Highway 104 - Antigonish Wetland 21 (South River)
Year 5 (2016) Monitoring Report

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Prepared for:
Nova Scotia Department of Transportation and Infrastructure Renewal
1672 Granville Street, Halifax, NS, B3J 2N2
Attention: Dr. Bob Pett   Bob.Pett@novascotia.ca

Prepared by:
East Coast Aquatics Inc.
P.O. Box 129, Bridgetown, NS, B0S 1C0
(902) 665-4682
www.eastcoastaquatics.ca

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Table of Contents

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Executive Summary

The Nova Scotia Department of Transportation and Infrastructure Renewal (NSTIR), as part of the larger upgrading of Highway 104 in Pictou and Antigonish Counties, altered a wetland at South River through the construction of a new bridge crossing. NSTIR retained East Coast Aquatics Inc. (ECA) to undertake post-alteration monitoring of the South River salt marsh (Antigonish Wetland 21) to determine the actual alteration area and if there were any additional unanticipated impacts to the remaining wetland area as a result of the alteration. ECA has completed monitoring at the wetland over the period of 2012 to 2016. This monitoring incorporated vegetation, ground surface elevations, soils and water quality at the wetland. Experienced wetland scientists and botanists completed the annual surveys of the wetland. The results of the vegetation monitoring were compared against thresholds to determine if an ecologically significant change had occurred at the wetland. Year 5 post-alteration monitoring at Antigonish Wetland 21 occurred between July and November 2016.

The Bray-Curtis Similarity Index analysis suggested a significant change in the wetland plant community during the 2012 to 2016 monitoring period for all seven transects. The Prevalence Index analysis indicated a mixed response, with approximately half of the vegetation zones having shifts in the plant community to one more typically associated with dryer conditions, and half indicating a shift to wetter conditions. A preliminary examination indicates that shading from the completed bridge lanes may be a factor in the Bray Curtis and Prevalence Index values observed for the vegetation transects north of the crossing. While no alien invasive species were identified at Antigonish Wetland 21, a number of exotic species were recorded, particularly as early colonizers in the bare soil of the former construction pad. Field surveys in 2016 confirmed the persistence of three previously identified species of conservation concern *Teucrium canadense* (American germander), *Samolus valerandi* (Seaside brookweed) and *Cuscuta cephalanth*i (Buttonbush dodder) as being abundant and widely scattered across the site.

Soils at the wetland were examined in 2016 by a series of six test pits, indicating generally similar conditions across the site with an organic-based horizon of varying thickness underlain by a silt horizon. Penetrometer surveys indicated soils within the footprint of the former construction pad, particularly the eastern portion, had significantly greater compaction, extending to a depth of at least 46 cm, compared to undisturbed salt marsh soils.

The six bridge piers and associated armour stone were found to have permanently altered 698 m^2 of salt marsh. The access road and construction pad were found to have temporarily impacted 14,319 m^2 of predominantly salt marsh wetland habitat. It is recommended that repeat monitoring of the South River wetland occur in 2017 with an emphasis on the presence and extent of exotic species across the former construction pad area.

While remedial actions in the form of seed/transplanting of salt marsh species could be undertaken within the construction pad area, there is considerable scientific and practical benefit in refraining from this at present. With the monitoring dataset that exists for the site (pre-construction through to the completion of construction) the potential exists to thoroughly evaluate the use of geotextile/gravel construction pads in salt marshes, as well as determine spatial and temporal extent of natural regeneration. For these reasons, no remediation actions are proposed at present for Antigonish Wetland 21.

Introduction

Wetland alteration proposals were prepared by NSTIR for 25 wetlands that have been affected by the upgrading of Highway 104 in Pictou and Antigonish Counties (Table 1; Stantec Consulting Ltd., 2005, 2006a, 2006b, 2008, 2009a, 2009b, 2009c, 2010; Maritime Testing, 2011; Neill and Gunter, 2001; CBCL, 2015). The subsequent approvals required long-term ecological monitoring and restoration plans to detect any further changes or unforeseen alterations to the wetlands.

In 2010, Year 1 monitoring was initiated at eight wetlands and the information summarized in respective reports prepared by Stantec Consulting Ltd. (2011). Monitoring was initiated at three additional wetlands in each 2011 and 2012. Monitoring commenced at an additional six wetlands in 2015 and four wetlands in 2016. The initiation and conclusion of the monitoring at each wetland is summarized in Table 1.

East Coast Aquatics was commissioned to conduct the wetland vegetation surveys in the designated key plant communities, and to develop, where appropriate, a long-term ecological monitoring and restoration plan at each of the project wetlands. This report describes the fifth year of monitoring at Antigonish Wetland 21, which was conducted between July and November 2016. The methodologies employed were based on the Nova Scotia Wetlands Delineation Manual (MCFT, 2009) and followed those described in further detail by East Coast Aquatics (2013).

The objectives of the project, as articulated in the Request for Proposals, were: (a) to provide detailed descriptions of sampling methods, locations of transects and other sampling sites, and databases with the collected field information; (b) to provide confirmation of direct wetland alteration areas; (c) to undertake soil, vegetation and hydrology characterization; and (d) to provide clear recommendations for any changes to future monitoring programs or restoration requirements.

The layout of this report corresponds to the above objectives. Part 1 describes the results of the 2016 monitoring; Part 2 provides an analysis of change between 2012 and 2016; and Part 3 addresses conclusions concerning the status of the wetland and recommendations for future monitoring.

Table 1: Summary of wetland monitoring associated with the twinning of Highway 104 in Pictou and Antigonish Counties

NS Environment Approval #	Wetland ID	County	Wetland Type	Monitoring Started	Most Recent Year Monitored	Monitoring Status	Original Size (ha)	Predicted Alteration Area (ha)
2006-055374	Wetland 1*	Pictou	Shrub Swamp - Fen	2010	2012	Completed	7.00	0.47
2008-061777	Wetland 2*	Pictou	Basin Marsh	2010	2012	Completed	0.33	0.24
2008-064297	Wetland 3	Pictou	Shrub-Tree Basin Swamp	2010	2012	Completed	0.97	0.06
2009-065789	Wetland 4	Pictou	Shrub Swamp – Seepage Track Marsh	2011	2013	Completed	0.52	0.35
2010-070764	Sutherlands River*	Pictou	Complex Salt Marsh & Coastal Freshwater Marsh	2010	2014	Completed	~32 (SM) + 0.9 (FM)	0.35
2009-066466	Atwater** Crosby Lake	Pictou	Complex Basin Swamp & Shallow Open Water	2010	2012	Completed	5.51	Wetland creation
2011-075950	Coalburn 3	Pictou	Treed and open water swamp	2012	2014	Completed	0.42	0.006
2011-075950	Coalburn 4	Pictou	Treed swamp	2012	2014	Completed	1.11	0.43
2009-066003	Wetland 1*	Antigonish	Basin Marsh – Shrub Basin Swamp	2010	2016	Ongoing	13.73	1.18
2009-066003	Wetland 2*	Antigonish	Basin Marsh – Shrub Basin Swamp	2010	2013	Completed	0.39	0.21
2009-066003	Wetland 3	Antigonish	Shrub-Tree Basin Swamp	2010	2012	Completed	1.27	0.58
2009-066003	Wetland 4	Antigonish	Tall Shrub Basin Swamp	2011	2012	Completed	0.74	0.24
2009-066003	Wetland 6*	Antigonish	Complex Basin Swamp & Shallow Open Water Marsh	2011	2013	Completed	4.29	0.74
2009-066003	Wetland 11	Antigonish	Complex – low & tall shrub stream swamp and shallow water wetland	2015	2016	Ongoing	3.60	0.66
2009-066003	Wetland 12	Antigonish	Tall shrub stream swamp	2015	2016	Ongoing	7.38	1.48

NS Environment Approval #	Wetland ID	County	Wetland Type	Monitoring Started	Most Recent Year Monitored	Monitoring Status	Original Size (ha)	Predicted Alteration Area (ha)
2009-066003	Wetland 13	Antigonish	Complex – mixed treed basin swamp and tall shrub basin swamp	2015	2016	Ongoing	1.19	0.56
2009-066003	Wetland 15	Antigonish	Tall shrub stream swamp	2015	2016	Ongoing	0.84	0.21
2009-066003	Wetland 16	Antigonish	Coniferous treed swamp	2015	2016	Ongoing	1.48	1.00
2009-066003	Wetland 17	Antigonish	Tall shrub basin swamp	2015	2016	Ongoing	2.05	0.37
2009-066003	Wetland 17B	Antigonish	Mixed treed swamp	2016	2016	Ongoing	1.04	0.30
2009-066003	Wetland 18	Antigonish	Treed swamp	2013	2015	Completed	1.13	0.43
2015-093928	Wetland 19	Antigonish	Shrub /treed swamp	2016	2016	Ongoing	1.14	0.02
2009-066003	Wetland 21* South River	Antigonish	Complex Salt marsh, coastal freshwater marsh	2012	2016	Ongoing	15.8	0.118 ha perm.; 0.178 ha temp.
2015-093928	CBCL 2	Antigonish	Mixed treed swamp	2016	2016	Ongoing	0.282	0.11
2015-093928	CBCL 3	Antigonish	Mixed treed swamp	2016	2016	Ongoing	0.16	0.03

* DFO HADD authorizations 5301-3-02-004 and 5301-3-04-006 for seven (7) of the wetlands.
** DFO and NSE-approved wetland compensation project

Part 1: 2016 Year 5 Post-Construction Monitoring of Antigonish Wetland 21 (South River)

Antigonish Wetland 21 (South River) Description

Neill and Gunter (2001) determined the Highway 104 crossing location of the South River (Antigonish Wetland 21) to be a mosaic of highly productive tidal habitats, with the site being classified as a coastal freshwater wetland. The crossing location is situated at the interface of salt and freshwater, and as such contains a variety of habitats and species typical of both communities. Field surveys documented 43 flora taxa within the wetland, with grasses, sedges and rushes being dominant (Neill and Gunter, 2001). Stantec (2010b) reports that the inter-tidal site has a large central peninsula with the main river channel to the east and a remnant backwater channel on the west of the central peninsula.

Possible Sources and Directions of Impacts on the Wetland

Stantec (2010b) predicted that construction of the South River bridges would result in the loss of fish habitat through the infilling of 300 m^2 of the back channel and 50 m^2 of the main channel. Approximately 829 m^2 of the wetland at the site would be permanently impacted by the construction of the bridge piers, with an additional 338 m^2 impacted for the west-bound abutment and toe of slope, for a total of 1179 m^2 (Table 2) of permanently lost wetland area. The construction of access roads and work areas were anticipated to temporarily impact 1775 m^2 of the wetland (Stantec, 2010b), as fill material associated with these structures was to be removed post construction. The central peninsula wetland, where construction occurred, has an area of approximately 3.3 ha (Figure 1).

Table 2: Direct and indirect predicted impacts on the Antigonish Wetland 21

Wetland	Area lost (ha)	Area lost (% of total)	Predicted Impacts from Wetland Alteration Report: Direct	Predicted Impacts from Wetland Alteration Report: Indirect
Antigonish Wetland 21	0.118	3	Loss of habitat	- disruption of drainage features - introduction of weeds - decrease in hydrologic function (surface water retention) - disturbance of sensitive species

Given the preliminary field assessment of the site by ECA staff in 2012 and the revised construction program, additional unforeseen impacts to Wetland 21 as a result of the twinning of Highway 104 were expected to have the greatest probability of occurring within the bridge corridor and the substantially larger construction pad area. It was anticipated that any unforeseen impacts would diminish both upstream and downstream from the crossing, perpendicular to the highway (Figure 1). The locations of predicted direct and unforeseen impacts were considered in the placement of monitoring transects.

Given the field assessment of the site by ECA staff, additional unforeseen impacts to Wetland 21, as a result of the twinning of Highway 104, were expected to have the greatest probability of occurring next to the road prism and to diminish perpendicular to the roadway to the south. It was predicted that any unforeseen sedimentation, contamination, altered hydrology, or introduction of weeds would most likely occur close to the road prism (Figure 1).

Prior to construction, NSTIR also commissioned CB Wetlands and Environmental Specialists (CBWES) Inc. to conduct high resolution, low altitude aerial photography using a helium-filled blimp. The area was photographed on June 26, 2012, and detailed mosaic and habitat maps prepared for future monitoring and wetland alteration assessment (see Appendix 7). As a follow-up to the 2012 surveys, ECA retained Mike Dembeck Photography to complete a repeat high-resolution aerial survey of Wetland 21 on July 26, 2016. A revised habitat map for site was prepared using the updated photography with input from the 2016 field surveys (Figures 2 and 3) (see Appendix 1 for methods used).

During the interval between the 2012 and 2016 photography series, the construction pad was placed in salt marsh, the east and westbound bridge lanes were completed, and the construction pad subsequently removed. Vigorous re-vegetation by a mixture of native species and opportunistic colonizing exotics was observed across the eastern portion of the former construction pad in 2016. The western portion of the former construction pad was characterized by extensive ponding of water at low tide and poor to very poor re-vegetation, with widespread areas of bare soil / sediment. The alignment of the former access road to the construction pad was largely re-vegetated by August 2016, principally with *Typha latifolia* (Broad-leaved Cattail). No other large-scale changes in the salt marsh vegetation community were observed to the north and south of the bridge crossing between the 2012 and 2016 aerial surveys.

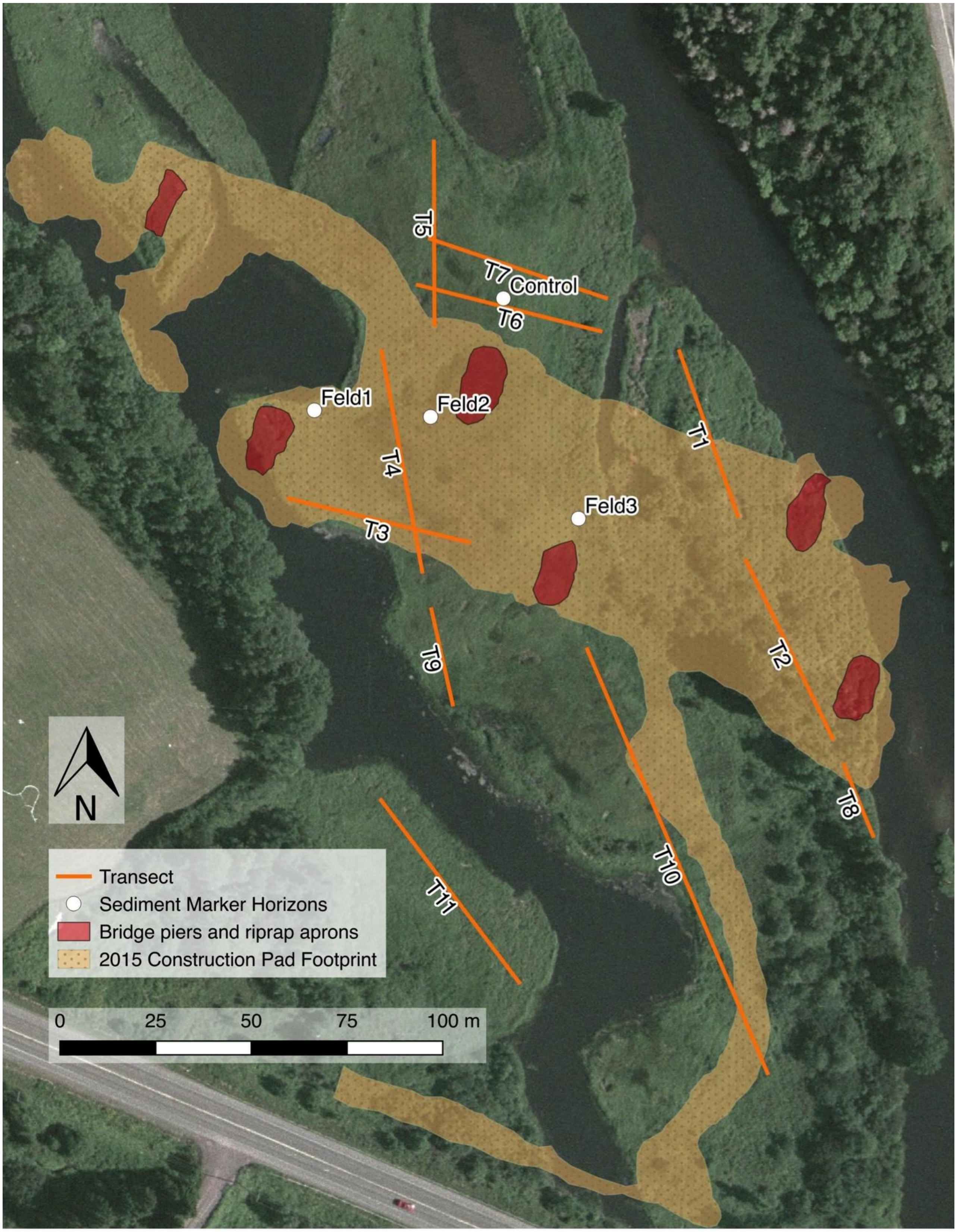


Figure 1: Antigonish Wetland 21 showing orientation of vegetation transects and associated features, with 2007 base photo. Impacted wetland boundary based on field surveys by ECA (2012 to 2016). Predicted permanent wetland alteration: 0.12 ha. Actual permanent wetland alteration at bridge piers: 0.070 ha.

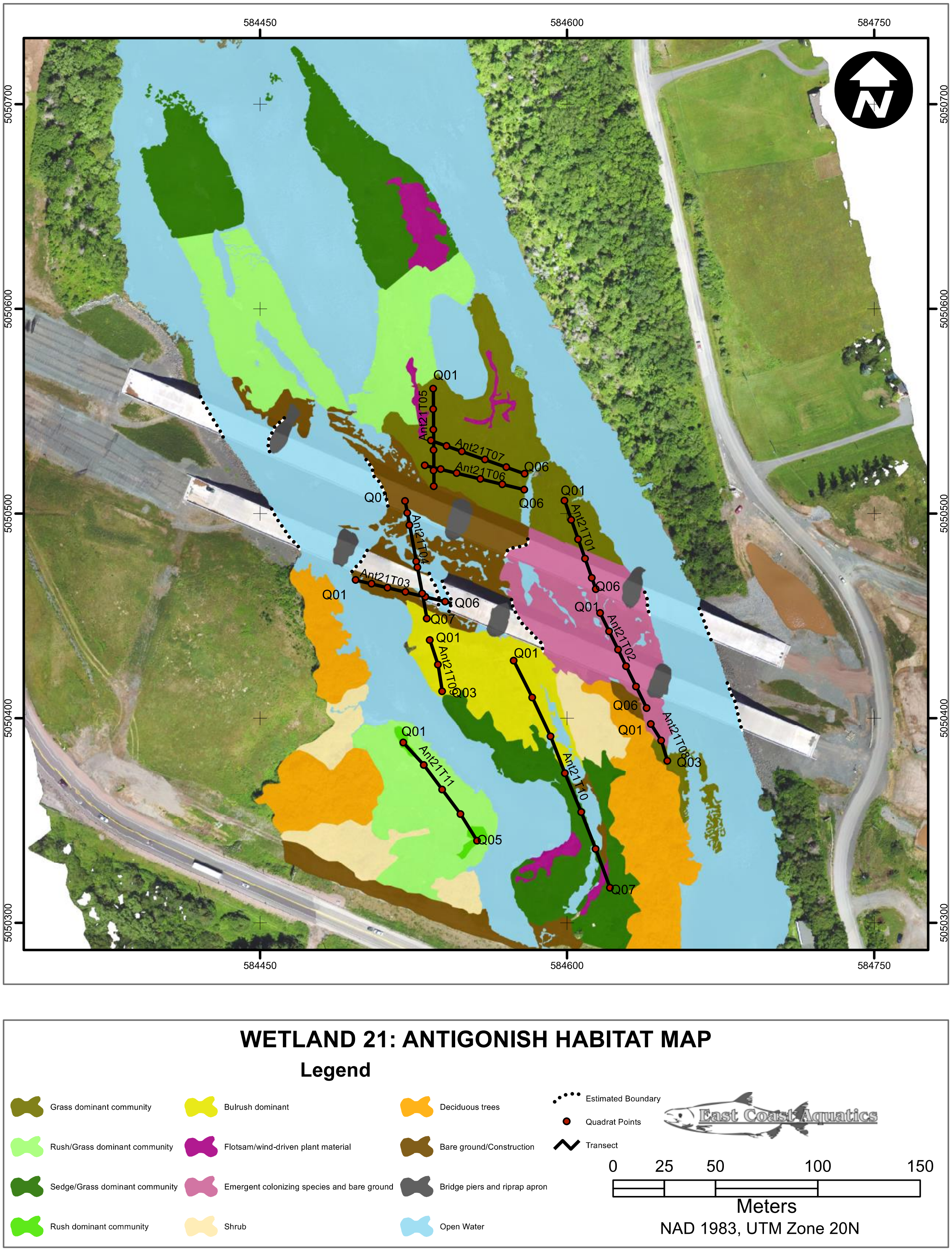


Figure 2: Habitat map of Antigonish Wetland 21, based on July 26, 2016 aerial photography.

Figure 3: Oblique image of Antigonish Wetland 21, with view to the southeast. Original Highway 104 bridge crossing is at rear of photo. Note poor re-vegetation and extensive standing water beneath the western (right-side) of crossing (photo July 26, 2016).

Methodology Overview

The methodology utilized in 2016 consisted of the survey of vegetation transects in the wetland, allowing for the representative and reproducible placement of monitoring quadrats. The percent abundance of wetland vegetation at the herb, shrub, sapling and tree strata was recorded at each quadrat. A description of the detailed methodology employed is contained in Appendix 1.

The methodology employed for the 2016 field monitoring drew on current NSE guidance and specifications for wetland delineations and reporting (MCFT (2009) and ECA (2013)). The ECA team was composed of Mike Parker (study design and field surveys), Tom Neily (botanical assessments) and Andy Sharpe (project management and field surveys), thus maintaining consistency within personnel since Year 1 to limit practitioner variability within the reported results.

As shown in Figure 1, a total of seven transects were established at Antigonish Wetland 21 by ECA on August 26, 2012, four perpendicular to the axis of highway and three parallel. The purpose of the perpendicular and parallel transects was to evaluate if a gradient exists for any measured impacts across the site. The transects were positioned to evaluate for potential impacts both upstream and downstream of the crossing location, as well as beneath the bridges where impacts were anticipated to be temporary. The transects ranged from 45 to 59 m in length and covered a total linear distance of 354 m. Each transect contained six to seven quadrats, with a total of 43 quadrats being established.

An additional four vegetation transects (transects 8 to 11) were established in 2016 in order to more fully characterize impacts immediately adjacent to the bridge construction pad and nearby unaltered portions of the wetland. As shown in Figure 1, the 2016-established transects were perpendicular to the bridge alignment, had a total linear length of 226 m and incorporated 18 monitoring quadrats.

As part of the survey methodology, ECA established a number of Quality Assurance/Quality Control (QA/QC) measures to verify the consistency and accuracy of the results, and to help quantify the magnitude of change that is likely detectable by the methods employed. These methods and QA/QC results are described in greater detail in Appendix 2.

Appendix 3 shows the coordinates for the benchmark, water quality monitoring locations, and transects as well as the ground surface elevation profiles. Substrate characteristics in each quadrat were recorded as part of the monitoring program and are reported in Appendix 4. These measures characterize the amount of moss, water, muck, and stone associated with the plant communities. Field data sheets are presented in Appendix 5 and site photographs are shown in Appendix 6.

Vegetation Monitoring

A total of six quadrats were surveyed along transect AntW21T1. Although transect 1 was established in 2012 as having one zone, the placement of the construction pad dissected the transect with three quadrats being undisturbed and three quadrats covered by the pad. So as to better compare these two conditions, the 2016 analysis had divided the transect into two zones. The transect was positioned perpendicular to the axis of the new Highway 104 crossing. Table 3 presents the dominant herbs for transect AntW21T1 in 2016.

The dominant herbs along transect AntW21T1 in zone 1 were *Calamagrostis canadensis* and *Spiraea* *alba* (Figure 4). The dominant herbs in zone 2 were *Calamagrostis canadensis,* Graminoids (other grass species) and *Juncus effusus*. There were no shrubs, saplings or trees on the transect. Quadrats 1, 2 and 3 had been largely undisturbed by the construction pad. Quadrats 4 and 6 had sparse vegetation cover, with significant coverage of muck and water (30 to 80% cover). The stakes marking the locations of quadrats 2 and 3 were not present in April 2016 and the quadrats were re-staked. It is suspected that winter ice movement across the salt marsh displaced the stakes.

Table 3: Dominant plant species by zone, transect AntW21T1

Zone	**1 (undisturbed)**	**2 (construction pad impact)**
Zone width (m)	**25**	**25**
No. of Quadrats	**3**	**3**
Herbs	*Calamagrostis canadensis* (Blue-joint reedgrass), *Spiraea alba* (Narrow-Leaved Meadow-Sweet)	*Calamagrostis canadensis* (Blue-joint reedgrass), Graminoid (Grasses), *Juncus effusus* (Soft Rush)
Shrubs	None	None
Saplings	None	None
Trees	None	None

A total of 22 plant species were recorded on the transect AntW21T1. No alien invasive species were recorded although the four exotics were recorded (with their cumulative absolute abundance): *Gnaphalium uliginosum* (Low Cudweed) (10%), *Phleum pratense* (Meadow Timothy) (10%), *Polygonum hydropiper* (Marshpepper Smartweed) (25%) and *Sonchus arvensis* (Field Sowthistle) (4%). The exotic species occurred exclusively in quadrats 5 and 6 (zone 2). No species at risk were documented.

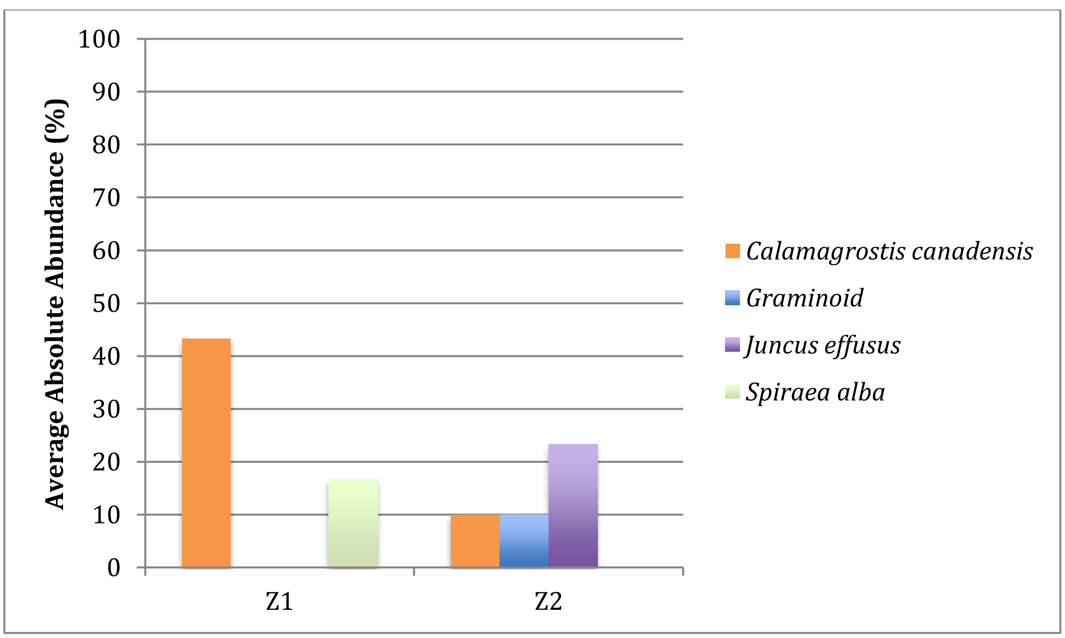


Figure 4: Dominant herb species, transect AntW21T1

A total of six quadrats were surveyed along a second transect (AntW21T2), two in each of the three zones. The transect was positioned perpendicular to the axis of the new Highway 104 crossing. Table 4 presents the dominant herbs for transect AntW21T2. In total, 28 plant species were documented along the transect. Transect 2, which had been uncovered with the removal of the construction pad in 2015, had experienced rapid vegetation colonization over the past year. Quadrats 2 and 3 were re-staked as the corner stakes were missing. Fresh ATV tracks were observed across the salt marsh, in the area of transects 1 and 2.

In zone 1, the dominant herbs were *Glyceria laxa, Phalaris arundinacea, Polygonum hydropiper, Carex lurida, Carex stipata, Juncus effusus, Leersia oryzoides, Polygonum sagittatum* and *Scirpus cyperinus*. In zone 2, the dominant herbs were *Ranunculus repens, Rumex crispus* and *Polygonum hydropiper*. The dominant herbs in zone 3 were *Polygonum hydropiper, Plantago major* and *Gnaphalium uliginosum.* There were no shrubs, saplings or trees on the transect (Figure 5).

Table 4: Dominant plant species by zone, transect AntW21T2

Zone	**1 (construction pad impact)**	**2 (construction pad impact)**	**3 (construction pad impact)**
Zone width (m)	**13**	**19**	**18**
No. of Quadrats	**2**	**2**	**2**
Herbs	*Glyceria laxa* (Northern Mannagrass), *Phalaris arundinacea* (Reed Canary Grass), *Polygonum hydropiper* (Marshpepper Smartweed), *Carex lurida* (Shallow Sedge), *Carex stipata* (Stalk-Grain Sedge), *Juncus effusus* (Soft Rush), *Leersia oryzoides* (Rice Cutgrass), *Polygonum sagittatum* (Arrow-Leaved Tearthumb), *Scirpus cyperinus* (Cottongrass Bulrush)	*Ranunculus repens* (Creeping Butter-cup), *Rumex crispus* (Curly Dock), *Polygonum hydropiper* (Marshpepper Smartweed)	*Polygonum hydropiper* (Marshpepper Smartweed), *Plantago major* (Nipple-Seed Plantain), *Gnaphalium uliginosum* (Low Cudweed)
Shrubs	None	None	None
Saplings	None	None	None
Trees	None	None	None

The substrate for AntW21T2 was recorded as stone, rock and exposed mineral soil (25%) and muck (20%) in zone 3. No invasive alien species were recorded although 10 exotic species (with their cumulative absolute abundance) were documented: *Daucus carota* (Wild carrot) (9%), *Echinochloa crus-galli* (Barnyard Grass) (4%), *Gnaphalium uliginosum* (Low Cudweed) (24%), *Hypericum perforatum* (A St. John's-Wort) (5%), *Matricaria discoidea* (Pineapple-Weed Chamomile) (4%), *Plantago major* (Nipple-Seed Plantain) (25%), *Polygonum hydropiper* (Marshpepper Smartweed) (95%), *Ranunculus repens* (Creeping Butter-Cup) (45%), *Rumex crispus* (Curly Dock) (54%) and *Vicia cracca* (Tufted Vetch) (5%).

No species at risk were documented although two species of conservation concern *Polygonum* *pensylvanicum* (Pennsylvania Smartweed) (S3 / Secure) and *Verbena hastata* (Blue Vervain) (S3 / secure) were recorded on transect AntW21T2.

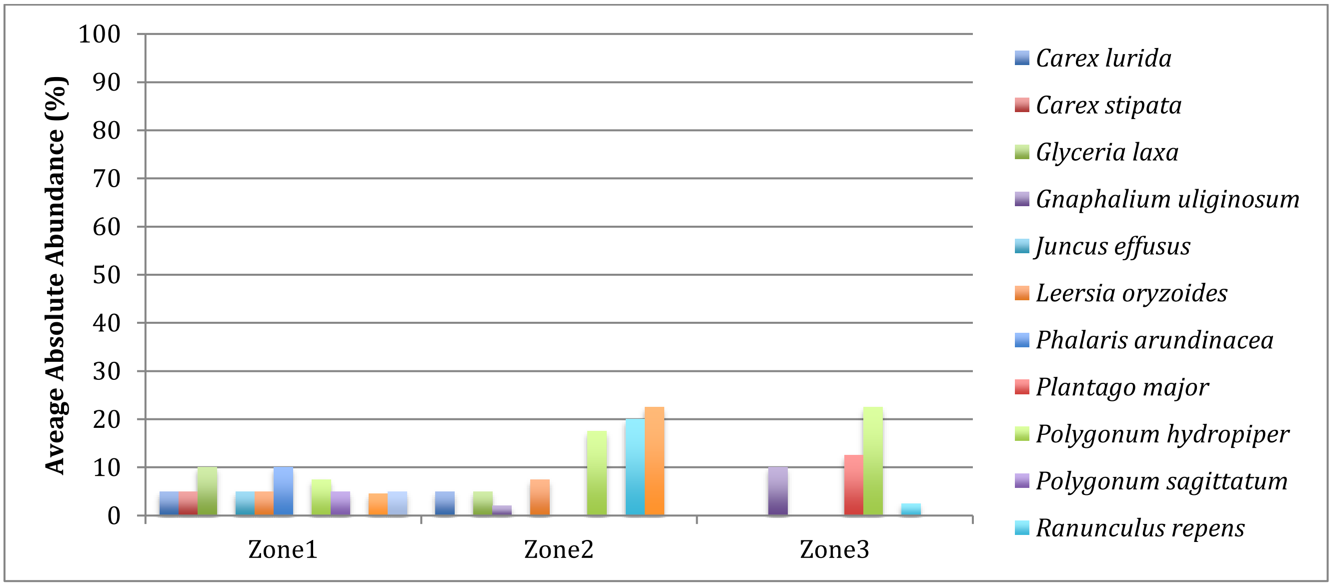


Figure 5: Dominant herb species, transect AntW21T2

A total of six quadrats were surveyed along a third transect (AntW21T3), orientated parallel to the new Highway 104 crossing; three in zone 1 and three in zone 2. Table 5 presents the dominant herbs for transect AntW21T3.

Table 5: Dominant plant species by zone, transect AntW21T3

Zone	**1 (construction pad impact)**	**2 (construction pad impact)**
Zone width (m)	**20**	**25**
No. of Quadrats	**3**	**3**
Herbs	Graminoids spp (Grasses)	*Juncus canadensis* (Canada Rush), *Schoenoplectus acutus* (Hardstem Rush)
Shrubs	None	None
Saplings	None	None
Trees	None	None

Graminoids were dominant in zone 1, however, given their small size, it was not possible to identify the species given the absence of key taxonomic features (Figure 6). The rushes, *Juncus canadensis* and *Schoenoplectus acutus,* were dominant in zone 2. There were no shrubs, sapling or trees on the transect (Figure 4). No alien invasive species were recorded although five exotic species (with their cumulative absolute abundance) were documented: *Gnaphalium uliginosum* (5%), *Plantago major* (3%), *Polygonum persicaria* (5%), *Rumex crispus* (15%) and *Sonchus arvensis* (3%). No species at risk were found, although one species of conservation concern (*Samolus valerandi*) (S3 / Sensitive) was recorded. The substrate for AntW21T3 consisted of water, with 43% cover in zone 1 and 100% cover in zone 2. Quadrat 1, located at the edge of the western backwater, had 100% water coverage with no plants.

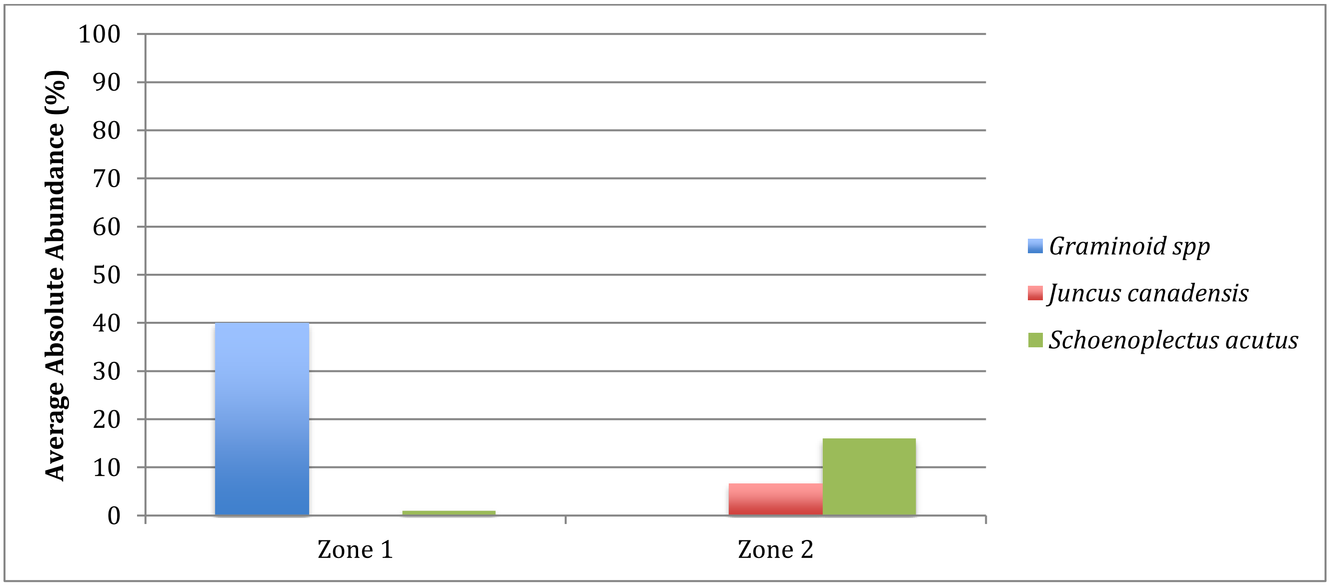


Figure 6: Dominant herb species, transect AntW21T3

A total of seven quadrats were surveyed along a fourth transect (AntW21T4), orientated perpendicular to the new Highway 104; three in zone 1 and four in zone 2. Table 6 presents the dominant herbs for transect AntW21T4. Quadrats 1 to 6 were uncovered in 2015 with the removal of the construction pad.

Table 6: Dominant plant species by zone, transect AntW21T4

Zone	**1 (construction pad impact)**	**2 (construction pad impact)**
Zone width (m)	**14**	**45**
No. of Quadrats	**3**	**4**
Herbs	*Schoenoplectus americanus* (Three-Square Bulrush)	*Schoenoplectus acutus* (Hardstem Bulrush), *Spartina pectinata* (Fresh Water Cordgrass)
Shrubs	None	None
Saplings	None	None
Trees	None	None

In total, six plant species were documented at AntW21T4, with very low abundances observed for both zones. The dominant species in zone 1 was *Schoenoplectus americanus* and in zone 2 *Schoenoplectus acutus* and *Spartina pectinata.* There were no shrubs, sapling or trees on the transect (Figure 7). No alien invasive species or exotic species were recorded. No species at risk were observed, although one species of conservation concern (*Schoenoplectus americanus*, S3 / Sensitive) was recorded. The substrate consisted of water at 100% and 75% cover in zones 1 and 2, respectively. The transect was covered by water 0.2 to 0.3 m deep (0.5 m in some depressions) at the time of the August 26, 2016 vegetation survey.

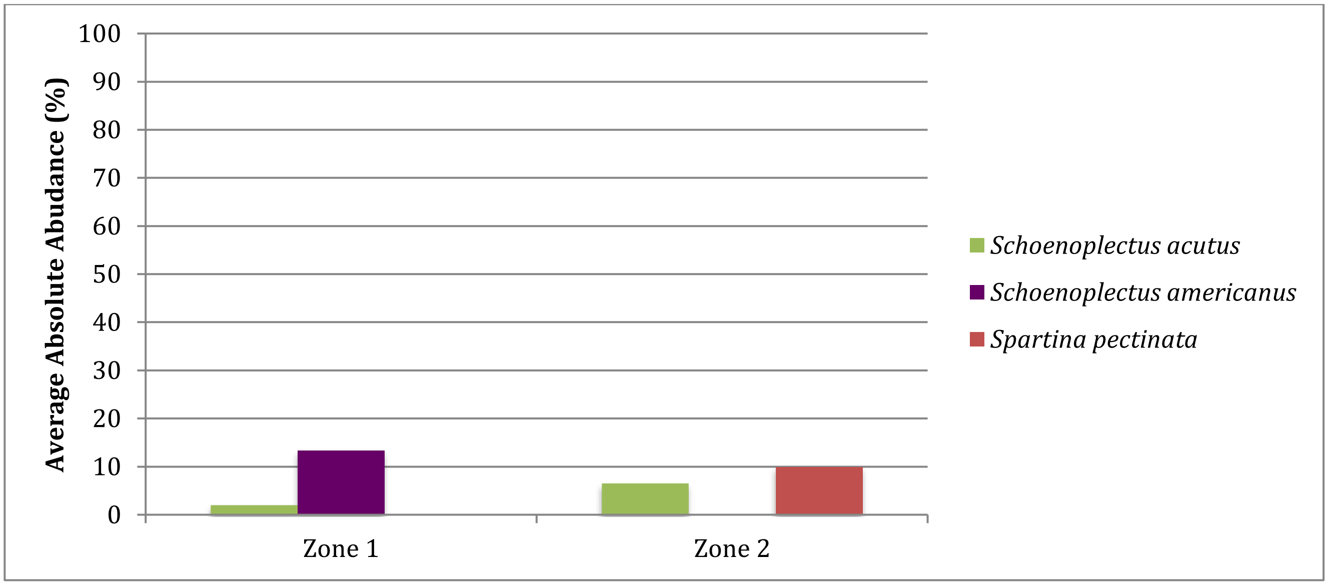


Figure 7: Dominant herb, transect AntW21T4

A total of six quadrats were surveyed along a fifth transect (AntW21T5), orientated perpendicular to the new Highway 104 across one zone. Table 7 presents the dominant herbs for transect AntW21T5. In total, 16 plant species were documented. The dominant herb species were *Calystegia sepium, Spartina pectinata* and *Teucrium canadense*. There were no shrubs, sapling or trees on the transect (Figure 8). No alien invasive or exotic species were recorded. No species at risk were observed, although one species of conservation concern *Teucrium canadense* (American germander) (S3 / Sensitive/Yellow) was recorded at 60% absolute abundance. One quadrat of transect 5 (Q6) was within the construction pad area and had no dominant species present during the 2016 survey.

Table 7: Dominant plant species, transect AntW21T5

Zone	**1 (undisturbed)**
Zone width (m)	**50**
No. of Quadrats	**6**
Herbs	*Calystegia sepium (*Hedge Bindweed), *Spartina pectinata* (Fresh Water Cordgrass), *Teucrium canadense* (American Germander)
Shrubs	None
Saplings	None
Trees	None

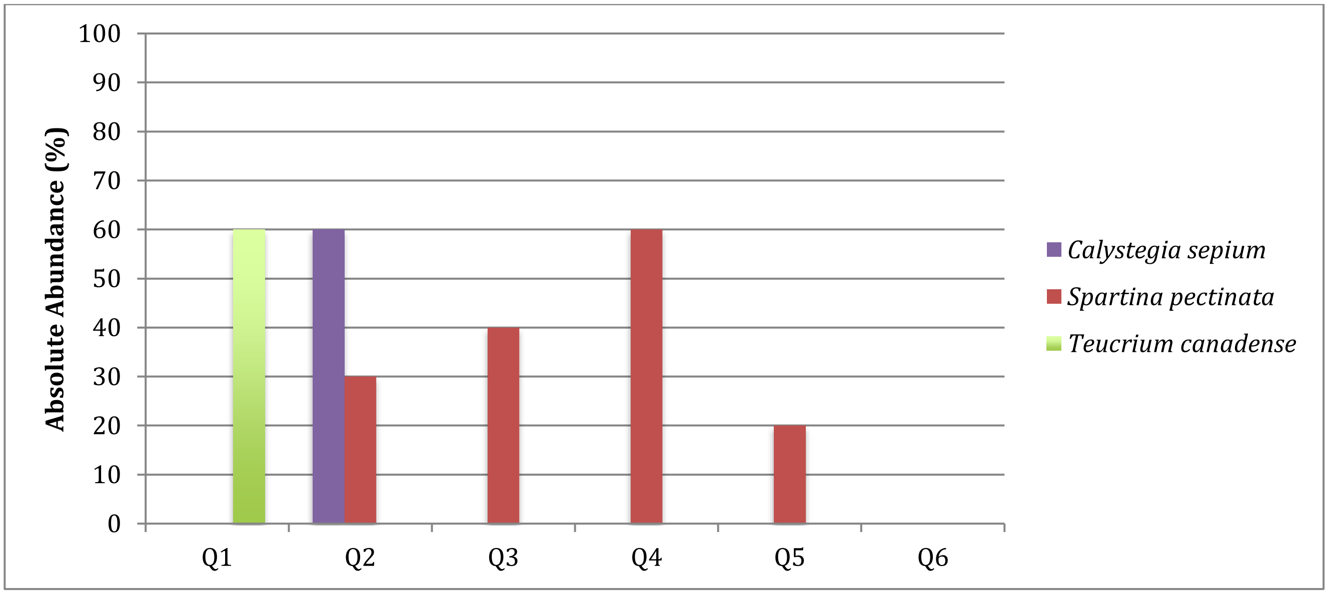


Figure 8: Dominant herb, transect AntW21T5

A total of six quadrats were surveyed along a sixth transect (AntW21T6), orientated parallel to the new Highway 104 across two zones. Table 8 presents the dominant herbs for transect AntW21T6. In total, 16 plant species were documented. The dominant herb species in zone 1 were *Spartina patens*, *Spartina pectinata*, *Schoenoplectus pungens* and *Typha latifolia*. In zone 2, the dominant herbs were *Spartina pectinata* and *Rosa* spp. There were no shrubs, sapling or trees on the transect (Figure 9). No alien invasive or exotic species were recorded. No species at risk were observed, although one species of conservation concern *Teucrium canadense* (American Germander) (S3 / Sensitive) was documented with a total absolute abundance of 5% in zone 2. The ground substrate was covered in a dense matt of roots and decaying vegetation.

Table 8: Dominant plant species by zone, transect AntW21T6

Zone	**1 (undisturbed)**	**2 (undisturbed)**
Zone width (m)	**23**	**27**
No. of Quadrats	**3**	**3**
Herbs	*Spartina pectinata* (Fresh Water Cordgrass), *Spartina patens* (Salt-Meadow Cordgrass), *Schoenoplectus pungens (*Three-Square Bulrush), *Typha latifolia* (Broad-Leaf Cattail)	*Spartina pectinata* (Fresh Water Cordgrass), *Rosa* spp (Rose)
Shrubs	None	None
Saplings	None	None
Trees	None	None

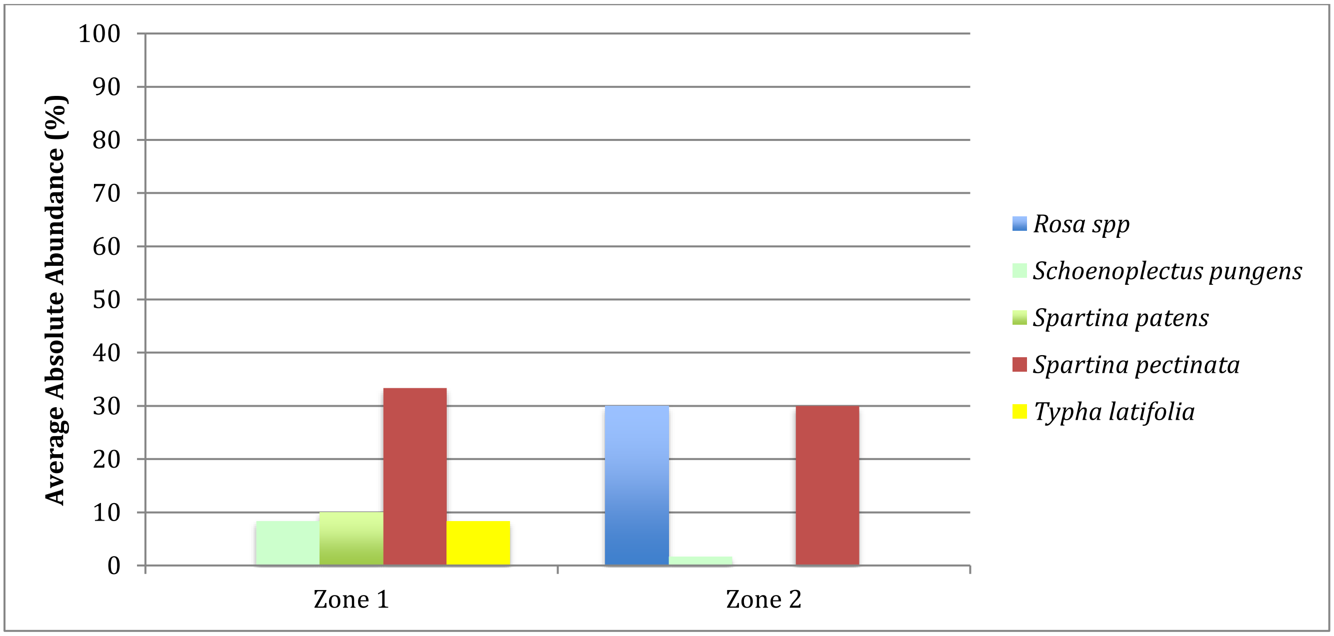


Figure 9: Dominant herb species, transect AntW21T6

A total of six quadrats were surveyed along a seventh transect (AntW21T7), orientated parallel to the new Highway 104 across two zones, with a 10 m parallel offset from AntW21T6. Table 9 presents the dominant herbs for transect AntW21T7. In total, 17 plant species were documented. The dominant herb species in zone 1 was *Spartina pectinata.* In zone 2, the dominant herbs were *Calamagrostis canadensis, Calystegia sepium* and *Toxicodendron radicans*. There were no shrubs, saplings or trees on the transect (Figure 10).

Table 9: Dominant plant species, transect AntW21T7

Zone	**1 (undisturbed)**	**2 (undisturbed)**
Zone width (m)	**23**	**27**
No. of Quadrats	**3**	**3**
Herbs	*Spartina pectinata* (Fresh Water Cordgrass)	*Calamagrostis canadensis* (Blue-Joint Reedgrass), *Calystegia sepium* (Hedge Bindweed)*, Toxicodendron radicans* (Eastern Poison Ivy)
Shrubs	None	None
Saplings	None	None
Trees	None	None

No alien invasive or exotic species were recorded. No species at risk or species of conservation concern were observed. The ground substrate was covered in a dense matt of roots and decaying vegetation.

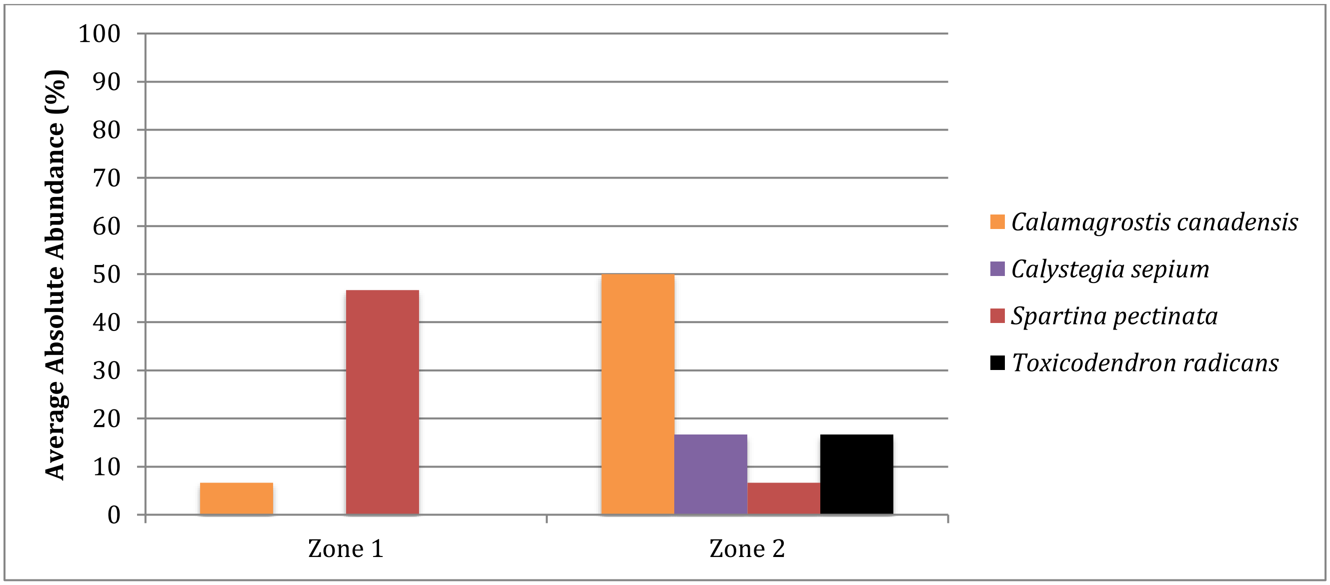


Figure 10: Dominant herb species, transect AntW21T7

A total of three quadrats were surveyed along an eighth transect (AntW21T8), established in 2016 and orientated perpendicular to the new Highway 104 across one zone. Transect 8 served to extend transect 2 in an upstream direction (south) and was located in a drier section of the wetland which transitions to upland, adjacent to mature deciduous trees. Table 10 presents the dominant herbs and shrubs for transect AntW21T8.

Table 10: Dominant plant species, transect AntW21T8

Zone	**1 (construction pad impact)**
Zone width (m)	**20**
No. of Quadrats	**3**
Herbs	*Solidago canadensis* (Canada Goldenrod), *Galium* spp (Bedstraw), *Calamagrostis canadensis* (Blue-Joint Reedgrass), *Hypericum perforatum* (A St. John's-Wort)
Shrubs	*Crataegus* spp (Hawthorn)
Saplings	None
Trees	*Fraxinus americana* (White Ash)

In total, 21 plant species were documented at AntW21T8. The dominant herb species were *Solidago canadensis, Galium spp, Calamagrostis canadensis* and *Hypericum perforatum*. The dominant shrub was *Crataegus* spp. There were no saplings on the transect (Figure 11). The dominant tree species was *Fraxinus americana*. No alien invasive species were recorded, although five exotic species (and their cumulative absolute abundances) were recorded: *Centaurea nigra* (Black Starthistle) (10%), *Daucus carota* (Wild Carrot) (20%), *Hypericum perforatum* (A St. John's-Wort) (30%), *Lotus corniculatus* (Birds-Foot Trefoil) (20%) and *Tanacetum vulgare* (Common Tansy) (5%). No species at risk or species of conservation concern were recorded. Stone, rock and exposed mineral soil were present at quadrat 1, at 25% cover. The 2016 Prevalence Index (PI) value for the transect was 2.04, indicating wetland conditions. The PI value must be used with caution though as >80% of the vegetation could not be identified to species-level due to their small size and lack of key taxonomic features.

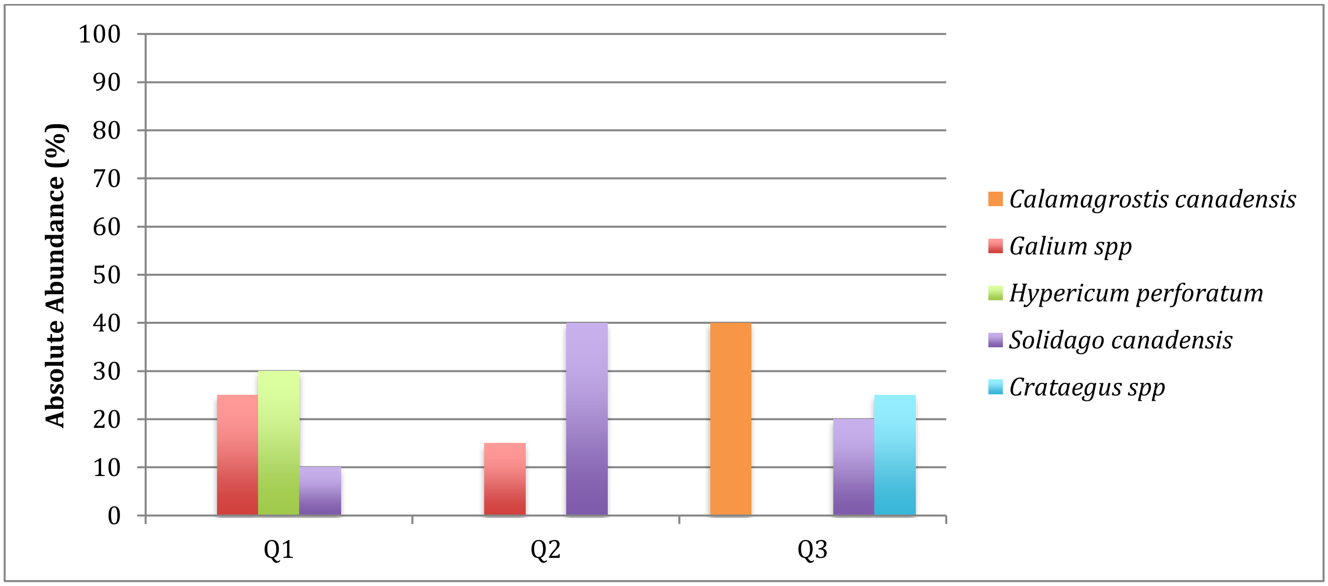


Figure 11: Dominant herb and shrub species, transect AntW21T8

A total of three quadrats were surveyed along a ninth transect (AntW21T9), established in 2016 and orientated perpendicular to the new Highway 104 across one zone. Transect 9 served to extend transect 4 in an upstream direction (south), ending at the water's edge of the western backchannel. Table 11 presents the dominant herbs for transect AntW21T9. In total, 11 plant species were documented. The dominant herb species were *Calystegia sepium* and *Schoenoplectus acutus*. There were no shrubs, saplings or trees on the transect (Figure 12). No alien invasive or exotic species were recorded. No species at risk were observed, but one species of conservation concern (*Samolus valerandi* (Valerand's Brookweed, S3 / Sensitive) was recorded. The ground substrate was covered in a dense matt of roots and decaying vegetation.

Table 11: Dominant plant species, transect AntW21T9

Zone	**1 (undisturbed)**
Zone width (m)	**26**
No. of Quadrats	**3**
Herbs	*Calystegia sepium* (Hedge Bindweed*)* and *Schoenoplectus acutus* (Hardstem Bulrush)
Shrubs	None
Saplings	None
Trees	None

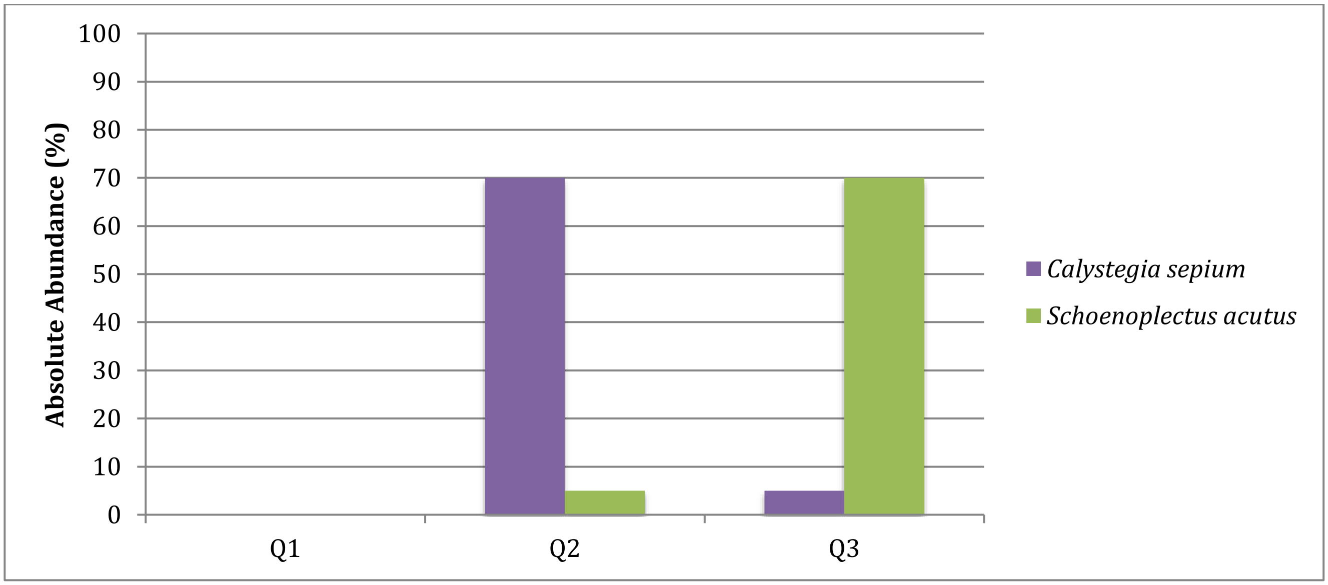


Figure 12: Dominant herb species, transect AntW21T9

A total of seven quadrats were surveyed along a tenth transect (AntW21T10), established in 2016 and orientated perpendicular to the new Highway 104 across one zone. Transect 10 was located adjacent to and across from the former access road to the bridge construction pad. Table 12 presents the dominant herbs for transect AntW21T10. In total, 16 plant species were documented. The dominant herb species were *Spartina pectinata* and *Typha latifolia*. There were no shrubs, saplings or trees on the transect (Figure 13). No alien invasive species were observed, although one exotic species was recorded (*Rumex crispus*, Curly Dock) (3% absolute abundance). No species at risk were observed, but one species of conservation concern (*Polygonum pensylvanicum*) (Pennsylvania smartweed, S3 / Secure) was recorded. Standing water was present at quadrat 3 at 100% cover.

Table 12: Dominant plant species, transect AntW21T10

Zone	**1 (undisturbed)**
Zone width (m)	**120**
No. of Quadrats	**7**
Herbs	*Spartina pectinata* (Fresh Water Cordgrass) and *Typha latifolia* (Broad-Leaf Cattail)
Shrubs	None
Saplings	None
Trees	None

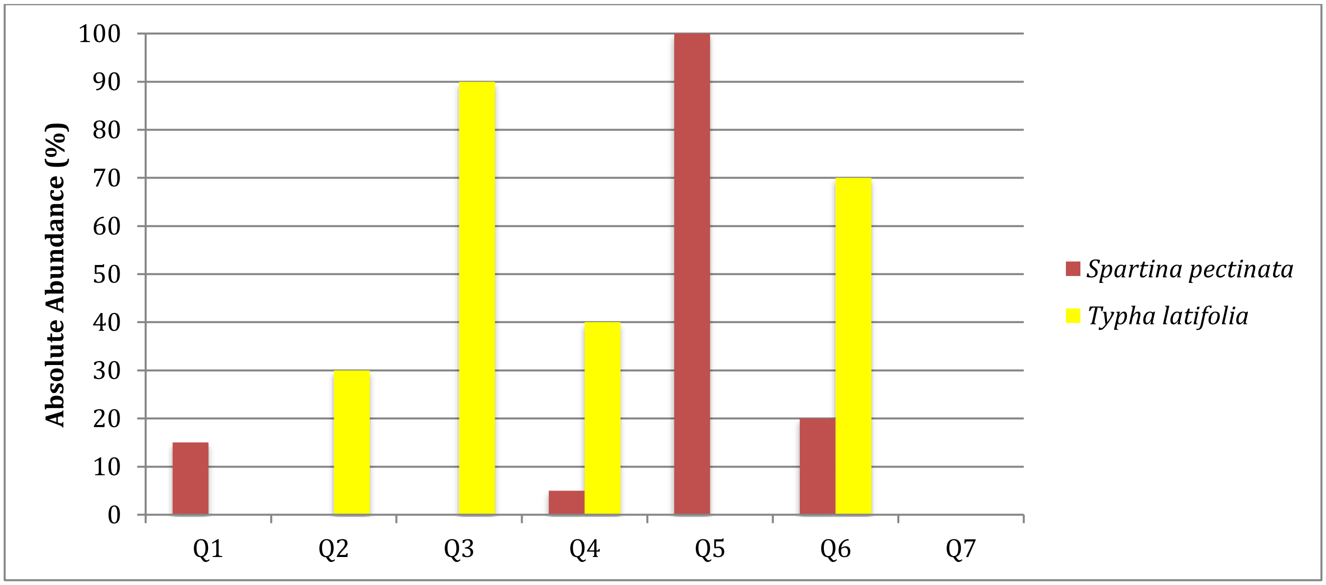


Figure 13: Dominant herb species, transect AntW21T10

A total of six quadrats were surveyed along an eleventh transect (AntW21T11), established in 2016 and orientated perpendicular to the new Highway 104 across one zone. Transect 11 was to the west of the western backwater in an undisturbed portion of the wetland. Table 13 presents the dominant herbs for transect AntW21T11. In total, 16 plant species were documented. The dominant herb species were *Spartina pectinata* and *Calamagrostis canadensis*. There were no shrubs, saplings or trees on the transect (Figure 14). No alien invasive species were observed, although one exotic species was recorded (*Vicia cracca*, Tufted Vetch) (15% absolute abundance). No species at risk or species of conservation concern were recorded. The ground substrate was covered in a dense matt of roots and decaying vegetation.

Table 13: Dominant plant species, transect AntW21T11

Zone	**1 (undisturbed)**
Zone width (m)	**120**
No. of Quadrats	**7**
Herbs	*Spartina pectinata* (Fresh Water Cordgrass) and *Calamagrostis canadensis* (Blue-Joint Reedgrass)
Shrubs	None
Saplings	None
Trees	None

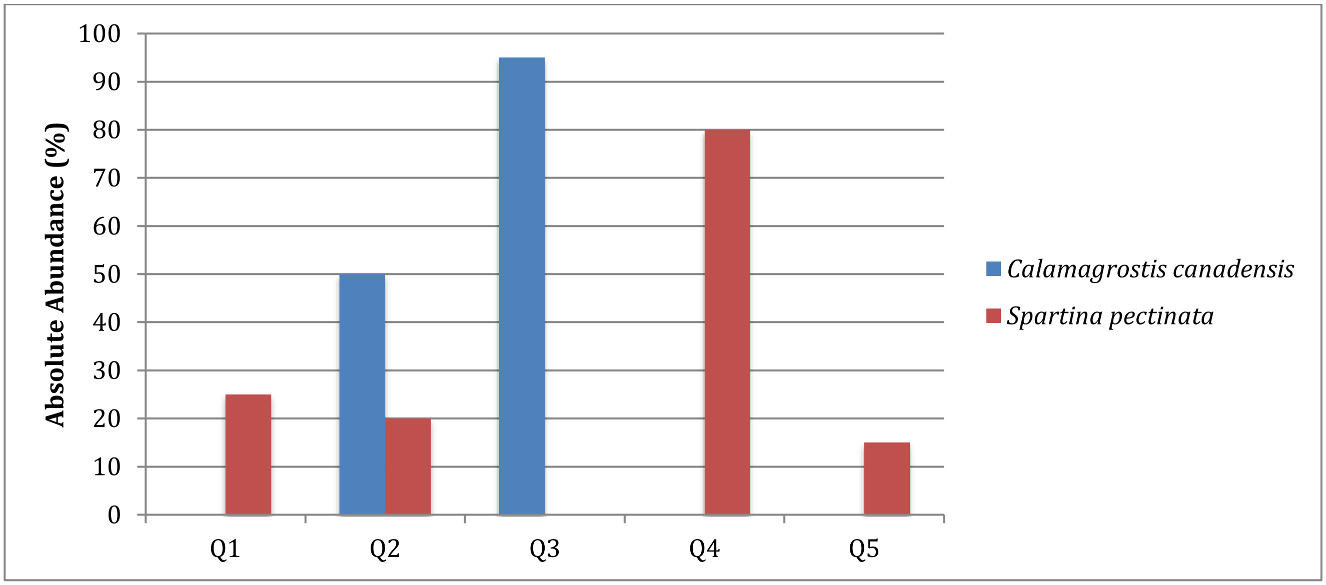


Figure 14: Dominant herb species, transect AntW21T11

Water Quality Monitoring

Water quality measurements were recorded at three locations at the Antigonish Wetland 21 on November 2, 2016 at 08:30 on a flood tide (Antigonish Harbour high tide at 12:48). See Table 14 for the water quality results for the 2012 to 2016 monitoring period. The locations of the water quality observations are shown at Figure 15 and described further below.

Water chemistry observations were recorded to serve as both an indicator of change within the wetland and to assist in the identification of the cause of any unforeseen impacts upon the wetland. For example, change in specific conductivity could indicate road salt impacts. Dissolved oxygen levels can be altered through changes in vegetation communities or contamination, while pH and temperature provide information on changes to the hydraulic regime within a wetland. Elevated turbidity may indicate natural or anthropogenic sedimentation.

There are limited published guidelines for water quality in wetland settings for the protection of wetland plants. No water quality measurements were recorded as part of the wetland alteration permitting process prior to construction, so no site baseline is available for direct comparison. The Canadian Water Quality Guidelines for the Protection of Aquatic Life (CCME, 2007) indicate a pH guideline of 6.5 to 9.0 and a guideline for dissolved oxygen of 5.5-9.5 mg/L for freshwater.

As shown in Figure 15, the water quality measurements for Antigonish Wetland 21 were recorded at three locations in 2016: (1) the back channel off the western side of the site; (2) in a small inlet off the South River main channel, near transect 6, quadrat 6; and (3) the main channel of the South River, beneath the east bound Highway 104 lane.

Table 14: Water quality observations for Antigonish Wetland 21, 2012 to 2016

Location	Year*	Temp. (°C)	Spec. Cond. (µS/cm)	DO (mg/L)	DO (% sat)	pH	TDS (mg/L)	Turbidity (NTU)
WQ1: Back channel at western side of site, at upstream edge of Hwy 104 East lane	2014	17.6	14435	7.4	82	7.52	10907	10.8
	2015	7.4	144	11.8	98	6.49	748	10.1
	2016	9.0	424	9.2	79	7.48	278	8.7
WQ2: Small inlet off South River main channel, near AntW21T6 quadrat 6	2012	20.8	867	9.1	101	7.58	566	1.2
	2013	8.1	435	9.0	75	7.34	283	8.2
	2014	17.4	3816	8.3	87	7.76	2899	12.5
	2015	4.6	229	11.7	90	6.31	243	8.2
	2016	8.3	311	6.4	54	7.30	202	7.6
WQ3: South River main channel at upstream edge of Hwy 104 East lane	2014	16.7	4228	11.7	121	7.68	3276	1.3
	2015	6.4	243	12.8	103	6.02	245	1.1
	2016	9.2	220	10.4	90	7.23	143	1.7

* Sample Dates: August 27, 2012; November 5, 2013; October 16, 2014; October 22, 2015; November 2, 2016.

Conductivity values were moderate to low in 2016, indicating limited marine influence at the time of sampling. The highest Conductivity was observed at WQ1, which is not unexpected as it was non-flowing with limited tidal exchange. The three sample sites had pH and Dissolved Oxygen values within the guideline range for the protection of freshwater aquatic life. Turbidity values were moderate at WQ1 and WQ2 (adjacent to recently removed construction pad), but well below regulatory thresholds. Turbidity was low at WQ3 within the main channel of South River. Within the range of variability expected for a tidal river, the 2016 water quality observations were largely consistent with those recorded in 2015 and earlier years.

Water quality at the South River marsh was examined at an additional thirteen locations on July 5, 2016 at approximately 13:30 during a spring tide event, during which the entire site was inundated (Table 15, Figure 15). Water sampling commenced at the high tide slack water and continued into the ebb tide.

As would be expected, standing waters across the site on July 5, 2016 had generally elevated specific conductivity and total dissolved solids, indicative of the strong marine influence across the entire site. Based on the observed values, conditions at the South River estuary can be considered oligohaline to mesohaline at the time of the July 5 sampling. Conductivity and TDS values were slightly higher within western backchannel, likely as a result of the absence of diluting freshwater inputs from the main channel of the South River at the east. Slightly higher temperatures and lower dissolved oxygen levels for stations WQ13 to WQ16 suggest reduced mixing at the head of the western backwater. pH values across the site were uniformly neutral to very slightly alkaline. The July 5, 2016 water quality results reinforce the brackish and tidal influences on the ecology of the Antigonish South River wetland and the resulting influences on soils and vegetation observed.

Table 15: Water quality data for July 5, 2016 flood tide event.

Location	Temp.	Spec. Cond.	DO	DO	pH	TDS	Water Depth
	(°C)	(µS/cm)	(mg/L)	(% sat)		(mg/L)	(m)
WQ4	22.7	7516	6.7	81	8.18	4914	0.7
WQ5	21.6	4774	7.5	86	7.46	3107	0.3
WQ6	21.7	5148	7.7	95	7.52	3900	0.4
WQ7	21.3	6266	7.6	89	7.73	4069	0.4
WQ8	21.6	9457	7.8	91	8.18	6155	0.5
WQ9	21.5	10,551	7.9	90	8.26	6877	0.7
WQ10	21.8	11,434	7.7	92	8.31	7423	0.8
WQ11	21.8	11,661	7.7	92	8.33	7579	0.8
WQ12	21.8	11,629	7.6	89	8.34	7566	0.8
WQ13	21.2	9615	5.1	60	7.18	6318	0.3
WQ14	22.8	10,857	7.3	88	8.10	7072	0.5
WQ15	23.0	8621	6.9	86	7.31	5655	0.3
WQ16	23.9	9170	7.6	93	8.24	5960	0.5

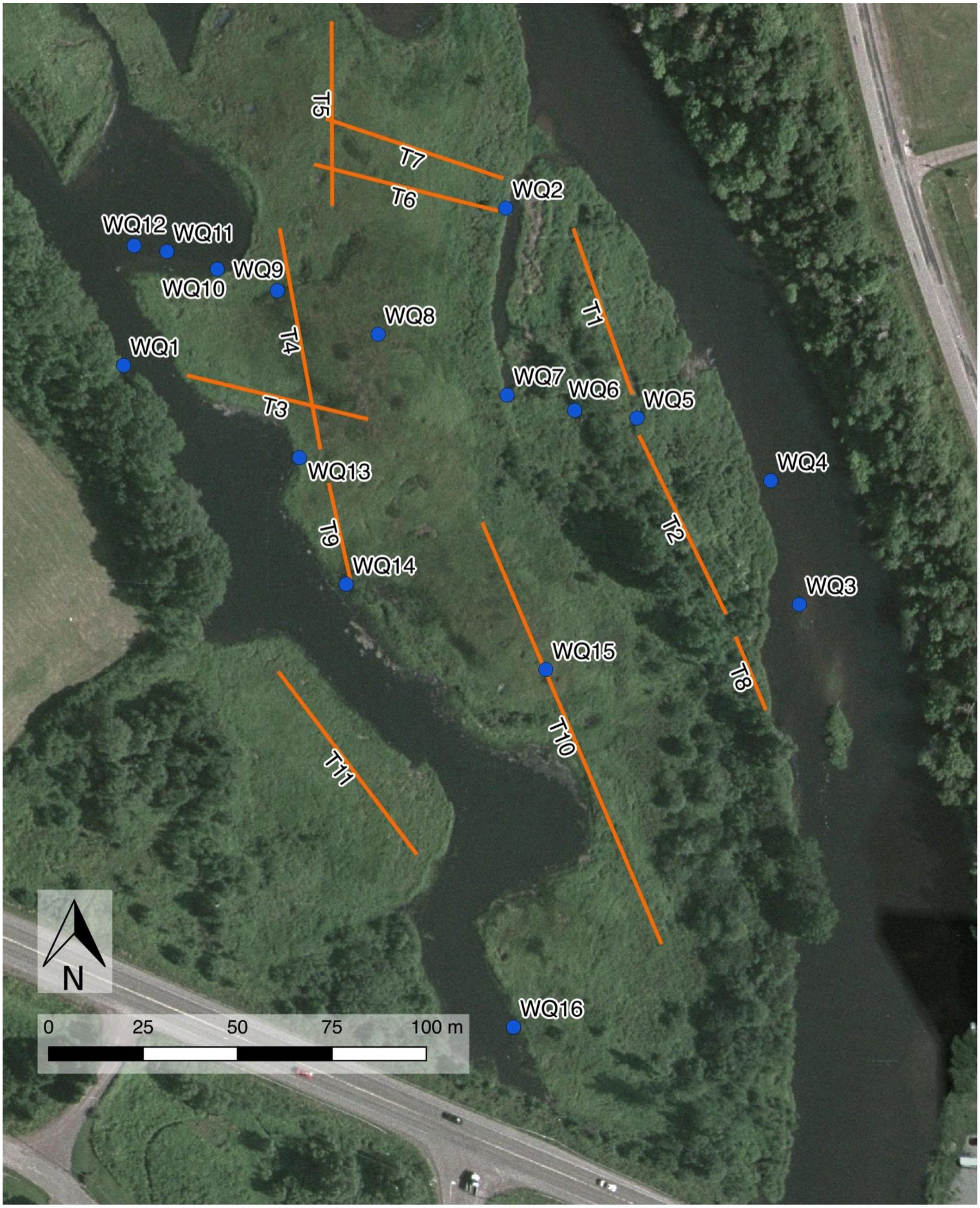


Figure 15: Locations of July and November 2016 water quality samples at Antigonish Wetland 21.

Wetland Soils

Wetland soils at the South River wetland were examined by two approaches in 2016: the excavation of a series of six test pits across the site and the survey of soil compaction using an electronic penetrometer. Pairs of soil pits were excavated in undisturbed salt marsh habitat upslope (Table 16), within the construction pad boundaries (Table 17) and downslope of the bridge construction pad (Table 18) (Figure 16). The objective of this survey was to gain a better understanding of the spatial pattern of soils across the site and to assess whether significant variability in soils exists.

Table 16: Soil pit profile, Antigonish Wetland 21, upslope (South) of Highway 104 bridge alignment.

ID		Soil Pit 1		**ID**		Soil Pit 2	
Location		Upslope West		**Location**		Upslope East	
Ground Cover		*Schoenoplectus acutus* (Hardstem Bulrush)		**Ground Cover**		*Spartina patens* (Saltmeadow cordgrass)	
Horizon	**Depth Range (cm)**	**Soil Colour**	**Texture**	**Horizon**	**Depth Range (cm)**	**Soil Colour**	**Texture**
O1	0 - 35	7.5YR 2.5/2	Organic Mesic 6	O1	0 – 14	7.5YR 3/3	Organic Fibric 4
M1	35 – 40+	7.5YR 3/3	Silt	O2	14 – 38	7.5YR 4/3	Organic Fibric 3
				M1	38 – 40+		Silt
Notes	Saturation to ground surface. Water recharge to 13 cm below surface.			Notes	Saturation to ground surface. Water recharge to 30 cm below surface. Located ~2m West of T9Q2.		

Table 17: Soil pit profile, Antigonish Wetland 21, within the Highway 104 bridge alignment and former construction pad.

ID		Soil Pit 3		**ID**		Soil Pit 6	
Location		Pad West		**Location**		Pad East	
Ground Cover		Sparse *Schoenoplectus acutus* (Hardstem Bulrush)		**Ground Cover**		Graminoid (grasses)	
Horizon	**Depth Range (cm)**	**Soil Colour**	**Texture**	**Horizon**	**Depth Range (cm)**	**Soil Colour**	**Texture**
O1	0 - 2	10YR 2/2	Organic Fibric 3	O1	0 – 16	7.5YR 3/2	Organic Humic 8
O2	2 – 15	7.5YR 4/2	Organic Fibric 3	M1	16 – 41+	7.5YR 3/3	Silt
M1	15 – 40+	7.5YR 4/2	Silt				
Notes	Saturation to ground surface. No water recharge although panne with standing water ~3m away. Horizon O1 had dark staining with H_2S odour.			Notes	Saturation to ground surface. No water recharge although standing water at surface ~2m away. M1 horizon very dense, with difficulty pushing in shovel and soil noticeably denser. Near start of T2.		

Table 18: Soil pit profile, Antigonish Wetland 21, downslope of Highway 104 bridge alignment.

ID		Soil Pit 4		**ID**		Soil Pit 5	
Location		Downslope West		**Location**		Downslope East	
Ground Cover		*Spartina patens* (Saltmeadow cordgrass)		**Ground Cover**		*Phalaris arundicacea* (Reed canary grass)	
Horizon	**Depth Range (cm)**	**Soil Colour**	**Texture**	**Horizon**	**Depth Range (cm)**	**Soil Colour**	**Texture**
O1	0 - 18	7.5YR 2.5/3	Organic Mesic 6	O1	0 – 14	7.5YR 4/2	Organic Humic 7
M1	18 – 21	10YR 4/1	Silt	O2	14 – 41+	7.5YR 3/2	Organic Humic 8
M2	21 - 25	10YR 4/1	Silt with sand & gravel				
O2	25 – 41+	7.5YR 4/2	Organic Humic 7				
Notes	Saturation to ground surface. Water recharge to 17cm below surface. Located 4m West of T5Q2			Notes	Saturation to ground surface. No water recharge. Located 10m northwest of T1.		

The six soil pits documented the presence of well-decomposed organic sediments in a continuous horizon from the ground surface to depths of 15 to 40+ cm (Figure 16). At five of the six soil pits, this horizon was underlain by silt. The two soil pits within the construction area (Pad W and Pad E) had notably thinner organic horizons (15 and 16 cm), respectively. The reason for this is unclear, but compaction from the construction pad and bridge construction equipment is a plausible explanation. The two sample locations within the construction pad had no water recharge following excavation of the pits although standing water was present in surface depressions within meters. Water recharge was observed in three of the four soil pits outside the construction pad. Soils at the Pad E pit were noticeably denser than that observed at the other five pits, with it being very difficult to push a trenching spade into the soil. The locations of the six soil test pits are shown at Figure 18.

The wetland soils to the north and south of the Highway 104 crossing were found to be largely similar and consistent with that expected for a tidal estuary in terms of composition and texture. It is very likely that the pre-alteration soils within the bridge right-of-way were consistent with those characterized to the north and south of the highway in 2016. Any persistent differences observed within the construction pad footprint are therefore believed to be the result of bridge construction activities.

Over a number of visits to the site in 2015, ECA staff had qualitatively observed that the western portion of the former construction pad appeared to have a lower elevation. ECA (2016) presented the possibility that the weight of the construction pad, equipment and supplies used for the construction of the bridge may have caused compaction and settlement of the ground surface. As part of a two step process to determine whether compaction occurred and could be quantified, soil density was measured in 2016. The results were to be considered along with surface profiles of the site, presented in the Section "Ground Surface Profiles" below, to determine whether post alteration compaction existed.

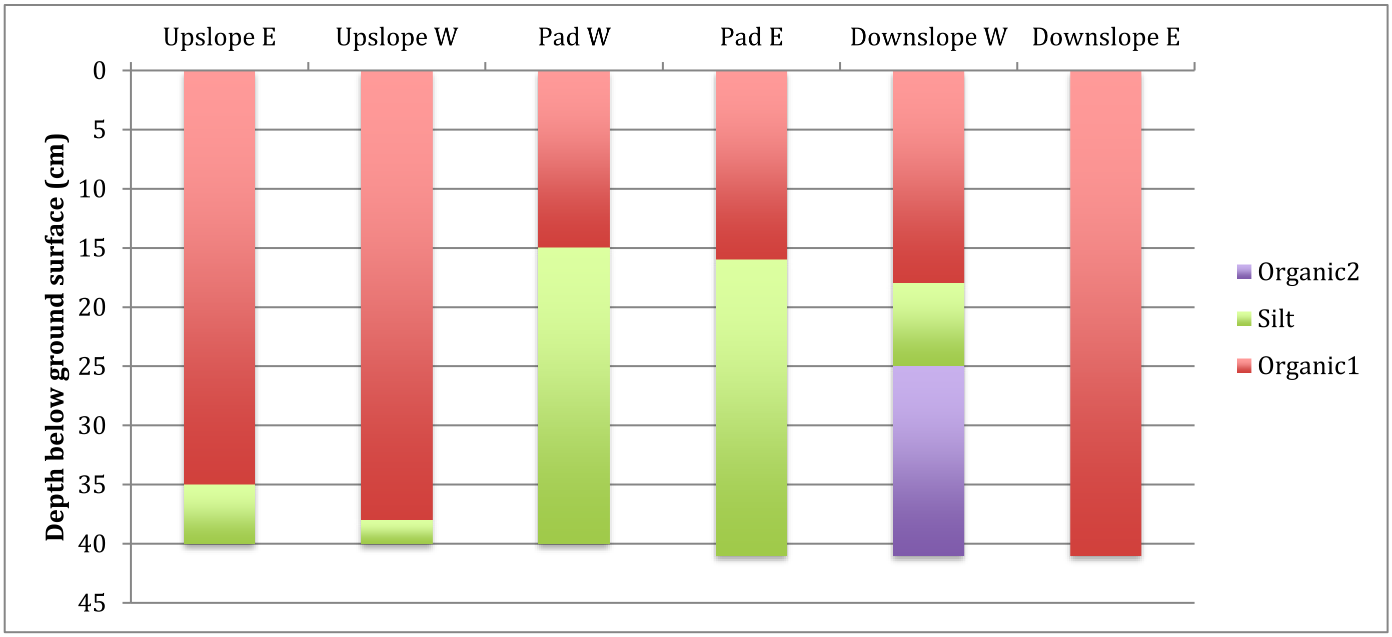


Figure 16: Soil profiles for South River wetland soil pits, 2016.

Soil compaction across a portion of the South River wetland was investigated in July 2016 using a Spectrum Technologies Inc. Field Scout SC900 Soil Compaction Meter fitted with a 0.5 inch (1.3 cm) drive cone. Soil compaction, as determined by a penetrometer instrument, can serve as a surrogate for soil density (Colorado State University, 2004). Three transects crossing the bridge construction pad were surveyed in a south to north direction at a total of 70 locations (Figure 18). Compaction was recorded as soil resistance in pounds per square inch (PSI) at each location at 2.5 cm (one-inch) depth increments from the ground surface to a depth of 46 cm (18 inches). The survey design sought to allow the comparison of soils from within the construction area to those in undisturbed portions of the wetland up and downslope of the crossing.

A consistent pattern of soil compaction was observed across the Antigonish Wetland 21 site, with undisturbed wetland soils being significantly less compacted than those within the construction pad area (Figure 17). Mean compaction values for the undisturbed wetland were 41, 62 and 77 psi for the 0 to 15 cm, 18 to 30 cm and 33 to 46 cm depth ranges, respectively. These compared to mean compaction values of 104, 120 and 132 psi for the construction pad for the same depth ranges. A consistent difference in compaction of ~60 psi was observed between the undisturbed and construction pad areas, regardless of the soil horizon. This suggests that the impacts of surface compaction within the construction pad area extend down in a uniform manner to a depth of at least 46 cm below the ground surface.

The Antigonish Landing Reference salt marsh, located approximately five kilometers to the northwest, was also examined to provide an off-site comparison of compaction values (ECA, 2017). Salt marsh soils at the Antigonish Landing site had very similar compaction values to those observed at undisturbed portions of the South River Wetland 21, with mean compaction values of 36, 52 and 69 psi over the three depth ranges.

The 2016 surveys indicated a strong spatial relationship between the location of the construction pad and increased soil compaction in the top 15 cm of the soil. A similar pattern was observed for the 18 to 30 and 33 to 46 cm horizons. Given the high soil densities qualitatively observed at the Pad E soil pit, it is very likely that the zone of elevated soil compaction extends to the east of the area encompassed by the 2016 penetrometer surveys (see Figure 18). Considerable variability existed in the soil compaction values for the construction pad area, particularly for the upper soil horizon.

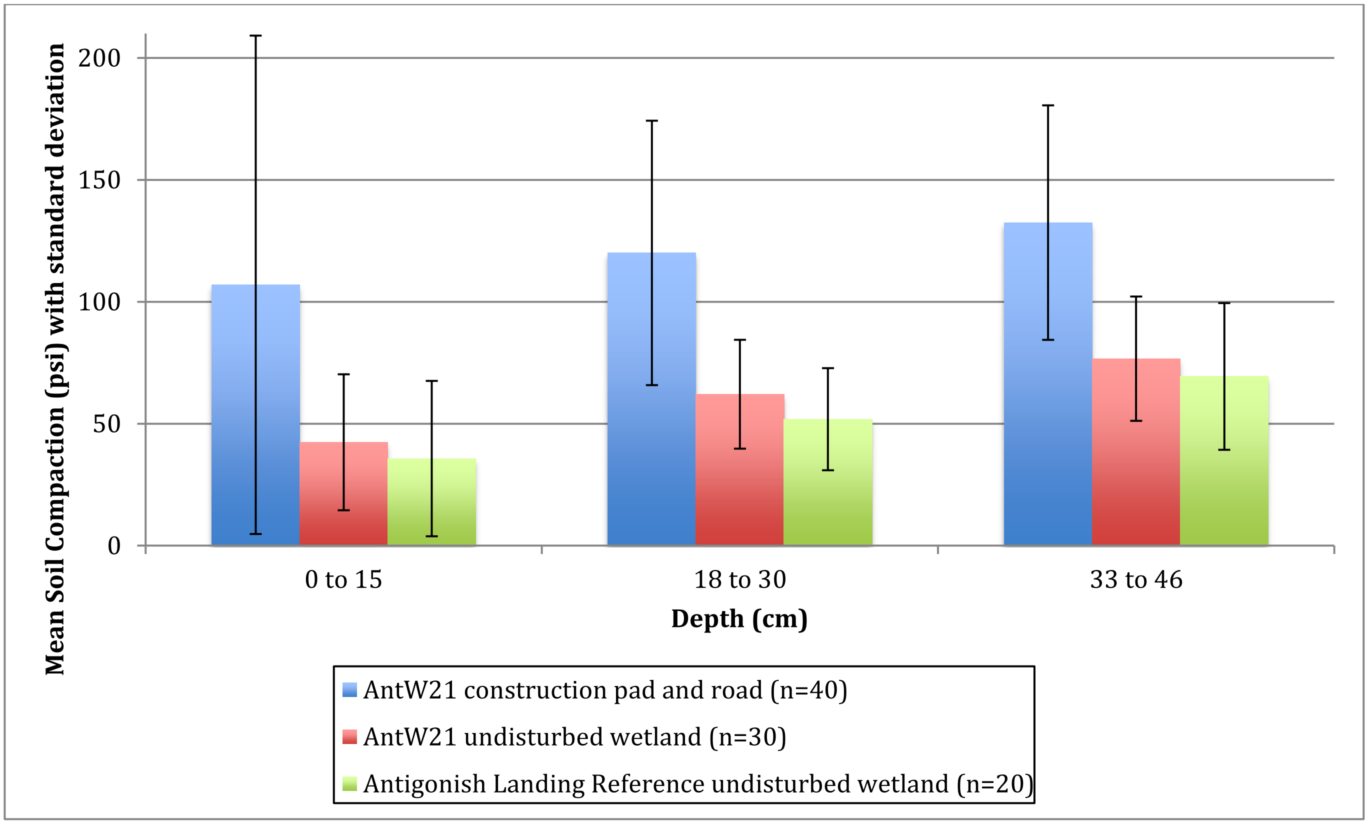


Figure 17: Mean soil compaction values for three soil horizons: 0 to 15 cm, 18 to 30 cm and 33 to 46 cm.

Based on the 2016 surveys at the Wetland 21 and the Antigonish Landing Reference salt marshes, soil compaction values within the footprint of the bridge construction pad are significantly higher than those observed in comparable undisturbed salt marsh. The increased soil compaction is very likely the result of the combined weight of the pad, equipment and materials used in the construction of the South River crossing.

Within terrestrial agricultural settings, penetrometer resistance values less than 150 psi are considered low, with values greater than 300 psi indicating soils where root penetration is significant impeded (Fee, 2005). Beyond slowing root growth, increased soil compaction reduces water movement within the soil and transport of nutrients, including nitrogen (Fee, 2005). ECA recorded soil compaction values greater than 300 psi at seven sample locations, all within the footprint of the construction pad. The maximum compaction value observed was 875 psi.

So as to better understand the potential implications of soil compaction at South River, ECA consulted Keith Fuller, Soil Research Biologist with Agriculture and Agri-Foods Canada, Kentville Research Station. Upland topsoil, with good structure and native microflora, will not remain compacted indefinitely. Once a compaction event has ended, topsoil will slowly loosen. Sodium dominated soils, with high fractions of silt, clay and organics, on the other hand, are inherently unstable. Once compacted, the only way to loosen these soils is to replace the sodium in the soil matrix with calcium through exclusion of the source of salt and introduction of fresh water. Mechanical loosening of the soil would only be effective if the soil could be first dried. Given the natural sodium-dominated silt/clay/organic soils at South River, and the impracticability of either drying or excluding salt water, it is possible that the soils would remain compacted indefinitely (K. Fuller, pers. comm.). Fuller cautioned though that his conclusions were speculative, as his profession experience did not extend to salt marshes.

Very little empirical data exists in the scientific literature on compaction impacts to salt marsh soils as well as the duration and implications of such impacts. Increased soil densities due to compaction are thought to impede water and nutrient movement in salt marsh soils (Roman and Burdick, 2012) and hinder the development of plant root systems (Spencer *et al*, 2008). A surrogate study investigated the impact of in-situ peat compaction from winter ice loading on salt marsh soils (Argow and FizGerald, 2006). Soils in northern salt marshes, in this case Maine, were reported to be more susceptible to compaction than those of southern marshes due to the higher organic content in soils. The authors found a strong correlation between the ice thickness (weight) and the decrease of the marsh surface elevation, for ice thicknesses greater than 10cm. Rebound of the marsh surface occurred rapidly (<2 weeks) for thin ice sheets following de-compaction. Rebound was however slow or nonexistent for thick ice sheets (>46 cm thickness).

The long-term ecological implications of soil compaction within the construction pad footprint remain unclear. Utilization of the habitat by salt marsh flora and fauna may be diminished as well as the derived ecosystem services. Given the absence of published studies on this subject, there is merit in continued monitoring of the site to evaluate the mid to long term biological response to soil compaction, in terms of the overall Antigonish Wetland 21 monitoring program and our larger understanding of construction in and around salt marshes.

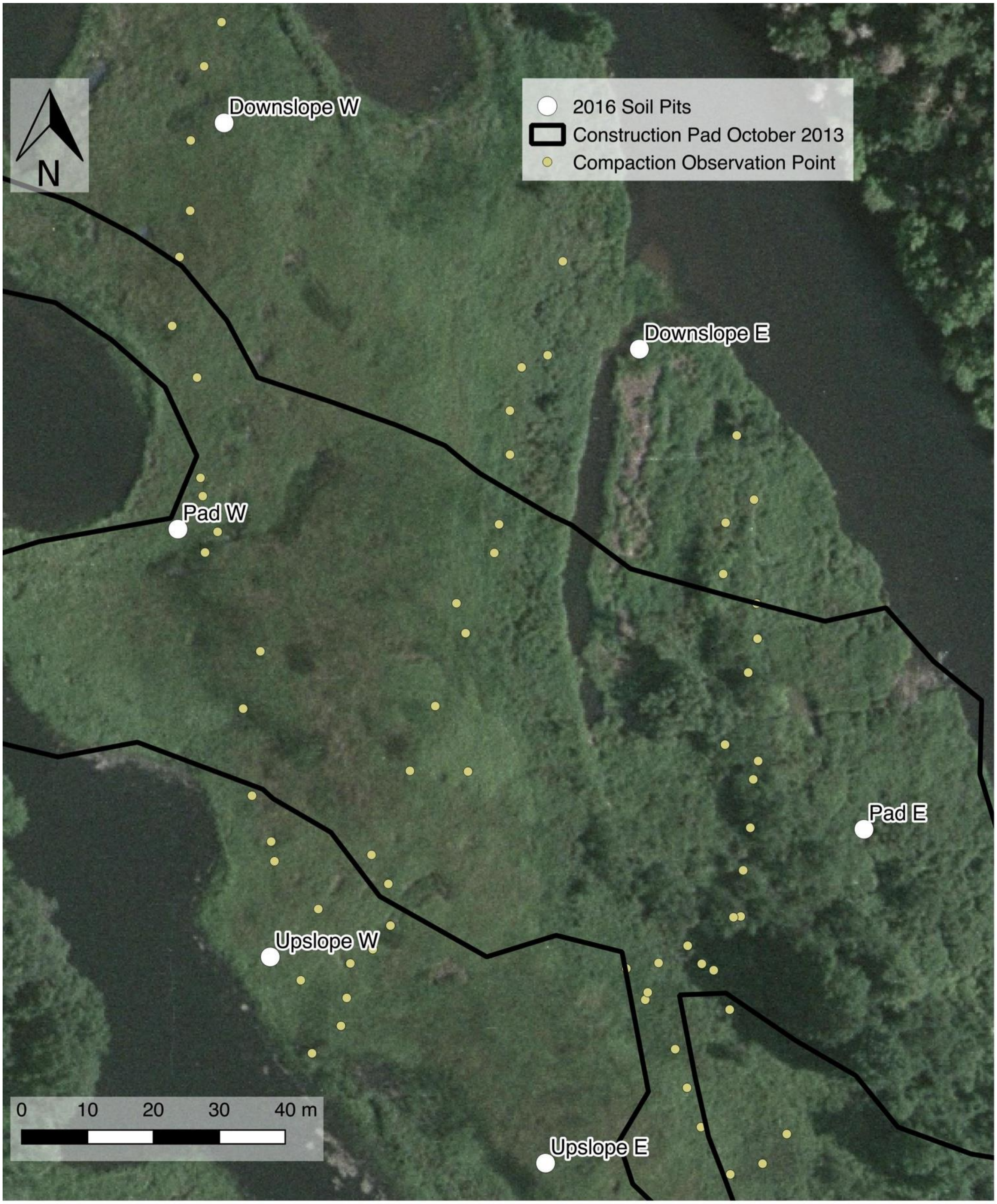


Figure 18: Detail of Antigonish Wetland 21 salt marsh construction pad area with locations of soil pits and compaction observations.

Ground Surface Profiles

Ground surface profile measurements at Wetland 21 were previously recorded in 2012, 2013 and 2015 (see Appendix 3). Observations were recorded on October 22, 2012 following the establishment of the construction pad. Bridge construction was on-going at the time of the October 16, 2014 survey, with the construction pad completely removed at the October 22, 2015 surveys. The topographic profile of all transects were surveyed on April 29, 2016 using a rod and level, with this survey repeated on October 28, 2016 using a high accuracy RTK-GPS system (see Appendix 3). A RTK position fix could not be obtained at several locations along transects 1, 2, 3 and 4 due to the overhead bridge lanes obscuring satellite reception.

Over a number of visits to the site in 2015/16, ECA staff had qualitatively observed that the western portion of the former construction pad appeared to have a lower elevation. ECA (2016) presented the possibility that the weight of the construction pad, equipment and supplies used for the construction of the bridge may have caused compaction and settlement of the ground surface. As part of the 2016 field surveys, both wetland soil densities and surface profiles were evaluated to determine if compaction was apparent. Penetrometer survey results for soil density are presented above in the Section titled "Wetland Soils".

Ground surface elevations to south of the bridge crossing (upslope), to the north of the crossing (downslope) and within the construction pad area for 2012 and 2016 have been examined to better understand potential changes across the site (Figure 19). At the establishment of the Wetland 21 monitoring program in 2012, the mean elevation of the undisturbed marsh surface to the north (downslope) of the crossing was 0.80 m, with the 2016 value for this area being 0.81 m. These two similar values would suggest negligible change in the surface elevation in this undisturbed area over the five-year period. The undisturbed marsh surface to the south (upslope) of the crossing had a mean elevation of 0.78 m in 2016, comparable to that found to the north and suggesting a relatively flat intertidal marsh surface across the site. The mean surface elevation for the former construction pad in 2016 was found to be 0.54 m, 0.24 to 0.27 m lower than the adjacent undisturbed marsh surfaces to the north and south.

No pre-construction baseline surface elevations exist for the transects covered by the pad, as this monitoring activity began shortly after pad construction. Therefore, it is not possible to quantitatively report on whether the post-pad surface elevations were different than the pre-pad levels. However, in two locations, quadrats that were native marsh vegetation at the time of the 2012 survey were subsequently covered by a slight expansion in the construction pad in 2014 before being uncovered again in 2015. The ground surface at Transect 2, Quadrat 6 was 0.30 m lower in 2015, compared to 2012. Similarly, the ground surface at Transect 5, Quadrat 6 decreased by 0.26 m over the same period.

Based on the 2012 to 2016 ground surface monitoring across the South River wetland, the area covered by the bridge construction pad is 0.24 to 0.30 m lower than the adjacent undisturbed wetland surface. There is evidence to suggest that this decrease surface elevation is the result of compaction from the weight on the construction pad and equipment, excessive excavation when the construction pad was being removed, or both.

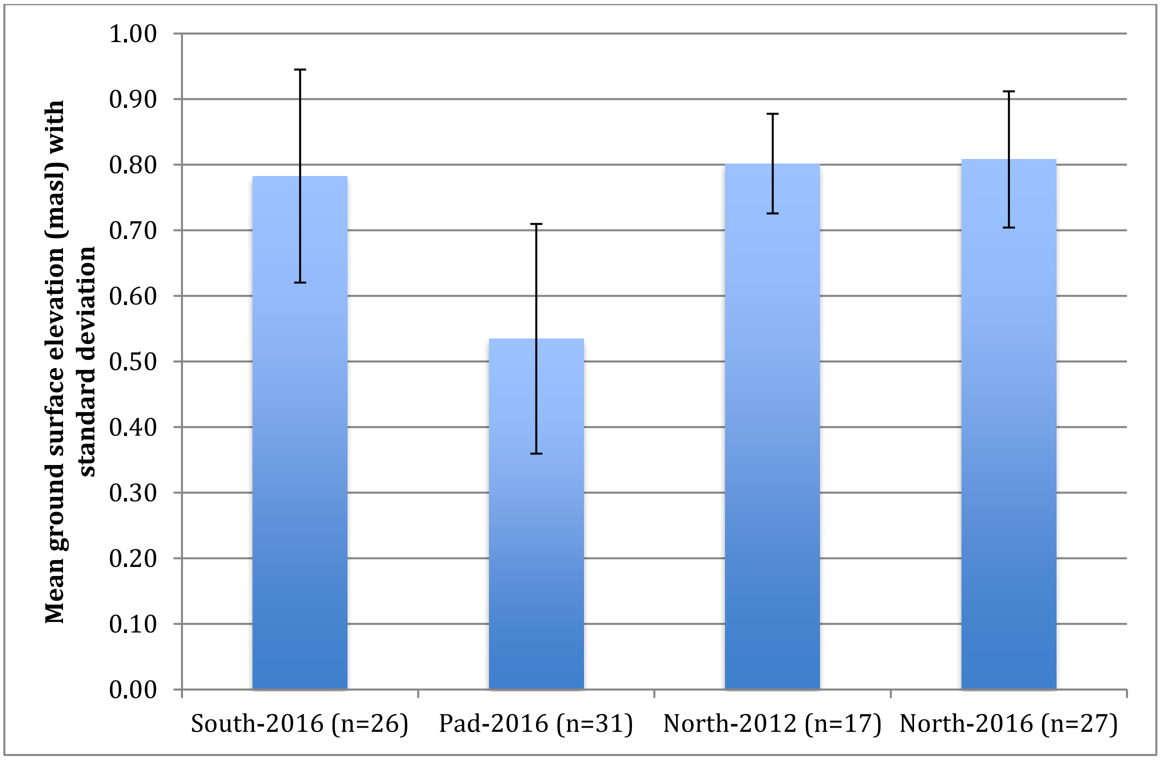


Figure 19: Mean ground surface elevations for undisturbed marsh to the south (upstream) and north (downstream) of the South River bridge crossing, as well as the construction pad area.

An east to west RTK elevation profile was completed on October 28, 2016 across the former pad area, approximately midway between the east and westbound bridge lanes (Figure 20). The vertical elevation difference between the eastern and western portions of the former construction pad was found to be approximately 0.3 m. Given that the tidal amplitude at the South River estuary is approximately 1.2 m, the 0.3 m vertical difference across the pad places the western portion significantly lower in the tidal prism. The increased frequency and duration of tidal inundation of the western portion of the former pad will very likely select for an ecological community which is distinct from that observed in the eastern portion of the pad should the wetland elevation not accrete following pad removal. At this point, it is unclear whether wetland elevation will return to pre-alteration levels following sediment accumulation, or if the western portion of the pad will develop towards a tidal flat / backwater area, largely devoid of macrophytic vegetation, a low marsh, characterized by low-diversity stands of *Spartina alterniflora* or a hybrid system with a more diverse mixture of *Spartina* (cordgrass) species, bulrushes, cattails, sedges and other graminoids.

Prior to the wetland alteration and bridge construction, vegetation across the western portion of the former construction pad consisted of sedge and bulrush dominant communities, with no tidal flats evident (see 2012 aerial photography at Appendix 7). While no pre-alteration elevation data exists for this area, the 2012 photography documented that vegetation across the eastern portion of the pad consisted of a sedge / grass dominant community and deciduous trees (the peninsula area described by Stantec (2010b). Within Antigonish Wetland 21, deciduous trees are typically found at locations having slightly higher elevation. This would suggest that the east to west vertical elevation difference observed in 2016 across the former construction pad may have been present pre-alteration.

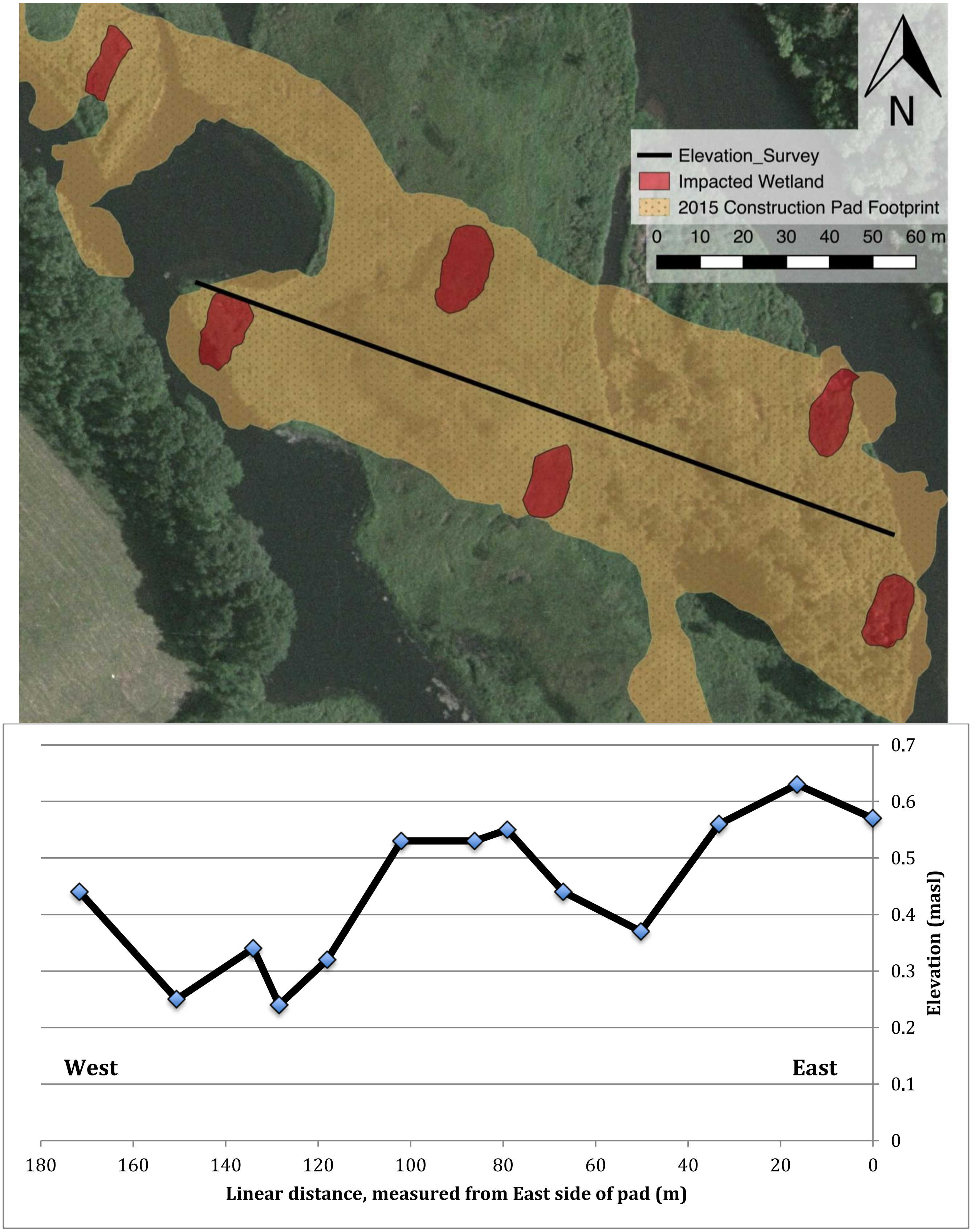


Figure 20: Ground surface elevation across former construction pad area between the two bridge lanes.

In order to better understand the ground elevation and sedimentation dynamics at the site, ECA established four 0.5 m x 0.5 m sediment accretion marker sites at Antigonish Wetland 21 on July 7, 2016 (Cahoon *et al*, 2006 and Turner *et al*, 2012). See Figure 1 for the locations and Appendix 3 for coordinates of the marker sites (Table 19). One control location was situated in undisturbed salt marsh north (downslope) of the bridge with three test sites established within the footprint of the construction pad. A 2" black PVC pipe was used to mark the centre of each plot, with white feldspar used as the marker horizon. The post-installation ground elevation was determined using the high accuracy RTK-GPS system (See Appendix 6 for photos). The marker horizons may be sampled in future years' to determine the extent of sediment accretion across the marsh surface, if field observations indicate that accretion processes may be occurring.

Table 19: Feldspar marker horizons establishment at the South River salt marsh, 2016.

Plot	***Location***	***Elevation (masl)***
Feld 1	Pad area near western backchannel in standing water at low tide.	0.28
Feld 2	Pad area in standing water southwest of west-bound central pier.	0.36
Feld 3	Pad area in standing water north of east-bound central pier.	0.56
Control	North of west-bound lane in undisturbed vegetation.	0.82

Part 2: Analysis of Change 2012 to 2016

The overarching goal of the Highway 104 wetland monitoring program was to evaluate if the overall ecological integrity of post-alteration wetlands was intact or further altered. ECA has proposed a number of preliminary criteria in order to evaluate if a significant change has occurred in a wetland over the monitoring period (ECA, 2011). These criteria sought to establish thresholds for changes in the plant communities within a wetland, including the presence of invasive alien species. These thresholds were based in part on the level of resolution available from the survey methods employed, taking into account natural and practitioner variability that was quantified through the QA/QC program. The review of the 2013 to 2016 field data has provided the opportunity for these criteria to be further evaluated, revised and expanded. The development of these criteria is viewed as an iterative process, requiring assessment of the criteria under different settings followed by revision.

Below, ECA presents several metrics for evaluating change in wetlands. This list draws on those presented in ECA (2011) and ECA (2013) and the work of others, including the Credit Valley Conservation Authority and its evaluation of wetlands in the Toronto area (Credit Valley Conservation, 2010) and U.S. Army Corps of Engineers (2009). The following approach seeks to use a variety of metrics and assessments to evaluate change within a wetland. This approach recognizes that no single indicator can capture the complexity of impacts and responses that may occur in post-alteration wetlands, therefore relying on a suite of measures to provide a composite picture.

As was described in ECA (2011), the monitoring program was established to provide a multi-year assessment of change relative to Year 1 within the post-altered wetland. A full plant, surface elevation, soils and water quality survey was undertaken in the initial year. The subsequent annual surveys during the intervening years have recorded plant species, water quality and shallow well water depth, when appropriate to the site. In the final year of monitoring, vegetation surveys and water quality observations will be repeated, together with a repeat of the surface elevation survey and the examination of wetland soils.

Indicators

<u>Indicator 1: Bray Curtis Similarity Index</u>

ECA (2011) proposed that a change in the vegetation community was indicated when the Bray-Curtis Similarity Index (BCI) of all herb and shrub species within a zone were less than 0.6 for a comparison of Year 1 to the current year data (Table 20). In cases where the herb stratum has low percent cover, the next two most abundant strata were used instead in this comparison. The BCI threshold was developed through the examination of replicate and duplicate transects. Based on the addition of the 2013/16 duplicate data to that collected between 2010 and 2012, the BCI threshold of **0.6** has been used in this report (Appendix 2). This value was felt to fairly reflect the level of change that can be routinely detected by the methods employed while taking into account natural and practitioner variability.

<u>Indicator 2: Invasive Alien Plants</u>

ECA (2011) recommended that an indicator for invasive alien plants should be incorporated into the monitoring program. A change in the vegetation community was indicated when the occurrence of alien invasive plants increased significantly. This indicator was satisfied when either of the following criteria were achieved: (a) the absolute percent cover of invasive alien species (IAS) increased by more than 20% within a single zone of a single transect, from the Year 1 value; or (b) the number of invasive alien species present within a single zone of a single transect increased by two or more between any two consecutive years of monitoring (Table 21). For additional information on the rationale used in the development of this indicator, please see ECA (2011).

Indicator 3: Prevalence Index

The Prevalence Index (PI) for each zone within a transect was calculated using the species-specific wetland codes and the respective absolute abundance of each species. The Prevalence Index uses the methodology described by the U.S. Army Corps of Engineers (2009). It draws on the concept of a Wetness Index proposed by Credit Valley Conservation (2010) and serves as a tool to evaluate change in vegetation communities (Spieles *et al*, 2006). The Prevalence Index incorporates plants occurring in the herb and shrub strata only.

The Prevalence Index sought to capture in a numerical value the overall “wetness” or “dryness” of the plant community within a zone, and as such was also a surrogate hydrology indicator. Plants of the herb and shrub strata were used since they were likely to be the first to exhibit changes resulting from altered hydrology and were almost always found in significant density (unlike the sapling and tree strata). An increase in the numerical value of the Prevalence Index indicated a greater proportion of plants which tend to occur in dryer conditions. The Prevalence Index would equal 1 where 100% of the plants within a zone were obligate wetland plants and 5 where 100% of the plants were upland plants.

Over the period of 2010 to 2016, a total of 15 duplicate vegetation transect pairs have been examined in eight different wetlands, being drawn from the Highway 101 (Kings and Hants counties), the Highway 104 (Pictou and Antigonish) and Highway 125 (Sydney) projects. The PI has been calculated for each of these pairs to better understand the variability of the metric within identical plant communities (Appendix 2). Within this data set, the relative percent difference (RPD) of the PI between identical plant communities was found to range from 0 to 27% and the initial threshold for change was established as 30%. The addition of the 2013/16 duplicate data has allowed for the re-analysis of this threshold, as the now larger data set allows for greater confidence in the observed results. Therefore, a year-to-year change in the PI greater than **20%** was considered an indicator of change that warranted further consideration. This threshold level was viewed as conservative and should be reviewed in the future as more duplicate analysis becomes available.

Table 22 presents the Relative Percent Difference (RPD) of Prevalence Index values over the monitoring period. A positive RPD, denoted by a (+), indicates an increase in the PI over time, suggesting a change in the plant community to one more typically found in dryer conditions. A negative RPD, denoted by a (-), indicates a decrease in the PI over time, suggesting a change in the plant community to one more typically found in wetter conditions.

Indicator 4: Visual Assessment of Wetland

Experienced wetland scientists conducted all annual monitoring of the post-alteration wetlands. Making use of photographic documentation, surface profile surveys and professional judgement, a qualitative assessment of changes to the wetland was made. This information was examined within the context of any quantitative changes observed. In undertaking the visual assessment of the wetland, surveyors were cognizant of overall changes in the wetland’s vegetation composition, hydrology, wetland class, adjacent land uses, wildlife usage and recent disturbances.

This indicator also includes an assessment of the predicted post-alteration size of the wetland relative to the current post-construction field measured boundary. This assessment focused on only the altered boundaries of the wetlands closest to the Highway 104, which were recorded using a hand-held GPS. These records were compared with those predicted in the original wetland alteration application (where available) to assess whether there have been additional, unpredicted spatial alterations to the wetland.

Analysis

Indicator 1: Bray-Curtis Similarity Index

While the year-to-year comparisons of the Bray Curtis Index are presented in Table 20, it is recognized that these values are preliminary for Transects 1 to 4, which fall almost entirely within the construction pad area, given the passage of only one growing season since the removal of the construction pad. Along these transects significant short term alteration of the community from placement of the pad is expected. However, the extent to which the community alteration persists is not known. The analysis will be repeated in subsequent years to better evaluate the recovery of the vegetation community along these transects. Transects 5 through 7, however, were almost completely outside of the construction footprint (see Figure 1), so the results for these locations are felt to better reflect true change over the time series.

While initially established in 2012 as having a single zone, transect 1 was examined here as having two zones: zone 1 (quadrats 1 to 3) north of the construction pad and undisturbed; and, zone 2 (quadrats 4 to 6) within the construction pad boundary and disturbed. The BCI for zone 1 was 0.45, falling below the <0.6 threshold of no change. The decreased BCI value was principally driven by the significant decrease in abundance of *Calamagrostis canadensis* over the 2012 to 2016 period. The BCI for transect 1, zone 2 was 0.12, indicating very little similarity with the 2012 plant community at this location. Transect 2 at the South River wetland had BCI values of 0 in all three zones, for the 2012 to 2016 period, indicating no similarity between the pre and post-alteration vegetation communities. This result was not unexpected given that the entire transect was covered by the construction pad. The BCI values for transect 3 were 0.04 for zone 1 and 0.32 for zone 2, indicating a significant change from the pre-alteration community. In case of transect 3 zone 1, small and immature graminoids recorded in 2016 may be the *Calamagrostis canadensis* and *Spartina pectinata* observed pre-alteration, but this cannot yet be confirmed. The BCI values for transect 4 were 0.19 in zone 1 and 0.18 in zone 2. The very low BCI values for transects 1, 2, 3 and 4 are not unexpected given the recent removal of the construction pad from most of the transect areas.

The BCI for transect 5 during the 2012 to 2016 monitoring period was 0.47, falling below the <0.6 threshold of no change. The reduced similarity for this transect was due to increase in abundance of *Spartina pectinata* and *Teucrium canadense,* with the reduction in abundance of *Typha latifolia.* One quadrat of the transect (Q6) occurred within the footprint of the construction pad and had only limited regeneration at the time of the 2016 surveys. When this quadrat was excluded from the analysis for the 2012 to 2016 period, the BCI was 0.40, indicating that significant change within the vegetation community had occurred along the remainder of the transect.

The BCI for transect 6 during the 2012 to 2016 period was 0.28 in zone 1 and 0.58 in zone 2. The reduced similarity for zone 1 was due to the increase in abundance of *Spartina patens,* with the reduction in abundance of *Carex aquatilis* and *Carex hormathodes.* The reduced similarity in zone 2 was due to the increase in abundance of *Rosa* spp, with the reduced abundance of *Calamagrostis canadensis*.

The BCI for both zones of transect 7, over the 2012 to 2016 period, fell below the <0.6 threshold, suggesting a significant change. The low BCI for zone 1 was principally due to the increase in abundance of *Spartina pectinata*. The reduced similarity in zone 2 was due to the increase in abundance of *Toxicodendron radicans* (Poison ivy).

Overall, the BCI analysis for the 2012 to 2016 period indicates change in the plant community composition may have occurred on the three transects which were not covered by the construction pad (T5, 6, and 7). The BCI data suggests considerable variability in the abundance of individual species within the wetland plant community. There does not appear to be any consistent pattern towards the favouring of one species over another, based on the available data.

Table 20: Bray-Curtis Similarity Index (BCI) comparison of herb and shrub species

Threshold of change: BCI <0.6

Transect	Transect Orientation	Zone 1	Zone 2*	Zone 3*
AntW21T1	Perpendicular	**0.45**	**0.12**	Not Applicable
AntW21T2	Perpendicular	**0**	**0**	**0**
AntW21T3	Parallel	**0.04**	**0.32**	Not Applicable
AntW21T4	Perpendicular	**019**	**0.18**	Not Applicable
AntW21T5	Perpendicular	**0.47**	Not Applicable	Not Applicable
AntW21T6	Parallel	**0.28**	**0.58**	Not Applicable
AntW21T7	Parallel	**0.41**	**0.57**	Not Applicable

* AntW21T5 had only one zone; AntW21T1, AntW21T3, AntW21T4, AntW21T6 and AntW21T7 had only two zones.

The remaining transects (8 through 11) were established in 2016 and will undergo comparative evaluation of BCI change in future years when additional data are collected for these areas.

Indicator 2: Invasive Alien Plants

Within the context of this analysis, invasive alien species (IAS) are aggressive, non-native plants, based on a number of provincial and regional sources: Hill and Blaney (2009), CARP (2007), Nova Scotia Weed Control Act (Revised 1989), Brazner (2011) and MTRI (2012). Exotic species describes those plants occurring outside their typical range, having arrived through human activity and is based on Nova Scotia Environment (2011).

No invasive alien species were documented at Antigonish Wetland 21 during the 2012 to 2016 monitoring period. Therefore the IAS threshold of change was not exceeded for transects 1 to 7. However, a significant number of exotic (16) species were recorded for the first time in 2015 and in particular during the 2016 field visits following the removal of the construction pad (Table 21).

The relative diverse and abundant suite of exotics is notable for transects 1, 2 and 3, in contrast to transects 5, 6 and 7, which were not impacted by the construction pad. Transect 4 is an anomaly in this pattern, having been covered by the construction pad, yet with no exotics observed in 2016. Transect 4,

Table 21: Exotic species recorded at Wetland 21 in 2016.

Transect	Transect Orientation	Exotic Species (cumulative absolute abundance)	Exotics as percentage of all herbaceous plants (based on absolute abundance)
AntW21T1	Perpendicular	*Gnaphalium uliginosum* (Low Cudweed) (10%) *Phleum pratense* (Meadow Timothy) (10%) *Polygonum hydropiper* (Marshpepper Smartweed) (25%) *Sonchus arvensis* (Field Sowthistle) (4%)	9%
AntW21T2	Perpendicular	*Daucus carota* (Wild carrot) (9%) *Echinochloa crus-galli* (Barnyard Grass) (4%) *Gnaphalium uliginosum* (Low Cudweed) (24%) *Hypericum perforatum* (A St. John's-Wort) (5%) *Matricaria discoidea* (Pineapple-Weed Chamomile) (4%) *Plantago major* (Nipple-Seed Plantain) (25%) *Polygonum hydropiper* (Marshpepper Smartweed) (95%) *Ranunculus repens* (Creeping Butter-Cup) (45%) *Rumex crispus* (Curly Dock) (54%) *Vicia cracca* (Tufted Vetch) (5%)	56%
AntW21T3	Parallel	*Gnaphalium uliginosum* (Low Cudweed) (5%) *Plantago major* (Nipple-Seed Plantain) (3%) *Polygonum persicaria* (Lady's Thumb) (5%) *Rumex crispus* (Curly Dock) (15%) *Sonchus arvensis* (Field Sowthistle) (3%)	11%
AntW21T4	Perpendicular	None	0%
AntW21T5	Perpendicular	None	0%
AntW21T6	Parallel	None	0%
AntW21T7	Parallel	None	0%
AntW21T8	Perpendicular	*Centaurea nigra* (Black Starthistle) (10%) *Daucus carota* (Wild carrot) (20%) *Hypericum perforatum* (A St. John's-Wort) (30%) *Lotus corniculatus* (Birds-Foot Trefoil) (20%) *Tanacetum vulgare* (Common Tansy) (5%)	22%
AntW21T9	Perpendicular	None	0%
AntW21T10	Perpendicular	*Rumex crispus* (Curly Dock) (3%)	0.4%
AntW21T11	Perpendicular	None	0%

being situated at a slightly lower elevation, is subject to more frequent and prolonged tidal inundation, which is thought to make this habitat less hospitable to the early colonizing exotics. The extent of coverage of transect 2 by ten exotic species (56% of all herbaceous plants) is significant and warrants further monitoring in the future.

Indicator 3: Prevalence Index

The relative percent difference of the Prevalence Index values for the 2012 to 2016 period in Antigonish Wetland 21 ranged from -45% to +32%. The bridge construction pad, which was removed in 2015, covered a significant portion of transects 1, 2, 3 and 4. At the time of the 2016 surveys, the quadrats of these transects had low herbaceous abundances, which can result in increased volatility in PI values. The PI values should therefore be used with caution.

Evaluation of PI for transects outside of the construction footprint (transects 5, 6 and 7) provides insight into changes in the wetland plant communities distinct from the direct alteration of the construction pad. The PI for transect AntW21T5 increased by 33% between 2012 and 2016, suggesting a significant shift in the plant community to one more typically found in dryer conditions. One quadrat (Q6) of the transect occurred within the footprint of the construction pad and had only limited regeneration at the time of the 2016 surveys. When this quadrat was excluded from the analysis, the PI for the remainder of the transect was calculated to have changed by +38% over the 2012 to 2016 period.

Similarly, transect 6 zone 1 had a significant positive change in the PI (+21%) whereas zone 2 of the transect had a negative change in the PI (-25%). No significant changes were observed for transect 7. Transects 5, 6 and 7 are located to the north of the bridge crossing and downslope of the construction pad. From a visual inspection of the wetland, there were no apparent reasons to explain the high degree of variability in the PI values observed for transects 5 and 6 in 2016.

Table 22: Relative Percent Difference (RPD) of Prevalence Index (PI) for Herb and Shrub Strata: 2012 to 2016
Threshold of change: Absolute RPD >20%

Transect	Transect Orientation	Zone 1	Zone 2	Zone 3
AntW21T1	Perpendicular	-6%*	**-24%***	Not Applicable
AntW21T2	Perpendicular	**-20%***	**+24%***	**+32%***
AntW21T3	Parallel	Not calculated	**-37%***	Not Applicable
AntW21T4	Perpendicular	**-45%***	+17%*	Not Applicable
AntW21T5	Perpendicular	**+33%**	Not Applicable	Not Applicable
AntW21T6	Perpendicular	**+21%**	**-25%**	Not Applicable
AntW21T7	Parallel	+10%	+19%	Not Applicable

* Transects 1, 2, 3, and 4 had low herbaceous abundances values and PI values should be used with caution.
Not Applicable: some transects had only one or two zones
Not Calculated: Guidance indicates that the Prevalence Index is not valid when less than 80% of the vegetation community can be identified to the species level.
Note: A positive RPD, denoted by a (+), indicates an increase in the PI over time, suggesting a change in the plant community to one more typically found in dryer conditions. A negative RPD, denoted by a (-), indicates a decrease in the PI over time, suggesting a change in the plant community to one more typically found in wetter conditions.

The remaining transects (8 through 11) were established in 2016 and will undergo comparative evaluation of PI change only in future years when a second data set is collected for these areas

Indicator 4: Visual Assessment of Wetland

A visual survey of Antigonish Wetland 21 was undertaken as part of the annual fieldwork. At the April 2016 visit, most of the stakes marking the locations of the vegetation quadrats for transects 1, 2, 3 and 4 were found to be missing, most likely through ice movement across the site. The quadrats were re-staked using field notes. Ice and water scour were evident across much of the pad area with a deep and wide wrack-line of debris along the southern pad margin. Numerous small-bodied fish were observed in water-filled depressions across the former pad area at low tide, including: Three-spined stickleback (*Gasterosteus aceleatus*), Nine-spined stickleback (*Pungitius pungitius*), Killifish (*Fundulus* spp) and Mummichog (*Fundulus heteroclitus*). Approximately 10 recent mortalities were collected from across the western portion of the site, including Sticklebacks, Killifish, and Mummichog (see Appendix 6, photograph 17). The cause and location of the mortalities is unknown. It is possible that the fish died offsite and were blown into the estuary with the strong northwest wind that occurred the day prior to the field observations.

The 2016 vegetation surveys occurred approximately 12 months following the removal of the construction pad. The eastern portion of the construction pad had vigorous establishment of both native species and opportunistic colonizing exotics. The western portion of the pad area had, in general, very poor re-vegetation since removal of the construction pad. The western portion of the pad was observed to be slightly lower in elevation than the eastern side, resulting in this area being lower in tidal prism and inundated a greater portion of the time.

A key assumption concerning natural restoration of the site following the removal of the construction pad was that suitable growth conditions, including light, would be present. Broome *et al.* (2005) has investigated the effects of bridge shading on estuarine wetlands, finding a strong correlation between the bridge Height to Width (HW) ratio and impacts to intertidal vegetation and benthic invertebrates. The authors noted the potential for the complete loss of vegetation under the lowest and widest bridges, with HW ratios of <0.3. Struck *et al.* (2004) documented significantly lower benthic invertebrate diversity and abundance under bridges with HW ratios of <0.7, compared to reference wetlands. Reductions in the stem density of *Spartina alterniflora* of 50 to 71% due to shading by docks have been documented by Sanger *et al.* (2004) in South Carolina and Alexander and Robinson (2006) in coastal Georgia. Logan *et al.* (2014) observed reductions in stem densities for low marsh vegetation of 20 to 34% under docks having a HW ratio of 1:1.

ECA has documented the failure of *Spartina* spp and other salt marsh vegetation to re-establish beneath the Sutherlands River Bridge where the Height to Width ratio was estimated to be 0.32 (ECA, 2015). Based on the bridge dimensions (height 16 m, lane width 12.2 m), the Height to Width ratio for the South River crossing was estimated to be 1.3, well above the threshold of where shading effects might be expected (NSTIR, 2009).

ECA has conducted a preliminary examination of the actual shading effects of the South River Bridge by constructing a 2-D graphic representation of the bridge and sun positions, and a 3-D scale mock-up of the crossing. The skewed northwest to southeast alignment of the crossing has a pronounced impact on the timing and extent of shading (Figure 21). At the summer solstice (June 21), morning to midday shading occurs directly below the bridge and extends only a short distance (~5 m) to the northeast. Predicted afternoon shading is more pronounced, starting near the north edge of the bridge footprint and extending more than 50 m to the northeast, covering transects 5 through 7. This shading effect would occur during the height of the growing season.

At the vernal and autumnal equinox (March 21/September 22), the lower sun angle results in a more extensive area of shading. During the morning, shade extends from below the bridge to ~30 m to the northeast. At noon, shading occurs from near the bridge footprint out to ~20 m to the northeast. By midafternoon, the shaded area starts approximately 15 m northeast of the bridge and extends out to ~60 m northeast of the bridge centerline.

The preliminary shading analysis suggests that undisturbed native salt marsh at transect 1 (northern end, quadrats 1, 2, and 3), transect 5 (southern end, quadrats 4, 5 and 6) and portions of transect 6 may be subject to regular and extensive afternoon shading during the growing season arising from both the east and west bound Highway 104 lanes. This shading may in part explain the changes observed with the Bray-Curtis and Prevalence Indices between 2012 and 2016 in otherwise undisturbed marsh. The shading may also have an impact on the re-vegetation of former construction pad area beneath and between the lanes. Perry (2001) has noted that dominant east coast salt marsh grasses (*Spartina* spp.) utilize the C4 photosynthetic pathway and do not flourish in shaded environments.

Field surveys in 2012 identified two previously undocumented species of conservation concern at the South River marsh: *Samolus valerandi* (Seaside brookweed) (NS General Status: Yellow / S3) and *Cuscuta cephalanthi* (Buttonbush dodder) (NS General Status: Red / S2?) (ECA, 2013). As part of the 2016 field surveys, ECA confirmed the widespread presence of *S. valerandi* and *C. cephalanthi* at multiple locations across the site. A particularly large patch of *C. cephalanthi* was identified in 2015 at the western boundary of the site, where the salt marsh transitions to upland. The large patch was approximately 5 m x 2 m in size, covering virtually all the vascular plants present, which were in poor condition. The principle host species were observed as *Symphyotrichum novi-belgii*, and in drier conditions, *Rosa* spp and *Alnus incana*. The persistence of this large patch was confirmed in 2016.

At the time *C. cephalanthi* was identified at the site in 2013, the taxonomy was strongly suspected but not confirmed, in part due to the absence of any provincial experts in the taxa. Sean Blaney, Atlantic Canada Conservation Data Centre (ACCDC), recommended contacting Dr. Mihai Costea at Wilfred Laurier University, with samples subsequently being collected and dispatched to Dr. Costea for identification. Dr. Costea was able to confirm via correspondence on May 5, 2016 that the multiple 2013 specimens collected were indeed *C. cephalanthi*.

The Antigonish Landing salt marsh, within the Rights / West River estuary, is located approximately five kilometres to the northwest of the Wetland 21 (South River) site. ECA staff, through the course of field surveys at the Antigonish Landing Reference site, documented the presence of what is strongly suspected to be *C. cephalanthi* at six locations in 2016 (ECA, 2017). The habitat setting was similar to those encountered at South River, at the upland edge transition from the salt marsh where wetland obligates (e.g., *Spartina* spp) give way to facultative species (e.g., *Rosa* spp). The marine influences for the two sites are very similar, being located in protected estuaries off the Northumberland Strait.

The confirmation of *C. cephalanthi* at Antigonish Wetland 21, and very likely at Antigonish Landing, is of considerable botanical and scientific interest, given the species' rarity and unusual life history. As is ECA's standard practice, the findings will be shared with ACCDC to contribute to the improved understanding of species at risk. Additional details on the Antigonish Landing site are presented at ECA (2017).

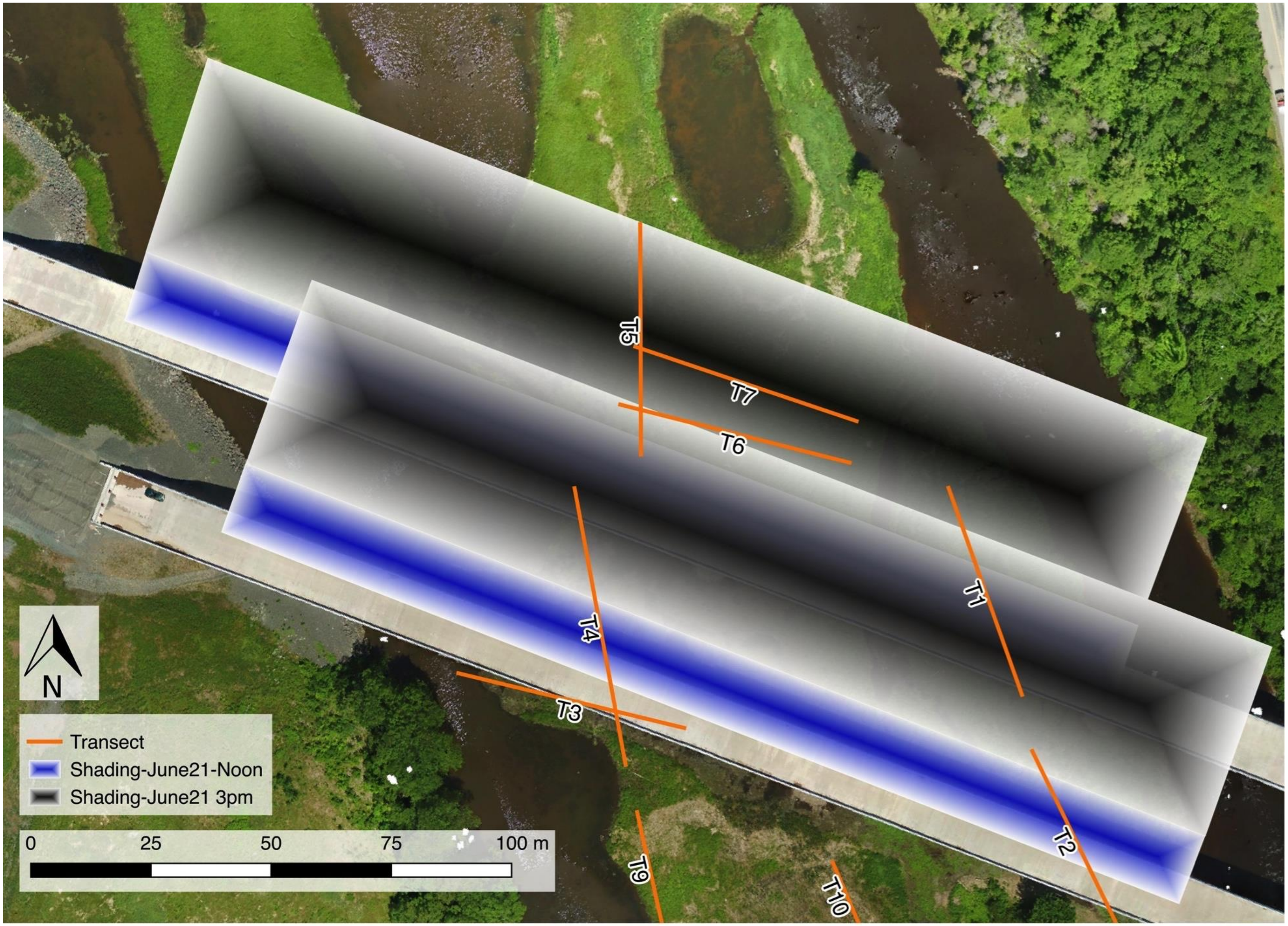


Figure 21: Preliminary shading analysis for South River crossing, summer solstice (June 21) at noon and 3 pm.

Part 3: Conclusions and Recommendations

Conclusion

Year 5 post-alteration monitoring was completed at Antigonish Wetland 21 between April and October 2016. This monitoring documented the vegetation community using a series of transects and quadrats, aerial photography, water quality, soils, and ground surface elevations. Seven vegetation transects established in 2012 were re-sampled in 2016, with an additional four transects established to more fully characterize changes at the South River salt marsh.

The Bray-Curtis Similarity Index analysis suggests significant change in the wetland plant community during the 2012 to 2016 monitoring period (Table 23) for the all seven transects. The Prevalence Index analysis indicated a mixed response, with approximately half of the vegetation zones having shifts in the plant community to one more typically associated with dryer conditions and half indicating a shift to wetter conditions. While no alien invasive species were identified at Antigonish Wetland 21, a significant number of exotic species were recorded, particularly as early colonizers in the bare soil of the former construction pad at transects 1, 2, 3 and 8. Field surveys in 2016 confirmed the persistence of three previously identified species of conservation concern (*Teucrium canadense* (American germander), *Samolus valerandi* (Seaside brookweed) and *Cuscuta cephalanthi* (Buttonbush dodder)) as being abundant and widely scattered across the site. The water quality monitoring results indicate conditions similar to those observed previously with a strong marine influence across most of the site.

Table 23: Indicators of change summary table, Antigonish Wetland 21 - 2012 to 2016

Transect	Bray Curtis Similarity Index	Invasive Alien Species	Prevalence Index	Visual Assessment	Transect Summary
AntW21T1	Threshold exceeded*	Threshold not exceeded**	Threshold exceeded	Construction pad removal	**Indication of change**
AntW21T2	Threshold exceeded*	Threshold not exceeded**	Threshold exceeded	Construction pad removal	**Indication of change**
AntW21T3	Threshold exceeded*	Threshold not exceeded**	Threshold exceeded	Construction pad removal	**Indication of change**
AntW21T4	Threshold exceeded*	Threshold not exceeded	Threshold exceeded	Construction pad removal	**Indication of change**
AntW21T5	Threshold exceeded	Threshold not exceeded	Threshold exceeded	No visible change	**Indication of change**
AntW21T6	Threshold exceeded	Threshold not exceeded	Threshold exceeded	No visible change	**Indication of change**
AntW21T7	Threshold exceeded	Threshold not exceeded	Threshold not exceeded	No visible change	**Indication of change**
Wetland summary	**Indication of change**	**No indication of change**	**Indication of change**	**Indication of change**	

* Former construction pad with very low plant abundances at the time of the 2016 surveys
** High relative abundance of colonizing exotic species.

Soils at the wetland were examined in 2016 by a series of six test pits, indicating generally similar conditions across the site with an organic-based horizon of varying thickness underlain by a silt horizon. The surveys indicated soils within the footprint of the former construction pad, particularly the eastern portion, had significantly greater compaction, extending to a depth of 46 cm, compared to undisturbed salt marsh soils. A preliminary examination indicates that shading from the completed bridge lanes may be a factor in the Bray Curtis and Prevalence Index values observed for the vegetation transects downslope of the crossing. Elevation surveys across the site suggest that the ground surface within the former construction pad is 0.25 to 0.30 m lower than the adjacent undisturbed salt marsh to the north and south of the crossing.

Post-Construction Wetland Monitoring and Remediation Recommendations

Monitoring at Antigonish Wetland 21 was initiated in 2012 immediately prior to the establishment of the construction pad and initially planned to be repeated annually for three years. Monitoring to date has established baseline conditions at the wetland and the physical extent of the temporary construction pad. Transect monitoring should be continued in order to establish the extent and pace of re-vegetation and restoration of the site, following removal of the construction pad in 2015. While the re-vegetation of the former construction pad was encouraging, the abundance of aggressive exotic species gives cause for concern. In the case of transect 2, 56% of the herbaceous cover in 2016 was composed of exotic species. Vegetation monitoring in 2017 should concentrate on the presence and extent of exotic species across the former construction pad area.

Surface profile data indicate that the marsh surface may have compacted under the construction pad, which could lead to a longer hydroperiod and altered plant community. For these reasons, it is recommended that repeat monitoring of the South River wetland occur so as to evaluate long-term changes to the wetland. Elevation profiles and density measures are considered central to the compaction evaluation.

An evaluation of the shading extent at South River is recommended, as it may be a driver of plant community changes across portions of the study area, particularly for the undisturbed wetland to the north of the crossing. Physical measures of spatial and temporal area of shading by the bridge will allow for better evaluation of potential shading impacts. A review of literature for shade tolerance by marsh species present at the site will further assist in confirming whether a shading impact is occurring.

While remedial actions in the form of seed/transplanting of salt marsh species could be undertaken within the construction pad area, there is considerable scientific and practical benefit in refraining from this at present. With the monitoring dataset that exists for the site (pre-construction through to the completion of construction), the potential exists to thoroughly evaluate the use of geotextile/gravel construction pads in salt marshes as well as determine the spatial and temporal extent of natural regeneration. For these reasons, no remediation actions are proposed at present for Antigonish Wetland 21.

References

Argow, B.A. and FitzGerald, D.M. 2006. Winter processes on northern salt marshes: Evaluating the impact of in-situ peat compaction due to ice loading, Wells, ME. Estuarine, Coastal and Shelf Science. 69:360-369.

Alexander, C., Robinson, M. 2006. Quantifying the ecological significance of marsh shading: the impact of private recreational docks in coastal Georgia. Submitted to Coastal Resources Division, Georgia Department of Natural Resources. 47 pp.

Brazner, J. Personal communication, Nova Scotia Environment, November 15, 2011.

Broome, S.W. Craft, C.B., Struck, S.D., SanClements, M. 2005. Effects of Shading from Bridges on Estuarine Wetlands: Final Report. Joint Environmental Research Program, CTE/NCDOT. 66 pp.

Cahoon, D. R., J. C. Lynch, and R. M. Knaus. 1996. Improved cryogenic coring device for sampling wetland soils. Journal of Sedimentary Research 66:1025-1027.

Canadian Council for Ministers of the Environment (CCME). Canadian Water Quality Guidelines for the Protection of Aquatic Life. Summary Table-Update 7.1, December 2007.

CBCL Ltd. 2015. Highway 104 Extension and Transition – Wetland Alteration Approval Application. Monitoring Plan. Prepared for NS Department of Transportation and Infrastructure Renewal. July 2015.

Clean Annapolis River Project. 2007. Checklist of Invasive Alien Plants for Nova Scotia's Annapolis Valley (including problematic garden plants) http://www.annapolisriver.ca/downloads/IAS_checklist.pdf

Colorado State University. 2004. Guide to Sampling Soil Compaction Using Hand-Held Soil Penetrometers. Centre for Environmental Management of Military Lands. Report CEMML TPS 04-01.

Credit Valley Conservation. 2010. Monitoring Wetland Integrity within the Credit River Watershed. Chapter 3: Wetland Vegetation 2005-2009. Credit Valley Conservation. ix + 102 p.

East Coast Aquatics Inc. 2011. Waterville Wetland: Results of 2010 Vegetation Surveys and Post-Construction Monitoring Plan. Prepared for NS Department of Transportation and Infrastructure Renewal. March 2011.

East Coast Aquatics Inc. 2013. Highway 104 – Coalburn Wetland 4 Year 1 (2012) Monitoring Report. Prepared for NS Department of Transportation and Infrastructure Renewal. June 2013.

East Coast Aquatics Inc. 2015. Highway 104 – Sutherlands River Marsh Year 5 (2014) Post-Alteration Monitoring Report. Prepared for NS Department of Transportation and Infrastructure Renewal. February 2015.

East Coast Aquatics Inc. 2016. Highway 104 – Antigonish Wetland 21 (South River) Year 4 (2015) Monitoring Report. Prepared for NS Department of Transportation and Infrastructure Renewal. March 2016.

East Coast Aquatics Inc. 2017. Antigonish Landing Salt Marsh Monitoring Report. Prepared for NS Department of Transportation and Infrastructure Renewal. In preparation March 2017.

Elzinga, C.L., Salzer, D.W., Willoughby, J.W., and Gibbs, J.P. 2001. Monitoring Plant and Animal Populations. Blackwell Science, Malden, Massachusetts.

Hill, N.M. and Blaney, C.S. 2009. Exotic and invasive vascular plants of the Atlantic Maritime Ecozone. In Assessment of Species Diversity in the Atlantic Maritime Ecozone. Edited by D.F. McAlpine and I.M. Smith. NRC Research Press, Ottawa, Canada. Pages 1-18.

Fee, R. 2005. Soil penetrometers. Successful Farming. Meredith Corporation.

Fuller, K. Personal communications, Agriculture and Agri-Foods Canada, May 4, 2016.

Logan, J. Voss, S., Ford, K. and Deegan, L. 2014. Shading Impacts of Small Docks and Piers on Salt

Marsh Vegetation in Massachusetts Estuaries. Massachusetts Bays Program. January 21, 2014.
Maritime Testing. 2011. Wetland Evaluation Supporting Information – Proposed MacKay Connector Road, Coalburn, NS. Prepared for Nova Scotia Department of Transportation and Infrastructure Renewal. March 16, 2011.
MCFT. 2009. Nova Scotia Advanced Wetlands Delineation & Evaluation Course. Maritime College of Forest Technology and Nova Scotia Department of Environment. Course Methods binder.
Mersey Tobeatic Research Institute. 2012. Invasive Alien Species in Nova Scotia: Identification and Information Guide. Prepared by Alain Belliveau, MTRI.
Neill and Gunter (Nova Scotia) Limited. 2001. Final Report: Highway 104 Antigonish South River Impact Study. Prepared for Nova Scotia Department of Transportation and Public Works. February 5, 2001.
Nova Scotia Environment 2011. Wetland Indicator Plant List. Based on the methodology of Reed, P.B. Jr. 1988. National List of Plant Species that Occur in Wetlands: 1988 National Summary. U.S. Fish and Wildlife Service Biological Report 88(24). Washington, D.C. USA. Revised by S. Blaney for application to Nova Scotia. http://www.gov.ns.ca/nse/wetland/indicator.plant.list.asp
Nova Scotia Weed Control Act, Revised 1989.
NSTIR. 2009. Highway 104 Antigonish Phase 2 South River Bridge, General Arrangement Sheet No. 1. File No. B-09-35.
Perry, J.E., Barnard, T.A. Jr., Bradshaw, J.G., Friedrichs, C.T., Havens, K.J., Mason, P.A., Priest, W.I, Siberhorn, G.M. 2001. Creating Tidal Salt Marshes in the Chesapeake Bay. Journal of Coastal Research, Special Issue No. 27 (Winter 2001), 170-191.
Roman, C.T. and Burdick. D.M. 2012. Tidal Marsh Restoration: A Synthesis of Science and Management. Society for Ecological Restoration. Island Press. Washington.
Sanger, D.M., Holland, A.F., Gainey, C. 2004. Cumulative impacts of dock shading on *Spartina alterniflora* in South Carolina estuaries. Environmental Management 33(5):741-748.
Spencer, K.L., Cundy, A.B., Davies-Hearn, S., Hughes, R., Turner, S., MacLeod, C.L. 2008. Physicochemical changes in sediments at Orplands Farm, Essex UK following 8 eyars of managed realignment. Estuarine, Coastal and Shelf Science. 76:608-619.
Spieles, D.J., Coneybeer, M., Horn, J. 2006. Community Structure and Quality After 10 Years in Two Central Ohio Mitigation Bank Wetlands. Environmental Management 38:837-852.
Stantec Consulting Limited (formerly Jacques Whitford Limited). 2005. Final Draft Report to Nova Scotia Department of Transportation and Public Works on Environmental Assessment of Highway 104 Antigonish. Prepared for NS Department of Transportation and Public Works. Project No. NSD16949, April 2005.
Stantec Consulting Limited (formerly Jacques Whitford Limited). 2006a. Wetland Alteration Proposal, Highway 104 Twinning. Prepared for NS Department of Transportation and Public Works. Project No. 1018446, December 18, 2006.
Stantec Consulting Limited (formerly Jacques Whitford Limited). 2006b. Wetland Alteration Proposal, Wetland 2, Highway 104 Twinning. Prepared for NS Department of Transportation and Infrastructure Renewal. Project No. 1018446.02, July 2008.
Stantec Consulting Limited (formerly Jacques Whitford Limited). 2008. Wetland Alteration Proposal, Wetland 3, Highway 104 Twinning. Prepared for NS Department of Transportation and Infrastructure Renewal. Project No. 1018446.02, August 26, 2008.
Stantec Consulting Limited (formerly Jacques Whitford Limited). 2009a. Wetland Alteration Proposal, Wetland 4, Highway 104 Twinning. Prepared for NS Department of Transportation and Infrastructure Renewal. Project No. 1018446.04, January 2009.
Stantec Consulting Limited. 2009b. Wetland Alteration Proposal, Wetlands 1, 2, 3, 4 and 6, Highway

104 Twinning, Addington Forks Road to Taylor Road. Prepared for NS Department of Transportation and Infrastructure Renewal. Project No. 1036538.01, February 19, 2009.

Stantec Consulting Limited. 2009c. Draft Report - Wetland Alteration Proposal Highway 104 Twinning. Prepared for NS Department of Transportation and Infrastructure Renewal. Project No. 1045167, April 2009

Stantec Consulting Limited. 2010a. Wetland Alteration Proposal, Sutherlands River Crossing, Highway 104 Twinning. Prepared for NS Department of Transportation and Infrastructure Renewal. File: 121510133, February 2010.

Stantec Consulting Limited. 2010b. HADD Compensation Proposal – Highway 104 Twinning – Antigonish Phase II. Prepared for NS Department of Transportation and Infrastructure Renewal. File: 121510062, May 2010.

Stantec Consulting Limited. 2011. Post-Construction Monitoring of Wetlands Affected by Twinning of Highway 104 Antigonish/Pictou Counties (8 reports). Prepared for NS Department of Transportation and Infrastructure Renewal. File: 121510597, March 2011.

Stantec Consulting Limited. 2016. Letter Report with respect to Hwy. 104 Construction (Phase 2 at Antigonish) – South River Bridge Easterly to the Taylor Road U/P Structure – Investigation of Work Conducted in Area of Wetlands 16, 17 and 17B. File #121413561. January 12, 2016.

Struck, S.D., Craft, C.B., Broome, S.W., Sanclements, M.D., Sacco, J.N. 2004. Effects of Bridge Shading on Estuarine Marsh Benthic Invertebrate Community Structure and Function. Environmental Management 34(1):99-111.

Turner, K., J.Y. Takekawa, I. Woo, C. Ellings, B. Root, and J.E. Takekawa. 2012. *Tidal Marsh Monitoring Online Handbook.* Available online at tidalmarshmonitoring.org (accessed July 10, 2016).

U.S. Army Corps of Engineers. 2009. Interim Regional Supplement to Corps of Engineers Wetland Delineation Manual: Northcentral and Northeast Region. ERDC/EL TR-09-19, October 2009.

Zinck, M. (1998) Roland's Flora of Nova Scotia. Nimbus Publishing and Nova Scotia Museum, Halifax.

Appendix 1: Detailed Methodology

Transects have been placed at locations where it is predicted that unforeseen residual impacts may be the greatest. Two or more transects were orientated at an angle perpendicular to the highway road prism, with the expectation that monitoring results would document a gradient from greatest potential to least potential for alteration. A minimum of one transect was orientated parallel to the highway road prism so as to better understand the spatial extent of any impact gradients.

Transects were at least 50 m in length, unless site conditions dictated otherwise. A continuous 50 m tape was used for quadrat placement, to reduce layout error. The beginning and end of each transect were permanently staked in the field, with the location of each quadrat also staked on two corners to facilitate future monitoring and proper placement of the monitoring quadrat. Beginning and end points of each transect were documented with a handheld GPS. The bearing of each belt transect was also documented. Wetland zones along each transect were then visually identified, measured from the point of origin, and flagged, based on the qualitatively observed generalizations of wetland vegetation composition. Establishment of zones created a stratification of the existing wetland classification. A series of 1 m x 1 m quadrats were located in each zone. The target number of quadrats within each zone was as least three, in order to provide a more meaningful representation of the zone being assessed. In some cases, if the zone was very narrow, it was not feasible to place multiple quadrats in the narrow zone, and less than three were employed. Quadrats were sited within a zone by dividing the zone length by the number of quadrats, ensuring that they were equally spaced across the zone.

A standard naming convention was used for transects and quadrats. A three or four letter abbreviation denoted the wetland name, followed by a capital “W” and the individual wetland number. This was followed by a capital “T” and the individual transect number. For example, transect CoalW3T2 was the second transect at the Coalburn Wetland 3. Quadrats were numbered in ascending order, beginning at the end of the transect closest to the road prism, in the case of perpendicular transects. For parallel transects, the beginning of the transect was indicated on the data sheet. Thus, CoalW3T1Q4 is the fourth quadrat on transect 1 at Coalburn Wetland 3.

Following the establishment of the wetland zones and quadrat points, vegetation composition was analyzed at each quadrat. Herb and shrub stratum were assessed by documenting all species and their absolute percent cover within a 1 m x 1 m quadrat. A rigid 1 m x 1 m sampling frame was used to clearly delineate the boundaries of the quadrat. Sapling stem counts were made within an estimated 5 m radius of the quadrat sampling position. Trees were counted via a prism count from each quadrat sampling location. These methods directly tie to NS Wetland Delineation methods. The vegetation cover in and immediately around each quadrat was documented with a digital photograph.

Experienced staff were utilized in conducting field assessments and data analysis. The same field staff were used annually in conducting all botanical assessments in order to ensure consistency and reduce variance associated with practitioner bias. In addition to NSE methodologies, ECA recorded environmental characteristics of the substrate for each quadrat, including percent water, muck, moss, and exposed stone or mineral soil. Finally, average shrub/herb plant height and water depth in each quadrat were recorded. All field collected data was entered on a standardized field data collection sheet for later entry into a custom-designed database. All data collected through the wetland monitoring project is available in spreadsheet format (Excel) from NSTIR.

For the herb, shrub, sapling and tree strata, the dominant species within each wetland zone was determined using the 50/20 rule (MCFT, 2009). The indicator status of wetland plants was assigned based on the Nova Scotia Wetland Indicator Plant List (Nova Scotia Environment, 2011) with Zinck (1998) used as a taxonomic reference.

During the 2016 field season, ECA transitioned from the use of a survey level, tripod and rod to a Real Time Kinematic (RTK) GPS system for recording surface elevations (Geneq SXPro Real Time Kinematic (RTK) field computer operating Micro Survey Field Genius 8 (version 8.3.17.4), with RTK processing provided by SmartNet). The horizontal datum used was UTM83-20 and vertical geoid model HTv2.0. The Geneq RTK has a reported horizontal accuracy of 0.008m +1ppm and vertical accuracy of 0.015m +1ppm. The field tolerances used by ECA in data collection were: horizontal 0.09m and vertical 0.05m. In order to improve consistency of observations, elevation observations were recorded at the same position at each quadrat (within the quadrat and immediately adjacent to the right-hand initial corner stake, when facing towards the end of the transect).

In order to ensure consistency in observations across multiple years, a comparison of elevation observations was made using the survey rod and level with the Geneq SXPro RTK unit at multiple locations. The average elevation difference between the two methods was 0.038m (n=23). ECA had previously estimated the accuracy for the rod and level method to be +/- 2 cm for sighting distances up to 80 m.

Water quality measurements were recorded in open water areas at each wetland using a YSI ProPlus multiprobe water meter, calibrated as per the manufacturer's instructions. Parameters recorded included pH, Dissolved Oxygen (mg/L), Dissolved Oxygen (Percent Saturation), Water Temperature (°C) and Specific Conductivity (µS/cm). Turbidity measurements were made in the field using a LaMotte 2020i turbidity meter.

Alien invasive species present in the wetland were identified using a list compiled from several sources: Hill and Blaney (2009), CARP (2007), Nova Scotia Weed Control Act (Revised 1989), Brazner (2011) and MTRI (2012).

Updated aerial photography was recorded at the wetland on July 19, 2016 using a fixed-wing aircraft. Images were recorded using a FC300X camera (3.61mm), which were stitched together to form a montage. The orthorectified image was then geo-referenced using ground control stations previously placed in the wetland, the locations of which had been determined using a high accuracy RTK-GPS system. Pixilation colour and density, together with logical assumptions concerning remote sensing of natural environments, allowed the generation of preliminary habitat boundaries and maps. Field-mapped vegetation boundaries and observed characteristics gathered were then used to refine the habitat map. A final quality control step involved comparing the generated habitat boundaries and classifications with the transect quadrat data at the wetland, allowing the production of the final maps.

Appendix 2: Quality Assurance and Quality Control Measures Implemented

One of the central objectives in the post-alteration monitoring of wetlands was to determine if residual or unpredicted effects were causing ongoing impacts to the wetland. Central to achieving this objective was the ability to determine when an ecologically significant change has occurred. Monitoring programs must encompass the natural variability of the system under investigation as well as variability inherent within the monitoring methodology.

ECA implemented a quality assurance/quality control (QA/QC) program throughout the post-alteration wetland monitoring program in order to ensure the accuracy and precision of the results. The QA/QC program included a series of controls within the methodology in order to limit variability, as well as duplicate and replicate surveys to assess the reliability and reproducibility of the data collection methods. The implementation of the QA/QC program has both reduced methodological variability to a minimum while allowing a meaningful estimate of ecological change to be determined.

Consistent QA/QC methods were employed in the post-alteration monitoring of wetlands along Highway 101 in Kings and Hants counties from 2010 to 2012; Highway 104 in Pictou and Antigonish counties from 2011 to 2016; Highway 125 in Sydney in 2013 and 2015; as well as at the Antigonish Landing Wetland in 2016. The field methodology and QA/QC approach from these five monitoring programmes were consistent; therefore, the results are combined here to increase the breadth of the evaluation and sample size. The broader examination of QA/QC results across multiple years and sites has allowed a more comprehensive picture to emerge of temporal and spatial variability within the data set. While the datasets from the four monitoring programs are combined here, the results have also been examined individually to ensure consistency.

During the 2016 monitoring season, one duplicate vegetation survey was conducted at Antigonish Wetland 11 (transects 1 and 2). As well, two replicate surveys were conducted at Antigonish Wetland 21 (transects 6 and 7) and the Antigonish Landing Wetland (transects 3 and 7).

Methodological Controls

ECA employed a number of quality assurance measures throughout the field program to ensure reliability of the results. The purpose of these actions was to reduce methodological error and variability to the lowest extent possible. These measures are summarized in Table A1.

Table A1: Quality Assurance Measures Employed

Type of Variability	Controls Employed
Spatial variability within the vegetation community	1. Both ends of each transect geo-referenced, with the location of each monitoring plot recorded. 2. Opposite corners of each monitoring plot staked. 3. All plots labeled with unique identifier code. 4. Use of a rigid 1m x 1m sampling frame.
Taxonomic and data recording variability	5. Consistent use of the same experienced botanist in year-to-year surveys. 6. Consistent use of the same experienced field staff.

	7. Written procedure for the implementation of field surveys. 8. Use of pre-printed wetland-specific data sheets, to minimize data gaps and coding errors. 9. Management of field day length to control crew fatigue. 10. Water quality and other instruments calibrated immediately prior to each field survey and in accordance with the manufacturer's directions. 11. Elevations of hydrology monitoring wells surveyed at both logger deployment and retrieval.
Seasonal Variability	12. Field surveys conducted during the same time period (typically the same week) each year.
Data Management and Analysis	13. Field data held in a custom designed database, providing off-site backup. 14. Automated generation of summary analysis by zone and transect. 15. Peer review of data analysis and conclusions.

Replicate Surveys

In order to better understand the level of spatial variability within wetland plant communities at the scale of 1 to 10 meters, ECA has made use of replicate surveys within the plot-based vegetation monitoring. The term replicate is used here to describe where two transects are placed in visually identical vegetation communities (parallel transects separated by 5 to 10 m) and surveyed using the same personnel on the same day. The purpose of the replicate is to better understand the heterogeneity and spatial variability in wetland plant communities and hence, the basic assumptions made as part of the sampling methodology.

During the 2010 to 2016 period for the Highway 101, 104, 125 and Antigonish Landing projects, ECA surveyed thirteen replicate pairs across four wetland types. The results of this analysis are presented in Table A2.

Table A2: Summary Survey Metrics for Thirteen Replicate Pairs

Metric	Mean	Worst	Best	Notes
BCI of Herbs and Shrubs	0.60	0.25	0.82	BCI=1 for identical communities; BCI=0 for completely dissimilar communities
RPD of Herb & Shrub Species Richness	15%	40%	0%	Species richness = total number of identified species
RPD of Total Herb Abundance	17%	38%	0%	Absolute abundance used
RPD of Prevalence Index	16%	67%	0%	PI calculated using absolute abundance and plant status codes
RPD of number of dominant herbs and shrubs	26%	111%	0%	Dominance determined using the 50/20 rule

BCI – Bray Curtis Index
RPD - Relative Percent Difference

The Bray Curtis Index analysis of the data suggests that, on average, the replicate pairs have a similarity of 0.60, where 1.0 is identical and 0.0 completely dissimilar. Comparisons of Species Richness, Herbaceous Abundance and Prevalence Index across the replicate pairs all have similar mean relative percent difference values. Comparison of the number of dominant herb and shrub species has a mean difference of 26% across the thirteen replicate pairs.

The data presented in Table A2 suggests that a moderate level of spatial variability exists within visually identical wetland plant communities. From this, it can be concluded that the placement of transects may have a significant influence on the vegetation species observed. Given the goal of monitoring post-construction change in wetlands, it would appear to be critical for successive vegetation surveys to occur on exactly the same transects and quadrats; otherwise the vegetation "signal" may be lost in the background noise caused by a shifting transect location. This variability has been recognized from the outset of the post-alteration wetland monitoring program, and is controlled for with sample quadrats being permanently staked and a 1 m x 1 m sampling frame being used to ensure that consistent areas are being surveyed year to year.

Duplicate Surveys

In order to better understand the level of internal error within the plot-based methodology (botanical identification and abundance estimates, data recording and encoding, systematic biases etc.), ECA has made use of duplicate surveys within the wetland vegetation surveys. In this context, the term duplicate is used to describe where vegetation communities on a single transect are surveyed a second time, using the same personnel. The interval between the first and second surveys was typically 6 to 24 hours. With this interval, it can be safely assumed that the vegetation community has not changed. Any differences between the two surveys are thus due to observer bias or other methodological limitations. The purpose of the duplicate is to better understand variability entering the data as a result of methodological errors and taxonomic misidentifications. This is also referred to as practitioner variability.

During the 2010 to 2016 period for the Highway 101, 104, 125 and Antigonish Landing projects, ECA surveyed 17 duplicate pairs across four wetland types. The results of this analysis are presented in Table A3.

Table A3: Summary Survey Metrics for 17 Duplicate Pairs

Metric	Mean	Worst	Best	Notes
BCI of Herbs and Shrubs	0.75	0.29	0.95	BCI=1 for identical communities; BCI=0 for completely dissimilar communities
RPD of Herb & Shrub Species Richness	18%	60%	0%	Species richness = total number of identified species
RPD of Total Herb Abundance	11%	31%	0%	Absolute abundance used
RPD of Prevalence Index	8%	27%	0%	PI calculated using absolute abundance and wetland plant status codes
RPD of number of dominant herbs and shrubs	22%	67%	0%	Dominance determined using the 50/20 rule

BCI – Bray Curtis Index
RPD - Relative Percent Difference

The Bray Curtis Index analysis of the data suggests that, on average, the duplicate pairs have a similarity of 0.75, where 1.0 is identical and 0.0 completely dissimilar. These results are shown graphically in Figure A1. From Figure A1, it is evident that BCI values for the duplicate pairs are largely consistent, over the 2010 to 2016 monitoring period. If the initial three results from the first year of the monitoring program and three outliers are removed, the resulting dataset, representing the best 75% of the BCI values, provides a good estimate of practitioner variability within the methodology.

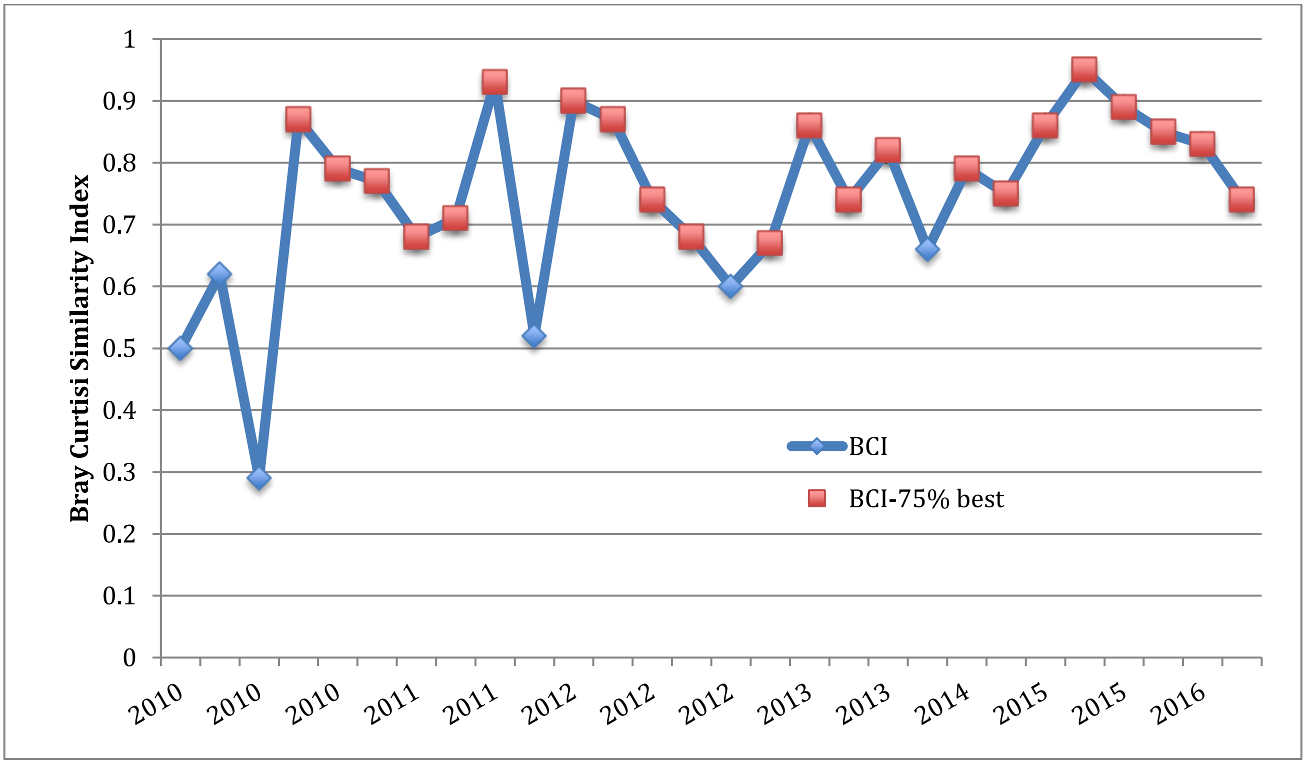


Figure A1: Bray Curtis Index values for duplicate pairs

Figure A2 presents the relative percent difference (RPD) values of Prevalence Index across the duplicate pairs. If the best 75% of these values are considered, this provides a reasonable estimate of practitioner variability for this metric.

The comparisons of Species Richness, Herbaceous Abundance and Prevalence Index in Table A3 across the duplicate pairs all have similar mean relative percent difference (RPD) values. Comparison of the number of dominant herb and shrub species has a mean difference of 22% across the 17 duplicate pairs. The level of variability between the duplicate pairs was lower for all metrics than that observed for the replicate analysis. This outcome is expected as the replicate pairs incorporated both spatial and methodological variability, whereas the duplicate pairs incorporated only methodological variability.

The data presented in Table A3 suggests that a consistent level of practitioner variability exists within the plant data, even when different wetland types are examined, across several years. This variability most likely originates within the sampling methodology used, with possible sources being misidentification of plant species and inconsistency in estimating plant abundances (observer bias), as well as recording errors and data inputting errors. The duplicate analysis establishes the minimum threshold level of post-alteration change that can be detected and attributed to an actual ecological impact.

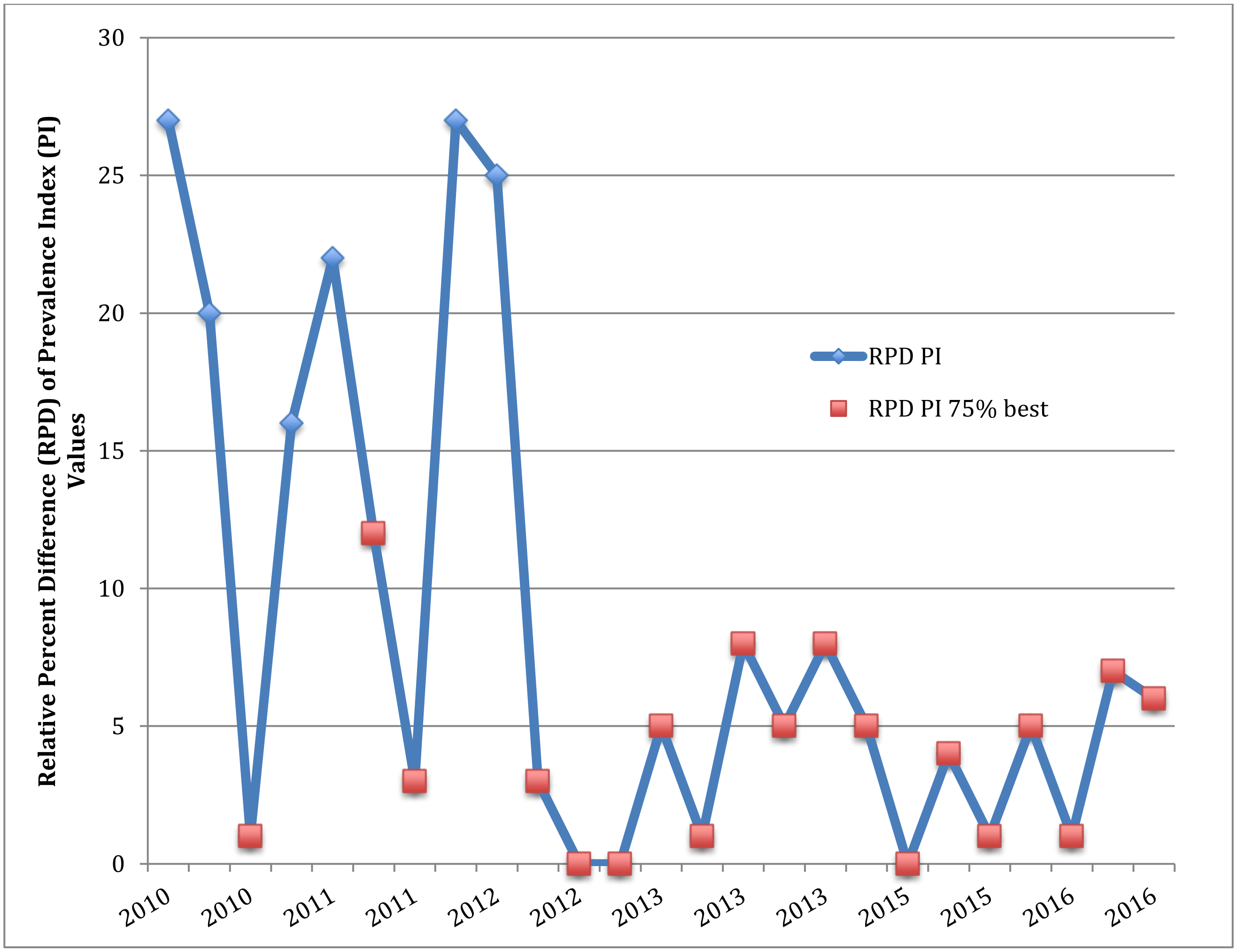


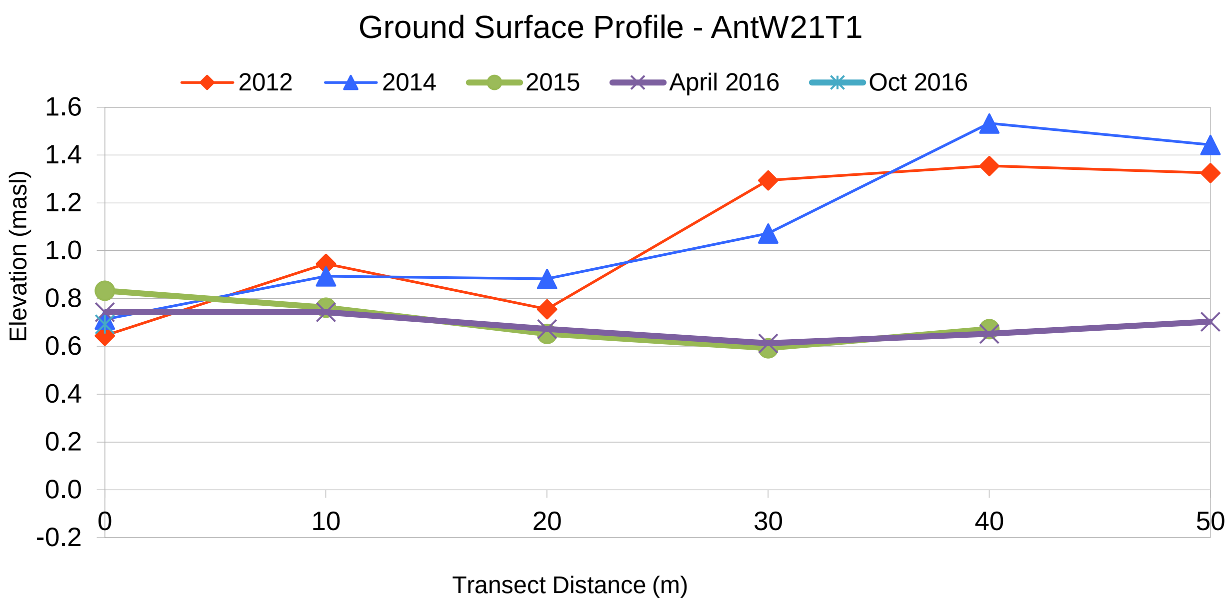
Figure A2: Relative Percent Difference of Prevalence Index values for duplicate pairs

Elzinga *et al* (2001) reports several studies where observer bias within botanical surveys (percent cover of all species) has been documented in the range 23 to 25%. In comparisons between two trained observers, differences of up to 39.5% are reported. The ECA duplicate results reported in Table A3 are consistent with these literature values. While ECA utilizes competently trained individuals and makes every effort to employ consistent methods with error checking, the data presented in Table A3 suggests that inherent variability exists within the dataset. It is highly likely that the repetitiveness of the surveys and fatigue on the part of the botanist, coupled with long field days under demanding conditions, are contributing factors to the observer bias. This variability must therefore be incorporated in any interpretation of the data.

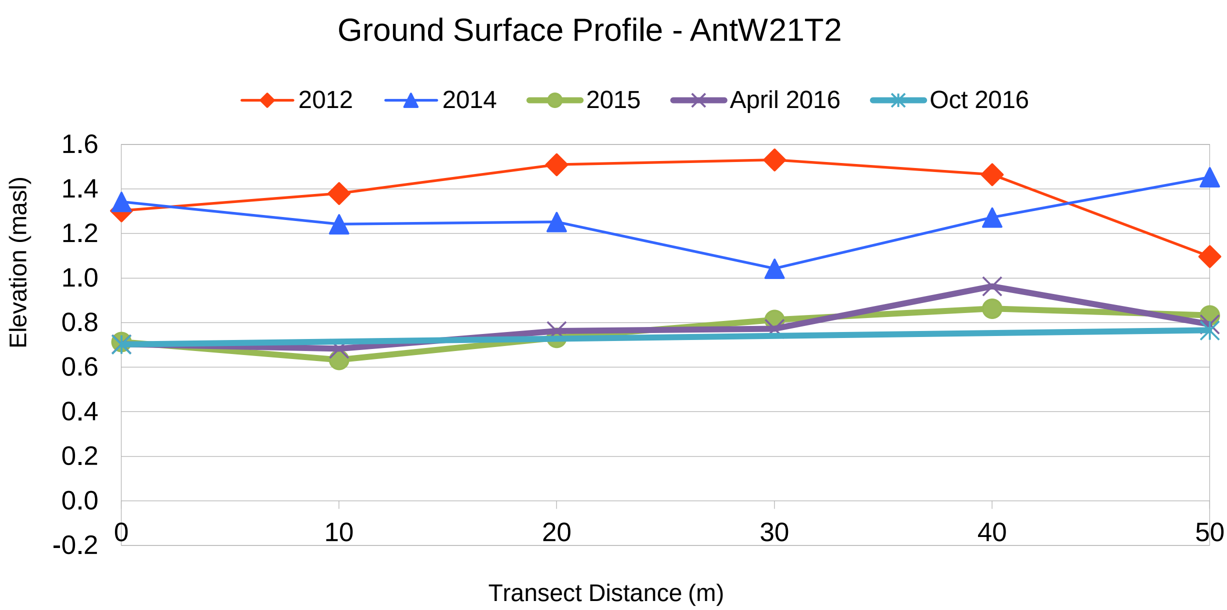
Appendix 3: Transect Location Data and Surface Elevation Profiles

Waypoint Description	Coordinates
Start of transect AntW21T1	20 T 0584595 5050508
End of transect AntW21T1	20 T 0584615 5050466
Start of transect AntW21T2	20 T 0584617 5050453
End of transect AntW21T2	20 T 0584639 5050408
Start of transect AntW21T3	20 T 0584498 5050468
End of transect AntW21T3	20 T 0584540 5050455
Start of transect AntW21T4	20 T 0584521 5050508
End of transect AntW21T4	20 T 0584531 5050450
Start of transect AntW21T5	20 T 0584534 5050565
End of transect AntW21T5	20 T 0584532 5050514
Start of transect AntW21T6	20 T 0584535 5050524
End of transect AntW21T6	20 T 0584580 5050511
Start of transect AntW21T7	20 T 0584532 5050535
End of transect AntW21T7	20 T 0584580 5050520
Start of transect AntW21T8	20 T 0584641 5050397
End of transect AntW21T8	20 T 0584649 5050379
Start of transect AntW21T9	20 T 058533 5050438
End of transect AntW21T9	20 T 058539 5050413
Start of transect AntW21T10	20 T 0584574 5050428
End of transect AntW21T10	20 T 0584621 5050317
Start of transect AntW21T11	20 T 0584520 5050388
End of transect AntW21T11	20 T 0584556 5050340
Water Quality Station #1	20 T 0584480 5050481
Water Quality Station #2	20 T 0584578 5050499
Water Quality Station #3	20 T 0584657 5050426
Feldspar Control	20 T 584552.71 5050519.98
Feldspar 1	20 T 584501.92 5050487.62
Feldspar 2	20 T 584533.70 5050488.99
Feldspar 3	20 T 584571.94 5050463.52
Local benchmark used for Antigonish Wetland 21 (2012) (bolt placed in trunk of maple tree)	20 T 0584619 5050418

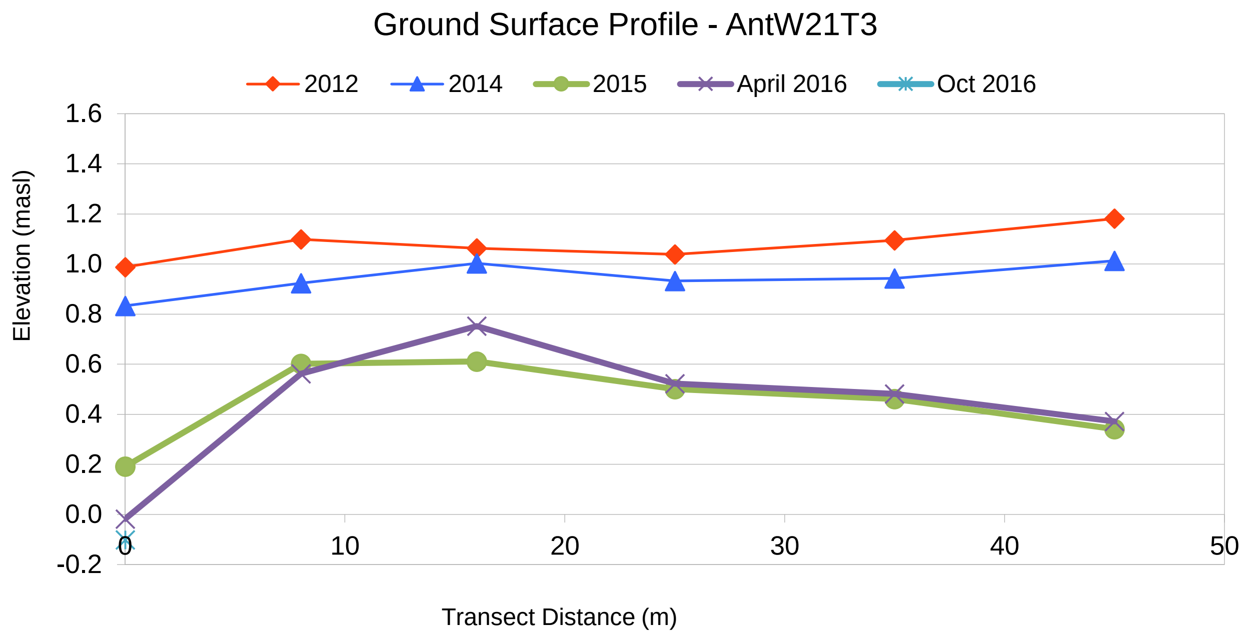
All coordinates recorded to UTM NAD83



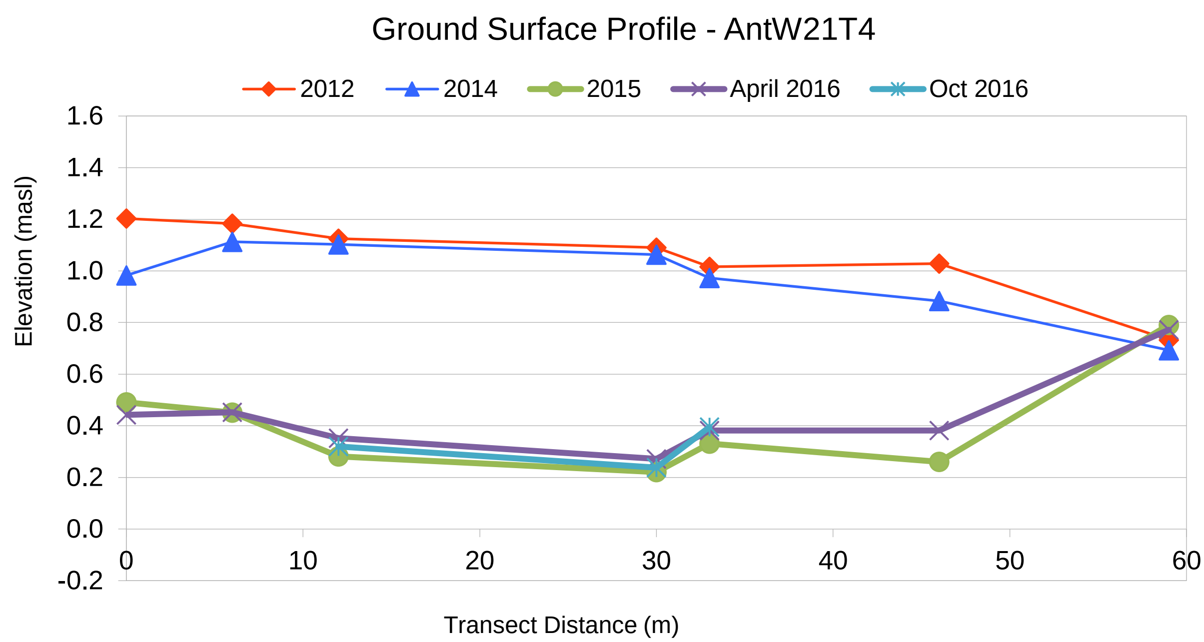
The orientation of AntW21T1 was north to south, with Q1, Q2 and Q3 in undisturbed marsh and Q4, Q5 and Q6 within the former construction pad area.



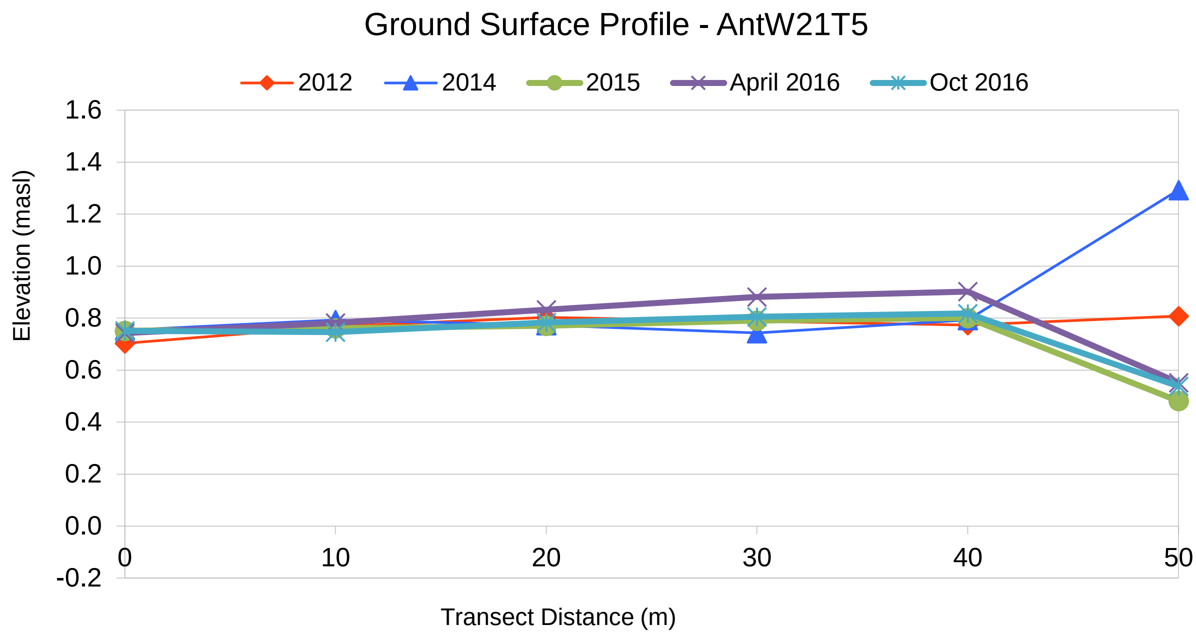
The orientation of AntW21T2 was north to south, with all quadrats within the former construction pad area.



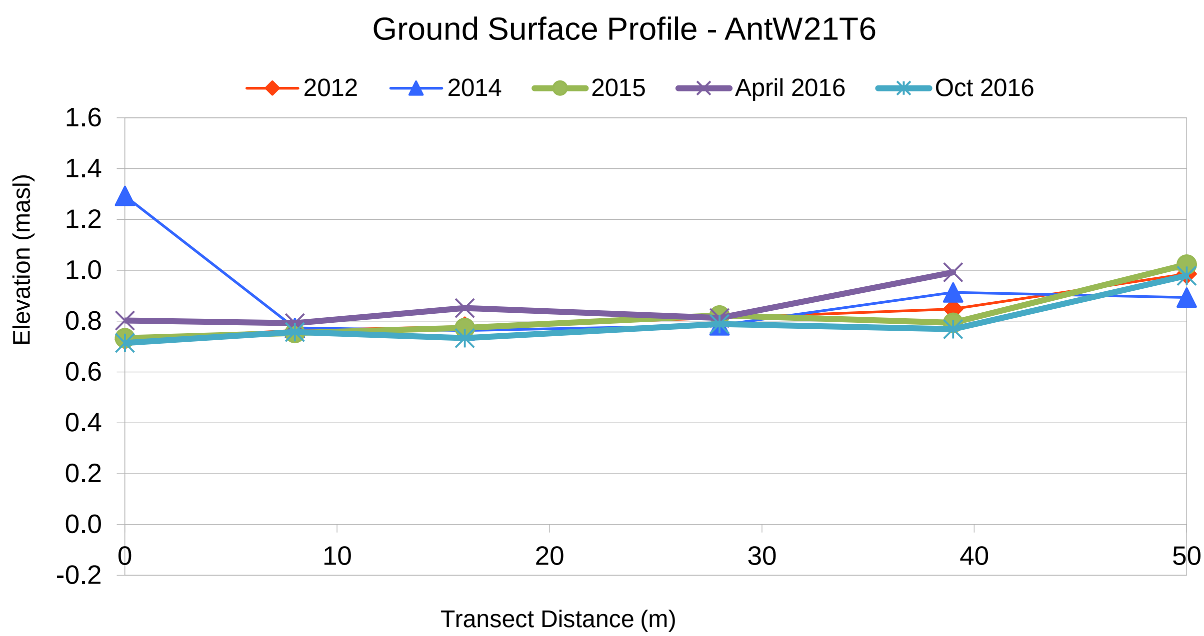
The orientation of AntW21T3 was west to east, with all quadrats within the former construction pad area.



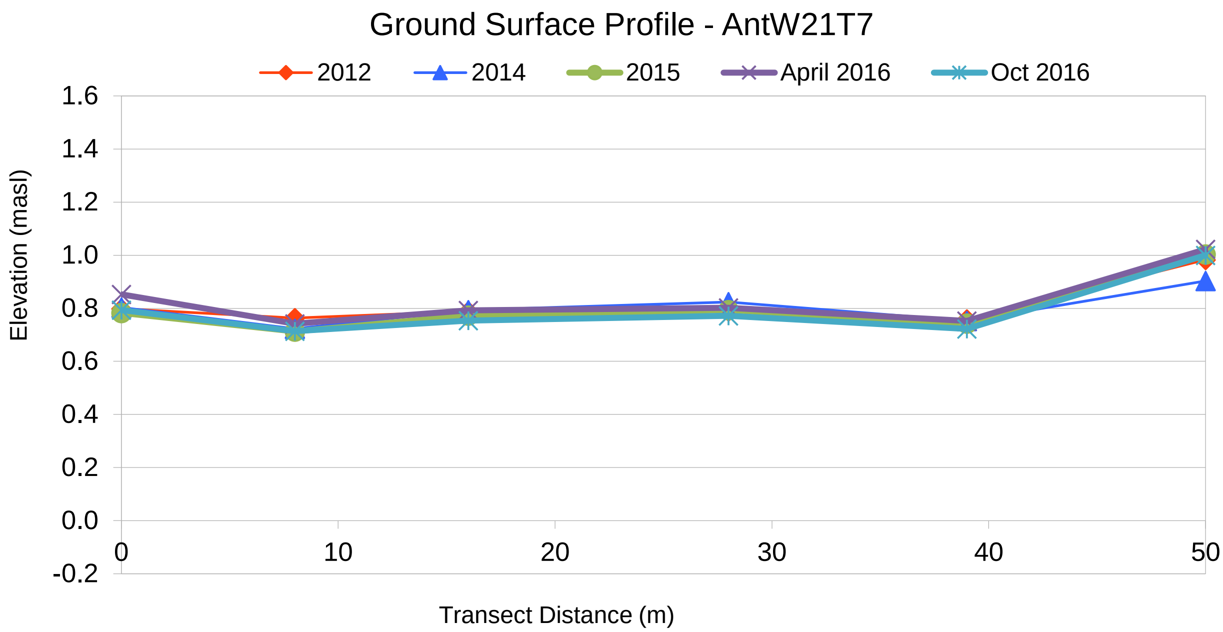
The orientation of AntW21T4 was north to south, with Q1 to Q6 within the former construction pad area and Q7 in undisturbed marsh.



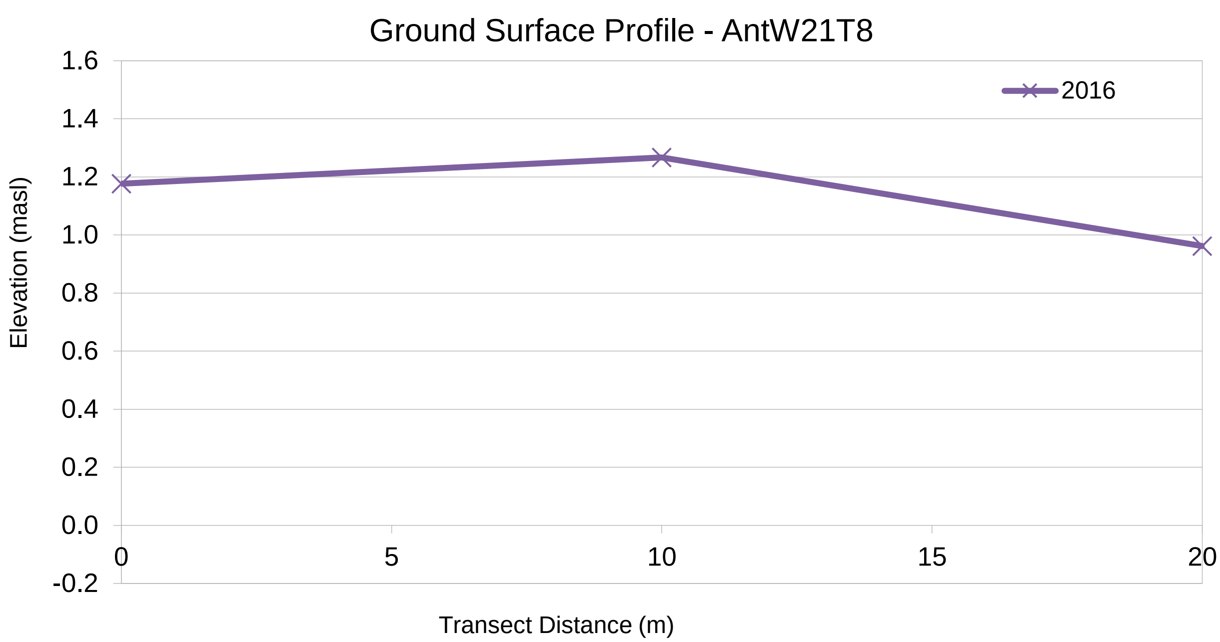
The orientation of AntW21T5 was north to south, with Q1 to Q6 in undisturbed marsh and Q6 within the former construction pad area.



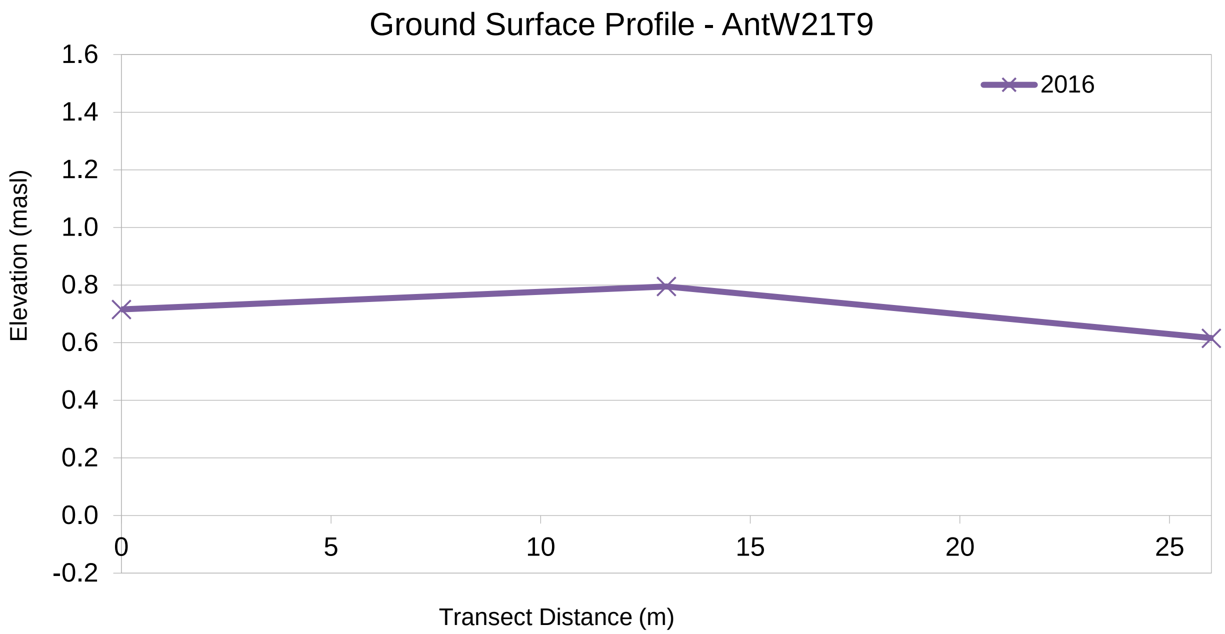
The orientation of AntW21T6 was west to east, with all quadrats in undisturbed marsh.



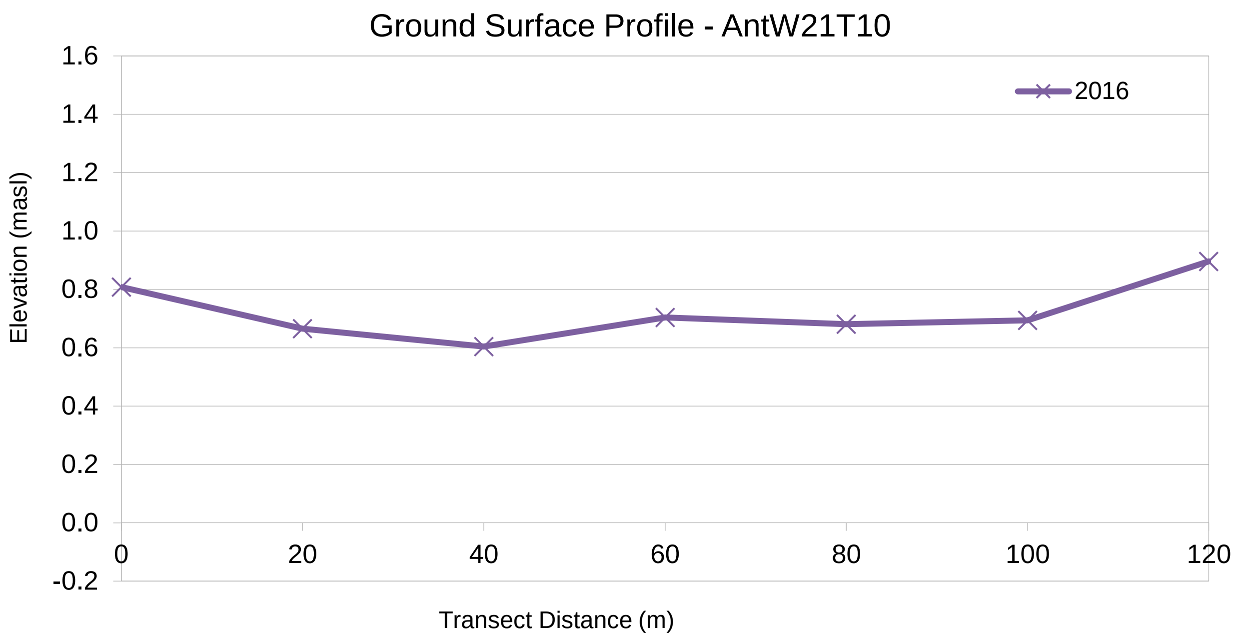
The orientation of AntW21T7 was west to east, with all quadrats in undisturbed marsh.



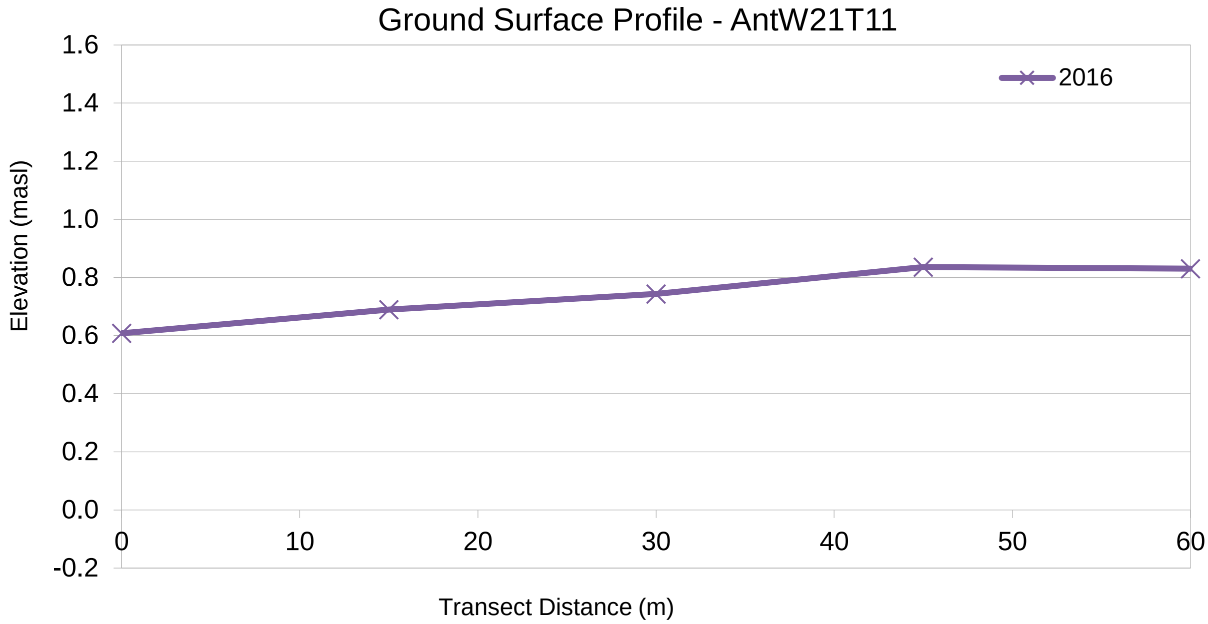
The orientation of AntW21T8 was north to south, with all quadrats within the footprint of the construction area.



The orientation of AntW21T9 was north to south, all quadrats in undisturbed marsh.

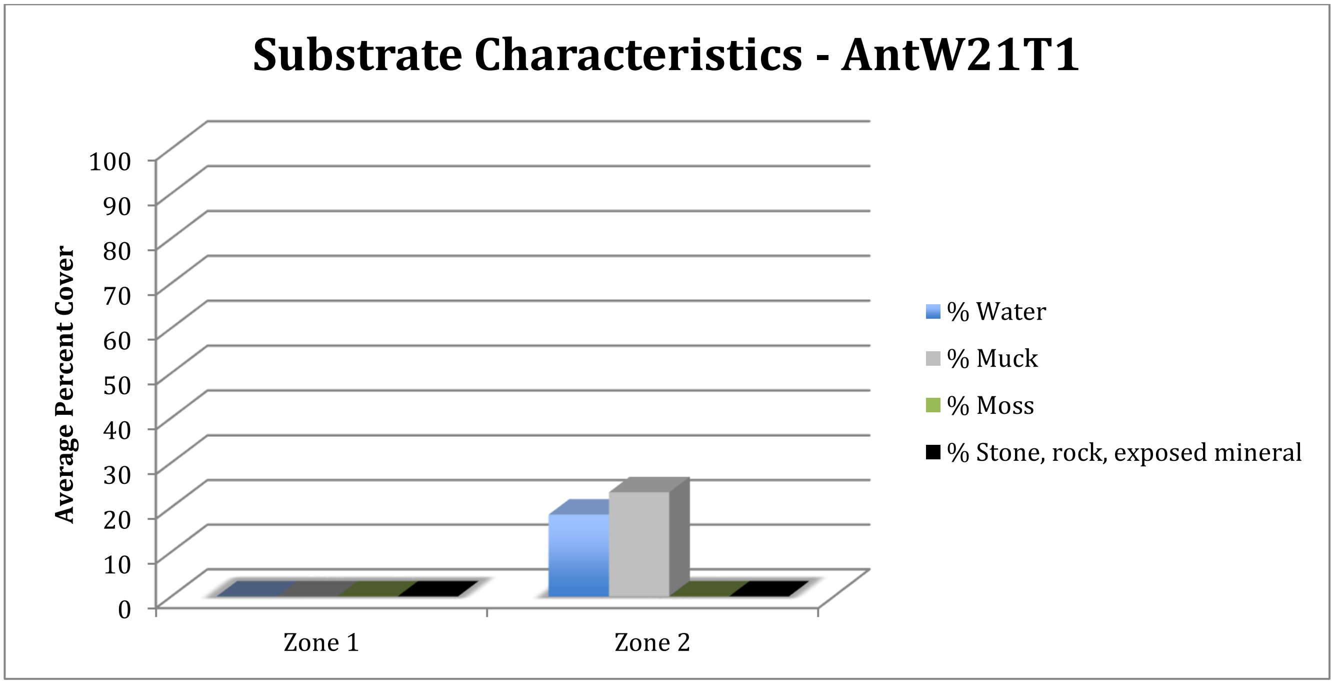


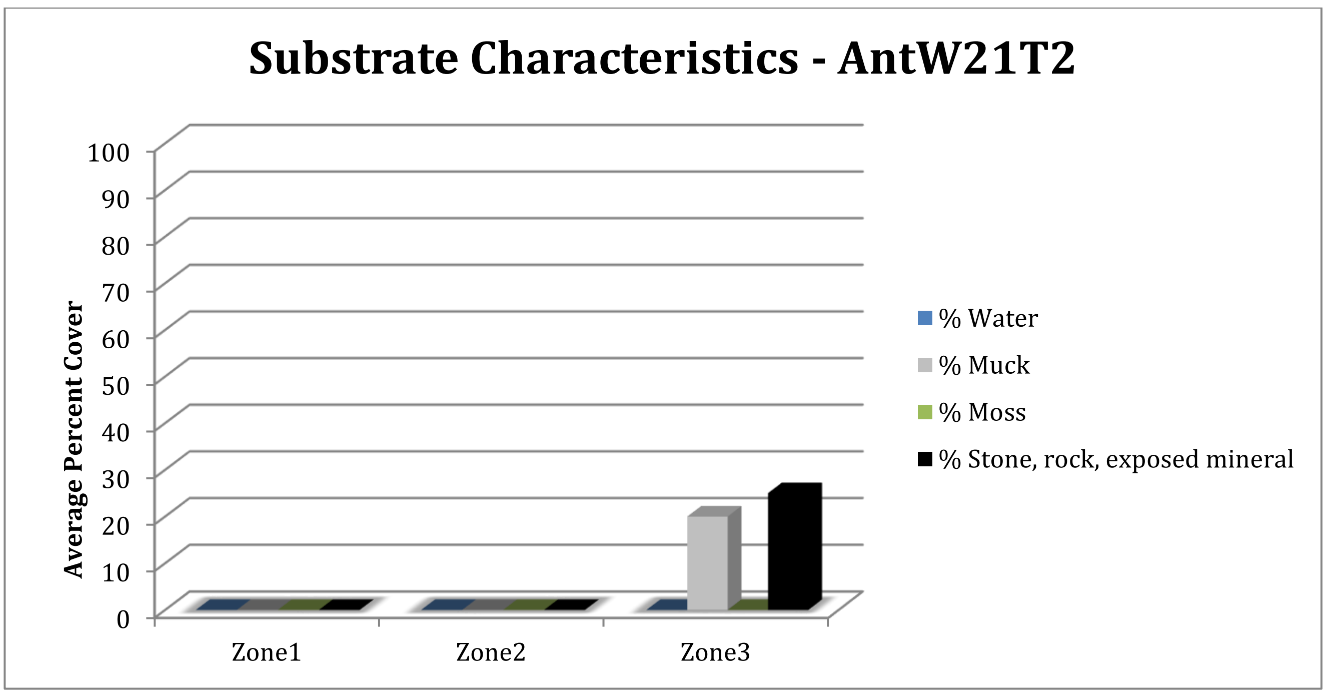
The orientation of AntW21T10 was north to south, with Q3 and Q6 at the western edge of the access road footprint, with all other quadrats in undisturbed marsh.

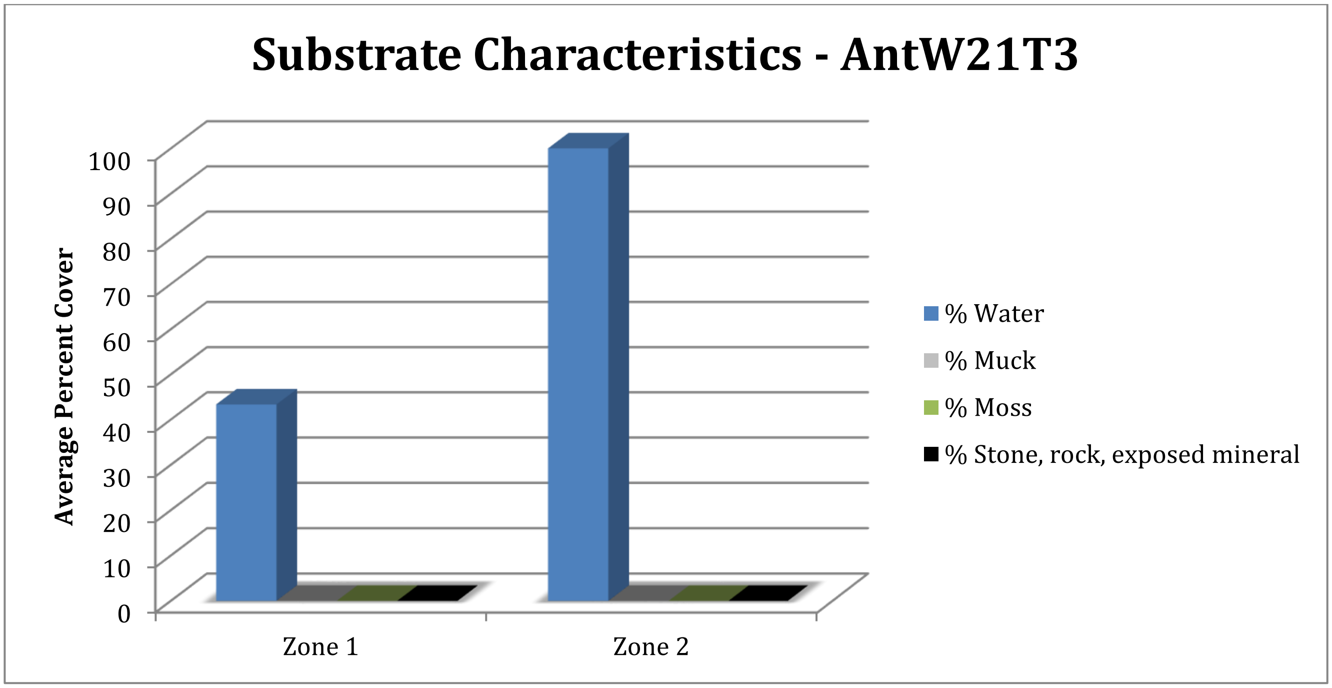


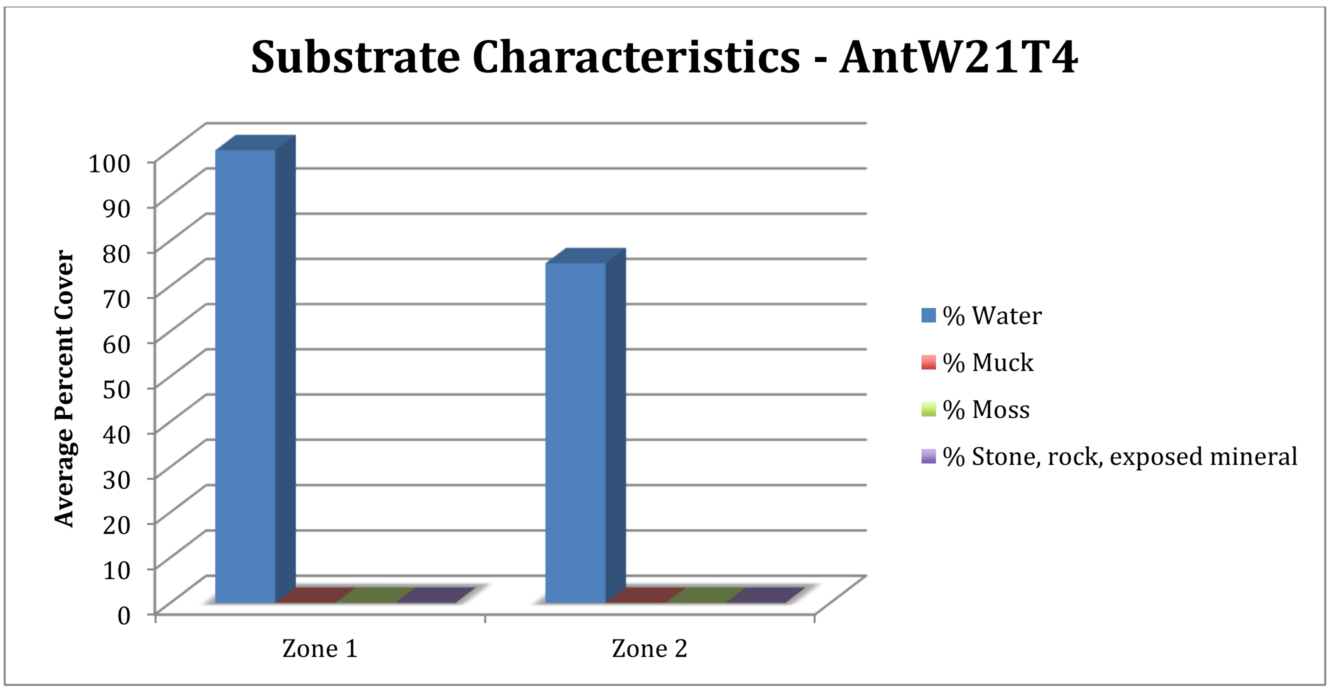
The orientation of AntW21T11 was northwest to southeast, with all quadrats in undisturbed marsh.

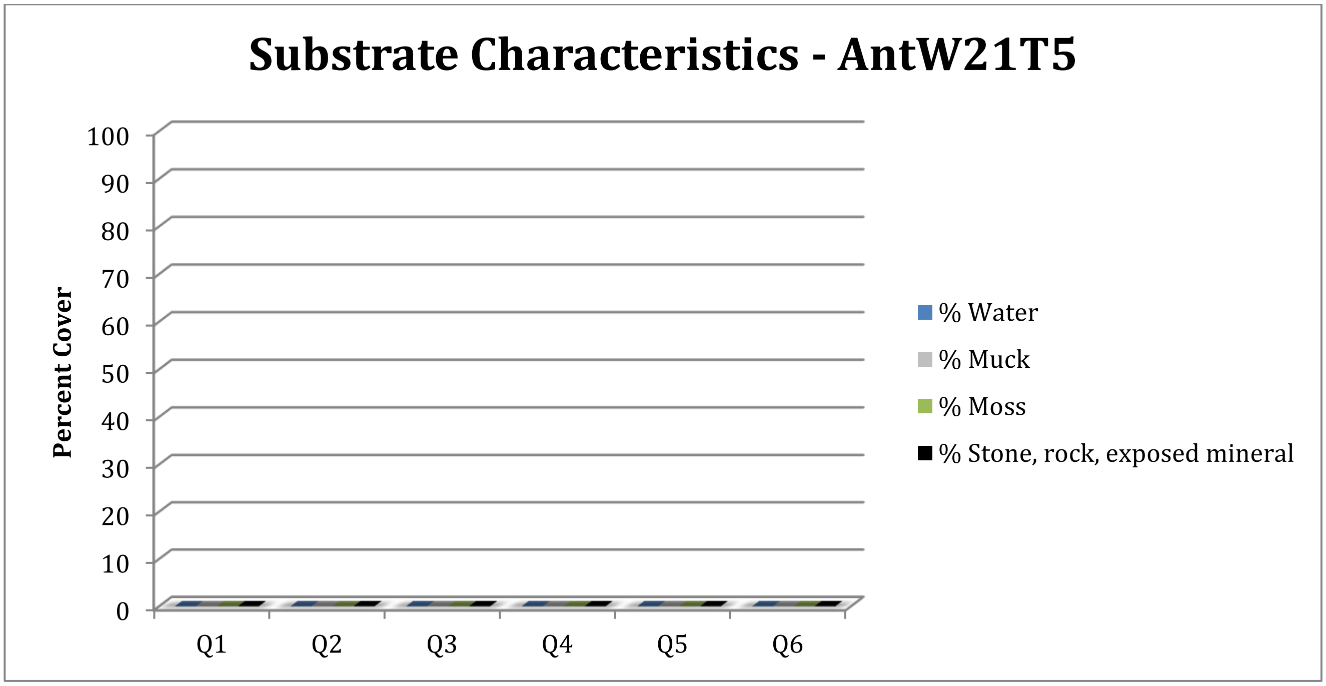
Appendix 4: Substrate Characteristics



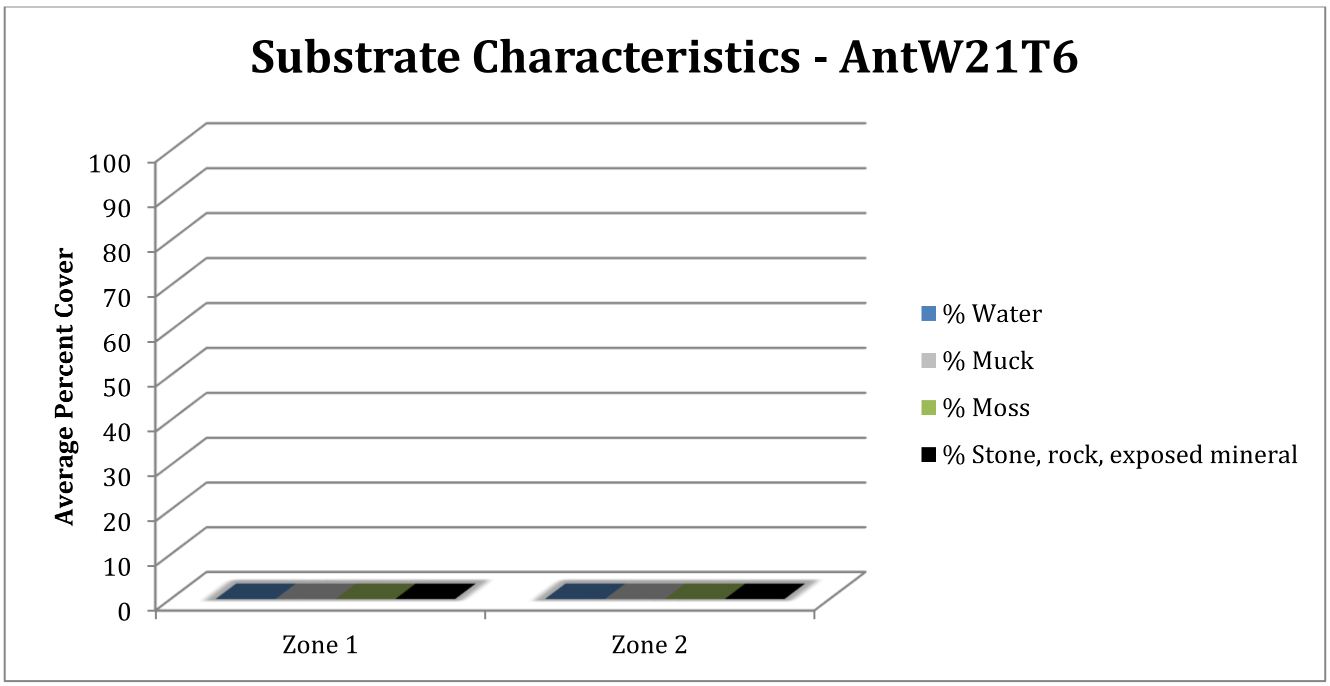



Substrate Characteristics - AntW21T3
Average Percent Cover
100
90
80
70
60
50
40
30
20
10
0
Zone 1
Zone 2
% Water
% Muck
% Moss
% Stone, rock, exposed mineral

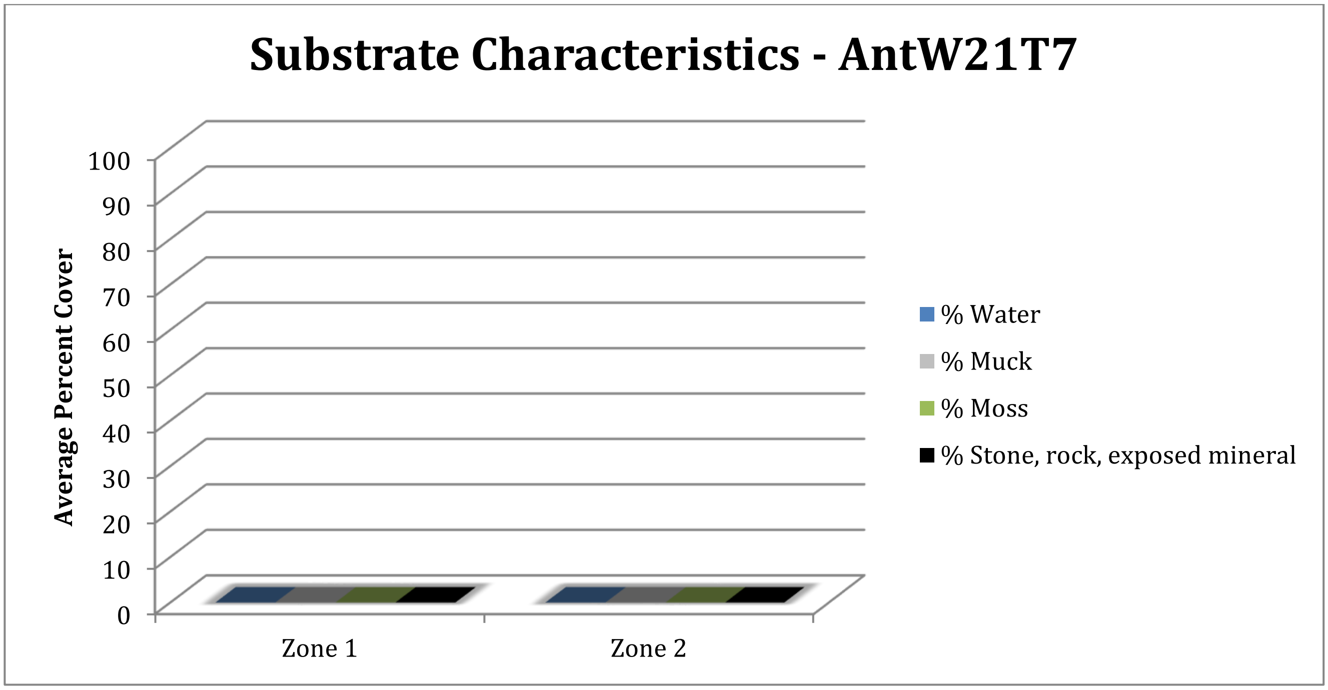

Substrate Characteristics - AntW21T4
Average Percent Cover
100
90
80
70
60
50
40
30
20
10
0
Zone 1
Zone 2
% Water
% Muck
% Moss
% Stone, rock, exposed mineral



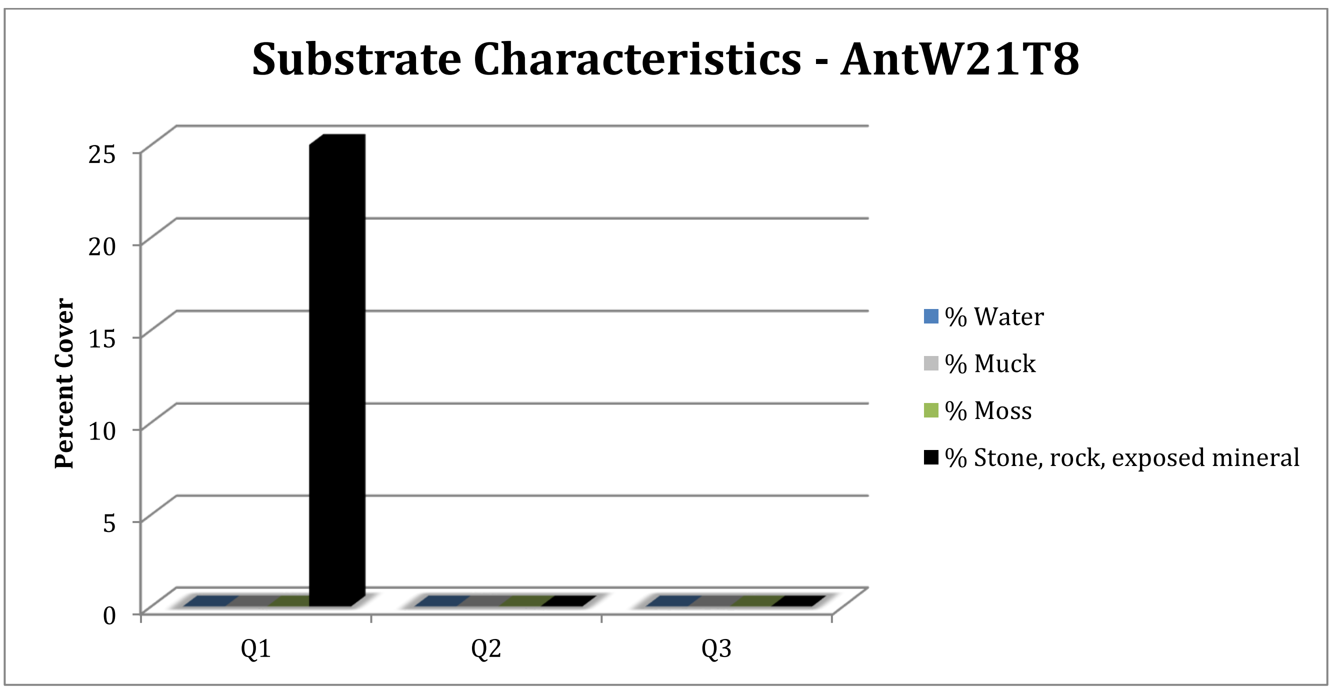
The ground substrate at T5 consisted of a dense mat of dead plant matter.

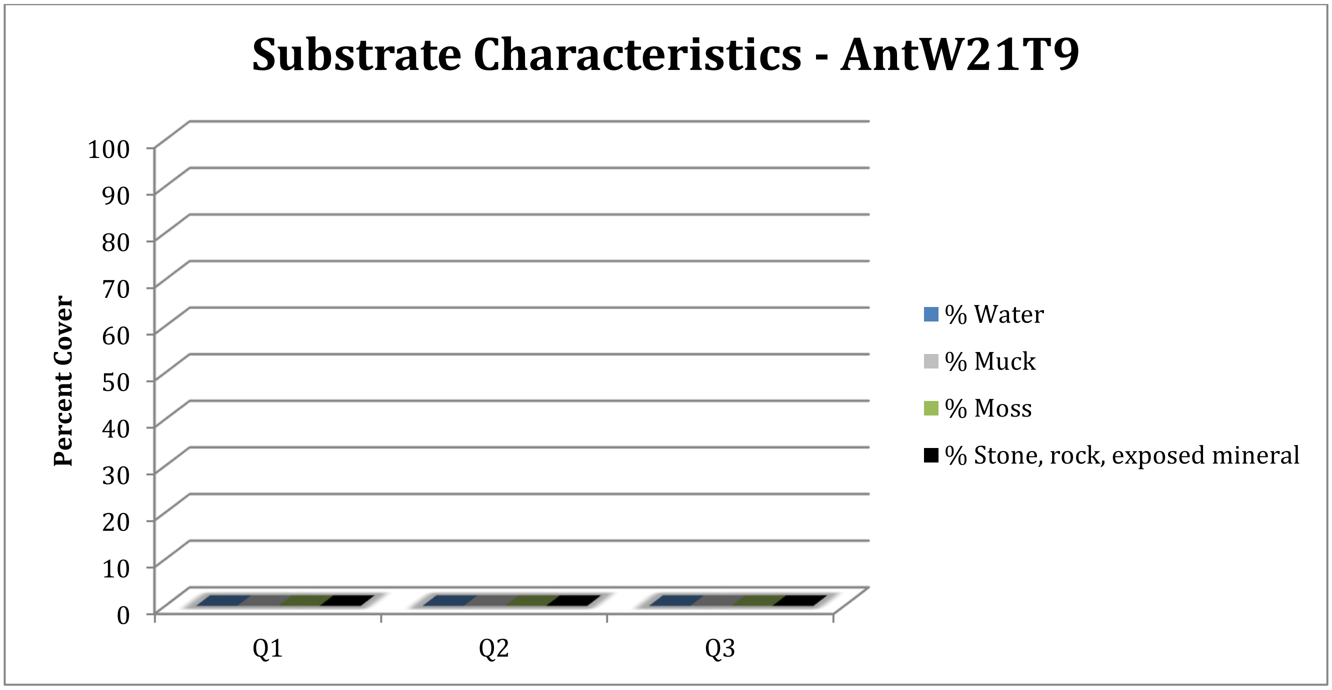


The ground substrate at T6 consisted of a dense mat of dead plant matter.

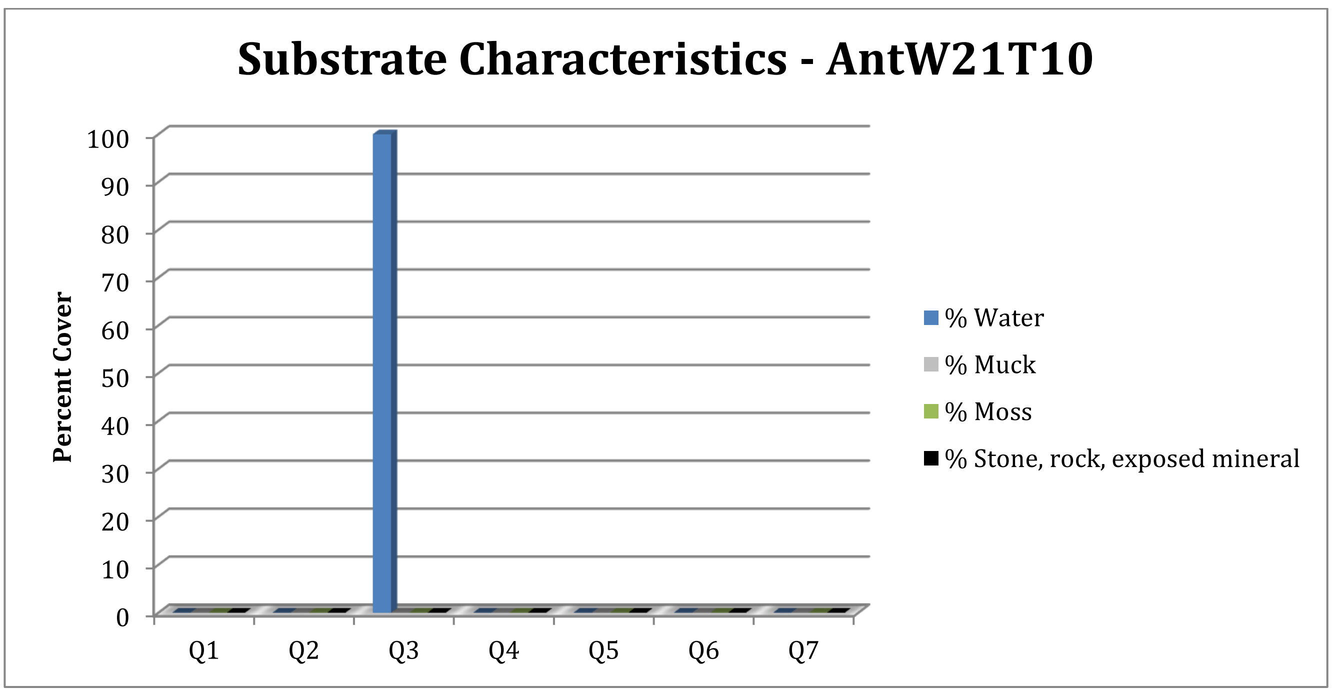


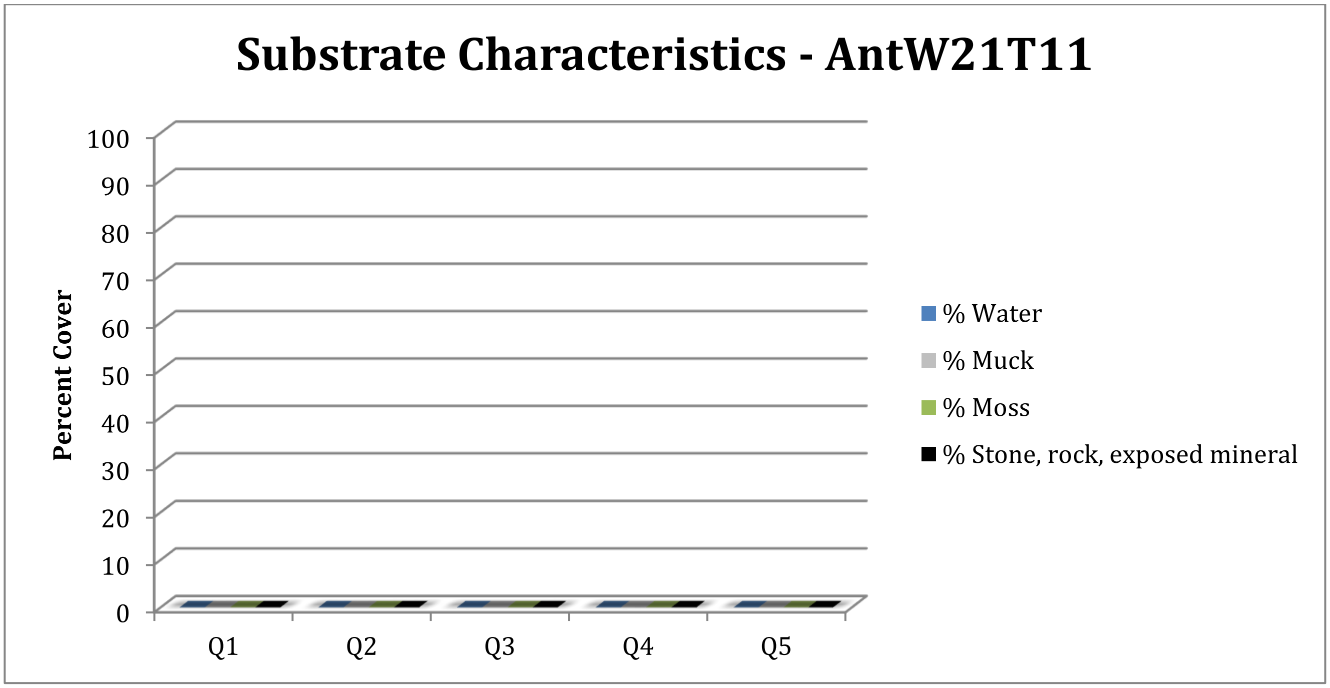
The ground substrate at T7 consisted of a dense mat of dead plant matter.





The ground substrate at T9 consisted of a dense mat of dead plant matter.





The ground substrate at T11 consisted of a dense mat of dead plant matter.

Appendix 5: Belt Transect Field Data Sheets

Project: NSTIR Monitoring | Location: Antigonish Wetland 21 (South R.) | Date: 2016-08-15
Investigator(s): Sharpe/Neily | BELT Site: AntW21T1 | BELT Bearing: 161
Zone: 20T | Origin UTM: 0584595 5050508 | End UTM: 0584615 5050466
E. Region: Northumberland-Bras Dor | Eco District: St Georges Bay | Eco Site: IFSM
Type: salt marsh | Map Datum: NAD83

Notes: Perpendicular - North and downstream of proposed bridge alignment; fresh ATV tracks. Stakes for Q2

Zone	Begin	End	Length(m)	# of Q	Q spacing(m)
1	0	50	50	6	10

	Zone1						
	Q1	**Q2**	**Q3**	**Q4**	**Q5**	**Q6**	
Hor Distance(m) from origin	0	10	20	30	40	49	
% Water	0	0	0	30	15	10	
% Muck	0	0	0	50	0	20	
% Moss	0	0	0	0	0	0	
% Stone, rock, exposed mineral	0	0	0	0	0	0	
Height shrubs/herbs (m)	2	1	0.6	0.2	0.3	0.4	
Herb Stratum	**Q1**	**Q2**	**Q3**	**Q4**	**Q5**	**Q6**	**Totals**
Alisma triviale	0	0	0	5	0	0	5
Bidens cernua	0	0	0	0	10	0	10
Bidens frondosa	0	0	0	0	0	10	10
Calamagrostis canadensis	0	30	100	30	0	0	160
Calystegia sepium	10	0	0	0	0	0	10
Gnaphalium uliginosum	0	0	0	0	0	10	10
Graminoid	0	0	0	20	10	0	30
Impatiens capensis	10	10	4	0	0	0	24
Juncus canadensis	0	0	0	0	0	20	20
Juncus effusus	0	0	0	0	70	0	70
Lemna minor	0	0	0	4	0	0	4
Lysimachia ciliata	0	15	0	0	0	0	15
Myosotis laxa	0	0	0	5	10	0	15
Onoclea sensibilis	0	30	0	0	0	0	30
Phleum pratense	0	0	0	0	0	10	10
Polygonum hydropiper	0	0	0	0	10	15	25
Rosa spp	10	0	0	0	0	0	10
Solidago canadensis	10	0	0	0	0	0	10
Sonchus arvensis	0	0	0	0	0	4	4
Spartina alterniflora	10	10	0	0	0	0	20
Spiraea alba	50	0	0	0	0	0	50
Typha latifolia	10	0	0	0	0	0	10
Shrub Stratum	**Q1**	**Q2**	**Q3**	**Q4**	**Q5**	**Q6**	**Totals**
None							
Sapling	**Q1**	**Q2**	**Q3**	**Q4**	**Q5**	**Q6**	**Totals**
None							
Tree Stratum	**Q1**	**Q2**	**Q3**	**Q4**	**Q5**	**Q6**	**Totals**
None							

Project: NSTIR Monitoring | Location: Antigonish Wetland 21 (South R.) | Date: 2016-08-15
Investigator(s): Sharpe/Neily | BELT Site: AntW21T2 | BELT Bearing: 155
Zone: 20T | Origin UTM: 0584617 5050453 | End UTM: 0584639 5050408
E. Region: Northumberland-Bras Dor | Eco District: St Georges Bay | Eco Site: IFSM
Type: salt marsh | Map Datum: NAD83
Notes: Aug 15/16 notes: fresh ATV tracks. stakes missing @ Q2

Zone	Begin	End	Length(m)	# of Q	Q spacing(m)
1	0	13	13	2	10
2	13	32	19	2	9
3	32	50	18	2	10

	Zone1	Zone2	Zone3				
	Q1	**Q2**	**Q3**	**Q4**	**Q5**	**Q6**	
Hor Distance(m) from origin	0	10	20	29	40	50	
% Water	0	0	0	0	0	0	
% Muck	0	0	0	0	40	0	
% Moss	0	0	0	0	0	0	
% Stone, rock, exposed mineral	0	0	0	0	0	50	
Height shrubs/herbs (m)	0.4	0.6	0.5	0.4	0.3	0.2	
Herb Stratum	**Q1**	**Q2**	**Q3**	**Q4**	**Q5**	**Q6**	**Totals**
Bidens frondosa	0	0	0	15	0	5	20
Carex lurida	0	10	0	10	0	0	20
Carex spp	5	0	0	0	0	0	5
Carex stipata	10	0	0	0	0	0	10
Daucus carota	0	0	0	0	5	4	9
Echinochloa crus-galli	0	0	0	0	0	4	4
Epilobium ciliatum	0	0	0	0	0	5	5
Fragaria virginiana	0	0	0	0	5	0	5
Galium palustre	0	0	0	0	4	0	4
Glyceria laxa	0	20	10	0	0	0	30
Gnaphalium uliginosum	0	0	0	4	15	5	24
Hypericum perforatum	0	0	0	0	0	5	5
Impatiens capensis	0	0	5	0	0	0	5
Juncus effusus	10	0	0	0	0	0	10
Leersia oryzoides	10	0	0	15	0	0	25
Matricaria discoidea	0	0	0	0	0	4	4
Myosotis laxa	0	0	0	10	0	0	10
Oenothera biennis	0	0	0	5	0	0	5
Phalaris arundinacea	0	20	0	0	0	0	20
Plantago major	0	0	0	0	10	15	25
Polygonum hydropiper	10	5	15	20	40	5	95
Polygonum pensylvanicum	0	0	10	0	0	5	15
Polygonum sagittatum	10	0	0	0	0	0	10
Ranunculus repens	0	0	35	5	0	5	45
Rumex crispus	5	4	20	25	0	0	54
Scirpus cyperinus	10	0	0	0	0	0	10
Verbena hastata	0	0	0	0	5	0	5
Vicia cracca	0	0	0	0	5	0	5
Shrub Stratum	**Q1**	**Q2**	**Q3**	**Q4**	**Q5**	**Q6**	**Totals**
None							
Sapling	**Q1**	**Q2**	**Q3**	**Q4**	**Q5**	**Q6**	**Totals**
None							
Tree Stratum	**Q1**	**Q2**	**Q3**	**Q4**	**Q5**	**Q6**	**Totals**
None							

Project: NSTIR Monitoring | Location: Antigonish Wetland 21 (South R.) | Date: 2016-08-17
Investigator(s): Sharpe/Neily | BELT Site: AntW21T3 | BELT Bearing: 105
Zone: 20T | Origin UTM: 0584498 5050468 | End UTM: 0584540 5050455
E. Region: Northumberland-Bras Dor | Eco District: St Georges Bay | Eco Site: IFSM
Type: salt marsh | Map Datum: NAD83

Notes: Parallel. To the south (upstream) of bridge crossing. samples taken at 0930hr. high tide @0900hrs. Q1 - all water - no plants western back channel.

Zone	Begin	End	Length(m)	# of Q	Q spacing(m)	
1	0	20	20	3	8	
2	20	45	25	3	10	
	Zone1	Zone2				
	Q1	Q2	Q3	Q4	Q5	Q6
Hor Distance(m) from origin	0	8	16	25	35	45
% Water	100	30	0	100	100	100
% Muck	0	0	0	0	0	0
% Moss	0	0	0	0	0	0
% Stone, rock, exposed mineral	0	0	0	0	0	0
Height shrubs/herbs (m)	0.1	0.1	0.3	0.1	0.1	0.1

Herb Stratum	**Q1**	**Q2**	**Q3**	**Q4**	**Q5**	**Q6**	**Totals**
Alisma triviale	0	5	0	0	3	0	8
Gnaphalium uliginosum	0	0	5	0	0	0	5
Graminoid spp	0	40	80	0	0	0	120
Juncus canadensis	0	0	0	5	15	0	20
Myosotis laxa	0	5	0	0	0	0	5
Plantago major	0	0	0	0	0	3	3
Polygonum persicaria	0	0	5	0	0	0	5
Rumex crispus	0	0	15	0	0	0	15
Samolus valerandi	0	3	0	0	0	0	3
Schoenoplectus acutus	0	3	0	5	40	3	51
Sonchus arvensis	0	3	0	0	0	0	3
Spartina pectinata	0	0	5	0	0	0	5
Typha latifolia	0	20	0	15	0	0	35
Shrub Stratum	**Q1**	**Q2**	**Q3**	**Q4**	**Q5**	**Q6**	**Totals**
None							
Sapling	**Q1**	**Q2**	**Q3**	**Q4**	**Q5**	**Q6**	**Totals**
None							
Tree Stratum	**Q1**	**Q2**	**Q3**	**Q4**	**Q5**	**Q6**	**Totals**
None							

Project: NSTIR Monitoring
Location: Antigonish Wetland 21 (South R.)
Date: 2016-08-17
Investigator(s): Sharpe/Neily
BELT Site: AntW21T4
BELT Bearing: 170
Zone: 20T
Origin UTM: 0584521 5050508
End UTM: 0584531 5050450
E. Region: Northumberland-Bras Dor
Eco District: St Georges Bay
Eco Site: IFSM
Type: salt marsh
Map Datum: NAD83
Notes: typical water depth approx 20-30cm, although some depressions to 0.5m Aug 17/16 - Q7 native

Zone	Begin	End	Length(m)	# of Q	Q spacing(m)			
1	0	14	14	3	6			
2	14	59	45	4	13			
	Zone1	**Zone2**						
	Q1	**Q2**	**Q3**	**Q4**	**Q5**	**Q6**	**Q7**	
Hor Distance(m) from origin	0	6	12	30	33	46	59	
% Water	100	100	100	100	100	100	0	
% Muck	0	0	0	0	0	0	0	
% Moss	0	0	0	0	0	0	0	
% Stone, rock, exposed mineral	0	0	0	0	0	0	0	
Height shrubs/herbs (m)	0.3	0.05	0.05	0	0.05	0.1	0.9	
Herb Stratum	**Q1**	**Q2**	**Q3**	**Q4**	**Q5**	**Q6**	**Q7**	**Totals**
Argentina anserina	0	0	0	0	0	0	10	10
Calystegia sepium	0	0	0	1	0	0	0	1
Schoenoplectus acutus	0	3	3	0	3	3	20	32
Schoenoplectus americanus	40	0	0	0	0	0	0	40
Spartina pectinata	0	0	0	0	0	0	40	40
Typha latifolia	5	0	5	0	3	3	10	26
Shrub Stratum	**Q1**	**Q2**	**Q3**	**Q4**	**Q5**	**Q6**	**Q7**	**Totals**
None								
Sapling	**Q1**	**Q2**	**Q3**	**Q4**	**Q5**	**Q6**	**Q7**	**Totals**
None								
Tree Stratum	**Q1**	**Q2**	**Q3**	**Q4**	**Q5**	**Q6**	**Q7**	**Totals**
None								

Project: NSTIR Monitoring | Location: Antigonish Wetland 21 (South R.) | Date: 2016-08-17
Investigator(s): Sharpe/Neily | BELT Site: AntW21T5 | BELT Bearing: 180
Zone: 20T | Origin UTM: 0584534 5050565 | End UTM: 0584532 5050514
E. Region: Northumberland-Bras Dor | Eco District: St Georges Bay | Eco Site: IFSM
Type: salt marsh | Map Datum: NAD83

Notes: Perpendicular - North (downstream) of crossing - water is deeper on western side of pad.

Zone	Begin	End	Length(m)	# of Q	Q spacing(m)	
1	0	50	50	6	10	
	Zone1					
	Q1	**Q2**	**Q3**	**Q4**	**Q5**	**Q6**
Hor Distance(m) from origin	0	10	20	30	40	50
% Water	0	0	0	0	0	0
% Muck	0	0	0	0	0	0
% Moss	0	0	0	0	0	0
% Stone, rock, exposed mineral	0	0	0	0	0	0
Height shrubs/herbs (m)	0.8	0.8	0.8	0.8	0.8	0.05

Herb Stratum	**Q1**	**Q2**	**Q3**	**Q4**	**Q5**	**Q6**	**Totals**
Bidens frondosa	0	0	0	0	3	0	3
Calamagrostis canadensis	30	0	0	0	0	0	30
Callitriche palustris	0	0	0	0	0	5	5
Calystegia sepium	0	60	0	0	0	0	60
Carex recta	0	0	10	20	0	0	30
Galium palustre	0	5	0	0	0	0	5
Lysimachia ciliata	0	0	0	0	5	0	5
Polygonum sagittatum	0	10	0	0	0	0	10
Schoenoplectus pungens	0	15	15	10	0	0	40
Schoenoplectus spp	0	0	0	0	0	5	5
Spartina patens	0	30	0	0	0	0	30
Spartina pectinata	0	30	40	60	20	0	150
Symphyotrichum novi-belgii	0	0	0	0	20	0	20
Teucrium canadense	60	0	0	0	0	0	60
Typha latifolia	20	10	10	0	5	3	48
Vicia spp	0	0	3	0	0	0	3
Shrub Stratum	**Q1**	**Q2**	**Q3**	**Q4**	**Q5**	**Q6**	**Totals**
None							
Sapling	**Q1**	**Q2**	**Q3**	**Q4**	**Q5**	**Q6**	**Totals**
None							
Tree Stratum	**Q1**	**Q2**	**Q3**	**Q4**	**Q5**	**Q6**	**Totals**
None							

Project: NSTIR Monitoring	Location: Antigonish Wetland 21 (South R.)	Date: 2016-08-17
Investigator(s): Sharpe Parker	BELT Site: AntW21T6	BELT Bearing: 105
Zone: 20T	Origin UTM: 0584535 5050524	End UTM: 0584580 5050511
E. Region: Northumberland-Bras Dor	Eco District: St Georges Bay	Eco Site: IFSM
Type: Salt marsh		Map Datum: NAD83

Notes: Parallel - to the north and downstream of bridge crossing

Zone	Begin	End	Length(m)	# of Q	Q spacing(m)		
1	0	23	23	3	8		
2	23	50	27	3	11		
	Zone1			**Zone2**			
	Q1	**Q2**	**Q3**	**Q4**	**Q5**	**Q6**	
Horizonal Distance(m) from origin	0	8	16	28	39	50	
% Water	0	0	0	0	0	0	
% Muck	0	0	0	0	0	0	
% Moss	0	0	0	0	0	0	
% Stone, rock, exposed mineral	0	0	0	0	0	0	
Height shrubs/herbs (m)	0.8	0.8	0.8	0.8	0.8	0.8	
Herb Stratum	**Zone1**			**Zone2**			
	Q1	**Q2**	**Q3**	**Q4**	**Q5**	**Q6**	**Totals**
Apios americana	0	0	0	0	0	20	20
Calamagrostis canadensis	0	0	20	0	30	30	80
Calystegia sepium	10	0	0	40	0	0	50
Carex recta	10	0	0	0	0	0	10
Galium palustre	0	0	5	0	0	0	5
Impatiens capensis	0	5	0	0	0	0	5
Iris versicolor	0	10	0	15	0	0	25
Juncus balticus	0	0	10	0	0	0	10
Rosa spp	0	0	0	0	50	40	90
Schoenoplectus acutus	0	0	10	0	0	0	10
Schoenoplectus pungens	10	15	0	5	0	0	30
Spartina patens	0	0	30	0	0	0	30
Spartina pectinata	40	20	40	60	30	0	190
Teucrium canadense	0	0	0	0	0	5	5
Thalictrum pubescens	0	0	0	0	0	10	10
Typha latifolia	10	15	0	0	0	0	25
Vicia spp	0	5	0	0	0	0	5
Shrub Stratum	**Q1**	**Q2**	**Q3**	**Q4**	**Q5**	**Q6**	**Totals**
None							
Sapling	**Q1**	**Q2**	**Q3**	**Q4**	**Q5**	**Q6**	**Totals**
None							
Tree Stratum	**Q1**	**Q2**	**Q3**	**Q4**	**Q5**	**Q6**	**Totals**
None							

Project: NSTIR Monitoring | Location: Antigonish Wetland 21 (South R.) | Date: 2016-08-17
Investigator(s): Sharpe Neilly | BELT Site: AntW21T7 | BELT Bearing: 111
Zone: 20T | Origin UTM: 0584535 5050535 | End UTM: 0584580 5050520
E. Region: Northumberland-Bras Dor | Eco District: St Georges Bay | Eco Site: IFSM
Type: Salt marsh | Map Datum: NAD83

Notes: Parallel. To the north and downstream of road crossing

Zone	Begin	End	Length(m)	# of Q	Q spacing(m)		
1	0	23	23	3	8		
2	23	50	27	3	11		
	Zone1			**Zone2**			
	Q1	**Q2**	**Q3**	**Q4**	**Q5**	**Q6**	
Hor. Distance(m) from origin	0	8	16	28	39	50	
% Water	0	0	0	0	0	0	
% Muck	0	0	0	0	0	0	
% Moss	0	0	0	0	0	0	
% Stone, rock, exposed mineral	0	0	0	0	0	0	
Height shrubs/herbs (m)	0.8	0.8	0.8	0.8	0.7	0.8	
Herb Stratum	**Zone1**			**Zone2**			
	Q1	**Q2**	**Q3**	**Q4**	**Q5**	**Q6**	**Totals**
Calamagrostis canadensis	0	0	20	40	100	10	170
Calystegia sepium	0	0	0	40	10	0	50
Carex hormathodes	0	5	0	0	0	0	5
Carex recta	20	30	0	0	0	0	50
Galium palustre	0	0	0	5	0	0	5
Impatiens capensis	0	0	0	0	5	30	35
Iris versicolor	10	0	20	5	0	0	35
Juncus balticus	0	0	10	0	0	0	10
Lysimachia ciliata	0	0	0	0	0	20	20
Polygonum sagittatum	0	0	0	0	5	0	5
Rosa spp	0	0	0	5	0	10	15
Schoenoplectus pungens	0	0	10	0	0	0	10
Solidago canadensis	0	0	0	0	0	30	30
Spartina patens	0	0	0	20	0	0	20
Spartina pectinata	60	50	30	20	0	0	160
Toxicodendron radicans	0	0	0	0	0	50	50
Typha latifolia	0	5	0	0	0	0	5
Shrub Stratum	**Q1**	**Q2**	**Q3**	**Q4**	**Q5**	**Q6**	**Totals**
None							
Sapling	**Q1**	**Q2**	**Q3**	**Q4**	**Q5**	**Q6**	**Totals**
None							
Tree Stratum	**Q1**	**Q2**	**Q3**	**Q4**	**Q5**	**Q6**	**Totals**
None							

Project: NSTIR Monitoring	Location: Antigonish Wetland 21 (South R.)	Date: 2016-08-15
Investigator(s): Sharpe/Neily	BELT Site: AntW21T8	BELT Bearing: 158
Zone:	Origin UTM: 584641 5050397	End UTM: 584649 5050379
E. Region: Northumberland BrasDor	Eco District: St Georges Bay	Eco Site: IFSM
Type: Salt marsh		Map Datum: NAD83

Notes: In effect, extension of T2 with same bearing and spacing.

Zone	Begin	End	Length(m)	# of Q	Q spacing(m)
1	0	20	20	3	10

	Zone1			
	Q1	**Q2**	**Q3**	
Hor Distance(m) from origin	0	10	20	
% Water	0	0	0	
% Muck	0	0	0	
% Moss	0	0	0	
% Stone, rock, exposed mineral	25	0	0	
Height shrubs/herbs (m)	0.5	0.5	0.8	
Herb Stratum	**Q1**	**Q2**	**Q3**	**Totals**
Ambrosia artemisiifolia	5	0	0	5
Apocynum spp	0	20	0	20
Calamagrostis canadensis	0	0	40	40
Centaurea nigra	10	0	0	10
Daucus carota	20	0	0	20
Galium spp	25	15	0	40
Hypericum perforatum	30	0	0	30
Impatiens capensis	0	0	20	20
Lotus corniculatus	20	0	0	20
Lysimachia ciliata	0	10	0	10
Phalaris arundinacea	5	10	0	15
Polygonum sagittatum	0	0	10	10
Rosa spp	0	15	0	15
Rubus idaeus	0	0	15	15
Solidago canadensis	10	40	20	70
Tanacetum vulgare	5	0	0	5
Trifolium spp	10	0	0	10
Shrub Stratum	**Q1**	**Q2**	**Q3**	**Totals**
Crataegus spp	0	0	25	25
Sapling	**Q1**	**Q2**	**Q3**	**Totals**
None				
Tree Stratum	**Q1**	**Q2**	**Q3**	**Totals**
Fraxinus americana	0	0	3	3
Malus spp	0	0	1	1
Salix alba	0	0	1	1

Project: NSTIR Monitoring | Location: Antigonish Wetland 21 (South R.) | Date: 2016-08-17

Investigator(s): Sharpe/Neily | BELT Site: AntW21T9 | BELT Bearing: 167

E. Region: Northumberland BrasDor | Eco District: St Georges Bay | Eco Site: IFSM

Type: Salt marsh | Map Datum: NAD83

Notes: In effect south extension of T4, carrying on same spacing and bearing. T9Q3 ends at open water-edge of back channel.

Zone	Begin	End	Length(m)	# of Q	Q spacing(m)
1	0	26	26	3	13

	Zone1			
	Q1	Q2	Q3	
Hor Distance(m) from origin	0	13	26	
% Water	0	0	0	
% Muck	0	0	0	
% Moss	0	0	0	
% Stone, rock, exposed mineral	0	0	0	
Height shrubs/herbs (m)	0.2	0.5	0	
Herb Stratum	**Q1**	**Q2**	**Q3**	**Totals**
Argentina anserina	0	0	5	5
Calystegia sepium	0	70	5	75
Carex recta	0	5	0	5
Galium palustre	0	0	5	5
Iris versicolor	15	0	0	15
Juncus balticus	3	0	0	3
Samolus valerandi	0	0	15	15
Schoenoplectus acutus	0	5	70	75
Schoenoplectus pungens	0	5	0	5
Spartina pectinata	5	20	0	25
Typha latifolia	5	10	0	15
Shrub Stratum	**Q1**	**Q2**	**Q3**	**Totals**
None				
Sapling	**Q1**	**Q2**	**Q3**	**Totals**
None				
Tree Stratum	**Q1**	**Q2**	**Q3**	**Totals**
None				

Project: NSTIR Monitoring
Location: Antigonish Wetland 21 (South R.)
Date: 2016-08-17
Investigator(s): Sharpe/Neily
BELT Site: AntW21T10
BELT Bearing: 158
Zone:
Origin UTM: 584574 5050428
End UTM: 584624 5050317
E. Region: Northumberland BrasDor
Eco District: St Georges Bay
Eco Site: IFSM
Type: Salt marsh
Map Datum: NAD83
Notes: Along west side of access road, then crosses

Zone	Begin	End	Length(m)	# of Q	Q spacing(m)
1	0	120	120	7	20

	Zone1							
	Q1	**Q2**	**Q3**	**Q4**	**Q5**	**Q6**	**Q7**	
Hor Distance(m) from origin	0	20	40	60	80	100	120	
% Water	0	0	100	0	0	0	0	
% Muck	0	0	0	0	0	0	0	
% Moss	0	0	0	0	0	0	0	
% Stone, rock, exposed mineral	0	0	0	0	0	0	0	
Height shrubs/herbs (m)	1	1.2	1.2	1	0.8	1	0.8	
Herb Stratum	**Q1**	**Q2**	**Q3**	**Q4**	**Q5**	**Q6**	**Q7**	**Totals**
Argentina anserina	0	0	0	5	0	0	0	5
Atriplex spp	0	0	0	0	0	5	0	5
Calamagrostis canadensis	0	0	0	5	0	0	40	45
Calystegia sepium	0	0	0	0	5	0	0	5
Galium palustre	10	0	0	0	0	0	0	10
Juncus balticus	20	0	0	0	0	0	0	20
Lysimachia ciliata	0	0	0	0	0	0	25	25
Polygonum pensylvanicum	15	0	0	0	0	20	0	35
Polygonum sagittatum	0	0	0	0	10	0	0	10
Rosa spp	0	0	0	0	0	0	15	15
Rumex crispus	0	0	0	0	0	3	0	3
Schoenoplectus acutus	30	70	10	0	0	3	0	113
Solidago canadensis	0	0	0	0	0	0	10	10
Spartina pectinata	15	0	0	5	100	20	0	140
Symphyotrichum novi-belgii	0	0	0	15	0	0	0	15
Typha latifolia	0	30	90	40	0	70	0	230
Shrub Stratum	**Q1**	**Q2**	**Q3**	**Q4**	**Q5**	**Q6**	**Q7**	**Totals**
None								
Sapling	**Q1**	**Q2**	**Q3**	**Q4**	**Q5**	**Q6**	**Q7**	**Totals**
None								
Tree Stratum	**Q1**	**Q2**	**Q3**	**Q4**	**Q5**	**Q6**	**Q7**	**Totals**
None								

Project: NSTIR Monitoring
Investigator(s): Sharpe/Neily
Zone: 20T
E. Region: Northumberland BrasDor
Type: Salt marsh
Notes: West of western backchannel

Location: Antigonish Wetland 21 (South R.)
BELT Site: AntW21T11
Origin UTM: 584520 5050388
Eco District: St Georges Bay

Date: 2016-08-17
BELT Bearing: 145
End UTM: 584556 5050340
Eco Site: IFSM
Map Datum: NAD83

Zone	Begin	End	Length(m)	# of Q	Q spacing(m)	
1	0	60	60	5	15	
	Zone1					
	Q1	**Q2**	**Q3**	**Q4**	**Q5**	
Hor Distance(m) from origin	0	15	30	45	60	
% Water	0	0	0	0	0	
% Muck	0	0	0	0	0	
% Moss	0	0	0	0	0	
% Stone, rock, exposed mineral	0	0	0	0	0	
Height shrubs/herbs (m)	0.4	0.6	0.7	0.4	0.4	
Herb Stratum	**Q1**	**Q2**	**Q3**	**Q4**	**Q5**	**Totals**
Argentina anserina	0	5	0	0	0	5
Calamagrostis canadensis	0	50	95	0	0	145
Calystegia sepium	0	25	10	20	20	75
Carex hormathodes	0	5	0	0	0	5
Galium palustre	0	0	0	0	5	5
Juncus balticus	30	0	0	0	40	70
Rosa spp	0	0	0	5	0	5
Solidago canadensis	0	0	0	0	20	20
Spartina pectinata	25	20	0	80	15	140
Symphyotrichum novi-belgii	25	0	0	0	0	25
Vicia cracca	0	10	5	0	0	15
Shrub Stratum	**Q1**	**Q2**	**Q3**	**Q4**	**Q5**	**Totals**
None						
Sapling	**Q1**	**Q2**	**Q3**	**Q4**	**Q5**	**Totals**
None						
Tree Stratum	**Q1**	**Q2**	**Q3**	**Q4**	**Q5**	**Totals**
None						

Appendix 6: Site Photographs

Photograph 1: Transect 1, quadrat 6, view to the west, showing dense establishment of native and exotic species in the former construction pad area. Photo taken August 15, 2016.

Photograph 2: Sparse re-vegetation, with a mix of native and exotic species at transect 2, quadrat 6. Photo taken August 15, 2016.


Photograph 3: View to south across bare soil and ponded water beneath east-bound lane. Central pier for east-bound lane is at far left of image. Photo taken November 2, 2016.


Photograph 4: Field Scout penetrometer being used to assess soil compaction at Antigonish Wetland 21. Photo taken July 2, 2016.

Photograph 5: Field Scout penetrometer being used to assess soil compaction at Antigonish Wetland 21. Photo taken July 2, 2016.

Photograph 6: Soil accretion marker horizon plot established using feldspar at control location, downslope (north) of bridge crossing in undisturbed wetland. Photo taken July 2, 2016.

Photograph 7: Soil accretion marker horizon plot established using feldspar at test location, in standing water at the western edge of the former construction pad area. Photo taken July 2, 2016.

Photograph 8: Soil accretion marker horizon plot established using feldspar at test location, within the former construction pad area. Photo taken November 2, 2016, five months post-installation.

Photograph 9: View to the northwest under the Antigonish Wetland 21 crossing at spring high tide event. Photo taken July 5, 2016.

Photograph 10: View to the west across Antigonish Wetland 21 at high tide event. Photo by Ian MacCallum, NSTIR, January 31, 2017.

Photograph 11: Soil pit in undisturbed wetland, Upslope East of crossing. Photo taken November 2, 2016.

Photograph 12: Soil pit in undisturbed wetland, Upslope West of crossing. Photo taken November 2, 2016.

Photograph 13: Soil pit in undisturbed wetland, Downslope East of crossing. Photo taken November 2, 2016.

Photograph 14: Soil pit in undisturbed wetland, Downslope West of crossing. Photo taken November 2, 2016.

Photograph 15: Soil pit in disturbed wetland, Pad East. Photo taken November 2, 2016.

Photograph 16: Soil pit in disturbed wetland, Pad West of crossing. Photo taken November 2, 2016.

Photograph 17: Recent mortalities of small-bodied fish, collected across the western portion of the former construction pad. Photo taken April 29, 2016.

Appendix 7: Pre-Construction Aerial Surveys Completed by CBWES

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