Environmental Implications of Expanding the Windsor Causeway (Part 2):

Comparison of 4 and 6 Lane Options

Final Report
prepared for
Nova Scotia Department of
Transportation and Public Works

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ACADIA CENTRE FOR ESTUARINE RESEARCH

Environmental Implications of Expanding the Windsor Causeway (Part 2):

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1.0 Introduction

Preliminary plans for twinning Highway 101 include expansion of the width of the Windsor Causeway to accommodate two or four additional lanes, creating a four or six lane divided highway. Because of the limitations imposed by infrastructure in the Town of Windsor, and by Fort Edward, such expansion is feasible only on the seaward side of the existing structure. Realignment of the existing roadway would also be designed to decrease the sharp curve at the western end, which currently requires a speed limit of 90 km per hour. The new construction would therefore cover part of the marsh and tidal channel adjacent to the existing causeway.

During 2002, studies of the mudflat—saltmarsh complex on the seaward side of the Windsor Causeway and of Pesaquid Lake, were carried out, in part, to provide information relevant to an assessment of the ecological implications of such an expansion. These studies also constituted the first step in a planned long term monitoring of continuing evolution of the marsh-mudflat complex that has resulted from construction of the original causeway. Reports on the 2002 studies were presented as ACER Publications 69 and 72 in 2003 (Daborn *et al.* 2003a, b). Subsequently, the Nova Scotia Department of Transport and Public Works indicated that it wished to have a comparison of the separate implications of the four and six-lane expansion options. The work was carried out by Dr. Danika van Proosdij of Saint Mary's University during 2003.

In 2003, biological research conducted by ACER personnel was focussed on the movements of migratory and resident fish in the lower Avon River, Pesaquid Lake, and adjacent to the Windsor Causeway. Elevational studies were continued by Dr. van Proosdij and her team at Saint Mary's University. The Final Report of the 2003 studies is in preparation (Daborn *et al.* 2004).

An alternative solution to the crossing issue, favoured by some local interest groups, is complete removal of the existing causeway and its replacement by a bridge of sufficient capacity to accommodate a four lane highway and the existing railway. While this alternative was not the subject of the 2002 study, the results provide information that is relevant to that issue.

2.0 Effects of causeway expansion on physical processes of the Avon Estuary.

It seems to be a common (public) perception that expansion (i.e. widening) of the existing causeway would initiate a significant change to the physical dynamics of the Estuary similar to construction of the original causeway. This is not probable. The major effect of the original construction in 1970 was a significant reduction in the tidal prism and consequent reduction in velocity and turbulence of tidal waters. These changes resulted in the progressive accumulation of deposited sediment that has given rise to the present marsh and mudflat complex. Widening the causeway would have a negligible effect on the tidal prism, because the expansion of the marsh and mudflat has itself reduced the volume of water able to move into the Avon Estuary.

Continued development of the marsh seems likely to favour the infilling of the Causeway Channel, a drainage channel that runs parallel to the causeway, which was kept open by tidal flows[1], until the late 1980s. Eventually the marsh would be expected to grow completely up to the present causeway, thus almost eliminating the mudflats that currently remain as part of the Causeway Channel. However, the geomorphology of this channel is influenced by extensive ice formation and movement in winter, which may both remove the surface sediment and the stabilising roots of marsh grasses. We have yet to examine the effects of higher than normal amounts of ice accumulation and scour during the 2004 winter months. It is likely that any erosion recorded in this region in 2004 will be balanced by accretion in the following years.

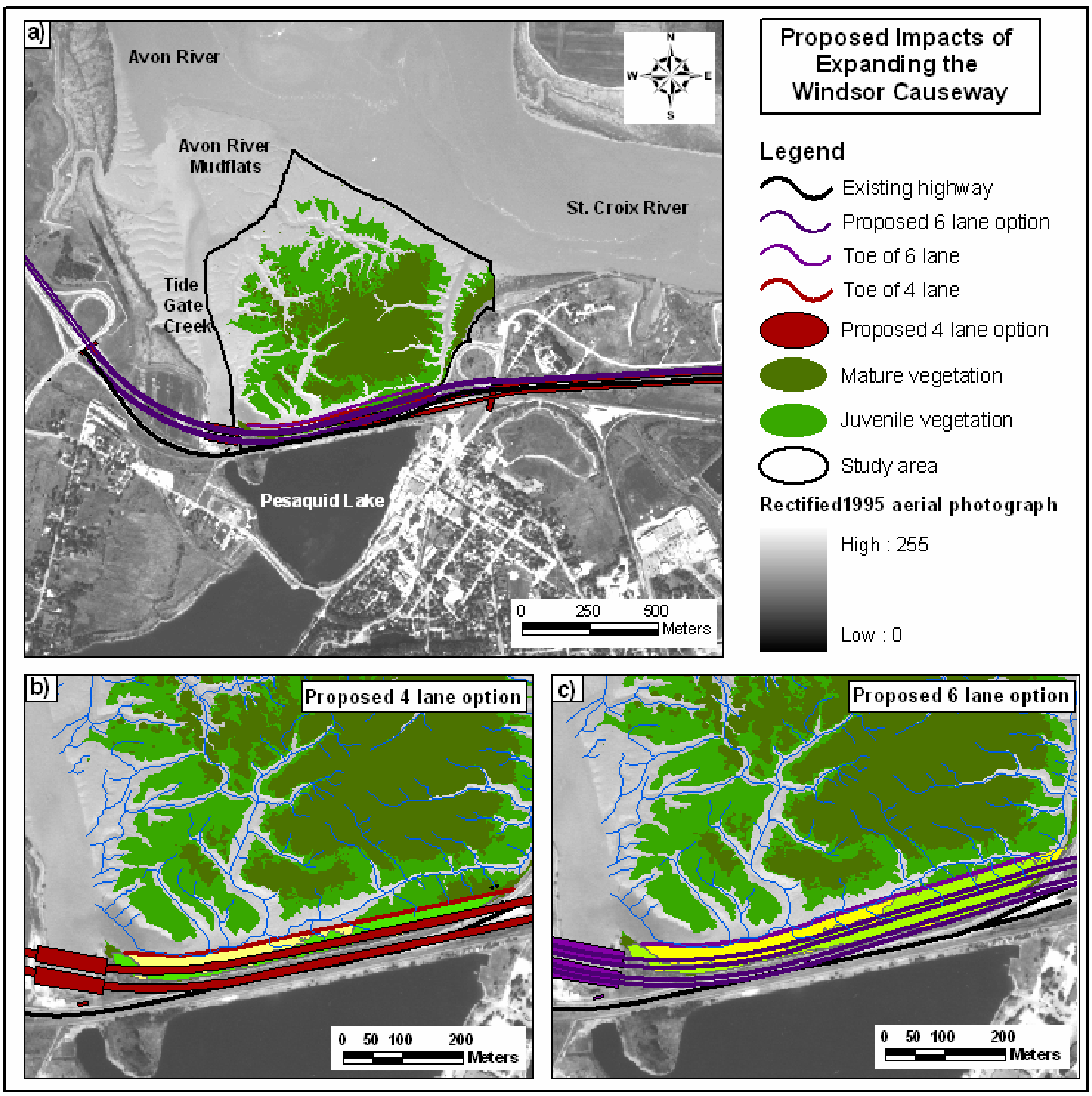
2.1 Direct and Indirect Impacts of Expanding the Windsor Causeway

Two options have been proposed regarding the expansion of the 101 Highway and the Windsor Causeway. Footprint/Option 1 involves the realignment and construction of 6

[1] And possibly some seaward seepage through the Causeway in early years after its construction.

lanes which would allow Exit 6 at Nesbitt Street to be preserved. Footprint/Option 2 may involve two scenarios: a) twinning the highway (i.e. creating 4 lanes) while removing Exit 6; or b) creating a 6 lane highway with a 'narrow median' (a 'Jersey Barrier'); the two latter scenarios would create nearly identical footprints. As presently contemplated, both Option 1 and 2 would involve construction over a small but significant fraction of the marsh and mudflat that lies adjacent to the causeway (cf. Figure 1).

Figure 1: Estimated 'footprint' of the Windsor Causeway following expansion associated with 'twinning' of Highway 101. Vegetation areas derived from Townsend, 2002.



The areas of intertidal habitat that would be directly and indirectly impacted by the expansion of the 101 Highway were determined using ArcView 8.3 with Spatial Analyst Extension and a digital CAD survey supplied by the Nova Scotia Department of Transportation and Public Works. The areas of vegetation and mudflat impacted by the expansion were derived using geoprocessing techniques and the GPS vegetation survey data conducted by Saint Mary's University in 2001.

Table 1 summarizes the area of intertidal habitat that will be directly impacted by the construction process. Areas of intertidal habitat located landward of the proposed toe were assumed to be completely removed or buried during the construction process. Although there will be some indirect impacts close to the toe of the new causeway, these impacts will likely be relatively minor and concentrated during the construction phase itself. The mudflat will likely re-stabilize after one winter season with vegetation following soon after.

Table 1: Estimates of the amount of intertidal habitat directly impacted by proposed expansion of the Windsor Causeway. Existing saltmarsh habitat determined from a fall 2001 survey by Townsend (2002).

Existing Habitat within Study Area	**Area (m^2)**	**Area (acres)**
Salt marsh vegetation	397,515	98
Mudflat	346,337	86
Total Intertidal Habitat	743,852	184
Analysis of Habitat Impacts from Construction Process		
Habitat	**Option 1 (6 lane)**	**Option 2 (4 lane or 6 lane narrow)**
Salt marsh vegetation (m^2)	23,023	14,971
Mudflat (m^2)	14,001	10,634
Total Intertidal Habitat (in m^2)	37,024	21,605
Total Intertidal Habitat (in acres)	9	5
% of existing salt marsh vegetation	6	3
% of existing mudflat	4	3
% of total intertidal area	5	3

Currently there are approximately 743, 230 m^2 (184 acres) of intertidal habitat within the study area. The construction of the additional eastbound and westbound lanes (Option 2, 4 lane or 6 lane narrow median) would result in the direct loss of approximately 3% of the total intertidal habitat (Table 1). The 6 lane alternative (Option 1) would preserve the existing Windsor exit but would result in a direct loss of approximately 5% of the total intertidal habitat (6% of existing salt marsh vegetation and 4% of all mudflat area).

It should be noted that these estimates were based on the assumption that the causeway will be expanded using standard construction techniques (e.g. toe fill added from the existing causeway). Given the steep slope of the mudflat bank and winter-time erosion of the marsh 'cliff' observed close to the existing tide gates, along the deepest portion of the Causeway Channel, additional armouring may be required. The construction 'footprint' in this area is likely to increase if extra armouring is used.

The effects of changes in channel morphology and erodibility that would arise as a result of causeway construction and protection will inevitably change current patterns in the vicinity of the Causeway Channel and the control gates. Rip-rap or other armouring will reflect at least some of the energy of the flood tide, and may induce accelerated erosion at other locations, particularly along the West Channel near to the gates. The effects on current velocities of the final design should be modeled in order to identify vulnerable banks so that these could be treated during the construction process.

2.3 Effects of causeway expansion on biological processes and resources of the Avon Estuary.

As described in Daborn *et al*. 2003a, the salt marsh appears to be one of the most productive marshes (on a unit area basis) in the Bay of Fundy, and possibly in North America. Although there is no evidence that the marsh cord grass is grazed directly by any organisms, the above ground production is largely sheared off in winter, and in fragmented form represents a considerable contribution of organic material to the estuarine ecosystem. In addition, the large seed production of *Spartina alterniflora* (cf. Figure 2) is probably utilized by Black ducks and other waterfowl.

The evidence from the 2002 study indicates that the Windsor marsh is unusual in the very low abundance of benthic animals in areas where the *Spartina* is particularly dense. The mudflats, however, harbour relatively large numbers of *Corophium volutator* and *Nereis diversicolor*, and smaller numbers of the bivalve *Macoma balthica* and other polychaetes. These muddy areas are potentially good feeding grounds for fish and birds. *Corophium volutator* is a species of great significance to the inner Bay of Fundy ecosystem. It is often a numerically dominant organism, and constitutes a major food item for most fish species (Gilmurray and Daborn 1981, Imrie and Daborn 1981, Dadswell *et al.* 1984a, b, Stone and Daborn 1987) and migratory shorebirds (Hicklin 1981, Hicklin *et al*. 1980). In recent years, there has been great concern about declining numbers of *Corophium* in areas such as Starrs Point and Johnson's Mills that used to be major feeding grounds (Shepherd *et al.* 1995).

It appears that the Windsor mudflats have become relatively attractive to shorebirds, and the data obtained in this study indicate that abundance of *Corophium* in the muddy areas surrounding the new marsh is comparable to that in other favoured feeding areas in years past.

Figure 2. *Spartina* seed detritus along the Windsor Causeway, 23 December 2002.

Construction over the mudflat and marsh adjacent to the causeway will therefore entail loss of 3 – 6 % of the potential foraging habitat for both fish and birds in the area adjacent to the causeway. The data obtained during 2002 and 2003, however, suggest that the major foraging area for shorebirds is on the distant mudflat (the Newport Bar) beyond the St. Croix Estuary channel (Daborn *et al.* 2003a). This region has not been adequately surveyed, but the limited marsh grass present, and the apparent use by 'peeps' (small waders, including sandpipers) of that area rather than the mudflats and channels adjacent to the causeway, suggest that there may be large numbers of *Corophium volutator* on the Newport Bar (Daborn *et al*. 2004). The principal users of the marsh and mudflats closest to the causeway appear to be plovers, herons, Black duck and gulls.

Information about fish usage of the channels and mudflats is absent. It would be expected, however, that a number of species -- especially Atlantic silverside (*Menidia menidia)*, tomcod (*Microgadus tomcod)*, and winter flounder (*Pseudopleuronectes americana*) -- would visit these channels on the rising tide (Dadswell *et al.* 1984a, b). Given the limited area of the mudflats of the Causeway Channel, its loss would be of little significance to the foraging area available to fish. It should also be noted that continued growth of the marsh is expected to diminish the area of mudflat remaining near to the causeway, and hence in the region that would be covered by its expansion. Since the vegetated area carries few invertebrates, the present favourable feeding area will be eliminated by growth of the marsh, regardless of any change to the causeway.

2.4 Effects of causeway expansion on Pesaquid Lake.

Other than direct construction activities, expanding the causeway will have no significant effect on the present condition of Pesaquid Lake, provided there are no changes to the current pattern of water level modifications. Although an impoundment such as this has the potential to become eutrophic[2] as a result of nutrient enrichment, and to trap sediments, lowering the water storage capacity, these will not change just because the causeway has been widened. There is potential, however, that construction would

[2] i.e. enriched with nutrients.

increase the mobility of deposited sediments, leading to greater accumulation of sediment in the headpond if these are able to pass upstream during construction. These additions to the sediment deposits of the headpond would probably be very small compared with the amount that has accumulated since original construction of the causeway more than 30 years ago.

The 2002 study included a single limnological survey of the lake, conducted in August when it was expected that conditions might be most degraded: high temperatures and low flushing would lead to declines in oxygen availability in deeper waters, and any nutrient enrichment would lead to high growth of phytoplankton. While there was some depletion of oxygen in deeper waters, because of the stratification, there was no evidence of anaerobic conditions. Similarly, water clarity remained high, and nitrogen concentrations were extremely low. The absence of a well developed benthic community is most likely due to periodic incursions of salt water through the causeway, as well as drawdown of the lake in spring for maintenance at the gates. It is apparent that a small salt wedge existed in the headpond, although confined to the channel leading to the gates, at the time of the survey, but we do not know how persistent this feature is. It is possible that the salt wedge is eliminated during periods of high river flow, and then re-established if salt water is able to pass back through the causeway[3]. Most benthic organisms are either adapted to fresh water or to relatively saline water. Periodic oscillations between fully fresh to almost full strength sea water tend to eliminate the vast majority of long-lived species such as clams or insects. A periodically stratified estuary is one of the most difficult habitats for benthic animals. In the case of Pesaquid Lake, the regular and prolonged drawdown is probably the major reason for the lack of benthic fauna, although any salt intrusion events could have additional long term effects.

A further consideration for planners is the potential implications of longer term global environmental changes, such as sea level rise, and the increased frequency of extreme

[3] There is some indication that portions of the causeway may still be somewhat porous, allowing salt water to penetrate the structure during high spring tides (K. Carroll, *pers. com*). Because of its density, it would tend to settle below the fresh water from the river. A small amount of leakage was observed during spring 2004 when the lake level had been lowered (M. Brylinsky observation).

events. The orientation of the Avon Estuary does not leave it particularly susceptible to strong wave action at the causeway, and as the marsh and mudflat continue to evolve, they act as a ‘soft’ shoreline barrier that would minimise effects of major storms that could be significant in other parts of the Bay of Fundy system. It seems probable that, left unchanged, the marsh will continue to trap sediment and rise with rising sea level, maintaining its dynamic equilibrium with tidal flows. Construction of a wider causeway will not change that.

A greater concern may be associated with the prospective increase in extreme precipitation events. At the present time, cooperation between Nova Scotia Power Inc. (which impounds and stores water upstream for hydroelectricity generation), and the Nova Scotia Department of Agriculture and Fisheries (which manages water levels in Pesaquid Lake), is usually able to accommodate release of large quantities of water downstream. However, there is concern that in recent years a considerable amount of sediment has accumulated in Pesaquid Lake because it is not being flushed out effectively. This limits the capacity of the impoundment to store water, and while there have been few instances in recent years where problems were encountered, the difficulty will only increase if extreme events do become more frequent as predicted, and the headpond volume is not maintained or increased.

3.0 Implications of Causeway Removal.

Although not the subject of the present study, the possibility of removing the existing causeway and replacing it with a bridge has been raised. There is a growing interest in North America in removing causeways that were constructed in the 1960s and 1970s in order to reverse the negative impacts that such obstructions have created. These effects include: reduced lengths of tidal rivers; stratification of upstream impoundments; changed freshwater discharges; elimination of salt marshes; sediment deposition upstream and/or downstream of the barrier; elimination of migratory fish stocks or impedence of movement because of anaerobic barriers; eutrophication of upstream freshwaters; reduced nutrient exchange with coastal waters; retention of contaminants and harmful bacteria; loss of tidal bores and other tourist attractions; and changes to groundwater (cf. Wells 1999). Concern about the negative effects of causeways in tidal areas has become enhanced in recent years by greater recognition of the role that salt marshes may have played in the ecology of coastal waters. It is estimated that, since 1604, more than 80% of the salt marshes in the Bay of Fundy have been lost through dyke and causeway construction, with undetermined effects on the productivity of coastal ecosystems. There is considerable public interest in the recovery of some of these lost marshes by reopening tidal restrictions. The benefits of barriers, which usually provided the rationale for their construction, include: flood control; cost-effective transportation; increased land for agriculture and residential/industrial development; and some forms of recreation.

If the Windsor Causeway were to be removed and replaced by a bridge, allowing free flow of water past the Town of Windsor, the consequences would not be trivial. There would be potential benefits, including recovery of migratory fish stocks that may have been reduced in size since causeway construction. The hazards of impounding water that is contaminated by residential and agricultural waste will be diminished because of the capacity of an estuarine system to process organic matter, including fecal bacteria and pathogens. Eventually there might be the development of marsh and mudflat systems in the area that is currently a freshwater impoundment, and this might well change local wildlife diversity. Ironically, removal of this causeway would probably eliminate what appears to be one of the most productive marshes in the Bay of Fundy system; normally construction of tidal barriers is associated with a loss of salt marshes.

It should be noted, however, that knowledge of estuarine systems, particularly of macrotidal estuaries like the Bay of Fundy, is not sufficient to forecast the rate at which the system will evolve following removal of the causeway. It is most likely that the current marsh—mudflat system that has grown up since the construction of the causeway will begin to erode along the existing steep mudflat banks and vegetated cliffs as tidal flows increase. Unless there is dredging to increase the cross-sectional area at the level of the present causeway, erosion of the marsh and mudflat is likely to be a slow process at first. It may take a number of years before sufficient erosion has taken place to significantly increase the flow of tidal water into what is now the headpond[4].

The fate of the sediment eroded from the marsh and mudflat is also uncertain. In general, estuaries tend to move sediments in a landward direction, because velocities on the flood tend to be higher than those on the ebb. Consequently, some sediment accumulation may be concentrated upstream, while another (probably larger) fraction of the several million tonnes that have settled there since 1970 may be distributed downstream or into the St. Croix estuary. There is, in fact, no guarantee that all of the existing mud and marsh will ever be removed: there was an intertidal bar in that place prior to construction of the causeway.

At all events, it will be many years before a stable dynamic system is re-established, and the nature of that equilibrium cannot be forecast with confidence.

4.0 Summary.

Consideration of the ecological implications of expanding (widening) the present causeway involves a) the effects on physical processes; b) the effects on biological processes and resources; and c) the effects on Pesaquid Lake.

1. Widening of the existing causeway will have negligible effects on the *physical* processes of the estuary, because the major effects have already been experienced with the original construction. Some erosion might be experienced along the steep western section of the causeway channel if 'hard protection' engineering structures are deployed, redirecting tidal currents.
2. Expansion of the causeway will cover a small but significant part of the present mudflat and marsh, removing some of the feeding habitat for fish and birds. Estimates are that the losses will represent 3—6 % of the intertidal area between the causeway and the St. Croix Estuary channel. However, continued growth of

[4] Dr. Carl Amos believes that erosion of the Windsor mudflat could be extremely rapid after opening of the Causeway, depending upon the width of the initial opening. In his view, most of the mudflat and marsh might be gone within the first few years. (Personal communication, February 2004).

the marsh will eliminate some of the mudflat in the vicinity of the causeway anyway.

3. Because of declines in *Corophium* populations elsewhere in the upper Bay of Fundy, there will be concerns about loss of some relatively productive areas that have developed near Windsor as a result of the causeway. Most foraging by birds (and possibly fish?) now occurs at more distant portions of the mudflat that would not be directly involved in construction of the wider highway.
4. Widening of the causeway will have no direct effect on Pesaquid Lake. Conditions in this impoundment are largely determined by management of water levels and contaminant sources.
5. Replacement of the causeway with a bridge will bring a complex mixture of favourable and unfavourable changes.

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Appendix : Revised Station Elevations on the Windsor Marsh and Mudflat, 2003.

All station elevations were re-surveyed in late Summer 2003 with the assistance of Darrell Hingley, survey technician with Nova Scotia Agriculture and Fisheries Division using a dual frequency real time kinematic GPS and a set base station. Data were collected with centimeter accuracy. These records replace those in Figure 2.3 and Table 2.3 in Daborn *et al.* 2003a. We gratefully acknowledge the assistance of Darrell Hingley, Ken Carroll and Hank Kolstee (NSAFD).

Figure 2.3: Interpolation of elevation mudflat and marsh surface elevation

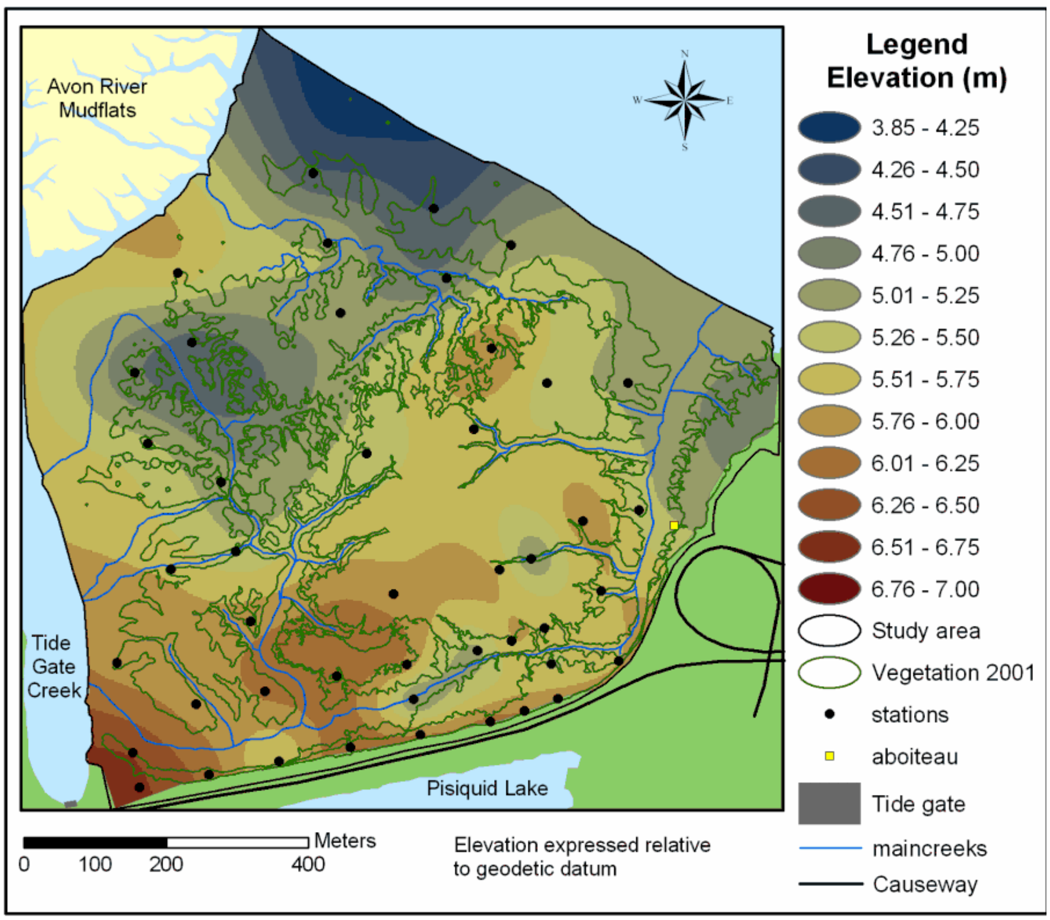

Table 2.3. Transect Stations: Elevations, Bulk Density, Water & Organic Contents

			EASTING	NORTHING	Elevation	water content	bulk density	organics
Line	Station	ID	(m NAD83)	(m NAD83)	(m)	(%)	(g/cm3)	(%)
L1	1SC	3	409569.801	4983210.223	6.546	29.66	1.03	6.60
	2C	4	409560.284	4983259.035	6.477	33.74	0.99	5.41
	3SC	25	409537.589	4983385.212	5.899	47.43	0.83	5.95
L2	1SC	8	409667.277	4983228.348	6.137	34.23	1.01	5.43
	2SC	26	409649.127	4983326.830	5.900	45.93	0.73	-
	3SC	27	409613.704	4983516.839	5.700	42.39	0.81	4.32
	4SC	29	409581.283	4983693.512	5.300	44.60	0.77	5.06
	5SC	30	409562.380	4983792.305	4.800	44.94	0.88	13.24
L3	1SC	11	409765.312	4983247.202	5.540	53.51	0.63	6.79
	2SC	-	409649.13	4983326.83	5.668	56.26	0.63	5.30
	3SC	36	409745.260	4983344.729	6.046	50.03	0.80	6.13
	4SC	35	409725.060	4983443.329	5.899	45.54	0.88	5.63
	5C	34	409704.740	4983541.450	5.332	49.61	0.77	5.18
	6SC	33	409684.278	4983638.901	5.113	47.32	0.61	3.78
	8SC	32	409643.356	4983835.398	4.638	47.00	0.73	5.31
	9C	31	409623.041	4983933.024	5.649	48.58	0.75	12.96
L4	1C	13	409864.865	4983266.027	6.234	38.24	0.85	5.67
	2SC	24	409846.052	4983366.426	6.179	47.97	0.69	5.95
L5	1SC	17	409963.303	4983284.803	6.023	44.01	0.75	6.91
	2C	22	409953.963	4983333.811	5.047	48.28	0.67	6.21
	3SC	23	409944.588	4983382.983	5.900	50.14	0.79	0.00
	4SC	37	409926.169	4983481.357	5.859	46.95	0.75	13.79
	6SC	39	409888.510	4983678.669	5.365	57.30	0.53	5.97
	8SC	41	409851.768	4983876.444	5.076	48.40	0.68	16.56
	9C	42	409833.437	4983974.728	5.211	47.19	0.60	0.17
	10SC	43	409813.112	4984072.808	4.555	37.33	1.00	3.68
L6	1SC	19	410061.318	4983302.737	6.108	39.71	0.80	6.61
	2C	20	410052.235	4983352.595	5.296	43.62	0.75	6.07
	3SC	21	410043.520	4983402.363	5.200	47.33	0.72	6.18
L7	1SC	66	410109.443	4983317.655	5.982	42.51	0.80	4.80
	3SC	53	410091.716	4983416.202	5.739	43.93	0.87	5.33
	4C	50	410074.068	4983515.511	5.709	41.32	0.86	5.90
	6SC	49	410038.496	4983712.839	5.600	50.63	0.76	6.33
	8SC	45	409999.810	4983924.721	4.855	43.73	0.77	2.68
	9C	44	409981.839	4984023.409	4.492	50.47	0.67	4.16
L8	1SC	60	410156.636	4983334.744	5.936	41.49	0.79	5.99
	2C	59	410147.224	4983383.715	5.469	48.67	0.71	5.69
	3SC	54	410137.936	4983433.543	5.687	49.95	0.69	5.72
	4C	51	410119.270	4983531.644	5.088	38.11	1.08	7.30
	5C	48	410063.265	4983827.140	5.957	48.25	0.83	4.47
L9	1SC	63	410242.290	4983387.971	5.752	50.52	0.48	5.59
	3C	55	410216.951	4983486.235	5.732	47.39	0.72	2.98
	4SC	56	410191.653	4983584.255	5.894	41.98	0.74	5.53
	6SC	47	410141.294	4983777.878	5.379	49.81	0.67	6.44
	8SC	46	410090.990	4983971.750	5.100	47.76	0.70	5.26

Table 2.3. Transect Stations: Elevations, Bulk Density, Water & Organic Contents

Line	Station	ID	EASTING (m NAD83)	NORTHING (m NAD83)	Elevation (m)	water content (%)	bulk density (g/cm3)	organics (%)
L10	1SC	58	410270.133	4983599.743	5.400	45.69	0.79	3.79
	2SC	57	410254.661	4983777.783	5.200	48.13	0.50	4.98
					Mean	**45.69**	**0.76**	**6.68**
					StDev	**5.47**	**0.13**	**5.82**