Manual for
Wetland Ecosystem Services Protocol for Atlantic Canada (WESP-AC):
Non-tidal Wetlands

New Brunswick Department of Environment and Local Government

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Electronic files:

NB WESP-AC Non-tidal Calculator_SingleSite_20March2018.xlsx
NS WESP-AC Non-tidal Calculator_SingleSite_20March2018.xlsx
NL WESP-AC Non-tidal Calculator_SingleSite_20March2018.xlsx
PEI WESP-AC Non-tidal Calculator_SingleSite_20March2018.xlsx

WESP-AC Tidal Calculator_SingleSite_20March2018.xlsx

SuppInfo_Nontidal_WESP-ACv1.1
SuppInfo_Tidal_WESP-ACv1.1

Files to open in Google Earth Pro (kmz extension):
NB Crown lands
NB Deer Wintering Areas
NB Protected Wellfields
NB Protected Natural Areas
NB Watershed Protected Areas
NB Watersheds All
NB Headtide

NS Protected Water Supply Areas
NS Watersheds Secondary
NS Growing Degree Days
NS Headtide

NL Provincial Protected Areas
NL Public Water Supply
NL Watersheds
NL Growing Degree Days

NB-PEI_GrowingDegree Days
PEI Watersheds
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 *non*-tidal wetlands in Atlantic Canada. An accompanying document contains a standardised method for rapidly assessing some of the important natural functions of *tidal* wetlands in the same region.

The non-tidal WESP-AC consists of this manual and its appendices and an Excel® spreadsheet calculator containing data forms and models (formulas). It is a regionalised adaptation of WESP (Wetland Ecosystem Services Protocol, Adamus et al. 2016 and updates) whose template for North American wetland assessments had previously been customised by resource agencies in Alberta, Alaska, and Oregon (Dorney et al. 2018).

WESP-AC generates scores (0 to 10 scale) and ratings (Lower, Moderate, Higher) for each of the following wetland attributes: Water Storage; Stream Flow Support; Water Cooling; Sediment Retention & Stabilisation; Phosphorus Retention; Nitrate Removal; Carbon Sequestration; Organic Nutrient Export; Invertebrate Habitat; Anadromous Fish Habitat; Resident Fish Habitat; Amphibian & Reptile Habitat; Feeding Waterbird Habitat; Nesting Waterbird Habitat; Songbird, Raptor, & Mammal Habitat; Pollinator Habitat; Native Plant Habitat; Public Use & Recognition; Ecological Condition; Wetland Sensitivity; and Stressors. For each attribute, the scores and ratings represent a particular wetland's standing relative to those in a statistical sample of non-tidal wetlands previously assessed by this study in the relevant province: 98 in New Brunswick, 121 in Nova Scotia, 102 in Newfoundland-Labrador, and 70 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 non-tidal WESP-AC, users initially answer a series of multiple-choice questions about a wetland by consulting aerial imagery (e.g., the free Google Earth Pro) and visiting specified web sites. The wetland is then visited and an additional set of questions are answered based on field observations and, if necessary and possible, on conversations with the person on whose property the wetland exists. 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 most data form questions (indicators) are applied to estimate several wetland attributes, users need only enter the data for each indicator in one place on the data form. In most cases, not all questions need to be answered because the data form allows many to be skipped if a wetland has specified characteristics. In its calculations, the spreadsheet accounts for differences among wetland types by ignoring, rather than scoring 0, the responses to questions that are not relevant to the type of wetland being assessed.

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 Appendix B of this manual). The spreadsheet contains a rationale for use of each metric or indicator in every model, often with citation of supporting scientific literature.

WESP-AC is a refinement of the first wetland assessment method peer-reviewed and widely used 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). WESP-AC also incorporates elements of the Hydrogeomorphic (HGM) Approach (Brinson 1983, Smith et al. 1985). Most components of WESP-AC or its predecessors have been peer-reviewed by scientists in the various disciplines that its models cover. 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 where regionalised versions of WESP were independently tested (mean confidence interval of ±0.60 around function scores on a 0-10 scale).

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 improved estimates of the levels of functions that a wetland performs. Christie Ward of New Brunswick Department of Environment and Local Government obtained the grants to support this project and later was assisted in project administration by Cassandra Colwell. Reid McLean and Jeff Stymiest of ELG provided the GIS support essential to create the database used for statistically selecting the calibration wetlands in NB. In NB, field assessments of many of the calibration wetlands were done by Christie Ward, Joanie Bertin, Cassandra Colwell, Arielle Demerchant, Melanie Godin, and Sophie Jensen from ELG; Kassandra Paillard from Ducks Unlimited Canada; and Kevin Connor and Todd Byers from NB Department of Natural Resources. In Nova Scotia, most of the calibration wetlands were assessed by McCallum Environmental Ltd. Under an agreement with Krista Hilchey (formerly of Nova Scotia Environment). 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). In Prince Edward Island, all calibration wetlands were assessed 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. Instead of attempting to measure a wetland's functions and their benefits directly (

Table 1), 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 and their associated benefits.

Nature is complex, and varies enormously from place to place. As natural systems, wetlands are no exception. Thus, the use of one word or phrase describing a wetland's type (e.g., bog, swamp, fen) or a short list of its characteristics cannot meaningfully predict what a particular wetland does and how it may benefit people and ecosystems. The roles of dozens of factors and their interactions must be considered and addressed systematically. Otherwise, assessments of what wetlands do-- and therefore decisions based on those assessments-- will be on shaky scientific ground.

Fortunately, there is a growing capacity to illustrate and encode some of nature's complexity in computer models. This, along with the commonplace availability of personal computers that make those models quick and easy to use, has made some types of models simple to apply in the support of decisions and policies, while at the same time reassuring users and decision-makers that assumptions in these models are transparent.

Table 1. Benefits of wetland functions scored by WESP-AC in Atlantic Canada.

Function	**Definition**	**Potential Benefits**
HYDROLOGIC FUNCTIONS:		
Water Storage & Delay	The effectiveness for storing runoff or delaying the downslope movement of surface water for long or short periods.	Flood control, maintain ecological systems
Stream Flow Support	The effectiveness for contributing water to streams especially during the driest part of a growing season.	Support fish and other aquatic life
WATER QUALITY MAINTENANCE FUNCTIONS:		
Water Cooling	The effectiveness for maintaining or reducing temperature of downslope waters.	Support coldwater fish and other aquatic life
Sediment Retention & Stabilisation	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 receiving waters. Protect shoreline structures from erosion.
Phosphorus Retention	The effectiveness for retaining phosphorus for long periods (>1 growing season)	Maintain quality of receiving waters.

Function	Definition	Potential Benefits
Nitrate Removal & Retention	The effectiveness for retaining particulate nitrate and converting soluble nitrate and ammonium to nitrogen gas while generating little or no nitrous oxide (a potent greenhouse gas).	Maintain quality of receiving waters.
Organic Nutrient Export	The effectiveness for producing and subsequently exporting organic nutrients (mainly carbon), either particulate or dissolved.	Support food chains in receiving waters.
ECOLOGICAL (HABITAT) FUNCTIONS:		
Fish Habitat	The capacity to support an abundance and diversity of native fish (both anadromous and resident species)	Support recreational and ecological values.
Aquatic Invertebrate Habitat	The capacity to support or contribute to an abundance or diversity of invertebrate animals which spend all or part of their life cycle underwater or in moist soil. Includes dragonflies, midges, clams, snails, water beetles, shrimp, aquatic worms, and others.	Support salmon and other aquatic life. Maintain regional biodiversity.
Amphibian & Reptile Habitat	The capacity to support or contribute to an abundance or diversity of native frogs, toads, salamanders, and turtles.	Maintain regional biodiversity.
Waterbird Feeding Habitat	The capacity to support or contribute to an abundance or diversity of waterbirds that migrate or winter but do not breed in the region.	Support hunting and ecological values. Maintain regional biodiversity.
Waterbird Nesting Habitat	The capacity to support or contribute to an abundance or diversity of waterbirds that nest in the region.	Maintain regional biodiversity.
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 wetlands or water.	Maintain regional biodiversity.
Native Plant Habitat, Pollinator Habitat	The capacity to support or contribute to a diversity of native, hydrophytic, vascular plant species, communities, and/or functional groups, as well as the pollinating insects linked to them.	Maintain regional biodiversity and food chains.
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, education, or research.	Commercial and social benefits of recreation. Protection of prior public investments.

* a benefit rather than a function of wetlands

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. 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 and benefits. The number of indicators that is applied to estimate a particular wetland function depends on which function is being assessed. The number may range from a few to as many as 61 (however, not all indicators need to be assessed in every wetland). The indicators are combined in a spreadsheet using mathematical formulas (models) to generate the score and rating for each wetland function and benefit. The models are logic-based rather than deterministic. Together they provide a profile of "what a wetland does." WESP-AC indicators and models attempt to incorporate the best and most recent scientific knowledge available on what determines the levels of functions provided by individual wetlands.

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 or benefit. The weights can be viewed in column E of the individual worksheets (tabs at bottom) contained in the calculator spreadsheet.

For most models of wetland functions, the indicators were grouped by the underlying *processes* they inform. Indicator and process 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 landscape. Further details about the development of WESP-AC are provided in Appendix B.

Non-tidal wetlands are vegetated wetlands that do not experience fluctuation of their surface water levels at any time during a year as a result of oceanic tides. They are commonly categorised as swamp, marsh, bog, or fen. A separate tool and manual addresses **tidal** wetlands in each of this region's provinces.

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 reducing regional flood damages or treating stormwater (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 wetland, regardless of how intact, pristine, or biodiverse it may be, can provide all functions at a high level because many 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

WESP-AC is a regionalised modification of WESP, the Wetland Ecosystem Services Protocol (Adamus et al. 2010 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). WESP and WESP-AC also incorporate elements of the Hydrogeomorphic (HGM) Approach (Brinson 1983, Smith et al. 1985) and the Millennium Ecosystem Assessment (Finlayson et al. 2005). 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, 2016). That tool is required for all major wetlands permitting and compensation in Oregon. Another WESP regionalisation was developed and calibrated during 2012-2016 for required use by the

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

Province of Alberta, and a regionalisation for Southeast Alaska was developed and calibrated from 2011-2015 for the U.S. Fish and Wildlife Service[2] .

The basic steps of the WESP regionalisation process are:

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 in Dorney et al. (2018) and as follows.

Literature Review

To better understand relationships among variables that might indicate functions of Atlantic Canada 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. In addition to using obvious keywords such as New Brunswick and wetlands, the author expanded the query to include various forms of terms such as lake, pond, stream, river, riparian, groundwater, catchment, watershed, and paired those with keywords describing geographic features within the study area and nearby regions. An indexed database was created that allows the citations to be sorted quickly by any combination of topics. Most of the citations refer to peer-reviewed scientific publications, and the abstracts of all (and sometimes the entire publication) were read. The database was subsequently used to document the reasons behind using particular variables in particular WESP-AC models, as well as to support generally the weights assigned to various conditions of a given indicator.

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,

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

the resulting range of the raw scores found among all sites will be quite narrow (e.g., 3 to 8) for some functions whereas for others it will be broad (e.g., 0 to 10). Thus, to facilitate rough comparisons among functions, all raw scores were converted mathematically to the same 0 to 10 scale. For each wetland function or other attribute assessed by WESP-AC, this was done by comparing the raw scores with the range of scores determined from all the wetlands that were visited and assessed in the respective province (Appendix C, and SuppInfo files). This comparison process is termed "calibration" or "normalisation" and the assessed wetlands are termed "calibration wetlands".

The calibration wetlands in each province were not selected randomly. That is because we were not trying to characterise the condition of wetlands in the study area overall. Rather, our aim was to define the likely range of WESP-AC score variation with as few wetlands as possible. The approach to selecting our calibration wetlands varied somewhat by province. For NS and NL, we used ecoregions to affect a reasonable spatial distribution of the sites. For NB and PEI, and secondarily in NS, we first performed a cluster analysis to ensure the chosen wetlands encompassed a wide range of characteristics important to wetland functions and considered ecoregions only secondarily. Cluster analysis is a statistical procedure which, unlike ecoregions, does not consider the geographical distribution of potential calibration sites. By analyzing multiple characteristics of all mapped wetlands in a province as measured from existing spatial data, cluster analysis assigns each wetland to a group or cluster such that the wetlands within a cluster are more likely to be similar in their characteristics (and thus, presumably, their functions) than those in a different cluster. Cluster analysis classifies each mapped wetland in a manner that is much more thorough and functionally relevant than simply classifying as a bog, fen, swamp, or marsh. Those familiar wetland types were taken into account by the clustering procedure but were not assigned greater weight than many other characteristics discernable from existing spatial data. To field-calibrate WESP-AC effectively, our aim was to visit and assess at least one wetland in each cluster. We succeeded in doing so for almost every cluster in each province.

The type of cluster analysis we used is termed k-means clustering, a procedure which allows the analyst to specify in advance the number of clusters ("k") desired rather than let statistical relationships within the input data to determine that. That procedure was chosen because it could be run without requiring massive computer capacities, and because for reasons of time and budget only a fixed number of sites, one per cluster, could be visited. The number of clusters we specified for the analysis was 80 for NB, 120 for NS, and 72 for PEI. The number of sites actually visited and assessed was 98,

121, and 70 respectively. Because NL did not have wetland maps covering the entire province, we simply drove roads within all 24 of Newfoundland's sub-ecoregions and 3 of Labrador's 12 ecoregions until an accessible wetland was noticed, and then assessed that. We set a goal of visiting 3-4 calibration sites per each NL ecoregion that we covered, and achieved that in nearly all (Northern Long Range had only one site assessed, and Twilick Steady had only two). In Labrador, more sites than usual were assessed in one ecoregion (Forteau Barrens, 9 sites) to help compensate for our inability to access sufficient sites in most other Labrador ecoregions.

To create the input data for the cluster analyses in NB, NL, and PEI, we first used GIS to intersect the province's wetlands spatial data layer with spatial data pertaining to hydrography (stream connectivity), watershed position, size, surrounding land cover, and other variables depending on what was functionally relevant and available for a province. Performing those intersects resulted in large databases for each province (except NL, which had no wetland spatial data), wherein each row was a different wetland polygon and each column a different characteristic of that wetland or its associated landscape as derived from the overlay. Those databases are available from the author in Excel format. Prior to doing the spatial data intersects and cluster analysis in NS, we improved the existing spatial data for wetlands by modeling the probable locations of forested wetlands. This expanded considerably the areas shown as wetlands as well as their apparent connectivity.

Because each statistical cluster contained multiple wetlands, a decision was required about which one to visit and assess. In making that decision we took into account (1) ease of access, limiting the selection to wetlands within 100 m of roads, (2) ownership, in nearly all instances preferring sites on Crown lands or lands managed by conservation groups, and (3) proximity to other calibration wetlands, preferring ones not too distant yet well-separated hydrologically.

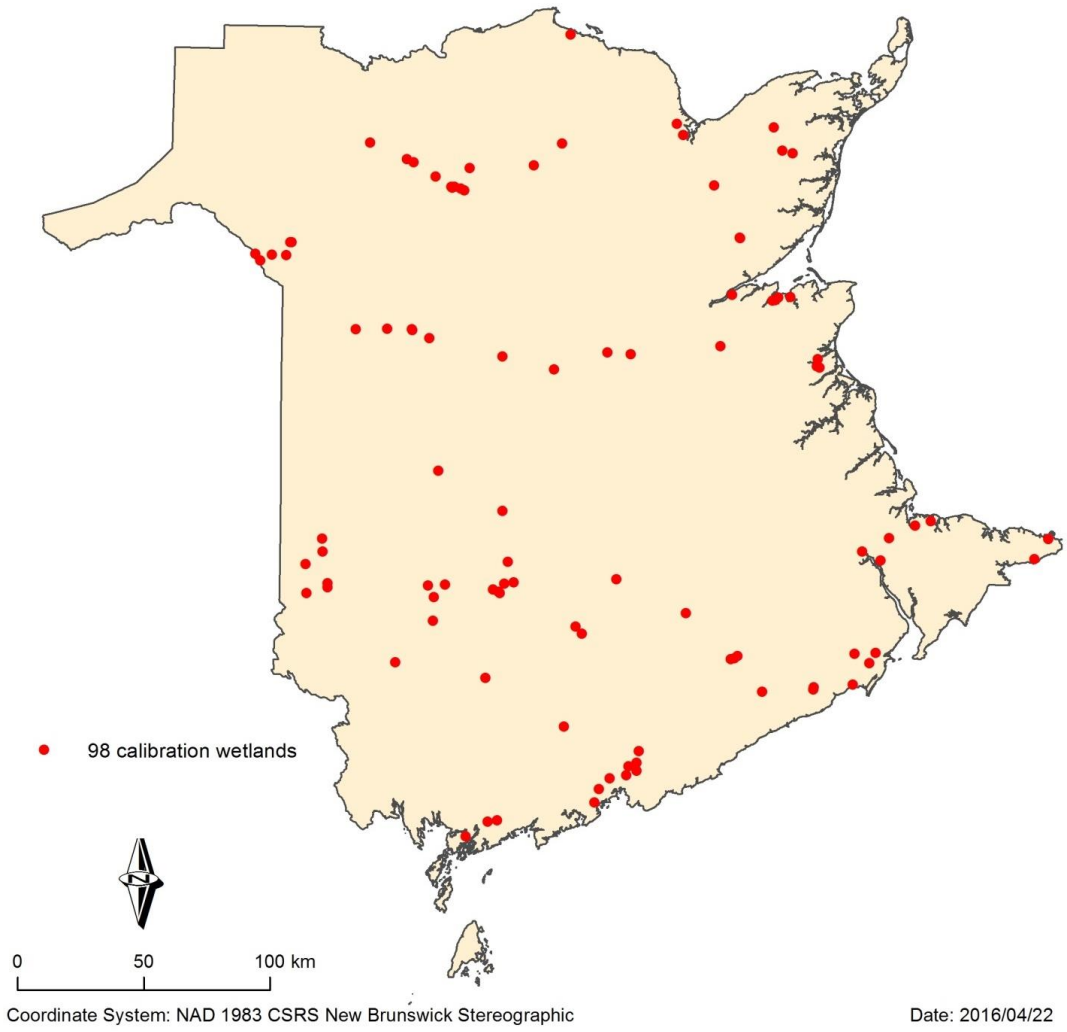


Figure 1. Locations of New Brunswick WESP-AC non-tidal wetland calibration sites

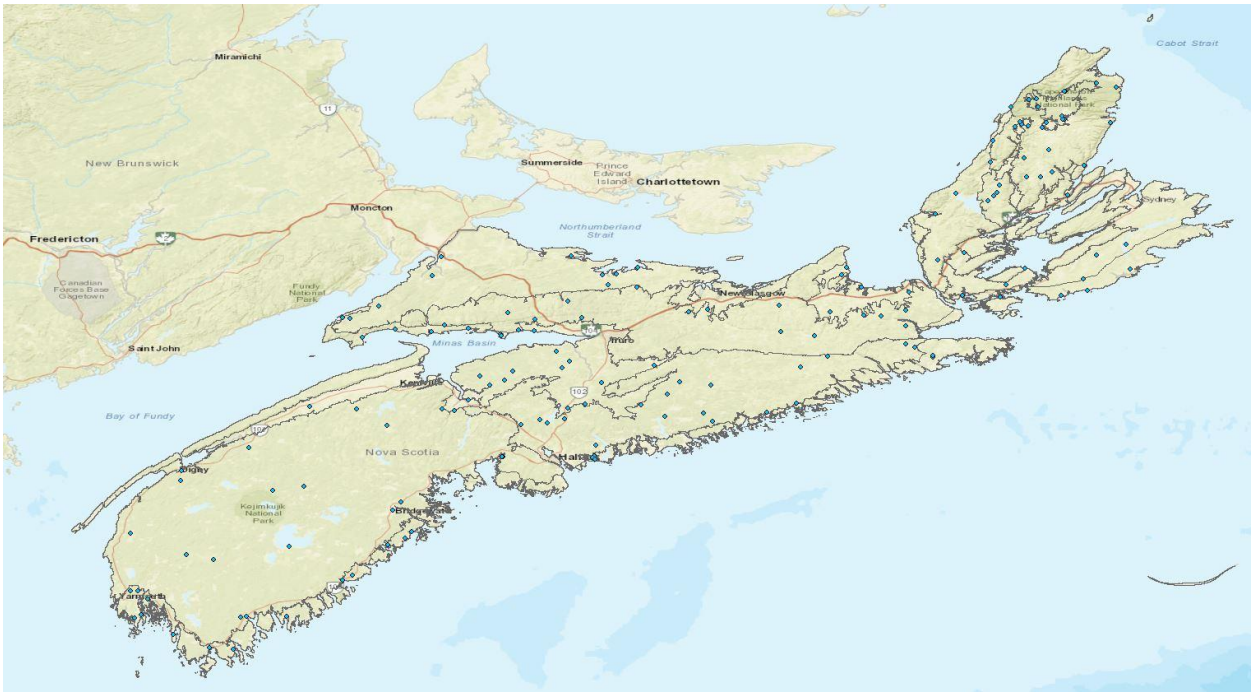


Figure 2. Locations of Nova Scotia WESP-AC non-tidal and tidal calibration wetlands (dots are sites, lines are ecoregion boundaries)

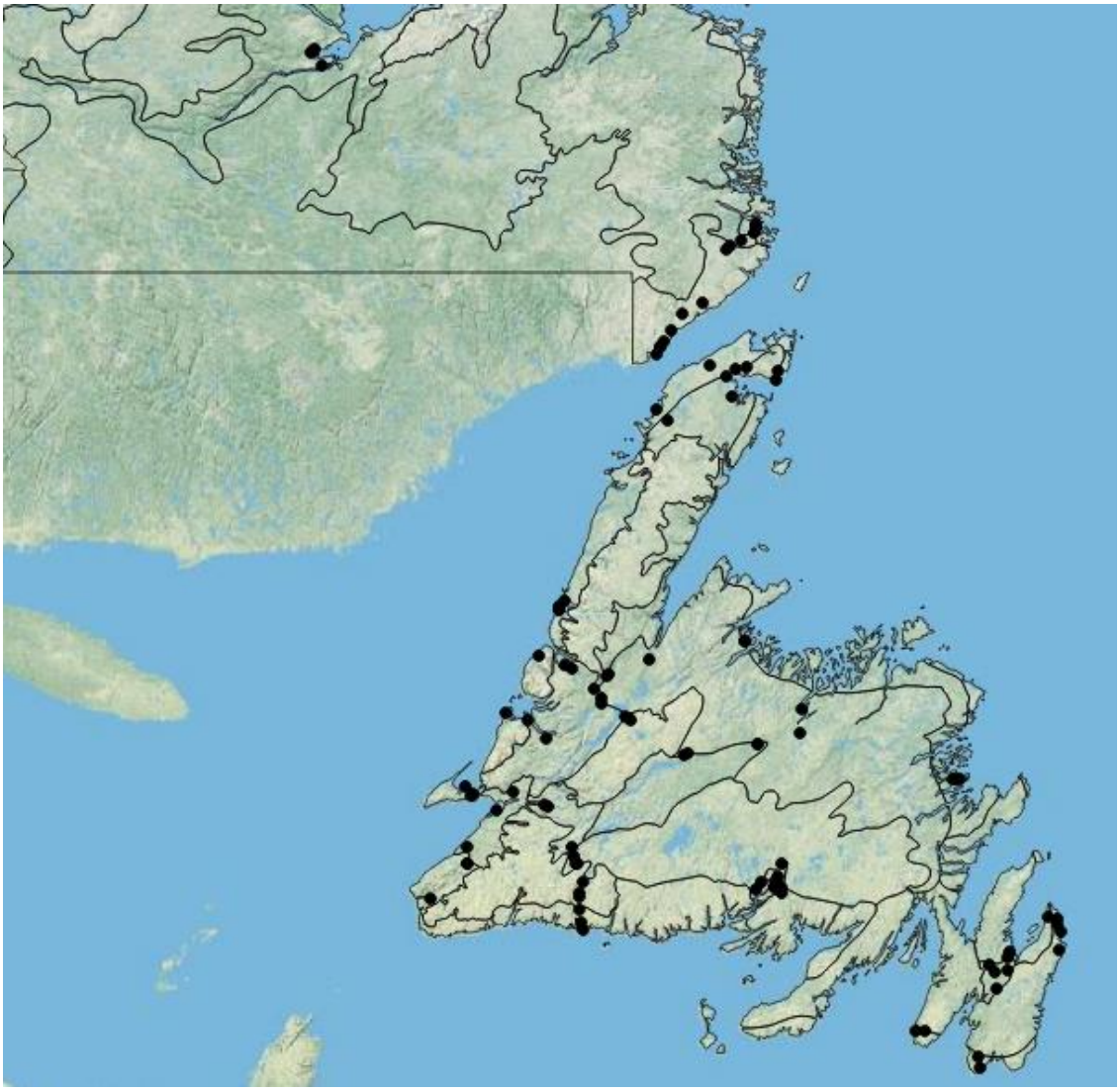


Figure 3. Locations of Newfoundland-Labrador WESP-AC non-tidal calibration wetlands (dots are sites, lines are ecoregion boundaries)

Figure 4. Locations of Prince Edward Island WESP-AC non-tidal calibration wetlands

Conducting the Field Component of the Assessments

In a few instances, the wetlands chosen for visitation and assessment proved to be inaccessible or non-existent. In most such cases, attempts were made at a later date to visit and assess an alternate wetland belonging to the same statistical cluster. Visiting and assessing a wide variety of 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 and streamline them by determining the most efficient order of questions , i.e., which sequencing allows users to skip the most questions in various contexts. 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 question wordings 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. Function and Benefits scores for each of the wetlands visited and assessed are presented in the CalibSiteScores worksheet in the SuppInfo_Nontidal_WESP-AC Excel file that accompanies this report.

Completing the Office Component of the Assessments

Field data alone are insufficient to accurately score a wetland's functions. Additional data must be obtained and interpreted from aerial images and existing databases and entered on Form OF of the spreadsheet. After all calibration sites were visited, the author answered all the Form OF questions for the NB, NS, and NL calibration sites, while the Form OF questions for the PEI calibration sites were answered by Derek Ellis who had visited all those sites.

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 the most common wetland plants and invasive plants in this region,
   - determine soil texture broadly (coarse, loamy, peat, other organic, or fine),
   - understand wetland hydrology and local climate,
   - delineate wetland catchment (contributing area) boundaries from a topographic map as explained in this manual.

Some of the requested information may not be accurately determinable during a single visit to a wetland, particularly if that visit occurs outside the growing season. Some wetland conditions vary dramatically from year to year and even within a growing season. Thus, the accuracy of results will be greater if users are able to visit a site during different water conditions, or are at least familiar with the changes in wetland conditions that typically occur locally, or can consult with landowners or others who know that.

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 the region's small 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 for land cover, may have changed since the layer was created years ago. Nonetheless, the advantages of

judiciously using the existing spatial data, as just one component of each wetland's WESP-AC scores, were felt to outweigh the disadvantages.

4. WESP-AC scores only indicate a wetland's functional effectiveness relative to other wetlands in the specified province. Intensive or long-term field measurements might subsequently determine that even the wetlands scored lowest by WESP-AC are, in fact, performing a particular function at a very high absolute level, or some wetlands that score very high are found to barely provide the function (see Appendix B for more on model validation). Thus, 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). The models systematically combine well-accepted indicators in a logically sophisticated manner that attempts to recognise context-specific, functionally contingent relationships among indicators, such as wetland type.

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 many have been subjected to multiple peer reviews.

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 and providing associated benefits.

6. WESP-AC converts raw scores to estimates of relative wetland function or benefits, and then normalises these to the scores of 98 wetlands that were assessed. 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 or benefit differs from those of other functions or benefits (some functions skew low, others high), the scores of different

functions are not comparable in the strictest sense. Speaking hypothetically, if 90% of the wetlands in a region had raw scores for the Fish Habitat function of 0 and among the remainder the maximum score was 4, after those raw scores are normalised (i.e., mathematically spread out into a scale of 0 to 1.0), a wetland with a score of 3 would have a normalised score of 9 (because 3 is close to the maximum score of 4 for this function in this region). The high normalised score implies the wetland is functioning very well for Fish Habitat, when in fact its very low raw score of 3 (out of a theoretically possible score of 10) indicates it probably is not.

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. 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, hydrologist, biogeochemist) 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 wetlands 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 and benefits that a wetland might support. Those which it addresses are ones ascribed to 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, analysis of existing spatial data, and manual interpretation of aerial images. Groundwater recharge, for example, is an important wetland function that is not scored because it has no reliable indicators that can be estimated rapidly in this region.

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 wetland as habitat for any individual wildlife or plant *species*. Models of greater accuracy, using the same spreadsheet calculator and heuristic modeling framework that WESP-AC uses, could easily be created for individual species, for more specific biological guilds (e.g., diving ducks vs. surface-feeding ducks 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 weed control. 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 wetland 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?” 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 Procedures

1. If training in the use of WESP-AC is offered by an qualified 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 F.

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

3. On an aerial image, draw the approximate boundary of the wetland. If part of the wetland cannot be observed during a field visit (due to property ownership status, physical hazards, or wetland is too large, **also** draw a line around just the part you are likely to observe effectively. This is called the **assessment area (AA).** Part of its boundary will likely be the same as the wetland boundary, but depending on the assessment objective it may comprise only a *subunit* of the entire wetland. Read section 2.2 for guidance before drawing this boundary.

4. Open the Excel calculator spreadsheet, click on the tab labeled "OF" (for office or off-site) and answer all questions, then give the file a name that describes it uniquely, e.g., Moncton_23. You do not need to print this worksheet beforehand because you will be answering the questions directly on a computer. However, once you've answered them, print a copy to take along when you visit the wetland.

5. If you cannot differentiate this region's major **invasive (exotic) plant species** from its native species, memorise photos of the invasives before visiting the wetland or use a field guide.

6. **Print** Forms F and S from the spreadsheet. Then **visit the wetland** during the growing season and do the following:

a. Evaluate soil, water, and vegetation to digitally delineate the boundary between wetland and upland according to agency guidance. Or, obtain a digital file with that boundary from a reliable source who determined it recently.
b. If necessary, adjust your drawing of the AA boundary.
c. Fill out a printed copy of Form F and Form S during your visit, following the field protocol described in section 2.3. Also fill out the Cover Page (**CovPg**) form.
d. If possible, conduct surveys for rare plants and animals listed in the accompaying SuppInfo file. Do so at an appropriate time of the season and using approved survey protocols if those are available.
e. Check to be sure every question on both data forms was answered, except where the form directed you to skip one or more questions. Be sure all data were correctly entered.
f. Review the answers you earlier provided on Form OF, and change any responses which observations during the subsequent on-site visit suggested were inaccurate.

7. 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
___aerial image of the site showing boundaries of the wetland and (if different) your AA
___ground-level photos from several angles and showing surface water (if any) and the dominant plants
___list of exotic plants you found within the wetland, if any.

2.2 Drawing Boundaries of the Wetland and the Assessment Area (AA)

Whenever feasible, entire wetlands should be assessed. However, as explained above, it sometimes will be necessary to delimit just a portion of the wetland -- called the Assessment Area (AA) -- and assess it separately. This happens if it is impractical to view most of the wetland up close because it is so large, conditions are physically too hazardous, and/or property ownership status does not allow examination of a significant part. The AA boundary does not need to be determined with the same precision that you might use to delineate the wetland boundary.

The AA will be smaller than the wetland and will normally consist of vegetated wetland ***and* --** if that wetland vegetation is in a depression (basin) -- all the **adjoining water and mudflat** within the depression as well, regardless of water depth. The AA boundaries may need to be adjusted during the field component. *Where* you draw the boundaries of the AA can dramatically influence the resulting scores, so provide a hand-drawn map clearly showing those boundaries. You should also estimate and describe the approximate percent of the mapped AA you were able to visit (taking into account both physical restrictions and private property restrictions). Space is provided for recording this on the CovPg worksheet.

There are at least three "special cases" in which more specific guidance is provided below for defining an appropriate AA boundary:

- Fragmented wetlands
- Lake-fringe wetlands
- River-fringe and floodplain wetlands

<u>Fragmented Wetlands</u>

If a wetland that once was a contiguous whole is now divided or separated from its formerly contiguous part by a road or dike (Figure 5), assess the two units separately (two AA's) unless a functioning culvert, water control structure, or other opening connects them, and their water levels usually are simultaneously at about the same level. *Boundaries of the AA should be based mainly on* ***hydrologic connectivity****.* They normally should not be based *solely* on property lines, fence lines, mapped soil series, vegetation associations, elevation zones, land use or land use designations.

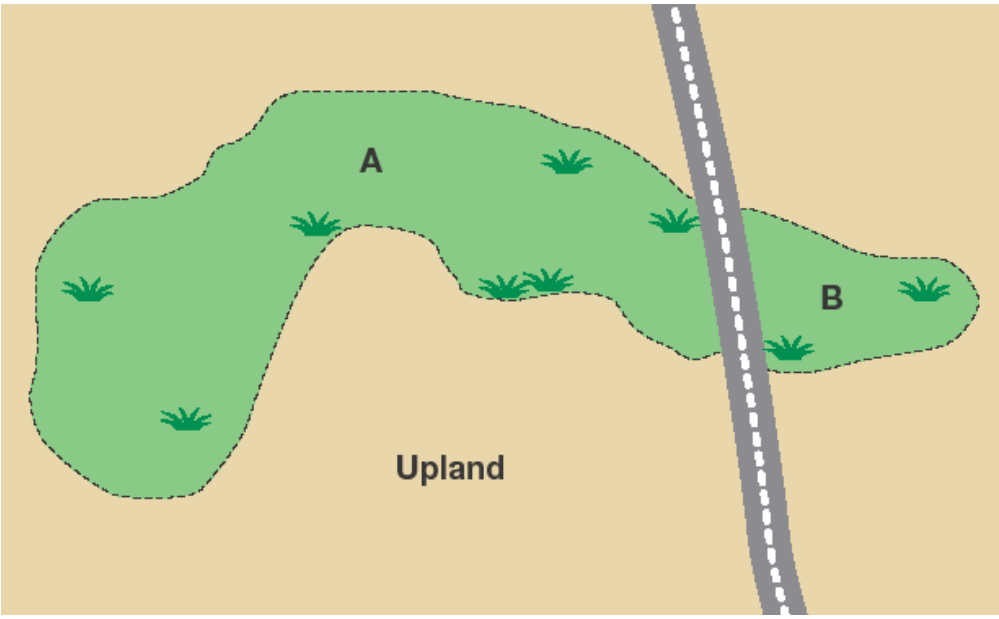


Figure 5. Dissected wetland.

A wetland is crossed by a road or filled area. Separate the wetland into two AA's and assess separately if A and B have different water levels and circulation between them is significantly impeded.

Lake-fringe Wetlands

If a lake or reservoir (or any ponded water body) that adjoins a vegetated wetland is longer than 1 km, and its open water part is much wider than the width of the vegetated wetland along the shoreline, then the AA should be delimited to include the vegetated wetland plus only the portion of adjoining open water that is believed to be shallower than 2 m during annual low water. If that cannot be estimated, extend the AA outward into the lake a distance equal to about the average width of the wetland that is along its shoreline (measured perpendicular to the shore).

If distinct units of vegetated wetland are located discontinuously along the shoreline, any two adjoining units separated by non-wetland can be combined if the distance separating them, measured parallel to shore, is less than the length of the larger of the two vegetated wetlands, measured parallel to shore.

River-fringe Wetlands

If a stream, ditch, or other flowing-water channel intersects a vegetated wetland, the AA should normally include that feature if the feature is narrower than the maximum width of the vegetated wetland, as measured perpendicular to shore along one side of the stream, ditch, or channel. If the adjoining stream or river is wider, the AA should

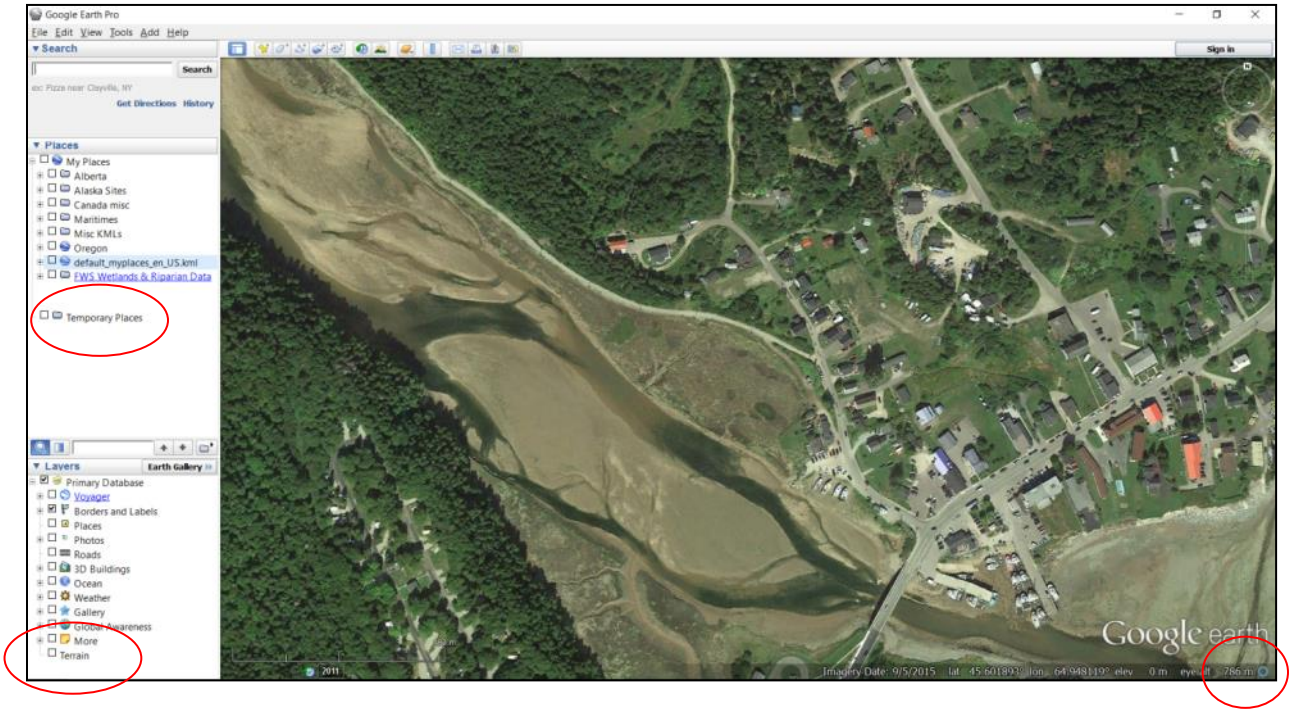
consist of the vegetated wetland plus the portion of the open water in the stream or river that is shallower than 2 m at annual low water. If that cannot be estimated, extend the AA outward into the channel a distance equal to about the average width of the wetland that is along its shoreline (width measured perpendicular to the shore). If the wetland is within an area that floods at least once every two years from river overflow, the AA should include all the contiguous overflow area (floodplain) that exists between the wetland and the channel.

If distinct units of vegetated 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.

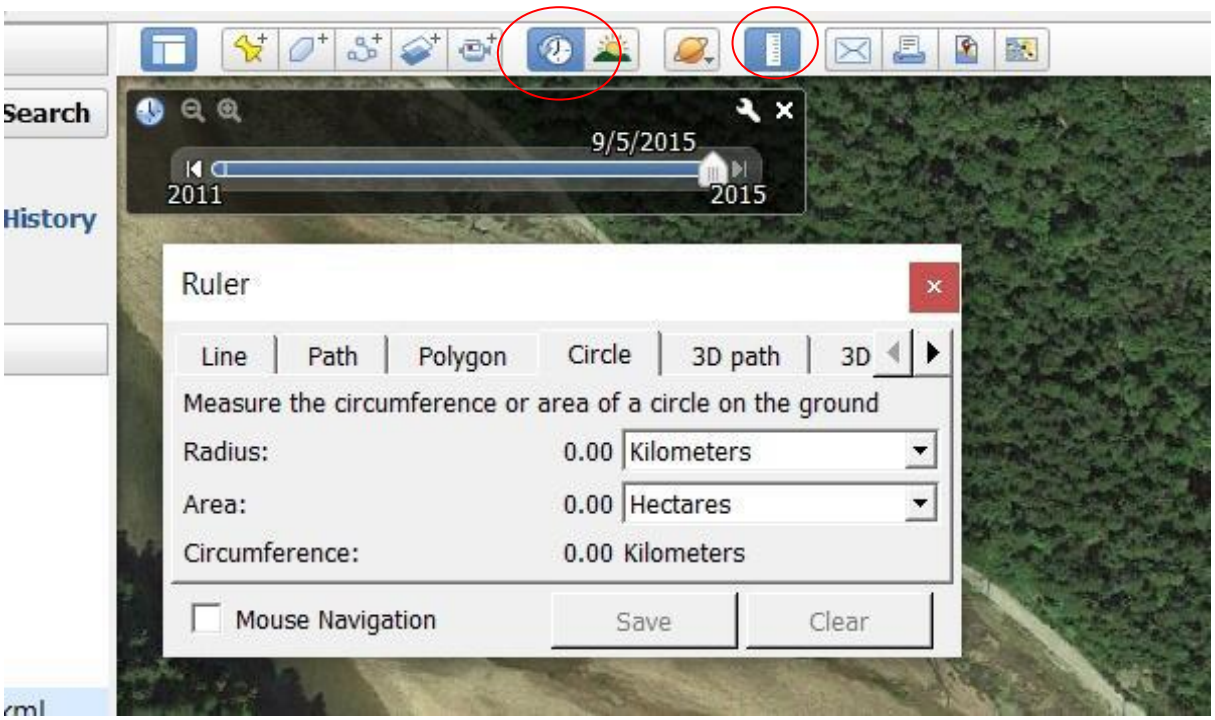
2.3 Instructions for Office Component

For many of the in-office questions (worksheet OF) you will use the free Google Earth Pro from: **http://www.google.com/earth/download/gep/agree.html**
Instructions for using it specifically to help answer the questions on Form OF can be found in column E of worksheet OF in the WESP-AC calculator. For a few questions, you will need to overlay a KML-format file on the GoogleEarth image. Those files are provided with this report in a folder called KMZs_forDistribution_wNontidal_WESPAC.
A few questions require you to view figures in Appendix A of this manual. And for assessments in NB or NS, you will be directed to go online to the province's map viewer, as explained in 2.3.3 and 2.3.4 below.

2.3.1 Google Earth Pro



The approximate elevation at the point where you place the cursor is shown in lower right, provided that the box next to "Terrain" in lower left is checked. When a separate KMZ or KML file containing a map overlay is opened, its title will show under the Temporary Places menu (upper left), and you will click on a box next to it to show or not show that map layer. When exiting Google Earth, a prompt will ask if you want to save that layer -- answer "yes."



In the Google Earth Pro toolbar at the top, clicking on the icon circled on the right will bring up the Ruler menu. To draw a buffer around a point, select "Circle" from the top of the Ruler menu. Then place the cursor on the point and drag it while watching the radius increase until it reaches the desired size. Also, you can select "Path" to measure indirect distance between points, or "Polygon" to measure area, clicking on various points to outline the path or shape.

Clicking on the clock icon circled on the left will bring up the blue bar. Clicking at different points on the bar will change the aerial image to those dates, if any available for this location.

2.3.2 Drawing the Catchment Boundary

The AA's catchment (CA, also called the "contributing area," Figure 2) includes all areas uphill from the AA until a ridge or topographic rise is reached, often many kilometers away, beyond which water would travel in a direction that would not take it to the AA. The water does not need to travel on the land surface; it may reach the AA slowly as shallow subsurface seepage[3]. The lowest part of a CA is usually the perimeter (upland-wetland edge) of the AA. The CA's highest point is often along a ridgeline or

[3] There are often situations where subsurface flow (especially deep groundwater), that potentially feeds a wetland, ignores such topographic divides. However, due to the limitations imposed by rapid assessment, no attempt should be made to account for that process.

topographic rim or mound located in the uplands. Although it is possible that roads, tile drains, and other diversions that run perpendicular to the slope may interfere with movement of runoff or groundwater into a wetland (at least seasonally), it is virtually impossible to determine their relative influence without detailed maps and hydrologic modeling. Therefore, in most cases draw the CA as it would exist *without* existing infrastructure, i.e., based solely on natural topography as depicted in the topographic map. The only exception is where maps, aerial images, or field inspections show artificial ditches or drains that *obviously* intercept and divert a *substantial* part of the runoff before it reaches the wetland, or where a runoff-blocking berm, dike, or elevated road adjoins all of a wetland's uphill perimeter.

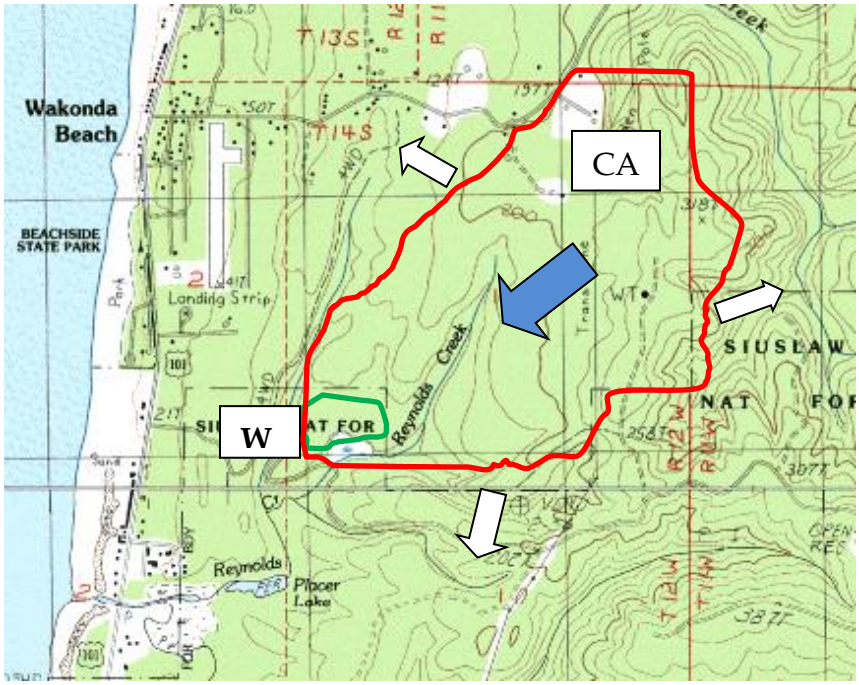


Figure 6. Approximating a wetland's catchment (CA).

Wetland (to the right of the "W") is fed by its catchment (CA) whose boundary is represented by the red line. The dark arrow denotes flow of water downgradient within the CA. The light arrows denote the likely path of water away from the CA and into adjoining drainages, as interpreted from the topography. Note that the CA boundary crosses a stream at only one point, that being the outlet of the wetland.

The CA may include other wetlands and ponds, even those without outlets, if they're at a higher elevation. Normally, the boundary of a CA will *cross a stream at only one point*—at the CA's and AA's outlet, if it has one. Include bordering perennial waters at the same elevation (such as a pond, lake, river). Especially in urban areas and areas of flat

terrain, the CA boundaries can be somewhat subjective and estimation in the field may be preferable. However, for WESP-AC's purposes a high degree of precision is not needed.

Although the amount of runoff received by an AA may vary annually as wetlands farther upslope connect or disconnect in response to varying precipitation, the size of the CA you draw will remain constant because it is based on topography rather than on presence of surface connections.

Topographic maps can be viewed at a number of online web sites, including the National Atlas of Canada (Toporama) at: http://atlas.gc.ca/toporama/en/index.html

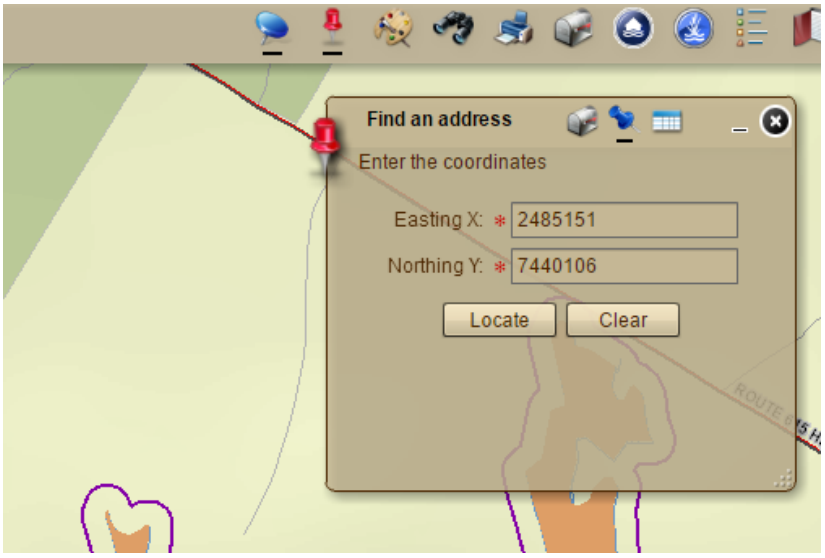
2.3.3 New Brunswick Map Viewer

Access the GeoNB Viewer at: **http://geonb.snb.ca/geonb/**

Note this toolbar at the top of the Viewer's opening page:

The Draw and Measure tool can be used to measure both area (hectares) and linear distances.

If you only have the X-Y coordinates of a site, you can move the Viewer to it by clicking on the red pushpin in the toolbar, then in the pop-up menu, click on the blue pushpin to enter the Easting and Northing, or click on the mailbox icon to enter a street address. GeoNB does not allow searching by decimal degrees of latitude and longitude, but coordinates in that format can be converted to Easting and Northing by using a tool at http://geonb.snb.ca/cts/index.html



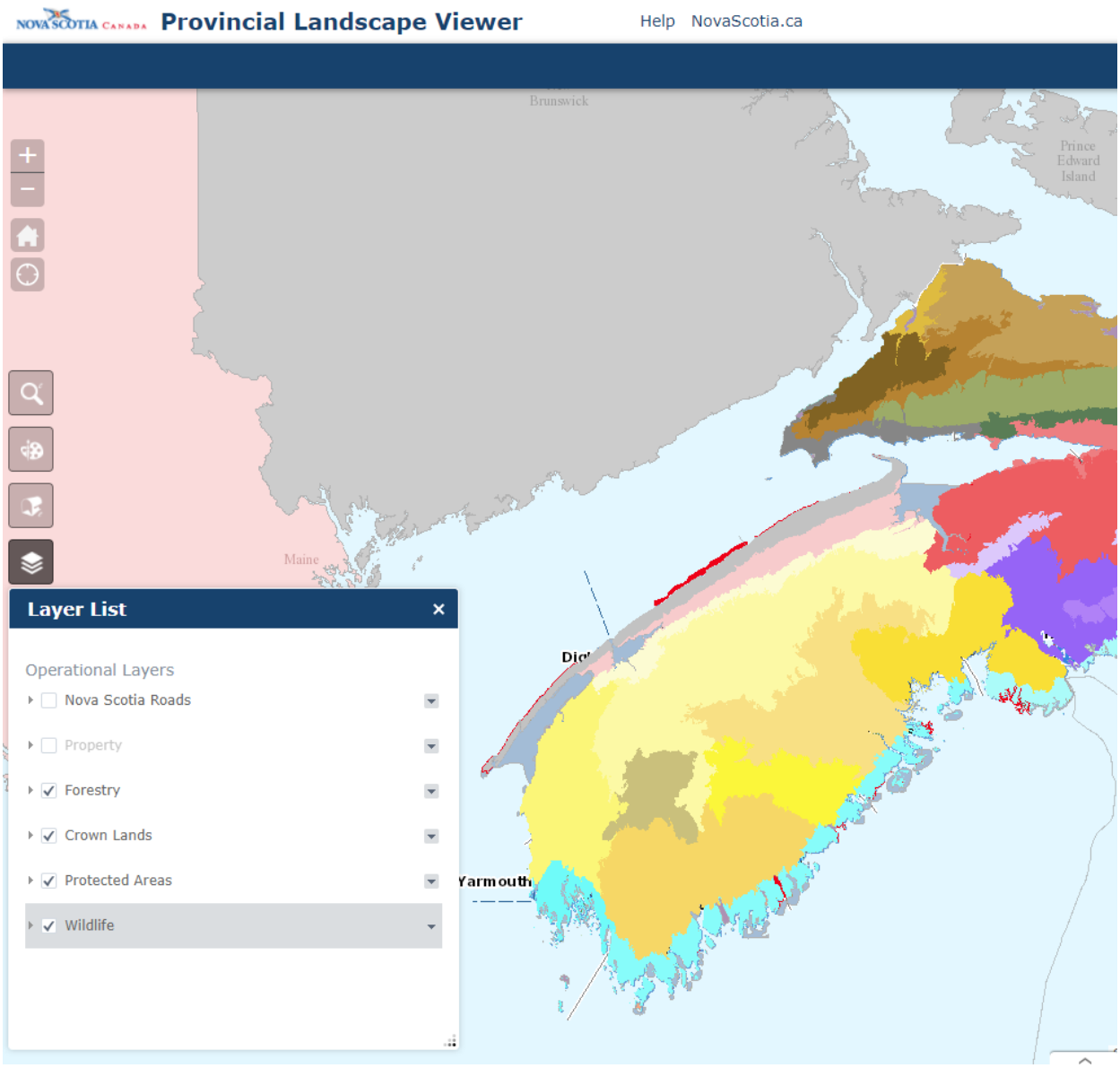
GeoNB pop-up menu for entering coordinates.

GeoNB pop-up menu for measuring line length (third icon from left) or polygon area (third polygon from right).

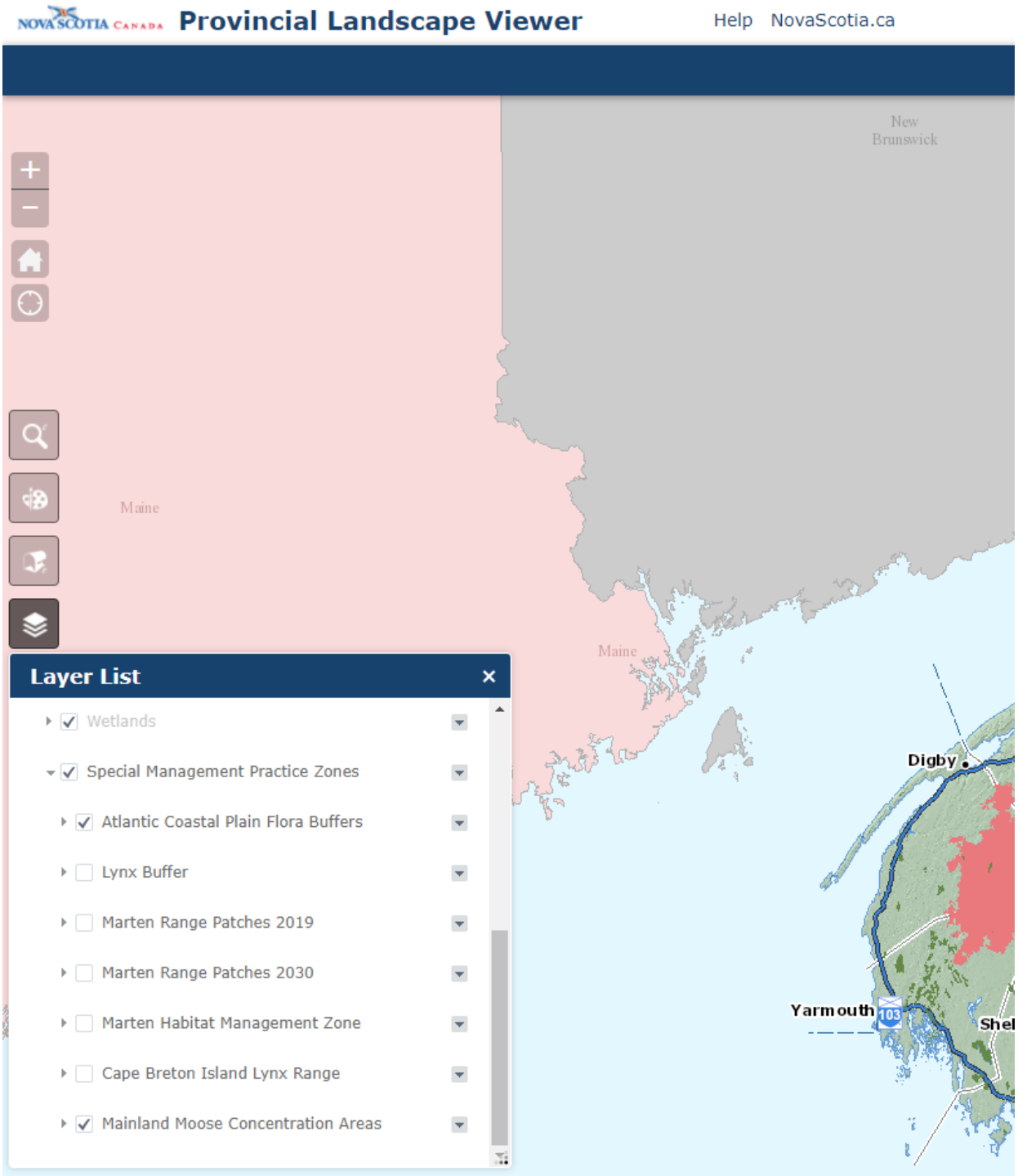
2.3.4 Nova Scotia Map Viewer

Access the Provincial Landscape Viewer at: **https://nsgi.novascotia.ca/plv/**
Navigate to your wetland using the cursor or by entering coordinates in the menu that pops up when you click on the mailbox icon on the left edge.

Click on the Layers icon on the lower left edge.
Click on the small triangular marker on the left of the folder to expand it.
Click on boxes whose themes you need to display on the map, then zoom in.



Some of the layers needed to answer the Form OF questions are checked in the menu below. They are in the Wildlife folder.



2.4 Instructions for Field Component

The field component involves visiting as much of the AA as possible and filling out the two field forms (F and S). The field component will generally require less than three hours (large or complex sites may take longer). If circumstances allow, visit the AA during both the wettest and driest times of the growing season. If you cannot, you must rely more on the aerial imagery, maps, other office information, and discussions with the landowner and other knowledgeable sources.

2.4.1 Items to Take to the Field

Take the following with you into the field:

- Blank data forms F and S
- Aerial image that includes entire wetland
- Detailed map of wetland, if any available
- List of exotic, invasive, rare, or other species expected to occur in your area
- Shovel or trowel for soil texture determination
- Handheld GPS, or a smartphone or camera that geo-tags the photographs you take (which you may also project onto a Google Earth image of the wetland using some freely-downloadable photo-viewing software)
- Clip board, pencil, other items you'd normally take in the field
- Conductivity-pH meter if available

2.4.2 Conduct the Field Assessment

Step 1. Review the questions on the F and S forms to refresh your memory of what to observe during the field visit. Be sure to read all the notes in the Explanations column (E) of form F.

Step 2. Plan your visit beforehand to visit each major vegetation type (these may be evident on the aerial imagery if the AA is large), each different soil type (if mapped), each area with different topography, each area with a different degree of management action or human disturbance, the wetland/upland edge, and all wetland/water feature edges (e.g., shores of bordering ponds, lakes, streams). After you have viewed all those areas adequately (at least from a distance), you are ready to begin filling out forms F and S.

Step 3. Generally note the extent of invasive and exotic plant cover within the AA and along its upland edge. If you have the skills to identify rare plants or wildlife and the

timing of your visit is appropriate, search for these as time allows, following any established survey protocols.

Step 4. If you have access to the entire wetland, look for inlets and outlets, even ones that may flow only for a few days each year (as evidenced by flood marks or culverts that may be dry at the time of visit).

Step 5. Fill out forms F and S, paying attention to all the explanatory notes and definitions in the last column. As you answer the questions dealing with "percent of the area," pay particular attention to the spatial context (area) which the question is addressing. Is it the entire wetland or just the vegetated part? Or just the part covered by emergent or by woody vegetation?

Step 6. 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 A.

Step 7. Look uphill of the wetland to see if any artificial feature that adjoins the wetland *unmistakably* diverts *most* of the surface runoff away from it (e.g., high berm) during normal runoff events. If such is found, reconsider the boundaries and extent of the catchment (contributing area) assumed by question F68 and some of the form S questions.

Step 8. If possible, talk with the landowner or other knowledgeable sources to determine the following, at a minimum:

- if the wetland and/or its bordering waters have gone completely dry during most recent years (if this is not obvious during your visit);
- how extensively the wetland floods during the peak of snowmelt or whenever it is wettest during most recent years;
- annual duration of surface-water connection with streams and other wetlands.

Local offices of municipal, provincial, tribal, and national agencies may also be sources of useful information that will improve the accuracy of your assessment. An online search of the name of a nearby feature can sometimes be productive. Also, for some areas, you can go online and easily view aerial images from other seasons and/or years. To do so, open GoogleEarth, zoom to your location, and click on the sundial icon in the toolbar in the middle top of the page.

Potentially Confusing Terms as Used in WESP-AC

Memorising the following hierarchies and their terms may help you apply WESP-AC with greater accuracy. Definitions of these terms are found in column E of the data forms.

Water:
- Ground water
- *vs.*
- Surface water
  - Ponded *vs.* Flowing
  - Open *vs.* Vegetated
  - Persistent *vs.* Seasonal-only *vs.* Saturated-only

Vegetation:
- Woody (trees, shrubs)
- *vs.*
- Non-woody:
  - Moss
  - Herbaceous
    - Emergent *vs.* Floating-leaved *vs*. Submerged *vs.* Other
    - Forbs *vs.* Graminoids

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 Appendix B (Modeling Principles, and Descriptions of the WESP-AC Models and Scoring) 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 with that attribute's code (e.g., NR for Nitrate Removal). 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 of year), change the 0 or 1 you entered on form F or S. Then check the AllSites 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 of an enhancement or restoration measure on function scores, 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 vs. Benefit Scores and Ratings

Your primary focus should be upon the normalised function scores in the Scores worksheet of the WESP-AC calculator for your province. In contrast, the normalised benefit score describes the context within which the associated function is being performed currently but is largely influenced by current land uses (which can change) and other factors not intrinsic to the particular wetland AA that is being considered. With rare exceptions, each benefit score is mathematically independent of its associated function score and draws from a different set of indicators.

Solely to make the results more understandable, a three-level categorical rating (Lower, Moderate, Higher) was assigned to each function and benefit score. A four- or five-level categorisation could alternatively been used. The thresholds used to separate these categories are shown in Appendix C and are based on natural breaks in the statistical distribution of scores among the calibration wetlands for **each** function or benefit, determined objectively using a statistical procedure known as Jenks Optimisation (Jenks 1967). ***Note that different functions and benefits 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 but Moderate or Higher for another function. That occurs because each function and each benefit 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. Thus it is invalid to define a single set of thresholds for Lower, Moderate, and Higher that would apply universally to all functions and benefits.

When a benefit rating is greater than its associated function rating, consideration should be given to raising the function rating by one step (e.g., Lower to Moderate, Moderate to Higher) and/or raising the function score by some fixed percentage or by an amount proportional to the difference between the function score and the benefits score. It is recognised that because the function score and its associated benefits score have different statistical skews, even for the same function, their combination in any manner is implicitly biased.

2.7 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 independent users, as well as efforts to refine the calibration of its scores by comparing with actual measures of wetland functions, as difficult and expensive as those are to make among a statistically significant number and variety of wetland sites.

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 wetlands. That is rightfully in the realm of public policy, not 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 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. Reference Figures for Use with Form OF

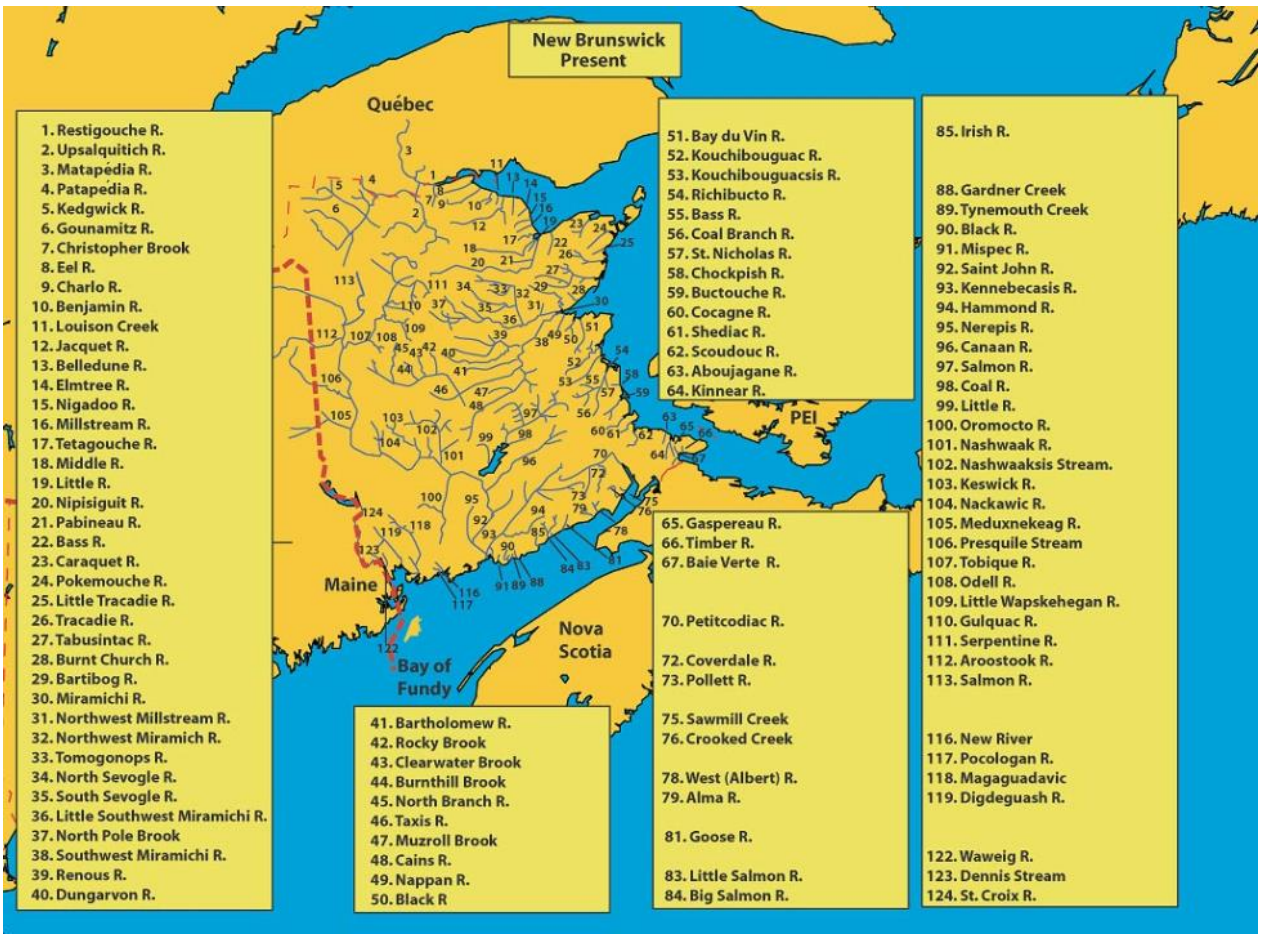

Figure A-1. Atlantic salmon rivers of New Brunswick
source: www.oldsalmon.ca

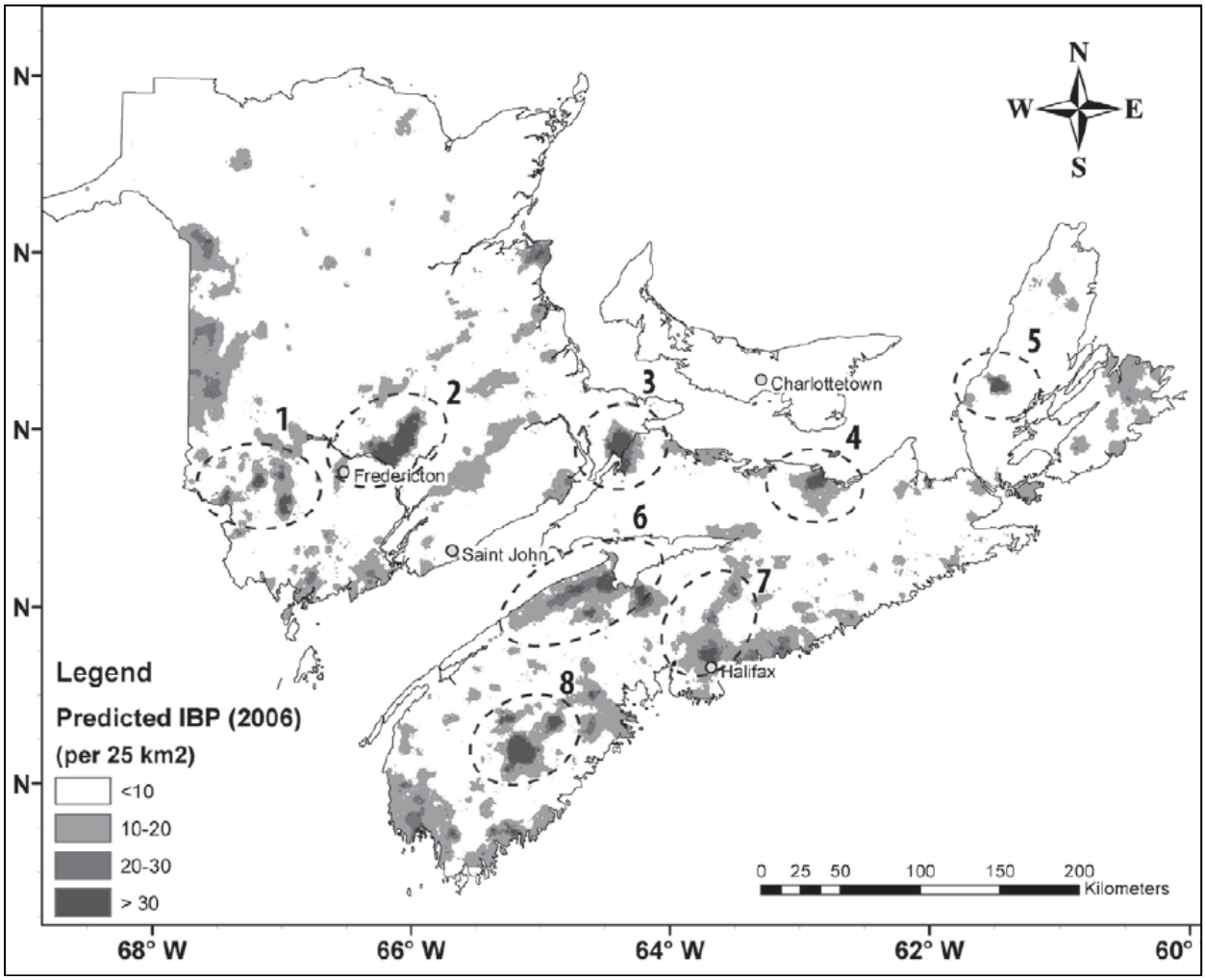

Figure A-2. Black duck nesting areas of regional importance.
source: Dr. David Lieske, Mount Allison University, Sackville, NB

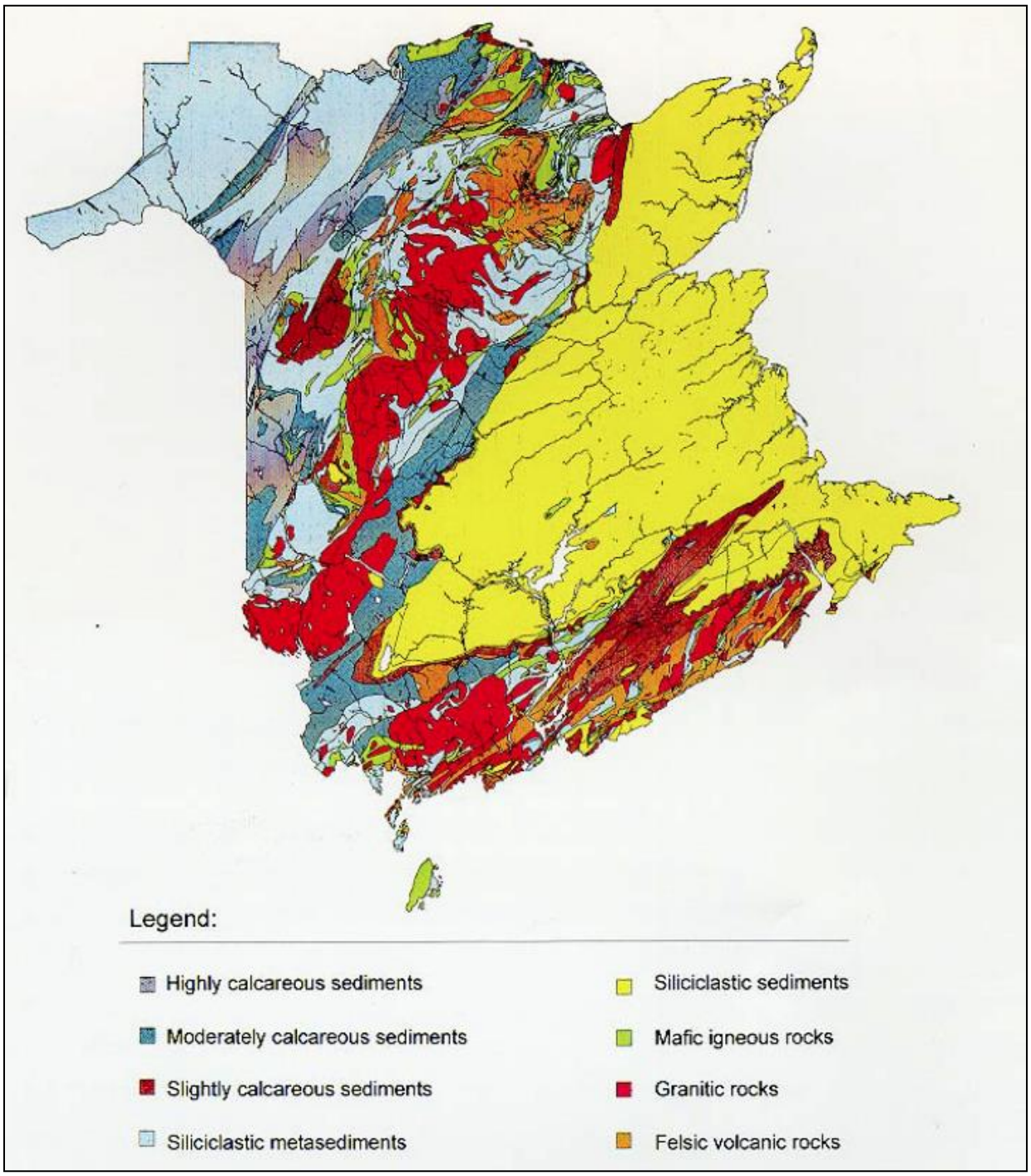

Figure A-3. General rock types of New Brunswick.
source: Colpitts et al. 1995

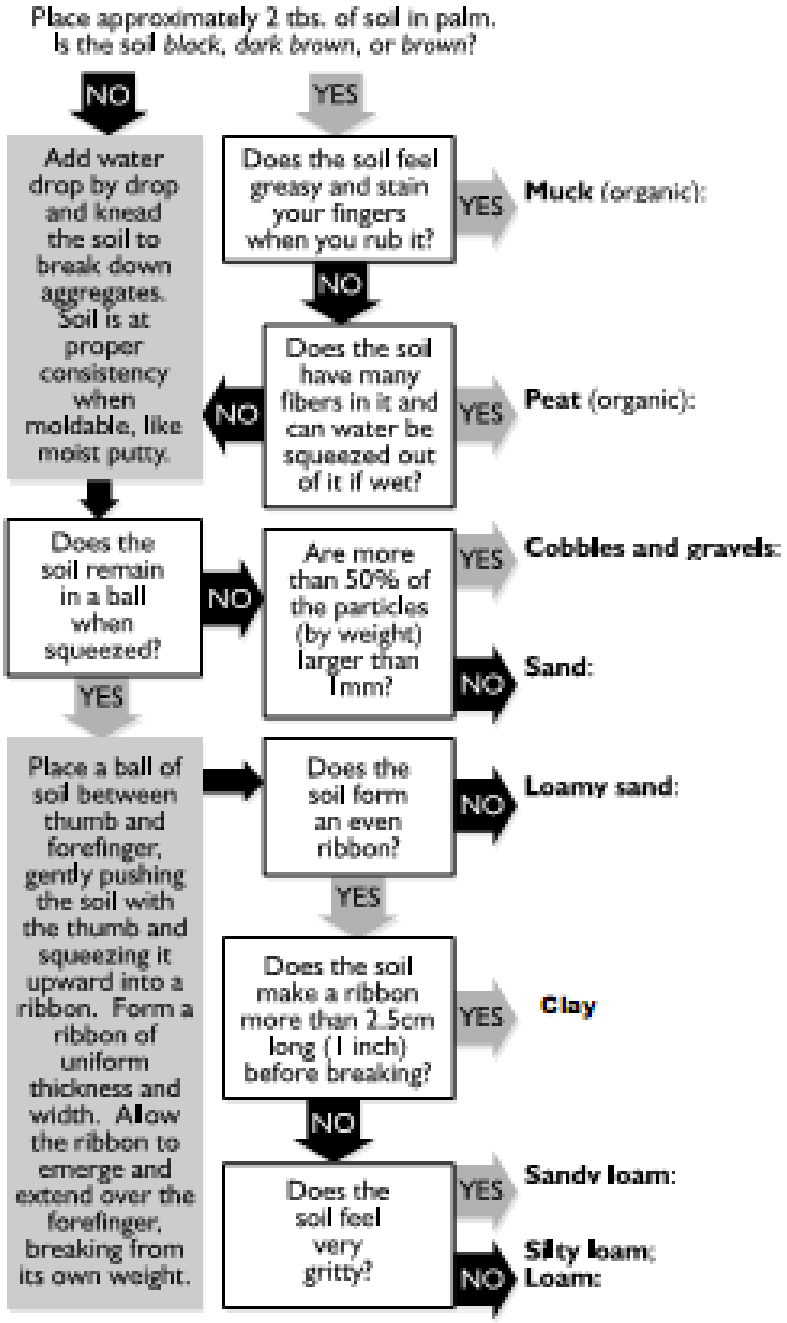

Figure A-4. Flow chart for identifying soil texture

source: Washington Dept. of Ecology 2004.

This should be used to diagnose the soil texture. However, you need only determine if the soil is Loam (including Sandy Loam, Silty Loam), Coarse (including Loamy Sand, Sand, Cobbles & Gravels), Fines (Clay), Peat, or other Organic.

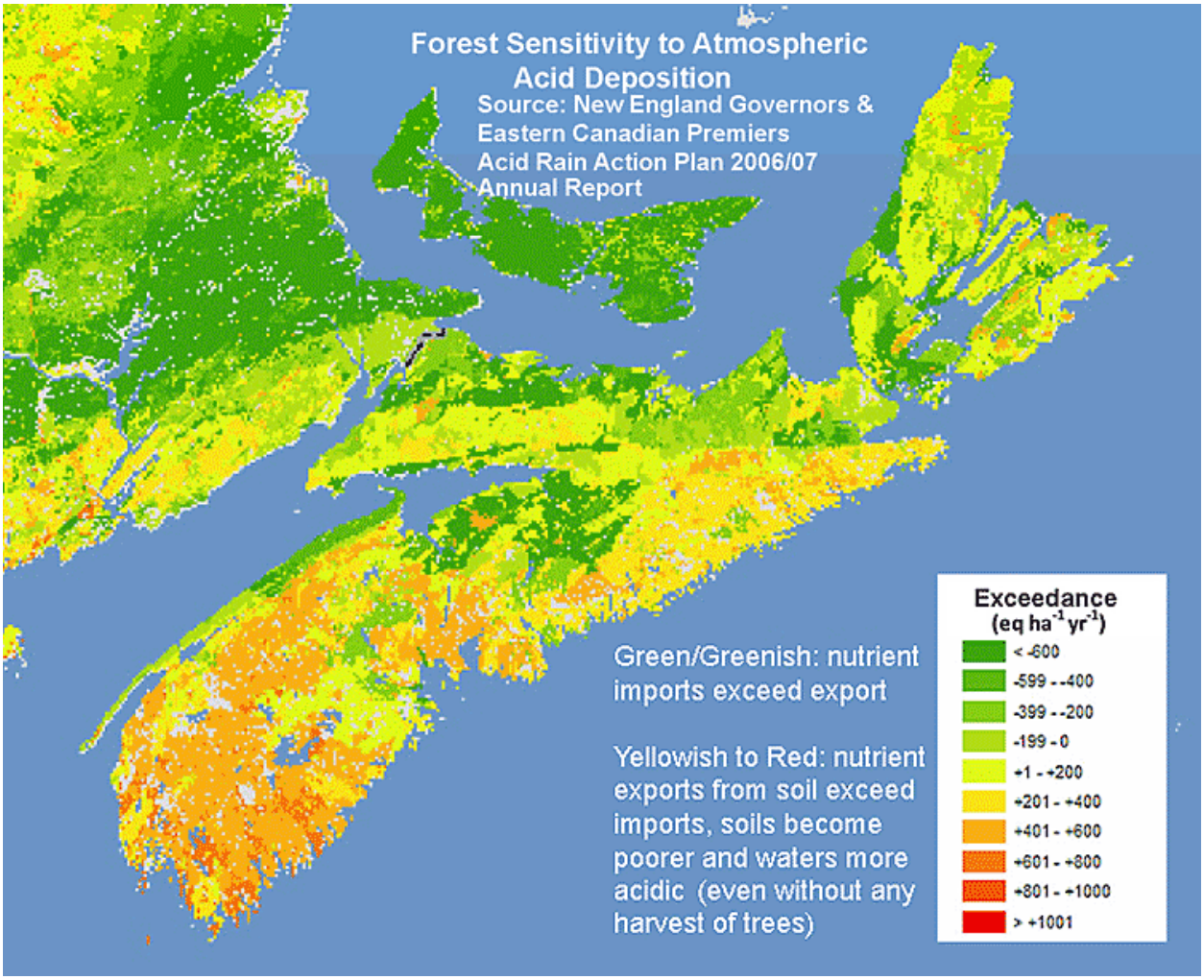

Figure A-5. Acidic deposition sensitivity.

For Nova Scotia, enter 1 in column D of question OF37 if the AA is in the yellow or green areas; otherwise enter a 0.

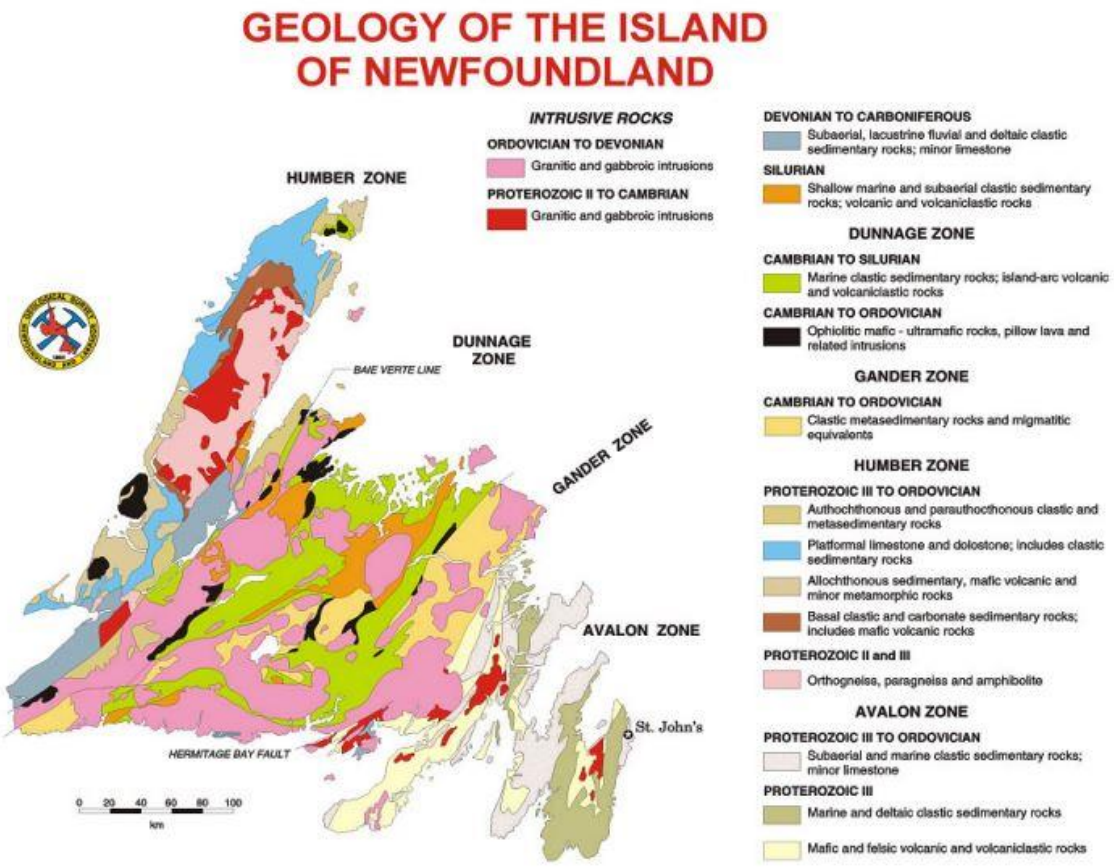

Figure A-6. Geology of Newfoundland

For Newfoundland, enter 1 in column D of question OF37 if the AA is in the light blue areas; otherwise enter a 0.

Appendix B. Modeling Principles, and Descriptions of the WESP-AC Models and Scoring

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B-1 Organisation of the Appendix

This appendix begins with a discussion of general principles used to score WESP-AC's indicator variables (questions in data forms) and to structure the WESP-AC models of wetland functions and benefits which the indicators are intended to predict. The narrative then proceeds to describe, for each function and its benefit, specifically how the indicator variables were combined in scoring models. The indicators mentioned in the descriptions in section 3.0 of this appendix are shorthand versions of indicators that are defined and explained fully in the WESP-AC data forms: worksheets OF (office form), F (field form), and S (stressor form) in the WESP-AC Excel calculator spreadsheet.

B-2 Principles Used to Score Indicators and Structure the Models

B2.1 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 river 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 wetlands, generally applicable measurements of the processes and the variables that determine them simply do not exist for the types of wetlands occurring in the region. Due to the lack of data involving direct measures of wetland function from a broad array of wetlands, 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 and heuristic. Such approaches are well-regarded as an interim or alternative solution when knowledge of system behaviour is scant (e.g., Haas 1991, Starfield et al. 1994).

B2.2 Indicators

For most WESP-AC models, physical or biological *processes* that influence a given function were first identified and then *indicators* of those processes were chosen and grouped accordingly. (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. None of WESP-AC's field-level indicators require *measurement*; they all are based on visual estimates. 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 all the 129 indicators needed to reasonably assess a common suite of functions and benefits.

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 and benefits of wetlands were also considered. To qualify as an indicator, a variable not only had to be correlated with or determining of the named process or function, but it also had to be rapidly observable during a single visit to a typical wetland during the growing season, or information on the indicator's condition had to be obtainable from aerial imagery, existing spatial data, and/or landowner interview.

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:
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, flood frequency and duration, amount of large woody debris, and presence of invasive 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. Examples are soil type and groundwater inflow rates. 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, water rights, local regulations, and cooperation among landowners. Examples are watershed land use, stream flow in wetland tributaries, lake levels, 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 and benefits.

B2.3 Weighting and Scoring

WESP-AC assigns relative weights or scores at three junctures:
1. Scoring of the *conditions* of an indicator, as they contribute to that indicator's prediction of a given wetland process, function, benefit, or other metric.
2. Scoring of *indicators* (metrics) relative to each other, as they together may predict a given wetland process, function, benefit, or other metric.
3. Scoring of wetland *processes*, 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 and benefits that it scores, e.g., does not assume that Amphibian Habitat is any more or less important than Nitrate Removal.

B2.3.1 Weighting of Indicator Conditions

As an example of #1, consider the following conditions of the indicator *% of Ponded Water that is Open,* as that indicator is applied to estimating the Waterbird Nesting Habitat function found in worksheet WBN of the calculator:

F33	% of Ponded Water that is Open	In ducks-eye aerial view, the percentage of the ponded water that is open (lacking emergent vegetation during most of the growing season, and unhidden by a forest or shrub canopy) is:				0.67
		None, or <1% of the AA and largest pool occupies <0.01 hectares. Enter "1" and SKIP to F41 (Floating Algae & Duckweed).	0	1	0	
		1-4% of the ponded water. Enter "1" and SKIP to F41 (Floating Algae & Duckweed).	0	3	0	
		5-30% of the ponded water.	1	4	4	
		30-70% of the ponded water.	0	6	0	
		70-99% of the ponded water.	0	4	0	
		100% of the ponded water.	0	2	0	

Each row following the first describes a possible *condition* of the indicator, *% of Ponded Water that is Open*. 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, Waterbird Nesting Habitat. In this case, the third condition was considered moderately supportive of that function, other factors being equal, and so had been given a weight of 4. This does not necessarily mean it is 4 times more influential than the first condition which has a weight of 1, because this is not a deterministic model. However, available literature seemed to suggest that this intermediate condition is distinctly better than the second condition and less desirable than the fourth condition. 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 33 indicators used to assign a score to the Waterbird Nesting Habitat function. To some degree, the use of so many indicators (including several related ones that are averaged together with this one because they probably correlate highly with it) 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 "normalised" 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 benefits pertaining to this indicator in that last column and divides it 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 benefit in the last column and divided it by the maximum weight pre-assigned to the indicator conditions.

Note also that the weight scale for some indicators begins at 0 while for others it begins at 1. Often, "0" was reserved for instances where, if the indicator was the only one being used, that condition of the indicator would suggest a nearly total absence of the function. Because each of the indicator scores is normalised, this difference (0 vs. 1) at the bottom end of the scales for different indicators is probably trivial.

B2.3.2 Weighting and Scoring of Indicators of Functions and Benefits

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 wetland dries up annually and it contains no inlets or outlets, the Resident Fish Habitat function is automatically scored "0". In this case, "access" (presence/absence of inlets or outlets) is a controlling indicator. If a few indicators are not individually so controlling but at least one is likely to be strongly limiting in some instances, WESP-AC takes the *maximum* among of the indicators, rather than the average. The latter is applied to situations where indicators are though to be compensatory, collinear, or redundant. 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.

There also are instances where the condition of one indicator (such as wetland type) is used to determine the relevance of others for predicting a wetland function. For example, the effect of vegetation structure within a wetland on the wetland's ability to slow the downslope movement of water in a watershed can be ignored if the wetland has no outlet channel.

B2.3.3 Weighting and Scoring of Wetland Processes That Influence Functions

For many functions, dozens of hydrologic (e.g., evapotranspiration) and/or ecological (e.g., juvenile dispersal) processes contribute to its ultimate level of performance. Often,

too little is know about the relative importance of these processes in determining a wetland function, and for some processes there are no known indicators that can be estimated visually. Nonetheless, WESP-AC attempted to use processes as an organising framework for the many indicators it employs to score each function. Processes associated with a given function and indicators associated with each process are named in the ochre-coloured cells near the bottom of each worksheet in the WESP-AC calculator file. For most functions, no more than 3 or 4 contributory processes are defined, with each containing a few to a dozen or more indicators. For most functions, the named processes are weighted like indicators and used as a "subscore" when computing the score for a function. For example, for the function Phosphorus Retention, the function model contains these processes:

[(3*AVERAGE(Adsorb, Desorb) + 2*Connectivity + AVERAGE(IntercepWet,IntercepDry)]/6

That means that the average of Adsorption and Desorption was given half (3/6) of the weight, the average of Connectivity was given one-third (2/6) of the weight, and the average of Dry Interception and Wet Interception was given 1/6 of the weight. They are divided by 6 because that is the sum of their weights (3 + 2 + 1) and the resulting function score, for the sake of clear comparisons, must be normalised to the 0 to 1 scale used by all functions (after being multiplied by 10).

B-3 Descriptions of the WESP-AC Models

B3.1 SURFACE WATER STORAGE (WS)

Function Definition: The effectiveness of a wetland for storing water or delaying the downslope movement of surface water for long or short periods (but for longer than a tidal cycle), and in doing so to potentially influence the height, timing, duration, and frequency of inundation in downstream or downslope areas.

Scientific Support for This Function in Wetlands Generally: Moderate to High. Many non-tidal wetlands are capable of slowing the downslope movement of water, regardless of whether they have significant storage capacity, simply because they are *relatively* flat areas in the landscape. When that slowing occurs in multiple wetlands, flood peaks further downstream are muted somewhat. When wetlands are, in addition, capable of storing (not just slowing) runoff, that water is potentially available for recharging aquifers and supporting local food webs.

In the Region's Wetlands: Many of the region's non-tidal wetlands should be capable of performing this function. Those intersected by channels and located on steep slopes are least capable. Where this function is performed to some degree, its *benefit* will depend partly on wetland location relative to areas potentially damaged by floods. Flood damages to infrastructure in this region have been relatively infrequent and local, and have occurred mainly as the result of ice jams or wave action associated with storms in marine waters. Also, it is likely that subsurface storage of water in many parts of this region (e.g., in deep peat, alluvium, colluvium) is more substantial than surface water storage. Unfortunately, in most cases subsurface storage cannot be estimated reliably with a rapid assessment method. Typically, it requires measurements of soil depth and texture (at greater depth than is practical to dig during a rapid assessment) and an understanding of subsurface water levels, flow direction, and exchange rate during different seasons.

WS Function Model

Structure:

- If a wetland never contains surface water, half of its score is from its duration of its connection to a stream (no connection or seasonal-only surface water connection scoring higher) and the other half of its score is based on the average of two factors: *Subsurface Storage* and *Friction*.
- If the wetland has a surface water outlet, half of its score again is based on increasing isolation from other surface waters, but the other half this time is accounted for not only by *Subsurface Storage* (weight of 1) and *Friction* (weight of 2), but also and most significantly by *Live Storage* (weight of 4).

In the above calculations:

- **Subsurface Storage** potential, which increases with increasing infiltration and evapotranspiration, is assumed to be indicated by deep peat soils, lack of evidence of groundwater discharging at the surface (which suggests that subsurface storage areas are nearly full and cannot receive new runoff), small catchment relative to wetland size, and two variables that may indicate less likelihood of a frozen (and thus impervious) surface being present around the time of spring runoff: south-facing aspect and more growing degree-days. These are averaged.
- **Live Storage** is assumed to be indicated by increasing amplitude of water level fluctuation and increasing percent of the wetland's area that floods only seasonally. These are averaged.
- In wetlands that never have surface water, **Friction** is the weighted average of decreasing gradient (weight of 3) and the average of increasing ground cover and increasing ground roughness (microtopographic variation). In wetlands that do

have surface water, Friction is assumed to be indicated by the average of 5 indicators: flatter internal gradient, mostly ponded condition, a longer flow distance from inlet to outlet, an artificially constricted outlet, and (if intersected by a channel) greater channel meandering within the wetland. These indicators are averaged.

Important Note: The model does not account for the wetland's surface area, and obviously, larger wetlands can store more water. Because the model is estimating relative effectiveness per unit area, some smaller wetlands will have higher scores for this function than larger ones. Thus, wetland size should also be considered in the case of this particular function.

Approach for Future Validation: The volume, duration, and frequency of water storage could be measured in a series of wetlands that encompass the scoring range, and flows could be measured at their outlets if any, and at various points downstream. Measurements should especially be made during major storm or snowmelt events. Procedures that might be used are partly described by Warne & Wakely (2000) and US Army Corps of Engineers (2005).

WS Benefits Model

Structure: If buildings or public infrastructure within 5 km downriver from the wetland have been damaged or are in a mapped floodplain, the wetland receives the highest possible score for Benefits. Otherwise, increasing Benefit for the Water Storage function is influenced mainly by the average of 3 indicators -- the extent of unvegetated upslope surfaces (more impervious or semi-pervious proportional surface indicates more opportunity for downslope wetlands to influence flood peaks), lower position in a regional watershed, and by the potential for runoff to be transported to a wetland as related to steeper slope and decreasing vegetation in its contributing area.

B3.2 STREAM FLOW SUPPORT (SFS)

Function Definition: The effectiveness of a wetland for prolonging surface water in headwater streams during seasonally dry periods. This is important for fish passage and overall ecological support.

Scientific Support for This Function in Wetlands Generally: Moderate.

In the Region's Wetlands: Many of the region's non-tidal wetlands should be capable of performing this function. If not feeding streams directly themselves, many wetlands at

least are discharge sites for groundwater which in turn feeds streams. Higher in a watershed, some wetlands are capable of recharging groundwater, which ultimately discharges to wetlands and then streams lower in the watershed.

SFS Function Model:

Structure: The model considers three factors: *Groundwater Input, Connectivity,* and *Climate. Connectivity* is considered the controlling factor, so if the wetland lacks both a surface flow outlet (at any season) and is not immediately upslope from a stream channel, the score is set at 0. Otherwise, the *Connectivity* score is multiplied by the weighted average of *Groundwater Input* (weight of 2) and *Climate* (unweighted).

In the above calculations:

- **Connectivity** is considered greater in wetlands with longer-duration surface water outflows. Wetlands without outflows are scored "0" for this function unless they are very near streams, in recognition of the possibility of a subsurface connection.
- **Groundwater Input** is assumed to be more likely if a wetland is of a particular type (e.g., fen) or there are other clues that groundwater may be discharging significantly to the wetland. These 2 indicators are averaged.
- **Storage** is assumed to influence wetland contribution to streamflow, and is represented by northerly aspect, greater water depth, and presence of soils with greater water-holding capacity, e.g., peat. All these indicators are considered to be about equally predictive and so are averaged together.

Important Note: The model does not account for the wetland's surface area, and obviously, larger wetlands could potentially deliver more water to streams if other factors support this function. Because the model for this function is estimating relative effectiveness per unit area, some smaller wetlands will have higher scores than larger ones. Thus, wetland size should also be considered in the case of this particular function.

SFS Benefits Model

The Benefit of the Streamflow Support function is assumed greater in wetlands that are either in the headwater of a watershed, or have high scores for supporting habitat of invertebrates, anadromous fish, and/or resident fish. These last 3 indicators are considered to be about equally predictive of the Benefit of this function and so are averaged.

B3.3 WATER COOLING (WC)

Function Definition: The effectiveness of a wetland for maintaining or reducing the water temperature, primarily in headwater streams.

Scientific Support for This Function in Wetlands Generally: Moderate.

In the Region's Wetlands: Many of the region's non-tidal wetlands should be capable of performing this function.

WC Function Model

Structure: If a wetland never contains surface water during the summer, then only *Groundwater Input* is considered by the model. In all other wetlands, the score is the average of groundwater input (various features suggest high likelihood of discharging groundwater), increases in percent shade, deeper water, greater proportion of wetland that lacks surface water, smaller proportion of open water, and decrease in the percent of the surface water that is ponded.

Important Note: The model does not account for the wetland's surface area, and obviously, larger wetlands could potentially provide a greater volume of cooled water if other factors support this function. Because the model for this function is estimating relative effectiveness per unit area, some smaller wetlands will have higher scores than larger ones. Thus, wetland size should also be considered in the case of this particular function.

WC Benefits Model

Wetlands are assumed to be more valuable for this function if (a) accessible to anadromous fish, and/or (b) are at low elevation, surrounded by impervious surfaces, not a fringe wetland, are south-facing, and have an input tributary whose water is predicted to be warmer than that in the wetland itself. The conditions in (b) are all considered to be equally influential so are averaged. That average is considered to be as important as access to anadromous fish (a) so the two are averaged. Then, that average is multiplied by the duration of the wetland's outlet flow, because longer outflows imply greater opportunity to deliver this function.

B3.4 SEDIMENT RETENTION AND STABILISATION (SR)

Function Definition: The effectiveness of a wetland for intercepting and filtering suspended inorganic sediments thus allowing their deposition, as well as reduce current velocity, resist erosion, and stabilise underlying sediments or soil.

Scientific Support for This Function in Wetlands Generally: High. Being relatively flat areas located low in the landscape, many wetlands are areas of sediment deposition, a process facilitated by wetland vegetation that intercepts suspended sediments and stabilises (with root networks) much of the sediment that is deposited.

In the Region's Wetlands: Many of the region's wetlands should be capable of performing this function. Those intersected by channels and located on steep slopes are least capable. In this region the abundance of clearcuts, logging roads, agriculture, and wind-exposed shorelines provides many opportunities for wetlands to trap sediment and/or stabilise underlying soils and sediments. Potentially, the performance of this function has both positive and negative aspects. Positives include reduction in turbidity in downstream waters, provision of substrate for outward expansion of marsh vegetation into deeper water (especially important in tidal wetlands), and improved detoxification of some contaminants associated with the retained sediment. Sediment serves as a carrier for heavy metals, phosphorus, and some toxic household chemicals, which routinely bind to surfaces of suspended clay particles (Hoffman et al. 2009, Kronvang et al. 2009). Negative aspects potentially include progressive sedimentation of productive wetlands, slowing of natural channel migration, reduction of water storage capacity, and increased exposure of organisms within a wetland to contaminants. The Benefits models address only the opportunity to perform this function, not its potential positive or negative effects which are too difficult to estimate with a rapid method.

SR Function Model

Structure:
At a coarse level, three types of non-tidal wetlands are analyzed separately as pertains to this function: (1) those that never contain surface water, (2) those that lack outlets, and (3) all others.

- If a wetland never contains surface water, its ability to stabilise underlying soil increases if its *Interception/Erosion Resistance (dry)* is great – see below for description.
- If a wetland lacks a surface-flow outlet, i.e., is isolated, then the highest possible score for this function (10.00) is assigned automatically.

- For all other wetland types, the score is the average of a wetland's increased *Hydrologic Entrainment* capacity (weighted 2x), *Storage Space* (weighted 2x), *and Interception/Erosion Resistance* (average of terrestrial and aquatic).

In the above calculations:

- **Interception/Erosion Resistance in the Terrestrial** (dry) environment is assumed to increase with decreasing wetland gradient, small catchment relative to wetland area, and the average of increasing ground cover, microtopographic variation, and lack of soil disturbance. It is assumed that wetlands without surface water can only stabilise soil, not trap suspended sediment carried in by surface flow.
- **Interception/Erosion Resistance in the Aquatic** (wet) environment is assumed to increase with increasing width of the vegetated zone, which is given the same weight as the combined average of scores for increased cover of emergent plants, longer growing season, more meandering of flow paths through the wetland, and presence of relatively equal amounts of vegetation and open water arranged in a patchwork. This factor and its indicators are ignored in the calculations if none of the vegetation is ever flooded or if the wetland contains no ponded areas.
- **Hydrologic Entrainment** capacity is assumed to be indicated by decreased wetland shoreline gradient and increased flow path length, ponded extent, water depth, and decreased duration of outflow. These are all considered equally predictive and so are averaged.
- **Live Storage Space** is assumed to be indicated by increasing amplitude of water level fluctuation and increasing percent of the wetland's area that floods only seasonally. These are considered equally predictive and so are averaged.

Important Note: The model does not account for the wetland's surface area, and obviously, larger wetlands could potentially trap and store more sediment if other factors support this function. Because the model for this function is estimating relative effectiveness per unit area, some smaller wetlands will have higher scores than larger ones. Thus, wetland size should also be considered in the case of this particular function.

<u>Approach for Future Validation</u>: The volume of accreted sediments could be measured in a series of wetlands that encompass the scoring range. This might be done with isotopic analysis of past sedimentation rates, or (going forward) with ground-level LiDAR imaging, SET tables (Boumans & Day 1993), or various sediment markers. Suspended sediment could be measured at inlets and outlets if any, with simultaneous measurement of changes in water volume and flow rate (e.g., Detenbeck et al. 1995).

SR Benefits Model

If water quality data indicates contamination (within 1 km upstream) has occurred with metals and other substances that readily adsorb to sediment, this counts for half the score. Otherwise, the Benefits scores increases if a tributary enters the AA, or a large proportion of the wetland contains surface water, or if the average of several factors is large: increased presence of recent erosive land use activities upslope from the wetland, greater amounts of impervious surface and less natural cover in the wetland's contributing area, steeper slopes surrounding the wetland, large water level fluctuations.

B3.5 PHOSPHORUS RETENTION (PR)

Function Definition: The effectiveness for retaining phosphorus for long periods (>1 growing season) as a result of chemical adsorption and complexation, or from translocation by plants to belowground zones or decay-resistant peat such that there is less potential for physically or chemically remobilizing phosphorus into the water column.

Scientific Support for This Function in Wetlands Generally: High. Being relatively flat areas located low in the landscape, many wetlands are areas of sediment deposition, a process facilitated by wetland vegetation that intercepts suspended sediments and stabilises (with root networks) much of the sediment. Because phosphorus (P) is commonly adsorbed to the suspended solids, it will consequently be deposited. Also, soluble forms of P can be chemically precipitated from the water column if there are sufficient levels of certain elements (iron, aluminum, calcium), the water is aerobic, and the pH is acidic (with iron, aluminum) or basic (calcium). This chemical precipitation of P also results in retention within a wetland. Subsequently, a variable proportion of the P will re-enter the water column (i.e., be desorbed from sediments or leached from organic matter) which makes it vulnerable to being exported from the wetland. This can happen when sediments or the water column become anaerobic or the pH changes. That can result from excessive loads of organic matter, rising temperature, and/or reduced aeration due to slowed water exchange rates, increased water depth, or ice that seals off diffusion of atmospheric oxygen into the water. The wetland's P balance also depends on the physical stability of deposited sediments or soil. Wind can resuspend sediments rich in P making the sediments and their associated P vulnerable to being exported downstream by currents, but wind can also aerate the water column, which helps retain the P in the sediments. Plant roots also can facilitate P retention by aerating the sediment and translocating aboveground P to belowground areas where P-bearing

sediments are less likely to be eroded. Phosphorus can potentially accumulate in wetlands more rapidly than nitrogen, and a state can be reached (perhaps after several decades of increased P loading) where sediments become saturated and no more P is retained, at least until some is desorbed and exported.

The **Benefits** model (as opposed to the function model) addresses only the opportunity to perform this function, not its potential positive or negative effects on ecosystems, which are too difficult to estimate with a rapid method. Phosphorus is essential for plant growth but in high concentrations can shift species composition and habitat structure in ways that sometimes are detrimental to rare plants, aquatic food chains, and valued species (Carpenter et al. 1998, Anderson et al. 2002).

PR Function Model

Structure: At a coarse level, three types of non-tidal wetlands are analyzed separately as pertains to this function: (1) those that never contain surface water, (2) those that lack outlets, and (3) all others.

- If a wetland never contains surface water, its ability to retain phosphorus is assumed to increase with decreased duration of ice cover and increased *Interception/Erosion Resistance (terrestrial)* and *Adsorption Potential* (see below for description of these terms). These are considered equally predictive so are averaged.
- If a wetland lacks a surface-flow outlet, i.e., is isolated, then the highest possible score (10.00) for this function is assigned automatically, based on an assumption that most phosphorus is associated with suspended sediment. However, some amount of phosphorus is soluble and could still escape in groundwater. That pathway cannot be estimated with a rapid assessment method.
- For all other wetland types, a high score depends on the average of a wetland's increased *Adsorption* and decreased *Desorption* potential (averaged together and weighted 3x), its reduced *Connectivity* (weighted 2x), and the average (unweighted) of shorter *Frozen Duration* (unweighted), greater *Interception/Erosion Resistance* in the wetland's dry zone, and the same in the aquatic zone.

In the above calculations:

- **Adsorption potential** is represented by the average of soil texture (greater in clay and peat soils, and lower in coarse-textured soils), presence of calcareous soils (which have higher adsorption potential), and occurrence of either very acidic or very basic pH conditions.
- **Desorption potential** is assumed to be least in wetlands with deep persistent water with stable water levels. Soil respiration, carbon accumulation rate, and subsurface

water table fluctuation can be important to phosphorus adsorption and desorption but cannot be assessed accurately with a rapid assessment method.

- **Connectivity** is assumed to be less in wetlands that have no outlets, export surface water through a ditch or artificial outlet, have low gradient, and a long flow path. These are considered about equally predictive and so are averaged.
- **Frozen Duration** is assumed to decrease with longer growing season and increasing proximity to tidal waters. These are considered equally predictive and so are averaged.
- **Interception/Erosion Resistance in the terrestrial** (dry) environment is assumed to increase mainly with a decrease in gradient and lengthening flow path. The remaining 1/3 of the score for this process is based on the average of increased ground cover, microtopographic variation, and wetland size in proportion to catchment size.
- **Interception/Erosion Resistance in the aquatic** (wet) environment is assumed to increase if the wetland is ponded, and has greater cover of emergent plants distributed in a patchy manner, and increased meandering of surface water as it travels through the wetland. These are considered equally predictive and so are averaged, and that average is then averaged with wetland width. This factor and its indicators are ignored in the calculations if none of the vegetation is ever flooded.

Important Note: The model does not account for the wetland's surface area, and obviously, larger wetlands could potentially retain more phosphorus if other factors support this function. Because the model for this function is estimating relative effectiveness per unit area, some smaller wetlands will have higher scores than larger ones. Thus, wetland size should also be considered in the case of this particular function.

Approach for Future Validation: Among a series of wetlands spanning the scoring range, total phosphorus could be measured simultaneously at wetland inlet and outlet, if any, and adjusted for any dilution occurring from groundwater or runoff (or concentration effect from evapotranspiration) over the intervening distance. Measurements should be made at least once monthly and more often during major runoff events (e.g., Detenbeck et al. 1995). A particular focus should be on the relative roles of soil vs. vegetation characteristics, as they affect adsorption vs. uptake processes.

PR Benefits Model

This function is considered most valuable if a wetland has greater opportunity to perform it. The score is calculated by taking the larger of four indicators: a score for

phosphorus load, known presence of a nutrient problem above or below the wetland, presence of a tributary, and the group average for several indicators of increased phosphorus delivery to the wetland, such as buffer slope, upland erodibility, lack of undisturbed upland cover.

B3.6 NITRATE REMOVAL AND RETENTION (NR)

Function Definition: The effectiveness for retaining particulate nitrate and converting soluble nitrate and ammonia to nitrogen gas, primarily through the microbial process of denitrification, *while generating little or no nitrous oxide* (a potent "greenhouse gas"). Note that most published definitions of Nitrate Removal do not include the important restriction on N_2O emission.

Scientific Support for This Function in Wetlands Generally: High. The Benefits models address only the opportunity to perform this function, not its potential positive or negative effects, which are too difficult to estimate with a rapid method. Nitrate is essential for plant growth but in chronically high concentrations, such as from urban and agricultural runoff, can be a significant "nonpoint source" that shifts species composition and habitat structure in ways that sometimes are detrimental to rare plants, aquatic food chains, and valued species (Carpenter et al. 1998, Anderson et al. 2002). High concentrations of nitrate in well water also are a human health hazard, and some levels of ammonia impair aquatic life. When excessive algal growths are triggered by abnormally high levels of nutrients in the tidal or marine water column, they block light needed by eelgrass (Williams & Ruckelshaus 1993), a submersed plant very important to fish and wildlife. Nitrate concentrations as low as 1 mg/L can change the structure of freshwater algae communities of streams (Pan et al. 2004) and contribute to blooms of toxic algae in lakes and wetlands.

NR Function Model

Structure:
At a coarse level, three types of non-tidal wetlands are analyzed separately as pertains to this function: (1) those that never contain surface water, (2) those that lack outlets, (3) all others.

- If a wetland lacks a surface-flow outlet, i.e., is isolated, then the highest possible score (10.00) for this function is assigned automatically.
- If a wetland never contains surface water, its ability to remove N is assumed to be greater if it has limited connection to downslope water bodies (*Connectivity*, weight of 2), is likely to capture sediment that enters it (*Interception/Erosion Resistance*), and

has a relatively warm microclimate (*Warmth)*, highly organic substrate (*Organic*), and strong potential for spatially and temporally alternating reducing conditions *(Redox).* The weighted average of these terms is calculated. Their indicators are described below.

- For all other wetlands, the same model is used but in calculating the weighted average, *Redox* is weighted more heavily (3x).

In the above calculations:

- Decreased **connectivity** is defined by shorter duration of surface outflow, flatter wetland gradient, and lack of any artificial drainage. These 3 indicators are considered equally predictive so are averaged.
- **Warmth** is assumed to increase with closeness to tidal waters, south-facing aspect, lack of tree canopy, and strong evidence of groundwater input. These are considered equally predictive and so are averaged.
- **Interception/Erosion Resistance** is assumed to increase mainly with increasing flow path length, extent of ponding, vegetated width, ground cover density, interspersion of open water and vegetation, headwater position, and size of wetland relative to size of its catchment. These are considered equally predictive and so are averaged.
- **Organic** content is assumed greater in peatlands, older wetlands, and wetlands with extensive plant cover and with little or no history of soil disturbance.
- **Redox** conditions favourable to denitrification are assumed likeliest to occur where a large portion of the wetland is inundated only seasonally. Considered equally important is the average of 4 indicators: presence of many upland inclusions, large ratio of upland edge to wetland area, greater water level fluctuation, and extensive microtopography.

Important Note: The model does not account for the wetland's surface area, and obviously, larger wetlands could potentially remove more nitrate if other factors support this function. Because the model for this function is estimating relative effectiveness per unit area, some smaller wetlands will have higher scores than larger ones. Thus, wetland size should also be considered in the case of this particular function.

<u>Approach for Future Validation</u>: Among a series of wetlands spanning the function scoring range and a range of wetland condition (integrity), nitrate and ammonia could be measured simultaneously at wetland inlet and outlet, if any, and adjusted for any dilution occurring from groundwater or runoff (or concentration effects from evapotranspiration) over the intervening distance. Measurements should be made at least once monthly and more often during major runoff events (e.g., Detenbeck et al.

1995). Monitoring should also measure denitrification rates (at least potential), the nitrogen fixing rates of particular wetland plants, and nitrous oxide emissions.

NR Benefits Model

Greater benefit is assigned based on the average of three factors: (a) either domestic wells are present within 1000 feet downslope from the wetland, (b) a tributary is present, (c) potential sources of N are present; this includes N-fixing plants, septic systems and various other human activities, closeness to populated areas, extent of impervious surface near the wetland, lack of an upland buffer around the wetland, and wetland contributing areas with limited extent of natural cover.

B3.7 CARBON SEQUESTRATION (CS)

Function Definition: The effectiveness of a wetland both for retaining incoming particulate and dissolved carbon, and through the photosynthetic process, converting carbon dioxide gas to organic matter (particulate or dissolved). And to then retain that organic matter on a net annual basis for long periods *while emitting little or no methane* (a potent "greenhouse gas"). Note that most published definitions of Carbon Sequestration do not include the important limitation on methane emission.

Scientific Support for This Function in Wetlands Generally: Although wetlands with high rates of primary productivity would seem to sequester (store) more carbon more rapidly, at northern latitudes it is likely that the amount of carbon that remains in storage will depend more on how slowly what has initially been sequestered will be decomposed. Artificial disturbances or extreme events, such as increased frequency of drought (e.g., from global warming, artificial drainage) and perhaps flood (e.g., from sea level rise) can quickly reverse gains in the amount of carbon sequestered in a wetland. Moreover, some of the most productive non-tidal wetlands also tend to be among the most significant emitters of methane, a potent greenhouse gas.

In the Region's Wetlands: Due partly to the northerly latitude (with cool temperatures and limited light), vegetation grows slowly in the region's wetlands and thus plants probably sequester carbon at a relatively slow rate. However, both cumulatively and on a per-unit-area basis, the carbon reserves (mainly in the form of peat) in these wetlands are enormous due to slow rates at which fixed carbon (plant organic matter) decomposes.

CS Function Model

Structure: A wetland is scored higher if its existing ("legacy") carbon stores (*Historical Accumulation*) are large, *Decomposition* of that carbon is likely to occur slowly, the wetland has a great ability to physically retain organic matter it produces or receives from upgradient sources (*Physical Accumulation*), and it lacks factors that suggest it has substantial methane emissions (*Methane Limitation*). In the final model, *Methane Limitation* is weighted equally with the average of *Historical Accumulation, Decomposition*, and *Physical Accumulation*.

In the above calculations:

- **Historical Accumulation** (existing carbon store is calculated as the average of greater extent of moss cover, peat soils, and lack of soil disturbance or recent burn. To a lesser degree, the score for this factor increases with increasing percent cover of conifers, growing season length, not a new wetland, and wetland vegetated width.
- **Decomposition** is assumed to be slower (thus facilitating carbon sequestration) when indicated by shorter growing season, wetland type is peatland, and moss cover is extensive. These are considered equally predictive so are averaged and then are averaged with the rating for wetland water depth, wherein intermediate water depths (if surface water is present at all) are hypothesised to support an optimal combination of elevated productivity and slowed decomposition.
- **Physical Accumulation** is assumed to increase with flatter wetland gradient, less persistent outflow, and an artificial (presumably more constricted) outlet if an outlet is present at all. These are considered equally predictive and so are averaged.
- **Methane emissions** are considered to be least when the wetland is not a sedge fen, tree cover (if any) is coniferous, moss cover is extensive, water level fluctuations and groundwater inputs are probably minimal, and the wetland has not recently shifted to a persistently flooded condition. These are considered equally predictive of Methane Limitation and so are averaged.

Important Note: The model does not account for the wetland's surface area, and obviously, larger wetlands could potentially retain more carbon if other factors support this function. Because the model for this function is estimating relative effectiveness per unit area, some smaller wetlands will have higher scores than larger ones. Thus, wetland size should also be considered in the case of this particular function.

Approach for Future Validation: Among a series of wetlands spanning the function scoring range and a range of wetland condition (integrity), particulate and dissolved organic carbon would need to be measured regularly at wetland inlet and outlet, if any,

along with measurements of changes in water volume. Equally important, emissions of methane and carbon dioxide would need to be measured regularly throughout the year and throughout the day/night cycle. Plant productivity rates (especially belowground), decomposition rates, hydrology, and net carbon accumulation in sediments or soils would require measurement as well.

B3.8 ORGANIC NUTRIENT EXPORT (OE)

Function Definition: The effectiveness of a wetland for producing, rapidly cycling, and subsequently exporting organic matter, either particulate (detritus) or dissolved, and including net export of nutrients (C, N, P, Si, Fe) comprising that matter. It does not include exports of carbon in gaseous form (methane and carbon dioxide) or as animal matter (e.g., emerging aquatic insects, fish).

Scientific Support for This Function in Wetlands Generally: Moderate-High. Wetlands which have outlets are potentially major exporters of organic matter to downstream or marine waters. That is partly because many wetlands support exceptionally high rates of primary productivity (i.e., carbon fixation, which provides more carbon that is available for export) or have large legacy reserves of undecomposed carbon. Numerous studies have shown that watersheds with a larger proportion of wetlands tend to export more dissolved and/or particulate carbon, as well as iron and other substances important to downstream and estuarine food webs (Bjorkvald et al. 2008). Value of the exported matter to food webs depends partly on the quality and timing of the export, but those factors cannot be estimated with a rapid assessment method.

In the Region's Wetlands: Both cumulatively and on a per-unit-area basis, the carbon reserves (mainly in the form of peat) in the region's wetlands are enormous, and due to large annual precipitation much of this carbon is exported to streams, rivers, lakes, and marine waters (D' Amore et al. 2015a, b). Once there, much of it can be expected to support food chains important to fish, wildlife, and people.

OE Function Model

Structure: If no surface flow ever exits a wetland, its OE function is automatically scored 0. For all other wetlands, the score is the weighted average of greater *Historical Accumulation, Export Potential* (weight of 3), and current *Productivity* (weight of 2).
In the above calculations:

- **Historical Accumulation** (existing carbon store) considers first if this is a new wetland. If so, Historical Accumulation is based only on its estimated age. If not a

new wetland (i.e., wetland is older than 100 years), this factor is based on soil texture, with peat soils considered most important.

- **Export Potential** is predicted by 4 items which are averaged: flow path length within the wetland, duration of surface water outflow, wetland gradient, and a group average based on less outlet constriction, less ponding, narrower vegetated width, lower elevation in a watershed, and greater interspersion of vegetation and open water.
- Current **Productivity** is comprised of three factors that are averaged: *Frozen Duration*, *Nutrient Availability*, and *Plant Cover*. These are described as follows:
  - *Frozen Duration* is assumed to decrease with longer growing season, proximity to tidal waters, and presence of discharging groundwater. These are considered equally predictive of Frozen Duration and so are averaged.
  - *Plant* input available for rapid export is assumed to be greater with more extensive cover of emergent and deciduous woody vegetation, decreasing bare ground extent, and shallower water depth. These are averaged.
  - Greater *Nutrient Availability* is reflected by wetland type (fen> marsh > swamp > open peatland), presence of calcareous soils, moderately fluctuating water levels, increased cover of nitrogen fixing plants, greater proportion of the wetland that is inundated only seasonally. These are considered equally predictive of Nutrient Availability and so are averaged.

Important Note: The model does not account for the wetland's surface area, and obviously, larger wetlands could potentially export more carbon if other factors support this function. Because the model for this function is estimating relative effectiveness per unit area, some smaller wetlands will have higher scores than larger ones. Thus, wetland size should also be considered in the case of this particular function. Also, this model is limited inasmuch as it does not attempt to estimate the immediate availability of the exported carbon to food chains. Some "more labile" forms of carbon are known to transform and then be taken up beneficially by aquatic organisms more quickly than other forms.

<u>Approach for Future Validation</u>: Among a series of wetlands spanning the function scoring range and a range of wetland condition (integrity), particulate and dissolved organic carbon would need to be measured regularly at wetland inlet and outlet, if any, along with measurements of changes in water volume and flow rate.

B3.9 ANADROMOUS FISH HABITAT (FA)

Function Definition: The capacity to support an abundance of native anadromous fish for functions other than spawning. The model described below will not predict habitat suitability accurately for every species, nor is it intended to assess the potential to restore fish access to a currently inaccessible wetland.

Scientific Support for This Function in Wetlands Generally: Moderate-high, depending mainly on accessibility of a wetland to anadromous fish. Many accessible wetlands provide rich feeding opportunities, shelter from predators, and a beneficial thermal environment.

FA Function Model

Structure: Wetlands are scored 0 if no information suggests they are accessible to anadromous fish or if no surface water is ever present. In all other wetlands, the score increases with increasing fish *access* to the wetland and persistence of the wetland's *outflow.* The scores for these two factors are averaged and then multiplied by the average of increased wetland *Productivity, Structure, Hydrologic Regime, Landscape Condition,* and a lack of human-related *Stressors.* The model assumes these factors are moot if access is lacking and/or are less important if outflow persistence is less. In these calculations:

- **Productivity** is assumed to be greater where the wetland contains or is adjoined by alder, is situated in areas with limestone bedrock, is at low elevation, is a fen/marsh, and/or there is evidence of significant groundwater input. These indicators are considered equally predictive and so are averaged.
- **Structure** beneficial to anadromous fish is represented by the average of beaver presence (considered a positive indicator) and a group average for increased shade and cover of aquatic plants, large instream wood, presence of both ponded and flowing water, and more favourable wetland type (Marsh > Fen > Swamp > Open Peatland).
- **Hydrologic Regime** is considered optimal when all or nearly all of the wetland has surface water at least seasonally and water depths are moderate. The remaining one-third of the score for this factor is based on the average of increasing interspersion of patches of vegetation and open water, wetland adjacency to a lake, wetland intersected by channels that wind indirectly and intersect flooded trees, and either a moderate proportion of habitat that remains persistently inundated or is inundated only seasonally.
- **Landscape** condition is assumed to be better when land cover in the contributing area and area closest to the wetland is mostly natural.

- **Stressors** (lack of) is represented by absence of known or suspected contaminants, absence of turbid water input, lack of other sediment inputs in excessive concentrations, and lack of altered flows. These indicators are considered equally predictive and so are averaged.

Approach for Future Validation: Among a series of wetlands spanning the function scoring range and a range of wetland condition (integrity), the number of anadromous fish and their duration of use would need to be measured regularly throughout the times when usually expected to be present, and weight gain during the period of wetland habitation should be measured when applicable.

FA Benefits Model

A wetland with the potential to support anadromous fish is assumed to be more valuable if it has a high habitat score for Feeding Waterbird Habitat, if there is evidence of fishing, near a road or population center, or is otherwise believed to be frequently visited.

B3.10 RESIDENT FISH HABITAT (FR)

Function Definition: The capacity to support an abundance and diversity of *native* non-anadromous fish. The model described below will not predict habitat suitability accurately for every species, nor is it intended to assess the ability to restore fish access to a currently inaccessible wetland.

Scientific Support for This Function in Wetlands Generally: High. Many accessible wetlands provide rich feeding opportunities, shelter from predators, and thermal refuge (especially if groundwater is a significant water source).

FR Function Model

Structure: A wetland automatically scores a 0 if there is no fish access and it is not known to contain resident fish, or if it never contains surface water. For all other wetlands, the score increases with increased wetland *Productivity*, *Hydrologic Regime*, and habitat *Structure,* and decreased *Stressors* and risk of winterkill from *Anoxia*. These 5 factors are considered equally predictive of resident fish habitat suitability and so are averaged.

In the above calculations:

- **Productivity** is assumed to be greater where the wetland contains both an inlet and outlet, contains or is adjoined by extensive alder, is situated in an area of limestone bedrock or water has moderately high connectivity, is not a new wetland, has evidence of significant groundwater input, and is a lake or (in order of decreasing productivity) is Marsh > Fen > Swamp > Open peatland. These indicators are considered equally predictive and so are averaged.
- **Structure** beneficial to resident fish is represented by the average of beaver presence (considered a positive indicator) and a group average that includes wetland type (see ranking above) as well as increased shade, an intermediate proportion of open water, and extent of aquatic cover.
- **Hydrologic Regime** is assumed most favourable for resident fish when surface water is present persistently or at least seasonally, both ponded and flowing water are present, interspersion of patches of vegetation and open water is good, there are complex internal channel networks that intersect woody vegetation, and a variety of water depths is present in fairly equal proportions. These indicators are considered equally predictive and so are averaged.
- **Stressors** are represented by the minimum of (worst of): known toxicity of contaminants, highly acidic water, artificially altered flow timing, and lack of vegetation in the upland buffer. These are considered equally predictive.
- **Anoxia Risk** is assumed to increase with shallower water depth, less outflow persistence, and shorter growing season. These are considered equally predictive of resident fish winterkill and so are averaged.

Approach for Future Validation: Among a series of wetlands spanning the function scoring range and a range of wetland condition (integrity), the number of resident fish and their onsite productivity and diversity would need to be measured regularly. For transient species, the duration of use and weight gain throughout the times when usually expected to be present should be determined.

FR Benefits Model

Structure: This function is presumably valued to a greater degree if its score for Feeding Waterbird Habitat is high or if the average of 4 other indicators is large: evidence of fishing, minimal distance to a population center, minimal distance to a road, and greater accessibility of the wetland to people.

B3.11 AQUATIC INVERTEBRATE HABITAT (INV)

Function Definition: The capacity to support an abundance and diversity of invertebrate animals which spend all or part of their life cycle underwater, on the water surface, or in moist soil. Includes dragonflies, aquatic flies, clams, snails, crustaceans, aquatic beetles, aquatic worms, aquatic bugs, and others, including semi-aquatic species. The model described below will not predict habitat suitability accurately for every species, nor the importance of any species or functional group in the diet of important fish or birds.

Scientific Support for This Function in Wetlands Generally: High. All wetlands support invertebrates, and many wetlands support aquatic invertebrate species not typically found in streams or lakes, thus diversifying the local fauna. Densities of aquatic invertebrates can be exceptionally high in some wetlands, partly due to high primary productivity and warmer water temperatures, and partly because submerged, floating, and emergent vegetation provide additional structure (vertical habitat space).

INV Function Model

Structure: In all types of non-tidal wetlands, the score is the weighted average of six factors: *Structure*, *Hydroperiod*, *Productivity (Food), Connectivity, Landscape, and Stressors.* The first two each account for one-third of the score and the average of the remaining ones together accounts for one-third.

- **Structure** is assumed to increase with increased ground cover, microtopographic variation, herbaceous plant diversity, downed wood, in-water large wood, interspersion of woody and herbaceous cover, and intermediate amounts of ponded open water. These indicators are considered equally predictive and so are averaged. That group average is then averaged (weighted equally with) cover of aquatic plants, for which intermediate cover is considered optimal.
- **Hydroperiod** is assumed most favourable when water levels fluctuate moderately and seasonally, there is evidence of groundwater discharging to the wetland, and there is an intermediate proportional extent of persistent water.
- **Productivity** score is based half on wetland type and half on a group average of several indicators: greater hardwood cover (especially alder), downed wood, situated in area of limestone bedrock, shallower water depth, and closer to tidal waters.
- **Connectivity** is reflected by a balanced mix of ponded and flowing water, greater patchiness of open water, greater interspersion of patches of vegetation and open water, and more sinuous internal channels that intersect woody vegetation. These indicators are considered equally predictive and so are averaged.

- **Landscape** condition is assumed better for invertebrates when land cover in the contributing area and wetland buffer is mostly natural, as represented by the average of 3 indicators which reflect that, and when wetland is adjoined by other wetlands of a different type.
- **Stressors** are represented partly by the average of (the lack of) increased soil disturbance, excessive sediment inputs, and altered timing of the water regime. That group average counts for half the stressor component, and the other half is represented by fish access (considered deleterious to wetland invertebrate richness).

Approach for Future Validation: The aquatic invertebrate richness, density, and (ideally) productivity would need to be measured regularly throughout the year among a series of wetlands spanning the function scoring range and a range of wetland condition (integrity).

INV Benefits Model

Structure: The benefits score for Invertebrate Habitat is the average for several other functions which Invertebrates support: Amphibians, Anadromous Fish, Resident Fish, Feeding Waterbirds, Nesting Waterbirds, and Songbirds & Mammals.

B3.12 AMPHIBIAN & REPTILE HABITAT (AM)

Function Definition: The capacity of a wetland to support an abundance and diversity of native amphibians (frogs, toads, salamanders) as well as turtles. The model described below will not predict habitat suitability accurately for **every** species.

Scientific Support for This Function in Wetlands Generally: High. Many amphibian and turtle species occur almost exclusively in wetlands. Densities can be noticeably higher in some wetlands, partly due to high productivity of algae and invertebrates, and partly because submerged vegetation provides shelter and sites for egg-laying and larval rearing.

AM Function Model

Structure: The function score is the average of three indicators. One is the wetland type, with types ranked for amphibian suitability as follows: Marsh > Fen or Swamp > Open Peatland. The second is the wetland's *Hydrologic Regime*, and the third is the average of *Aquatic Structure*, *Terrestrial Structure*, wetland *Productivity*, *Waterscape*, *Landscape*, and *Stressors*.

In the above calculations:

- **Hydrologic Regime** is assumed more suitable in ponded wetlands with at least 20% of their water persisting throughout the growing season and water level fluctuations that are relatively small.
- **Aquatic Structure** that is more suitable for amphibians is represented by a wide zone of aquatic plants, some large woody debris, and large interspersion of intermediate proportions of vegetation and open water. These indicators are considered equally predictive and so are averaged.
- **Terrestrial Structure** is considered to be best for amphibians in wetlands with moderate ground cover and cover of shrubs, extensive microtopographic variation, some upland inclusions, much downed wood, and which are adjoined by wetlands of a different type.
- **Productivity** is assumed to be highest in flat-gradient, south-facing wetlands in areas with longer growing season, strong evidence of groundwater inputs, larger-diameter trees, and/or which are in regions of limestone bedrock. All these indicators of productivity are considered equally predictive so are averaged together.
- **Waterscape** is represented by increasing proximity to the nearest other ponded wetland.
- **Landscape** conditions are considered better for amphibians when natural cover comprises a large and proximate part of the upland cover. Seven indicators of this are averaged, with absence of roads that interfere with dispersal being considered the most important.
- **Stressors** of potential detriment to amphibians are considered to include increasing proximity to nearest road, documented toxicity from contaminants, frequent human visitation, and lack of fences and other measures that otherwise limit trampling of soil and vegetation. These indicators are averaged and the average considered equally with actual or potential presence of fish, which can be a powerful stressor in many situations.

Note that some assessment methods, as an indicator of biodiversity, include “number of wetland types” or “number of hydroperiod types” present within a single wetland AA. WESP-AC does not use those explicitly because the boundaries between such types are seldom clearly distinguishable either in the field or from aerial imagery. WESP-AC addresses habitat heterogeneity (both within and surrounding an AA) using other indicators.

Approach for Future Validation: Among a series of wetlands spanning the function scoring range and a range of wetland condition (integrity), amphibian density and (ideally) productivity and survival would need to be measured during multiple years and seasons by comprehensively surveying (as applicable) the eggs, tadpoles, and adults.

AM Benefits Model

Structure: If a regionally rare amphibian or turtle has been documented from the wetland, the Benefits score is automatically a 10. Otherwise, the score is the average of two factors. One is a score indicating that either herbaceous or woody vegetation comprises less than 10 percent of the surrounding (100 m, 1 km, 5 km) landscape yet is significantly present in the wetland. The second is the average of scores for Feeding Waterbird Habitat and Songbird-Raptor-Mammal habitat, because amphibians are important foods for some species in those groups.

B3.13 WATERBIRD HABITAT - FEEDING (WBF)

Function Definition: The capacity to support an abundance and diversity of feeding waterbirds, primarily the migratory species present outside of the usual nesting season. The model described below will not predict habitat suitability accurately for every species in this group.

Scientific Support for This Function in Wetlands Generally: High. Dozens of waterbird species occur almost exclusively in wetlands during migration and winter. Densities can be exceptionally high in some wetlands, partly due to high productivity of vegetation and invertebrates, and partly because wetland vegetation provides shelter in close proximity to preferred foods.

WBF Function Model

Structure: Wetlands are scored 0 if they are very small (<0.01 ha), or on very steep (>10%) slope, or if no water is ever present. In all other wetlands, the score is the weighted average of two groups. One is the average of *Landscape, Stressors*, and wetland *Productivity*. Those have similar effects on shorebirds and other waterbirds. The other, with twice the weight of the first group, consists of whichever is greater: the score for Shorebird Habitat (i.e., mudflats, very shallow water), or the average of *Hydrologic Regime* and *Structure*.

In the above calculations:

- **Landscape** context is included only if the wetland is a marsh or fen. In those cases, an average is taken of the scores of indicators that reflect closer proximity to ponds and especially lakes, presence of beaver, and presence of a different wetland type nearby.
- **Stressors** of significant concern to feeding waterbirds include harmful concentrations of metals and other contaminants, and frequent visitation of nearly the entire wetland by people.
- **Productivity** for feeding waterbirds is assumed to include wetlands with extensive duckweed or algae, flatter gradients, larger area, adjoining lakes, longer growing season, closer to tidal areas, and/or belonging to wetland types favoured by waterbirds in this order: Marsh > Fen > Open Peatland ~ Swamp. These indicators are considered equally predictive of aquatic productivity and so are averaged.
- Habitat **Structure** is scored higher if interspersion of emergent vegetation with open water is great, fish are present, and the average of the scores for extent of ponded open water and percent cover of emergent vegetation is large -- intermediate conditions of both being considered most favourable.
- **Hydrologic Regime** is assumed to be more suitable if surface water is present at least seasonally, is ponded, its depth is mostly shallow (<1 m), its level fluctuates mildly, and a variety of depth classes is present in relatively equal proportions. These indicators are considered equally predictive and so are averaged.

Approach for Future Validation: Among a series of wetlands spanning the function scoring range and a range of wetland condition (integrity), feeding waterbird species richness and density would need to be determined monthly and more often during migration (see USEPA 2001 for methods). Ideally, daily duration of use and seasonal weight gain should be measured.

WBF Benefits Model

If the wetland is known to host a rare migratory waterbird species or if has been officially designated an IBA (Important Bird Area), the Benefits score is automatically a 10. Otherwise it is the maximum of three indicators: greater distance to open water; greater scarcity of herbaceous cover (if it is an herbaceous wetland) within 100 m, 1 km, and/or 5 km; and a third group that averages the scores for documented use by hunters, greater proximity to a population center, and/or most of wetland is visible from public land or a road. This third group is meant to reflect the potential for more frequent enjoyment by recreationists.

B3.14 WATERBIRD HABITAT - NESTING (WBN)

Function Definition: The capacity to support an abundance and diversity of nesting waterbirds. The model described below will not predict habitat suitability accurately for every species in this group.

WBN Function Model

Structure: The model first eliminates (assigns a score of 0) wetlands on slopes of greater than 10 percent, wetlands that never contain surface water, and very small (<0.01 ha) wetlands. For all remaining types of wetlands, the weighted average is taken of three groups. One group (with weight of 3) is the average of increased area of emergent vegetation, aquatic plant cover percentage (intermediate being best), preferred wetland type, and *Waterscape* indicators (described below). A second group (weight of 2) is the average of *Hydrologic Regime, Structure*, and *Productivity* (described below). The third group (unweighted) is the average of *Stressors* and *Landscape* indicators. These are determined as follows:

- **Waterscape** is represented by increasing proximity to ponds and especially lakes, and actual or potential presence of beaver. These are assumed to be equally predictive so are averaged. The Waterscape group is included in the calculations only if the wetland is a marsh or fen.
- **HydroRegime** is assumed to be more suitable in moderately shallow ponded wetlands with a large proportion of vegetation that is inundated at least seasonally, with only mild annual water level fluctuation, and with a variety of depth classes in relatively equal proportions. These indicators are considered equally predictive and so are averaged.
- **Structure** is assumed to be more suitable in herbaceous ponded wetlands that have intermediate amounts of open water interspersed well with aquatic plants. This counts for half the *Structure* score, with the other half based on the group average of several indicators: increasing vegetated width, snags suitable for cavity-nesting ducks, total area of wetland plus open water, and intermediate percent cover of emergent vegetation.
- **Productivity** is assumed to be greater in non-acidic, fish-accessible wetlands with flat gradients and mostly flat shorelines, that contain an island and/or are a more productive wetland type (in descending order, this is believed to be: Marsh > Fen > Open Peatland > Swamp). These indicators are assumed to be equally predictive so are averaged.

- **Stressors** are represented by increased proportion of the wetland visited often by people on foot, lack of measures to reduce human disturbance of nesting waterbirds, and evidence of toxic contaminants. These are averaged.
- **Landscape** factors beneficial to nesting waterbirds are assumed to include increased wetland distance from roads, and extensive natural cover contiguous with the wetland and/or in its upland buffer. These are averaged.

Approach for Future Validation: Among a series of wetlands spanning the function scoring range and a range of wetland condition (integrity), nesting waterbird species richness and density would need to be determined during the usual breeding period -- approximately May through July (see USEPA 2001 for methods). Ideally, nest success and juvenile survival rates should be measured.

WBN Benefits Model

If the wetland has been officially designated an IBA (Important Bird Area) or is known to host a rare breeding waterbird species, it automatically scores a 10. Otherwise, its Benefits score increases with increasing distance from a different pond or wetland, and scarcity of other herbaceous wetlands within 100 m, 1 km, and/or 5 km.

B3.15 SONGBIRD, RAPTOR, AND MAMMAL HABITAT (SBM)

Function Definition: The capacity to support, at multiple spatial scales, an abundance and diversity of songbirds, raptors, and mammals, especially species that are most dependent on wetlands or water. The model described below will not predict habitat suitability accurately for every species in this group.

Scientific Support for This Function in Wetlands Generally: High. Several large mammals, such as moose and bear, as well as several species of songbirds and raptors, depend on wetlands. Densities can be exceptionally high in some wetlands, due partly to high productivity of vegetation and invertebrates, and partly because wetland vegetation provides nest sites in close proximity to preferred foods.

SBM Function Model

Structure: In the unlikely event that the entire assessment area is always >99% water-covered, the model assigns the lowest score (0). For all other wetland types, half of the score is based on the wetland having relatively little surface water (thus more habitat space and structure for songbirds and most mammals), and the other half on the

average of 6 metrics: *Productivity, StructureA, StructureB, Landscape, Waterscape*, and *Stressors*. The metrics are described as follows:

- **Productivity** is assumed to be greatest in wetlands with an extensive or wide zone of vegetation, especially herbaceous vegetation. After averaging the scores for these two indicators, that average is multiplied by the average of scores for five indicators: greater cover of nitrogen-fixing plants, high edge-to-area ratio, presence of numerous upland inclusions, and predominance of hardwood cover (if the wetland is wooded). These are all considered to be equally predictive of SBM habitat.
- **StructureA** is a group of indicators that together represent some beneficial components of SBM habitat. This includes cliffs, snags, downed wood, known deer wintering areas, increased ground cover, and varied microtopography. These indicators are assumed to be equally predictive so are averaged.
- **StructureB** is another group of indicators that together reflect beneficial components of SBM habitat. This includes increased amounts of tree and shrub cover in and around the wetland, more mature trees, some small forest gaps, and a diversity of shrubs. These indicators are assumed to be equally predictive so are averaged.
- **Landscape** condition is assumed better for SBM if the wetland is near and connected with a large tract of natural vegetation, has a naturally vegetated buffer, and is adjoined by a different wetland type. These indicators are assumed to be equally predictive so are averaged.
- **Waterscape** condition is assumed better for SBM where a large proportion of the wetland lacks surface water (thus providing more habitable space for songbirds), is near a pond, has vegetation that is well-interspersed with patches of open water, and is actually or potentially used by beaver. These indicators are assumed to be equally predictive so are averaged.
- **Stressors** which could affect SBM use of a wetland include frequent human visitation, proximity to population centers, lack of a vegetated buffer around most of the wetland perimeter, close proximity to a road, and road blockage of wildlife access to the wetland. These indicators are assumed to be equally predictive so are averaged.

Note that some assessment methods, as an indicator of biodiversity, include "number of wetland types" or "number of hydroperiod types" present within a single wetland AA. WESP-AC does not use those because the lines between such types are seldom clearly distinguishable either in the field or from aerial imagery. WESP-AC addresses habitat heterogeneity (both within and surrounding an AA) using other indicators.

<u>Approach for Future Validation</u>: Among a series of wetlands spanning the function scoring range and a range of wetland condition (integrity), species richness and density

of songbirds, raptors, and mammals would need to be determined monthly and more often during migration or seasonal movements (see USEPA 2001 for methods). Ideally, daily duration of use and seasonal weight gain of key species should be measured.

SBM Benefits Model

If the wetland has been officially designated an IBA (Important Bird Area) or is known to host a rare breeding waterbird species, it automatically scores a 10. Otherwise, its Benefits score is based on whether it is nearly the only herbaceous wetland or only wooded wetland within 100 m, 1 km, and/or 5 km (if it is, the score is 10 but if not, the score is 0).

B3.16 NATIVE PLANT HABITAT (PH)

Function Definition: The capacity to support, at multiple spatial scales, a diversity of native vascular and non-vascular (e.g., bryophytes, lichens) species and functional groups, especially those that are most dependent on wetlands or water. See worksheet *WIS-plants* for list of the wetland vascular plant species in this region.

Scientific Support for This Function in Wetlands Generally: High. Many plant species grow only in wetlands and thus diversify the local flora, with consequent benefits to food webs and energy flow.

PH Function Model

Structure: The model is the weighted average of 7 factors: *Species-Area* (weighted 4x), *Competition/Light* (weighted 3x), *Aquatic Fertility* (weighted 2x), *Terrestrial Fertility* (weighted 2x), and unweighted: *Landscape* and *Stressors*. These are calculated as follows:

- **Species-Area** score increases with increased vegetated wetland size, vegetated width, connectivity to large tracts of natural land cover, and proportion of the wetland that is inundated only seasonally. The scores these are averaged.
- **Competition/ Light** encompasses several indicators. The absence of invasive plant species counts for half the score. The other half is the average of: lack of strongly dominant species in the shrub and herbaceous layers, relatively even mix of scattered patches of herbaceous and woody plants, predominance of hardwood cover (if forested), varied microtopography, and not recently burned.
- **Aquatic Fertility** is assumed to be greater if the wetland is a calcareous fen. If not, the score is greater if the wetland has a tributary, there is evidence of groundwater

input and/or circumneutral pH, shallow water depth, well-interspersed vegetation and open water, seasonal-only flooding, and moderate water level fluctuation. These indicators are assumed to be equally predictive so are averaged.

- **Terrestrial Fertility** is assumed to increase with increased cover of nitrogen-fixers, limestone bedrock, presence of finer-textured and moderately organic soils, limited cover of moss, longer growing season, and wetland type (in this order of descending assumed fertility: Fen > Open Peatland > Swamp> Marsh. These indicators are all assumed to be equally predictive so are averaged.
- **Landscape** condition is assumed better for native plants where the proximate upland land cover is mostly natural, ponded areas are numerous and actual or potential use by beaver has been noted. These indicators are assumed to be equally predictive and so are averaged.
- **Stressors** are represented by increased wetland visitation by humans without measures to minimise soil disturbance; proximity to roads and population centers; more-altered timing of runoff reaching the wetland; and increased soil disturbance. These indicators are assumed to be equally predictive and so are averaged.

Note that some assessment methods, as an indicator of biodiversity, include "number of wetland types" or "number of hydroperiod types" present within a single wetland AA. WESP-AC does not use those because the boundaries separating such types are not often clearly distinguishable either in the field or from aerial imagery. WESP-AC addresses habitat heterogeneity (both within and surrounding an AA) using other indicators.

Approach for Future Validation: Among a series of wetlands spanning the function scoring range and a range of wetland condition (integrity), all plant species would be surveyed and percent-cover determined at their appropriate flowering times during the growing season.

PH Benefits Model

The Benefits score is automatically set to 10 if a rare plant species is present in or near the wetland, or if <10 percent of the surrounding 100 m, 1 km, or 5 km contains herbaceous vegetation (but the wetland does), or if <10 percent of the surrounding 100 m, 1 km, or 5 km contains woody vegetation (but the wetland does). Otherwise, the score is the average of the scores for Pollinator Habitat and Songbird & Mammal Habitat.

B3.17 POLLINATOR HABITAT (POL)

Function Definition: The capacity to support pollinating insects, such as bees, wasps, butterflies, moths, flies, and beetles, and also pollinating birds (hummingbirds and perhaps others). No model is provided here for tidal wetlands due to their presumed limited capacity to support pollinating insects and birds, and due to lack of knowledge of features that would be predictive.

Scientific Support for This Function in Wetlands Generally: Moderate. Many wetlands may be important to pollinators because they host different plant species than those in surrounding uplands, which implies they may flower at different times than those in the uplands, and may do so over a prolonged season due to greater water availability in wetlands.

In the Region's Wetlands: Very little is known about the habitat requirements of pollinators in this region, and there have been no studies specifically of wetlands.

POL Function Model

Structure: The model is comprised of three metrics: *Pollen Onsite, Nest Sites,* and *Stress*. These indicators are assumed to be equally predictive so are averaged. They are calculated as follows:

- **Pollen Onsite** is calculated as the average of two groups. One represents either high forb cover or a predominance of low woody shrubs, both of which are favoured by pollinators. The other is a group average based on lack of strongly dominant herbaceous species and presence of diverse size classes of both hardwood and conifer trees.
- **Nest Sites** available for pollinating insects are assumed to increase with increased snags, large-diameter trees, downed wood, microtopographic variation, cliffs, and intermediate extent of vegetative ground cover. Together, these account for half the NestSites score and the other half is determined by the percentage of the wetland that is not persistently flooded.
- **Stressors** (lack of) are represented by lack of obvious toxic sources, proximity to natural vegetation, and greater extent of wetland perimeter adjoined by natural vegetation.

POL Benefits Model

Pollination is presumably valued to a greater degree if a wetland contains a rare plant (although not all plants are insect-pollinated), or if the wetland contains some of the only herbaceous or woody vegetation within 5 km, 1 km, or 100 m.

B3.18 PUBLIC USE & RECOGNITION (PU)

Definition: The potential and actual capacity of a wetland to sustain low-intensity human uses such as hiking, nature photography, education, and research. The model assumes that more human use of a wetland means that the particular wetland is more valued by the public. However, it is recognised that some individuals would benefit more those wetlands that receive less human use, because heavy use compromises the solitude sought and valued by some.

Structure: The score for Public Use Benefit of a wetland is assumed to increase with an increase in scores for 3 metrics: *Convenience*, *Investment*, and *Recreation Potential.* These are considered equally predictive so are averaged. They are comprised of the following indicators:

- **Convenience**: score is greater where most of wetland is physically accessible, publicly owned (especially as a conservation area), visible from roads, near marine waters and/or near a population center. Scores for these are averaged.
- **Investment**: This is intended to reflect positively any past expenditure of public funds for the wetland's conservation, as well as designation as a mitigation site or regular use for scientific research or non-regulatory monitoring. The metric's score is based on the maximum of these indicator scores.
- **Recreation Potential**: score is greater if wetland is on a lake, near a visitor center or has similar educational or recreational enhancements, while also featuring best management practices to reduce ecological impacts of overuse. Scores for these are averaged.

B3.19 WETLAND SENSITIVITY (Sens)

Definition: the lack of intrinsic resistance and resilience of the wetland to human and natural stressors (Niemi et al. 1990), including but not limited to changes in water chemistry, shade, frequency and duration of inundation or soil saturation, water depth, biological invasion, habitat fragmentation, and others as described in the USEPA report by Adamus et al. (2001).

Structure: The model assumes that wetland sensitivity, especially to human activities, can be represented by the unweighted average of the following 6 metrics, all considered equally predictive:

- **Abiotic Resistance** is assumed to be less (i.e., wetland more sensitive) in wetlands with no outlets, relatively small contributing areas, and with a large portion that lacks surface water.
- **Biotic Resistance** is assumed to be less (i.e., wetland more sensitive) in wetlands that are small; have a narrow vegetated width; are already dominated by native plant species; also support rare amphibians, waterbirds, songbirds, mammals, or plants; and (less predictably) have limited ground cover, convoluted upland edge, and few shrub species. Indicators in this last group are averaged, and their average is then combined with the average of the preceding more-predictive indicators.
- **Site Fertility** is assumed to speed recovery time from disturbance, which is a component of Wetland Sensitivity. It is predicted to be greater in wetlands that have more cover of nitrogen-fixing plants, are in an area with a shorter growing season, have poorly-buffered water chemistry (low conductivity), and are a new wetland or a type of wetland that typically has less nutrient availability. The assumed order of *increasing* nutrient availability is: Open Peatland > Swamp > Fen > Marsh.
- **Availability of Colonisers** also affects the recovery rate. Recovery times in wetlands might be greater if surrounding lands are dominated by natural land cover, the wetland is near other wetlands or lakes, the wetland is not located in the headwaters of a watershed, and no herbaceous species is strongly dominant.
- **Growth Rates** of wetland vegetation, and thus the time to full recovery, also depend on the plant species. Trees grow the slowest and live the longest, so if a wetland contains much tree cover, especially of large-diameter trees, and that is removed, full recovery takes longer. Thus, such wetlands could be considered less resilient and more sensitive.

B3.20 WETLAND ECOLOGICAL CONDITION (EC)

Definition: The integrity or health of the wetland as defined primarily by its vegetation composition (because that is the only meaningful indicator that can be estimated rapidly). More broadly, ecological condition is defined by the structure, composition, and functions of a wetland as compared to relatively intact reference wetlands of the same type, operating within the bounds of natural or historic disturbance regimes. However, in the case of WESP-AC, the model outputs were not scaled to intact reference wetlands due to the subjectivity involved in defining those.

Non-tidal wetlands in excellent ecological condition often have no invasive plants and at least one species of conservation concern. Equally, they have little bare ground, no strongly dominant herbaceous or shrub species, and may have varied microtopography and no extensive algal blooms. However, many wetlands perceived to be in excellent condition do not have any of these characteristics.

B3.21 WETLAND STRESS (STR)

Definition: The degree to which the wetland is or has recently been altered by, or exposed to risk from, human-related factors that degrade its ecological condition and/or reduce its capacity to perform one or more of the functions listed in this document.

Structure: Stressors were organised in four groups: Hydrologic Stress, Water Quality Stress, Fragmentation Stress, and general Disturbance Stress. The maximum score among these is added to their average score and divided by 2.

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Appendix C. Calibration Wetland Statistical Summaries

Table C-1. By function, the number of New Brunswick non-tidal wetland calibration sites with various ratings and function+benefit rating combinations (H= Higher, M= Moderate, L= Lower)

	# of sites (of 98) with rating of:			# of sites with each function-benefit rating combination (first letter is function rating, second is the associated benefit rating)								
Function:	H	M	L	HH	HM	HL	MH	MM	ML	LH	LM	LL
Amphibian Habitat (AM)	31	**44**	23	15	11	5	19	20	5	5	15	3
Anadromous Fish Habitat (FA)	23	15	**60**	4	4	15	1	3	11	11	16	33
Aquatic Invertebrate Habitat (INV)	29	**39**	30	15	7	7	16	13	10	16	10	4
Native Plant Habitat (PH)	34	**47**	17	16	18	0	10	35	2	3	11	3
Nitrate Removal & Retention (NR)	30	**34**	**34**	16	9	5	15	12	7	22	12	0
Phosphorus Retention (PR)	21	**42**	35	8	2	11	19	6	17	15	1	19
Pollinator Habitat (POL)	**52**	41	5	15	6	31	8	5	28	0	0	5
Resident & Other Fish Habitat (FR)	29	**37**	32	7	11	11	10	15	12	10	13	9
Sediment Retention & Stabilization	13	**57**	28	5	1	7	6	15	36	4	8	16
Songbird, Raptor, & Mammal Habitat	**51**	41	6	24	13	14	17	11	13	4	0	2
Stream Flow Support (SFS)	12	34	**52**	4	5	3	10	14	10	19	13	20
Streamwater Cooling (WC)	24	**44**	30	5	11	8	7	14	23	7	9	14
Surface Water Storage (WS)	31	32	**35**	0	6	25	2	4	26	2	6	27
Waterbird Feeding Habitat (WBF)	27	**50**	21	13	11	3	20	19	11	4	9	8
Waterbird Nesting Habitat (WBN)	31	**43**	24	17	9	5	14	18	11	6	10	8

Table C-2. By function, the number of Nova Scotia non-tidal wetland calibration sites with various ratings and function+benefit rating combinations (H= Higher, M= Moderate, L= Lower)

	# of sites (of 121) with rating of:			# of sites with each function-benefit rating combination (first letter is function rating, second is the associated benefit rating)								
Function:	H	M	L	HH	HM	HL	MH	MM	ML	LH	LM	LL
Amphibian Habitat (AM)	29	**60**	32	14	12	3	25	34	1	5	13	14
Anadromous Fish Habitat (FA)	40	12	**69**	11	26	3	1	7	4	0	0	69
Aquatic Invertebrate Habitat (INV)	28	**58**	35	13	2	13	31	17	10	3	28	4
Native Plant Habitat (PH)	16	**60**	45	5	5	6	6	11	43	4	9	32
Nitrate Removal & Retention (NR)	**54**	33	34	9	18	27	20	8	5	21	6	7
Phosphorus Retention (PR)	30	**55**	36	5	5	20	22	7	26	10	10	16

Function:	# of sites (of 121) with rating of:			# of sites with each function-benefit rating combination (first letter is function rating, second is the associated benefit rating)								
	H	M	L	HH	HM	HL	MH	MM	ML	LH	LM	LL
Pollinator Habitat (POL)	**67**	51	3	11	15	41	7	9	35	0	0	3
Resident & Other Fish Habitat (FR)	29	36	**56**	7	22	0	2	28	6	0	1	55
Sediment Retention & Stabilization	42	26	**53**	0	12	30	8	9	9	27	15	11
Songbird, Raptor, & Mammal Habitat	**61**	57	3	30	17	14	35	10	12	0	0	3
Stream Flow Support (SFS)	38	25	**58**	22	16	0	9	15	1	0	3	55
Streamwater Cooling (WC)	27	**62**	32	11	13	3	20	12	30	0	0	32
Surface Water Storage (WS)	24	33	**64**	0	15	9	5	14	14	9	29	26
Waterbird Feeding Habitat (WBF)	31	**64**	26	19	6	6	31	24	9	0	0	26

Table C-3. By function, the number of Newfoundland-Labrador non-tidal wetland calibration sites with various ratings and function+benefit rating combinations (H= Higher, M= Moderate, L= Lower)

Function:	# of sites (of 102) with rating of:			# of sites with each function-benefit rating combination (first letter is function rating, second is the associated benefit rating)								
	H	M	L	HH	HM	HL	MH	MM	ML	LH	LM	LL
Amphibian Habitat (AM)	27	**51**	24	7	19	1	9	37	5	2	6	16
Anadromous Fish Habitat (FA)	10	5	**87**	8	2	0	3	2	0	0	0	87
Aquatic Invertebrate Habitat (INV)	23	**46**	33	12	5	6	17	21	8	10	19	4
Native Plant Habitat (PH)	27	**54**	21	3	18	6	4	33	17	2	8	11
Nitrate Removal & Retention (NR)	**46**	31	25	10	16	20	20	6	5	16	5	4
Phosphorus Retention (PR)	24	**52**	26	2	5	17	16	11	25	16	6	4
Pollinator Habitat (POL)	**72**	28	2	6	4	62	3	1	24	0	0	2
Resident & Other Fish Habitat (FR)	26	26	**50**	11	15	0	6	20	0	0	0	50
Sediment Retention & Stabilization	**43**	36	23	1	15	27	16	11	9	14	7	2
Songbird, Raptor, & Mammal Habitat	**55**	45	2	11	15	29	9	22	14	0	0	2
Stream Flow Support (SFS)	28	22	**52**	10	18	0	12	7	3	1	6	45
Streamwater Cooling (WC)	34	**49**	19	4	18	12	5	12	32	0	0	19
Surface Water Storage (WS)	14	34	**54**	5	3	6	10	16	8	13	24	17
Waterbird Feeding Habitat (WBF)	**42**	**42**	18	10	23	9	6	27	9	0	0	18

Table C-4. By function, the number of Prince Edward Island non-tidal wetland calibration sites with various ratings and function+benefit rating combinations (H= Higher, M= Moderate, L= Lower)

	# of sites (of 102) with rating of:			# of sites with each function-benefit rating combination (first letter is function rating, second is the associated benefit rating)								
Function:	H	M	L	HH	HM	HL	MH	MM	ML	LH	LM	LL
Amphibian Habitat (AM)	24	**26**	20	10	10	4	10	12	4	0	7	13
Anadromous Fish Habitat (FA)	5	1	**64**	5	0	0	0	1	0	0	0	64
Aquatic Invertebrate Habitat (INV)	10	**36**	24	3	2	5	9	12	15	3	19	2
Native Plant Habitat (PH)	18	**27**	25	0	18	0	3	24	0	6	16	3
Nitrate Removal & Retention (NR)	**36**	19	15	13	17	6	16	2	1	11	4	0
Phosphorus Retention (PR)	13	**30**	27	0	3	10	3	7	20	10	12	5
Pollinator Habitat (POL)	**42**	25	3	1	1	40	7	6	12	0	0	3
Resident & Other Fish Habitat (FR)	12	11	**47**	4	8	0	4	7	0	0	0	47
Sediment Retention & Stabilization	20	22	**28**	0	8	12	5	9	8	16	8	4
Songbird, Raptor, & Mammal Habitat	**39**	28	3	12	14	13	17	7	4	0	0	3
Stream Flow Support (SFS)	19	19	**32**	12	7	0	3	8	8	0	0	32
Streamwater Cooling (WC)	10	22	**38**	4	5	1	3	6	13	0	0	38
Surface Water Storage (WS)	**36**	13	21	3	14	19	0	6	7	1	10	10
Waterbird Feeding Habitat (WBF)	20	**28**	22	10	8	2	9	13	6	0	0	22

Table C-5. Thresholds used to determine the rating associated with each normalised score, non-tidal WESP-AC for New Brunswick

	Thresholds for Function Rating		Thresholds for Benefit Rating	
Function or Other Attribute:	"Lower" IF ≤:	"Higher" IF ≥:	"Lower" IF ≤:	"Higher" IF ≥:
Water Storage & Delay	2.48	5.12	2.58	5.67
Stream Flow Support	2.92	6.56	2.08	6.16
Water Cooling	1.80	5.30	1.45	4.79
Sediment Retention & Stabilisation	1.76	5.26	3.75	7.95
Phosphorus Retention	2.66	4.17	1.71	4.55
Nitrate Removal	2.27	4.36	2.50	7.19
Carbon Sequestration	3.13	5.70		
Organic Nutrient Export	3.12	5.26		
Anadromous Fish Habitat	1.80	6.71	0.00	4.44
Resident Fish Habitat	1.40	6.29	0.00	4.48
Aquatic Invertebrate Habitat	2.58	5.58	0.85	5.74
Amphibian & Turtle Habitat	3.30	6.25	2.27	6.30
Waterbird Feeding Habitat	0.00	6.84	0.83	6.67
Waterbird Nesting Habitat	1.95	5.42	0.00	6.67

	Thresholds for Function Rating		Thresholds for Benefit Rating	
Function or Other Attribute:	"Lower" IF ≤:	"Higher" IF ≥:	"Lower" IF ≤:	"Higher" IF ≥:
Songbird, Raptor, & Mammal Habitat	2.50	7.24	3.33	6.67
Native Plant Habitat	3.96	5.98	0.00	6.33
Pollinator Habitat	0.00	7.81	0.00	6.67
Public Use & Recognition			2.40	5.51
Wetland Sensitivity			2.88	5.30
Wetland Ecological Condition			3.25	6.39
Wetland Stressors			2.15	4.97
Wetland Risk			2.71	4.33
Grouped Functions:				
HYDROLOGIC Group	2.48	5.12	2.58	5.67
WATER QUALITY SUPPORT Group	3.07	5.39	4.15	7.64
AQUATIC SUPPORT Group	3.82	6.04	1.34	4.99
AQUATIC HABITAT Group	2.41	6.22	3.15	6.29
TRANSITION HABITAT Group	4.68	7.60	0.00	5.33

Table C-6. Thresholds used to determine the rating associated with each function or benefit normalised score, non-tidal WESP-AC for Nova Scotia

	Thresholds for Function Rating		Thresholds for Benefit Rating	
Function or Other Attribute:	"Lower" IF ≤:	"Higher" IF ≥:	"Lower" IF ≤:	"Higher" IF ≥:
Water Storage & Delay	3.80	7.63	3.02	6.17
Stream Flow Support	1.51	4.62	2.15	6.33
Water Cooling	1.50	4.67	1.72	5.67
Sediment Retention & Stabilisation	3.75	7.27	1.13	3.13
Phosphorus Retention	4.84	6.67	1.07	2.59
Nitrate Removal	2.30	4.62	3.50	7.50
Carbon Sequestration	3.31	6.36		
Organic Nutrient Export	4.13	7.10		
Anadromous Fish Habitat	0.00	2.22	1.35	4.34
Resident Fish Habitat	1.90	5.48	1.38	4.54
Aquatic Invertebrate Habitat	2.83	5.10	2.60	5.96
Amphibian & Turtle Habitat	3.69	6.57	2.29	5.10
Waterbird Feeding Habitat	0.00	6.66	2.50	6.67
Waterbird Nesting Habitat	2.36	6.34	2.50	6.67
Songbird, Raptor, & Mammal Habitat	0.00	7.69	3.33	6.67
Native Plant Habitat	3.19	5.72	5.36	7.71
Pollinator Habitat	0.00	7.95	0.00	6.67
Public Use & Recognition			1.41	4.42
Wetland Sensitivity			3.67	6.19
Wetland Ecological Condition			3.91	6.52
Wetland Stressors			2.91	6.05

	Thresholds for Function Rating		Thresholds for Benefit Rating	
Function or Other Attribute:	"Lower" IF ≤:	"Higher" IF ≥:	"Lower" IF ≤:	"Higher" IF ≥:
Wetland Risk			3.85	5.78
Grouped Functions:				
HYDROLOGIC Group	3.80	7.63	3.02	6.17
WATER QUALITY SUPPORT Group	4.36	6.66	2.84	6.16
AQUATIC SUPPORT Group	4.20	6.58	1.73	5.11
AQUATIC HABITAT Group	2.67	6.04	2.75	5.92
TRANSITION HABITAT Group	0.97	7.09	5.50	8.31

Table C-7. Thresholds used to determine the rating associated with each function or benefit normalised score, non-tidal WESP-AC for Newfoundland-Labrador

	Thresholds for Function Rating		Thresholds for Benefit Rating	
Function or Other Attribute:	"Lower" IF ≤:	"Higher" IF ≥:	"Lower" IF ≤:	"Higher" IF ≥:
Water Storage & Delay	4.13	7.89	1.76	3.98
Stream Flow Support	1.81	4.39	1.94	5.44
Water Cooling	0.67	4.17	1.89	5.93
Sediment Retention & Stabilisation	3.21	6.86	1.02	4.21
Phosphorus Retention	6.44	8.54	0.83	3.33
Nitrate Removal	1.76	3.93	3.33	6.76
Carbon Sequestration	3.70	6.61		
Organic Nutrient Export	4.65	6.80		
Anadromous Fish Habitat	0.00	5.45	0.00	4.51
Resident Fish Habitat	0.00	6.15	0.00	6.04
Aquatic Invertebrate Habitat	2.96	5.45	1.36	5.95
Amphibian & Turtle Habitat	3.90	7.02	2.01	3.89
Waterbird Feeding Habitat	0.00	7.04	1.67	5.83
Waterbird Nesting Habitat	2.52	6.38	0.00	5.00
Songbird, Raptor, & Mammal Habitat	0.00	7.76	0.00	5.00
Native Plant Habitat	3.68	6.08	4.35	6.72
Pollinator Habitat	0.00	7.53	0.00	6.67
Public Use & Recognition			2.23	4.32
Wetland Sensitivity			2.99	5.65
Wetland Ecological Condition			3.73	6.39
Wetland Stressors			2.75	5.22
Wetland Risk			2.87	4.39
Grouped Functions:				
HYDROLOGIC Group	4.13	7.89	1.76	3.98
WATER QUALITY SUPPORT Group	5.29	7.87	2.59	5.12
AQUATIC SUPPORT Group	4.61	6.36	1.90	4.87
AQUATIC HABITAT Group	2.15	6.11	2.56	5.30
TRANSITION HABITAT Group	3.81	7.57	5.13	7.57

Table C-8. Thresholds used to determine the rating associated with each function or benefit normalised score, non-tidal WESP-AC for Prince Edward Island

	Thresholds for Function Rating		Thresholds for Benefit Rating	
Function or Other Attribute:	"Lower" IF ≤:	"Higher" IF ≥:	"Lower" IF ≤:	"Higher" IF ≥:
Water Storage & Delay	2.99	4.69	1.79	4.89
Stream Flow Support	0.90	3.64	0.00	4.96
Water Cooling	1.59	4.82	0.98	4.73
Sediment Retention & Stabilisation	3.18	6.59	1.00	2.18
Phosphorus Retention	2.90	4.79	3.33	6.25
Nitrate Removal	1.41	3.11	2.22	6.67
Carbon Sequestration	3.14	6.99		
Organic Nutrient Export	3.93	7.06		
Anadromous Fish Habitat	0.00	2.97	0.00	5.41
Resident Fish Habitat	0.00	5.98	0.00	5.91
Aquatic Invertebrate Habitat	2.98	5.93	1.63	6.78
Amphibian & Turtle Habitat	3.69	7.09	3.27	5.79
Waterbird Feeding Habitat	0.00	7.27	2.50	6.67
Waterbird Nesting Habitat	2.26	6.17	2.50	6.67
Songbird, Raptor, & Mammal Habitat	0.00	7.35	2.50	6.67
Pollinator Habitat	0.00	6.58	0.00	6.67
Native Plant Habitat	3.35	6.37	1.11	6.14
Public Use & Recognition			1.80	5.76
Wetland Sensitivity			3.03	5.65
Wetland Ecological Condition			3.33	6.97
Wetland Stressors			2.65	5.72
Wetland Risk			3.33	6.97
Grouped Functions:				
HYDROLOGIC Group	2.99	4.69	1.79	4.89
WATER QUALITY SUPPORT Group	3.48	6.10	2.74	5.58
AQUATIC SUPPORT Group	4.12	6.10	2.29	5.52
AQUATIC HABITAT Group	3.10	6.51	2.86	5.87
TRANSITION HABITAT Group	1.83	7.03	0.74	4.66

Table C-9. Number of functions rated “Higher” at WESP-AC non-tidal calibration wetlands

# of functions (of 21) rated "Higher"	New Brunswick # of Sites (of 98)	Nova Scotia # of Sites (of 121)	Newfoundland-Labrador # of Sites (of 102)	Prince Edward Island # of Sites (of 70)
15 functions	0	1	0	0
14 functions	0	1	0	1
13 functions	0	4	1	0
12 functions	5	3	4	1
11 functions	3	6	5	5
10 functions	10	3	8	5
9 functions	8	3	15	9
8 functions	5	14	11	13
7 functions	18	17	21	17
6 functions	14	34	13	7
5 functions	15	11	5	8
4 functions	11	14	6	2
3 functions	4	8	6	0
2 functions	2	0	1	1
1 functions	0	2	1	1
0 functions	3	0	1	0

Table C-10. By function and benefit, the minimum number of non-tidal calibration sites needed to statistically encompass the full score range in New Brunswick and Nova Scotia.

These estimates were based on the measured variance in the normalised score range among the assessed sites. They likely underestimate the ideal number of sites because it is unknown by how much an assessment of additional sites would increase the variance. The estimates were generated through use of 100 random simulations.

	Approx. # of sites needed to calibrate Function score		Approx. # of sites needed to calibrate Benefits score	
Wetland Functions or Other Attributes:	NB	NS	NB	NS
Water Storage & Delay (WS)	90	100	70	80
Stream Flow Support (SFS)	40	70	60	70
Water Cooling (WC)	70	70	60	80
Sediment Retention & Stabilisation (SR)	70	70	90	80
Phosphorus Retention (PR)	70	80	70	80
Nitrate Removal & Retention (NR)	70	80	70	70
Carbon Sequestration (CS)	90	100		
Organic Nutrient Export (OE)	90	100		
Anadromous Fish Habitat (FA)	60	80	60	80
Resident Fish Habitat (FR)	60	80	70	70
Aquatic Invertebrate Habitat (INV)	80	90	80	100
Amphibian & Turtle Habitat (AM)	90	100	70	80
Waterbird Feeding Habitat (WBF)	60	80	20	10
Waterbird Nesting Habitat (WBN)	70	90	20	10
Songbird, Raptor, & Mammal Habitat (SBM)	70	90	20	30
Pollinator Habitat (POL)	60	80	70	10
Native Plant Habitat (PH)	80	100	70	80
Public Use & Recognition (PU)			90	90
Wetland Sensitivity (Sens)			70	90
Wetland Ecological Condition (EC)			40	70
Wetland Stressors (STR)			80	100
WETLAND RISK			80	100
Grouped Functions:				
HYDROLOGIC	90	100	70	80
WATER QUALITY SUPPORT	80	100	90	100
AQUATIC SUPPORT	80	100	80	100
AQUATIC HABITAT	80	100	70	100
TRANSITION HABITAT	80	100	70	90