# Manual for
# Wetland Ecosystem Services Protocol for Atlantic Canada (WESP-AC):
## Tidal Wetlands

**New Brunswick Department of Environment and Local Government**

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**Electronic files.** The following accompany this manual and are relevant to WESP-AC assessments of tidal wetlands:

WESP-AC Tidal Calculator_SingleSite_20March2018.xlsx
SuppInfo_Tidal_WESP-AC_20March2018.xlsx

*Files to open in Google Earth Pro (kmz extension):*
NB Crown lands
NB Protected Natural Areas
NB Headtide

NS Growing Degree Days
NS Headtide

NL Provincial Protected Areas
NL Growing Degree Days

NB-PEI_GrowingDegree Days
Black Duck Nesting Pairs
IBAs Canada
Shorebird Concentration Sites

## Executive Summary

WESP-AC is a standardised method for rapidly assessing some of the important natural functions of *tidal* wetlands in Atlantic Canada. An accompanying document contains a standardised method for rapidly assessing some of the important natural functions of *non-tidal* wetlands in the same region.

**Tidal wetlands** are defined as areas predominantly vegetated by vascular plants which experience surface water flooding by tides at least once annually, regardless of salinity. Normally, their vegetation is predominantly herbaceous, i.e., salt marsh, but in estuaries such as the St. John where tidal influence extends dozens of kilometers inland, water becomes fresh rather than saline as one proceeds upriver, and tidal floodplains in many segments are wooded. This Tidal WESP-AC is recommended for assessing functions of those areas. This version is not applicable to assessing the functions of mud flats, eelgrass, or macroalgal beds.

The tidal WESP-AC consists of this manual and its appendices, some supporting electronic files, and an Excel® spreadsheet calculator containing data forms and models (formulas). WESP-AC generates scores (0 to 10 scale) and ratings (Lower, Moderate, Higher) for each of the following wetland attributes: Storm Surge Interception; Water Purification; Organic Nutrient Export; Fish Habitat; Waterbird Habitat; Songbird and Raptor Habitat; Biodiversity Maintenance; Wetland Stability; Public Use or Recognition. For each attribute, the scores and ratings represent a particular wetland's standing relative to those in a statistical sample of tidal wetlands previously assessed by this study in the relevant province: 43 in New Brunswick, 34 in Nova Scotia, 39 in Newfoundland-Labrador, and 19 on Prince Edward Island.

The scores and ratings are intended to inform decisions about wetland avoidance, minimisation, and replacement. WESP-AC can also be used with other tools and measurements to monitor wetland restoration projects and to help assure that wetland restoration efforts offset the unavoidable loss of specific functions and benefits in other wetlands, not just loss of their area.

After being trained in the use of this Tidal WESP-AC, users initially consult aerial imagery (e.g., the free Google Earth Pro) and a few web sites in order to answer 28 mostly multiple-choice questions about a wetland. The wetland is then visited and 18 questions are answered based on field observations and, if necessary and possible, on conversations with the landowner of the property adjacent to the wetland. Completing the on-site part of WESP-AC typically takes 1-3 hours, depending on wetland size,

access, and the user's prior experience applying the tool and familiarity with the area. Although several data form questions (indicators) are applied to estimate multiple wetland functions, users need only enter the data for each indicator in one place on the data form (spreadsheet).

WESP-AC's scoring is based on logic models programmed into the calculator spreadsheet. Although this has the potential to create a "black box" wherein underlying assumptions and calculations are not transparent to the user, transparency has been assured by the open architecture of the Excel™ spreadsheet as well as by detailed explanations of the assumptions and mathematics of each scoring model (viewable both in the spreadsheet and section 4 of this manual). The spreadsheet contains a rationale for use of each metric or indicator in every model. WESP-AC is a refinement of the first wetland assessment method that was peer-reviewed and then used widely throughout the U.S. (Wetland Evaluation Technique, WET; Adamus 1983, Adamus et al. 1987) and a similar protocol (ORWAP) developed, peer-reviewed, and adopted for routine use by Oregon Department of State Lands with funding from the US Environmental Protection Agency (EPA; Adamus et al. 2009 & 2016). Although users sometimes differ in their interpretation of particular WESP-AC questions, the overall repeatability of the scores and ratings has been shown to be quite high in other places where regionalised versions of WESP were independently tested, i.e., Alberta, Southeast Alaska, and Oregon.

As was the case with non-tidal wetlands, wetlands used to calibrate the method were selected with minimal bias through a statistical procedure intended to encompass as much variation as possible with a limited sample. Collecting calibration data was necessary to determine the range of scores that exists among the region's tidal wetlands, and to then normalise the scores to a consistent a 0-to-10 decimal scale and rating.

Major differences between this tidal version of WESP-AC and its non-tidal predecessor are as follows:

- Somewhat different and fewer functions, and indicators of those functions
- Fewer and shorter data forms, and simpler models of wetland functions.
- No separate calculation of wetland benefits. Seven of the scores represent functions, two represent other attributes.

For technical questions about WESP-AC, the primary author (Dr. Paul Adamus) may be contacted at: swamps21@gmail.com

**Acknowledgments**

We thank the National Wetland Conservation Fund of Environment Canada for helping support this significant effort. John Brazner of Nova Scotia Department of Natural Resources initially identified the need for a rapid tool to link Atlantic Canada's wetland decisions to improve estimates of the levels of functions that a wetland performs. Christie Ward of NB ELG administered the grant for this project and coordinated the outstanding assistance of her staff in the field calibration effort. Reid McLean and Jeff Stymiest of ELG provided the GIS support essential to create the database used for statistically selecting the calibration wetlands. In addition to those done by the author, field assessments of NB calibration wetlands were done by Christie Ward, Joanie Bertin, Cassandra Colwell, and Sophie Jensen from ELG; and Kevin Connor from NB Department of Natural Resources. Harry Collins, Executive Director of the Miramichi River Environmental Assessment Committee, kindly assisted with assessments in that area. In Nova Scotia, the author's calibration visits to tidal wetlands were augmented by assessments by Ryan Power of McCallum Environmental Ltd. In Newfoundland-Labrador, many of the calibration wetlands were assessed by the Stewardship Association of Municipalities (Laura King), Nature Conservancy of Canada (Megan Lafferty, Julia Lawler), Ducks Unlimited (Danielle Fequet, Emma Bocking), and Tegan Padgett (Memorial University of Newfoundland) with overall coordination by Jonathan Sharpe (NL Department of Fisheries & Land Resources) . On Prince Edward Island, all were done by Derek Ellis under the direction of Garry Gregory (Department of Communities, Land, & Environment) with GIS support from Mary Lynn McCourt.

# 1.0 Introduction

## 1.1 General Description

Measuring the natural functions of wetlands directly is expensive and may require years of data. Alternatively, instead of attempting to measure a wetland's functions directly (Dorney and Adamus 2018), a team of multidisciplinary experts could visit a wetland and render opinions about each of its functions. However, few project applicants can afford this, and many do not have access to personnel who are knowledgeable of wetland biogeochemistry as well as hydrology, botany, aquatic biology, and wildlife, as would be necessary to properly assess all important wetland functions. Agencies responsible for managing and protecting Atlantic Canada's wetlands do not have the unlimited staff to provide such services and expertise, either. Thus, a need has existed for a tool that can be applied rapidly by one trained person during a single visit to a wetland, which standardises the data collected and the way it

is interpreted, to indirectly yield *relative* estimates of a wide variety of important wetland functions while at the same time having some basis in science.

Table 1. Wetland functions and other attributes scored by Tidal WESP-AC in Atlantic Canada.

| **Function** | **Definition** | **Potential Benefits** |
|---|---|---|
| Storm Surge Reduction | The effectiveness for buffering surges of tidal water for short periods before they reach vulnerable uplands. | Flood control, protect shoreline structures from erosion. |
| Water Purification | The effectiveness for intercepting and filtering suspended inorganic sediments thus allowing their deposition, as well as reducing energy of waves and currents, resisting excessive erosion, and stabilising underlying sediments or soil. | Maintain quality of coastal waters. Protect shoreline structures from erosion. |
| Organic Nutrient Export | The effectiveness for producing and subsequently exporting organic nutrients (mainly carbon), either particulate or dissolved. | Support food chains in coastal waters. |
| Fish Habitat | The capacity to support an abundance and diversity of native fish (both anadromous and resident species) | Support recreational and ecological values. |
| Waterbird Habitat | The capacity to support or contribute to an abundance or diversity of waterbirds, mainly those that migrate or winter in the region. | Support hunting and ecological values. |
| Songbird, Raptor, & Mammal Habitat | The capacity to support or contribute to an abundance or diversity of native songbird, raptor, and mammal species and functional groups, especially those that are most dependent on tidal wetlands or water. | Maintain regional biodiversity and food webs. |
| Biodiversity Support | The capacity to support or contribute to a diversity of native plant and animal species, communities, and/or functional groups. | Maintain food webs and system stability. |
| Stability* | The potential for long term persistence of a tidal wetland in the face of direct or indirect effects of sea level rise. | Protection of the above functions & benefits. |
| Public Use & Recognition* | Prior designation of the wetland, by a natural resource or environmental agency, as some type of special protected area. Also, the potential and actual use of a wetland for low-intensity outdoor recreation, sustainable consumptive uses, education, or research. | Commercial and social benefits of recreation. Protection of prior public investments. |

* a tidal wetland attribute that is not considered a function

As a standardised approach, WESP-AC provides consistency and comparability when using wetland functions as a way to prioritise wetlands. It also can be used to assess the consequences of wetland alterations, in terms of the wetland functions that may be affected and the likely direction of change. WESP-AC's assessment of a specific wetland function may not always be more accurate than ratings of that wetland made by someone who is a specialist on a specific wetland function, particularly if such a person

is experienced locally. However, such multi-discipline expertise is seldom routinely available to wetland regulators for every function of concern.

WESP-AC uses visual assessments of weighted ecological characteristics (indicators) to generate the scores and ratings for a wetland's functions. For measuring indicators, the cost and time requirements of more sophisticated and accurate techniques and equipment, such as LiDAR (e.g., Millard et al. 2007), unfortunately makes them not feasible for widespread use as part of wetland regulatory programs. They may, however, be appropriate for use in monitoring of larger restoration projects. Other limitations of WESP-AC are described in section 1.5.

The number of indicators that WESP-AC uses to estimate a particular wetland function depends on which function is being assessed. The indicators are combined in a spreadsheet using mathematical formulas (models) to generate the score and rating for each wetland function. The models together provide a profile of "what a wetland does."

Each indicator has a suite of *conditions,* e.g., different categories of percent-slope. For each wetland function, weights have been pre-assigned to all conditions potentially associated with each indicator used to predict the level of that function. The weights can be viewed in column F of the individual worksheets (tabs at bottom) contained in the calculator spreadsheet. Indicator selection was based on the author's experience and review of much of the literature compiled initially in an indexed bibliography of science relevant to functions of Atlantic Canada's tidal wetlands. Further details about the development of WESP-AC are provided in Section 3.

Unfortunately, several important functions of tidal wetlands, such as carbon sequestration and support of shellfish and other intertidal invertebrates, were not included. That was because scientific information pertinent to this region was judged to be insufficient to support indicators that could be observed rapidly and accurately during a single site visit, in order to yield credible rankings of any series of tidal wetlands with regard to those functions. Some other functions known to occur commonly in *non*-tidal wetlands were excluded from the tidal WESP-AC because they seldom occur in tidal wetlands or when they do, they provide little benefit to humans or ecosystems. Those include groundwater recharge, water storage, stream flow support, amphibian habitat, and water cooling.

Nature is complex but fortunately there is a growing capacity to illustrate and encode some of nature's complexity in computer models. WESP-AC attempts to do so, while

avoiding the use of coding that would be so complex most users wouldn't be able to easily see or understand all the steps in the calculation of the wetland function scores.

## 1.2 Conceptual Basis

Fundamentally, the levels and types of functions that wetlands individually and collectively provide are determined by the processes and disturbances that affect the movement and other characteristics of water, soil/sediment, plants, and animals (Zedler & Kercher 2005). In particular, the frequency, duration, magnitude and timing of these processes and disturbances shapes a given wetland's functions (Smith et al. 2008). Climate, geology, topographic position, and land use strongly influence all of these. Well-functioning wetlands can reduce the need for humans to construct and maintain some types of expensive infrastructure at other locations that would otherwise be necessary to perform the same services, such as treating stormwater before it damages estuarine resources (Costanza et al. 1987, Finlayson et al. 2005).

Despite popular perceptions, high-functioning wetlands are not always healthy and intact or healthy wetlands are not always high-functioning. This is true for at least two reasons: (1) There exists no widely-accepted scientific definition of wetland "health" (or integrity, or ecological condition, or "intactness") or accepted protocols for measuring any of those concepts comprehensively, and (2) No single tidal wetland, regardless of how intact, pristine, or biodiverse it may be, can provide all functions at a high level because some wetland functions operate naturally in opposing directions. Thus, it is inappropriate to describe a wetland as having "high function" or being "highly functional" without specifying the function or combination of functions to which one is referring and how they are being weighted. No research has yet confirmed that maintaining biodiversity alone will preserve all or perhaps even most wetland functions that are important at local, watershed, or province-wide scales. Any correlation will depend on how functions and health are measured, the types of stressors to which particular wetlands are being exposed, spatial variation of natural factors within the landscape, and other influences.

## 1.3 WESP-AC Origins, Evolution, and Regionalisation

This tidal WESP-AC is a regionalised modification of WESP, the Wetland Ecosystem Services Protocol (Adamus et al. 2016 and updates). WESP and WESP-AC build upon indicator-function relationships first described by the author in the early 1980s and in several agency publications since then (Adamus 1983, Adamus et al. 1987, Adamus et al. 1982, Adamus 1982a, 1982b). From 2006 to 2009 a regionalisation of WESP was

conducted in Oregon, resulting in ORWAP[1], the Oregon Rapid Wetland Assessment Protocol (Adamus et al. 2009, recalibrated and updated in 2016). That version is now required for all major wetlands permitting and compensation in Oregon. Another WESP regionalisation was developed and field-calibrated during 2016 for all intertidal habitats (not just salt marshes) in Southeast Alaska, for the U.S. Fish and Wildlife Service[2] .

The basic steps of the WESP regionalisation process were:

1. Identify and review technical literature from the region and other regions as relevant. Use that review to modify or add to the indicator variables that WESP uses to assess wetland functions.
2. Select a set of wetlands to which WESP-AC will be applied in order to (a) calibrate and normalise WESP-AC scores to those of wetlands in the particular region, and (b) identify technical weaknesses in the WESP indicators, assumptions, and models as applied to the region and correct those.
3. Collect WESP-AC data from the calibration wetlands.
4. Modify as needed and then complete the calculator and manual.

Details of these steps are described as follows.

### 1.3.1 Literature Review

To better understand relationships among variables that might indicate functions of Atlantic Canada tidal wetlands specifically, it was first necessary to identify and read previously published studies. The author used keyword searches of *Web of Science* and *Google Scholar* to identify those. An indexed database:

BibliographySortable_TidalWetlands_Maritimes.xlsx

was created that allows the 404 citations to be sorted quickly by topics. Most of the citations refer to peer-reviewed scientific publications. During the creation of WESP-AC, the abstracts of all (and sometimes the entire publication) were read. The database was used to inform decisions about using particular variables in the WESP-AC tidal wetland models, as well as to support generally the weights assigned to various conditions of each function's indicators.

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[1] http:// http://www.oregon.gov/dsl/WW/Pages/ORWAP.aspx

[2] WESPAK-SE (Wetland Ecosystem Services Protocol for Southeast Alaska): http://southeastalaskalandtrust.org/wetland-mitigation-sponsor/wespak-se/

While developing this tidal version of WESP-AC, the following documents were found to be particularly useful in understanding the regional setting:

Allard, K., A. Hanson, & M. Mahoney. 2014. *Important Marine Habitat Areas for Migratory Birds in Eastern Canada*. Technical Report Series Number 530, Canadian Wildlife Service, Sackville, NB.

Davis, D.S. and Browne, S. 1996. *Natural History of Nova Scotia: Topics and Habitats* (Vol. 1). Nova Scotia Museum, Halifax, NS.

Hatcher, A. & D. Patriquin (eds.). 1981. Saltmarshes of Nova Scotia: A Status Report of the Salt Marsh Working Group. Institute for Resource and Environmental Studies and Department of Biology. Dalhousie Univ., Halifax, NS.

Greenlaw, M.E., Gromack, A.G., Basquill, S.P., Agatsuma, Y., MacKinnon, D.S., Lynds, J.A., Taylor, R.B., Utting, D.J., Hackett, J.R., Grant, J. and Forbes, D.L. 2013. A physiographic coastline classification of the Scotian Shelf bioregion and environs: the Nova Scotia coastline and the New Brunswick Fundy Shore. *CSAS Research Document 51*, Canadian Science Advisory Directorate, Fisheries & Oceans Canada, St. Andrews, NB.

Manuel, P.M. 1992. A landscape approach to the interpretation, evaluation and management of wetlands. Dissertation. Dalhousie Univ., Halifax, NS.

Neily, P.D., Quigley, E., Benjamin, L., Stewart, B. and Duke, T. 2003. *Ecological Land Classification for Nova Scotia*. Nova Scotia Department of Natural Resources, Renewable Resources Branch, Halifax, NS.

Webb, K.T. and Marshall, I.B. 1999. *Ecoregions and Ecodistricts of Nova Scotia*. Crops and Livestock Research Centre, Research Branch, Agriculture and Agri-Food Canada, Truro, NS.

Ecological Classification Working Group. 2003. *Our landscape heritage: the story of ecological classification in New Brunswick.* New Brunswick Department of Natural Resources and Energy, Fredericton, NB.

### 1.3.2 Selection of Regional Calibration Wetlands

Although each of WESP-AC's scoring models has a *theoretical* minimum score of 0 and a maximum of 10, the *actual* range for any given function is usually narrower, even when WESP-AC is applied to a large number of wetlands. Moreover, in such an application, the resulting range of the raw scores found among all sites may be quite narrow (e.g., 3 to 8) for some functions whereas for others it may be broad (e.g., 0 to 10). Thus, to facilitate rough comparisons among functions, all raw scores are converted mathematically to the same 0 to 10 scale. This is done by comparing them with the range of scores determined for all the tidal wetlands that were visited and assessed in the region (Figures 1-4). This comparison process is termed "calibration" or "normalisation."

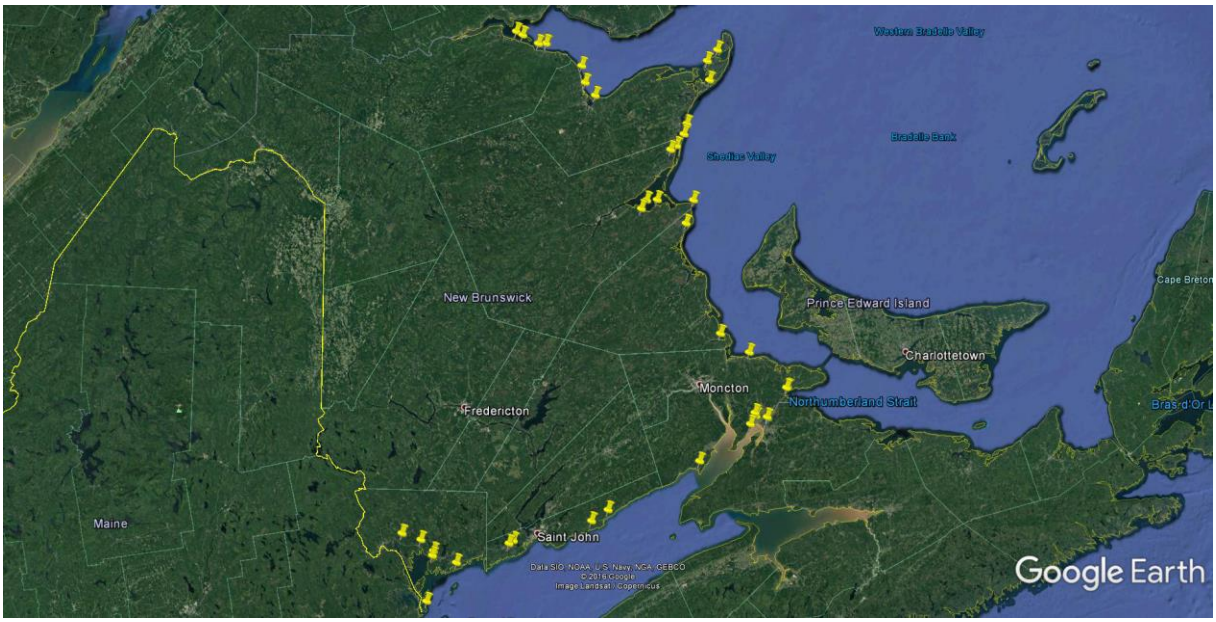


Figure 1. Locations of tidal WESP-AC calibration sites visited in New Brunswick in 2016.

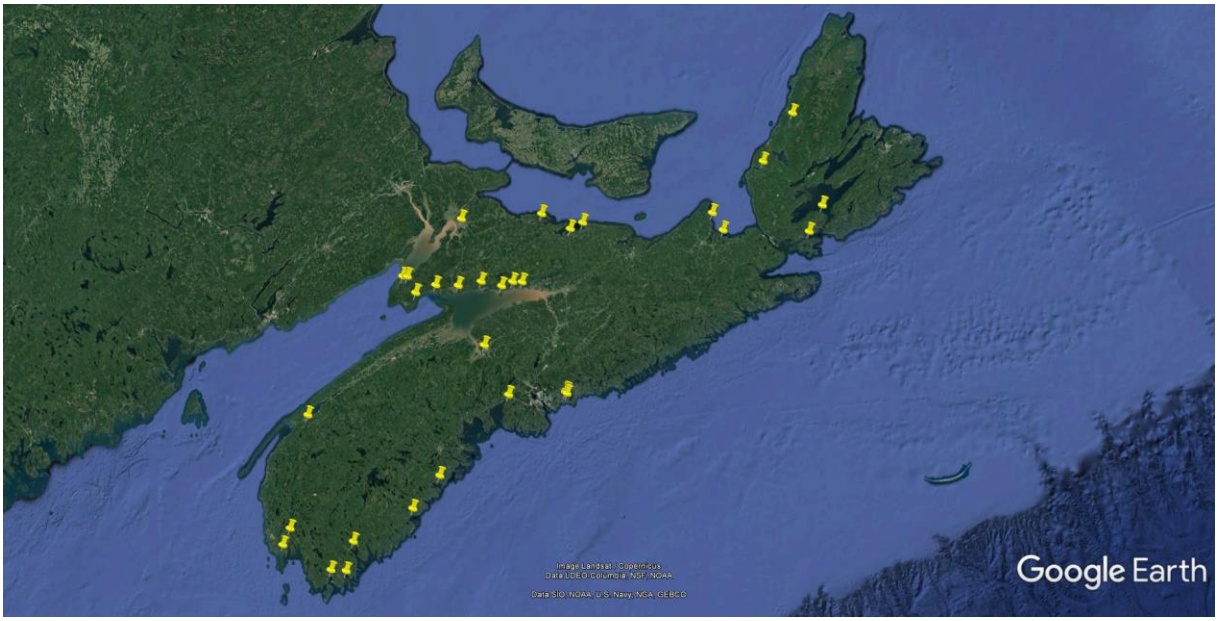


Figure 2. Locations of tidal WESP-AC calibration sites visited in Nova Scotia in 2016.

Figure 3. Locations of tidal WESP-AC calibration sites visited in Newfoundland-Labrador in 2017

Figure 4. Locations of tidal WESP-AC calibration sites visited in PEI in 2017.

The wetlands that served as this base of comparison were chosen in a systematic manner from a regional population of over 5000 mapped tidal wetlands. The calibration wetlands were not selected in a statistically random manner because our objective was to define the likely range of WESP-AC score variation with as few wetlands as possible -- not to use a sample to characterise the condition of tidal wetlands in the study area generally. Our non-random but systematic sample from the combined wetland layers was limited to wetlands located within 30 m of roads because wetlands located farther would require too much time to access.

Because the conditions of the WESP-AC indicators could not be determined prior to field inspection, we used existing spatial data available for all or most of the region as surrogates for some of our indicators which otherwise would more accurately be determined on-site. Doing so required (1) identifying those relevant layers, (2) using GIS to intersect them with the layer showing all the region's mapped wetlands that exist within a 30-m road-proximate buffer, (3) compiling the spatial data for each wetland in an Excel database, and (4) conducting a k-means cluster analysis to place each of the road-proximate wetlands into one of several groups based on similarity of the wetland's attributes (as represented by existing spatial data) with those of the other mapped tidal wetlands.

The number of groups (50 for New Brunswick, 30 for Nova Scotia) we specified *a priori* for the clustering was based on the maximum number we initially estimated could be visited and assessed by field personnel within the time available for the calibration field effort. Our objective was to assess at least one wetland from each of the clusters because that approach would most likely maximise the variation in indicator variables and thus scores for functions. Attributes used to define the statistical clusters included size (area), presence/absence of an intersecting stream or river, geography, and surrounding land cover. We did not assess 9 of the 50 New Brunswick clusters and 2 of the 30 Nova Scotia clusters (in NB some statistical clusters were found to be comprised entirely of non-tidal wetlands that we had misclassified as tidal during the GIS processing). For PEI, we dispersed the 16 calibration sites geographically along the coast and included a mix of both brackish and saline marshes. In NL, 1-4 tidal wetlands per ecoregion (for ecoregions that had tidal waters) were visited and assessed, for a total of 38 (30 in Newfoundland, 8 in Labrador).

### 1.3.3 How Field and Office Components Were Completed

Visiting and assessing a wide variety of tidal wetlands was essential not only to calibrate the indicators and model scores as described previously, but also to clarify the wording of questions on the data forms. Thus, limited parts of the data forms (but not the formulas in the scoring models) were changed iteratively by the author in the midst of the field efforts. Revisions were made in response to field observations of the author and field crews. The changing of questions throughout the data collection effort could potentially complicate data interpretation. However, close track was kept of revisions made to the data forms, allowing all data to later be successfully "cross-walked" to the final version.

Field data alone are insufficient to accurately score a tidal wetland's functions. Additional data must be obtained and interpreted from aerial images and existing databases. After site visits had been completed, the author used Google Earth and provincial interactive mapping web sites to answer questions on Form OF as described in section 2.3.

Raw and normalised function scores for each of the calibration wetlands visited and assessed are presented in the **Scores_TidalCalibSites** worksheet for each province in the **SuppInfo_tidal_WESP-AC** Excel file that accompanies this report.

## 1.4 Limitations

WESP-AC is not intended to answer all questions necessary for wetland decisions. Users should understand the following important limitations:

1. WESP-AC users must be able to:

- delineate a wetland boundary according to formal governmental definitions and guidance, or utilise the services of someone knowledgeable of the guidance and having that specialised skill,
- recognise most of the plants that occur in tidal wetlands in this region (list in Appendix A),
- determine soil texture broadly (coarse, loamy, organic, or fine),
- understand local climate and tides.

The WESP-AC Tidal Calculator requires the user to visit the tidal wetland only once, and during (or close to) daily **high** tide. However, the ability to observe many indicators of wetland function varies dramatically throughout a tidal cycle, as well as from year to year and within a growing season. Thus, the accuracy of results will be greater if users are able to visit a site during different tidal and seasonal conditions, or are at least familiar with the changes in those conditions that typically occur locally. This may require consulting with landowners or others who know that, and examining aerial images taken at different times.

3. For the portion of WESP-AC which incorporates existing digital data, it is understood that many of those data were originally created at scales much coarser than represented by maps of the region's tidal wetlands. Consequently, when those data are interpolated to the scale of an individual wetland, some of the data are likely to be inaccurate. Also, some of the conditions described by the spatial data, such as land ownership boundaries, may have changed since the layer was created. Nonetheless, the advantages of judiciously using the existing spatial data, as just one component of each tidal wetland's WESP-AC scores, were felt to outweigh the disadvantages.

4. WESP-AC scores only indicate a tidal wetland's functional effectiveness relative to other tidal wetlands in the NB-NS region. Intensive or long-term field measurements might subsequently determine that even the tidal wetlands scored lowest by WESP-AC are, in fact, performing a particular function at a very high absolute level, or some tidal wetlands that score very high are found to barely provide the function (see section 3 for more on model validation). This is because the numeric estimates that WESP-AC provides of wetland functions are *not actual measures* of those attributes, and WESP-AC does not combine the data using deterministic models of ecosystem processes. Rather,

the scores, like those of most rapid assessment methods (Hruby 1989), are estimates arrived at by using standardised criteria (models).

There is an inherent conflict in attempting to develop a rapid assessment method based on science without over-simplifying complex natural systems to the point of disconnect. The sponsors are fully aware of this conflict and its implications. While it has been necessary for WESP-AC to employ some untested assumptions, those assumptions are based on scientific principles and the limited technical literature.

5. As is true of all other rapid assessment methods, WESP-AC's scoring models have not been validated in the sense of comparing their outputs with those from long-term direct measurement of wetland processes. That is the case because the time and cost of making the measurements necessary to fully determine model accuracy would be exorbitant. Nonetheless, the lack of validation is not, by itself, sufficient reason to avoid use of any standardised rapid method, because the only practical alternative—relying entirely on non-systematic judgments (best professional judgment)—is not demonstrably better overall. When properly applied, WESP-AC's scoring models and their indicators are believed in most cases to adequately describe the *relative* effectiveness of a wetland for performing particular functions.

6. WESP-AC converts raw scores to estimates of relative wetland function and then normalises these to the scores of the tidal wetlands that were assessed in each province. This is necessary to facilitate comparisons among levels of functions by spreading out their raw scores to fully encompass a 0 to 10 scale. However, because the statistical distribution of the scores for any given function differs from those of others (some functions skew low, others high), the scores of different functions are not comparable in the strictest sense.

7. It is possible that two WESP-AC users, viewing the same wetland, will interpret some indicator questions differently. This could result in different scores for one or more of the wetland functions or attributes. This is true regardless of whether they use WESP-AC, another tool, or their professional judgment. However, when other versions of WESP were tested in different regions (Oregon, Alaska, Alberta) the statistical confidence intervals around the scores, depending on the particular function, averaged ± 0.76 of the score mean on a scale of 0 to 10. That means, for example, that a score of 6.00 could be interpreted as actually being between 5.24 (6.00 - 0.76) and 6.76 (6.00 + 0.76). By most standards this would be considered to be a high level of repeatability. The relative narrowness of the score variance among users stems partly from the fact

that some WESP indicators are intentionally redundant, and averaging is often used to combine indicators in the WESP models.

8. WESP-AC may be used to augment the data or interpretations of a subject professional (e.g., a fisheries biologist, plant ecologist, ornithologist, oceanographer) when such expertise or finer-resolution data are available. WESP-AC outputs, like those of other rapid methods, are not necessarily more accurate than judgments of a subject expert, partly because WESP-AC's spreadsheet models lack the intuitiveness and integrative skills of an actual person knowledgeable of a particular function. Also, a model cannot anticipate every situation that may occur in nature. WESP-AC outputs should always be screened by the user to see if they "make sense." Nonetheless, WESP-AC's scoring models provide a degree of standardization, balance, and comprehensiveness that seldom is obtainable from a single expert or limited set of measurements.

9. WESP-AC's logic-based process for combining indicators has attempted to reflect currently-understood paradigms of wetland hydrology, biogeochemistry, and ecology. Still, the scientific understanding of tidal wetlands in this region is far less than optimal to support, as confidently as some might desire, the models WESP-AC and other rapid methods use to score wetland functions.

10. WESP-AC does not assess *all* natural functions that a tidal wetland might support. Those which it addresses are ones ascribed to tidal wetlands most commonly in this region, and which also are susceptible to estimation using indicators (metrics) that can be observed during a single visit to a wetland at daily high tide, analysis of existing spatial data, and manual interpretation of aerial images.

11. Science is constantly evolving as new studies refine, refute, or support what currently is known. It is incumbent that planning tools keep pace with new findings and their models be revised at regular intervals, perhaps every 5-10 years, to reflect that. This poses challenges to wetland regulatory programs if necessary revisions to a method create a "moving target".

12. WESP-AC does not assess the suitability of a tidal wetland as habitat for any individual wildlife or plant *species*. Models of greater accuracy, using the same spreadsheet calculator and modeling framework that WESP-AC uses, could easily be created for individual species, for more specific biological guilds (e.g., ducks vs. shorebirds instead of Waterbird Habitat) and functions (export of dissolved vs. particulate carbon instead of Organic Nutrient Export). However, as functions are split

into finer categories, the amount of output information increases, perhaps gaining accuracy and specificity but losing simplicity in the interpreting and applying of results.

13. In some wetlands, the scores that WESP-AC's models generate may not be sufficiently sensitive to detect, in the short term, mild changes in some functions. For example, it is unknown whether WESP-AC can meaningfully quantify small year-to-year changes in a slowly-recovering restored wetland, or minor changes in specific functions as potentially associated with limited "enhancement" activities such as relict channel plugging. Nonetheless, in such situations, WESP-AC can use information about a project to predict at least the *direction* of change to all functions as a result of some action. Quantifying the actual change will often require more intensive (not rapid) measurement protocols that are complementary.

14. WESP-AC outputs are not intended to address the important question, "Is a proposed or previous wetland creation or enhancement project in a *geomorphically appropriate* location?" That is, is the site in a location where key processes can be expected to adaptively sustain the wetland and the particular functions which other wetlands of its type usually support, e.g., its "site potential?" (Millard et al. 2013). Although WESP-AC uses many landscape-scale indicators to estimate wetland functions, WESP-AC is less practical for identifying the relative influence of multiple *processes* that support a single wetland.

# 2.0 Procedures for Using WESP-AC

## 2.1 General

1. If training in the use of WESP-AC is offered by an agency-approved trainer, attend that training, which generally lasts 2 or 3 days. Although training is not required at this time, your attendance at a training is strongly encouraged. In any case you must have read this manual as well as any definitions or other sidenotes in the last column of data forms OF and T which are in Appendix A.

2. Obtain the most recent version of this manual, the WESP-AC Tidal calculator spreadsheet, and supporting files from provincial government or from:
http://people.oregonstate.edu/~adamusp/
and open the folder Atlantic Maritimes Wetland Assessment Tools, then the folder Tidal WESP-AC.

3. Assuming the province has mapped your area of interest as a tidal wetland ("salt marsh" or other), you should **use the boundary of the tidal wetland polygon on that map** to define the area for which you will attempt to answer the questions on data forms T and OF, generating scores for the functions. Identify one or more safe and legal access points that are likely to give you the best view of that area.
However:

**a.** If the mapped tidal wetland is enormous, as many are, you may not be able to provide a reasonably accurate or complete answer to some of the field-based questions on form T, let alone walk safely in much of the wetland as it has been mapped. In that case, on an aerial image draw the approximate boundary of what you can see from your chosen access point(s) and by walking into the wetland as safely as possible from there. This sub-area within the tidal wetland polygon which you are able to explore or reasonably view from a distance is called the **Assessment Area (AA)**. Even though you will not be able to walk into all of it during high tide, the AA should include at least a portion of the part of the wetland that is flooded at high tide, e.g., the low marsh. Be sure to read the instructions in the header of Form T. The AA should also include the marsh's internal tidal channels (those that are narrower than the wetland) even though they may lack vegetation.

**b.** You may adjust slightly the boundary of the tidal wetland polygon shown on the provincial map if recent aerial imagery or field observations suggest an adjustment is physically warranted, e.g., recent expansion of an existing marsh due to restoration of tidal inflow to an adjoining dyked (previously non-tidal) area.

**c.** If your site adjoins a river or stream (i.e., riparian wetland) and provincial maps label it as being a freshwater marsh, bog, or other wetland, it is possible that it may actually meet WESP-AC's definition of tidal wetland. If you are in NB or NS, you can determine its status by locating the nearest head of tide point on the associated river or stream by opening the **NB_HeadOfTide** and **NS_HeadOfTide** KMZ files distributed with WESP-AC and viewing them in Google Earth. If your riparian wetland is downriver from the reported head-of-tide, there is a strong possibility that it actually is a tidal wetland by WESP-AC definition. During your site visit, determine if at least part of your site receives river inflow via ditches, culverts, or berm spill-over during the highest annual tide and/or river discharge. Attempt to determine this by asking adjoining landowners, observing recent water marks on trees at the projected time of daily low tide, and looking for seaweed or other debris of obvious marine origin, possibly scattered among trees and shrubs within the river's floodplain.

**d.** If provincial maps do not identify <u>any</u> wetland at this location but you know one to be present, use aerial imagery and field observations to draw approximate boundaries on an aerial image. Verify it is a tidal wetland as described in (c.) above. If distinct units of vegetated tidal wetland are located discontinuously along a river shoreline, any two adjoining units separated by non-wetland can be combined if the distance separating them, measured parallel to flow, is less than the length of the larger of the two vegetated wetlands, measured parallel to flow.
**e.** The upper (landward) boundary of your tidal wetland is the HHWMT, that is, the higher high water mean tide. This is the farthest (highest) reach of tide-associated flooding during an average year. In forested landscapes near the ocean, it is often at or near the tree line, since most woody plants do not germinate well where there is prolonged high salinity. In other landscapes, it is marked by a gradual shift in dominance from wetland indicator plants (e.g., seaside plantain and cordgrass) to grasses, forbs, or shrubs more typical of uplands. In some places driftwood accumulations mark the approximate HHWMT line.

## 2.2 Before the Site Visit

1. Consult tide tables (online or otherwise) for the location closest to your wetland[3]. You must visit your site at or near the time of **high tide** for that location. Therefore, from the tide table, note the **time** of the daytime high tide projected for the day you intend to visit. Also note its **height**. Record these on the **CoverPage** data form (in Appendix A).

2. While examining tide tables, calculate the **annual tidal range** for that location closest to your wetland. You will need this to answer WESP-AC's question OF18, and it will also help you estimate the landward boundary of your tidal wetland during your visit. Read the instructions in the last column of question OF18.

3. Open Google Earth, zoom to the wetland, and on WESP-AC's Cover Page data form, record the coordinates of the approximate center of your wetland and (if different) the AA. Also write down coordinates of access points where you can best view the wetland, so you can quickly drive to those using GPS navigation.

[3] www.tides.gc.ca or www.mobilegeographics.com

4. Also in Google Earth, click on the sundial icon in the toolbar in the middle top of the page and see if there are aerial images for your wetland that show conditions during other tidal phases, seasons, and/or years. Print the best of those to take in the field.

5. Open the WESP-AC calculator spreadsheet, click on the tab labeled "OF" (for office or off-site) and answer all questions. You do not need to print a blank copy of this worksheet because you will be answering the questions directly on a computer. Some questions require you to view, in Google Earth, information from the KMZ files that are being distributed with this tidal version of WESP-AC. See Appendix B for instructions.

6. After answering all the OF questions in the spreadsheet, give the file a name that describes it uniquely, e.g., Moncton_23. Print a copy to take along when you visit the wetland.

7. As you prepare for the site visit, take the following: salinity or high-range conductivity meter, GPS, trowel, Plant List data form, Cover Page, data form T, data form OF (completed), aerial image with coordinates, smartphone or camera that is set so that it geo-tags and dates the photographs you will take, clip board, pencil, other items you'd normally take in the field. Binoculars are recommended to help you answer some questions if the wetland is wider that about 50 m.

8. If you are uncertain of your ability to recognise the **exotic plant species** that are known to occur along the upland edge of this region's tidal wetlands, go online and memorise their photos before visiting the wetland or use a field guide. See question T9 on data form T for list of exotic species you should know.

9. Similarly, if you are uncertain of your ability to differentiate most of the species on the **Plant List** data form (in Appendix A), view images of those online and/or in reference books *before* you visit the wetland.

## 2.3 During the Site Visit

10. Spend no less than 10 minutes identifying plants while walking through safely-accessible parts of the AA. Mark the species on the Plant List data form as you go. If a species isn't listed, add it only if it is a dominant or is a species strongly associated with tidal wetlands.

11. For question T14, determine the soil texture category nearest the ground surface after removing dead leaves and other loose non-soil materials. You will be asked to

categorise the soil simply as *Organic, Peat, Clayey, Loamy,* or *Coarse*. Use the *Soil Composition by Feel* diagnostics flow chart in Appendix B.

12. For question T17, measure salinity (in ppt) with a calibrated meter, below the water surface in flowing water (not in pannes), as distant as possible from any fresher tributaries.

13. Fill out the rest of data form T, paying attention to all the explanatory notes and definitions in the last column. If possible, ask for assistance from the adjacent landowner or other knowledgeable source to estimate the following:

- how extensively the wetland floods at the highest annual and highest monthly tide during most years,
- how far out into the adjoining bay or river the vegetation extends during the average daily low tide.

14. Check to be sure every question was answered and all data were correctly entered. Also review the answers you earlier provided on Form OF, and change any responses which observations during the subsequent on-site visit suggested were inaccurate.

15. Take photos of the marsh from an elevated point.

16. On the aerial image, draw the approximate boundary of the AA (i.e., the part of the wetland you focused on while answering the form T questions).

## 2.4 After the Site Visit

17. Enter the data (if any) from the Plant List and data form T into the corresponding worksheets in the WESP-AC calculator spreadsheet – the one in which you already answered the worksheet OF questions.

18. With the coordinates of your site, submit a request to the Atlantic Canada Conservation Data Centre (ACCDC) for any records they have of rare species they track that have been detected within 1 km of those coordinates. You will need that information for question OF25.

19. Review the resulting function scores and ratings in the Scores worksheet. See section 2.5 below.

20. If you are submitting this in support of an application for wetland approvals or as

documentation of restoration progress, provide the recipient agency or organization with:

___your completed spreadsheet, including the Cover Page with the time and date of visit, tidal conditions, and other requested information

___aerial image of the site showing boundaries of the wetland and (if different) the portion you were able to observe (the AA)

___ground-level photos showing surface water (if any) and the dominant plants

If you wish, you may enter data from multiple wetlands in a single WESP-AC calculator spreadsheet. To do so, start a new data column for each site, beginning in column E, with a unique ID label at the top of the column. Then enter its data. You will need to manually count the number of species on the Plant List data form and enter it for question T18. Then for each site, copy the data from BOTH worksheet OF and worksheet T and paste it into column D of those worksheets, pasting it on top of (replacing) data already there from the preceding site. Finally, go to the Scores worksheet, copy that table containing the scores, and use the Paste-**Values** command of Excel to paste it into a separate spreadsheet. Repeat this process for each site, moving across the columns (sites) from left to right.

## 2.5 Reviewing the Output

Before accepting the scores and rating provided by the calculator, think carefully about those results. From your knowledge of wetland functions, do they make sense for this wetland? If not, review the worksheet for that function as well as the model descriptions in section 4 to see how the score was generated. If you disagree with the results, write a few sentences explaining your reasoning. Remember, WESP-AC is just *one* tool intended to help the decision-making process, and other important tools are your common sense and professional experience with a particular function, wetland type, or species. Review again the caveats given in the Limitations section (section 1.5).

If you believe some of the scores which WESP-AC generated do not match your understanding of a particular wetland function or other attribute, first examine the summary of your responses that pertain to that by clicking on the worksheet named for that function. If you want to reconsider one of your responses (perhaps because you weren't able to see part of the AA or view it during a preferred time in the tidal cycle), change the 0 or 1 you entered on form T. Then check the Scores worksheet to see what effect that has.

You may do the same (changing various 0's and 1's) if you'd like to simulate the potential effect on function scores of an enhancement or restoration measure, or the impact on those scores from some controllable or uncontrollable alteration or management activity within the AA or wetland, its catchment, or surrounding landscape. Note that WESP-AC is not intended to *predict changes* to a wetland – only to estimate the likely direction and relative magnitude shifts in various functions if specific wetland characteristics are altered. However, if proposed changes to a wetland are projected to cause little or no change in a particular function score, it cannot be assumed automatically that no impacts will occur. That is because WESP-AC is a fairly coarse tool and no method or model is capable of anticipating all possible changes.

## 2.6 Interpreting Function Scores and Ratings

Solely to make the results more understandable, a three-level categorical rating (Lower, Moderate, Higher) was assigned to each function score. A four- or five-level categorisation could alternatively been used. The thresholds used to separate these categories are shown in Apppendix C and are based on natural breaks in the statistical distribution of scores among the calibration wetlands for **each** function, determined objectively using a statistical procedure known as Jenks Optimisation (Jenks 1967). ***Note that different wetland attributes use different numeric thresholds to define associated ratings***. This leads to a situation where, say, a score of 4.21 gets a rating of Lower for one function or attribute but Moderate or Higher for another. That occurs because each attribute has a different statistical distribution, resulting in different locations of natural breaks in the scores from the series of calibration wetlands. This uneven statistical distribution of scores occurs partly because of unavoidable characteristics of the indicators and the ways the indicators are combined by the models.

# 3.0 Principles Used to Score the Indicators and Structure the Models

## 3.1 Introduction

Many models in ecology and especially hydrodynamics are deterministic. That is, rates are first estimated or measured for individual processes that comprise (for example) a tidal channel function, and then mathematical formulas (e.g., hydraulic or thermodynamic equations) are prescribed to combine variables that determine those processes into an actual rate for a function, e.g., grams of phosphorus retained per

square meter per year. However, in the case of tidal wetlands, measurements of the processes and the variables that determine them do not exist in this region or are of unknown applicability. Thus, WESP-AC uses a different approach to model the various things that wetlands do naturally. Rather than being deterministic, that approach is at times speculative but logic-based. Such approaches are regarded as an interim or alternative solution when knowledge of system behaviour is scant (e.g., Haas 1991, Starfield et al. 1994).

## 3.2 Indicators

For the WESP-AC models, physical or *indicators* of functions were chosen and applied (The term *indicators* is roughly comparable to the term *metrics* used by some other methods). The indicators then were phrased as questions in the data forms. Most of WESP-AC's field-level indicators are based on visual estimates, not *measurement*. While the *precision* of measurements is typically greater than for visual estimates, their *accuracy* in predicting functions may or may not be. That is because it is often difficult to obtain sufficient measurements of an indicator, in the span of time typically available to wetland regulators or consultants, to create a full representation of any particular indicator of wetland function, let alone the 44 indicators needed to reasonably assess a common suite of tidal wetland functions in this region.

WESP-AC's indicators were mainly drawn from inferences based on scientific literature and the author's experience throughout North America (e.g., Adamus et al. 1987, 2013, Adamus et al. 1992, 2009, 2015, 2016). Indicators used by other methods for rapidly assessing functions of wetlands were also considered. To qualify as an indicator, a variable not only had to be correlated with or determining of the named function or attribute, but it also had to be rapidly observable during a single high-tide visit to a typical tidal wetland during the growing season, or information on the indicator's condition had to be obtainable from aerial imagery, existing spatial data, and/or interview with an adjacent landowner.

When developing models of any kind, the factors that contribute to the output can be categorised in three ways: (1) unknown influencers, (2) known influencers that are difficult to measure within a reasonable span of time, and (3) influencers that can be estimated visually during a single visit and/or from existing spatial data. WESP-AC provides an incomplete estimate of wetland functions because it incorporates only #3. Also, some of the indicator variables it uses may be *correlates* of wetland functions rather than actual influencers. For example, changes in water levels are correlated with changes in nutrient cycling, but it is the difficult-to-measure changes in sediment

oxygen and pH that induce the changes in nutrient cycling, not the water level changes themselves (which happen to correlate loosely with those changes in oxygen and pH). These types of limitations apply to all rapid assessment methods.

For regulatory and management applications (e.g., wetland functional enhancement), it's often helpful to understand to which of four categories an indicator belongs (Dorney et al. 2018):
1. *Onsite modifiable*. These indicators are features that may be either natural or human-associated and are relatively practical to manage. Examples are water depth, tidal inundation frequency and duration, and presence of exotic species. More important than the simple presence of these are their rates of formation and resupply, but those factors often are more difficult to control.
2. *Onsite intrinsic*. These are natural features that occur within the wetland and are not easily changed or managed, such as soil type. They are poor candidates for manipulation when the goal is to enhance a particular wetland function.
3. *Offsite modifiable.* These are human or natural features whose ability to be manipulated in order to benefit a particular wetland function depends largely on property boundaries, regulations, and cooperation among landowners. Examples are watershed land use, stream flow in tidal wetland tributaries, and wetland buffer zone conditions.
4. *Offsite intrinsic*. These are natural features such as a wetland's topographic setting (catchment size, elevation) and regional climate that in most cases cannot be manipulated. Still, they must be included in a wetland assessment method because of their sometimes-pivotal influence on wetland functions.

## 3.3 Weighting and Scoring

WESP-AC assigns relative weights or scores at two junctures:
1. Scoring of the *conditions* of an indicator, as they contribute to that indicator's prediction of a given wetland function or other attribute.
2. Scoring of *indicators* (metrics) relative to each other, as they together may predict a given wetland function or other attribute.

Each of these is now described. Note that WESP-AC does not assign weights to the functions that it scores, e.g., does not assume that Waterbird Habitat is any more or less important than Storm Surge Interception.

### 3.3.1 Weighting of Indicator Conditions

As an example of #1, consider the following conditions of the indicator, *High Zone Extent*:

| | | | | |
|---|---|---|---|---|
| High Zone Extent | The percentage of the AA's vegetation that has NO tidal water beneath it during most daily high tides of the year (i.e., the HIGH ZONE) is: | | | 0.33 |
| | none, or <1% and narrower than 2 m. | 0 | 6 | 0 |
| | 1-10% | 0 | 5 | 0 |
| | 10-25% | 0 | 4 | 0 |
| | 26-50% | 0 | 3 | 0 |
| | 51-75% | 1 | 2 | 2 |
| | 75-90% | 0 | 1 | 0 |
| | >90% | 0 | 0 | 0 |

Each row following the first describes a possible *condition* of this indicator. WESP-AC users must select the one condition that best describes the wetland they are assessing (they do so by entering a "1" next to that condition in the column to the right of the text). In the column after that, WESP-AC's author previously assigned relative weights (which cannot be altered by WESP-AC users) to each of these conditions as they relate to the function, in this case *Organic Nutrient Export*. Also in this case, the fifth condition was considered weakly supportive of that function, other factors being equal, and so had been given a weight of 2. This does not necessarily mean it is twice as influential as the first condition which has a weight of 1, because this is not a deterministic model. However, available literature seemed to suggest that this condition is distinctly better than the condition after it and less desirable than the one preceding it. When the same indicator is used to score a different function, the weight scheme might be reversed or otherwise differ.

In many instances, considerable scientific uncertainty surrounds the exact relationship between various indicator conditions and a function, and thus which weights should be assigned. However, keep in mind that the above indicator is just one of 10 indicators used to assign a score to the Organic Nutrient Export function. To some degree, the use of multiple indicators will serve to buffer the uncertainty in our knowledge of exact relationships.

WESP-AC users will also notice that the weighting scale for some indicators ranges from 1 to 8 (especially if there are 8 condition choices) while for others it ranges only from 0 to 2, or some other range. This does not mean that the first indicator is secretly being weighted 4 times that of the second, because before the indicators are combined,

their scores are "standardised" to a 0 to 1.00 scale. The Excel spreadsheet accomplishes that by multiplying the "1" signifying a user's choice (here in the second column) by the pre-determined condition weight in the third column, and placing the product in the last column, whereupon a formula in the green cell (not visible here) takes the maximum of the values in the cells below it and divides by the maximum weight in the condition weight column. The formula in the green cell could just as easily have taken the only non-zero value in the last column beneath it and divided it by the maximum weight pre-assigned to the indicator conditions.

3.3.2 Weighting and Scoring of Indicators of Functions

If one indicator is so important that occurrence of a particular condition of that indicator can solely determine whether a function even exists in a wetland, then conditional ("IF") statements are used in WESP-AC models to show that. For example, if a tidal wetland is behind a berm that connects it to the ocean only via a pipe that is inadequate to allow fish passage, the *Fish Habitat* function is automatically scored "0". In this case, "access" (presence/absence of inlets or outlets) is a controlling indicator. WESP-AC uses averaging as the default operator unless situations can be identified where there is compelling evidence that an indicator is controlling or strongly limiting.

# 4.0 Tidal Wetland Functions and Their WESP-AC Models

The indicators mentioned in the following sections are shorthand versions of complete questions that are defined and explained fully in the WESP-AC data forms: worksheets OF (office form) and T (field form).

## 4.1 Storm Surge Interception

Definition: The effectiveness for intercepting tidal surges associated with infrequent but severe storm events, and reducing their height. Storm-surge elevation is the difference between the observed water level during the surge and the level that the tide would normally rise to in the absence of storm activity.

Scientific Support and Regional Context

Storm surge events result from a combination of changing atmospheric pressure and strong shoreward winds. Damage from storm surges will increase where sea levels are increasing as a result of climate change.

Vegetation in tidal wetlands provides friction, potentially reducing the height of incoming tidal surges and thus protecting coastal infrastructure. The magnitude of potential height reduction attributable to tidal wetlands, compared with that of any comparably flat and wide surface that is seaward of coastal infrastructure, is probably not large. However, even small reductions in surge height can have major economic implications. The rates of surge height attenuation attributable to coastal wetlands have been measured or modeled elsewhere and found to range from 1 m per 4 km of wetland width to 1 m per 50 km of wetland width, depending on storm direction and intensity (Wamsley et al. 2010). Although this region's wetlands do not come close to approaching most of the modeled widths, another study (Stark et al. 2015) measured a surge attenuation rate of 0.7 m per 1 km.

The degree of infrastructure protection from storm surges that is provided by wetlands depends on timing of the surge. Storm surges occurring at high tide are most devastating because wetland vegetation is quickly overtopped and flattened, reducing its frictional contribution to height reduction. Surprisingly, one study found flexible deep-rooted salt marsh vegetation provided more resistance to surges than taller stiff vegetation (Stark et al. 2015). That was because the taller vegetation more easily fractured and then offered almost no resistance.

Within the Maritime provinces, storm surges are likely to be greatest along the coastline adjoining the Gulf of St. Lawrence and Prince Edward Island (PEI) (Savard et al. 2016). In Charlottetown, PEI, a storm surge that occurred at high tide briefly drove water levels to at least 3.6 m above chart datum, and a potential exists for even larger storm surges at that location (Parkes and Ketch 2002). The probabilities of storm surges of various heights have been projected for nearly the entire shoreline of New Brunswick by Daigle (2014) and for Nova Scotia and PEI by Richards & Daigle (2011).

<u>Scoring Model</u>:
[3*Width + AVERAGE(Area, PctHigh, PctKing)]/ 4

*Where:*
Area = Marsh Area
PctHigh = High Marsh Extent
PctKing = Extreme High Marsh as % of Entire High Zone
Width = Marsh Width

By assigning width ¾ of the score, this formula recognises the predominant role of wetland width in attenuating storm surges. Because the formula is intended to only represent wetland function, it does not account for a particular wetland's likelihood of being exposed to storm surges, nor the likelihood of surges causing property damage.

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## 4.2 Water Purification

Definition: Effectiveness for maintaining or restoring naturally-occurring levels of suspended sediment, salinity, inorganic nutrients, metals, hydrocarbons, and other substances in coastal waters.

Scientific Support and Regional Context

In this region, water quality has been measured in connection with monitoring of major permitted industrial and agricultural point dischargers, and also in offshore waters as part of oceanographic studies, but very little monitoring has been done in estuaries and their associated wetlands. Likewise, apparently no research has been published on the ability of some of the region's tidal wetlands to retain or remove excess nutrients and various other chemical substances from upland runoff and wastewater, as has often been documented elsewhere. Heavy metals and hydrocarbons are often bound to suspended sediment, so tidal marshes that are accreting (retaining and depositing sediment over the long term) are most likely to also be purifying the water they receive. Naturally high levels of sulfur in tidal wetlands also favor the chemical bonding, deposition, and retention of many metals.

Scoring Model:

[2*AVERAGE(UpContact, Width, Area)+ AVERAGE(Ditch, SoilCompac)] /3

*Where:*

Area = Marsh Area
Ditch = Ditching Extent
SoilCompac = Soil Compaction Extent
UpContact = % of Perimeter That Is Upland

Width = Marsh Width

By assigning 2/3 of the score to the first set of indicators shown, this formula makes an assumption that they usually have more influence on wetland water purification capacity than do ditching and soil compaction. Because the formula is intended to only represent wetland function, it does not account for a particular wetland's likelihood of being exposed to pollutants originating either from adjoining upland or marine waters, nor does it consider the likelihood that retention of some pollutants in tidal wetlands may harm their plants and animals while simultaneously reducing chemical threats to organisms in adjoining estuarine waters.

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## 4.3 Organic Nutrient Export

Definition: The effectiveness for producing and subsequently exporting organic nutrients, either particulate or dissolved, along with associated compounds and elements such as iron.

Scientific Support and Regional Context

Research listed in the References below supports the hypothesis that at least some of this region's tidal wetlands are net exporters of carbon and perhaps other nutrients essential to supporting nearshore food webs. Especially where naturally high turbidity occurs in nearshore waters, as in the upper Bay of Fundy, the usual role of light-dependent phytoplankton in supporting nearshore food webs diminishes relative to the role of the area's tidal wetland plants. Salt marshes worldwide are renowned for their high productivity, attributable largely to frequent resupply of nutrients by tides. This production, in the form of carbon and nutrients contained in marsh plant foliage, is readily exported by the region's legendary tides, river currents, waves, and in some places by scouring from river and bay ice.

Scoring Model:

3*(UpContact, Waves, TideChan, Tribs, TideAmp, PctHigh, Restrict) + AVERAGE(GrowDays, Bare, Salinity) /4

*Where:*

Bare = Bare Ground or Thatch
GrowDays = Growing Degree Days
PctHigh = High Marsh Extent
Restrict = Restricted Tidal Inflow
Salin = Salinity (measured or estimated)
TideAmp = Tidal Range
TideChan = Extent of Branched Tidal Channels
Tribs = River or Tributary Intersect
UpContact = % of Perimeter That Is Upland
Waves = Wave Exposure

The model specifies that a group of 7 indicators intended to represent physical exporting forces account for 75% of this function's score, and that the remainder be accounted for by a group of 3 indicators intended to partially reflect potential marsh productivity. Tidal wetland width and area are not included because rates (not amounts) of marsh productivity and carbon export, which is what this model is intended to represent, do not necessarily correlate with those indicators.

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## 4.4 Fish Habitat

Definition: The capacity to support an abundance and/or diversity of resident and/or anadromous fish species. Support occur only seasonally or for brief times, and may be for spawning, rearing, or feeding. The scoring model will not predict habitat suitability accurately for every tidal wetland fish species in this region.

Scientific Support and Regional Context

Several fish species, some of direct or indirect commercial or sport value, feed in tidal wetlands during high tides (**Error! Reference source not found.**). A few, such as mummichog, persist and thrive in pools and pannes that remain inundated even during low tides. Although fish have often been surveyed in intertidal areas in the Maritimes,

seldom has the survey effort in this region focused specifically on tidal wetlands, quantifying fish use at different seasons and throughout daily, monthly, and annual tide cycles, as well as across geographic gradients of salinity and tidal amplitude.

Scoring Model:
IF((NoAccess=1), 0, ELSE:
4*AVERAGE (PctHigh, PctKing, Pans) + 2*AVERAGE(Tribs, Wetscape) + AVERAGE(Restrict, TideChan, TideAmp, Ditch)

*Where:*
Ditch = Ditching Extent
Pans = Salt Panne & Pool Extent
PctHigh = High Marsh Extent
PctKing = Extreme High Marsh as % of Entire High Zone
Restrict = Restricted Tidal Inflow
TideAmp = Tidal Range
TideChan = Extent of Branched Tidal Channels
Tribs = River or Tributary Intersect
Wetscape = Extent of Other Marsh in Vicinity

The model first asks if fish can access the tidal wetland. If not, and if the wetland contains no pannes, the score is set to 0. Otherwise, the score depends mostly (4/7) on a group of indicators that describe the inundation frequency of the marsh plain (i.e., fish accessibility) and/or number of pannes that are present. Secondarily (2/7), the positive influence of a tributary or adjoining river is taken into account, as is the extent of other tidal wetlands in the vicinity. Finally, some credit is given for the presence of complex internal channel networks, lack of ditching and partial access restrictions, and naturally low or moderate tidal amplitudes.

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Table 2. Fish species known to occur in salt marshes in the Gulf of Maine region.
from: Neckles & Dionne (2000).

| | |
|---|---|
| Alosa aestivalis (blueback herring) | Morone americana (white perch) |
| Alosa mediocris (hickory shad) | Morone saxatilis (striped bass) |
| Alosa pseudoharengus (alewife) | Mugil cephalus (striped mullet) |
| Alosa sapidissima (American shad) | Myoxocephalus aeneus (grubby) |
| Ammodytes americanus (American sand lance) | Myoxocephalus oxtodecimspinosus (longhorn sculpin) |
| Anguilla rostrata (American eel) | Myoxocephalus scorpius (shorthorn sculpin) |
| Apeltes quadracus (fourspine stickleback) | Osmerus mordax (rainbow smelt) |
| Brevoortia tyrannus (Atlantic menhaden) | Peprilus tricanthus (butterfish) |
| Clupea harengus (Atlantic herring) | Petromyzon marinus (sea lamprey) |
| Cryptacanthodes maculatus (wrymouth) | Pholis gunnellus (rock gunnel) |
| Cyclopterus lumpus (lumpfish) | Pleuronectes ferrugineus (yellowtail flounder) |
| Decapterus macarellus (mackerel scad) | Pollachius virens (pollock) |
| Fundulus heteroclitus (mummichog) | Pomatomus saltatrix (bluefish) |
| Fundulus majalis (striped killifish) | Pseudopleuronectes americanus (winter flounder) |
| Gadus morhua (Atlantic cod) | Pungitius pungitius (ninespine stickleback) |
| Gasterosteus aculeatus (threespine stickleback) | Salmo salar (Atlantic salmon) |
| Gasterosteus wheatlandi (blackspotted stickleback) | Salmo trutta (brown trout) |
| Hemitriperus americanus (sea raven) | Salvelinus fontinalis (brook trout) |
| Liparis atlanticus (seasnail) | Scomber scombrus (Atlantic mackerel) |
| Menidia beryllina (inland silverside) | Scopthalmus aquosus (windowpane flounder) |
| Menidia menidia (Atlantic silverside) | Sphyraena borealis (northern sennet) |
| Menidia peninsulae (tidewater silverside) | Syngnathus fuscus (northern pipefish) |
| Microgadus tomcod (Atlantic tomcod) | Tautogolabrus adspersus (cunner) |
| | Urophycis chuss (red hake) |
| | Urophycis tenuis (white hake) |

## 4.5 Waterbird Habitat

Definition: The capacity to directly support an abundance or diversity of waterbirds, mainly those that migrate or winter in the region but including a few that sometimes nest in tidal wetlands. This includes shorebirds (sandpipers, plovers, phalaropes, etc.), waterfowl (ducks, geese, swans), gulls, cormorants, loons, grebes, and others. The scoring model will not predict habitat suitability accurately for every species in this group.

Scientific Support and Regional Context

Some of the largest concentrations of migrating shorebirds (sandpipers, plovers, and relatives) observed in North America have been recorded from tidal flats and salt

marshes in the Maritime provinces. At least two priority species -- American black duck and willet – regularly nest in or along the edge of the region's tidal wetlands. Geese and many other waterbirds customarily feed and rest in the region's tidal marshes, especially during migration and on daily high tides.

Scoring Model:
6*MAX(IbirdArea, BirdConc, Bduck) + 3*AVERAGE(Width, Area, Wetscape) + 2*AVERAGE(Waves, Tribs, Pans, Island, PctHigh) + AVERAGE(DistLake, Openland, TideChan, NoVis, MuchVis) /12

*Where:*
Area = Marsh Area
Bduck = Black Duck Nesting Density (from Lieske et al. 2012)
BirdConc = Wetland Bird Concentration Area (from eBird data)
DistLake = Distance to Lake or Pond
IbirdArea = Important Bird Area or RAMSAR wetland
Island = Near a Barrier Island
MuchVis = % Visited Daily by People
NoVis = % Never Visited by People
Openland = Extent of Open Land in Vicinity
Pans = Salt Panne & Pool Extent
PctHigh = High Marsh Extent
TideChan = Extent of Branched Tidal Channels
Tribs = River or Tributary Intersect
Waves = Wave Exposure
Wetscape = Extent of Other Marsh in Vicinity
Width = Marsh Width

The model is a weighted average of four groups of indicators:
1. In the first group, if the wetland is part of a designated Important Bird Area, or is likely to support high densities (>30 pairs per 25 sq. km) of nesting American black duck, or contains or adjoins an intertidal area that had the highest reported numbers of one or more shorebird species according to the eBird database[4], then the group gets the highest score (1) which accounts for half the score for the Waterbird Habitat function.

[4] eBird Basic Dataset. Version: EBD_relAug-2014. Cornell Lab of Ornithology, Ithaca, New York. From the supplied data, points were plotted if the counts equaled or exceeded the thresholds shown in **Error! Reference source not found.**. Most eBird data are contributed by volunteers and are not standardised by area surveyed. Counts from the Atlantic Canada Shorebird Survey (ACSS) (previously Maritimes Shorebird Surveys) were not retrieved but some of those data are in the eBird database.

2. The score for the second group, which accounts for ¼ the overall score, reflects larger wetland area and width as well as percent of the nearby landscape with other tidal wetlands.
3. The third group's score, which contributes 1/6 to the overall score, increases if the wetland is relatively sheltered, borders a river or has a tributary, contains many pannes, is near a barrier island, and is extensively inundated during most daily high tides.
4. The remaining part of the overall score reflects greater internal channel complexity, extensive open land in the wetland's vicinity, proximity to a lake, and likelihood of minimal human disturbance.

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## 4.6 Songbird and Raptor Habitat

Definition: The capacity to directly support an abundance or diversity of songbirds and raptors, both residents and migrants, and especially those that commonly feed or nest in tidal saline wetlands and ones that commonly feed or nest in tidal fresh or brackish wetlands. The scoring model will not predict habitat suitability accurately for every species in this function group.

Scientific Support and Regional Context

One native songbird species (Nelson's sparrow) nests in salt marshes nearly to the exclusion of all other habitat types. Dozens of others visit the region's tidal marshes regularly to feed or rest during migration, and some nest within the high marsh or along its border with uplands. These include savannah sparrows, belted kingfishers, marsh wrens, common yellowthroats, swallows, blackbirds, and several others. In addition, northern harriers, ospreys, bald eagles, short-eared owls, and several other raptors frequently hunt in the region's tidal marshes.

Scoring Model:

3*AVERAGE(Width, Area, PctHigh, PctKing) +
AVERAGE(UpContact, Forbs, Shrubs, Perch, Tribs, Wetscape)/ 4

*Where:*

Area = Marsh Area
Forbs = Forb Cover

PctHigh = High Marsh Extent
PctKing = Extreme High Marsh as % of Entire High Zone
Perch = Perches
Salin = Salinity (measured or estimated)
Shrubs = Shrub Cover
UpContact = % of Perimeter That Is Upland
Wetscape = Extent of Other Marsh in Vicinity
Width = Marsh Width

The function score for tidal wetland songbirds and raptors increases with increasing wetland width, area, and proportion that is high rather than low marsh. The other 25% of the score increases with increasing forb cover, shrub cover, upland contact, perching sites for raptors, and extent of other tidal wetlands in the vicinity.

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## 4.7 Biodiversity Maintenance

Definition: The capacity to directly support plant and animal species which, by their rarity or narrow habitat requirements, contribute disproportionately to the overall richness of flora and fauna of this region.

Scientific Support and Regional Context

Compared with other cover types in this region, tidal wetlands are relatively uncommon. Thus, several species whose distribution is closely linked to tidal wetlands are currently rare or uncommon in the region. As such, they contribute importantly to the region's overall biodiversity. In this region, the primary source of rare species occurrence records is the Atlantic Canada Conservation Data Centre (ACCDC).

Scoring Model:

=IF(MAX(RareWbird, RareSbird, RareOther>0), THEN 1, ELSE:
[3*AVERAGE(Width, Area, Wetscape) + 2*AVERAGE(Forbs, Pdom, PlantRich, Invas, Salin) + AVERAGE(DistRd, DistPollu, BuffPctDevel] /6

*Where:*
Area = Marsh Area
BuffPctDevel = Developed Land in Runoff Contributing Area (or lack of)
DistPollu = Distance to Nutrient or Contaminant Source (or lack of)
DistRd = Distance to Road (or lack of)
Forbs = Forb Cover
Invas = Invasive Plant Cover
Pdom = Plant Species Dominance
PlantRich = Plant Richness (from informal survey)
RareWbird = Species of Conservation Concern (waterbirds)
RareSbird = Species of Conservation Concern (songbirds & raptors)

RareOther = Species of Conservation Concern (insects & others)
Salin = Salinity (measured or estimated)
Wetscape = Extent of Other Marsh in Vicinity
Width = Marsh Width

A tidal wetland automatically gets the highest score for Biodiversity if at least one of the priority animals or plants tracked by the ACCDC has been found within it or within 1 km of it, or if a qualified observer has detected it in the wetland. Otherwise, the score is the weighted average of three groups. The most influential group (accounting for half the score) reflects increasing wetland width and area as well as increasing cumulative area of other tidal wetlands in the vicinity. A second group, accounting for one-third of the score, reflects increasing cover of forbs and increasing plant richness, fresher salinity, and less percent cover of invasive plants and strongly dominant native plants. The remainder of the Biodiversity score reflects absence of (or greater distance from) nearby roads, potential pollution sources, and urban development.

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## 4.8 Wetland Stability

Definition: The likelihood that the tidal wetland will persist physically in the face of rising sea levels and climate change.

Scientific Support and Regional Context

As global sea levels rise in response to climate change, vast areas of tidal wetlands will be submerged, killing off their vegetation. The result will be a highly concerning loss of the services they provide, such as support of fish and wildlife, storm surge buffering, and water purification. However, not all of the region's tidal wetlands will be affected equally. Some are more likely than others to persist. Their odds of survival will be determined by their elevation, local topography, sediment supply, and other factors which the model attempts to recognise.

Scoring Model:

=AVERAGE(UpContact, Waves, Width, PctHigh, PctKing, TideAmp, Spread, SoilTex, Salin)

*Where:*

PctHigh = High Marsh Extent
PctKing = Extreme High Marsh as % of Entire High Zone
Restrict = Tidal Inflow Restriction (lack of)
Salin = Salinity (measured or estimated)
SoilTex = Soil Texture
Spread = Steepness of Nearby Upland Slope
TideAmp = Tidal Range
UpContact = % of Perimeter That Is Upland
Waves = Wave Exposure
Width = Marsh Width

Lacking more refined supportive information, the model is configured simply as the average of several indicators of tidal wetland stability (after the information on each indicator is converted to a 0 to 1 scale, as is true of all WESP-AC models). To maintain focus on the wetland (not its location) the scoring assumes all portions of the region will experience the same amount of sea level rise, although that is unlikely to be the case. Scores generated by the model do not reflect societal or ecological costs of losing a particular tidal wetland. Scores may be used to help prioritise local adaptive strategies to deal with potential losses of particular tidal wetlands.

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## 4.9 Public Use or Recognition

Definition: The potential and/or actual capacity to support non-consumptive (e.g., birding, education, research) and/or sustainable consumptive (e.g., hay harvesting, fishing) uses.

Support and Regional Context
In recognition of their outstanding ecological importance, all tidal wetlands in New Brunswick have been designated as Provincially Significant Wetlands and as such have been accorded a higher level of legal protection than some non-tidal wetlands. Appreciable amounts of public and private funds have been spent to restore or protect particular tidal wetlands, and financial common sense suggests it is wise to continue to protect that investment. As with any protected open space, in some communities the open space provided by tidal wetlands can enhance the market value of homes located along the wetland edge. While tidal wetlands are seldom considered "walkable" except to the most dedicated duck hunters, birders, researchers, and fishermen, they provide an expanse of open space that contributes aesthetically to the appeal of the region's coastal areas, helping boost ecotourism, as well as helping support commercially important seafood species, purifying coastal waters, and providing other ecosystem services valued by humans.

Scoring Model:
= [AVERAGE(ConsInvest, MitInvest, AVERAGE(Visibil, NoVis, MuchVis), SciUse, Consump]

*Where:*
ConsInvest = Conservation Investment
Consump = Consumptive Uses (Provisioning Services
MitInvest = Mitigation Investment
MuchVis = % Visited Daily by People
NoVis = % Never Visited by People
SciUse = Sustained Scientific Use
Visibil = Visibility

The model combines several indicators simply by averaging them, once each of those indicators has been represented on the 0 to 1 scale. Indicators with no data are dropped from this model rather than being assigned a value of 0. Part of the model assumes that more human use of a wetland (sustainable use) means that the particular wetland is more valued by the public. However, it is recognised that some individuals would

value more those wetlands that receive less human use because heavy use compromises the solitude sought and valued by some.

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# 5.0 Future Refinements

Although no further work is contemplated or considered necessary to begin using WESP-AC widely in Atlantic Canada, it is recommended that efforts be expanded to quantify the repeatability of its ratings among different users independently assessing the same sites, as well as efforts to refine the calibration of its scores by comparing with actual measures of tidal wetland functions, as difficult and expensive as those are to make among a statistically significant number and variety of tidal wetlands.

In any of the provinces, assessments of additional wetlands could be added to the existing calibration database to increase the range of variability captured by the province's calibration database. However, because this could introduce a new regional maximum and/or minimum for the scores of some functions, raw scores from all the existing calibration wetlands would subsequently need to be re-normalised statistically and thresholds for the natural breaks between rating categories would need to be redetermined using the Jenks algorithm. This would not be difficult to do, but unless the scores database was frozen at various points, applicants for wetland approvals and persons monitoring restoration projects would encounter a "moving target" and that would complicate interpretation of WESP-AC outputs.

This project was not tasked with proposing specific procedures or criteria for using WESP-AC outputs to make decisions about individual tidal wetlands. That is rightfully in the realm of public policy, not just science. Decision-makers may wish to give greater weight to some functions than to others, depending on local concerns and needs. For a given site, consideration might be given to the number of function-benefit combinations that scored high and/or the diversity of functions among those scoring high. For wetland restoration or enhancement projects, the function score profiles could be compared before and at successive years after the project to ensure that targeted functions are increasing as planned. In any case, it is likely that decisions about protecting or developing particular tidal wetlands will take into account not only the WESP-AC ratings, but also development costs, biological survey data not accounted for by WESP-AC, the likelihood that the wetland will remain intact if not protected, and other factors. For additional discussion of this topic see Dorney and Adamus (2018).

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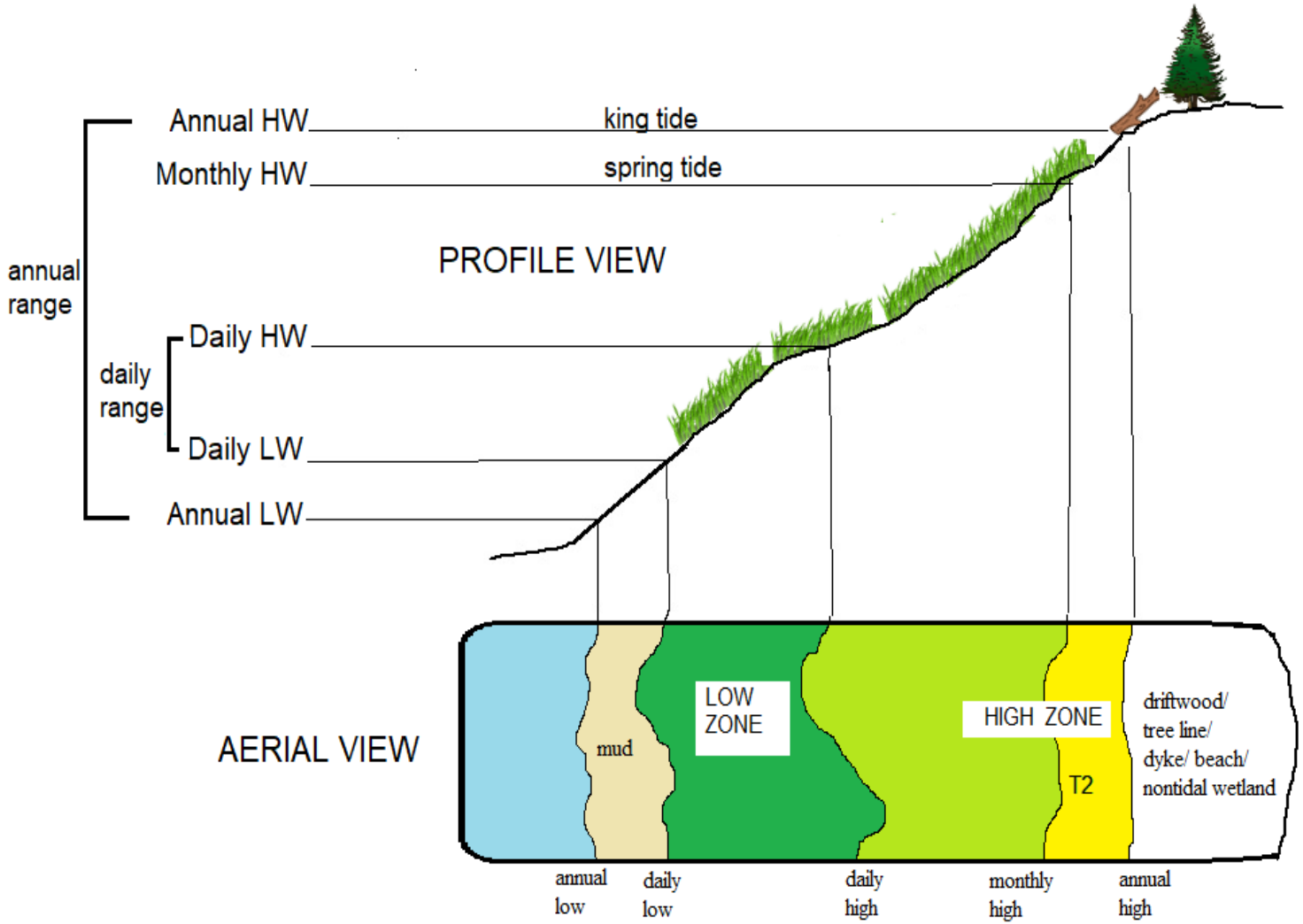
# Appendix A. Data Forms to Copy for Tidal WESP-AC

| **CoverPage: Basic Description of Assessment** | | |
|---|---|---|
| Site Name: | | |
| Investigator Name: | | |
| Date and Time of Field Assessment: | | |
| Time and Height (m) of High Tide on this date near this location | | |
| Time and Height (m) of Low Tide on this date near this location | | |
| Latitude (decimal degrees): | | |
| Longitude (decimal degrees): | | |
| Is a map based on a formal on-site wetland delineation available? | | |
| What percentage (approx.) of the entire wetland polygon, as shown on the Province's map, could you see well enough to answer most of the Form T questions? i.e., the Assessment Area. | | |
| Indicate here if you intentionally surveyed for rare plants or rare animals: | | |
| Were you able to ask the site owner/manager about any of the questions? | | |
| Have you attended a WESP-AC training session? If so, indicate approximate month & year. | | |
| How many **tidal** wetlands have you assessed previously using WESP-AC? (approx.) | | |
| Attach an aerial or map showing the approximate boundary of the AA, if smaller than the entire tidal wetland polygon mapped by the province. | | |
| Comments about the site or this WESP-AC assessment (attach extra page if desired): | | |

**Form T. WESP-AC for Tidal Wetlands. Version T2.** *IMPORTANT*: Review the diagram and explanatory text below before answering the questions. You will need to estimate boundaries of the zones of your wetland in order to answer those questions accurately.



First, estimate the full extent of the wetland (Low Zone + High Zone). If visiting at high tide, be sure to include emergent vegetation that is underwater (i.e., Low Zone), estimating its seaward edge by interpreting topography, reviewing any maps or aerial imagery taken at low tide, or asking neighbors how far out the vegetation extends at low tide. Also estimate it by noting, from tide tables, today's tide range nearest this location and visually subtracting that height from where you see water beneath plants at high tide. If you are visiting closer to daily low tide, determine the lower boundary of the High Zone by looking for recent (wet) deposits of wrack (dead plants & debris carried into the site and deposited, often clinging to stems of living vegetation beneath its canopy) to define the upper limit of the day's high tide.

The Low Zone is typically dominated by smooth cordgrass (*Spartina alterniflora*) and sometimes glasswort (*Salicornia*) in the near-absence of saltmeadow cordgrass (*Spartina patens*), goose-tongue (*Plantago maritima*), and most other vascular plant species. However, in freshwater tidal wetlands these plants will be mostly absent, so in those situations it will be necessary to use water marks, wrack, and local tidal range to approximate the lower edge of the High Zone.

The lower boundary of the T2 (yellow) portion is difficult to distinguish unless visiting during a monthly or annual high tide. This is typically where saltmeadow cordgrass and goose-tongue lower in the wetland give way to semi-terrestrial plants such as beach pea, rose, dock, yarrow, vetch, clover in a landward direction. Well-weathered wrack deposits sometimes mark the lower boundary, and the zone sometimes occurs above a visible change in the marsh surface profile, or behind a low dyke, berm, or barrier beach that is overtopped by tidewater only rarely.

| # | Indicator | Categorical Choices | Data | Explanations |
|---|---|---|---|---|
| T1 | High Zone Extent | The percentage of the wetland's vegetation that has NO tidal water beneath it during most daily high tides of the year (i.e., the HIGH ZONE) is: | | See diagram and note in header above. This is the percentage that the High Zone comprises of the combined Low + High Zone (light green shading in diagram). |
| | | None, or <1% and narrower than 2 m. | 0 | |
| | | 1-10%. | 0 | |
| | | 10-25%. | 0 | |
| | | 26-50%. | 0 | |
| | | 51-75%. | 0 | |
| | | 75-90%. | 0 | |

| | | | | |
|---|---|---|---|---|
| | | >90%. | 0 | |
| T2 | Extreme High as % of Entire High Zone | Within the High Zone (i.e., the part of the wetland you can still see at daily high tide), the percentage that is flooded only monthly or even less often (T2 yellow area in the above diagram) is: | | See diagram and note in header above. This is the percentage that the T2 zone comprises of the entire High Zone. |
| | | <10% of the High Zone. | 0 | |
| | | 10-25% of the High Zone. | 0 | |
| | | 26-50% of the High Zone. | 0 | |
| | | >50% of the High Zone. | 0 | |
| T3 | Bare Ground or Thatch: High Zone | The ground condition in the HIGH ZONE, as it would exist in late summer and **when viewed from about 1 m above the ground**, is: | | Note that this is being assessed on two scales: up-close (from 1 m above) and overall (patches of bare/thatch). "Bare" **does not include mud flats** adjacent to the wetland **or tidal channels** within it (because they would be flooded daily and thus outside of the High Zone). **Do not count wrack (drifted-in material) as "thatch."** The amount of thatch (which counts as Bare) varies seasonally and annually, so consider just the condition that would exist **in late summer**. |
| | | Little or no (<5%) *bare ground* or dead *attached* plant material (thatch) is visible between erect stems or under canopy. This can occur if ground surface is extensively blanketed by graminoids with great stem densities. | 0 | |
| | | Some (5-20%) bare ground or thatch is visible. Herbaceous plants have moderate stem densities. | 0 | |
| | | Much (20-50%) bare ground or thatch is visible. Low stem density and/or tall plants with little near-ground foliage. | 0 | |
| | | Mostly (>50%) bare ground or thatch. | 0 | |
| T4 | Salt Pannes & Pools [Pans] | Within the High Zone, the number of pannes and pools (natural semi-circular depressions or ponds with radius >1 m which hold stagnant surface water between high tides, and may be flooded by tides only infrequently) is: [Note: Check the aerial image before answering this.] | | These are unlikely to be present in freshwater tidal wetlands. |
| | | Few (<2 per hectare) or none. | 0 | |
| | | Intermediate. | 0 | |
| | | Several (>5 per hectare). | 0 | |
| T5 | Forb Cover [Forbs] | In the High Zone (and entirely within the TIDAL wetland), the areal cover of **forbs** reaches an annual maximum of: | | Forbs are mostly flowering plants, such as seaside plantain (goose-tongue, *Plantago*), arrowgrass (*Triglochin*), grasswort (*Salicornia*), aster, and silverweed. Cattail, |
| | | <1% of the herbaceous cover. | 0 | |
| | | 1-25% of the herbaceous cover. | 0 | |

| | | | | |
|---|---|---|---|---|
| | | 25-50% of the herbaceous cover. | 0 | bulrush, sedges, and other grasslike plants are **not** forbs. |
| | | 50-95% of the herbaceous cover. | 0 | |
| | | >95% of the herbaceous cover. | 0 | |
| T6 | Shrub Cover [Shrubs] | In the High Zone (and entirely within the TIDAL wetland), living woody vegetation shorter than 3 m and not beneath a tree canopy comprises: | | Include beach pea, rose, and others (and in freshwater tidal wetlands include alder, willow), but do not include upland shrubs that are never flooded by tides. |
| | | <1% (or none) of the vegetated area reached only by monthly or annual high tide. | 0 | |
| | | 1-5% of the vegetated area reached by monthly or annual high tide. | 0 | |
| | | 5-25% of the vegetated area reached by monthly or annual high tide. | 0 | |
| | | >25% of the vegetated area reached by monthly or annual high tide. | 0 | |
| T7 | Perches [Perch] | Within the wetland, objects that project >1 m above the ground surface and could serve as perches (e.g., fenceposts, utility poles, boardwalks, goose nesting structures, stumps, boulders, islands of shrubs or trees) are: | | Do not include trees or other perches on the wetland edge but outside the wetland. |
| | | Few (<1 per hectare) or none . | 0 | |
| | | Intermediate. | 0 | |
| | | Several (>3 per hectare). | 0 | |
| T8 | Plant Species Dominance [Pdom] | In the High Zone, the 2 most common vascular plant species together comprise: | | For example, if smooth cordgrass and saltmeadow cordgrass together cover >80% of the High Zone, as is often the case, the last choice is correct. But if goose-tongue (*Plantago martima*) is also substantially present, the third or fourth choice might be better. |
| | | <20% of the zone's vegetated area (most species-rich, no dominants or co-dominants). | 0 | |
| | | 20-40% of the zone's vegetated area. | 0 | |
| | | 40-60% of the zone's vegetated area. | 0 | |
| | | 60-80% of the zone's vegetated area. | 0 | |
| | | >80% of the zone's vegetated area (monotypic or nearly so). | 0 | |
| T9 | Exotic Plant Cover [Invas] | In the High Zone (and entirely within the TIDAL wetland), the areal cover of exotic plants (just the species in last column) is: | | Ones known to be present in at least one of this region's tidal wetlands are: purple loosestrife (*Lythrum salicaria*), reed canary-grass (*Phalaris arundinacea*), brassbuttons |
| | | None, or trace. | 0 | |
| | | 1-5% of the herbaceous cover. | 0 | |

| | | | | |
|---|---|---|---|---|
| | | 5-25% of the herbaceous cover. | 0 | (*Cotula coronopifolia*), grassleaf orache (*Atriplex littoralis*), Japanese rose (*Rosa rugosa*), Canada thistle (*Cirsium arvense*), branched centaury (*Centaurium pulchellum*), flowering rush (*Butomus umbellatus*). |
| | | 25-50% of the herbaceous cover. | 0 | |
| | | >50% of the herbaceous cover. | 0 | |
| T10 | Core Area 1 [NoVis] | The percentage of the High Zone almost never visited by humans during an average growing season probably comprises: [Note: Do not include visitors on trails outside of the wetland unless more than half the wetland is visible from the trails and they are within 30 m of the wetland edge. In that case include only the area occupied by the trail.] | | |
| | | <5% and no inhabited building is within 100 m of the wetland. | 0 | |
| | | <5% and inhabited building is within 100 m of the wetland. | 0 | |
| | | 5-50% and no inhabited building is within 100 m of the wetland. | 0 | |
| | | 5-50% and inhabited building is within 100 m of the wetland. | 0 | |
| | | 50-95%. | 0 | |
| | | >95% of the High Zone. This is the most frequent choice for tidal wetlands in this region. | 0 | |
| T11 | Core Area 2 [MuchVis] | The percentage of the High Zone visited by humans almost daily for several weeks during an average year probably comprises: [Note: Do not include visitors on trails outside of the wetland unless more than half the wetland is visible from the trails and they are within 30 m of the wetland edge. In that case include only the area occupied by the trail.] | | |
| | | <5%. This is the most frequent choice for tidal wetlands in this region, except in some visited often by many hunters. | 0 | |
| | | 5-50%. | 0 | |
| | | 50-95%. | 0 | |
| | | >95% of the High Zone. | 0 | |

| | | | | |
|---|---|---|---|---|
| T12 | Visibility [Visibil] | The maximum percent of the wetland that is visible from the best vantage point on public roads, public parking lots, public buildings, or public maintained trails that intersect, adjoin, or are within 100 m of the wetland is (select one): | | |
| | | <25%. | 0 | |
| | | 25-50%. | 0 | |
| | | >50%. | 0 | |
| T13 | Consumptive Uses (Provisioning Services) [Consump] | Recent evidence was found within the wetland of the following potentially-sustainable consumptive uses. Mark all that apply. | | Do not speculate. Base this on evidence, which may include communication with landowner or other knowledgeable source. |
| | | Haying. | 0 | |
| | | Grazing. | 0 | |
| | | Shellfish or bait worm harvest. | 0 | |
| | | Waterfowl hunting or furbearer trapping. | 0 | |
| | | Fishing. | 0 | |
| | | None of the above (no evidence). | 0 | |
| T14 | Soil Texture [SoilTex] | The texture of soil in the **uppermost** layer, but excluding live roots, in the majority of the HIGH ZONE, is: | | See chart at end of Appendix A. Check the soil at one or more locations away from the wetland edge that seem representative of the whole. |
| | | Loamy: includes loam, sandy loam. | 0 | |
| | | Fines: includes silt, clay, clay loam, silty clay, silty clay loam, sandy clay, sandy clay loam. | 0 | |
| | | Organic. | 0 | |
| | | Coarse: includes sand, loamy sand, gravel, cobble, stones, boulders, fluvents, fluvaquents, riverwash. | 0 | |
| T15 | Salinity | Was surface water salinity measured? If yes, continue with next question. If no, **go to T18.** | | |
| T16 | Measured Salinity [Salin] | The surface water salinity along the wetland's seaward edge is: [Insert reading in next column, in parts per thousand; 1 ppt = 1000 ppm = 1000 mg/L]. | | Measure this as far as possible from fresh tributaries and seeps, and well below the water surface. While measuring, wait until salinity readings have stabilised. It is recognized that salinity at some locations will vary greatly by tide, currents, time of year, |

| | | | | |
|---|---|---|---|---|
| | | | | and recent precipitation. |
| T17 | Inferred Salinity [SalinClass] | Based on the wetland's dominant plant species (see the PlantList worksheet) and proximity to contributing freshwater rivers and streams, the summertime salinity in most of the wetland is likely: | | Note: ppt = parts per thousand. 1 ppt = 1000 mg/L. |
| | | Oligohaline (mostly fresh or slightly brackish plants, usually < 5 ppt). | 0 | |
| | | Mesohaline (brackish). | 0 | |
| | | Euryhaline (few or no freshwater plants, near seawater strength, usually >30 ppt). | 0 | |
| T18 | Plant Richness [PlantRich] | See the PlantList worksheet. If you have the skills to identify ALL the plants, survey as much of the wetland as time and safety allow. In the worksheet, mark with a "1" the species you find. The number of species will be automatically tallied. Transfer that number to the next column. If you are not confident of your skills to identify ALL the species or for other reasons cannot survey the plants, **change the next column to blank.** | 0 | It is recognized that not all WESP-AC users are capable of identifying all the species on the PlantList worksheet, and so the "blank" option is included. Leaving a blank will not reduce a score. Results will vary by month of the year and level of effort. However, this question is used to assess only one function (Biodiversity) and accounts for less than 7% of the score for that. and that is only for one function (Biodiversity). |

**PLANT CHECKLIST for Tidal WESP-AC. DIRECTIONS**: Print list & take in field. In first column mark with "1" all species found, transfer to spreadsheet. **Bold font**= common species. Red= rare. Blue= exotic. All have been found in the region's tidal wetlands, many only near the upland edge or in tidal wetlands with substantial freshwater inflow.

| Data | Scientific Name | Common Name | Freshwater Indicator |
|---|---|---|---|
| | Achillea millefolium | Common yarrow | |
| | Agalinis maritima [RARE in NS] | Saltmarsh agalinis | |
| | Agrostis gigantea | Redtop | Yes |
| | **Agrostis stolonifera** | Creeping bentgrass | |
| | Anthoxanthum nitens | Vanilla sweet grass | |
| | **Argentina egedii (Potentilla anserina)** | Pacific silverweed | |
| | Atriplex franktonii [RARE] | Frankton's saltbush | |
| | **Atriplex spp.** | Saltbush or orache | |
| | Baccharis halimifolia [RARE in NS] | Eastern baccharis | |
| | Bidens hyperborea [RARE in NS] | Estuary beggarticks | |
| | Blysmus (Scirpus) rufus [RARE in NB-PEI] | Red bulrush | |
| | Bromus inermis | Smooth brome | Yes |
| | Calystegia (Convolvulus) sepium | Hedge false bindweed | |
| | Carex hormathodes | Marsh straw sedge | |
| | Carex mackenziei | Mackenzie's sedge | |
| | **Carex paleacea** | **Chaffy sedge** | |
| | Carex salina [RARE in NB] | Salt marsh sedge | |
| | Carex tenera | Quill sedge | |
| | Centauria nigra | Lesser knapweed | |
| | Chenopodium spp. | Goosefoot spp. | |
| | Cotula coronopifolia [EXOTIC] | Common brassbuttons | |
| | Deschampsia caespitosa [RARE in PEI] | Tufted hairgrass | |
| | **Distichlis spicata** | **Saltgrass** | |
| | Eleocharis parvula | Dwarf spikerush | |
| | Eleocharis rostellata | Beaked spikerush | |

| | | | |
|---|---|---|---|
| | Eleocharis uniglumis | Single-glumed spikerush | |
| | Elymus spp. | Wildrye spp. | |
| | Erechtites hieraciifolius | Eastern burnweed | |
| | **Festuca rubra** | Red fescue | |
| | Galium palustre | Common marsh bedstraw | |
| | **Glaux maritima** | **Sea milkwort** | |
| | Hierochloe odorata | Sweetgrass | |
| | Hordeum jubatum | Foxtail barley | |
| | Iva frutescens | Big-leaved marsh-elder | |
| | **Juncus balticus (arcticus)** | Arctic sedge | |
| | Juncus bulbosus | Bulbous rush | |
| | Juncus filiformis | Thread rush | |
| | **Juncus gerardii** | **Saltmeadow rush** | |
| | **Lathyrus japonicus** | **Beach pea** | |
| | Ligusticum scoticum | Scottish licorice-root | |
| | **Limonium carolinianum (nashii)** | **Lavender thrift** | |
| | Limosella australis [RARE in PEI] | Southern mudwort | Yes |
| | Myrica gale | Sweetgale | Yes |
| | Phalaris arundinacea [EXOTIC] | Reed canary-grass | Yes |
| | Phragmites australis [EXOTIC] | Common reed | |
| | Plantago major [EXOTIC] | Common plantain | Yes |
| | **Plantago maritima** | **Seaside plantain, goose tongue** | |
| | Poa spp. | Grass spp. | Yes |
| | Polygonum spp. | Knotweed spp. | Yes |
| | **Puccinellia spp.** | **Alkaligrass spp.** | |
| | Ranunculus cymbalaria | Seaside buttercup | |
| | Ranunculus sceleratus | Cursed buttercup | Yes |
| | Rosa rugosa [EXOTIC] | Rugosa rose | |
| | Rumex pallidus [RARE in NB] | Seaside dock | |
| | Rumex spp. | Dock spp. | |
| | Ruppia maritima | Widgeongrass | |
| | Sagina nodosa | Knotted pearlwort | Yes |
| | **Salicornia maritima (europaea)** | **Slender grasswort** | |
| | Samolus valerandi (ssp. parviflorus= RARE in NS & PEI] | Seaside brookweed | Yes |

| | | | |
|---|---|---|---|
| | Scirpus (Bolboschoenus) maritimus | Saltmarsh bulrush | |
| | Scirpus (Schoenoplectus) americanus | Olney's bulrush | |
| | **Scirpus (Schoenoplectus) tabernaemontanii** | **Softstem bulrush** | Yes |
| | Scirpus microcarpus (rubrotinctus) | Panicled bulrush | Yes |
| | Scutellaria galericulata | Marsh skullcap | Yes |
| | Senecio spp. | Ragwort spp. | Yes |
| | Solidago canadensis | Canada goldenrod | Yes |
| | Solidago gigantea | Giant goldenrod | Yes |
| | **Solidago sempervirens** | **Seaside goldenrod** | |
| | **Spartina alterniflora** | **Smooth cordgrass** | |
| | **Spartina patens** | **Saltmeadow cordgrass** | |
| | **Spartina pectinata** | **Prairie cordgrass** | |
| | Spergularia spp. | Sandspurry spp. | |
| | Stellaria humifusa [RARE in NS & PEI] | Saltmarsh starwort | |
| | Suaeda linearis | Annual seepweed | |
| | Suaeda maritima | Herbaceous seepweed | |
| | Suaeda rollandi [RARE in NS & NB] | Horned sea-blite | |
| | Symphyotrichum laurentianum [RARE in NB-PEI] | Gulf of St. Lawrence aster | |
| | Symphyotrichum subulatum [RARE in NB-PEI] | Annual saltmarsh aster | |
| | Thinopyrum pycnanthum | Tick quackgrass | |
| | Trifolium spp. | Clover spp. | |
| | Triglochin gaspensis [RARE in PEI] | Gaspé Peninsula arrowgrass | |
| | **Triglochin maritima** | **Seaside arrowgrass** | |
| | **Typha angustifolia** | **Cat-tail** | Yes |
| | **Vicia spp.** | **Vetch** | Yes |
| | Zannichellia palustris | Horned pondweed | Yes |
| | Zostera marina | Common eelgrass | |
| | | | |
| | | | |

| | | | |
|---|---|---|---|
| | | | |
| | | | |
| | | | |
| | | | |
| | | | |

# Appendix B. Supplemental Guidance for Answering Spreadsheet Questions and Diagnosing Soil Texture

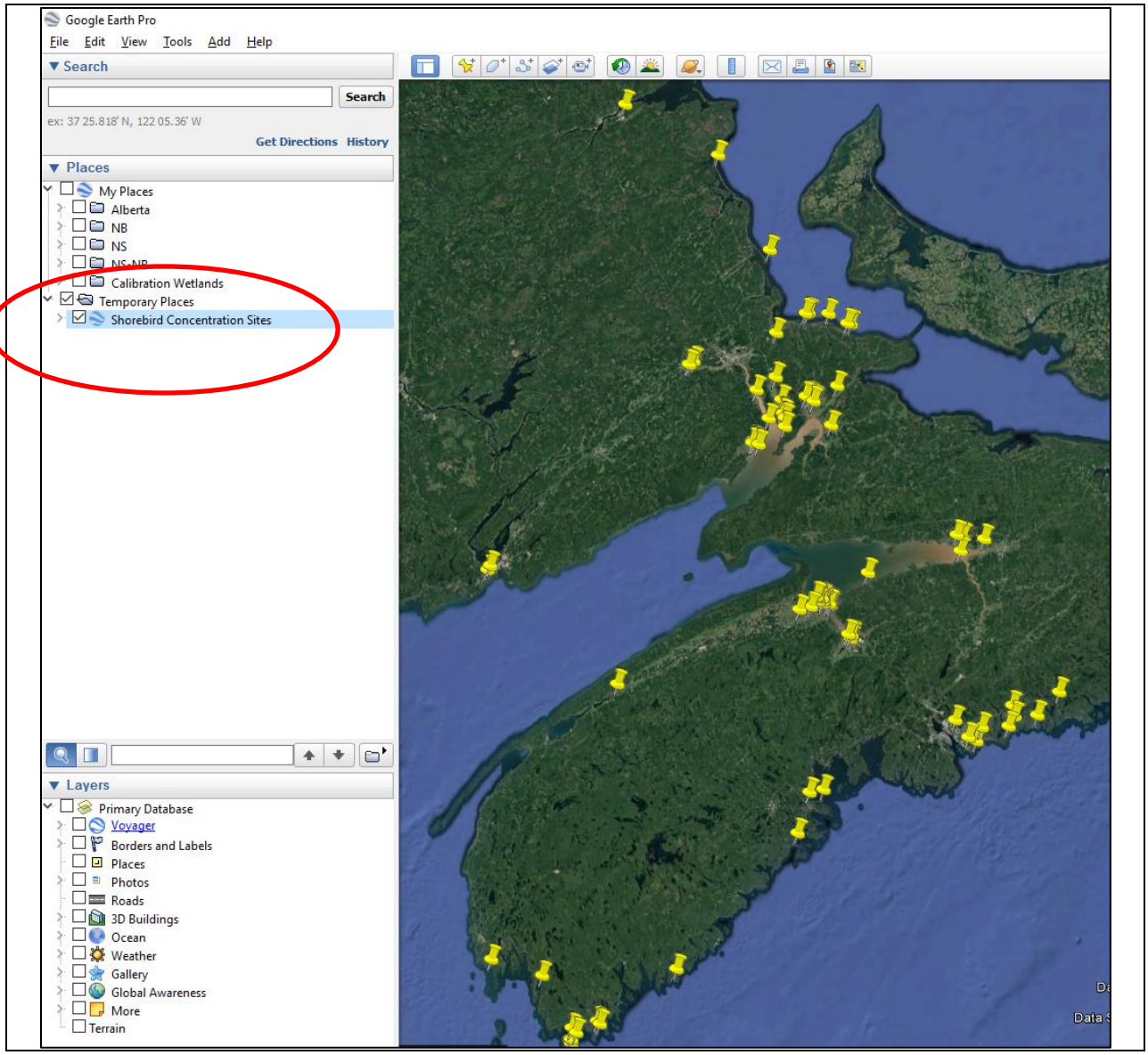
**DATA FORM OF (Office):**

Using KMZ Files

When you received this manual you should also have received or downloaded the calculator spreadsheet and the following files:

NB_Headtide.kmz
NS_Headtide.kmz
NB-PEI_GrowingDegreeDays.kmz
NS_GrowingDegreeDays.kmz
Shorebird Concentration Sites.kmz
Black Duck Nesting Pairs.kmz
IBAs Canada.kmz

When you're ready to answer questions in the office data form (Form OF) which is part of the Tidal WESP-AC calculator spreadsheet, you should download the free Google Earth Pro from the internet if you don't already have it, and then click on each of the above files when called for by a particular form OF question. The compressed (.kmz) file will decompress (into a .kml) and a spatial data layer covering one or more of the provinces will display on the Google Earth image (example below).



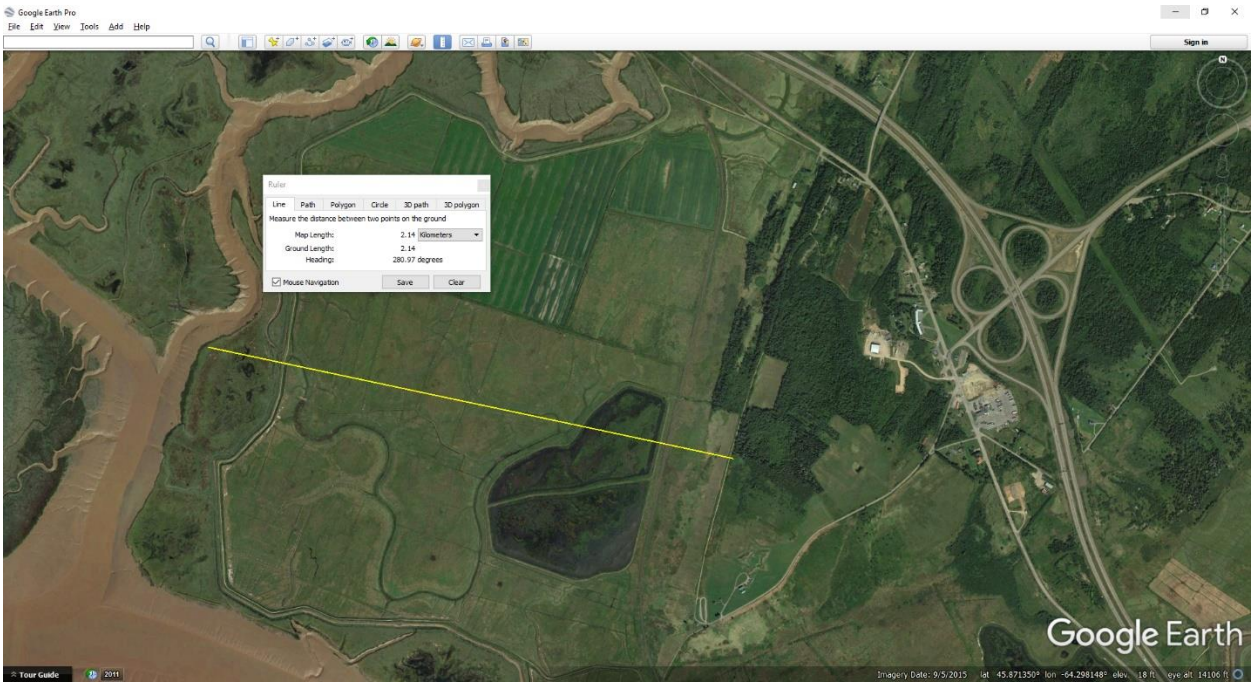

The file name with a checked box will appear in the Places menu in the left margin, under "Temporary Places", and the information from the file will be displayed on the regional map. You may then enter coordinates of your site in the search bar in the top left and by hitting Enter it will zoom into your site so you can see if it coincides with the displayed information. You can then repeat with the other kmz files. Checking and unchecking their boxes will turn their layer on and off. It is advisable to check only one layer at a time in order to avoid potential confusion of the information. When you exit Google Earth it will ask if you want to move the unsaved items in the Temporary Places folder to the My Places folder. Say "yes" so that you don't have to upload the kmz files every time.

OF3. Marsh Width

Form OF asks the following, and is followed by several choices of widths:

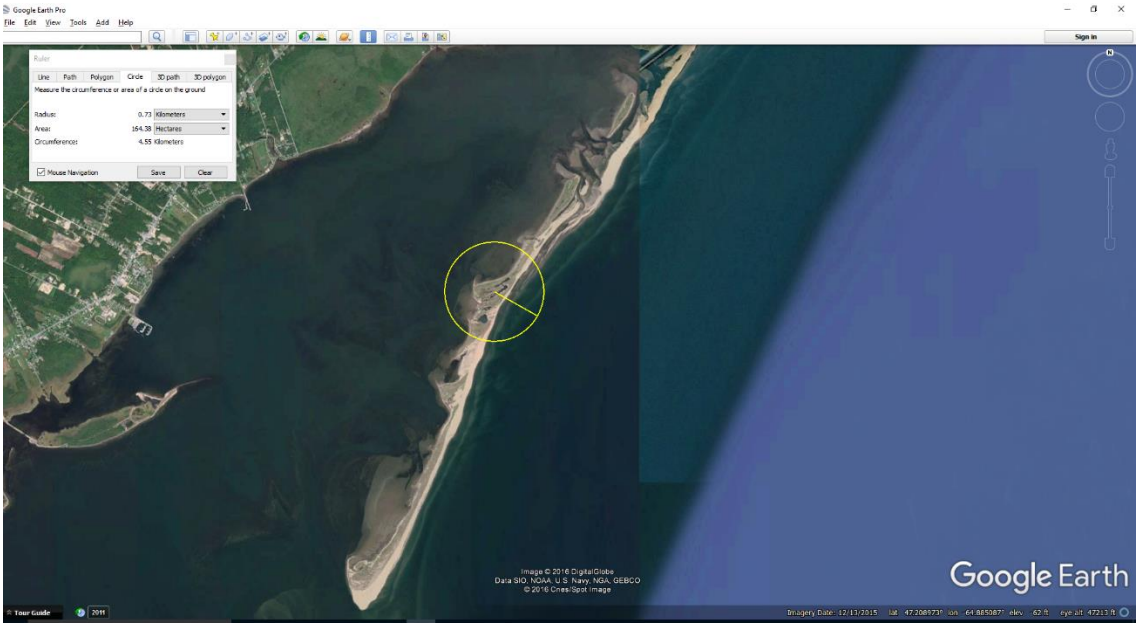
| |
|---|
| Including any adjacent marsh (whether tidal or not, separated by narrow berm or not), the wetland's vegetated width **at the widest point** measured as straight-line distance along the approximate runoff flow path (line semi-perpendicular to nearby wide channel, bay, or ocean; see example in Appendix B) is: |

In the image below, the longest imagined runoff flow path (yellow line), measured with the Google Earth Ruler tool, is from the upland forest on the right to the wide channel on the left. Along that path it crosses impounded non-tidal marshes but those are included in the path measurement. To ensure that the line represents downhill flow throughout its length, note the elevation at different points along the line as reported in the bar in the bottom right, after first marking "Terrain" in the Layers menu in the lower left (not shown). Note that the measurement does not need to be exact because the question's choices are just six very broad ranges.

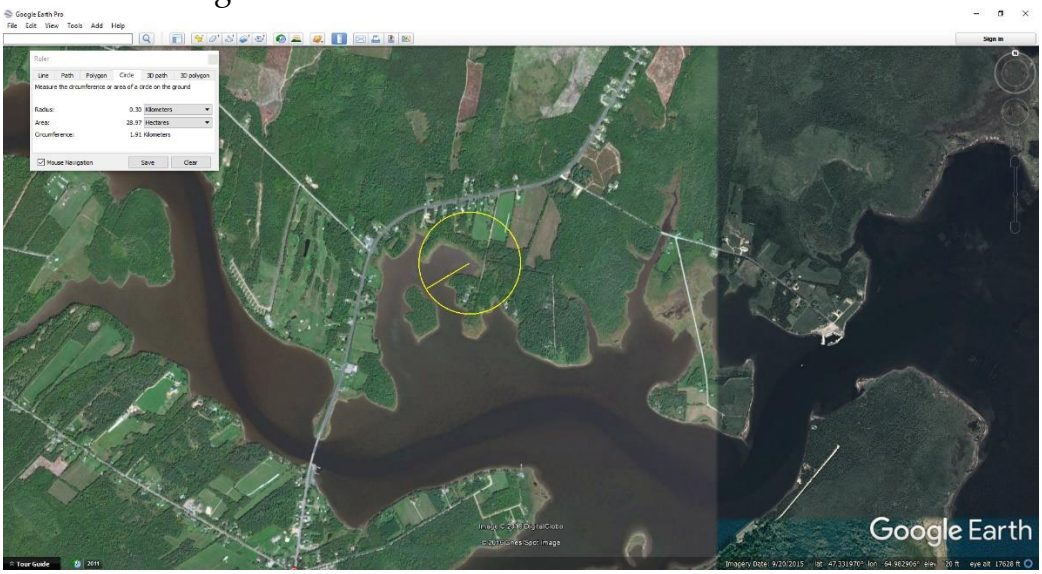


## OF5. Wave Exposure

| |
|---|
| Part of the wetland is occasionally exposed to waves from a stretch of open subtidal water that is considerably wider than the wetland, and those waves are likely to force flooding of the wetland higher and deeper than usually caused by tides alone. Enter 1= yes, 0= no. |




Despite being on the back side of a peninsula and separated from the ocean by a narrow sand spit, the circled wetland above is judged to be occasionally exposed to significant ocean waves. On-site inspection would confirm that the sand spit is too low to provide much sheltering.




The circled wetland above is deep within an estuary and mostly sheltered from large waves by topography and a nearby island.

OF6. Branched Tidal Channels

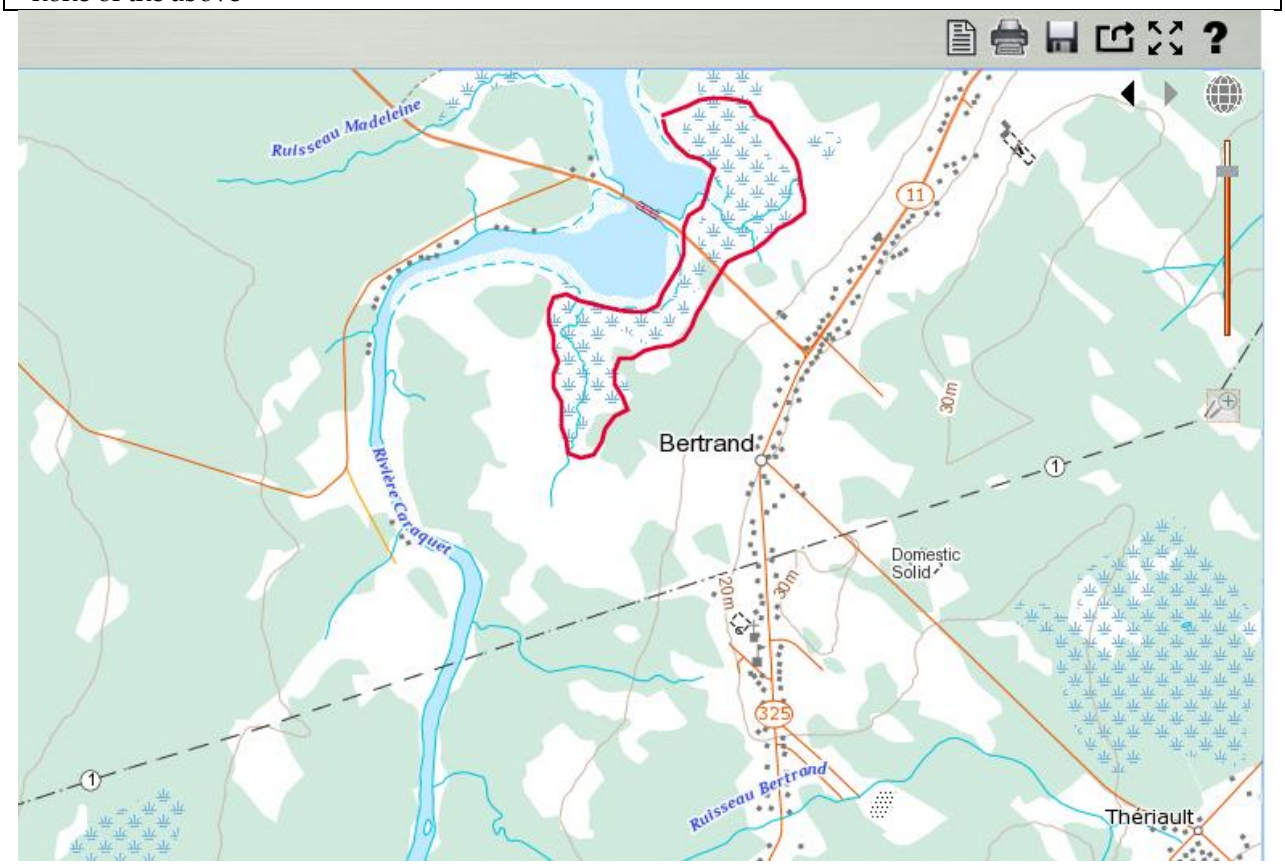
| Small "blind" channels (not connected to freshwater streams) are: |
|---|
| absent. |
| present, but multibranched networks are few and/or not well developed. |
| present, and multibranched networks are extensive and well developed. |

Snow highlights the extensive multibranched blind channels within the above wetland.

The above wetland appears to have only one blind channel and its branches are few. If that channel originated as an upland stream it would not count as a blind channel.

OF7. Rivers and Tributaries

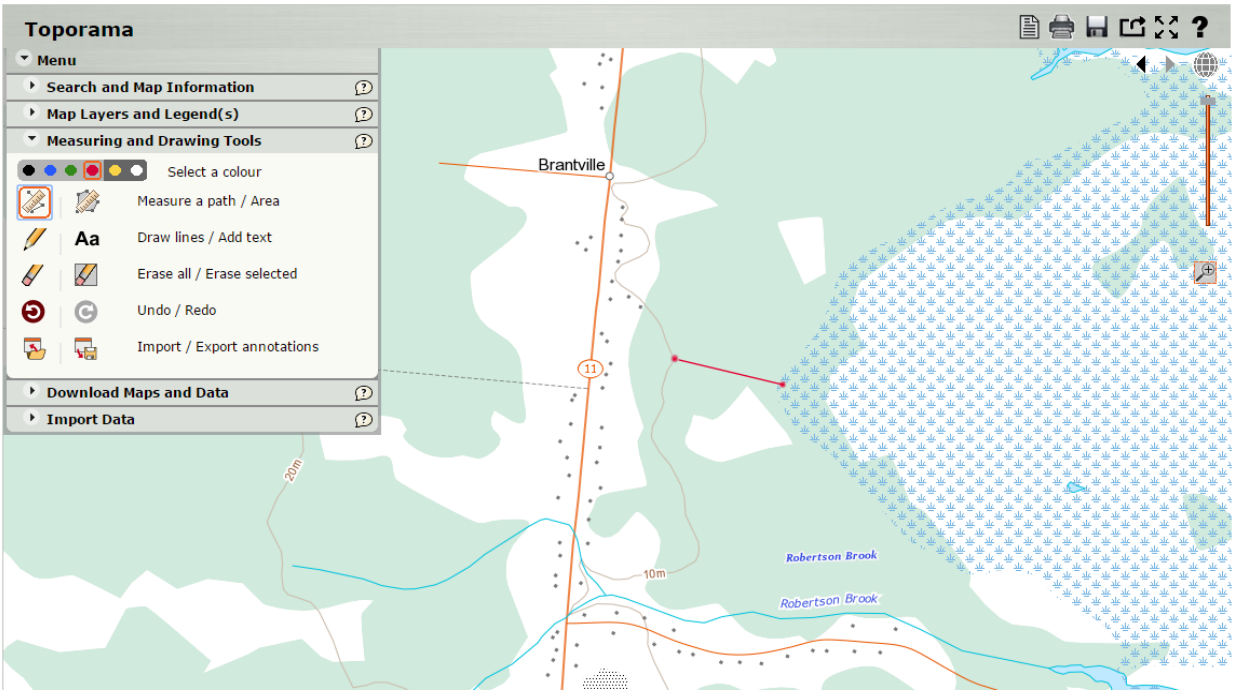
| Select first true statement. The wetland: | |
|---|---|
| is fed directly by a major tidal river (channel extends >5 km inland with no fish blockages insofar as is known, large watershed) | |
| is fed only by a mapped stream (channel extends <5 km inland, smaller watershed) | |
| neither of above, but a mapped stream or river is within 1 km | |
| none of the above | |




This wetland at its south end is fed by a small tributary while also fed by a large tidal river. In the question above the first choice is the correct one.

## OF14. Slope Nearby

As viewed in the Toporama map ( http://www.atlas.gc.ca/toporama/ ) at maximum zoom, 10 m vertical interval, there is a **topographic contour line** within 1 km of the wetland's upland edge or within a distance that is less than the wetland's maximum width. Enter 1= yes, 0= no.



OF16. Ditching

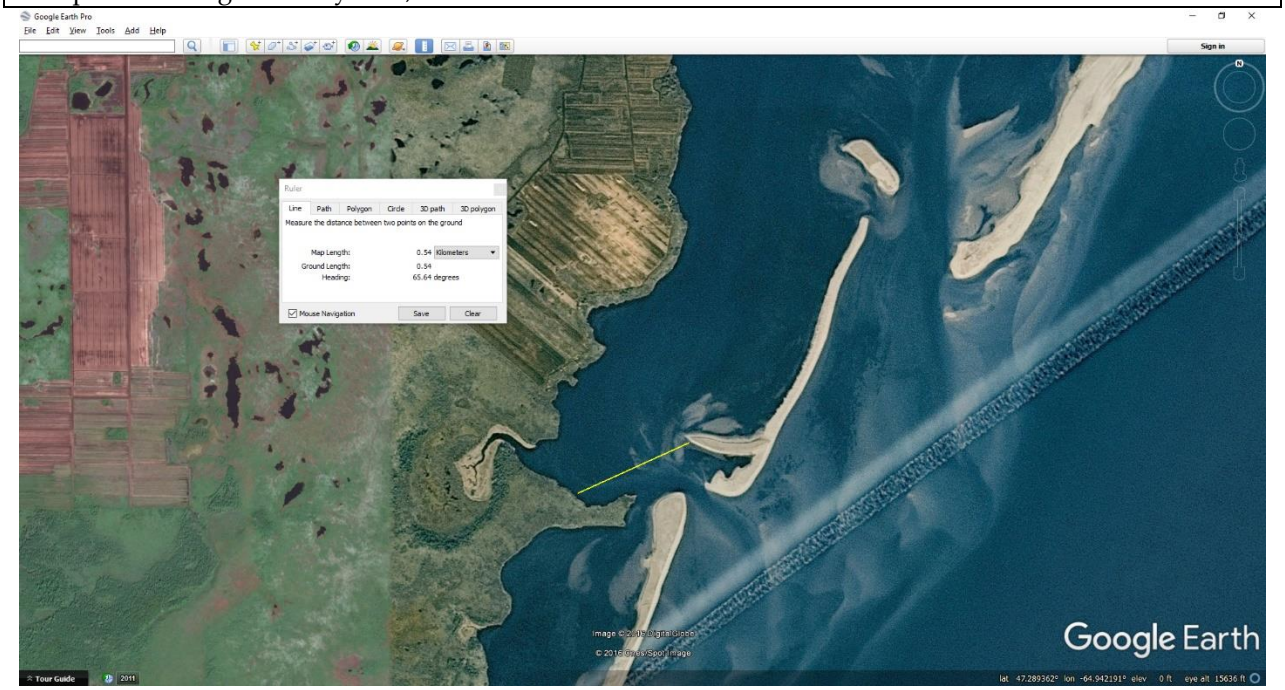
| | |
|---|---|
| Ditches, artificially straightened channels, and/or channel connectors are: | |
| absent. | |
| present, but few and localised within the wetland. | |
| present, and a few large/long ditches or a dense network. | |

Narrow straight channels throughout the above wetland are a network of ditches.

Only a few ditches amongst mostly natural channels are apparent in the above wetland.

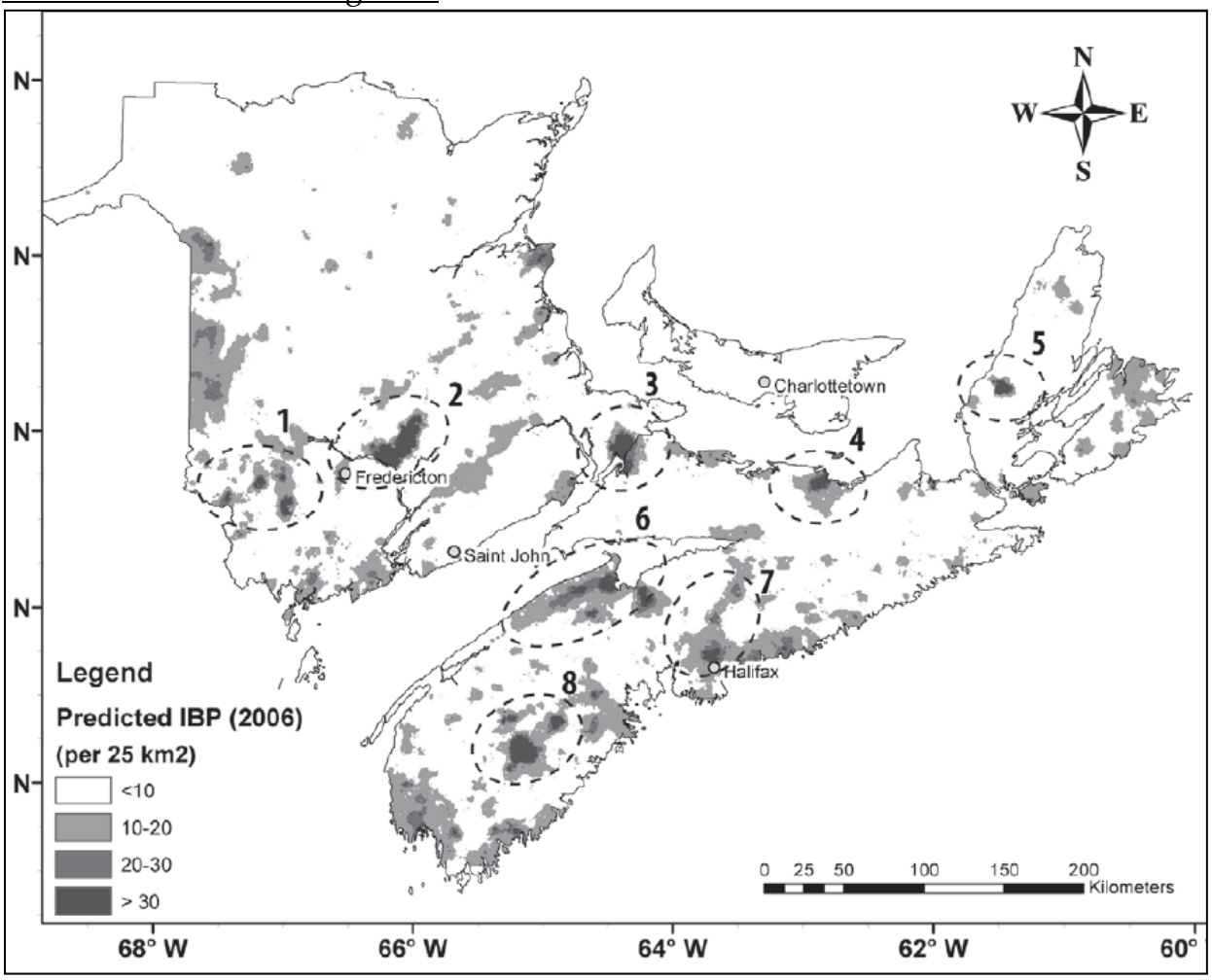
## OF19. Barrier Island

The wetland is within 1 km of a barrier island with >1 ha bare or sparsely vegetated area, and with no occupied buildings. Enter: yes= 1, no= 0.




A measure line <1 km separates the wetland on the left with a barrier island to its right.

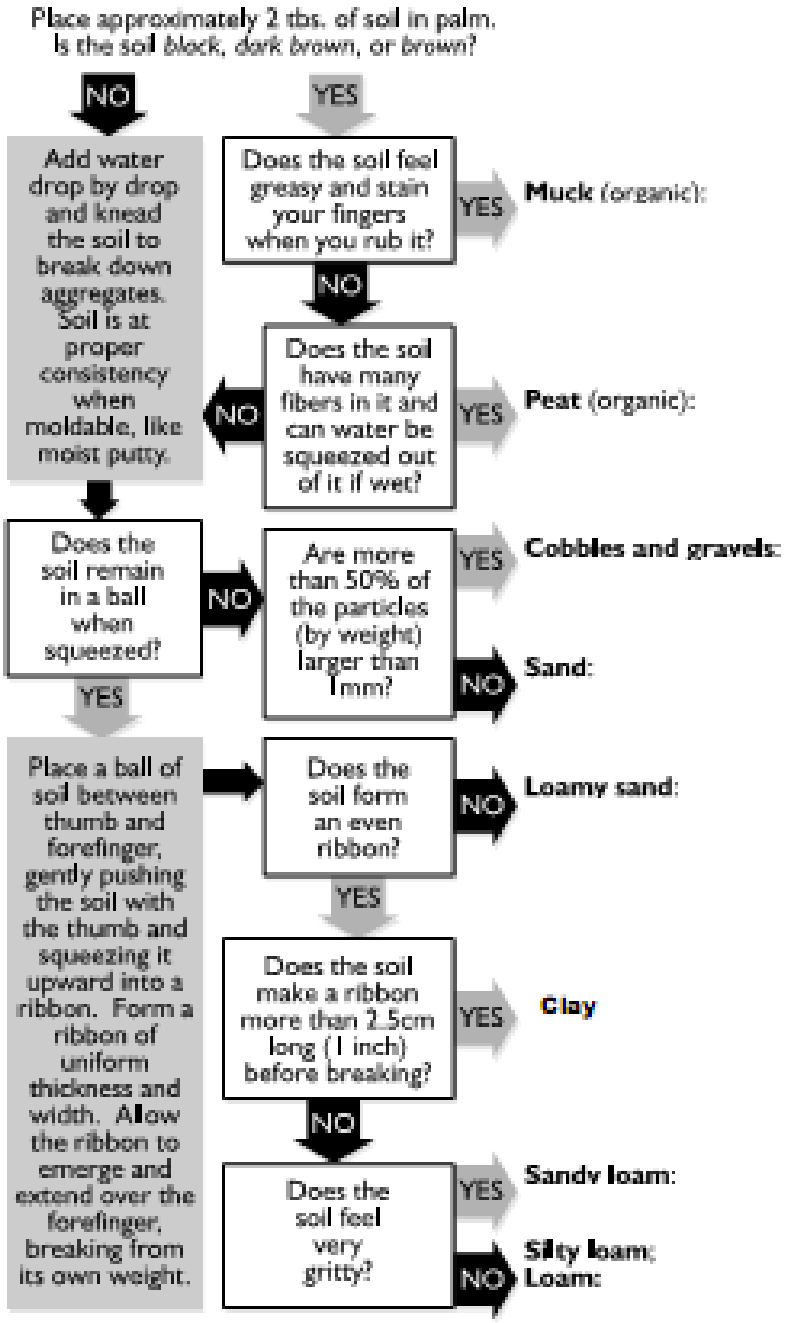
OF28. Black Duck Nesting Area




It may be easier to differentiate the shades of gray on this printed version than on the KML version distributed with WESP-AC. source: Dr. David Lieske, Mount Allison University, Sackville, NB.

**DATA FORM T (Field)**

T14. Soil Texture




Print and take this in the field to diagnose the soil texture. However, you need only determine if the soil is Loam (including Sandy Loam), Coarse (including Loamy Sand, Sand), Fines (silt, clay, clay loam, silty clay, silty clay loam, sandy clay, sandy clay loam), or Organic (muck or peat). Source: Washington Dept. of Ecology 2004.

## Appendix C. Statistical Summaries of Tidal WESP-AC Calibration Data

Table C-1. Thresholds of normalised scores used to determine each attribute rating, WESP-AC for tidal wetlands, New Brunswick and Nova Scotia.

| | NB Thresholds for Rating | | NS Thresholds for Rating | |
|---|---|---|---|---|
| Function or Other Attribute: | "Lower" IF < | "Higher" IF ≥ | "Lower" IF | "Higher" IF ≥ |
| Storm Surge Reduction | 2.09 | 4.63 | 3.04 | 5.54 |
| Water Purification | 2.55 | 5.45 | 2.22 | 5.83 |
| Organic Nutrient Export | 2.12 | 5.49 | 2.78 | 6.21 |
| Fish Habitat | 2.50 | 7.43 | 3.22 | 7.46 |
| Waterbird Habitat | 2.96 | 5.85 | 3.18 | 6.35 |
| Songbird, Raptor, & Mammal Habitat | 3.57 | 6.87 | 2.14 | 5.68 |
| Biodiversity Support | 2.15 | 6.39 | 2.00 | 3.76 |
| Wetland Stability* | 2.72 | 5.10 | 3.66 | 6.62 |
| Public Use & Recognition* | 1.14 | 2.27 | 1.39 | 4.17 |

* an attribute, not a wetland function

Table C-2. Thresholds of normalised scores used to determine each attribute rating, WESP-AC for tidal wetlands, Newfoundland and Prince Edward Island

| | NL Thresholds for Rating | | PEI Thresholds for Rating | |
|---|---|---|---|---|
| Function or Other Attribute: | "Lower" IF < | "Higher" IF ≥ | "Lower" IF | "Higher" IF ≥ |
| Storm Surge Reduction | 3.17 | 6.65 | 1.83 | 4.51 |
| Water Purification | 2.82 | 5.90 | 2.27 | 6.36 |
| Organic Nutrient Export | 2.92 | 6.14 | 3.26 | 6.71 |
| Fish Habitat | 0.01 | 6.18 | 0.00 | 3.27 |
| Waterbird Habitat | 1.15 | 2.87 | 1.21 | 3.89 |
| Songbird, Raptor, & Mammal Habitat | 3.55 | 6.73 | 1.47 | 4.64 |
| Biodiversity Support | 2.63 | 5.57 | 1.55 | 3.45 |
| Wetland Stability* | 2.59 | 5.40 | 2.26 | 6.57 |
| Public Use & Recognition* | 1.23 | 4.32 | 1.22 | 2.44 |

* an attribute, not a wetland function

Table C-3. Number of New Brunswick tidal wetland calibration sites rated "Higher" for each assessed attribute.

| Function or Attribute: | # of sites (of 43) with rating of: | | |
|---|---|---|---|
| | Higher | Moderate | Lower |
| Biodiversity Maintenance (BM) | 22 | 11 | 6 |
| Fish Habitat (FH) | 11 | 17 | 11 |
| Organic Nutrient Export (OX) | 16 | 20 | 3 |
| Public Use & Recognition (PUR) | 11 | 25 | 3 |
| Songbird & Raptor Habitat (SRH) | 17 | 11 | 11 |
| Storm Surge Interception (SS) | 11 | 18 | 10 |
| Water Purification (WP) | 7 | 9 | 23 |
| Waterbird Habitat (WH) | 21 | 13 | 5 |
| Wetland Stability (WS) | 15 | 11 | 13 |

Table C-4. Number of Nova Scotia tidal wetland calibration sites rated "Higher" for each assessed attribute.

| Function or Attribute: | # of sites (of 34) with rating of: | | |
|---|---|---|---|
| | Higher | Moderate | Lower |
| Biodiversity Maintenance (BM) | 15 | 8 | 11 |
| Fish Habitat (FH) | 13 | 14 | 7 |
| Organic Nutrient Export (OX) | 14 | 11 | 9 |
| Public Use & Recognition (PUR) | 16 | 14 | 4 |
| Songbird & Raptor Habitat (SRH) | 7 | 10 | 17 |
| Storm Surge Interception (SS) | 15 | 15 | 4 |
| Water Purification (WP) | 16 | 9 | 9 |
| Waterbird Habitat (WH) | 9 | 16 | 9 |
| Wetland Stability (WS) | 7 | 18 | 9 |

Table C-5. Number of Newfoundland-Labrador tidal wetland calibration sites rated "Higher" for each assessed attribute.

| Function or Attribute: | # of sites (of 39) with rating of: | | |
|---|---|---|---|
| | Higher | Moderate | Lower |
| Biodiversity Maintenance (BM) | 13 | 10 | 16 |
| Fish Habitat (FH) | 14 | 21 | 4 |
| Organic Nutrient Export (OX) | 8 | 21 | 10 |
| Public Use & Recognition (PUR) | 10 | 22 | 7 |
| Songbird & Raptor Habitat (SRH) | 13 | 17 | 9 |
| Storm Surge Interception (SS) | 10 | 12 | 17 |
| Water Purification (WP) | 9 | 21 | 9 |
| Waterbird Habitat (WH) | 6 | 13 | 20 |

| Function or Attribute: | # of sites (of 39) with rating of: | | |
|---|---|---|---|
| | Higher | Moderate | Lower |
| Wetland Stability (WS) | 15 | 21 | 3 |

Table C-6. Number of Prince Edward Island tidal wetland calibration sites rated "Higher" for each assessed attribute.

| Function or Attribute: | # of sites (of 19) with rating of: | | |
|---|---|---|---|
| | Higher | Moderate | Lower |
| Biodiversity Maintenance (BM) | 3 | 5 | 11 |
| Fish Habitat (FH) | 10 | 8 | 1 |
| Organic Nutrient Export (OX) | 6 | 7 | 6 |
| Public Use & Recognition (PUR) | 3 | 9 | 7 |
| Songbird & Raptor Habitat (SRH) | 6 | 9 | 4 |
| Storm Surge Interception (SS) | 10 | 5 | 4 |
| Water Purification (WP) | 5 | 10 | 4 |
| Waterbird Habitat (WH) | 5 | 5 | 9 |
| Wetland Stability (WS) | 9 | 7 | 3 |

Table C-7. Number of functions rated "Higher" at Tidal WESP-AC calibration wetlands

| # of functions (of 9) rated "Higher" | New Brunswick # of Sites (of 43) | Nova Scotia # of Sites (of 34) | Newfoundland-Labrador # of Sites (of 39) | Prince Edward Island # of Sites (of 19) |
|---|---|---|---|---|
| 8 functions | 0 | 1 | 1 | 0 |
| 7 functions | 1 | 1 | 0 | 1 |
| 6 functions | 4 | 4 | 5 | 1 |
| 5 functions | 10 | 3 | 2 | 2 |
| 4 functions | 7 | 4 | 1 | 1 |
| 3 functions | 6 | 10 | 10 | 2 |
| 2 functions | 7 | 4 | 5 | 7 |
| 1 function | 6 | 4 | 6 | 2 |
| 0 functions | 2 | 3 | 9 | 3 |