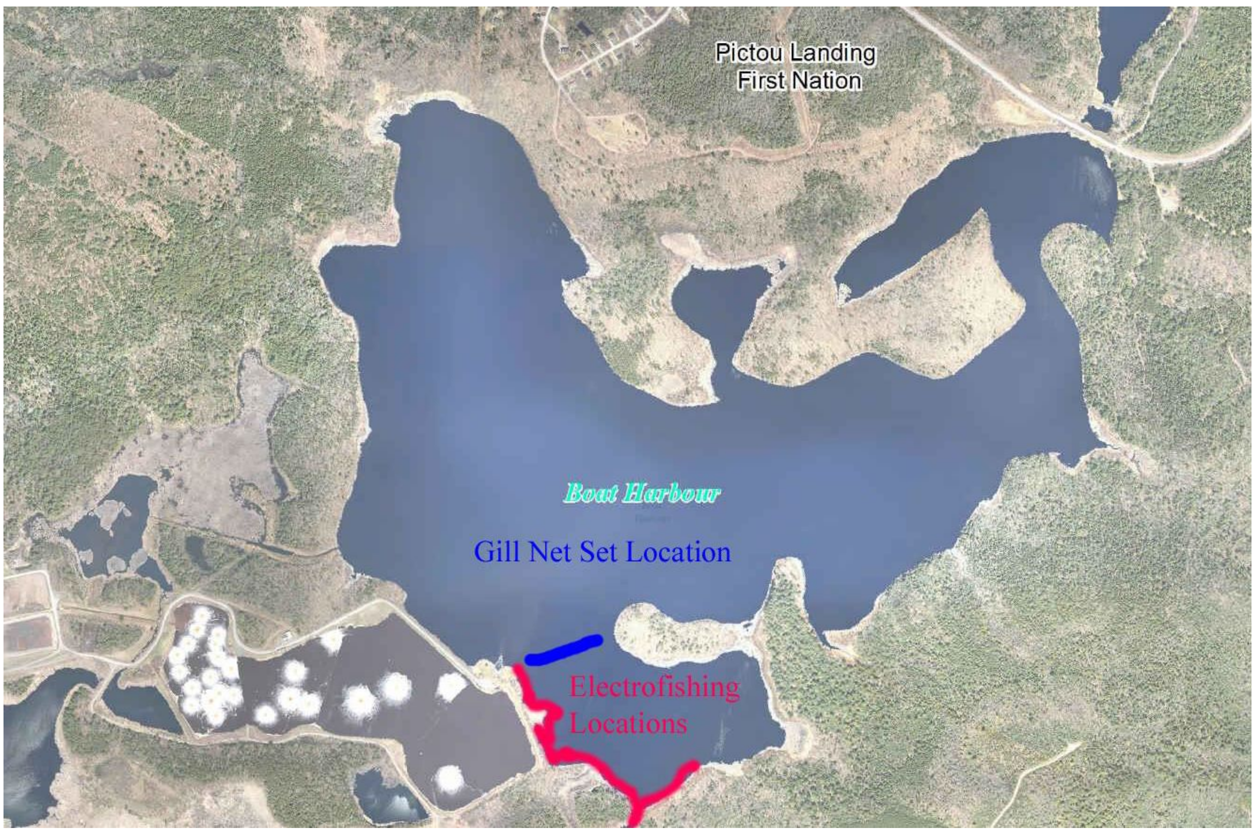

Figure 2. Gill net and electroshocking locations in Cove C, Boat Harbour

A total of 7 fish were located in the cove, 5 ninespine stickleback and 2 mummichog. Both species are known to be pollution tolerant. All fish were located around the margins of Boat Harbour, where freshwater would be entering the body of water (Oakes, 2016). Dr Oakes noted several invertebrates along the electroshocking route including: snails, backswimmers, dragonfly, water striders and tadpoles (Oakes, 2016).

In 2017, field surveys were done on the watercourses around Boat Harbour by consulting firm GHD as part of the Boat Harbour Remediation Project. Only two fish were observed, one species was successfully identified, a three-spined stickleback (GHD, 2018). Just beyond Boat

Harbour, GHD noted the sandy substrate of the Pictou Road section of the Northumberland Strait provides significant foraging habitat for some marine species, and is a diverse habitat for various marine species including fish and shellfish, including at least eight species at risk (GHD, 2018). From July- October 2017 the environmental baseline assessment observed various wildlife species within the Boat Harbour treatment facility site including white tailed deer, black bear, coyote, skunk, hare, porcupine, raccoon, muskrat, beaver, as well as snakes, frogs, and toads (GHD, 2018). GHD's work also included bird surveys, and over 1000 individuals were observed from 81 species, in the area.

In Fall of 2019, researchers from Cape Breton University conducted a fish survey within Boat Harbour itself, its estuary, and several key wetland and tributary streams flowing into Boat Harbour to determine species composition and abundance prior to remediation. Species and totals are listed below. Within Boat Harbour itself, very few fish were captured, greater fish abundance was found in the watercourses and estuary (Hoover & Oakes, 2019).

	Boat Harbour	BH Wetlands and Watercourses	Estuary
Total	**16**	**101**	**402**
Mummichog (*Fundulus heteroclitus)*	5	3	393
Ninespine stickleback (*Pungitius pungitius*)	1	55	7
Golden shiner (*Notemigonus crysoleucas*)	10	1	0
Juvenile golden shiner (*Notemigonus crysoleucas*)	0	42	0
Tomcod (*Microgadus tomcod*)	0	0	1
White perch (*Morone americana*)	0	0	1

Fish Survey, 2019. (Hoover & Oakes, 2019)

The Future

In the weeks prior to January 31, 2020, the legislated deadline for cessation of effluent addition to Boat Harbour, provincial authorities declined to grant an extension, resulting in the mill being idled until an approved treatment and disposal process is developed in the future. The community consultation in 2016 produced a storyboard for Saponuk'wey The Future (Figure 3, below) outlining the potential return to tidally-influenced conditions. Many in the community hope for a time when A'se'k will be restored to its natural state as a tidal estuary, and they can once again use it in their traditional ways.

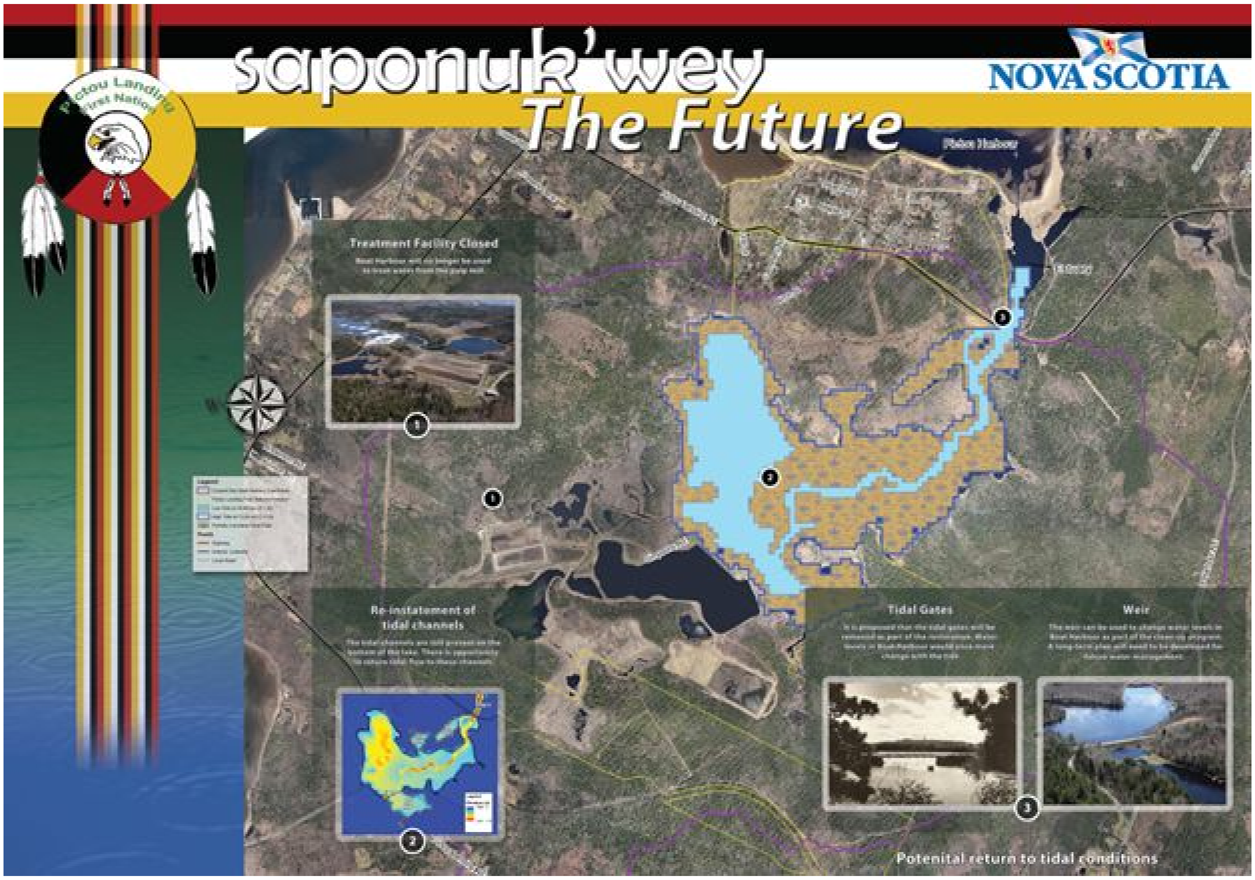

Figure 3. Saponuk'wey The Future, Potential return to tidal conditions (Pictou Landing First Nation & Government of Nova Scotia, 2016a)

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Appendix A, Aquatic Species list in Boat Harbour

Pre- Effluent

Cod	*Gadus morhua*
Eel	Anguilliformes (but almost certainly *Anguilla rostrata*)
Clams	Unclear from report context - potentially *Mercenaria*
Smelt	Osmeridae (but almost certainly rainbow smelt *Osmerus mordax*)
Quahog	*Mercenaria mercenaria*
Lobster	Nephropidae - (but almost certainly *Homarus americanus*)
Trout	likely *Salvelinus fontinalis* in a freshwater context
Fish	Osteichthyes (greater specificity impossible from early reports)
Salmon	likely Atlantic salmon (*Salmo salar*)
Shellfish	Mollusca

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Post- Effluent

Nine-spine stickleback	*Pungitius pungitius*
Mummichog	*Fundulus heteroclitus*
Golden shiner	*Notemigonus crysoleucas*
Tomcod	*Microgadus tomcod*
White perch	*Morone americana*
Three-spined stickleback	*Gasterosteus aculeatus*

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