RAPID ASSESSMENT OF FRESHWATER WETLAND CONDITION
Atlantic White Cedar Swamps, Bogs, and Fens

Development and Demonstration of a Rapid Assessment Method for Freshwater Wetlands in Rhode Island, Year 4

Final Report

Prepared for
Rhode Island Department of Environmental Management
Office of Water Resources

April 2011

RHODE ISLAND NATURAL HISTORY SURVEY
Providing Ecosystem Science and Information

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Executive Summary

The State of Rhode Island Department of Environmental Management (DEM) and the Rhode Island Natural History Survey (RINHS) are working to develop a rapid assessment method (RAM) for freshwater wetland condition to address a set of objectives identified by the *Rhode Island Freshwater Wetland Monitoring and Assessment Plan* (WMAP). WMAP identifies short-term and long-term objectives focused on enhancing the protection and management of wetlands within the State. The RAM is being developed under guidance and funding from the EPA in accordance with the Clean Water Act, and represents the second level of an EPA-recommended three-level approach to wetland monitoring and assessment that includes landscape-level assessment (L1), rapid assessment (L2), and intensive assessment (L3). The State-specific RAM, RIRAM, is in its fourth year of development and demonstration. In years 1 through 3, RIRAM demonstrations were conducted according to a rotating basin monitoring approach to characterize wetland condition across areas of interest (i.e. basins). This Year-4 project applies RIRAM to characterize the status and condition of Atlantic white cedar swamps (cedar swamps) and bogs and fens (bogs/fens), two wetland types of State conservation concern. These wetland types are unique in that they depend on a narrow set of physical and biological factors that develop over decades or longer and thus may not be feasibly recreated under mitigation or restoration circumstances.

In its current version, RIRAM v.2 is an evidence-based RAM designed to characterize wetland condition by producing a set of sub-indices that can be summed to generate a numeric index of overall freshwater wetland condition. The sub-indices can also be applied to explore various relationships between human activities and wetland condition. RIRAM v.2 aims to minimize user subjectivity by estimating intensity and proportionality of stress, separately. The RAM is organized in a field checklist by four sections that characterize (A) wetland characteristics and classification, (B) landscape stress, (C) in-wetland stress, and (D) the observed state of wetland characteristics; sections B through D are scored, while section A is not.

RIRAM v.2.10 was applied to assess the condition of 28 cedar swamps and 25 bogs/fens located on public and conserved properties across Rhode Island. Sites were randomly selected along a gradient of increasing surrounding land use intensity. Field assessments were conducted between September 10 and October 22, 2009 and supporting GIS research was conducted directly following. Data were documented on hard-copy field forms and entered into Excel spreadsheet software for QA/QC, analysis, and archiving. Statistical analyses were applied to summarize baseline and conditional data and demonstrate RIRAM data applications.

RIRAM scores for the total Year-4 sample were skewed toward unstressed and un-degraded condition when compared with a Year-3 basin characterization, and evidence suggests that both cedar swamps and bogs/fens are in relatively good condition. For each wetland type, 90th percentile RIRAM Index scores equaled 100 (indicating no stresses or

degradation of integrity noted), median index scores were above 95, and surrounding land use intensity and buffer degradation were low, on average.

RIRAM data were applied to demonstrate their utility in addressing wetland and monitoring objectives identified in WMAP. RIRAM metric C.4 *Draining or diversion of water from wetland* scores were significantly higher for sites located within wellhead protection areas than those not within the areas. This trend held for both Year-4 and Year-3 data (Mann-Whitney, $P<0.01$ and $P=0.01$, respectively) and suggests that RIRAM can detect evidence of changes in hydrology due to groundwater withdrawals.

RIRAM *buffer degradation* and *surrounding land use* metrics were most closely associated with in-wetland metrics estimating the intensity of fluvial inputs and filling/dumping for both cedar swamps and bogs/fens, while *buffer degradation* was associated with invasive plant intensity for bogs/fens. RIRAM indices were correlated with an independent measure of land use intensity out to 4000' for cedar swamps and out to 500' for bogs/fens, indicating a stronger influence of proximate stresses on bogs/fens.

Seven invasive plant species were detected at eight (8) of the 53 sites. Intensity ranged from nearly absent (<5% cover) to moderate (6-25% cover). Nutrients and impoundments were the stresses most closely associated with invasive species occurrence in cedar swamps, while degradation of buffers and filling/dumping were most closely associated in bogs/fens. Invasive plant cover and richness were correlated with the *Observed State* index, representing observed wetland degradation, for bogs/fens, but not for cedar swamps.

The RIRAM *Observed State* index was most closely associated with landscape stresses, draining or diversion of water, and fluvial inputs for cedar swamps, while the index was most closely associated with fluvial inputs, impoundment, and landscape stresses in bogs/fens. These findings suggest that these wetlands may be particularly sensitive to hydrologic stresses. For both wetland types, the RIRAM *Total Stress* index, representing cumulative stresses, was much more strongly associated with the *Observed State* index than was any single metric; this may reflect the additive effect of cumulative stresses on these wetland types.

RIRAM index scores were significantly higher (indicating better condition) for wetlands occurring on State lands than those occurring on other public or conserved properties (Mann-Whitney, $P<0.001$), a trend likely due to larger average property size. This supports the convention that larger conservation properties better protect the natural resources within and suggest successful State strategies in creating and conserving large conservation parcels. Year-3 properties conserved specifically for habitat protection showed modestly higher RIRAM scores than those designated for other purposes, suggesting better protection under that strategy.

Analyses presented in this and former RIRAM demonstration and development studies demonstrate the efficacy of RIRAM in generating valid indices of freshwater wetland condition and producing useful information on wetland characterization. More

specifically, this report further demonstrated that RIRAM has the capacity to effectively address the State monitoring and assessment objectives outlined in WMAP, which concern factors such as groundwater withdrawals, surrounding land uses, invasive species, cumulative impacts, and management-strategy efficacy. However, until RIRAM v.2 is further validated against other indicators of wetland condition under varied circumstances, RIRAM data should be applied with respective cautions.

1. Introduction

1.1 Background

1.1.1 Rhode Island Freshwater Wetland Monitoring and Assessment Plan

The State of Rhode Island Department of Environmental Management (DEM) and the Rhode Island Natural History Survey (RINHS) are working to develop a rapid assessment method (RAM) to characterize freshwater wetland condition. The project is being conducted in accordance with the *Rhode Island Freshwater Wetland Monitoring and Assessment Plan* (hereafter WMAP; NEIWPCC and DEM 2006), with support and guidance from the United States Environmental Protection Agency (EPA). The work detailed in this report builds upon work conducted in 2006 through 2009 by DEM and its partners, which is detailed in previous reports (DEM 2006; Kutcher 2009; Kutcher 2010a and b). The project is intended to fulfill expectations of DEM and EPA, pursuant to the *Rhode Island freshwater monitoring and assessment: expanded pilot demonstration project work plan for EPA QAPP review – year 4 continuation* (DEM 2009a).

Informed by wetland partners, the State, and EPA, WMAP identifies gaps and needs in freshwater monitoring and assessment and outlines a strategy to meet those needs. The strategy includes the development and application of long-term monitoring and assessment methods aimed to address a set of State-identified objectives, which are outlined in WMAP as follows:

Short-term objectives

- *Prioritize wetlands (and adjacent upland habitat) for protection through open space acquisition and other land protection mechanisms.*
- *Develop and implement methods for monitoring impacts to wetlands due to water withdrawals.*
- *Monitor and assess impacts to wetlands due to loss and degradation of adjacent upland habitats (buffer zones).*
- *Monitor location and extent to which invasive species are present and affecting wetland condition.*

Long-term objectives

- *Develop a database of information necessary to evaluate trends in wetland condition.*
- *Identify causes and sources of wetland degradation including cumulative impacts to wetlands.*
- *Identify program and policy changes needed to improve overall wetland condition statewide.*
- *Evaluate the effectiveness of wetland management and protection programs with respect to wetland condition.*

1.1.2 EPA Three-Level Approach

The WMAP strategy incorporates elements of an EPA-recommended three-level approach to wetland monitoring and assessment that was developed to address policies set by the Clean Water Act (U.S. EPA 2006). The approach supports validation and interoperability between various data types and promotes a comprehensive and coordinated strategy to data collection, storage, analysis, and application. Descriptions and applications of the three levels are outlined in Table 1.

Table 1. EPA-recommended three-level approach to wetland monitoring and assessment

USEPA Recommended Level
Level 1: Landscape Assessment Use GIS and remote sensing to gain a landscape view of watershed and wetland condition. Typical assessment indicators include wetland coverage (NWI), land use and land cover.
Level 2: Rapid Wetland Assessment Evaluate the general condition of individual wetlands using relatively simple field indicators. Assessment is often based on the characterization of stressors known to limit wetland functions e.g., road crossings, tile drainage, ditching.
Level 3: Intensive Site Assessment Produce quantitative data with known certainty of wetland condition within an assessment area, used to refine rapid wetland assessment methods and diagnose the causes of wetland degradation. Assessment is typically accomplished using indices of biological integrity or hydrogeomorphic function.

Source: USEPA 2006

1.1.3 Development and Testing of Rapid Assessment Methods

The WMAP strategy aims to develop and integrate the three levels of monitoring in the State of RI over time. As a central part of that strategy, the plan calls for a Level 2, rapid wetland assessment method (RAM) to be developed from 2006 to 2011. The EPA (2006) views rapid assessment as a prerequisite component of state monitoring programs. In an effort to take an evolutionary approach to RAM development, NEIWPPC and DEM researched existing RAM protocols being implemented by other states with the intent of adapting an existing method for use in RI. At least 13 states have developed wetland RAMs. Based on research, including a review of various State RAMs published by the EPA (Fennessy et al. 2004), DEM selected two methods that would be piloted to assess their utility in addressing the State's monitoring objectives: (1) the *Ohio Rapid Assessment Method* (ORAM; Mack 2001) and (2) the *Delaware Rapid Assessment Procedure* (DERAP; Jacobs 2003), which has since been updated (Jacobs 2007).

In 2006 (Year 1), the ORAM and DERAP were simultaneously piloted in the Woonasquatucket River basin in Northern RI. The study, conducted by NEIWPPC and DEM (2006), involved the strict application of ORAM protocols, while DERAP was applied as an ancillary checklist. The RAMs were piloted at 27 sites selected across a gradient of land use intensity. In 2007 (Year 2), findings and recommendations of 2006 investigations were incorporated into efforts by DEM and RINHS to enhance and adapt the two methods for use in RI. ORAM and DERAP were modified *a priori* to improve

their regional and functional relevance and were applied to 54 sites in the Upper Pawcatuck drainage basin in southwestern RI. The protocols were further modified *a posteriori* based on justifications and analyses detailed in the Year-2 report (Kutcher 2009). The outcomes of those efforts included a Rhode Island-specific RAM, RIRAM v.1, which was further developed, demonstrated, and validated in Year 3. A second version of RIRAM, RIRAM version 2 (v.2) was developed and piloted alongside RIRAM v.1 in Year 3. The outcomes of that effort (refer to Kutcher 2010b) resulted in a shift in focus to the new RIRAM version for future development and demonstrations of rapid assessment of wetland condition by the State. RIRAM v.2 was applied in Year 4 to characterize the relative condition of (1) Atlantic white cedar swamps (cedar swamps) and (2) bogs and fens (bogs/fens), which are wetlands of conservation concern in Rhode Island; Year-4 work is the focus of this report.

1.2 RIRAM v.2.09

RIRAM v.2 was developed in response to feedback from Federal, State, regional, and academic peer reviewers to address deficiencies and inconsistencies of RIRAM v.1. RIRAM v.2 produces conditional indices by rating and summing stressor intensity and wetland integrity, which closely follows EPA wetland monitoring and assessment guidelines (U.S. EPA 2006). Three sub-indices evaluating landscape stresses, in-wetland stresses, and the observed state of the wetland can be summed to generate a single relative index of overall wetland condition. The index (hereafter *RIRAM* index) is based on 100 possible points; where a score of 100 indicates pristine condition, and a score approaching zero would indicate severely degraded condition. Sub-indices (hereafter identified as specific indices) and metrics can also be applied separately for various decision-support efforts. RIRAM v.2.09 represents the initial developmental sub-version applied in this study.

In the first scored section, Section B, RIRAM v.2.09 utilizes two metrics ranking surrounding landscape stress by estimating the proportions of land use categories within 100 and 500 feet (30 and 150 meters, respectively; App. 1, B). These metrics are weighted ten points each and are summed to generate the *Landscape Stress* index, which represents 20% of the *RIRAM* index.

In the next section, Section C, RIRAM v.2.09 utilizes seven metrics ranking in-wetland stress by the intensity and proportionality of effect (App. 1, C). In-wetland stress (hereafter *Wetland Stress*) metrics are categorized by stress type and include the following (listed by metric number):

3) Impoundment
4) Draining or diversion of water from wetland
5) Anthropogenic fluvial inputs
6) Filling and dumping within wetland
7) Excavation, grading, and other substrate disturbances within wetland
8) Vegetation and detritus removal within wetland
9) Invasive species within wetland

Where applicable, each *Wetland Stress* metric includes a checklist to document evidence, stressors, and sources associated with the stress type. Each *Wetland Stress* metric is given

equal weight; they are summed, and then subtracted from 50 to generate the *Wetland Stress* index score, which comprises 50% of the *RIRAM* index.

In the final scored section, Section D, RIRAM v2.09 summarizes and documents the observed state of six key wetland characteristics that can control previously-identified wetland functions and values (e.g. USACOE 1993). Specifically, the section ranks each of the following metrics along a continuum ranging from *characteristic* to *destroyed*.

- Vegetation structure
- Vegetation composition
- Hydrologic connectivity
- Habitat connectivity
- Microhabitat structure
- Water and soil quality

The metric ranks are summed to generate an index that comprises 30% of the *RIRAM* index. The index is based upon interpretation of visible indications of wetland integrity, reconciled with evidence gathered from all previous RIRAM sections and may require a strong understanding of wetland processes.

1.3 Project Objectives

EPA (2006) recommends a wetland monitoring program strategy designed to address State-identified objectives. Accordingly, a primary focus of RIRAM development has been refining it to more effectively address the objectives identified in WMAP and demonstrating its effectiveness in doing so. Refinements have aimed to increase data utility, accuracy, and defensibility, while minimizing subjectivity between users. In this study, RIRAM was applied to cedar swamps, and bogs/fens—two wetland habitat types of State concern—to demonstrate its effectiveness in rapidly characterizing baseline and condition of targeted resources. RIRAM was also analyzed to refine and assess its utility in serving various State monitoring needs.

Specifically, Year-4 project objectives were to: (1) demonstrate the application of RIRAM in the characterization and inventory of targeted wetland resources, (2) further demonstrate the utility of RIRAM data in directly addressing State freshwater monitoring and assessment objectives, (3) further refine, as necessary, RIRAM metrics to enhance its utility for the assessment of freshwater wetland condition, (4) develop guidelines for identifying reference conditions based on wetland condition, and (5) develop users' guidance for RIRAM application. Objectives one through three, above, are addressed in this report. Reference guidelines and users' guidance will be delivered as separate documents.

1.4 Peat-dominated Wetlands in Rhode Island

Atlantic white cedar swamps and bogs/fens are peat-dominated wetlands that thrive in deep, saturated basins and are most often associated with sphagnum moss or muck (i.e. peat) substrates. The two types may occur within a single system, often adjacently, with bogs/fens generally inhabiting deeper and wetter portions of a given system than cedar swamps. Hydrogeomorphic settings that support these wetland types in Rhode Island range widely from small confined basins to expansive outwash-plain wetland systems

associated with glacial lakes. But, water regimes are limited to *seasonally-flooded* and *saturated* (per Cowardin et al. 1979), with soils typically remaining saturated permanently or nearly so. Low oxygen levels associated with long-term soil saturation facilitates the accumulation of peat and largely controls habitat development of peat-dominated wetlands; other controlling factors may include low or mineral-dominated nutrient levels and high acidity in the substrate (Enser and Lundgren 2006). These conditions support the establishment of unique vegetation communities adapted to hold niches within a relatively narrow range; in Rhode Island, cedar swamps and bogs/fens dominate these niches. Because these conditions would be difficult to reproduce, and in fact, may only develop over decades or centuries, replacing these wetland types may not be possible (Cavallaro and Golet 2002). Protection may therefore represent the only means to their conservation.

In Rhode Island, Atlantic white cedar swamps generally grow in muck soils with long-period, seasonally-flooded hydroperiods and seasonally to semi-permanently saturated substrates (mean water level ~1cm above the surface), although hydroperiods may vary among sites and within sites, seasonally and annually (Lowry 1984). The canopy is dominated or co-dominated by Atlantic white cedar (*Chamaecyparis thyoides*) with an understory generally dominated by tall shrubs, often including sweet pepperbush (*Clethra alnifolia*), highbush blueberry (*Vaccinium corymbosum*), rhododendron (*Rhododendron maximum*), and other heaths (*Ericaceae*) (Enser and Lundgren 2006). According to Rhode Island's Comprehensive Wildlife Conservation Strategy (DEM 2005), cedar swamps are listed as a key wildlife habitat under moderate threat and in overall good condition. But cedar swamps are listed globally as G3 *vulnerable* and it is estimated that only 22% of the world's cedar swamps remain, mostly due to the harvest of valuable cedar timber and draining (NatureServe 2010; DEM 2005; Zampella, 1987). Cedar swamps support at least four moth and butterfly species of conservation concern in Rhode Island (DEM 2005).

Bogs and fens generally grow on peat substrates with permanently-saturated, semi-permanently-saturated, or seasonally-flooded water regimes, usually on a mat of sphagnum or fibric detritus, respectively. These are open peatlands that occur along a gradient of nutrient concentrations, with bogs generally occurring in oligotrophic conditions and fens generally occurring in minerotrophic conditions; this may also relate to hydrogeomorphic setting; bogs largely occur in confined basins or in basins with very limited flow, whereas fens often occur as fringes in slow-moving riverine or lacustrine settings, where nutrients are more abundantly available. It has been suggested that in certain circumstances, fens may progress into bogs as sphagnum mats develop and, in turn, block nutrient inputs (Gorham 1987). While plant assemblages may differ considerably at the extreme ends of the bog/fen gradient (e.g. bogs are generally sphagnum dominated while fens may lack sphagnum), bogs and fens occurring toward the middle of the gradient may be difficult to differentiate; thus, they are combined for study here and elsewhere. Bogs and fens may be dominated by low shrubs, stunted trees, sphagnum, or emergent vegetation (Enser and Lundgren 2006). According to Rhode Island's Comprehensive Wildlife Conservation Strategy (DEM 2005), bogs/fens are listed as a key habitat for species of conservation concern, are under moderate threat, and

are in overall fair to good condition. Bogs are listed globally as G5 *secure*, while shrub fens are listed as G4/G5 *apparently secure* and emergent fens of RI are not listed (NatureServe 2010). Bogs and fens support many rare plants and numerous faunal species of conservation concern in Rhode Island, including moths, butterflies, dragonflies, beetles, and two reptile species (DEM 2005).

Because they are important habitats to several species of conservation concern, and are difficult to replace or restore, cedar swamps and bogs/fens have been a priority for monitoring and protection in Rhode Island. Ecological condition of these wetland types has been inferred from prior studies and expert knowledge, but it has not been specifically studied or documented in the State. Conducting RIRAM assessments on a sample of these unique wetlands will provide the State with important information on their condition and may elucidate relationships among human activities, wetland stress, and wetland response, which could inform future management strategies.

2. Methods

2.1 Overview

RIRAM v.2.09 was revised and applied to assess the condition of 53 peat-dominated wetlands across Rhode Island. Sites were randomly selected along a gradient of increasing surrounding land use intensity, from the pool of all mapped Atlantic white cedar swamps, bogs, and fens located on public or preserved (i.e. "open-space") properties within the state. Assessment units were delimited by habitat community and may represent all or part of a wetland complex. Two habitat community types were represented: (1) Atlantic white cedar swamps and (2) bogs/fens. Field assessments were conducted between September 10 and October 22, 2009; supporting GIS research was conducted directly following. Data were documented on hard-copy field forms and entered into Excel spreadsheet software for QA/QC, analysis, and archiving.

Statistical analyses were applied to summarize baseline and conditional data, and demonstrate RIRAM data applications. Data from cedar swamp (CS) and bog/fen (BF) assessment units were combined or split, depending on the intent of the specific analysis. Where useful, Year-3 data (from previous assessments) were incorporated into analyses to support Year-4 analysis results or increase statistical power. Rank-based, non-parametric analysis was used throughout. Demonstration analyses focused on utilizing RIRAM data to address wetland monitoring and assessment objectives identified in WMAP.

2.2 Study Area and Site Selection

The study utilized 53 wetland assessment units, comprising 28 CS and 25 BF habitat types (Fig. 1). Assessment units were randomly selected along a gradient of land use intensity from the population of all mapped CS and BF habitats located on public and conserved properties within Rhode Island. Utilizing ESRI ArcMap® GIS software, assessment units were selected as follows:

- Public and NGO properties were identified by merging RIGIS (2009) geospatial vector data-layers *State Conservation and Park Lands* and *Local and NGO Conservation and Park Lands*. The resulting layer was used to clip a selection of polygons representing FOA (needle-leafed evergreen forested), EMB (emergent bogs and fens), and SSB (scrub-shrub bogs and fens) wetlands from the data-layer *Wetlands of Rhode Island, 1995* using the intersect command. FOA habitats were further refined to those having their centriods fall within muck soil classes using the RIGIS *Soils* dataset, to narrow the selection from all evergreen wetlands to primarily CS wetlands.
- The resulting polygons (of all public/NGO CS and BF mapped polygons) were each buffered by 500' (150m), and a shapefile of the buffered habitats was created. This shapefile was intersected with the RIGIS data-layer *2003-04 Land Use for RI*, which classifies land use and land cover by the Andersen Classification Scheme (1976).
- The resulting polygons (land use in buffers surrounding public/NGO CS and BF wetlands) were analyzed to determine the proportion of developed (i.e. *Urban or*

Built-up Land; the remainder being natural lands) within each, and coded accordingly. Polygons were separated into two groups, representing potential CS and BF units, separately. The polygons were then sorted (i.e. ranked) according to their land use proportions; proportions ranged from 0.00 to 0.59 developed land. Those polygons tied at 0.00 developed cover were sorted by size. For each habitat type (CS and BF), 30 wetland polygons (associated with sorted buffers) were selected evenly along the entire gradient from a random starting point between 0 and *n*/60.

- From those polygons, privately owned conservation properties were replaced with the associated unit closest on the sorted buffer list to alleviate anticipated access problems.
- Unit classifications were then each reinterpreted using six-inch leaf-off pictometry (RIGIS 2009). Those determined not to be the documented (or otherwise fitting) wetland type were replaced with the closest associated unit from the sorted buffer list. Some units could not be replaced within the range between previously-selected units and were eliminated from the study.

Final selections were heads-up digitized as detailed in Section 2.3. Permission to access study sites was gained through telephone and email solicitation of fee and easement owners.

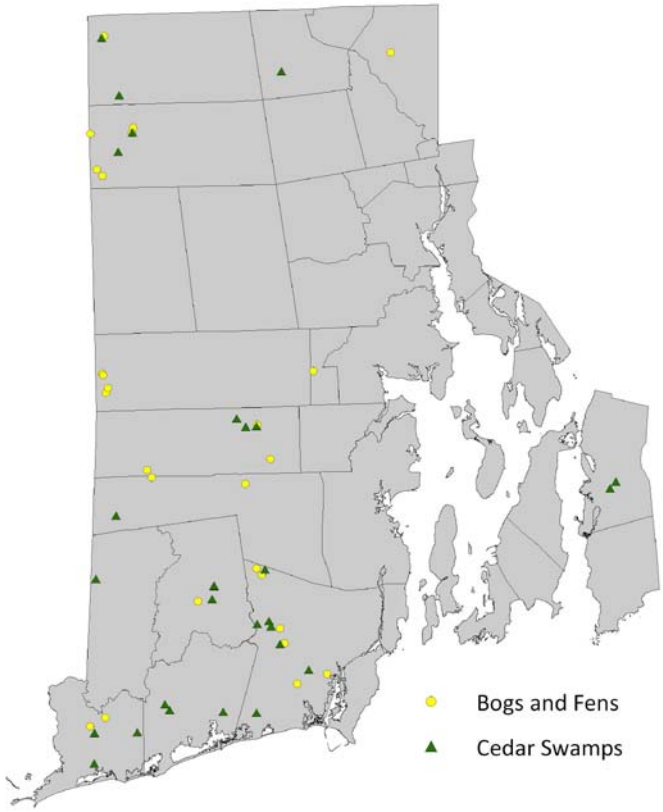

Figure 1: Fifty-three wetland assessment units selected for Year-4 development and demonstration of RIRAM v.2.

2.3 Determination of Assessment Unit Boundaries

GIS was used to delineate assessment units roughly according to Enser and Lundgren (2006) natural community types and Cowardin et al. (1979) classification methods. Specifically, CS and BF units were selected according to Enser and Lundgren habitat definitions and were delineated based upon the dominant vegetation for CS units; or the presence of floating or saturated-mat substrates in conjunction with dominant vegetation type(s) for BF units, following Cowardin vegetation-cover parameters. At least 30% cover of Atlantic white cedar (*Chamaecyparis thyoides*) qualified a CS type, while detritus-or-sphagnum-mat substrate with dominant scrub-shrub or emergent vegetation and <30% cover of trees qualified a BF type.

This approach differs from protocols used in previous years, in which assessment units each comprised an entire hydrogeomorphic (HGM) system (strictly separated by hydrologic discontinuities) that may have contained a single or multiple vegetation communities and habitats (i.e. Kutcher 2009; Kutcher 2010a and b). Year-4 assessment units may represent a relatively small part of a larger HGM system. However, as a rule, if CS or BF habitat covered >50% of an HGM system, the entire system was treated as a single assessment unit. The existing geospatial wetlands data-layer, *Wetlands of Rhode Island, 1995* (RIGIS 2009) was used as a preliminary wetland identification tool. However, the RIGIS data were insufficient in accuracy to determine assessment unit boundaries or wetland types, so actual assessment unit delineations and interpretations were *heads-up* (on-screen) digitized from 2008 leaf-off color digital pictometry (RIGIS 2009).

2.4 Modification of RIRAM v.2

Prior to conducting assessments, RIRAM protocols were reviewed by RINHS, DEM, and other technical advisors to assess their consistency and applicability to goals identified by WMAP. The RIRAM v.2 F08 field form (Kutcher 2010a) was modified to address reviewer feedback. Refer to the modified version 2.09 field form (App. 1) for clarification on the following protocol adaptations for assessments conducted in Year 4:

- Background information and Section A. *Wetland Characteristics* were condensed and reformatted to a single page. Substantive changes were as follows:
    - Detailed investigator, owner, access, and location information was removed from the field form, since they were not determined in the field.
    - Classification information was formatted to a checklist of possible classes.
    - Attribute A6 *Wetland Values* replaced F08 A4 *Special Wetlands*.
- In Metric 1, buffer width assessed for cultural land cover was changed from 50m to 100’ (30m) to separate it functionally from Metric 2 and align it with DEM measurement conventions.
- In Metric 2, buffer width assessed for land use intensity was changed from 100m to 500’ (150m) to maximize it effectiveness, separate it functionally from Metric 1, and align it with DEM measurement conventions.
- Section C *Stresses affecting the assessment unit* was re-ordered to put stronger size and type-altering stresses toward the front.
- A checklist category, *Primary Stressor Type*, was added to each metric in Section C to document the source of each stress type.

- In Section C, *Hydroperiods* tables were renamed *Water Regimes*, and organized to separate saturated and flooded water regimes and make change determinations clearer.
- Metric 3b *Artificial barrier to movement of resources through water* was reconfigured to be additive to add flexibility.
- A scoring category, *Change in velocity only*, was added to Metric 4 *Draining or diversion of water from wetland*.
- Configuration and terminology was changed in Metric 5 *Anthropogenic fluvial inputs* to clarify scoring.
- A checkbox of abutting stressors was added to Metric 9 *Invasive species within wetland.*
- Some terminology in Section D was changed, but this was not substantive.

2.5 Rapid Assessment

2.5.1 Field Investigations

Assessment sites were accessed with written or oral permission from fee or easement owners of properties, or their representatives (e.g. park managers, town planners, land trust directors). Assessment units were accessed on foot or by canoe, when necessary. Two investigators—the principal investigator and a trained field assistant—conducted the site investigations. The perimeter and multiple transects of each site were assessed when possible, otherwise assessments were made by observing as many areas within and around the unit as possible.

Field maps of each site, produced using GIS, were utilized for field orientation and determining wetland community and buffer characteristics. Each map contained a backdrop of 2008 leaf-off color aerial photography at a scale sufficient to illustrate wetland habitats and surrounding land uses. Maps included a delineation of the assessment unit, delineations of 100’ and 500’ buffer-zones, a delineation of the boundary of conserved land, a scale bar, and identifying information. A Trimble™ *GeoXT* cartographic GPS unit was loaded with the same information, primarily for spatial confirmation and ground-truthing site delineations.

An interim field guide of all invasive freshwater wetland plants documented in RI was utilized in the field to help in invasive plant species identification. The guide was compiled by RINHS using information from existing data sources (RINHS, unpublished data).

2.5.2 Remote Investigations

Data obtained during field investigations were complemented using GIS analysis before data entry. The following GIS operations were undertaken; refer to RIRAM v.2.09 field datasheet (App. 1) for clarification:

- Assessment unit size was measured to answer Attribute A.1.
- The RIGIS (2009) *FEMA Statewide Flood Zone Map* data-layer was overlaid to determine whether each wetland fell within a designated 100-year floodplain to partly answer Attribute A.5.

- RINHS (2009) rare species geospatial data were laid over sites to determine any occurrences of state/federal threatened or endangered species, to partly answer Attribute A.5.
- The RIGIS (2009) *Sewered Areas* data-layer was overlaid to support Metric 2 by determining the presence of sewers.
- The RIGIS (2009) *Community Wellhead Protection Areas* and *Non-community Wellhead protection Areas* data-layers were overlaid to support any observed evidence documented in Metric 4 by locating the estimated cone of depression associated with large groundwater pumps.

2.6 Analysis

2.6.1 Statistical Analysis

Statistical analyses were conducted using WinSTAT® statistical software (2006, R. Fitch Software) appended to Microsoft Excel® spreadsheet software. For each study sample (CS and BF), basic, descriptive statistics of RIRAM indices were generated. Rank-based and non-parametric methods were utilized in all other statistical analyses to compensate for the ordinal nature of RAM data and any skews or gaps that may be inherent in the samples.

Mann-Whitney U-test analysis was applied to determine if RIRAM could detect evidence of water withdrawals from large wells. Spearman rank correlation analysis was used to demonstrate the utility of RIRAM data for examining the various relationships among landscape degradation, invasive species cover and richness, in-wetland stresses, and wetland degradation. Three statistical tests were applied to analyze the effects of conservation status on wetland condition; these were Spearman rank correlation analysis, Kruskal-Wallis test, and Mann-Whitney U-test.

2.6.2 Surrounding Landscape Analysis

ESRI ArcMap® was utilized to generate land use intensity values for five spatially-exclusive buffer-zone rings around each assessment unit to investigate the expected decay of land use effects on wetland condition with increased distance. Zones reflected land us intensity within 0-100 ft; 100-500 ft; 500-1000 ft; 1000-2000 ft; and 2000-4000 ft, respectively. Zones were clipped to the RIGIS (2009) data-layer *2003-04 Land Use for RI*, which classifies land use and land cover by the Andersen Classification Scheme (1976). Percent cover of developed land was used as an independent index of land use intensity for each zone. Spearman rank correlation analysis was used to compare the strength of correlations among the various zones and RIRAM indices.

3. Results

3.1 A Posteriori Modifications to RIRAM

Minor modifications to RIRAM v.2.09 were made based on an ongoing examination of its utility during the Year-4 field applications and subsequent data analyses presented below. During this period, it was determined that some terminological and metric changes would enhance and clarify the interpretations and presentation of the analysis results in the following sections, so the modifications are presented prior to the analysis results. Modifications were made as outlined here. Refer to RIRAM v.2.09b field datasheet (App. 2) for further clarification.

- Under Attribute 3 *Habitat Characteristics, Habitat stratum diversity*, Perennial surface water was changed to *Surface water, today*, to clarify its intent.
- Under Attribute 3 *Habitat Characteristics, Microhabitat diversity, Presence scale* terminology was modified to increase clarity as follows: The scale was renamed *Ecological significance scale*; *Absent* was changed to *None Noted*; *Present in very small amounts* was changed to *Minor Feature*; *Present in small to moderate amounts* was changed to *Significant Feature*; and *Present in moderate or greater amounts* was changed to *Dominant Feature*.
- Under Attribute 4, *Wetland Classification, RINHP natural community types*, minor changes in classification terminology and groupings were made to better reflect Enser and Lundgren (2006).
- For metrics 3 through 9, *Sources of Stress* boxes were changed from a basic checklist to a modified checklist requiring the user to indicate whether the stress resulted from current or historic sources by entering "C" for current or "H" for historic, rather than simply entering a check mark. This was applied at the onset of Year-4 assessments and is reflected in Year-4 data.
- For metrics 3 and 4, *Water Regimes* were reconfigured to more completely and accurately represent possible documented classes.
- An additional piece of potential evidence, *Change in vegetation across barrier*, was added to metric 4 *Draining or diversion of water from wetland*.
- Section D was renamed *Observed State of Wetland Characteristics* to better reflect its function.

3.2 Data Summary

RIRAM assessments were conducted on a sample of 53 peat-dominated wetlands, including 28 Atlantic white cedar swamps (CS) and 25 Bogs/Fens (BF). Appendix 3 presents Year-4 RIRAM data in chart format. The total area of assessed wetlands was 490 acres and assessment units ranged in size from 0.28 to 63 acres with a mean size of 9.2 acres. The dominant wetland classes within the sample were forested wetland, shrub swamp, and emergent wetland. The dominant HGM classes were Connected Depression, Isolated Depression, and Floodplain (Riverine). The majority (59%) of wetlands were interpreted to be primarily groundwater-fed, while 39% were mainly surface-water-fed.

Cedar swamps were dominated by trees and shrubs, with groundcover most often being sphagnum or bare soil (Fig. 2, left). Atlantic white cedar or, less often, cedars and red

maples (*Acer rubrum*) dominated or co-dominated the canopy. The vegetation structure of bogs/fens was dominated by shrubs or emergent vegetation, and sphagnum mosses (Fig. 2, right). Most (63%) BF units were dominated or co-dominated by leatherleaf (*Chamaedaphne calyculata*), and less often by highbush blueberry, Twig rush (*Cladium mariscoides*), or sweet pepper-bush.

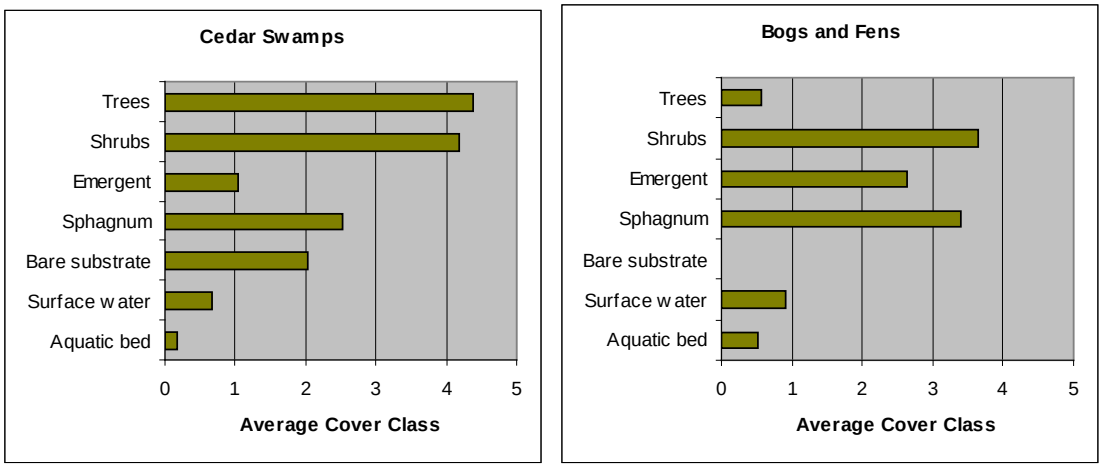

Figure 2: Average estimated cover classes of vegetation strata within targeted wetland types; 0 = <1%, 1 = 1-5%, 2 = 6-25%, 3 = 26-50%, 4 = 51-75%, 5 = >75%.

Wetland values were distributed across the combined sample as follows: 43% of the units fell within FEMA-designated 100-year floodplains; 40% were located between surface waters and human land use; 91% were part of a habitat complex or corridor; 25% fell within aquifer recharge zones; 57% contained documented threatened or endangered species; and 13% were of educational or historical significance.

RIRAM Index scores ranged from 69.9 to 100 with a mean of 92.5 ± 8.9 (Table 2). Buffer degradation was generally low within the combined sample, with 43 (81%) units having <5% total cultural land cover within 100 feet of the wetland edge; the remaining sites contained between 6% and 50% cultural cover. Surrounding land use intensity was, on average, very low, with 11 (21%) of sites having zero land uses within 500 feet of the wetland edge; another 28 (53%) were only slightly degraded, scoring at least 9.0 of 10 possible points, according to the RIRAM surrounding landscape intensity metric (Fig. 3).

Table 2: Basic statistics of RIRAM v.2 index scores from 53 peat-dominated wetlands in Rhode Island.

	Atlantic White Cedar Swamps				Bogs / Fens			
	Landscape	Stress	Indicators	RIRAM	Landscape	Stress	Indicators	RIRAM
Sample Size	28	28	28	28	25	25	25	25
Mean	18.3	47.6	26.5	92.4	18.3	47.1	27.2	92.7
Std. Deviation	2.5	3.7	3.6	9.0	2.8	3.7	3.3	9.0
Skew	-1.6	-1.7	-1.1	-1.3	-2.3	-1.1	-1.3	-1.2
Minimum	11.9	36.5	18.0	71.0	9.2	37.6	18.0	69.9
Maximum	20.0	50.0	30.0	100.0	20.0	50.0	30.0	100.0
Range	8.1	13.5	12.0	29.0	10.8	12.4	12.0	30.1
5th percentile	12.2	38.2	18.5	71.5	9.9	38.4	19.2	71.0
10th percentile	12.8	41.2	19.9	74.9	13.2	41.2	22.0	76.7
25th percentile	17.8	45.8	24.3	87.0	17.9	44.5	25.0	86.1
Median	19.6	49.2	28.0	96.7	19.7	49.0	29.0	97.4
75th percentile	19.7	50.0	29.0	98.7	19.9	50.0	30.0	99.7
90th percentile	20.0	50.0	30.0	100.0	20.0	50.0	30.0	100.0
95th percentile	20.0	50.0	30.0	100.0	20.0	50.0	30.0	100.0

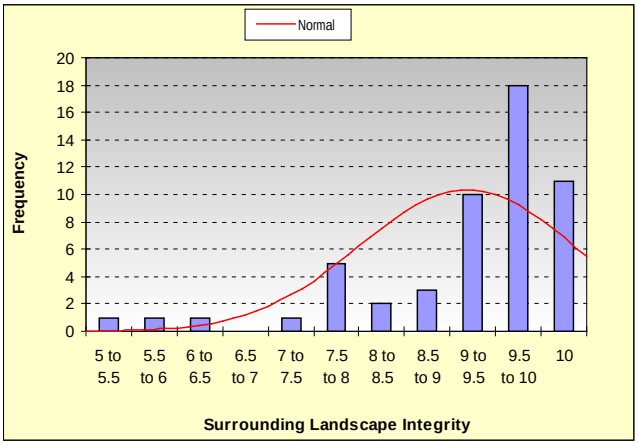

Figure 3: RIRAM v.2.09 Metric B.2 score frequencies among the 53 peat-dominated wetland units. A score of 10 indicates zero land use within 500 feet of the wetland edge; a score of 1.0 would indicate 100% high-intensity (e.g. urban) land uses within that zone. The line represents the smoothed distribution curve.

Seventeen (32%) of the assessment units were affected by some impoundment, which mostly contributed to water regime change intensities of one regime or less. Five (9%) of the units were created by an impoundment; the majority (66%) of these affected the entire wetland unit. Dams were the most common cause of impoundment, largely from historic commercial and agricultural practices (35% and 24%), followed by public roads (35%).

Only six (11%) of the wetland units were affected by the draining or diversion of water; half of these sites contained drainage ditches, while half fell within active wellhead protection areas. The ditches were associated with historic and current agricultural practices.

Fluvial input sources or effects were documented at 21 (40%) of the units. Associated stressors were sheet runoff, road runoff, and non-point; main sources of inputs included private/residential development, public transportation, and public recreation.

Filling or dumping was documented at 12 (23%) of the units. Wetlands were partially filled to upland grade or above in eight (15%) of the units. Most filling affected a relatively small portion of the wetland (20% of the unit or less). The majority (58%) of fill was associated with the construction of public roads, but filling was also distributed among numerous other land uses (refer to App. 3).

Excavation or other substrate disturbances were noted at eight (15%) of the assessment units, causing water regime changes at most (63%) of these; although the proportion of the unit affected was small for all of these (~10% or less of the unit area). Ditching, footpaths and vehicle disturbances, from public recreation, residential development and other sources were among the stressors. Only two sites (4%) were affected by the cutting or removal of vegetation or detritus. Emergent vegetation was removed from ~10% of one site, while historic timber harvest of the canopy affected ~ 50% of the other.

Eight sites (15%) contained invasive plants. Abutting stressors included roads, footpaths, dams, organic/yard waste, and stormwater inputs, among others; these were mainly associated with residential development, public recreation, and historic commercial uses. Refer to Section 3.3.4 for a more detailed summary of invasive occurrences within the sample.

3.3 Demonstration Analyses

Five analyses were conducted to demonstrate the utility of RIRAM in addressing wetland monitoring objectives identified in WMAP (NEWIPCC and DEM 2006). The following objectives were addressed:

Short-term objectives

- *Develop and implement methods for monitoring impacts to wetlands due to water withdrawals.*
- *Monitor and assess impacts to wetlands due to loss and degradation of adjacent upland habitats (buffer zones).*
- *Monitor location and extent to which invasive species are present and affecting wetland condition.*

Long-term objectives

- *Identify causes and sources of wetland degradation including cumulative impacts to wetlands.*
- *Evaluate the effectiveness of wetland management and protection programs with respect to wetland condition.*

For some analyses, RIRAM data from Year-3 (collected in fall 2008) were utilized in addition to Year-4 data to broaden the scope of the analysis or increase statistical power. Year-4 sites were selected from a State-wide population, but were targeted by wetland type, while Year-3 sites were randomly selected by type, but were contained in a targeted set of basins.

3.3.1 Wetland Impacts due to Groundwater Withdrawals

Wetland impacts due to groundwater withdrawals have been a concern of wetland managers and conservationists in the State. Developing methods of substantiating and quantifying any such impacts has been a subject of recent intensive study (e.g. Narcissi and Golet, unpublished data). A rapid method of detecting and quantifying impacts at sites with known withdrawal rates would allow the State to efficiently identify sites requiring action or further investigation. Although RIRAM does not contain the rigorous sampling protocols necessary to quantify the effects of withdrawals on hydrology and biota, it could potentially serve to signal further investigations by detecting evidence of hydrologic impacts.

Preliminary metrics developed to detect and rank the effects of water withdrawal were tested in earlier versions of RIRAM, but no differences in metric or index scores were detected between sites overlaying documented well-head protection areas (hereafter WHPAs: areas overlaying the estimated cone of depression generated by large wells) and those not overlaying WHPAs (Kutcher 2009). Metrics in RIRAM v.2 differ considerably from those preliminary metrics. Specifically, Metric C.4, *Draining or Diversion of Water from Wetland*, documents evidence and estimates the intensity and proportion of hydrologic changes due to anthropogenic decreases in wetland water, including those associated with groundwater withdrawals. Mann-Whitney U-test analysis was applied to C.4 metric scores and to the RIRAM Index to determine whether RIRAM detected evidence of water withdrawals from large wells.

Applied using a blind method (assessors having no prior knowledge of WHPA locations), RIRAM C.4 metric scores differed significantly between assessment units located on WHPAs (YES) and those not on WHPAs (NO) among Year-4 sites ($U_{(52)} = 122$, $Z = 2.62$, $P < 0.01$; Fig. 4, left), but total RIRAM Index scores did not (Mann-Whitney, $P > 0.05$). Similarly, Year-3 RIRAM metric C.4 scores also differed between these treatments ($U_{(49)} = 14.5$, $Z = 2.50$, $P = 0.01$; Fig. 4, right), while RIRAM Index scores again did not.

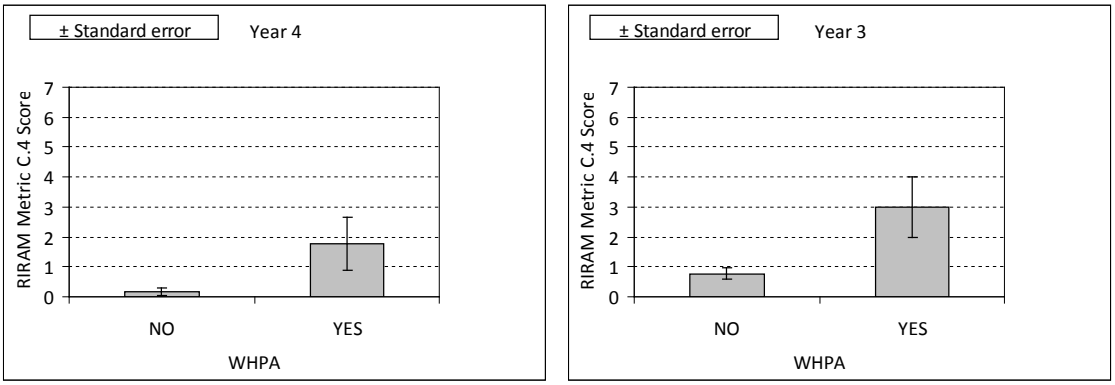

Figure 4: Mean RIRAM Metric C.4 scores and standard error distributions from Year-4 (left figure) and Year-3 (right figure) assessment units occurring not within (NO) versus within (YES) designated wellhead protection areas

These findings suggest that RIRAM detected changes in hydrology associated with groundwater withdrawals, but the impacts of water withdrawal were not a controlling

factor in overall wetland condition in the study samples. However, because (1) Metric C.4 also scores the intensity of draining-and-diversion stresses *not* associated with groundwater wells and (2) the actual intensity of water withdrawals at the assessment sites were unknown, the strength of this relationship cannot be fully determined without (1) examining RIRAM data to determine which assessment units showed evidence of water-depletion stress with no evident above-ground stressors (thus more likely to be sourced underground) and (2) knowledge of actual withdrawal rates at the assessment sites. Nonetheless, RIRAM may be an effective tool for flagging further study of sites associated with documented withdrawals.

3.3.2 Effects of Surrounding Land Use on Wetland Condition

Earlier RIRAM analyses demonstrated the combined effects of surrounding land use intensity and buffer width (within nested buffer zones) on wetland condition (Kutcher 2010a and b). Results indicated that increased surrounding land use intensity may be associated with increased wetland degradation out to 1000 feet (300m) among wetland units of random habitat type delimited by hydrogeomorphic setting. Land use intensity was found to be significantly correlated with observed degradation of habitat connectivity, water and soil quality, vegetation composition, and microhabitat structure, and was correlated with increased invasive species cover and richness. The analysis presented below similarly investigates the effects of buffer degradation and surrounding land use intensity, but on targeted wetlands—cedar swamps and bogs/fens—delimited by habitat type (per Cowardin et al. 1979).

Tables 3 and 4 present outcomes of Spearman rank correlation analyses conducted among RIRAM *Landscape Stress* metrics versus *Wetland Stress* and *Observed State* metrics to demonstrate the relative relationships of buffer and surrounding landscape degradation with in-wetland stresses and the observed integrity of certain wetland functional characteristics. Total landscape stresses were most strongly associated with in-wetland filling/dumping and anthropogenic fluvial inputs for both CS and BF units. Surrounding land use intensity was most strongly correlated with degradation of habitat connectivity for both wetland types. In bogs/fens, buffer degradation was most strongly correlated with degradation of vegetation composition; a relationship likely due to associated introductions of invasive plant species (see also Section 3.3.4).

Table 3: Outcomes of Spearman rank correlation analyses conducted among RIRAM *Landscape Stress* versus *Wetland Stress* and *Observed State* metric scores from 28 Atlantic white cedar swamps (CS). Higher *Wetland Stresses* metric values indicate more stress; otherwise higher metric and index values indicate less stress or degradation. *not significant

	Buffer Integrity		Surrounding Land Use	
	r_s	P	r_s	P
Wetland Stresses				
5. Fluvial Inputs	-0.72	<0.01	-0.81	<0.01
6. Filling and Dumping	-0.74	<0.01	-0.45	0.02
7. Substrate Disturbance	-0.43	0.02	-0.49	0.01
4. Draining or Diversion	-0.61	<0.01	-0.39	0.04
Observed State				
Water and soil quality	0.62	<0.01	0.64	<0.01
Vegetation composition	0.58	<0.01	0.44	0.02
Microhabitat structure	0.60	<0.01	0.43	0.02
Habitat connectivity	0.40	0.04	0.82	<0.01
Hydrologic connectivity	0.56	<0.01	0.40	0.04
Vegetation structure	0.47	0.01	*	*

Table 4: Outcomes of Spearman rank correlation analyses conducted among RIRAM *Landscape Stress* versus *Wetland Stress* and *Observed State* metric scores from 25 bogs and fens (BF). Higher *Wetland Stresses* metric values indicate more stress; otherwise higher metric and index values indicate less stress or degradation. *not significant

	Buffer Integrity		Surrounding Land Use	
	r_s	P	r_s	P
Wetland Stresses				
6. Filling and Dumping	-0.68	<0.01	-0.54	0.01
5. Fluvial Inputs	-0.56	<0.01	-0.62	<0.01
9. Invasive Plant Richness	-0.67	<0.01	*	*
9. Invasive Plant Cover	-0.63	<0.01	*	*
Observed State				
Habitat connectivity	0.55	<0.01	0.88	<0.01
Water and soil quality	0.47	0.02	0.54	0.01
Hydrologic connectivity	0.55	<0.01	*	*
Vegetation composition	0.73	<0.01	*	*
Microhabitat structure	0.59	<0.01	*	*
Vegetation structure	0.40	0.05	*	*

RIRAM indices were compared to land use intensity across five spatially-exclusive buffer-zone rings ranging from 0-100 ft to 2000-4000 ft. to investigate the expected decay of land use effects on wetland condition with increased distance. Percent cover of developed land was used as an independent index of land use intensity for each zone. Spearman rank correlation analysis revealed a moderately-strong relationship between CS condition and land use intensity out to 2000 ft and moderately weak relationship from 2000-4000 ft (Fig. 5). BF condition was moderate-to-strongly correlated with land use intensity out to 500 ft, beyond which there was not a significant relationship between

land use and in-wetland stress and a moderately weak relationship between land use and *RIRAM* and *Observed State* indices. These data suggest that CS sites were influenced by surrounding landscape stresses out to 2000 ft, while BF sites were most strongly influenced by proximate landscape stresses.

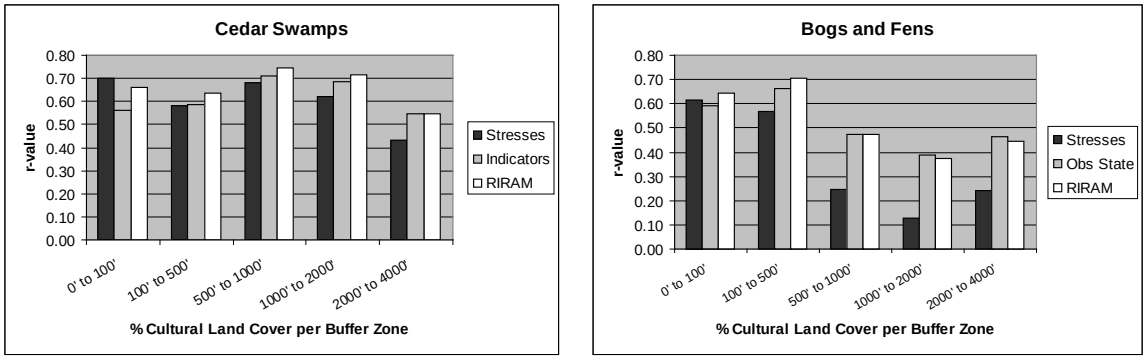

Figure 5: Relative values of Spearman rank correlation coefficients (y-axis) between land use cover indices (x-axis) at various surrounding buffer zones and RIRAM v.2 indices (series) for 25 bog / fen and 27 Atlantic white cedar swamp assessment units. $P < 0.05$ for all except > 500 feet versus bog and fen stresses

3.3.3 Relationships between Invasive Plants and Wetland Condition

In this analysis, RIRAM data were applied to demonstrate the utility of RIRAM in supplying baseline and analytical data to characterize the occurrence of invasive species in CS and BF habitat types. Seven invasive species were observed at eight (8) of the 53 sites. These included two narrow-leaved emergent species, reed canary grass (*Phalaris arundinacea*) and common reed (*Phragmites australis*); one submergent forb, milfoil (*myriophyllum* sp.); two facultative shrubs, wild rose (*Rosa multiflora*) and glossy buckthorn (*Rhamnus frangula*); and two typically upland species, the shrub, autumn olive (*Elaeagnus umbellata*) and the robust forb, Japanese knotweed (*Polygonum cuspidatum*; Fig. 6). Upland species were found mostly encroaching into wetland edges. Invasive species cover ranged from none (0%) to moderate (26 to 50% cover). Most occurrences were documented as nearly absent (>5% total cover), while moderate cover was observed at one site only, where common reed was growing in a fringe fen (Fig. 7).

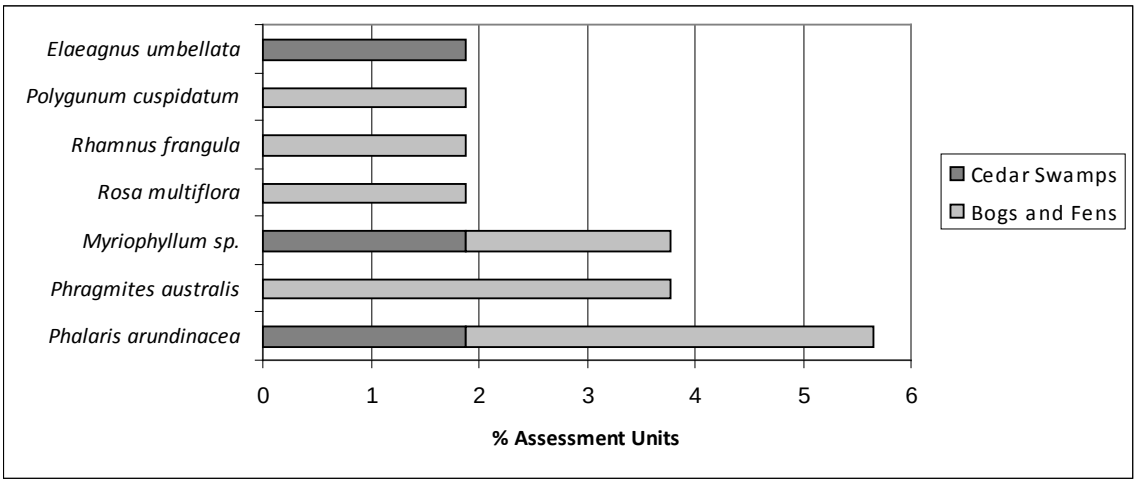

Figure 6: Occurrences of invasive plant species observed at 53 wetland assessment units in Rhode Island

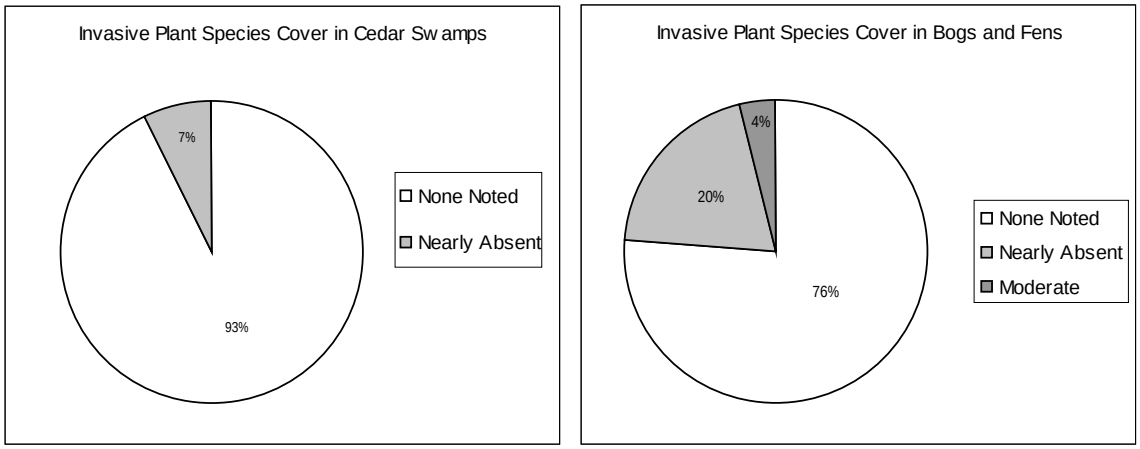

Figure 7: Distributions of invasive plant intensity at 28 Atlantic white cedar swamps (left) and 25 bogs and fens in Rhode Island. Nearly absent represents <5% total cover; moderate represents 6 to 25% total cover

Year-4 RIRAM data were analyzed to examine the stresses associated with invasive species and the effects that invasive species may have on the integrity of targeted wetland types. Tables 6 and 7 present Spearman rank correlation coefficients generated by comparing invasive species cover class and richness values with RIRAM *Wetland Stress* and *Observed State* metric scores for CS and BF assessment units, respectively. Correlation coefficients are listed in descending order of combined strength (ascending P value).

Table 5: Significant Spearman rank correlation coefficients (r_s) of RIRAM *Wetland Stress* and *Observed State* metrics versus invasive plant species cover class scores and species richness in 28 cedar swamps in Rhode Island. Higher *Wetland Stresses* values indicate more stress. Higher *Observed State* values indicate less degradation, while higher invasive species cover and richness values indicate more intense invasion.

Cedar Swamps	**Invasive Species Cover**		**Invasive Species Richness**	
	r_s	*P*	r_s	*P*
Wetland Stresses				
5a Nutrients	0.58	<0.01	0.69	<0.01
3 Impoundment	0.56	<0.01	0.42	0.03
4 Draining or Diversion	0.45	0.02	*	*
Observed State				
Vegetation composition	-0.49	0.01	*	*
Water and soil quality	*	*	-0.40	0.04

Table 6: Significant Spearman rank correlation coefficients (r_s) of RIRAM *Wetland Stress* and *Observed State* metrics versus invasive plant species cover class scores and species richness in 25 bogs/fens in Rhode Island. Higher *Observed State* values indicate less degradation, while higher invasive species cover and richness values indicate more intense invasion.

Bogs and Fens	**Invasive Species Cover**		**Invasive Species Richness**	
	r_s	*P*	r_s	*P*
Wetland Stresses				
1 Degradation of buffers	-0.63	<0.01	-0.67	<0.01
6 Filling and dumping	0.53	0.01	0.58	<0.01
5 Anthropogenic fluvial inputs	0.49	0.01	0.53	0.01
a Nutrients	0.59	<0.01	0.63	<0.01
c Toxins / Salts	0.49	0.01	0.55	<0.01
Observed State				
Vegetation composition	-0.90	<0.01	-0.91	<0.01
Vegetation structure	-0.61	<0.01	-0.61	<0.01
Microhabitat structure	-0.55	<0.01	-0.57	<0.01
Hydrologic connectivity	-0.55	<0.01	-0.54	0.01
Water and soil quality	-0.45	0.02	-0.49	0.01

Among CS units, invasive plant species cover and richness were modestly correlated with nutrient input, impoundment, and draining stresses (Table 5). Abutting stressors were organic/yard waste, fill, footpaths, and ditches; sources of these stressors were private/residential, public recreation, and historic commercial land uses (App. 3). Invasive species cover was expectedly correlated with degradation of vegetation composition, while invasive species richness was weakly correlated with degradation of water and soil quality (Table 5). This suggests that although changes in water quality and hydroperiod may increase cedar swamps' susceptibility to invasion, invasive species did not strongly impact the CS wetlands.

Among BF units, both invasive species cover and richness were most closely correlated with the degradation of buffers within 100 ft (Table 7). Invasive species intensity was also moderately correlated with in-wetland filling/dumping and fluvial inputs of nutrients and salts. Abutting stressors were (in descending order) roads, dams, stormwater inputs, footpaths and organic/yard wastes, which were sourced from private/residential, public transportation, public recreation, and historic land uses (App. 3). Invasive species richness and cover were strongly correlated with observed degradation of vegetation composition among BF units. Wetland invasion intensity was also correlated with degradation of habitat structure and connectivity, and with water quality. This suggests that in bogs and fens, human encroachment activities, comprising a wide range of proximate stressors from various sources, may enable invasive species and, in turn, invasive species may be associated with the degradation of a host of bog/fen functional wetland characteristics.

3.3.4 Relationships between Stresses and Wetland Integrity

This analysis was conducted to demonstrate how RIRAM data can be applied to determine the most influential stresses acting upon wetland resources of concern.

Spearman rank analysis was used to investigate relationships between various RIRAM *Wetland Stress* metric scores and the RIRAM *Observed State* index scores (representing wetland integrity) of Year-4 assessment units (Tables 8 and 9). Here, the absolute value of the coefficient suggests the relative strength of each stress's association with wetland integrity in each sample (CS and BF wetlands).

Table 7: Significant Spearman rank correlation coefficients (r_s) of RIRAM *Landscape Stress* and *Wetland Stress* metric scores versus *Observed State* index scores at 28 Cedar Swamps in 2009. Higher *Wetland Stress* metric values indicate more stress; otherwise higher metric and index values indicate less stress or degradation.

Cedar Swamps	D. *OBSERVED STATE*	
	r_s	*P*
Landscape Stress		
2. Intensity of surrounding land use	0.72	<0.01
1. Degradation of buffers	0.60	<0.01
B. LANDSCAPE STRESS INDEX	0.76	<0.01
Wetland Stress		
4. Draining or Diversion of Water	-0.70	<0.01
5. Anthropogenic fluvial inputs	-0.69	<0.01
5.a Nutrients	-0.53	<0.01
5.c Toxins / Salts	-0.47	0.01
5.b Sediments	-0.38	0.05
7. Excavation or Substrate Disturbance	-0.57	<0.01
6. Filling and dumping	-0.47	0.01
3. Impoundment	-0.41	0.03
3.a Increase in Depth	-0.41	0.03
3.b Artificial barrier	-0.38	0.05
C. WETLAND STRESS INDEX	0.83	<0.01
B.+ C. TOTAL STRESS INDEX	0.88	<0.01

Table 8: Significant Spearman rank correlation coefficients (r_s) of RIRAM *Landscape Stress* and *Wetland Stress* metric scores versus *Observed State* index scores at 25 bogs/fens in 2009. Higher *Wetland Stress* metric values indicate more stress; otherwise higher metric and index values indicate less stress or degradation.

Bogs and Fens	D. *OBSERVED STATE*	
	r_s	*P*
Landscape Stress		
2. Intensity of surrounding land use	0.65	<0.01
1. Degradation of buffers	0.60	<0.01
B. LANDSCAPE STRESS INDEX	0.70	<0.01
In-wetland Stress		
5. Anthropogenic fluvial inputs	-0.82	<0.01
C.5.a Nutrients	-0.72	<0.01
C.5.b Sediments	-0.71	<0.01
C.5.c Toxins / Salts	-0.47	0.02
3. Impoundment	-0.73	<0.01
C.3.b Artificial barrier	-0.69	<0.01
C.3.a Increase in Depth	-0.68	<0.01
6. Filling and dumping	-0.64	<0.01
9. Invasive species richness	-0.59	<0.01
9. Invasive species cover	-0.58	<0.01
C. WETLAND STRESS INDEX	0.87	<0.01
B.+ C. TOTAL STRESS INDEX	0.93	<0.01

A number of stresses were correlated with the RIRAM *Observed State* index for each wetland type. Landscape stresses, draining, and fluvial inputs were strongly correlated with *Observed State* (i.e. apparent integrity) among CS wetlands (Table 7); again suggesting that cedar swamps may be vulnerable to increased surrounding land use intensity (see also Section 3.3.2) and changes in water quality and hydroperiod (see also Section 3.3.3). Similarly, among BF wetlands, fluvial inputs (mainly nutrient and sediment inputs), impoundments, and landscape stresses were strongly correlated with *Observed State* (Table 8). For both wetland types the *Total Stress* index, representing additive wetland stresses, was more closely correlated with the *Observed State* index than was any individual stress metric. This suggests that landscape and in-wetland stresses acting together had stronger impacts on these wetlands than any stress acting alone.

3.3.5 Relationships between Property Management and Wetland Condition

The final long-term objective identified in WMAP involves the evaluation of management strategies as they relate to wetland condition. This analysis demonstrates the utility of RIRAM data in investigating relationships between management practices and wetland condition, including the common assumption that larger conservation areas more effectively protect the ecological resources they contain. Based on existing RIGIS (2009) data, three categories of conservation status were analyzed to determine their influences on wetland condition among our Year-4 and Year-3 assessment units; these were (1) public access, (2) conservation purpose, and (3) State versus local management.

Public Access
Three categories of public access were analyzed for difference in mean RIRAM scores; these were (1) no access, (2) limited access, and (3) full access. No differences in RIRAM Index scores per access category were indicated among Year-4 targeted sites or among Year-3 basin-specific sites (Kruskal-Wallis, $P > 0.05$). This suggests that, in itself, public access may not be a significant factor in wetland preservation.

Conservation Purpose
Two categories of conservation purpose were analyzed for differences in median RIRAM scores; these were (1) for habitat protection (HAB) and (2) for all other purposes (USE), including (mostly) recreational, multi-purpose, and water-supply protection. No differences in index scores were detected between the two groups among Year-4 sites (Mann-Whitney, $P > 0.05$), in which only four (4) of 53 sites were conserved for USE. However, RIRAM index scores were modestly higher for assessment units on HAB properties among Year-3 sites ($U_{(40)} = 125$, $Z = -2.15$, $P = 0.03$), where the two treatments were distributed more evenly ($n = 18$ and $n = 23$ for HAB and USE, respectively; Fig. 8). The data suggest that properties conserved for habitat protection may better preserve the condition of wetlands within. This finding supports the strategy of designating properties specifically for habitat protection (in lieu of for recreation or multi-purpose uses) where environmental conservation is a goal.

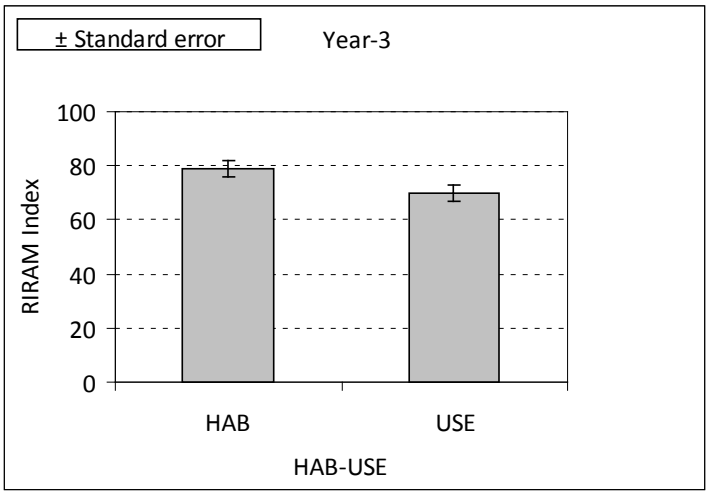

Figure 8: Mean RIRAM Index scores and standard error distributions from Year-3 assessment units occurring on properties designated for habitat conservation (HAB) and other uses (USE).

State versus Local Management
Two categories of management responsibility, State-managed and otherwise (hereafter "local"), were analyzed for differences in RIRAM Index scores. Mann-Whitney U-test analysis indicated that index scores were significantly higher for Year-4 assessment units occurring on State-managed properties than for those on local lands ($U_{(52)} = 158.5$, $Z = -3.06$, $P = 0.002$; Fig. 9). This difference was likely an effect of conservation property size, which was, on average, an order of magnitude larger for State-managed properties ($U_{(52)} = 62$, $Z = -4.86$, $P < 0.001$). Supporting this deduction, property size was positively correlated with RIRAM Index scores in Year 4 ($r_s = 0.46$, $P < 0.001$; Fig. 10) and a

similar relationship was found between RIRAM Index scores and conservation property size among Year-3 sites (r_s = 0.47, P = 0.001). These findings help substantiate the assumption that larger conservation properties generally provide more effective ecosystem protection than smaller properties. Importantly, the findings indicate that State efforts focused on maintaining or piecing-together continuous tracts of natural land have effectively protected habitat condition in those areas.

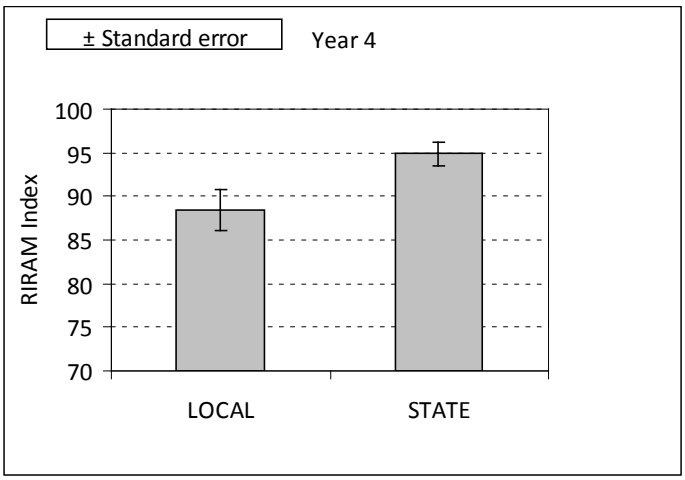

Figure 9: Mean RIRAM Index scores and standard error distributions from Year-4 assessment units occurring on non-State (local) versus State-managed properties

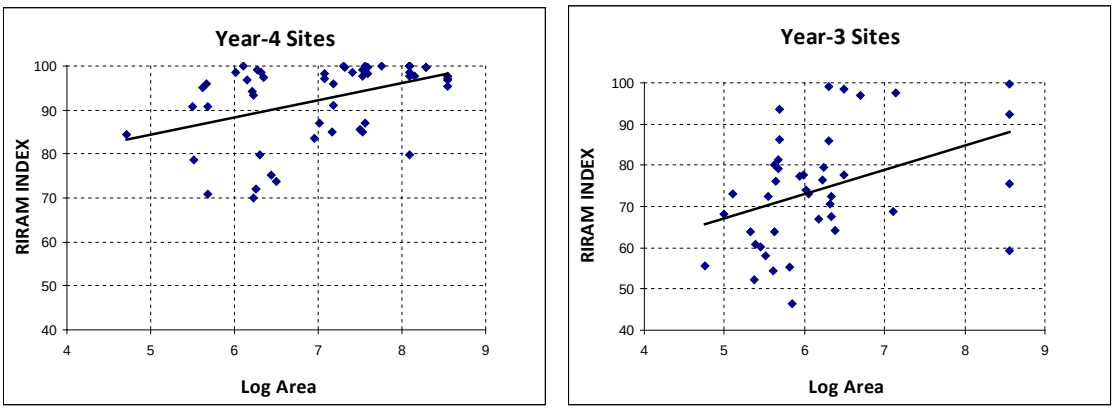

Figure 10: RIRAM scores in relation to the size (ft^2) of the conservation area containing each wetland assessment unit, from two successive monitoring efforts in RI. Areas have been log transformed in these figures to better illustrate the relationships.

3.4 Conclusions

RIRAM scores for CS and BF habitats were skewed toward unstressed and un-degraded (i.e. high integrity) condition (Table 2), when compared with the Year-3 basin characterization (see Kutcher 2010a and b); this may be partly due to sampling and assessment-unit-delimitation biases (discussed in Sections 5.1.1 and 5.1.2). However, other evidence presented in this report suggests that both CS and BF resources are in relatively good condition. For both types, 90th percentile RIRAM Index scores equal 100; this represents no detection of stress or degradation. Median index scores for both were above 95; this represents only slight stress and degradation detected. The large majority

of units had little or no buffer degradation within 100 feet or landscape development within 500 feet.

The evident relatively-good condition of CS and BF wetlands may be partly explained by State efforts to preserve open space in Rhode Island. The findings of this report indicate that the conservation of large tracts of land, primarily in the western and southern sections of the State, may contribute to preserving the integrity of CS and BF resources. This report's findings suggest that properties conserved specifically for habitat protection may also better protect wetlands in general, while public access limitations may have little effect.

Although most assessment units occurred within relatively undeveloped landscapes, degradation of surrounding landscapes and buffers was moderately-to-strongly correlated with degradation of observed wetland state and with certain in-wetland stresses. Both surrounding land use and buffer degradation were associated with evident fluvial inputs and filling/dumping for both wetland types. Surrounding land use was (expectedly) strongly correlated with degradation of habitat connectivity and was moderately correlated with water/soil quality degradation ratings for both types. All related analyses indicated that BF wetlands were most strongly affected by proximate landscape stresses, while CS wetlands responded to broader landscape stresses. Factors contributing to this difference may include a greater susceptibility of BF wetlands to invasive species due to buffer intrusion.

Twenty four percent (24%) of BF units contained invasive species compared to only 7% of CS units. Among BF, invasive species cover and richness were more closely associated with the degradation of buffers than with any single in-wetland stress. Invasive species cover and richness had a very strong relationship with observed degradation of vegetation composition in BF and were moderately correlated with the degradation of observed wetland state overall, while invasive species had no significant relationship with overall degradation in CS; this may be partly due to canopy cover. Closed or partly-closed canopy wetlands seem to be more resistant to invasive species, possibly due to limited light resources (personal observation). The combination of limited light resources and long hydroperiods may preclude the establishment of many likely wetland invaders in cedar swamps. In contrast, perhaps since bogs and fens are open-canopy habitats, they appear to be susceptible to invasion with the introduction of aerobic substrates (such as mineral fill) and nutrients. Both of these stresses may widen the narrow-range ecological parameters that support vegetation unique to these wetland types, including low oxygen, peat substrates (that may decompose in aerobic environments), and low nutrients (see Section 1.4).

Overall *Observed State* values for both the CS and BF wetlands were most strongly associated with total, additive stresses. Fluvial inputs, impoundments, and draining of water were the strongest in-wetland-stress contributors to this relationship. These findings support the conventional view that stresses may act in concert to degrade wetland integrity, and suggest that cedar swamps and bogs/fens are subject to this effect. They also suggest that peat-dominated wetlands may be particularly sensitive to stresses

affecting hydrologic integrity; this is an expected outcome, since these wetlands depend upon a narrow hydrologic niche for their sustainability (see Section 1.4).

4. Discussion

4.1 RIRAM Methodology and Recommendations

4.1.1 Determination of Assessment Boundaries

Determining assessment unit boundaries is a critical first step in wetland rapid assessment, since it may affect the index scores. Methods for determining assessment boundaries in Year 4 differ from those applied in previous RIRAM efforts, which were based on ORAM v.5.0 methods (Mack 2001). To accommodate the focus of Year-4 assessment efforts, which was to characterize two specific wetland-habitat types across the State, RINHS delimited assessment unit boundaries roughly according to Enser and Lundgren (2006) natural community types. As a result, some assessment units comprised only a small portion of the basins they were contained within. This may have been partly responsible for higher RIRAM index scores in Year-4 than in previous years, since these units were often buffered by other wetlands within the larger basins.

In many respects, the higher scores are valid in characterizing the wetland units, wherein an inner wetland unit is in better actual condition than the wetland (the inner unit's effective buffer) surrounding it. This concept is employed by RAMs that utilize fixed assessment unit areas surrounding random points (e.g. the California RAM, Collins et al. 2008). But, issues may arise when comparing habitat-based assessment unit data with data collected over entire wetland basins, where scores for habitat-based units could potentially exceed those for basin-based units as an artifact of delimitation method. Although removing *value-added* metrics from the scoring in RIRAM reduced the importance of using highly-standardized unit determination methods, protocols should be applied as strictly as possible, unless the objectives of the specific effort require otherwise. For characterizing wetland condition in a given area and across wetland type, delimiting units based upon basin continuity has been successfully piloted and is therefore recommended (Kutcher 2009; Kutcher 2010a and b). For characterizing the condition of a set of specific wetland types, such as in this Year-4 effort, unit delimitation by vegetation structure or community type may be necessary.

4.1.2 Site Selection

Assessment units were selected from CS and BF wetlands occurring on public and conserved properties, across a gradient of surrounding land use intensity. During these RAM development and demonstration efforts, only public and conserved properties have been utilized to alleviate anticipated challenges associated with landowner solicitation for site access. This may have introduced a bias in the distribution of RIRAM index scores for each sample. However, since assessment units were selected across a gradient of landscape condition, it was expected that the bias was not an overriding factor in the characterization of relative condition across the larger population of interest. Many preserved properties are limited to the wetlands themselves, with little or no preserved surrounding upland, which may further reduce this bias. However, for accurately characterizing any given population of interest, assessment units should ideally be randomly selected from the entire population.

For statewide characterization and change analysis of wetland condition, it may be most effective to randomly select a fixed sample or set of samples that are monitored at fixed intervals in perpetuity. Fixed monitoring sites would provide long-term, probabilistic monitoring data for understanding and reporting on statewide status and changes in wetland condition. True random selection may require a one-time investment of site-access solicitation resources. But, data collected from assessment units contained on private properties may also be biased, since landowners may modify their typical (representative of the population) land use practices, knowing that their wetlands are under regular State surveillance. It is therefore unknown whether a sample utilizing private lands would be any more or less representative than a sample discounting private lands.

4.1.3. Scoring Modifications to RIRAM v.2

Some recent feedback has favored downgrading the contribution of Section D to reduce subjectivity in RIRAM scoring. Up to this point, the scoring of metrics within RIRAM v.2 have been weighted according to metric categories as follows: *Landscape* metrics (B) were weighted 10 points each for as total of 20% of the RIRAM Index; in-wetland *Stresses* (C) were weighted 7 points each for a total of 50% of the Index; and *Observed State* submetrics (D) were weighted five points each for a total of 30% of the Index. This report recommends that the scoring of Section D is devalued to 10 points total and that the scoring of Section C in-wetland *Stresses* is upgraded to 70 points. Section B will remain as 20% of the Index. This change evens the value of each individual metric to 10 points, relegating Section D as a single metric. Scoring each metric evenly has the benefit of removing any assumptions of weighting among the metrics.

Reviewers have also recommended other changes in Section D *Observed State*. Accordingly, this report recommends the following changes: first, *hydrologic integrity* will be incorporated into Section D, since it can be degraded by various stresses and may control numerous functions and values; second, *hydrologic connectivity* will be incorporated into *habitat connectivity*, since they are conceptually analogous; and third, *microhabitat structure* will be combined with *vegetation structure*, since the two are often interdependent. This changes result in Section D comprising a single metric with five components scored at two points each.

The resulting new version is presented as RIRAM v. 2.10 in Appendix 4. An analysis applying the new RIRAM v.2.10 to this project's RIRAM data indicated that the changes from v.2.09 did not significantly affect RIRAM index scores (Mann-Whitney; $Z = -0.63$, $P = 0.53$) and that the versions (2.09 versus 2.10) are functionally identical (Spearman Rank Correlation; $r_s = 0.997$, $P < 0.001$, $df = 52$).

4.2 RIRAM Applications

4.2.1 RIRAM Data Utility

Section 3.3 demonstrates the application of RIRAM in addressing State-identified freshwater monitoring and assessment objectives according to WMAP. Demonstration

analyses addressing buffer-zone degradation, invasive species, and causes and sources of degradation have been presented in earlier work (e.g. Kutcher 2010b); outcomes of this report generally support earlier findings. RIRAM v.2 had not been previously assessed in addressing objectives pertaining to groundwater withdrawal or management effectiveness. Section 3.4, which summarizes some findings of demonstration RIRAM applications, further suggests the utility of RIRAM data in addressing WMAP objectives. The findings are discussed here in the context of assessing RIRAM metric and index functionality.

Findings in this report suggest that RIRAM metric C.4 detected evident changes in water regime associated with designated well-head protection areas. This was an unexpected outcome due to low sample size and the complexity of variables associated with both groundwater drawdown and estimating changes in water regime; these may include variation in well pump rates, substrate composition, and model error in the former, and interpretation of expected vegetation or soil composition in the latter. Another variable—the fact that metric C.4 also ranks draining and diversion intensity *not* associated with groundwater withdrawal—also could confound detection of this relationship. Nonetheless, analysis of Year-4 data, in concurrence with Year-3 results, indicated a highly-significant difference in metric scores between assessment units located on well-head protection areas and all other units. This suggests that RIRAM assessments may be capable of identifying wetlands that are obviously stressed by groundwater withdrawals, although it is unlikely that RIRAM would be a dependable tool for detecting hydrologic stress in all wetlands stressed by groundwater drawdown. However, as an ancillary outcome of regular monitoring, RIRAM could potentially be used as a flagging mechanism to alert DEM to potential problems at wetlands where drawdown stresses are detected.

Tables 3 and 4 summarize correlation coefficients among RIRAM *Landscape Stress*, *Wetland Stress*, and *Observed State* metric scores, while Figure 6 presents correlation coefficients between RIRAM sub-indices and an independent proxy of land use intensity. Landscape degradation was associated with expected in-wetland stresses involving runoff and filling and was more closely associated with direct degradation of wetland characteristics (such as to habitat connectivity) than with indirect degradation (such as to vegetation composition). These findings suggest proper RAM function and concur with earlier findings (Kutcher 2010b). RIRAM data may help clarify pathways of direct and indirect relationships among landscape development, wetland stress, and wetland degradation. Managers could apply such information to inform watershed planning and land acquisition strategies.

RIRAM data may be particularly useful in inventorying and quantifying the occurrences, causes, and impacts of invasive species in project samples. Section 3.3.3 illustrates the types of products that can be produced to characterize invasive plant occurrence within a sample of concern. Tables 5 and 6 clarify stresses associated with invasive species success and suggest their impacts to particular wetland characteristics that may determine wetland function. Tables 7 and 8 indicate the strength of the association between invasive species and the degradation of overall wetland integrity, relative to other wetland stresses.

These outcomes directly address the WMAP objective regarding invasive species. Expected analysis results included moderate to strong relationships between invasive plant success and evident nutrient inputs, buffer degradation, and filling. These findings concur with conventional understanding of plant-invasion processes and with Year-3 results, and thus suggest proper RAM function. RIRAM data supply monitoring baseline and clarify relationships between stress, stressors, and invasive plant success. This information could be applied to inform policy and management or development planning.

In Section 3.3.4, RIRAM data are applied to suggest which stress types may be most strongly associated with overall degradation of CS and BF integrity, represented by the *Observed State* index. Here, comparing correlation coefficient (r) values of RIRAM metric ranks replaces simple tallying of stress occurrences. It also incorporates the elements of intensity and proportion to clarify the relationships at play and better indicate the relative strengths of these relationships. Year-4 demonstrations suggest that peat-dominated wetlands may be sensitive to hydrologic stresses; this is an expected outcome (see Section 3.4), which may further suggest proper RAM function.

RIRAM data are applied to assess the effectiveness of management strategies in Section 3.3.5. The data suggested strong relationships between conservation property size and wetland condition within for both Year-3 and Year-4 data; this is not a revolutionary discovery. However, RIRAM data may supply the State with scientific evidence that efforts to assemble, maintain, and preserve large parcels are effective in resource preservation. Significant differences in RIRAM Index scores between properties conserved for habitat protection versus otherwise also demonstrate RIRAM data's potential in providing information toward better understanding and supporting management effectiveness. Comparisons between RIRAM data and higher-resolution management data could provide further insights.

4.2.2 RIRAM Applications and Limitations

This study supports previous efforts that have demonstrated the ability of RIRAM to generate meaningful data on wetland characterization, classification, and condition. RIRAM data can be applied to directly address WMAP objectives and identify reference conditions for reference-based monitoring efforts. And, RIRAM data have been shown to correlate with biological and physical indicators of wetland condition, and with various independent measures surrounding land use intensity.

The analyses suggest that RIRAM v.2 provides effective relative indices for elucidating relationships between individual stressors, cumulative stressors, wetland condition, invasive species, and landscape degradation, and may detect stresses associated with groundwater withdrawals. The data provided by RIRAM may be further utilized in queries to shed light on other common and unforeseen questions regarding wetland condition. But RIRAM data must be applied with some caution until its validity in representing relative wetland condition has been thoroughly confirmed through further analysis. Confidence in RIRAM application will only grow relative to a growing body of supporting evidence of its functionality and utility; this should be a focus of further work.

RIRAM produces relative indices; they are not absolute measures of condition or stress. Similarly, RIRAM does not quantify wetland functions or values and is not intended to categorize wetlands by levels of protection. RIRAM is designed to compare each wetland to its own theoretical pristine state. Deviations from pristine are given scores, based on proportion and intensity. The scores are summed to characterize total deviation from pristine; i.e. the change from full integrity, which defines condition (U.S. EPA 2006). This allows RIRAM to be applied in characterizing relative condition across wetland types and in identifying reference conditions.

RIRAM data are not based on any direct measurements. All metrics are based on estimation or interpretation. *Landscape Stress* metrics utilize estimation and measurements based on photo-interpretation. In-wetland *Stress* metrics are based on estimation of stress intensity and the proportion of the assessment unit affected. *Observed State* metrics are largely based upon interpretation of observed evidence in reconciliation with *Landscape Stress* and *Wetland Stress* evidence. Although analysis has indicated that producer errors are minimized (as opposed to magnified) by the summing of estimated/interpreted metrics (see Kutcher 2010b), respective cautions should be used when applying and interpreting RIRAM data.

To produce RIRAM v.2 indices, metrics are summed according to an empirical modification of the scoring scheme in RIRAM v.1. Metric scores and their relative weights have not been calibrated in any way since. Thus, metric and index scores should be treated as ordinal (rank) data, as they are throughout this document (as indicated by the application of non-parametric, rank-based analysis). Future calibrations could set RIRAM data on a predictive scale, which could be useful in interpreting scores (e.g. a score of 95 is always “excellent” and a score of 55 is always “poor”) or adjust metric scoring models to better predict independent quantitative data. However, it is unlikely that standard model calibration strategies (to increase power by removing overlapping covariates) would be helpful in enhancing this RAM’s utility, since RIRAM metrics may work in unison or separately, and have variable relative power in the model, depending on the situation.

Accordingly, correlation analyses presented in this report are intended to indicate the *relative* strength of associations. Because individual stresses and their impacts may interact considerably, depending on the circumstances, stress and integrity (i.e. *Observed State*) metric correlations should not be interpreted as directly causal; rather, they should be considered associations that may work singly, in unison, or in series with other factors to influence net or cumulative outcomes. For these reasons, correlation probability (P) values have been presented here unadjusted. Additionally, while efforts have been made to be as comprehensive as possible within the constraints of rapid assessment protocol, none of the sections of RIRAM should be viewed as containing all the variables associated with wetland condition. For example, Section D only ranks the state of wetland characteristics that can be evaluated through the interpretation of observable evidence; impacts that don’t present themselves visibly may not be captured.

In its finished form, RIRAM will be a useful component in wetland monitoring and assessment. RIRAM provides stress and integrity data for studies of specific wetland processes. It provides baseline data that may be useful for prioritizing wetlands for protection, detecting change, and assessing wetland response to changes such as development and climate change. It produces an index that can provide a central conditional gradient and identify control sites for comparative analysis and for the development of reference-based assessment models (such as landscape and IBI models). Finally, it provides a defensible way to rapidly quantify and illustrate (relative) wetland condition, which may provide the State with scientific evidence needed to affect policy.

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Appendix 1

RIRAM v.2.09 Field Datasheet

RIRAM V.2 Investigators_____ Site Number_____ Date_____

A. Wetland Characteristics; apply to the *current* state of the wetland. Not Scored.

1) Assessment Unit Area; select one:

- ☐ <0.25 acres
- ☐ 0.25 to <1.0 acres
- ☐ 1.0 to <3.0 acres
- ☐ 3.0 to <10 acres
- ☐ 10 to <25 acres
- ☐ 25 to 50 acres
- ☐ >50 acres

2) Hydrologic Characteristics

Source of water; select main source:

- ☐ Precipitation
- ☐ Groundwater
- ☐ Surface water

Maximum water depth, today; select one:

- ☐ Dry
- ☐ Saturated
- ☐ <1 foot
- ☐ 1 to 3 feet
- ☐ >3 feet

Water Regime; select one or two dominant regimes:

- ☐ Semi- to permanently flooded
- ☐ Seasonally flooded
- ☐ Temporarily flooded
- ☐ Semi- to permanently saturated
- ☐ Seasonally saturated
- ☐ Regularly flooded (tidal)
- ☐ Irregularly flooded (tidal)

3) Habitat Characteristics

Habitat stratum diversity; estimate total cover of all habitat strata within unit using classes at right:

___ Trees
___ Shrubs
___ Emergent
___ Aquatic bed
___ Sphagnum
___ Perennial surface water
___ Bare substrate

Cover Classes:
0…..< 1%
1…..1-5%
2…..6-25%
3…..26-50%
4…..51-75%
5…..>75%

Microhabitat diversity; rate each present using the scale at right:

___ Vegetated hummocks or tussocks
___ Coarse woody debris >4 inches
___ Standing dead >8 inches DBH
___ Amphibian breeding pools

Presence Scale:
0…..Absent
1…..Present in very small amounts
2…..Present in small to moderate amounts
3…..Present in moderate or greater amounts

4) Wetland Classification

Hydrogeomorphic Class; select main one:

- ☐ Isolated Depression
- ☐ Connected Depression
- ☐ Floodplain (riverine)
- ☐ Fringe
- ☐ Slope
- ☐ Flat

NWI Classes; select all comprising unit and indicate *Dominance Type*:

- ☐ Forested _____
- ☐ Scrub-shrub _____
- ☐ Emergent _____
- ☐ Aquatic Bed _____
- ☐ Unconsolidated Bottom or Shore
- ☐ Rock Bottom or Shore

RINHP natural community types; select all present within unit:

- ☐ Freshwater tidal marsh*
- ☐ Interdunal swale*
- ☐ Intermittent stream
- ☐ Eutrophic Pond
- ☐ Coastal plain pondshore*
- ☐ Coastal plain quagmire*
- ☐ Deep emergent marsh
- ☐ Shallow emergent marsh
- ☐ Dwarf shrub bog*
- ☐ Atlantic white cedar bog*
- ☐ Acidic level fen*
- ☐ Scrub-shrub wetland
- ☐ Floodplain Forest*
- ☐ Red Maple Swamp
- ☐ Vernal pool*
- ☐ Hemlock-hardwood swamp
- ☐ Atlantic white cedar swamp*
- ☐ Black Spruce Bog*
- ☐ Other Type: _____

5) Wetland values; select all known or observed:

- ☐ Within 100 year flood plain
- ☐ Between stream or lake and human use
- ☐ Part of a habitat complex or corridor
- ☐ Falls in aquifer recharge zone
- ☐ Contains known T/E species
- ☐ Significant avian habitat
- ☐ Contains *GCN** habitat type
- ☐ Educational or historic significance

*Identified by RIDEM as habitat of *Greatest Conservation Need*

RIRAM V.2 Investigators_____ Site Number_____ Date_____

B. Stresses within the Surrounding Landscape. Sum metrics 1 and 2

1) Degradation of Buffers

a. Estimate % cultural cover within 100-foot buffer. Select one.

- ☐ <5% (10)
- ☐ 6 to 25% (7)
- ☐ 26-50% (4)
- ☐ 51-75% (1)
- ☐ >75% (0)

2) Intensity of Surrounding Land Use

Land Use Intensity weighted average within 500-foot buffer.
Estimate proportion of each class to the nearest tenth and multiply.

	Proportion	Score	Weighted Value
Very Low	_____	× 10 =	_____
Low	_____	× 7 =	_____
Moderately High	_____	× 4 =	_____
High	_____	× 1 =	_____

Sum weighted values for score = _____

Associated Stressors: Check all that apply

- ☐ Commercial or industrial development
- ☐ Unsewered Residential development
- ☐ Sewered Residential development
- ☐ New construction
- ☐ Landfill or waste disposal
- ☐ Channelized streams or ditches
- ☐ Raised road beds
- ☐ Foot paths / trails
- ☐ Row crops, turf, or nursery plants
- ☐ Poultry or livestock operations
- ☐ Orchards, hay fields, or pasture
- ☐ Piers, docks, or boat ramps
- ☐ Golf courses / recreational development
- ☐ Sand and gravel operations
- ☐ Other _____

Very Low……Natural areas
Low……Recovering natural lands, passive recreation, low trails/dirt roads
Mod High……Residential, pasture/hay, mowed areas, raised roads to 2-lane
High……Urban, impervious cover, new construction, row crops, turf crops, paved roads > 2-lane

Sum of Metrics 1 and 2 = ☐ B. Landscape Stressors Score

C. Stresses affecting assessment unit. Sum metrics 3 to 9 and subtract from 50.

3) Impoundment within or abutting wetland.

Sum a and b (Max = 7)

a. Increase in depth or hydroperiod. Select one and multiply by the proportion of the unit affected to the nearest tenth. = _____

- ☐ None (0)
- ☐ Wetland was *created* by impoundment (1)
- ☐ Change in velocity only (1)
- ☐ Change of less than one water regime (1)
- ☐ Change of one water regime (3)
- ☐ Change of two or more water regimes (5)
- ☐ Change to deepwater (7)

Proportion of unit affected (circle one)
0 .1 .2 .3 .4 .5 .6 .7 .8 .9 1.0

b. Artificial barrier to movement of resources through water.
Select all that apply and sum. = _____

- ☐ None (0)
- ☐ Barrier to upstream movement at low water (1)
- ☐ Barrier to downstream movement at low water (1)
- ☐ Barrier to upstream or downstream movement above low water (1)

Evidence: check all that apply

- ☐ Physical barrier across flow downstream of wetland
- ☐ Deepening of wetland upstream of barrier
- ☐ Widening of wetland upstream of barrier
- ☐ Abrupt and unnatural edge downstream of wetland
- ☐ Dam or restricting culvert downstream of wetland
- ☐ Dead or dying vegetation

Primary Associated Stressors;
Check all evident:

- __ Road
- __ Railway
- __ Weir / Dam
- __ Raised Trail
- __ Development Fill
- __ Other _____

Primary Stressor Type;
Check best one:

- __ Private / Residential
- __ Commercial
- __ Agricultural
- __ Public transportation
- __ Public utilities
- __ Public recreation

Water Regimes

Temporarily Saturated …… Temporarily Flooded
Seasonally Saturated …….. Seasonally Flooded
Semipermanently Saturated …… Semipermanently Flooded
Permanently Saturated …… Permanently Flooded

RIRAM V.2 Investigators_____ Site Number_____ Date_____

4) Draining or Diversion of water from wetland.

Decrease in depth or hydroperiod. Select one and multiply by the proportion of the unit affected to the nearest tenth.

- ☐ None (0)
- ☐ Change in velocity only (2)
- ☐ Change of less than one water regime (2)
- ☐ Change of one water regime (5)
- ☐ Change of two or more water regimes or to upland (7)

Water Regimes
Temporarily Saturated …… Temporarily Flooded
Seasonally Saturated …….. Seasonally Flooded
Semipermanently Saturated …… Semipermanently Flooded
Permanently Saturated …… Permanently Flooded

Proportion of unit affected (circle one)
0 .1 .2 .3 .4 .5 .6 .7 .8 .9 1.0

Evidence: check all that apply
- ☐ Drainage ditches or tiles evident
- ☐ Evident impoundment upstream of wetland
- ☐ Severe root exposure
- ☐ Moderate root exposure
- ☐ Soil fissures
- ☐ Uncharacteristically dry groundcover
- ☐ Dead or dying vegetation

Primary Associated Stressors; check all evident:
__ Road __ Drainage ditch / tile
__ Railway __ Major well withdrawals
__ Dike __ Surface water pumps
__ Fill __ Other _____

Primary Stressor Type; check best one:
__ Private / Residential __ Public transportation
__ Commercial __ Public utilities
__ Agricultural __ Public recreation

5) Anthropogenic fluvial inputs.

Rank the evidence of impact for each and sum (Max = 7).

____ a. Nutrients

____ b. Sediments / Solids

____ c. Toxins / Salts

____ d. Increased flashiness

Evidence-of-Impact Ranks
0…..No evidence
1…..Sources evident, only
2…..Slight impact evident
3…..Moderate to strong impact evident

Evidence: check all that apply
- ☐ Runoff sources evident
- ☐ Point sources evident
- ☐ Excessive algae or floating vegetation
- ☐ Excessive rooted submerged or emergent vegetation
- ☐ Uncharacteristic sediments
- ☐ Obvious plumes or suspended solids
- ☐ Chemical smell
- ☐ Strangely tinted water
- ☐ Dead, dying, or patchy vegetation
- ☐ Dead fauna or stark lack of life
- ☐ Root exposure or bank erosion due to scouring

Primary Associated Stressors; check all evident:
__ Stormwater inputs __ Road runoff
__ Other sheet runoff __ Effluent discharge
__ Organic / yard waste __ Other point _____
__ Riverine (up-stream) __ Other non-point
__ Channelization

Primary Stressor Type; check best one:
__ Private / Residential __ Public transportation
__ Commercial __ Public utilities
__ Agricultural __ Public recreation
__ Multiple / non-point

6) Filling and dumping within wetland. Select one and multiply by the proportion of the unit affected to the nearest tenth (Max = 7).

Impact of fill
- ☐ None (0)
- ☐ Affects aesthetics only (2)
- ☐ Affects water regime, vegetation, or soil quality (5)
- ☐ Changes area to upland (7)
- ☐ Fill is above surrounding upland grade (10)

Proportion of unit (or perimeter) affected (circle one)
0 .1 .2 .3 .4 .5 .6 .7 .8 .9 1.0

Evidence: check all that apply
- ☐ Unnaturally abrupt change in ground level
- ☐ Abrupt change in soil texture or content
- ☐ Unnaturally straight or abrupt wetland edge
- ☐ Unnatural items on or within the sediments

Primary Associated Stressors; check all evident:
__ Road __ Raised Trail
__ Railway __ Trash
__ Fill __ Organic / yard waste
__ Dam __ Dike
__ Other _____

Primary Stressor Type; check best one:
__ Private / Residential __ Public transportation
__ Commercial __ Public utilities
__ Agricultural __ Public recreation

7) Excavation and other substrate disturbances within wetland. Select one and multiply by the proportion of the unit affected to the nearest tenth.

Intensity of disturbance
- ☐ None (0)
- ☐ Wetland unit was *created* by excavation (1)
- ☐ Soil quality or vegetation disturbed (3)
- ☐ Changes water regime (5)
- ☐ Excavated to deep water (7)

Proportion of unit (or perimeter) affected (circle one)
0 .1 .2 .3 .4 .5 .6 .7 .8 .9 1.0

Primary Associated Stressors; check all evident:
__ Vehicle disturbance __ Plowing / cultivation
__ Grading __ Channelization
__ Footpaths __ Ditching
__ Excavation __ Dredging
__ Trampling __ Other _____

Evidence: check all that apply
- ☐ Unnaturally abrupt lowering in ground level
- ☐ Loss of vegetation
- ☐ Unnaturally straight and abrupt wetland edge
- ☐ Direct evidence of disturbance

Primary Stressor Type; check best one:
__ Private / Residential __ Public transportation
__ Commercial __ Public utilities
__ Agricultural __ Public recreation

8) Vegetation and detritus removal within wetland. Rank extent and multiply by the estimated proportion affected for each layer; then sum (Max = 7).

Layers affected	Extent	Proportion
☐ Aquatic Bed	_____×	_____=_____
☐ Detritus	_____×	_____=_____
☐ Emergent	_____×	_____=_____
☐ Shrub	_____×	_____=_____
☐ Canopy	_____×	_____=_____

Sum =_____

Proportion of unit affected
0 .1 .2 .3 .4 .5 .6 .7 .8 .9 1.0

Primary Associated Stressors; check all evident:
__ Power lines __ Development clearing
__ Grazing __ Trails / non-raised roads
__ Cultivation __ Excavation / ditching
__ Timber Harvest __ Other _____

Evidence: check all that apply
- ☐ Cut stems
- ☐ Immature vegetation strata
- ☐ Missing vegetation strata
- ☐ Mowed areas
- ☐ Browsing or grazing

Extent of removal
0…..None
1…..Partial or recovering
2…..Complete

Primary Stressor Type; check best one:
__ Private / Residential __ Public transportation
__ Commercial __ Public utilities
__ Agricultural __ Public recreation

9) Invasive species within wetland.

9a. Select one class for total coverage.
- ☐ None noted (0)
- ☐ Nearly absent <5% cover (2) ……. Cover Class 1
- ☐ Low 6-25% cover (3) ……. Cover Class 2
- ☐ Moderate 26-50% cover (4) ……. Cover Class 3
- ☐ High 51-75% cover (5) ……. Cover Class 4
- ☐ Extensive >75% cover (7) ……. Cover Class 5

9b. List and select a cover class for each invasive plant species noted.

Cover Class	Species
_____	_____
_____	_____
_____	_____
_____	_____
_____	_____

Abutting Stressors;
Check all evident:
__ Road
__ Railway
__ Raised Trail
__ Footpath
__ Dam / Dike
__ Fill
__ Drainage ditch / tile
__ Organic / yard waste
__ Stormwater input
__ Clearing
__ Other _____

Primary Stressor Type; check best one:
__ Private / Residential __ Public transportation
__ Commercial __ Public utilities
__ Agricultural __ Public recreation

Sum of C3 to C9 Scores = ☐ **50 Minus Sum =** ☐ **C. Wetland Stresses Score**

D. Net Result of Cumulative Stress. Circle one score for each component and sum.
Refer to Sections C and D. Consider current wetland types.

	Characteristic*	Degraded		Destroyed
Vegetation Structure……...	5	4	3	2	0
Vegetation Composition…….	5	4	3	2	0
Hydrologic Connectivity……	5	4	3	2	0
Habitat Connectivity……...	5	4	3	2	0
Microhabitat Structure……	5	4	3	2	0
Water and Soil Quality……	5	4	3	2	0

SUM = ☐ **D. Net Result Score**

B. Landscape Stresses Score (max 20) _____ **+**

C. Wetland Stresses Score (max 50) _____ **=**

Index of Human Impact ☐ **+**

D. Net Result Score (max 30) _____ **=**

RIRAM V. 2 Condition Index ☐

* Characteristic of wetland type in an unstressed setting

Appendix 2

RIRAM v.2.09b Field Datasheet

RIRAM V.2.10 Investigators_____ Site Number_____ Date_____
Longitude (DD) _____ Latitude (DD) _____

A. Wetland Characteristics; apply to the *current* state of the wetland. Not Scored.

1) Assessment Unit Area; select one:

- ☐ <0.25 acres
- ☐ 0.25 to <1.0 acres
- ☐ 1.0 to <3.0 acres
- ☐ 3.0 to <10 acres
- ☐ 10 to <25 acres
- ☐ 25 to 50 acres
- ☐ >50 acres

2) Hydrologic Characteristics

Source of water; select main source:

- ☐ Precipitation
- ☐ Groundwater
- ☐ Surface water

Maximum water depth, today; select one:

- ☐ Dry
- ☐ Saturated
- ☐ <1 foot
- ☐ 1 to 3 feet
- ☐ >3 feet

Water Regime; select one or two dominant regimes:

- ☐ Permanently flooded
- ☐ Semi-permanently flooded
- ☐ Seasonally flooded
- ☐ Temporarily flooded
- ☐ Permanently saturated
- ☐ Seasonally saturated
- ☐ Regularly flooded (tidal)
- ☐ Irregularly flooded (tidal)

3) Habitat Characteristics

Habitat stratum diversity; estimate total cover of all habitat strata within unit using classes at right:

___ Trees
___ Shrubs
___ Emergent
___ Aquatic bed
___ Sphagnum
___ Surface water, today
___ Unvegetated substrate, today

Cover Classes:
0…..< 1%
1…..1-5%
2…..6-25%
3…..26-50%
4…..51-75%
5…..>75%

Microhabitat diversity; rate each present using the scale at right:

___ Vegetated hummocks or tussocks
___ Coarse woody debris
___ Standing dead trees
___ Amphibian breeding habitat

Ecological Significance Scale:
0…..None Noted
1…..Minor Feature
2…..Significant Feature
3…..Dominant Feature

4) Wetland Classification

Hydrogeomorphic Class; select main one:

- ☐ Isolated Depression
- ☐ Connected Depression
- ☐ Floodplain (riverine)
- ☐ Fringe
- ☐ Slope
- ☐ Flat

NWI Classes; select all comprising unit and indicate *Dominance Type*:

- ☐ Forested _____
- ☐ Scrub-shrub _____
- ☐ Emergent _____
- ☐ Aquatic Bed _____
- ☐ Unconsolidated Bottom or Shore
- ☐ Rock Bottom or Shore

RINHP natural community types; select all present within unit:

- ☐ Freshwater tidal marsh*
- ☐ Interdunal swale*
- ☐ Intermittent stream
- ☐ Eutrophic Pond
- ☐ Coastal plain pondshore*
- ☐ Coastal plain quagmire*
- ☐ Deep emergent marsh
- ☐ Shallow emergent marsh
- ☐ Emergent fen*
- ☐ Dwarf shrub bog / fen*
- ☐ Dwarf tree bog*
- ☐ Scrub-shrub wetland
- ☐ Floodplain Forest*
- ☐ Red Maple Swamp
- ☐ Vernal pool*
- ☐ Hemlock-hardwood swamp
- ☐ Atlantic white cedar swamp*
- ☐ Black Spruce Bog*
- ☐ Other Type: _____

5) Wetland values; select all known or observed:

- ☐ Within 100 year flood plain
- ☐ Between stream or lake and human use
- ☐ Part of a habitat complex or corridor
- ☐ Falls in aquifer recharge zone
- ☐ Contains known T/E species
- ☐ Significant avian habitat
- ☐ Contains *GCN** habitat type
- ☐ Educational or historic significance

_____
*Identified by DEM as habitat of *Greatest Conservation Need*

RIRAM V.2.10 Investigators_____ Site Number_____ Date_____

B. Landscape Stresses. Sum metrics 1 and 2

1) Degradation of Buffers

Estimate % cultural cover within 100-foot buffer. Select one.

- ☐ <5% (10)
- ☐ 6 to 25% (7)
- ☐ 26-50% (4)
- ☐ 51-75% (1)
- ☐ >75% (0)

Associated Stressors: Check all that apply

- ☐ Commercial or industrial development
- ☐ Unsewered Residential development
- ☐ Sewered Residential development
- ☐ New construction
- ☐ Landfill or waste disposal
- ☐ Channelized streams or ditches
- ☐ Raised road beds
- ☐ Foot paths / trails
- ☐ Row crops, turf, or nursery plants
- ☐ Poultry or livestock operations
- ☐ Orchards, hay fields, or pasture
- ☐ Piers, docks, or boat ramps
- ☐ Golf courses / recreational development
- ☐ Sand and gravel operations
- ☐ Other _____

2) Intensity of Surrounding Land Use

Land Use Intensity weighted average within 500-foot buffer.
Estimate proportion of each class to the nearest tenth and multiply.

	Proportion	Score	Weighted Value
Very Low	_____	× 10 =	_____
Low	_____	× 7 =	_____
Moderately High	_____	× 4 =	_____
High	_____	× 1 =	_____

Sum weighted values for score = _____

Very Low…….Natural areas
Low……Recovering natural lands, passive recreation, low trails/dirt roads
Mod High……Residential, pasture/hay, mowed areas, raised roads to 2-lane
High……Urban, impervious cover, new construction, row crops, turf crops, paved roads > 2-lane

Sum of Metrics 1 and 2 = ☐ B. Landscape Stress Score

C. Wetland Stresses. Sum metrics 3 to 9 and subtract from 50.

3) Impoundment.

Sum a and b (Max = 7)

a. Increase in depth or hydroperiod. Select one and multiply by the proportion of the unit affected to the nearest tenth. = _____

- ☐ None (0)
- ☐ Wetland was *created* by impoundment (1)
- ☐ Change in velocity only (1)
- ☐ Change of less than one water regime (2)
- ☐ Change of one water regime (3)
- ☐ Change of two or more water regimes (5)
- ☐ Change to deepwater (7)

Proportion of unit affected (circle one)
0 .1 .2 .3 .4 .5 .6 .7 .8 .9 1.0

Evidence: check all that apply

- ☐ Physical barrier across flow downstream of wetland
- ☐ Abrupt and unnatural edge downstream of wetland
- ☐ Dam or restricting culvert downstream of wetland
- ☐ Deepening of wetland upstream of barrier
- ☐ Widening of wetland upstream of barrier
- ☐ Change in vegetation across barrier
- ☐ Dead or dying vegetation

Primary Associated Stressor; check one:

- ☐ Road
- ☐ Railway
- ☐ Weir / Dam
- ☐ Raised Trail
- ☐ Development Fill
- ☐ Other

b. Artificial barrier to movement of resources through water. Select all that apply and sum. = _____

- ☐ None (0)
- ☐ Barrier to upstream movement at low water (1)
- ☐ Barrier to downstream movement at low water (1)
- ☐ Barrier to upstream or downstream movement above low water (1)

Primary Source of Stress; indicate as current (C) or historic (H):

- __ Private / Residential
- __ Commercial
- __ Agricultural
- __ Public transportation
- __ Public utilities
- __ Public recreation
- __ Undetermined

Water Regimes

(Upland)……Temporarily Flooded……..Irregularly Flooded
Seasonally Saturated ……Seasonally Flooded……Regularly Flooded
Permanently Saturated ……..Semi-permanently Flooded
Permanently Flooded

4) Draining or diversion of water from wetland.

Decrease in depth or hydroperiod. Select one and multiply by the proportion of the unit affected to the nearest tenth.

- ☐ None (0)
- ☐ Change in velocity only (2)
- ☐ Change of less than one water regime (2)
- ☐ Change of one water regime (5)
- ☐ Change of two or more water regimes or to upland (7)

Water Regimes
(Upland)……Temporarily Flooded…… Irregularly Flooded
Seasonally Saturated ……Seasonally Flooded……..Regularly Flooded
Permanently Saturated ……Semi-Permanently Flooded
Permanently Flooded

Proportion of unit affected (circle one)
0 .1 .2 .3 .4 .5 .6 .7 .8 .9 1.0

Evidence: check all that apply
- ☐ Drainage ditches or tiles evident
- ☐ Evident impoundment upstream of wetland
- ☐ Severe root exposure
- ☐ Moderate root exposure
- ☐ Soil fissures
- ☐ Uncharacteristically dry groundcover
- ☐ Dead or dying vegetation
- ☐ Change in vegetation across barrier

Primary Associated Stressor; Check one:
- ☐ Road
- ☐ Railway
- ☐ Dike
- ☐ Fill
- ☐ Drainage ditch / tile
- ☐ Major well withdrawals
- ☐ Surface water pumps
- ☐ Other

Primary Source of Stress; indicate as current (C) or historic (H):
- __ Private / Residential
- __ Commercial
- __ Agricultural
- __ Public transportation
- __ Public utilities
- __ Public recreation
- __ Undetermined

5) Anthropogenic fluvial inputs.

Rank the evidence of impact for each and sum (Max = 7).

____ a. Nutrients

____ b. Sediments / Solids

____ c. Toxins / Salts

____ d. Increased flashiness

Evidence-of-Impact Ranks
0…..No evidence
1…..Sources evident, only
2…..Slight impact evident
3…..Moderate to strong impact evident

Evidence: check all that apply
- ☐ Runoff sources evident
- ☐ Point sources evident
- ☐ Excessive algae or floating vegetation
- ☐ Excessive rooted submerged or emergent vegetation
- ☐ Uncharacteristic sediments
- ☐ Obvious plumes or suspended solids
- ☐ Chemical smell
- ☐ Strangely tinted water
- ☐ Dead, dying, or patchy vegetation
- ☐ Dead fauna or stark lack of life
- ☐ Root exposure or bank erosion due to scouring

Primary Associated Stressor; Check one:
- ☐ Point runoff
- ☐ Sheet runoff
- ☐ Effluent discharge
- ☐ Organic / yard waste
- ☐ Other point _____
- ☐ Riverine (up-stream)
- ☐ Multiple / non-point
- ☐ Channelization

Primary Source of Stress; indicate as current (C) or historic (H):
- __ Private / Residential
- __ Commercial
- __ Agricultural
- __ Public transportation
- __ Public utilities
- __ Public recreation
- __ Multiple / non-point
- __ Undetermined

6) Filling and dumping within wetland. Select one and multiply by the proportion of the unit affected to the nearest tenth (Max = 7).

Intensity of filling
- ☐ None (0)
- ☐ Affects aesthetics only (2)
- ☐ Affects water regime, vegetation, or soil quality (5)
- ☐ Changes area to upland (7)
- ☐ Fill is above surrounding upland grade (10)

Proportion of unit (or perimeter) affected (circle one)
0 .1 .2 .3 .4 .5 .6 .7 .8 .9 1.0

Evidence: check all that apply
- ☐ Unnaturally abrupt change in ground level
- ☐ Abrupt change in soil texture or content
- ☐ Unnaturally straight or abrupt wetland edge
- ☐ Unnatural items on or within the sediments

Primary Associated Stressor; Check one:
- ☐ Road
- ☐ Raised Trail
- ☐ Railway
- ☐ Trash
- ☐ Fill
- ☐ Organic / yard waste
- ☐ Dam
- ☐ Dike
- ☐ Other

Primary Source of Stress; indicate as current (C) or historic (H):
- __ Private / Residential
- __ Commercial
- __ Agricultural
- __ Public transportation
- __ Public utilities
- __ Public recreation
- __ Undetermined

7) Excavation and other substrate disturbances within wetland. Select one and multiply by the proportion of the unit affected to the nearest tenth.

Proportion of unit (or perimeter) affected (circle one)
0 .1 .2 .3 .4 .5 .6 .7 .8 .9 1.0

Intensity of disturbance
- ☐ None (0)
- ☐ Wetland unit was *created* by excavation (1)
- ☐ Soil quality or vegetation disturbed (3)
- ☐ Changes water regime (5)
- ☐ Excavated to deep water (7)

Evidence: check all that apply
- ☐ Unnaturally abrupt lowering in ground level
- ☐ Loss of vegetation
- ☐ Unnaturally straight and abrupt wetland edge
- ☐ Direct evidence of disturbance

Primary Associated Stressor; Check one:
- ☐ Vehicle disturbance
- ☐ Plowing / cultivation
- ☐ Excavation / Grading
- ☐ Channelization / Dredging
- ☐ Ditching
- ☐ Footpaths
- ☐ Trampling
- ☐ Other

Primary Source of Stress; indicate as current (C) or historic (H):
- __ Private / Residential
- __ Commercial
- __ Agricultural
- __ Public transportation
- __ Public utilities
- __ Public recreation
- __ Undetermined

8) Vegetation and detritus removal within wetland. Rank extent and multiply by the estimated proportion affected for each layer; then sum (Max = 7).

Proportion of unit affected
0 .1 .2 .3 .4 .5 .6 .7 .8 .9 1.0

Layers affected	Extent		Proportion		
☐ Aquatic Bed	_____	×	_____	=	_____
☐ Detritus	_____	×	_____	=	_____
☐ Emergent	_____	×	_____	=	_____
☐ Shrub	_____	×	_____	=	_____
☐ Canopy	_____	×	_____	=	_____

Sum =_____

Evidence: check all that apply
- ☐ Cut stems or stumps
- ☐ Immature vegetation strata
- ☐ Missing vegetation strata
- ☐ Mowed areas
- ☐ Browsing or grazing

Extent of removal
0.....None
1.....Partial or recovering
2.....Complete

Primary Associated Stressor; Check one:
- ☐ Power lines
- ☐ Grazing
- ☐ Cultivation
- ☐ Timber Harvest
- ☐ Development clearing
- ☐ Trails / non-raised roads
- ☐ Excavation / ditching
- ☐ Other

Primary Source of Stress; indicate as current (C) or historic (H):
- __ Private / Residential
- __ Commercial
- __ Agricultural
- __ Public transportation
- __ Public utilities
- __ Public recreation
- __ Undetermined

9) Invasive species within wetland.

9a. Select one class for total coverage.
- ☐ None noted (0)
- ☐ Nearly absent <5% cover (2).....Cover Class 1
- ☐ Low 6-25% cover (3).....Cover Class 2
- ☐ Moderate 26-50% cover (4).....Cover Class 3
- ☐ High 51-75% cover (5).....Cover Class 4
- ☐ Extensive >75% cover (7).....Cover Class 5

9b. List and select a cover class for each invasive plant species noted.

Cover Class	Species
_____	_____
_____	_____
_____	_____
_____	_____
_____	_____

Primary Abutting Stressor; Check one:
- ☐ Road
- ☐ Railway
- ☐ Raised Trail
- ☐ Footpath
- ☐ Dam / Dike
- ☐ Organic / yard waste
- ☐ Other Fill
- ☐ Drainage ditch / tile
- ☐ Stormwater input
- ☐ Clearing
- ☐ Multiple
- ☐ Other

Primary Source of Stress; indicate as current (C) or historic (H):
- __ Private / Residential
- __ Commercial
- __ Agricultural
- __ Undetermined
- __ Public transportation
- __ Public utilities
- __ Public recreation

Sum of C3 to C9 Scores = ☐ **50 Minus Sum =** ☐ **C. Wetland Stress Score**

D. Observed State of Wetland Characteristics. Circle one score for each characteristic and sum. Refer to Sections A through C to inform scores. Consider current wetland types.

Characteristics	Characteristic*		Degraded		Destroyed
Vegetation Structure……	5	4	3	2	0
Vegetation Composition……	5	4	3	2	0
Hydrologic Connectivity……	5	4	3	2	0
Habitat Connectivity……	5	4	3	2	0
Microhabitat Structure……	5	4	3	2	0
Water and Soil Quality……	5	4	3	2	0

SUM = [ ] **D. Observed State Score**

B. Landscape Stress Score (max 20) _____ **+**

C. Wetland Stress Score (max 50) _____ **=**

B+C. Total Stress Score (max 70) [ ]

D. Observed State Score (max 30) _____ **=**

RIRAM V. 2.10 Condition Index [ ]

* Characteristic of wetland type in an unstressed setting

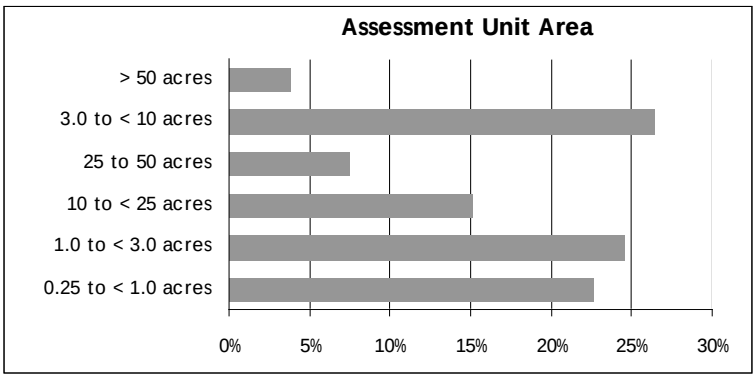
Appendix 3

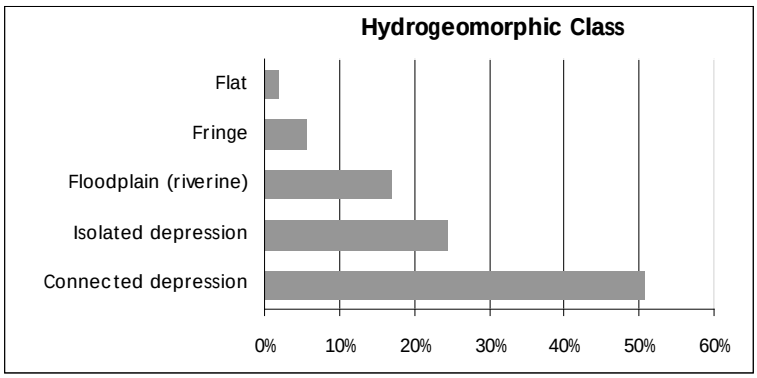
Summary Statistics from Year-4 RIRAM Assessments

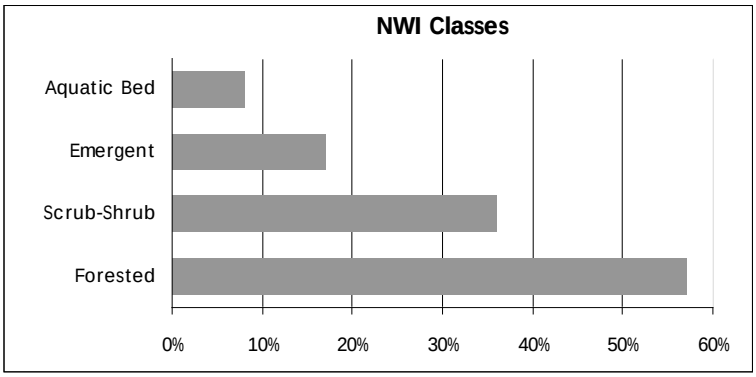
Appendix 3, RIRAM V.2 .09, Year-4

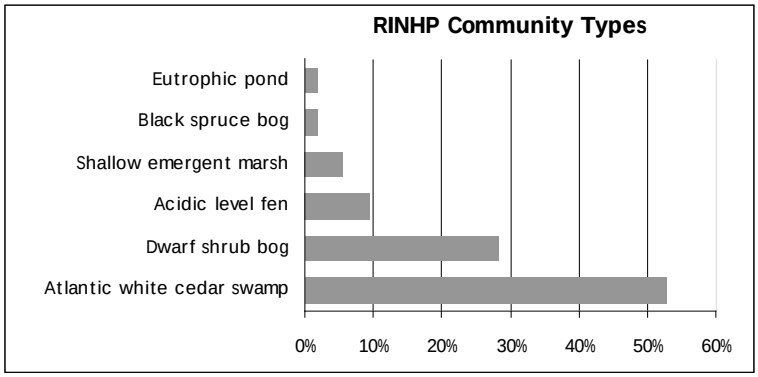
I. Summary attribute and metric statistics across all assessment units

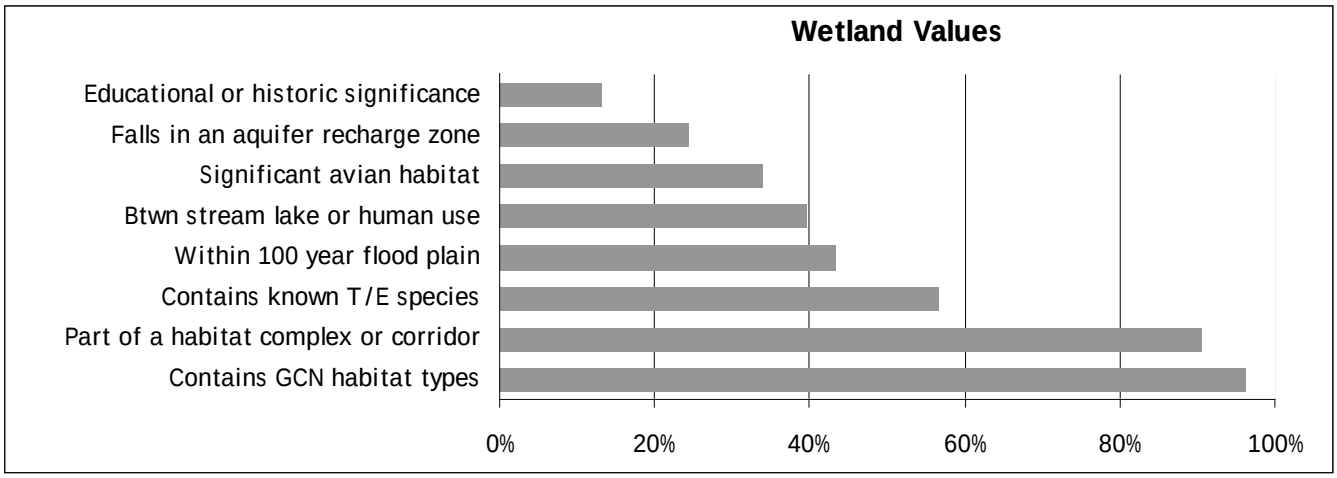
A. Wetland Characteristics





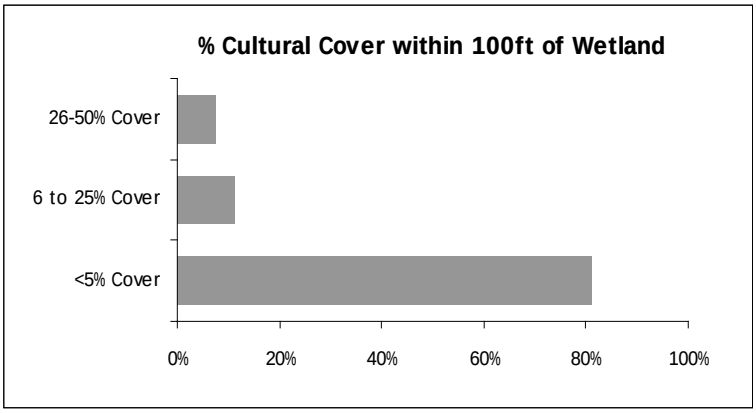


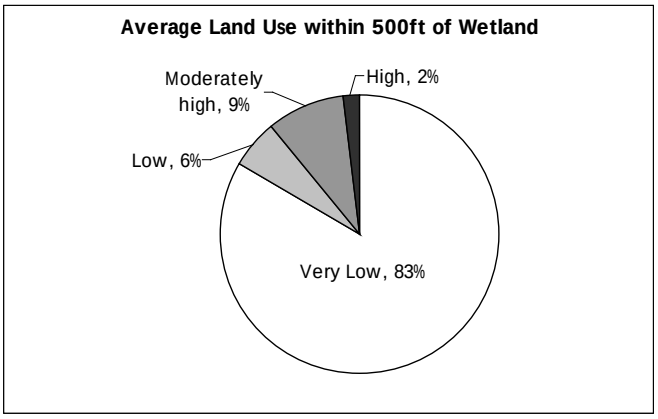


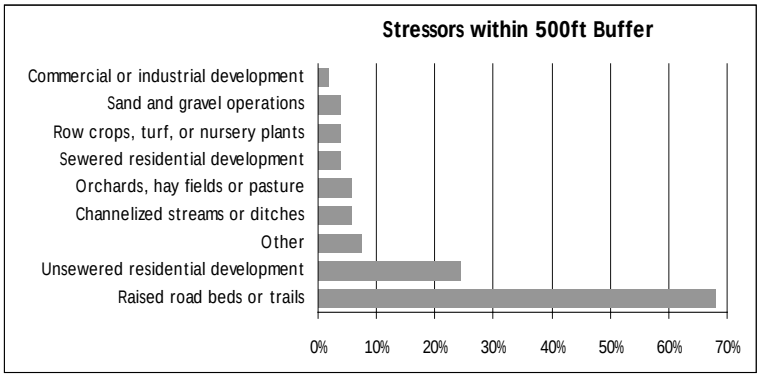


B. Stresses within the surrounding landscape

B.1 & B.2 Degradation of 100ft & 500ft buffers



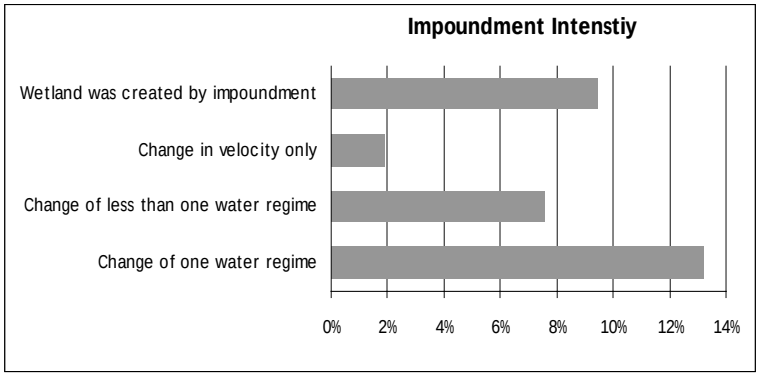


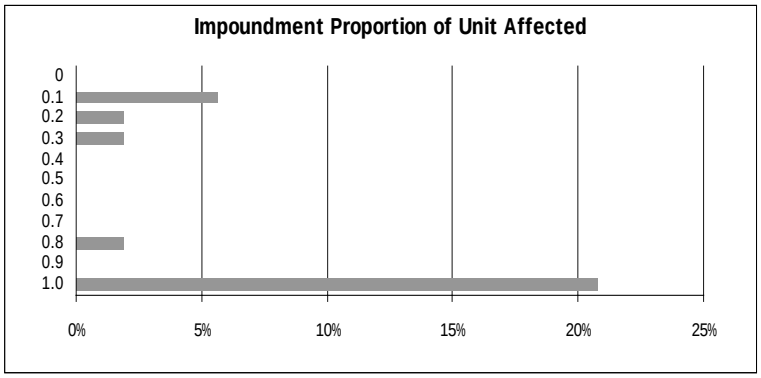


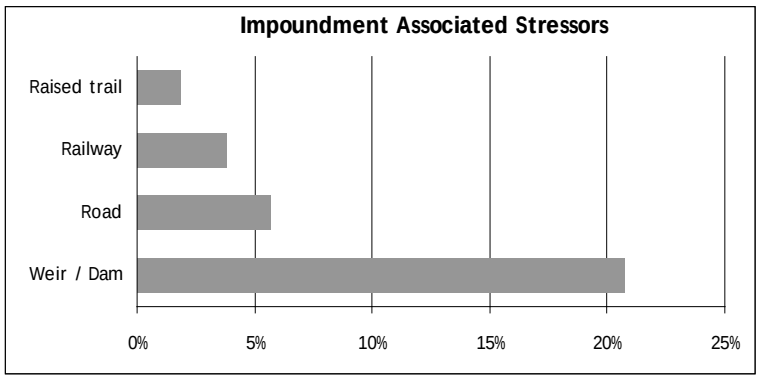
C. Stresses affecting assessment units

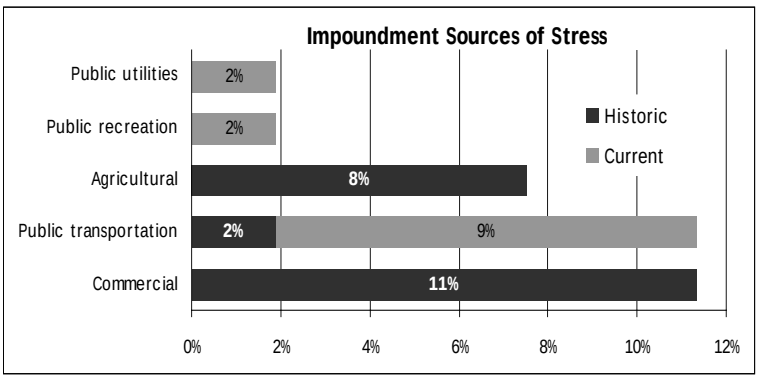
C.3 Impoundment within or abutting wetland

C.3.a Increase in depth or hydroperiod

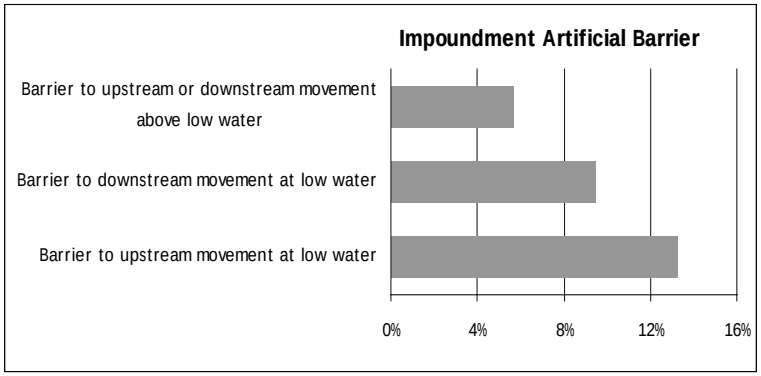




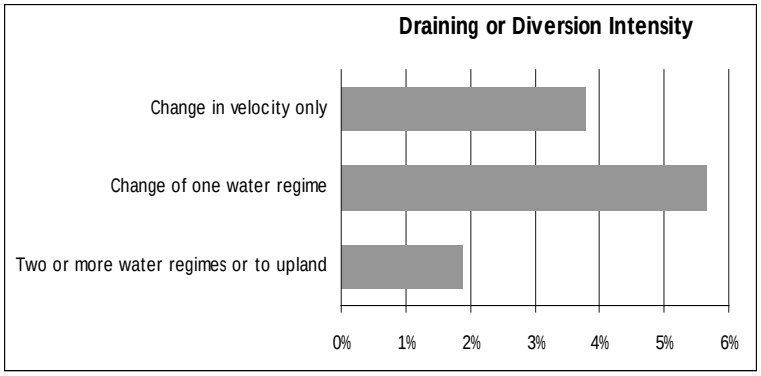


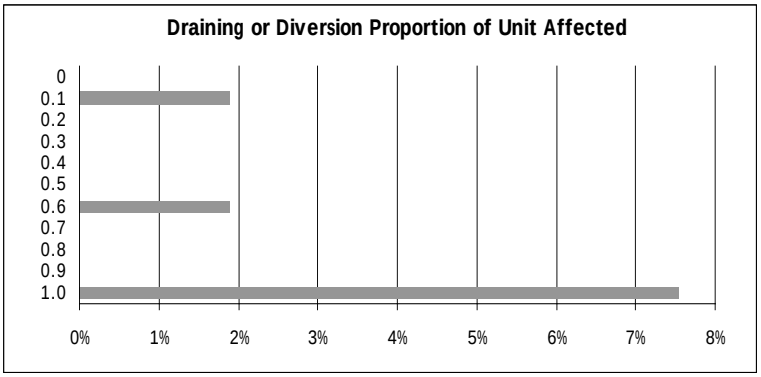


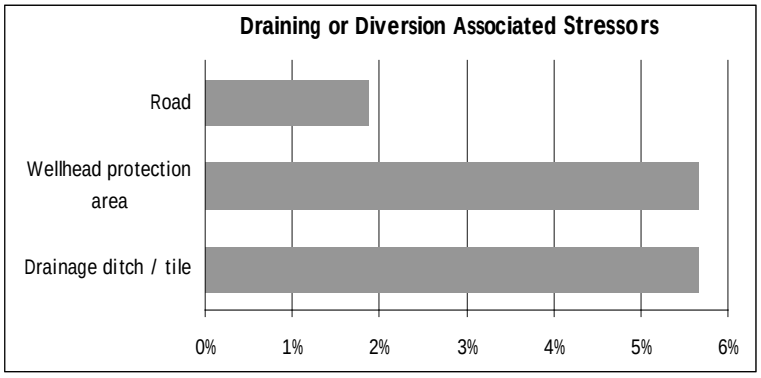
C.3.b Artificial barrier to movement of resources through water

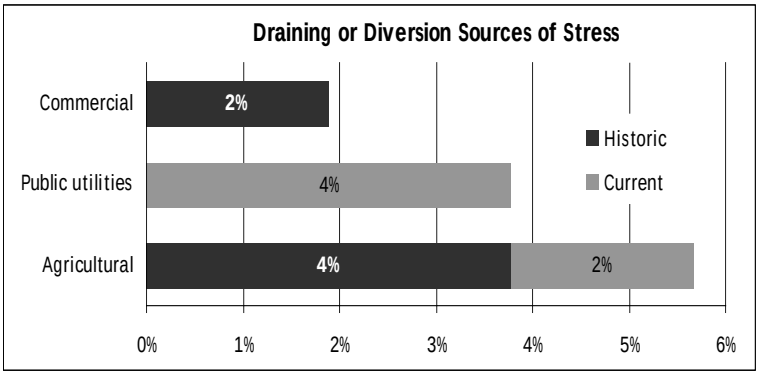


C.4 Draining or diversion

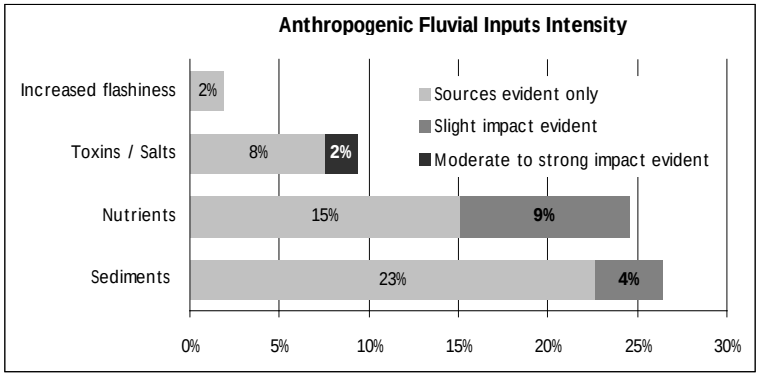


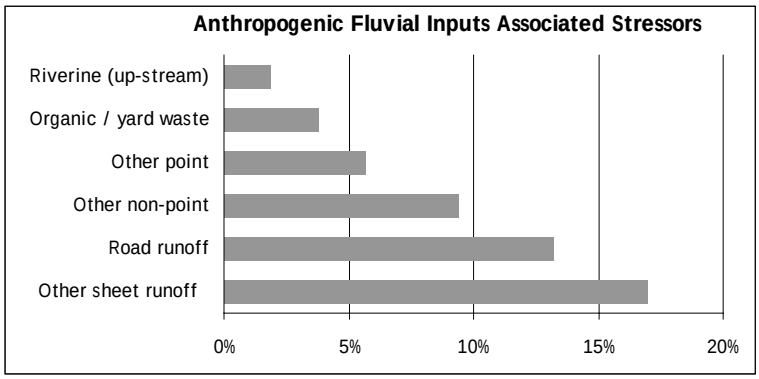


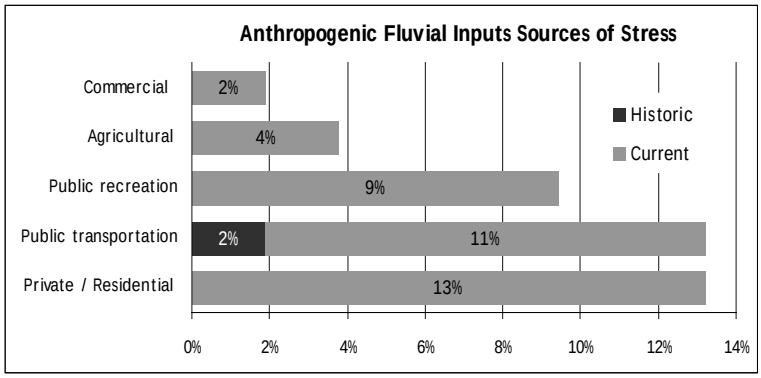




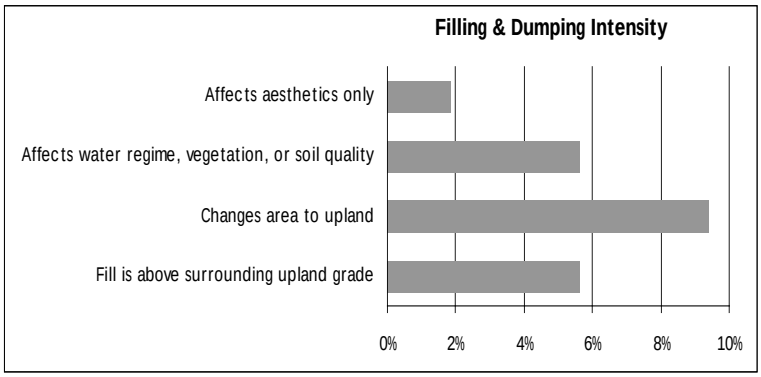
C.5 Anthropogenic Fluvial Inputs

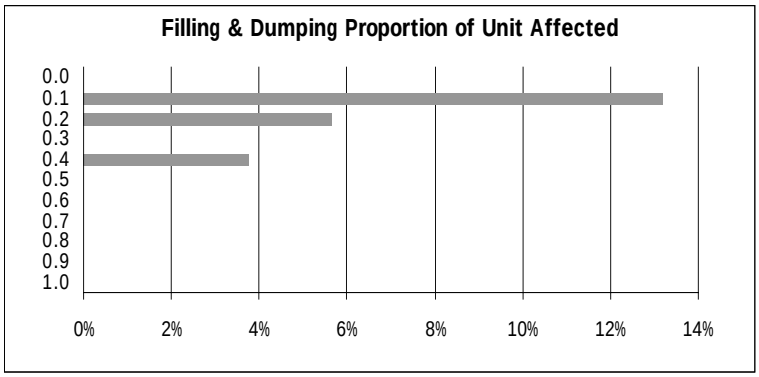


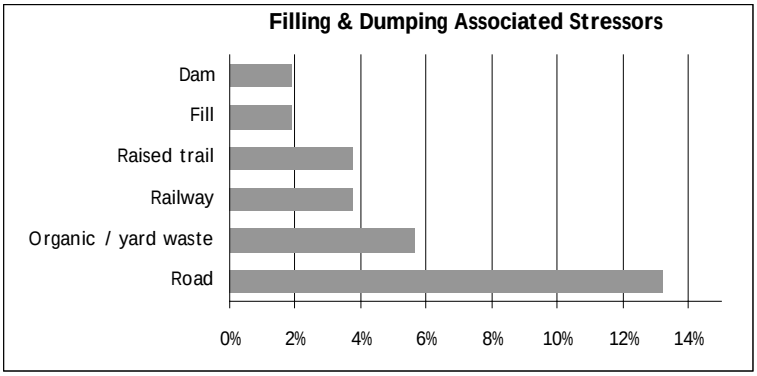


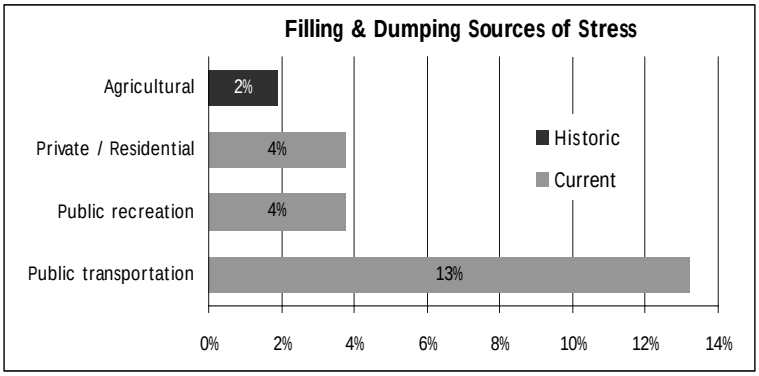


C.6 Filling & dumping

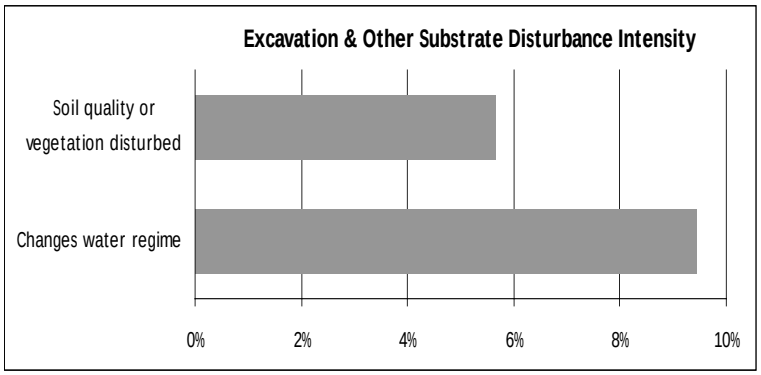


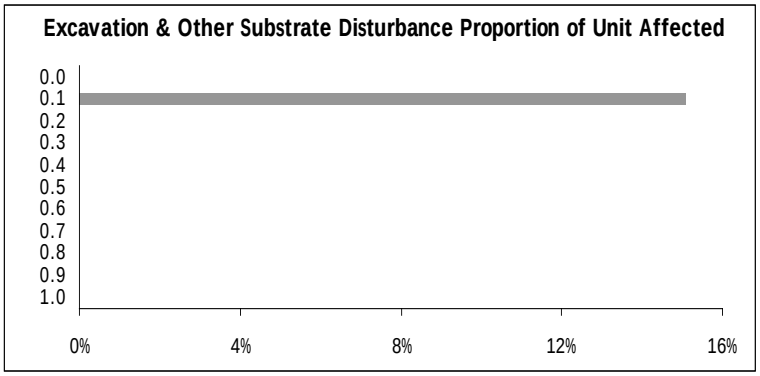


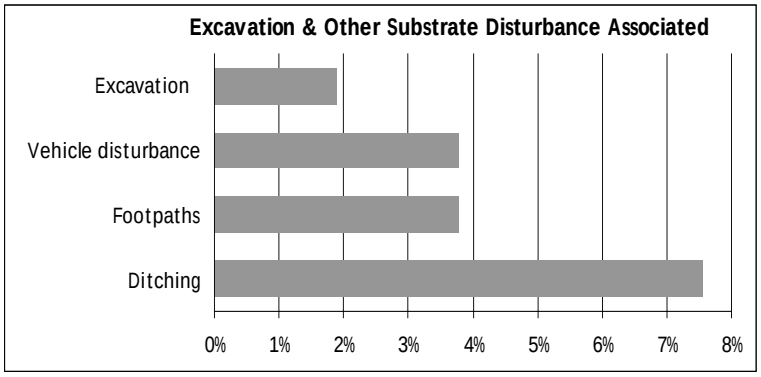


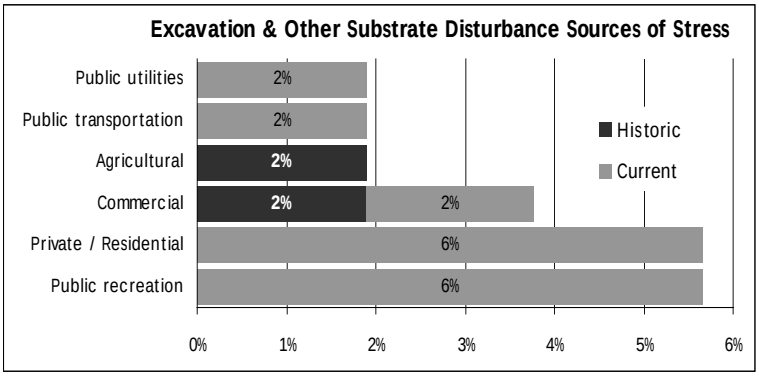


C.7 Excavation & other substrate disturbances

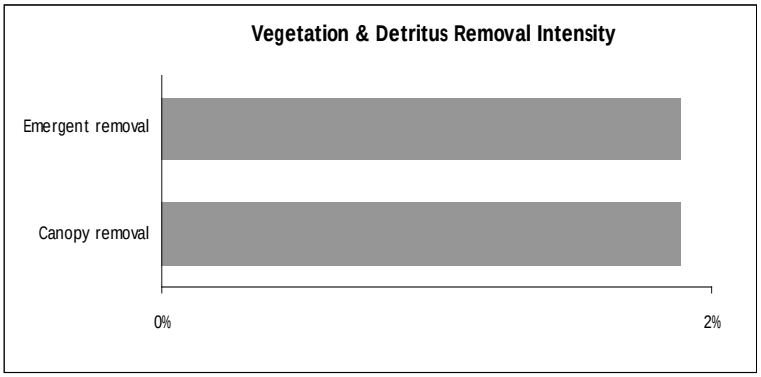


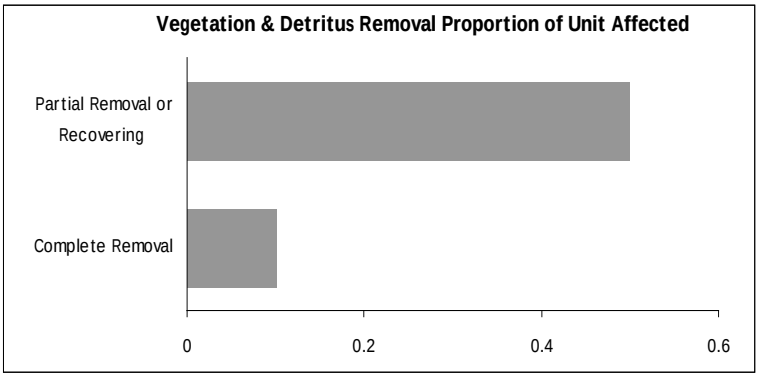


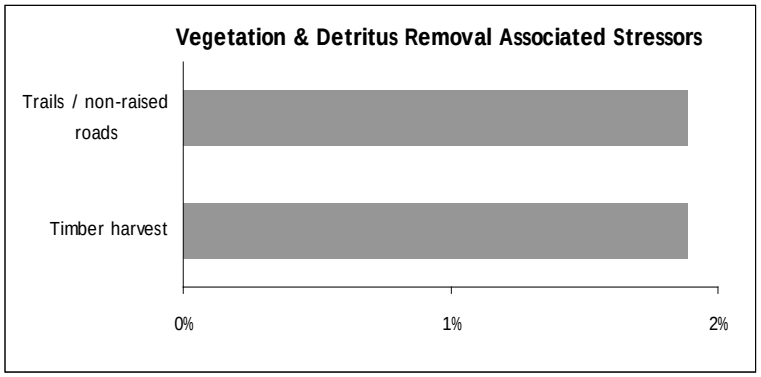


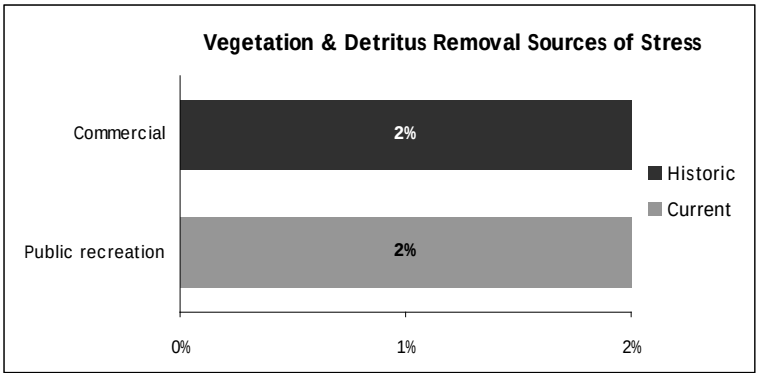


C.8 Vegetation and detritus removal

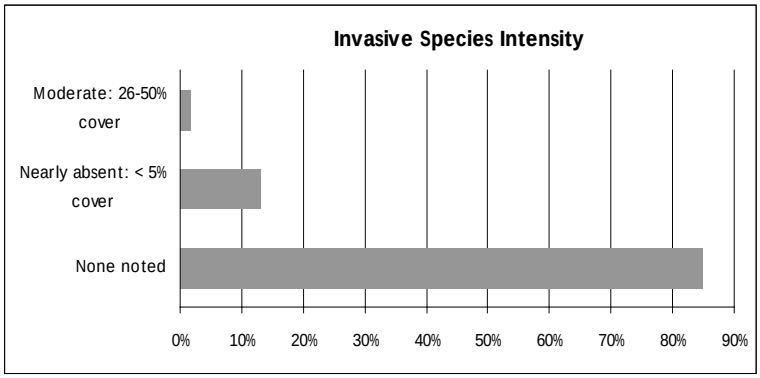


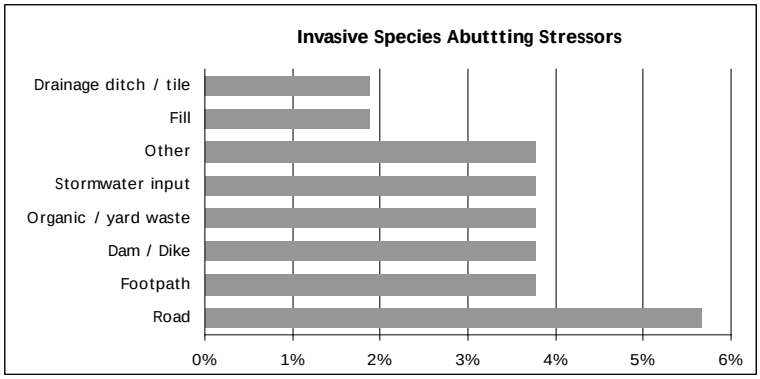


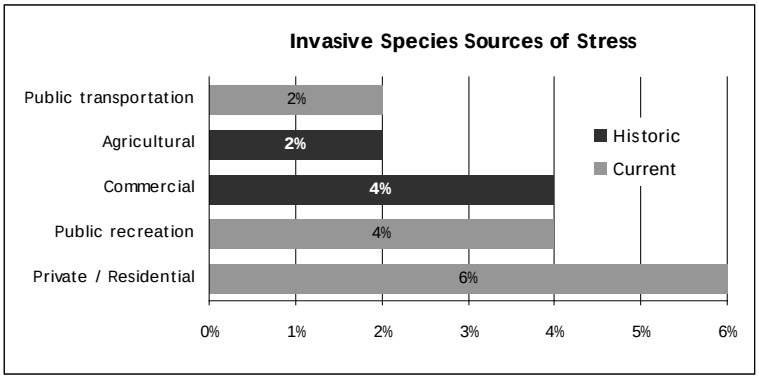


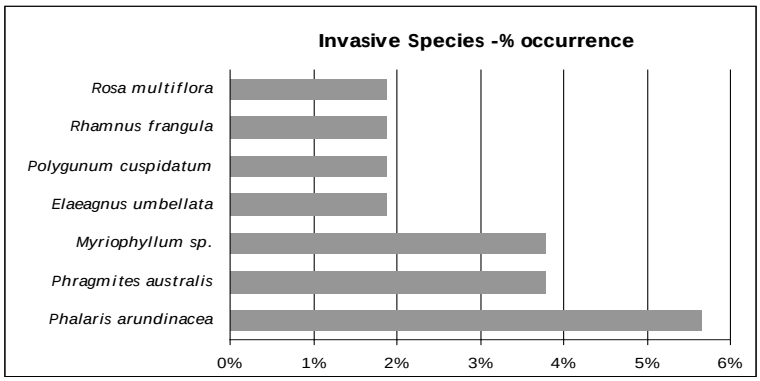


C.9 Invasive species

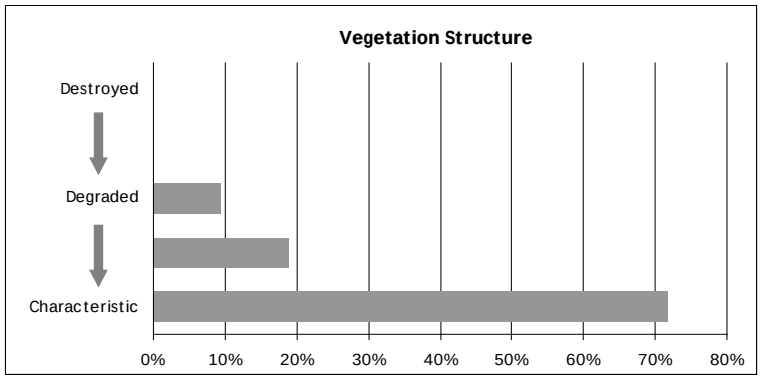


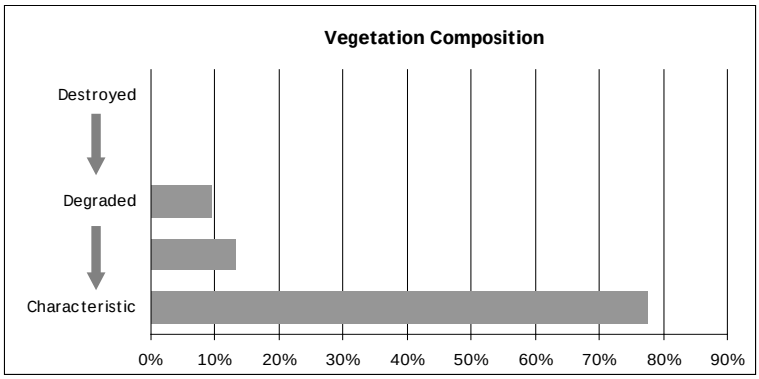


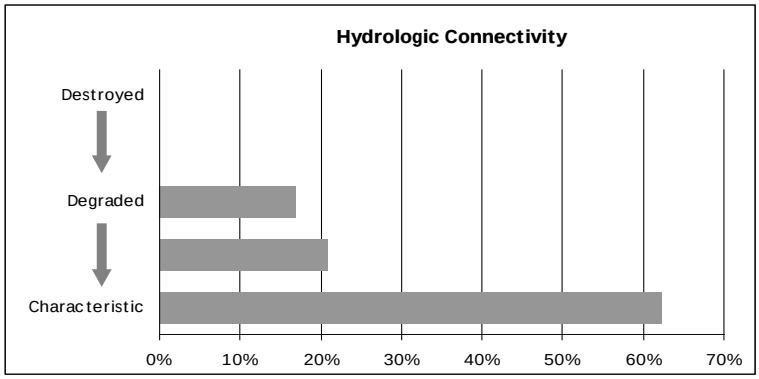


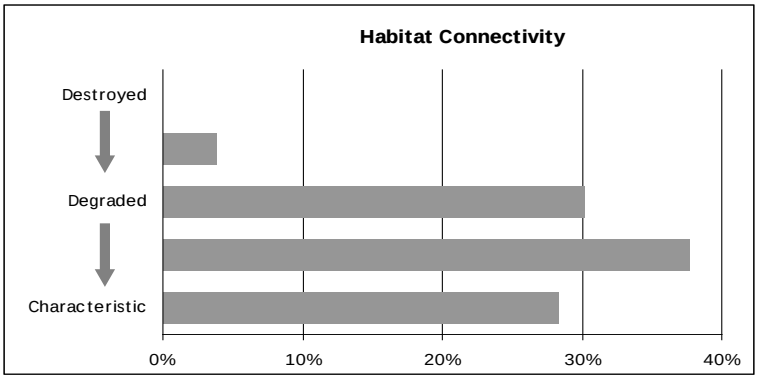


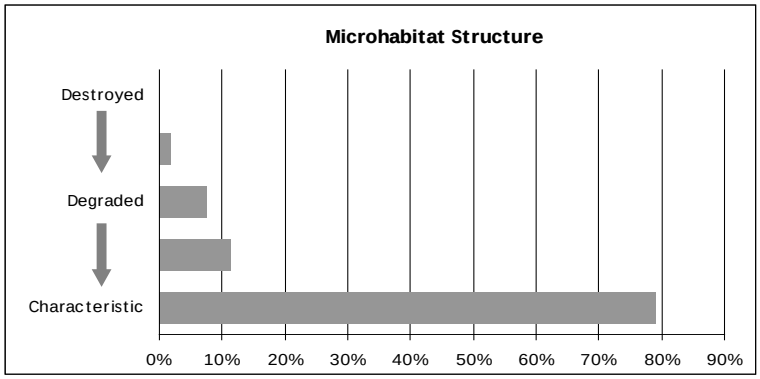
D. Net result of cumulative stress

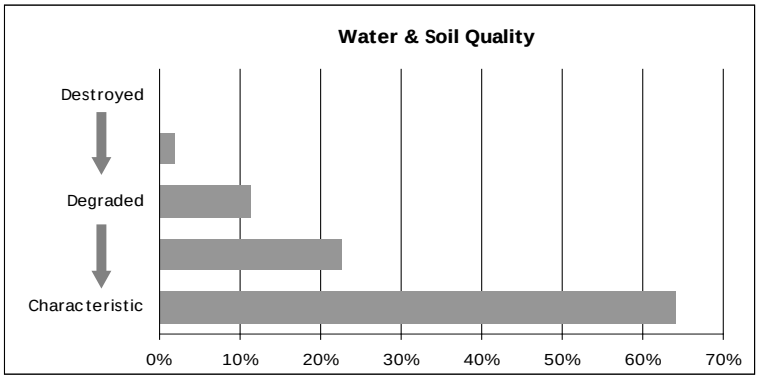




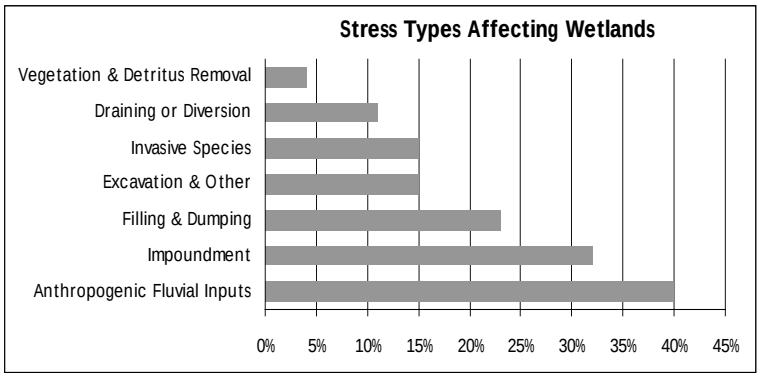


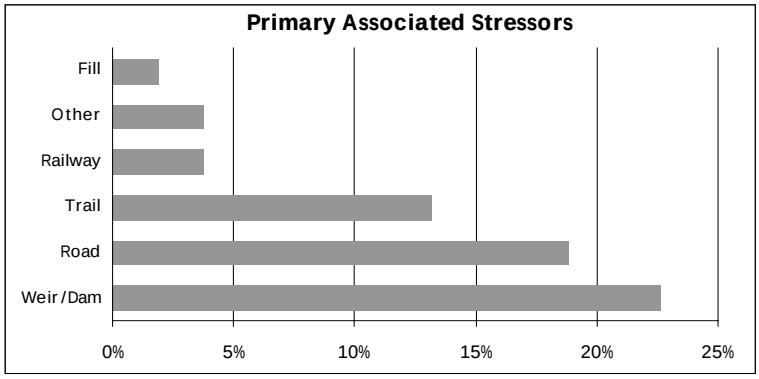


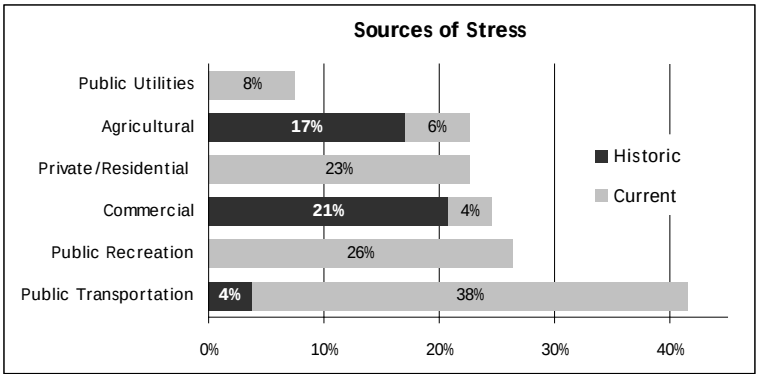


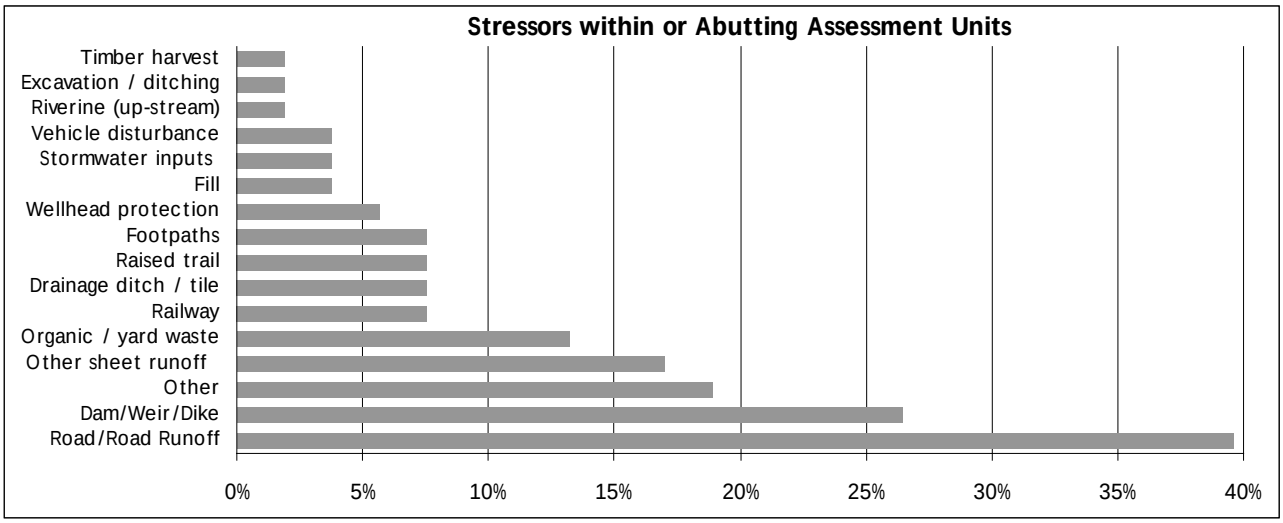


E. Other: summary statistics across all assessment units



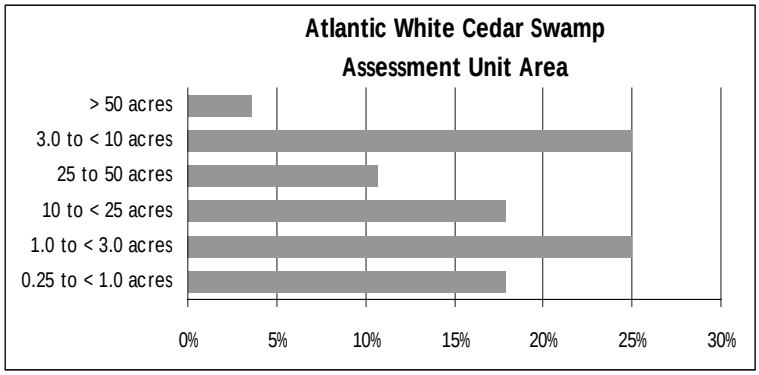


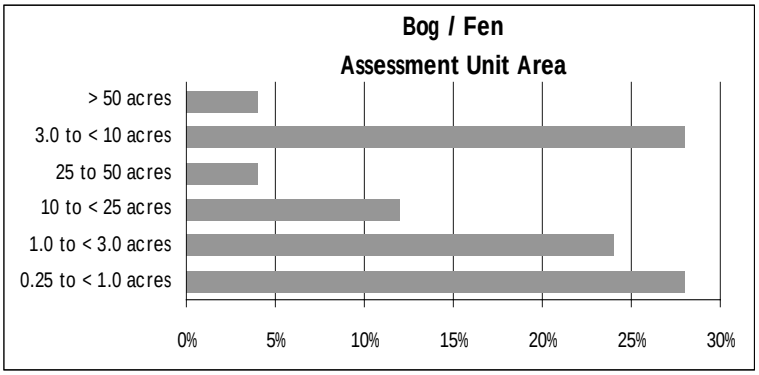


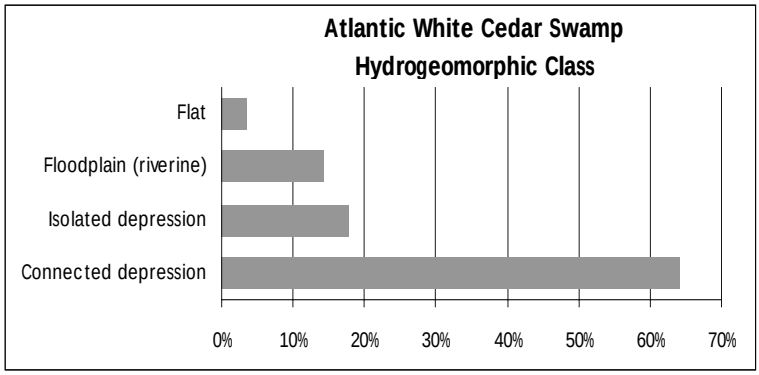


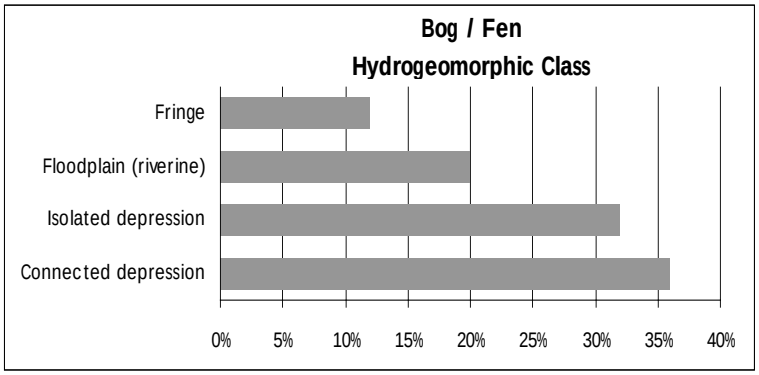
II. Summary attribute and metric statistics by Wetland Type: Atlantic White Cedar Swamp & Bogs/Fens

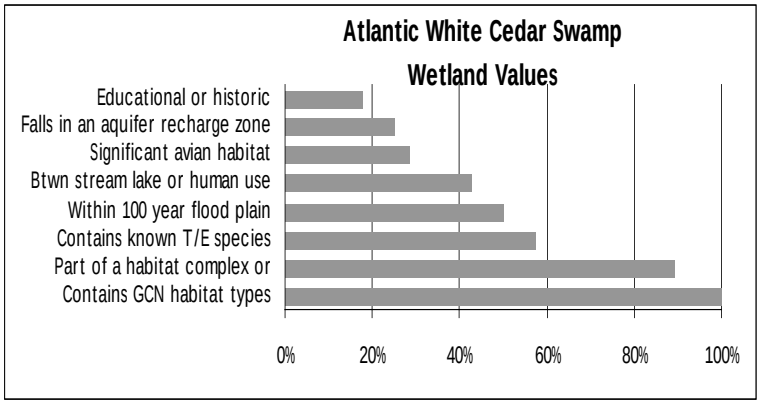
A. Wetland Characteristics

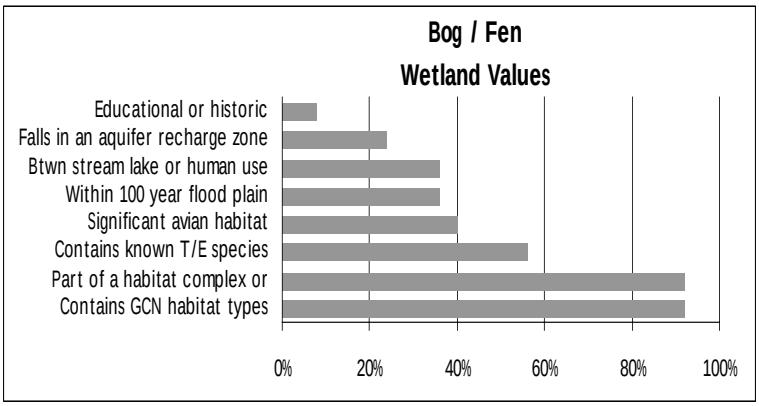






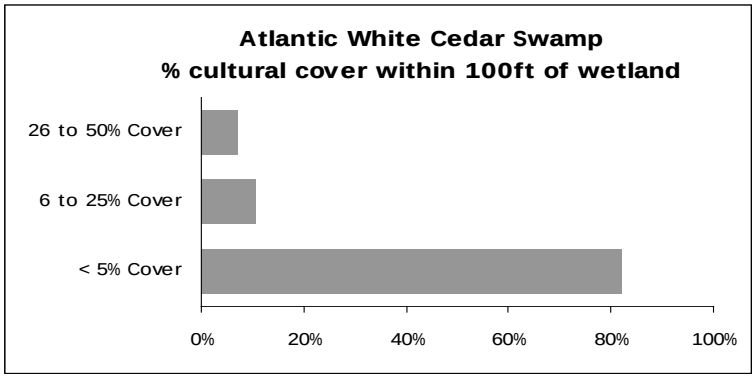


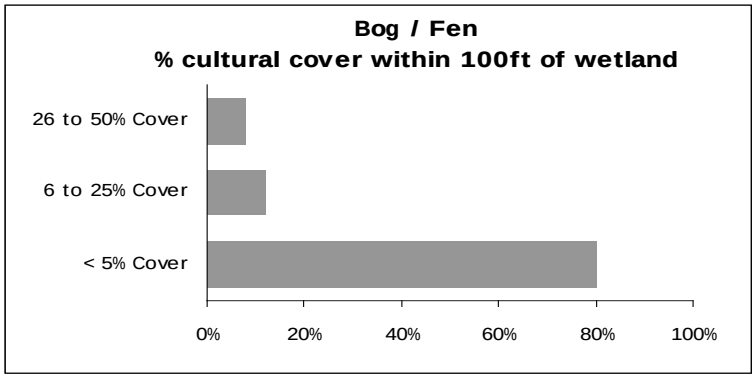


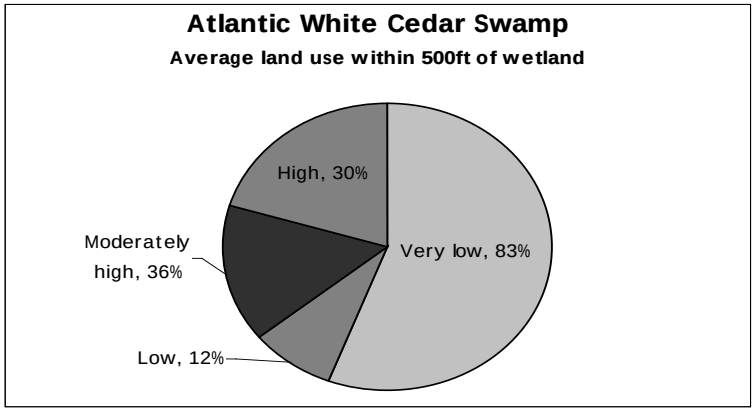


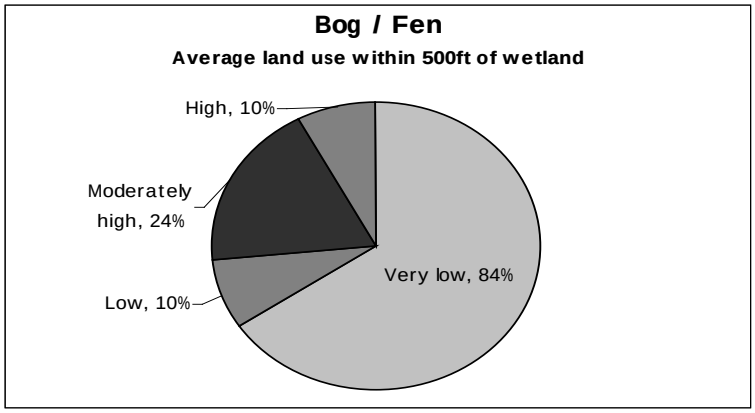
B. Stresses within the surrounding landscape

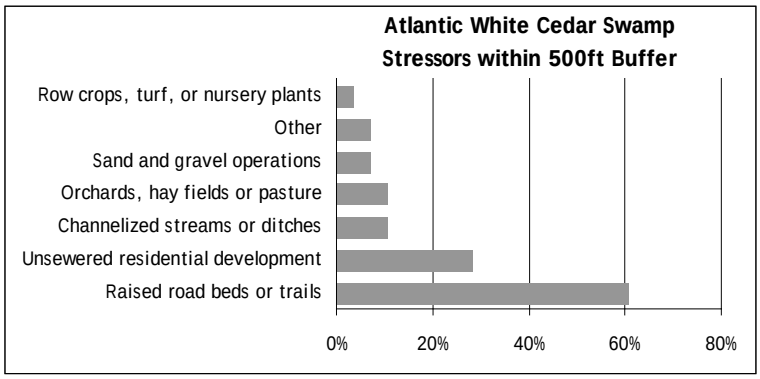
B.1 & B.2 Degradation of 100ft & 500ft Buffers

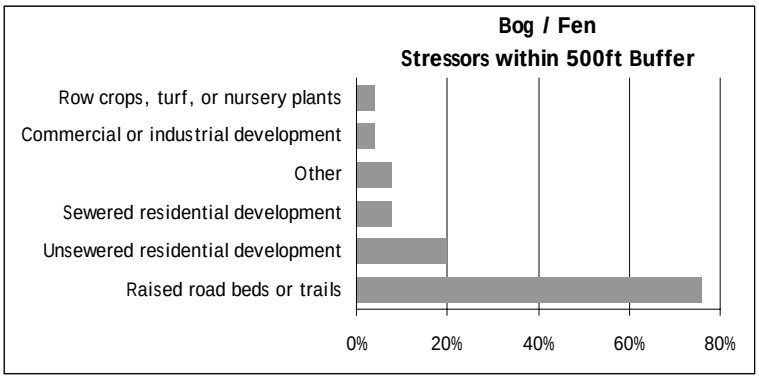








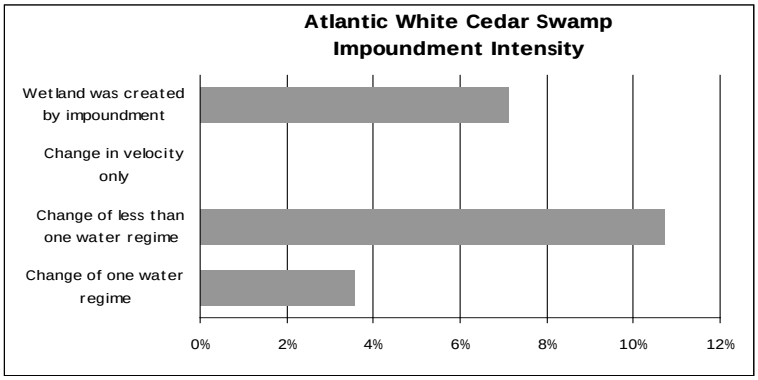


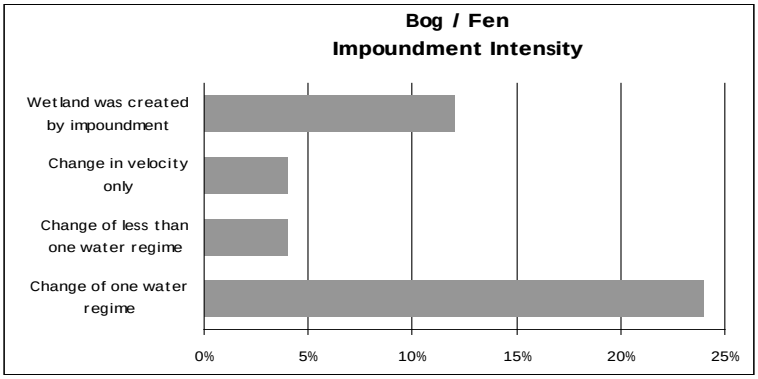


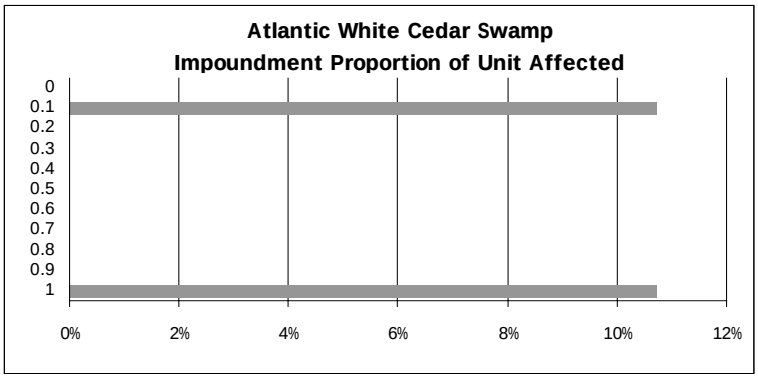
C. Stresses affecting assessment units

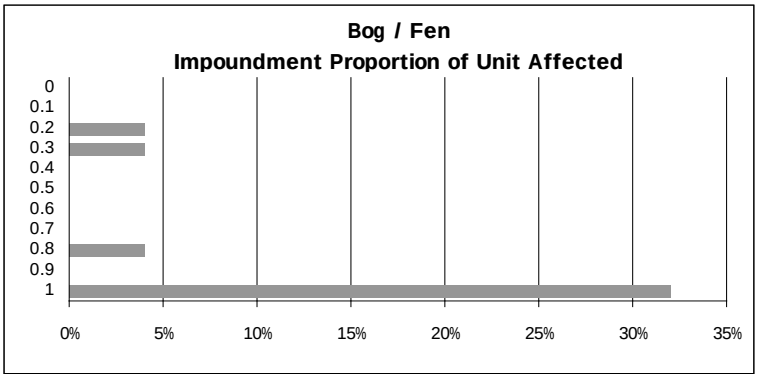
C.3 Impoundment within or abutting wetland

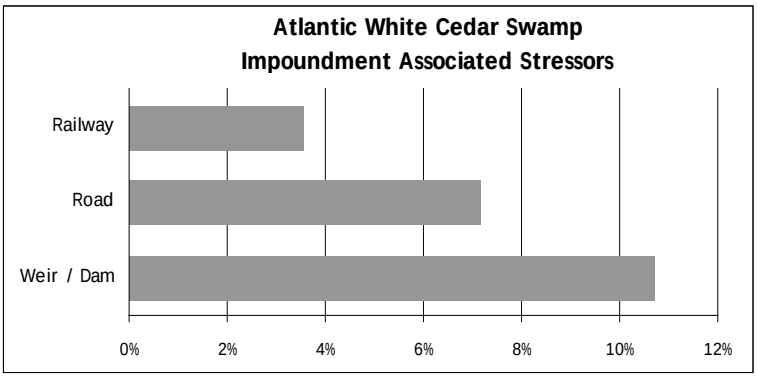
C.3.a Increase in depth or hydroperiod

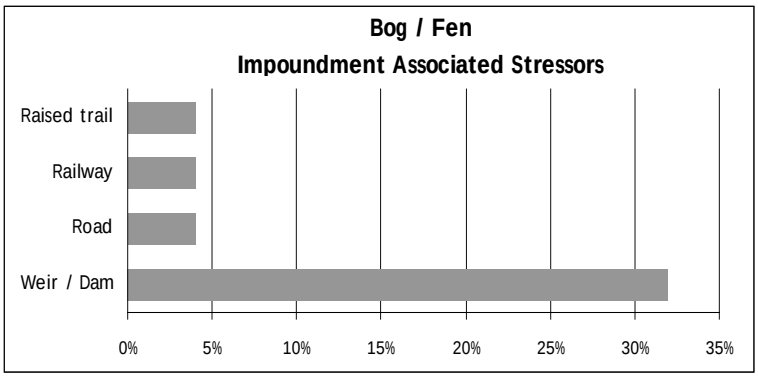


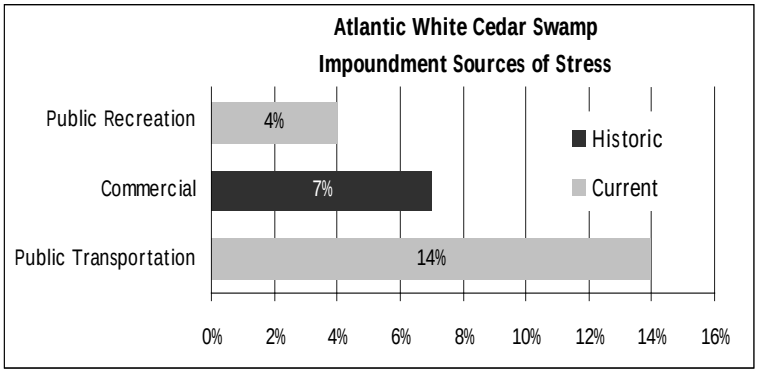


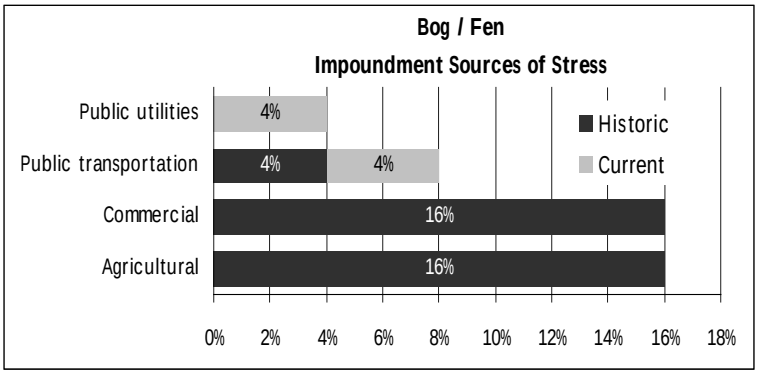




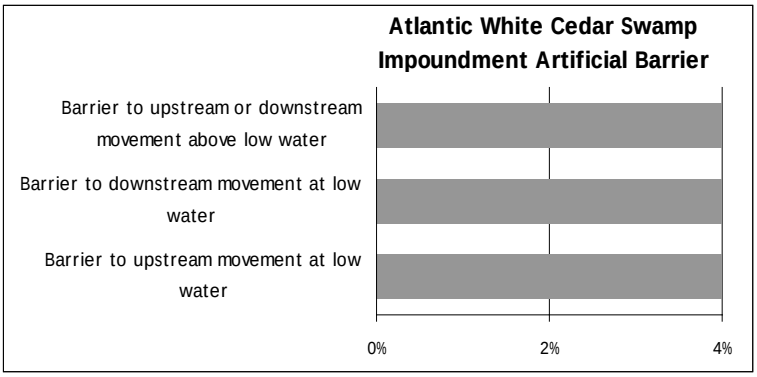


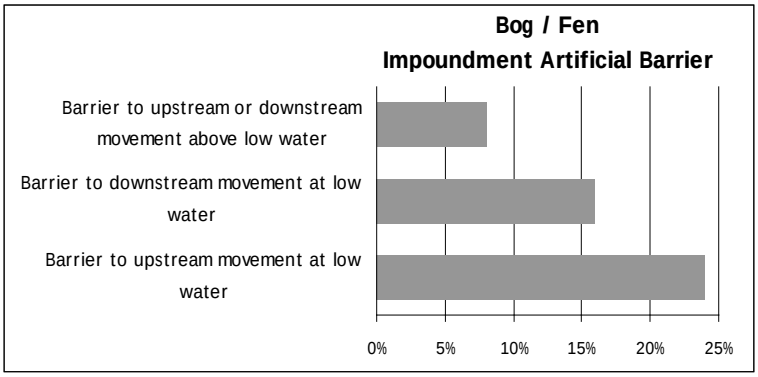






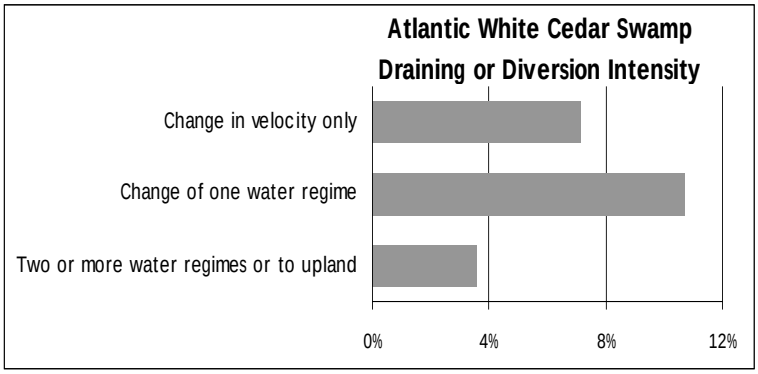
C.3.b Artificial barrier to movement of resources through water

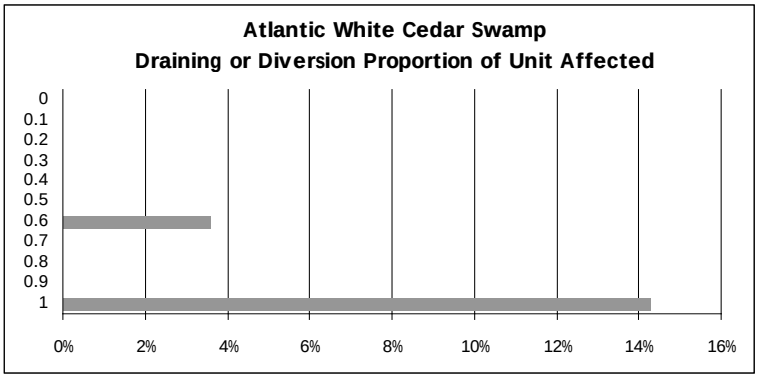

Atlantic White Cedar Swamp
Impoundment Artificial Barrier
Barrier to upstream or downstream movement above low water
Barrier to downstream movement at low water
Barrier to upstream movement at low water
0%
2%
4%

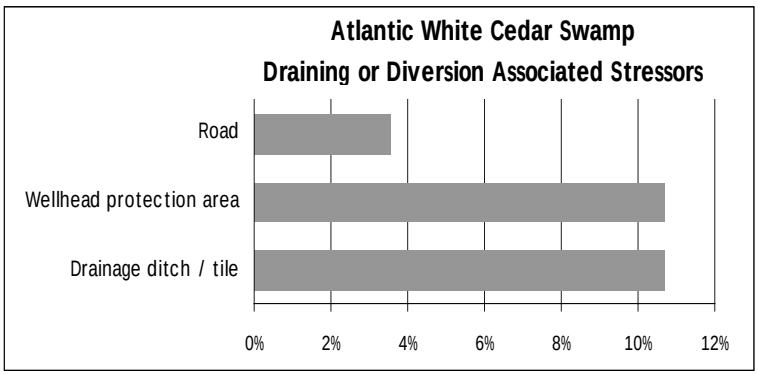

Bog / Fen
Impoundment Artificial Barrier
Barrier to upstream or downstream movement above low water
Barrier to downstream movement at low water
Barrier to upstream movement at low water
0%
5%
10%
15%
20%
25%

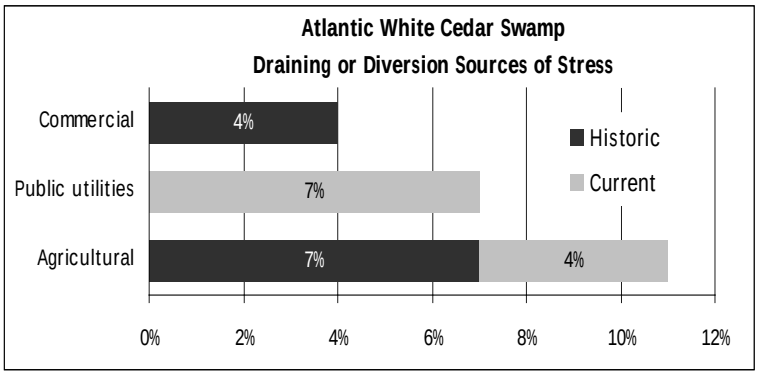
C.4 Draining or diversion

* No Bog or Fen type wetlands had draining or diversion stressors

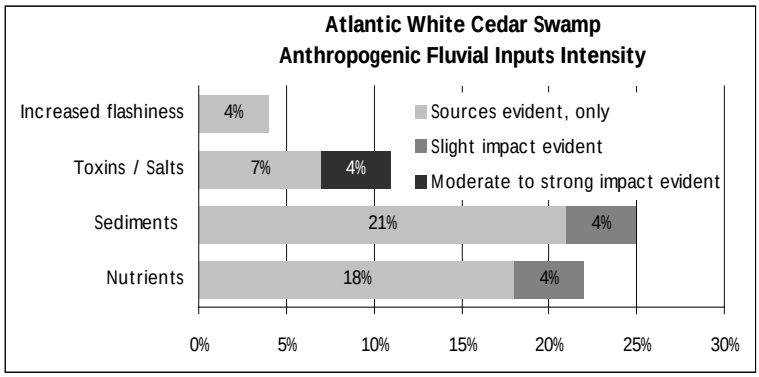


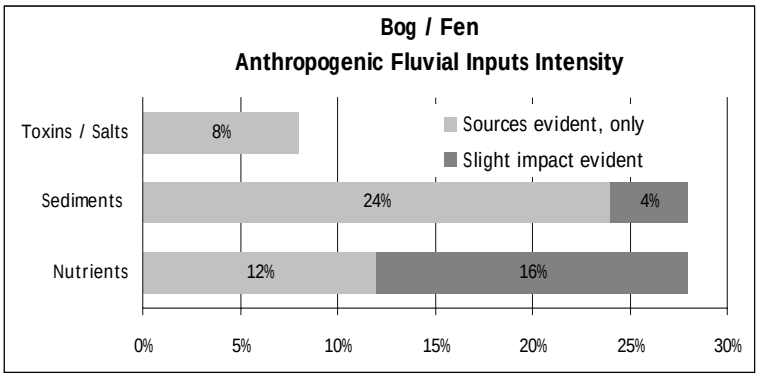


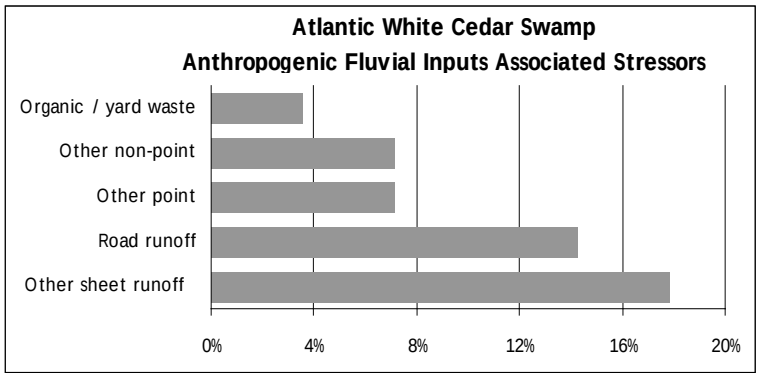


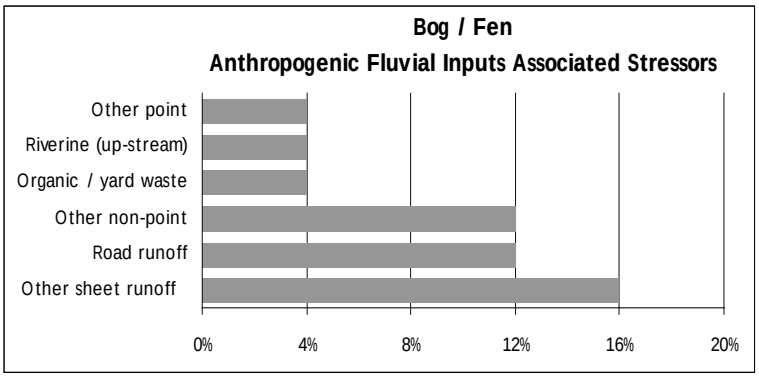


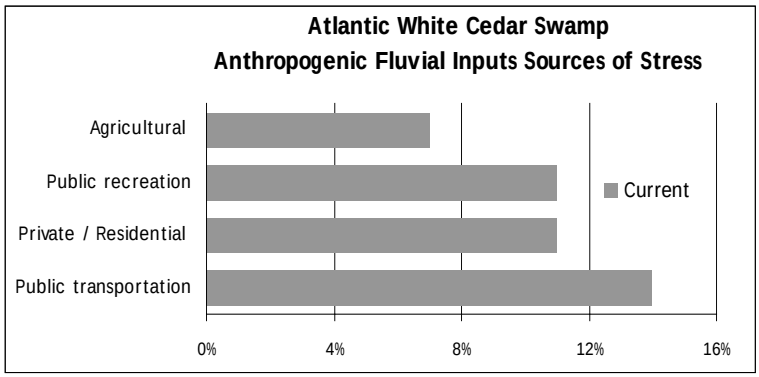
C.5 Anthropogenic fluvial inputs

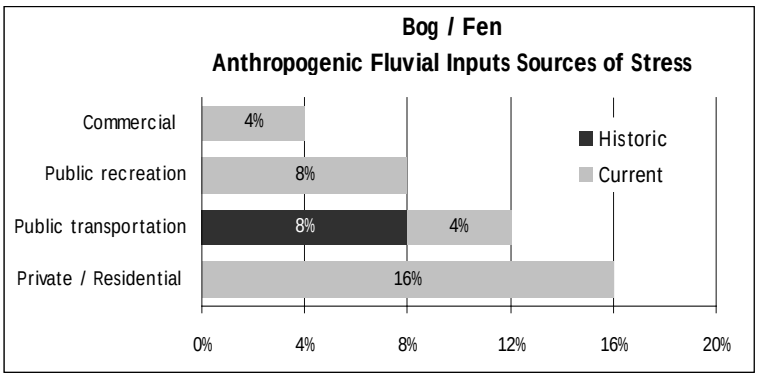




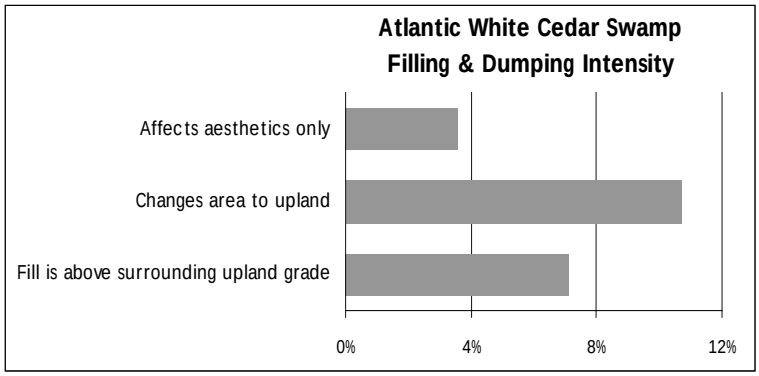


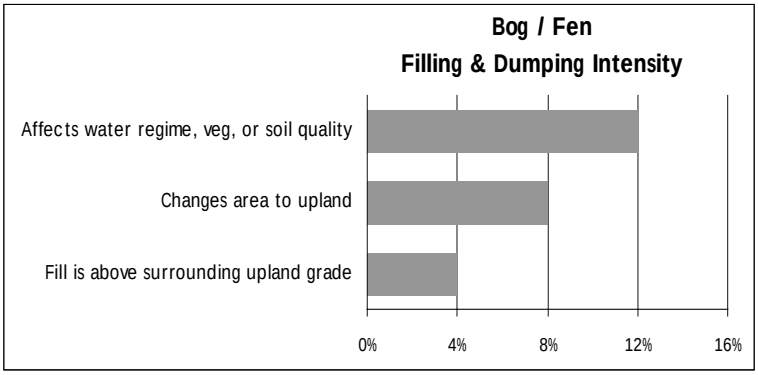


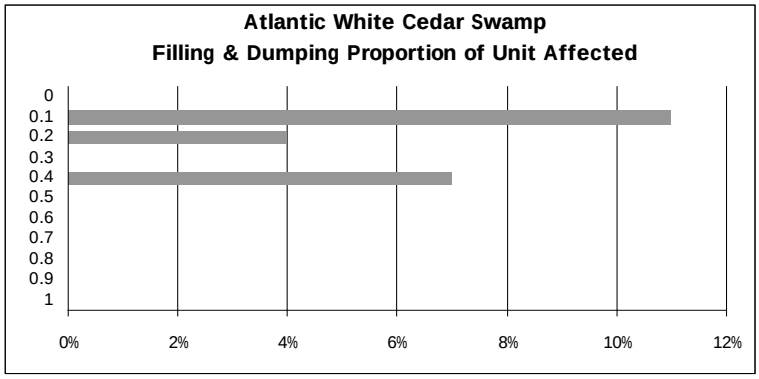


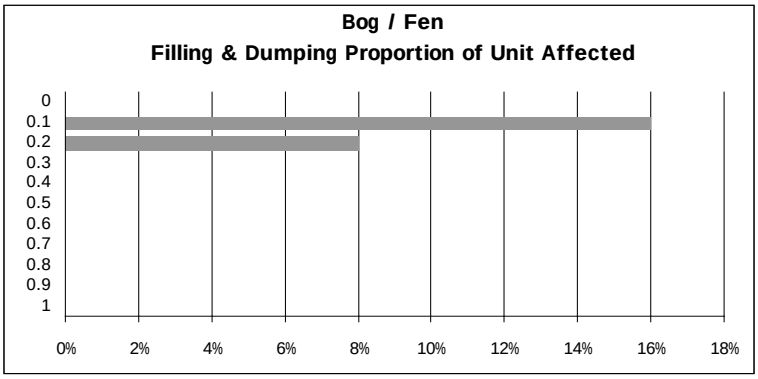


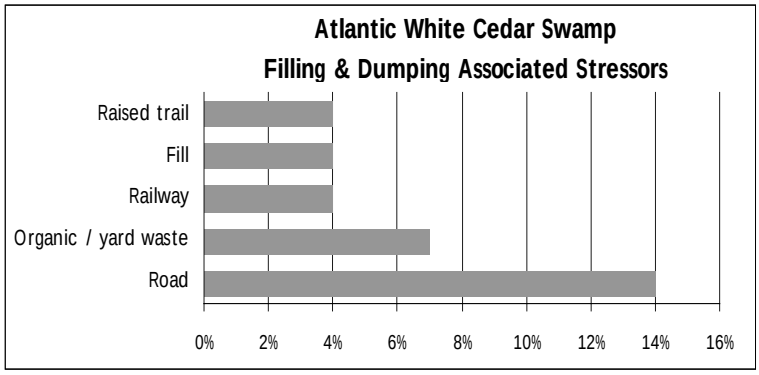
C.6 Filling & dumping

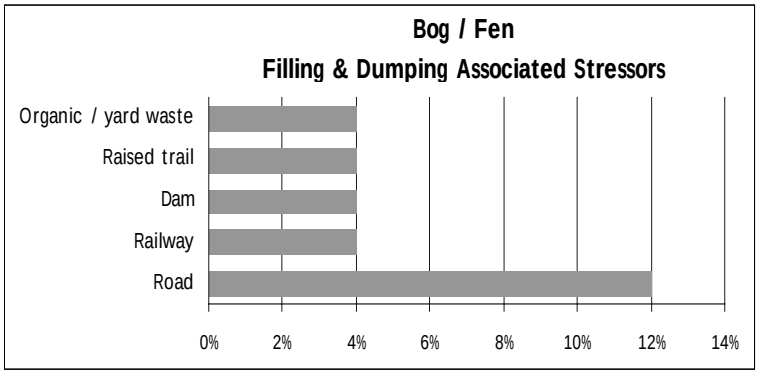


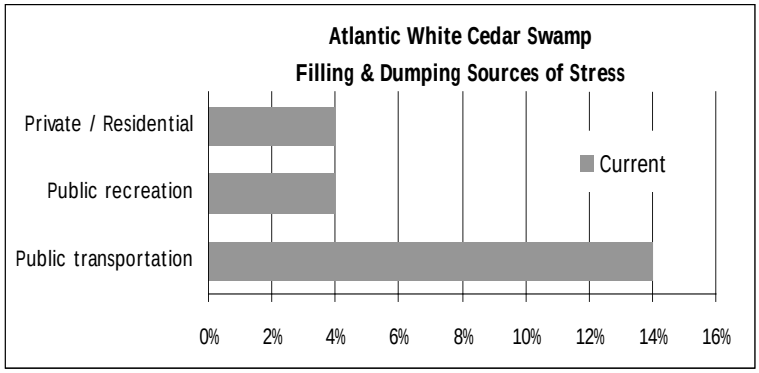


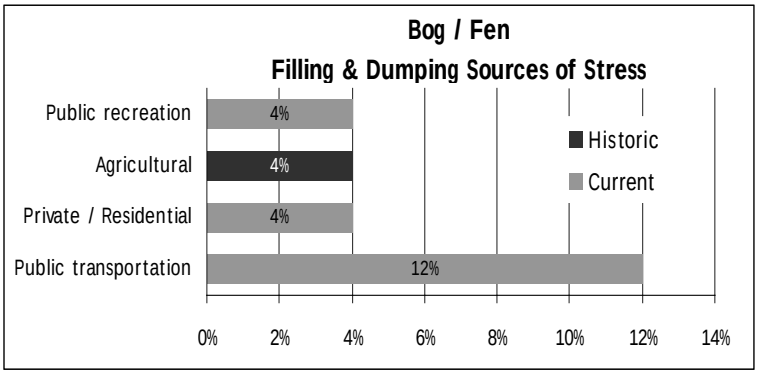




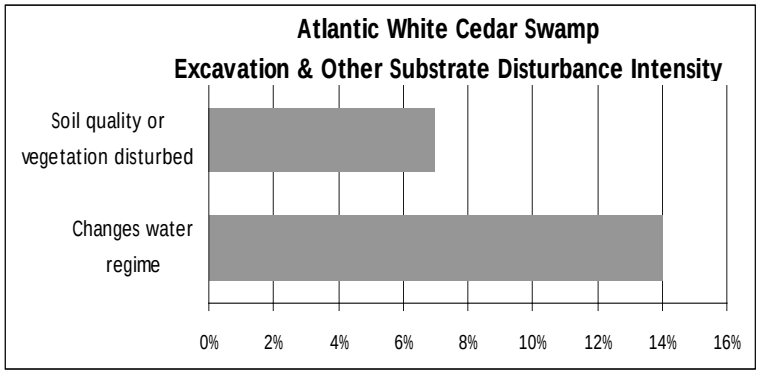


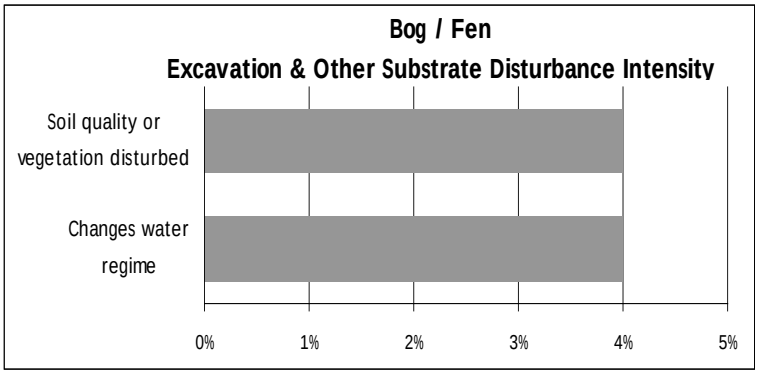


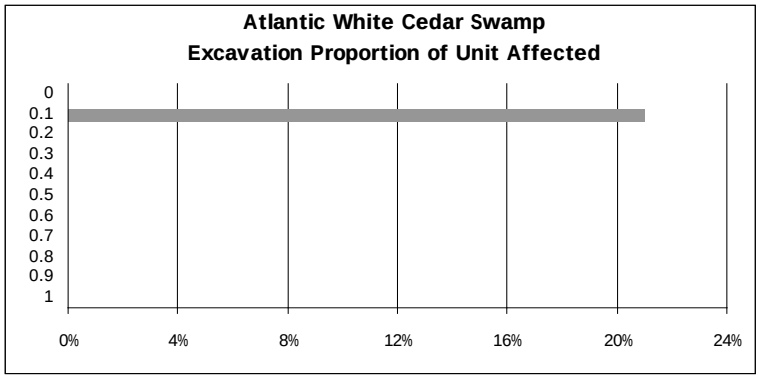


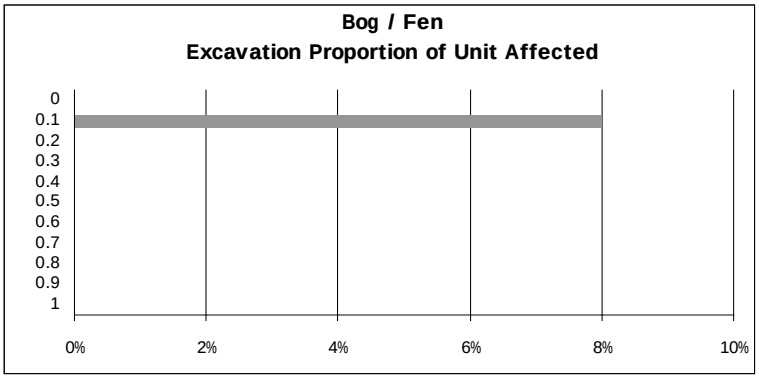


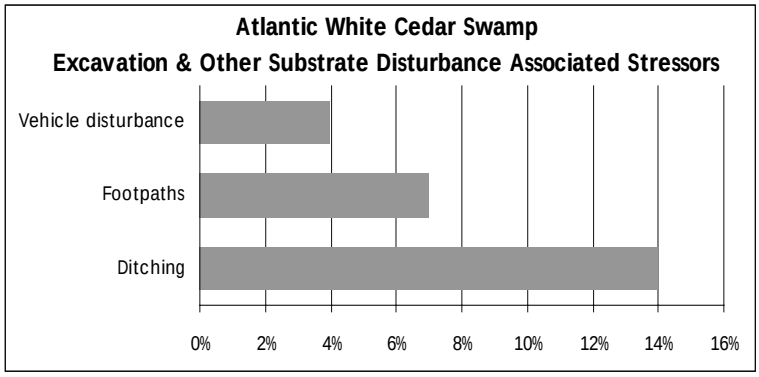
C.7 Excavation and other substrate disturbance

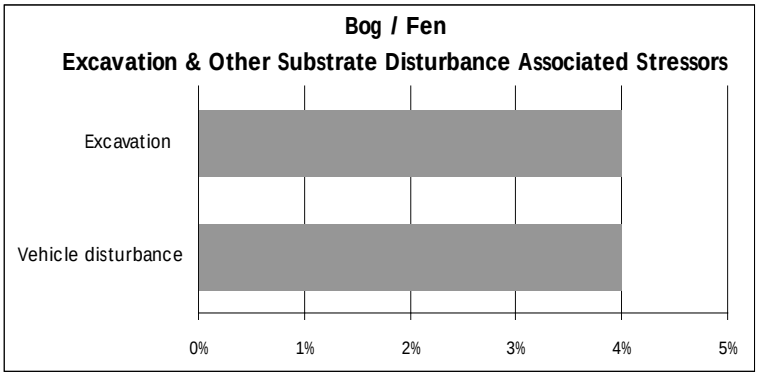


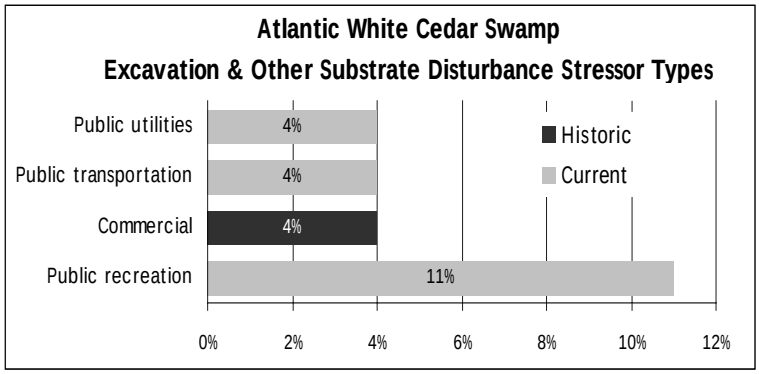


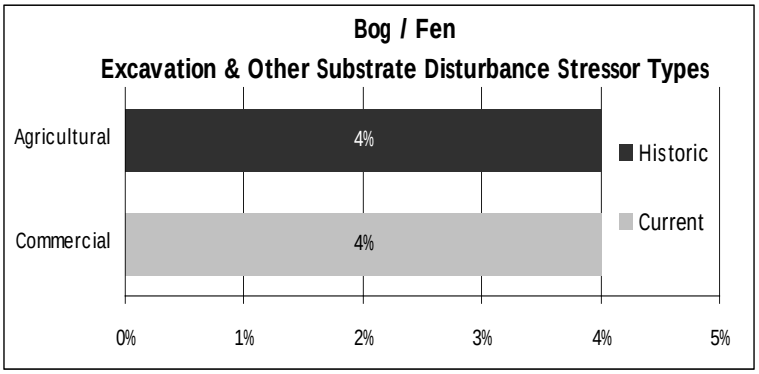






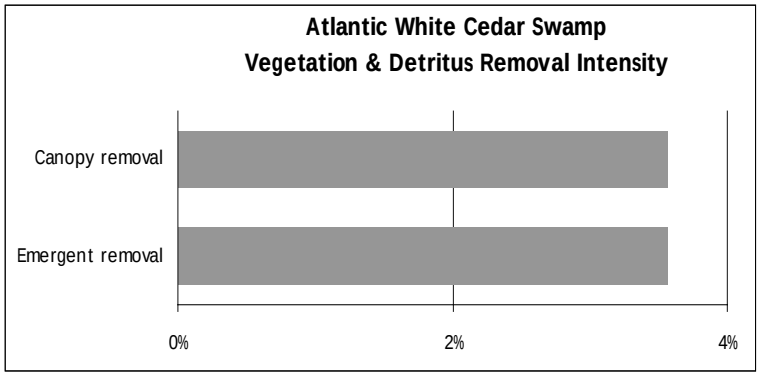


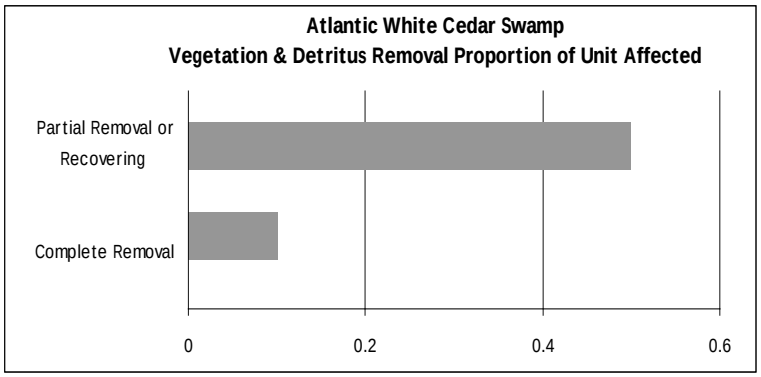


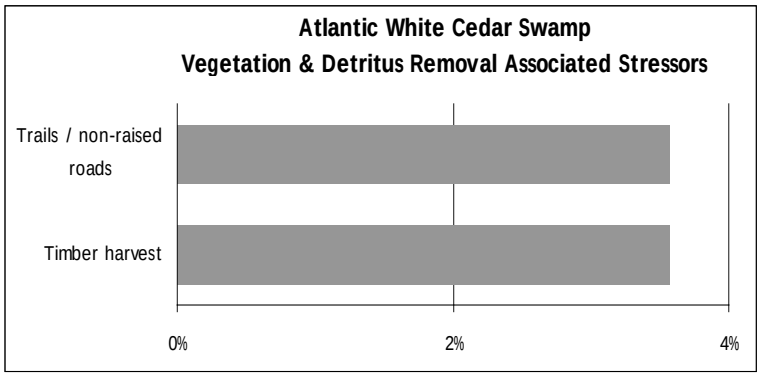


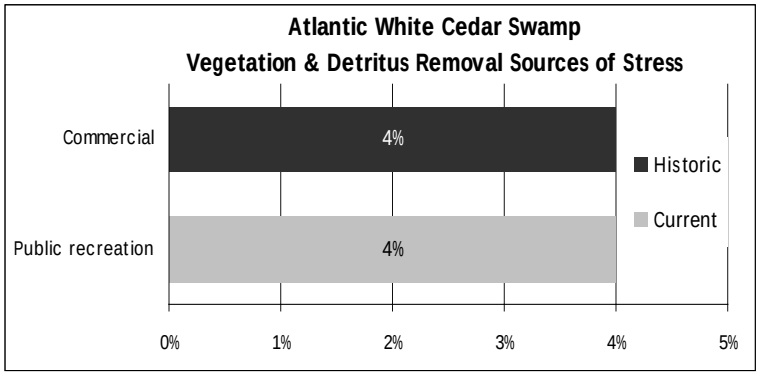
C.8 Vegetation and detritus removal

* No Bog or Fen type wetlands had draining or diversion stressors

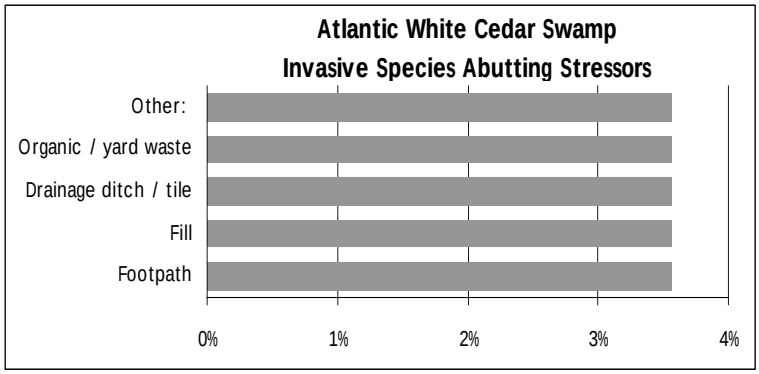


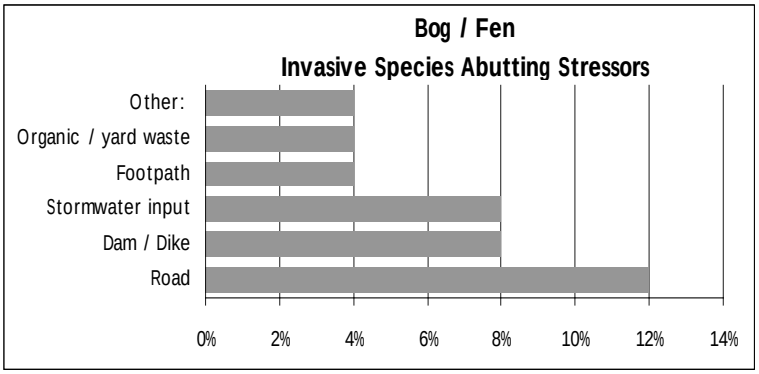


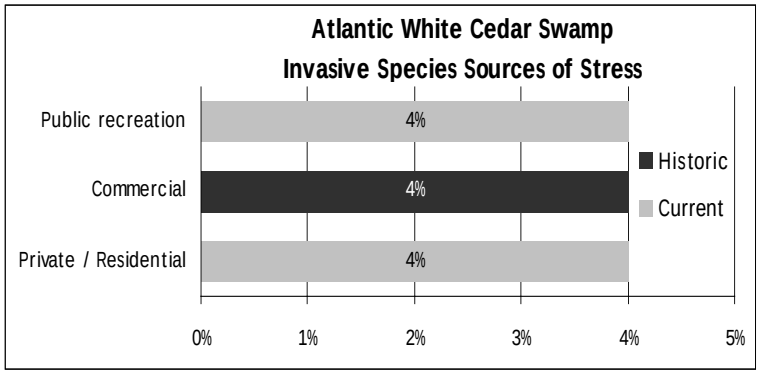


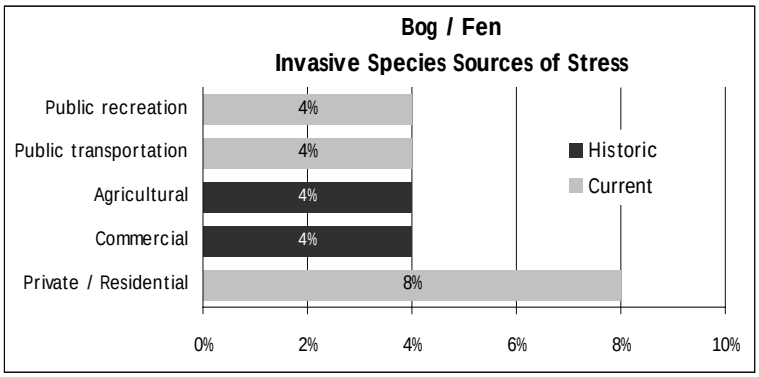


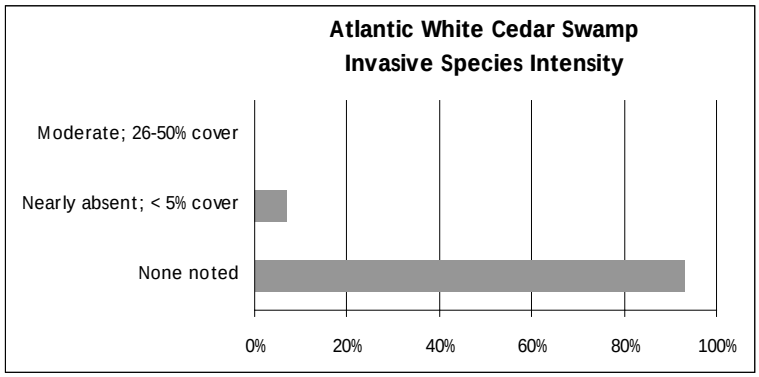
C.9 Invasive species

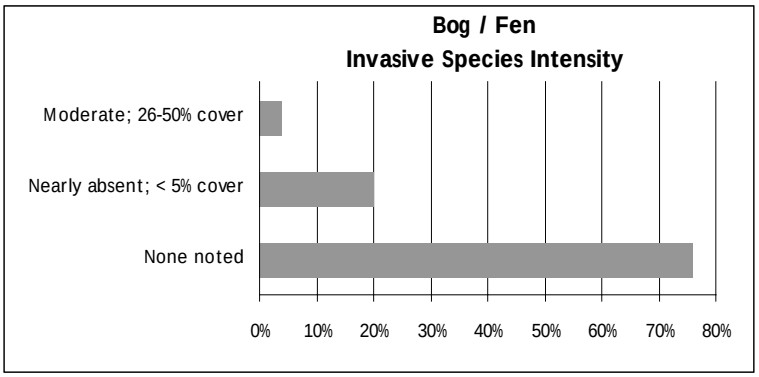


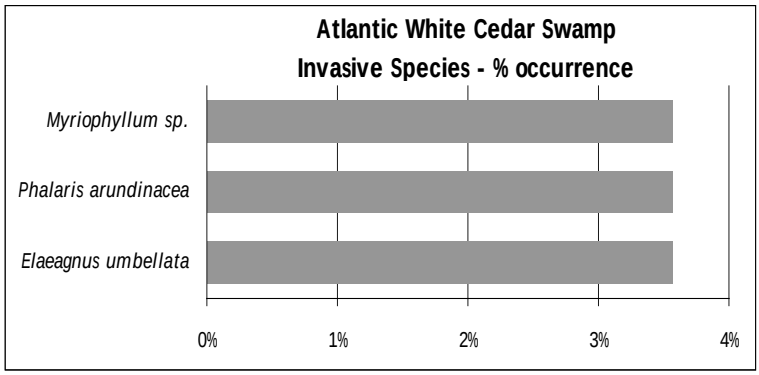


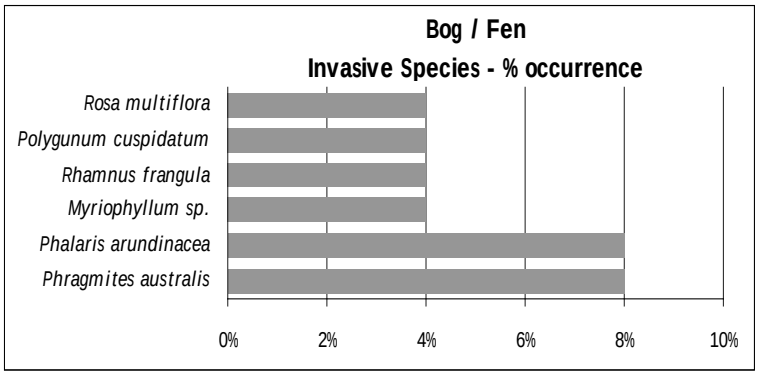




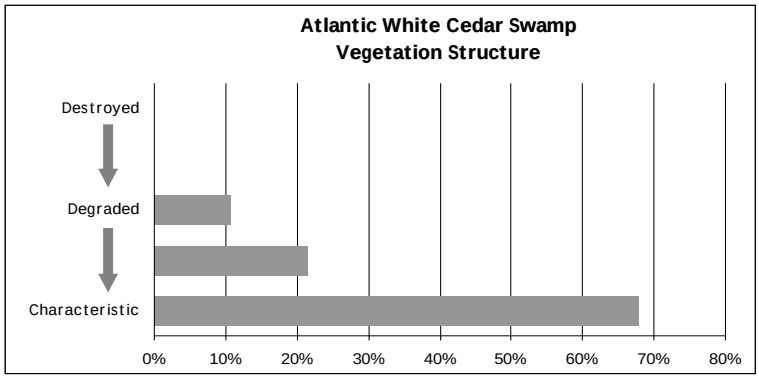


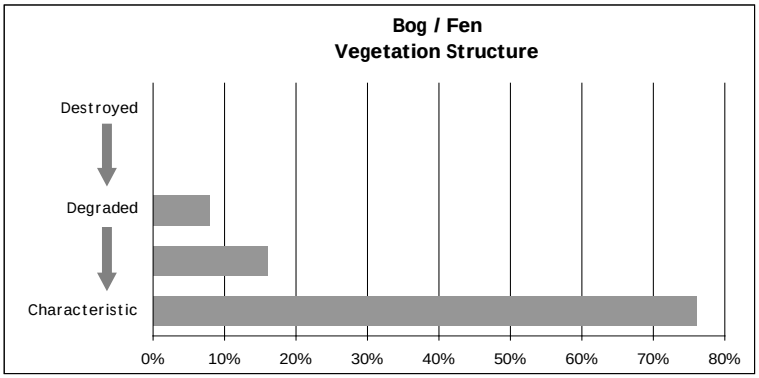


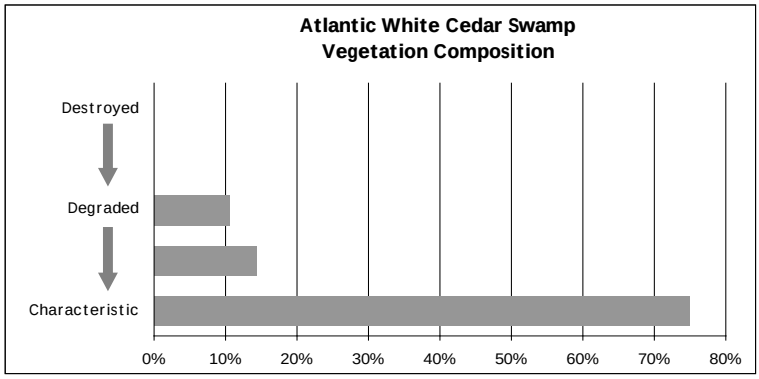


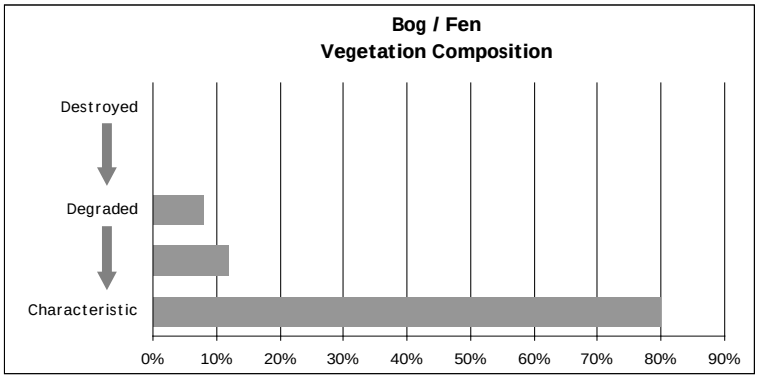


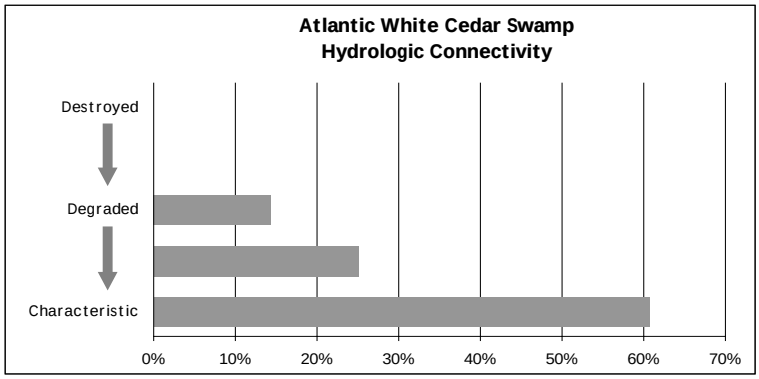
D. Net result of cumulative stress

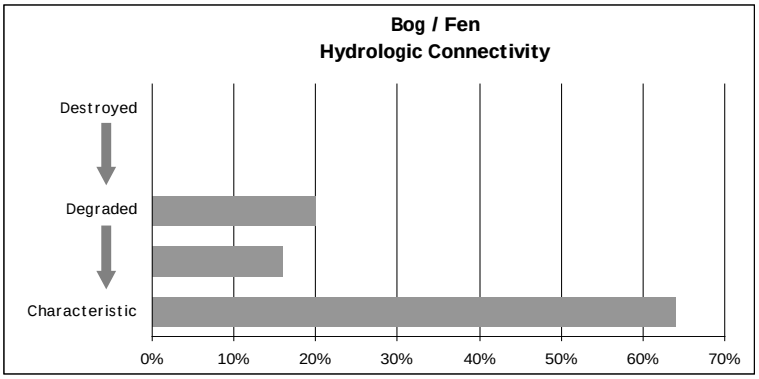


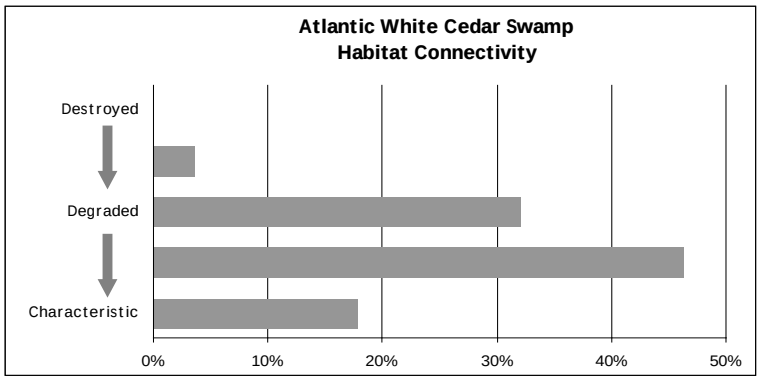


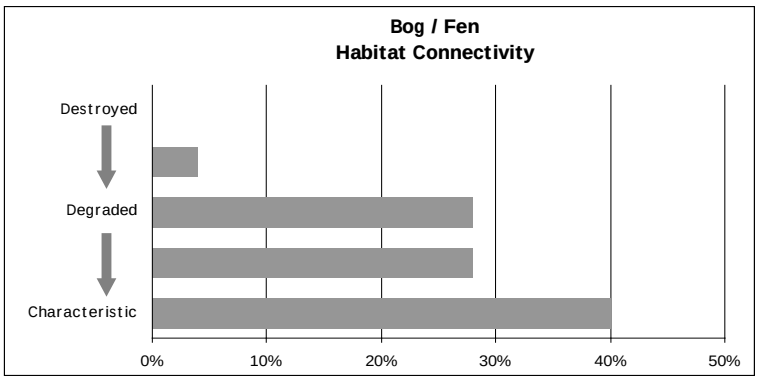


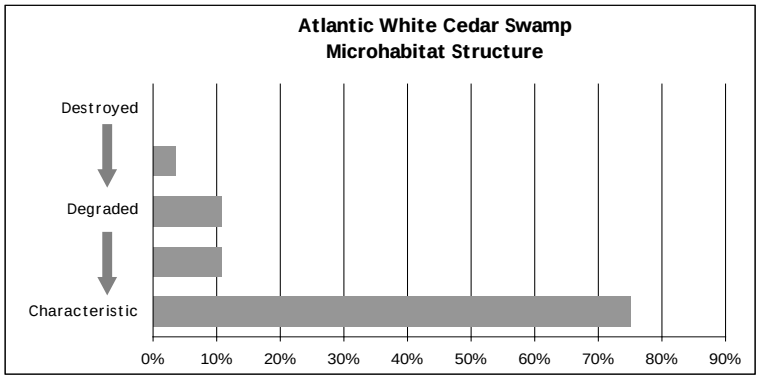


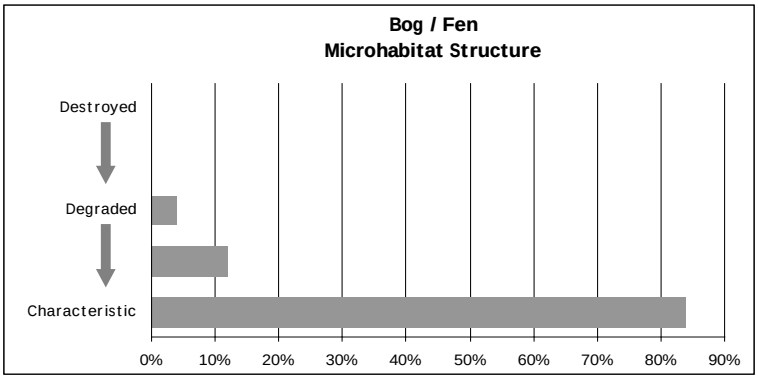


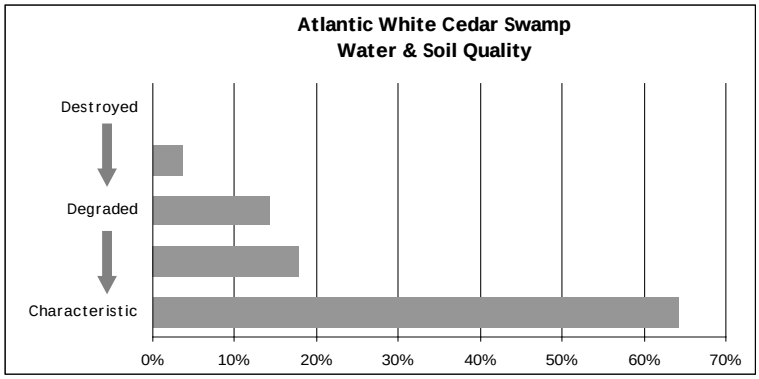


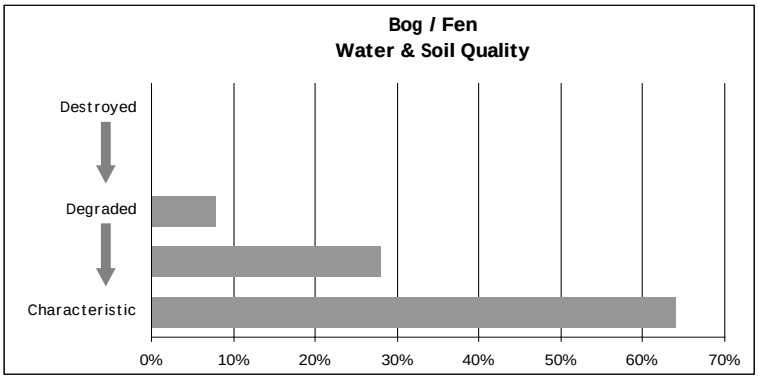




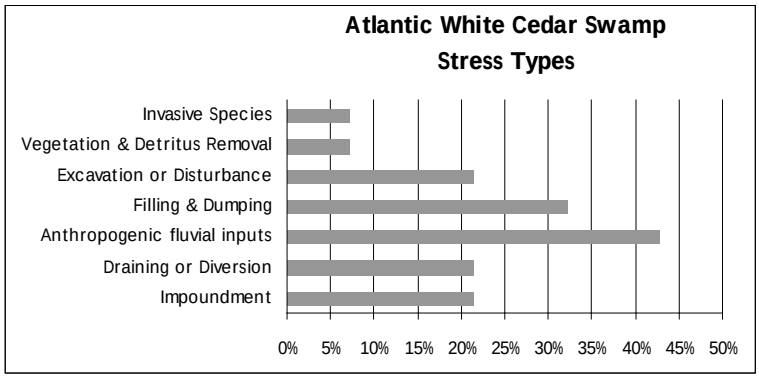

Atlantic White Cedar Swamp
Microhabitat Structure
Destroyed
Degraded
Characteristic
0%
10%
20%
30%
40%
50%
60%
70%
80%
90%

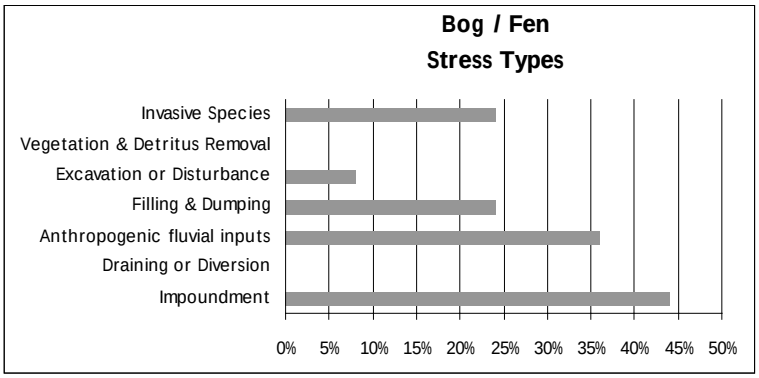

Bog / Fen
Microhabitat Structure
Destroyed
Degraded
Characteristic
0%
10%
20%
30%
40%
50%
60%
70%
80%
90%

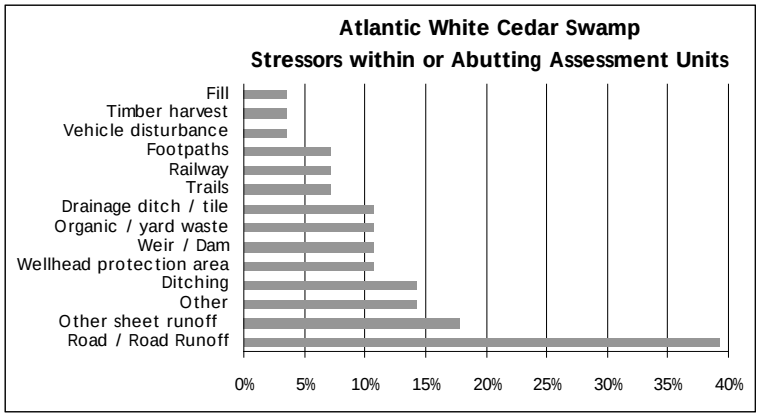

Atlantic White Cedar Swamp
Water & Soil Quality
Destroyed
Degraded
Characteristic
0%
10%
20%
30%
40%
50%
60%
70%

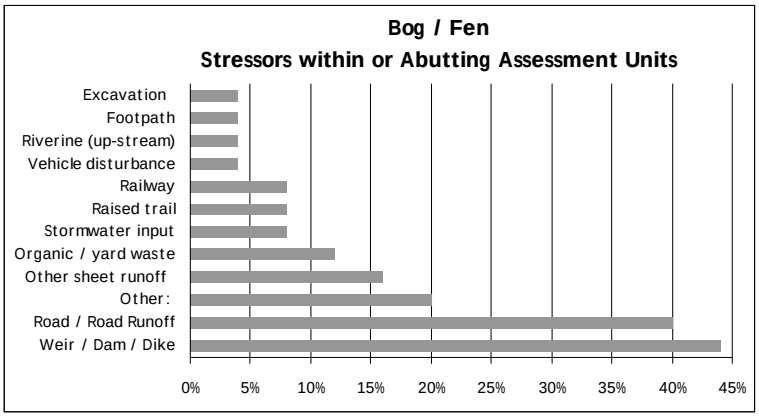

Bog / Fen
Water & Soil Quality
Destroyed
Degraded
Characteristic
0%
10%
20%
30%
40%
50%
60%
70%

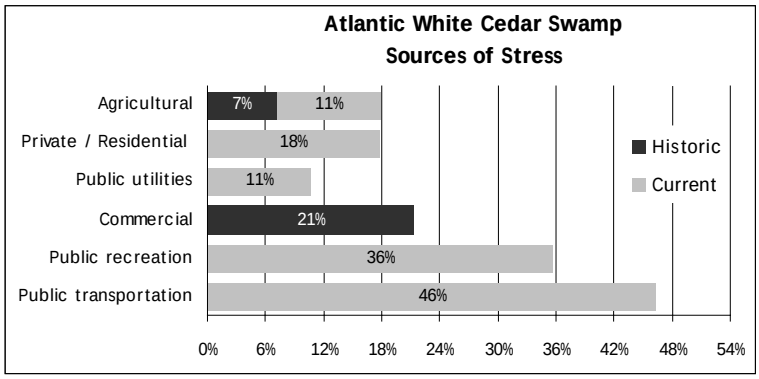
E. Other: summary statistics for wetland types

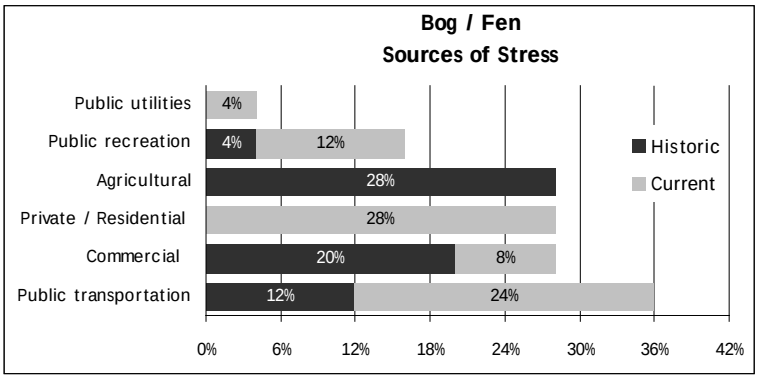






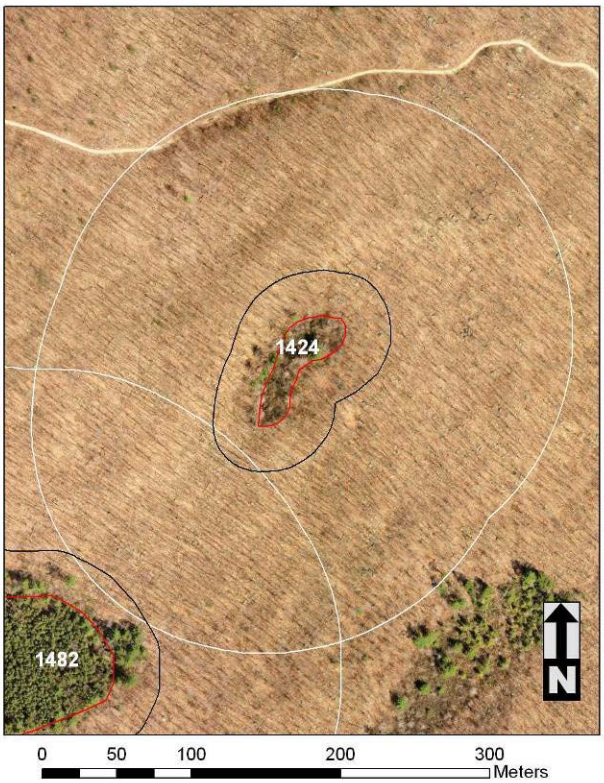


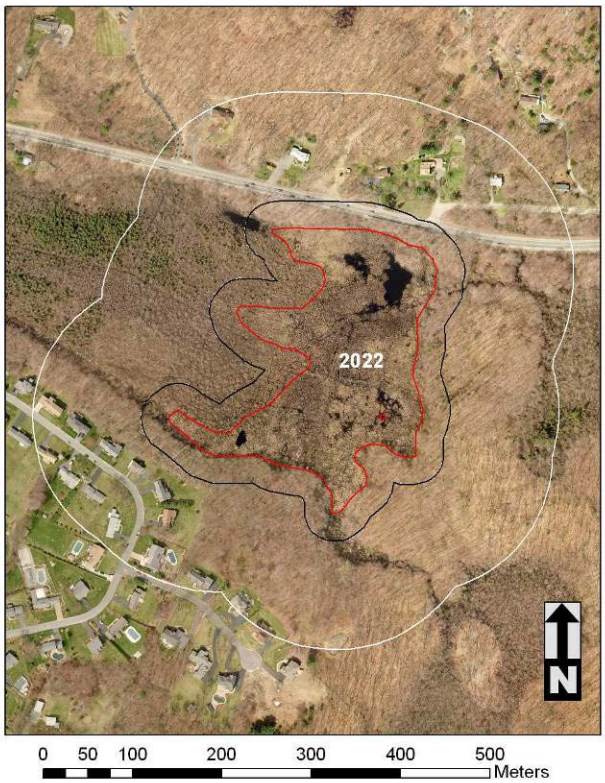


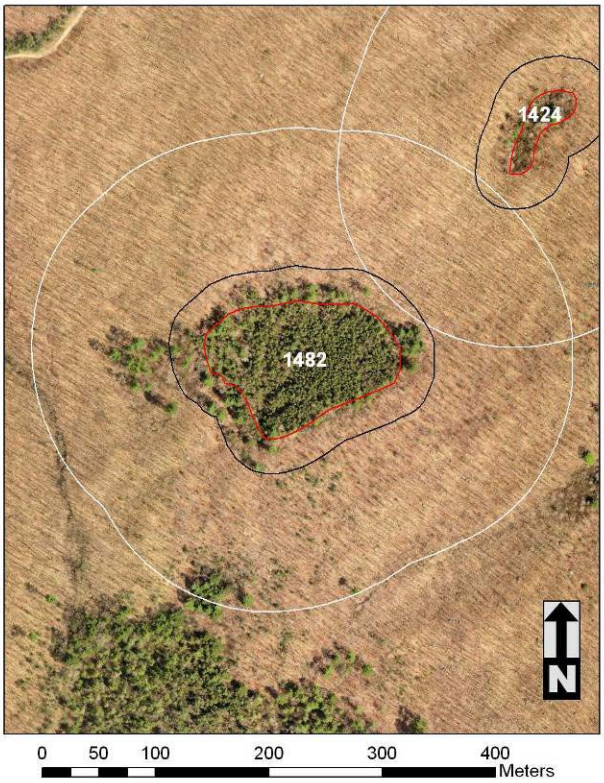


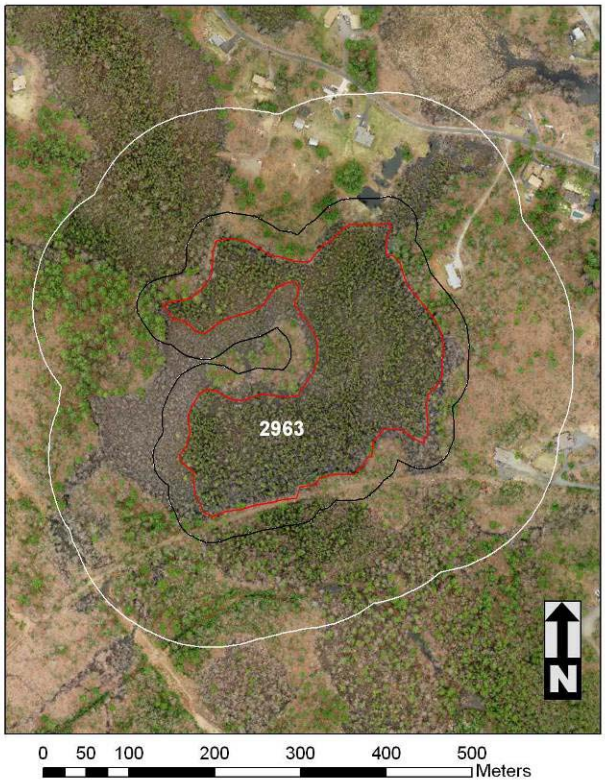
Appendix 4

Site Maps Depicting 2009 RIRAM Assessment Units and 100’ and 500’ Buffers





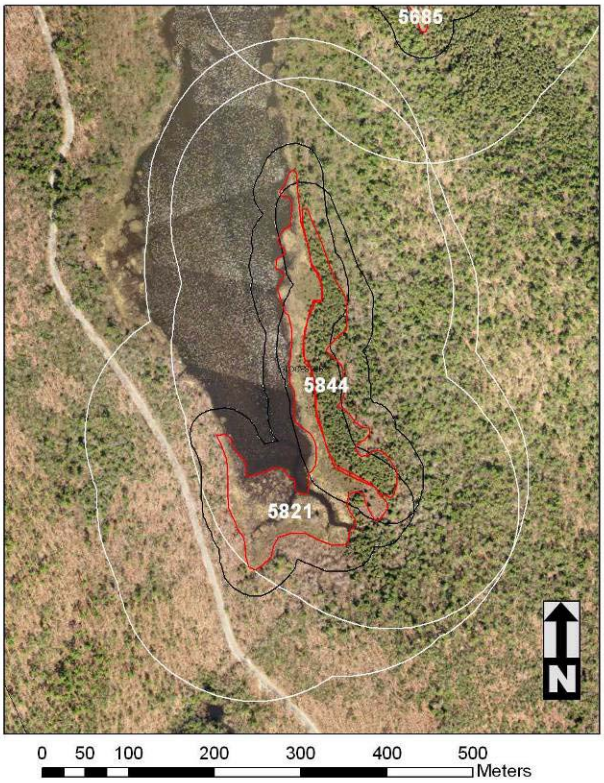




Study Sites 2009

100' Buffer

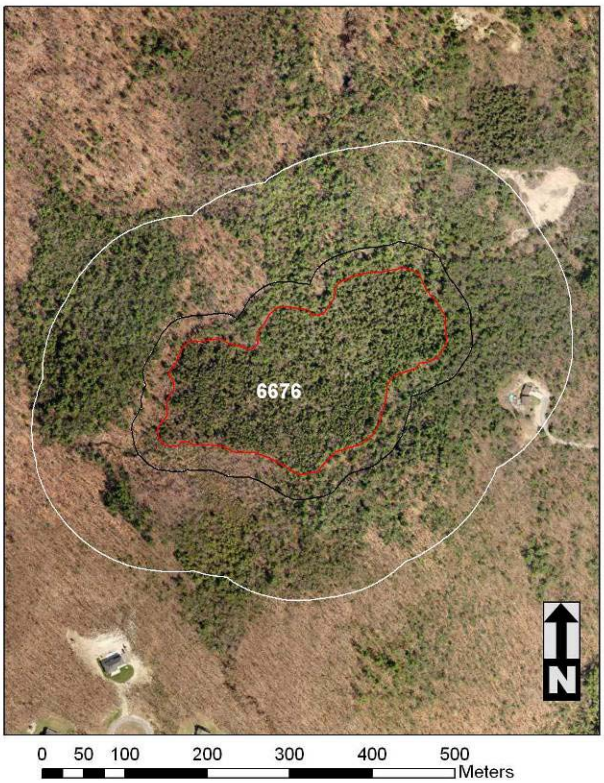
500' Buffer

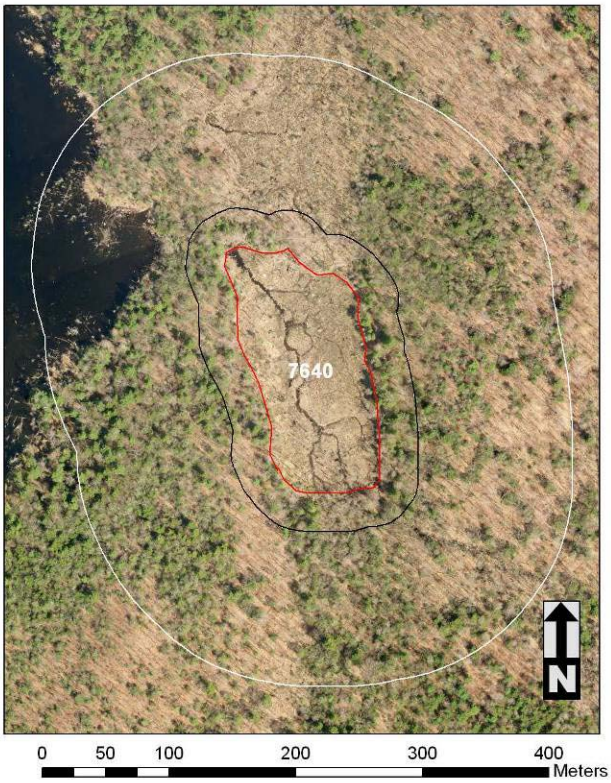


Study Sites 2009

100' Buffer

500' Buffer





Study Sites 2009

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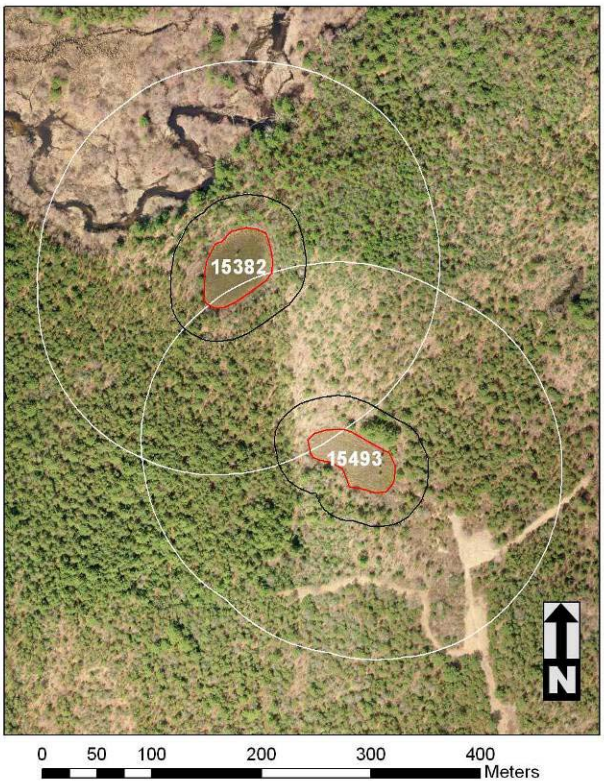

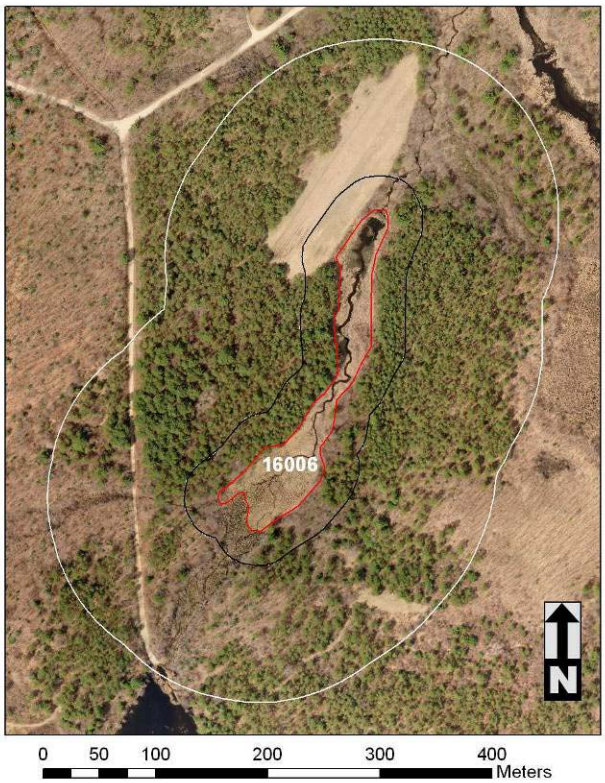

Study Sites 2009

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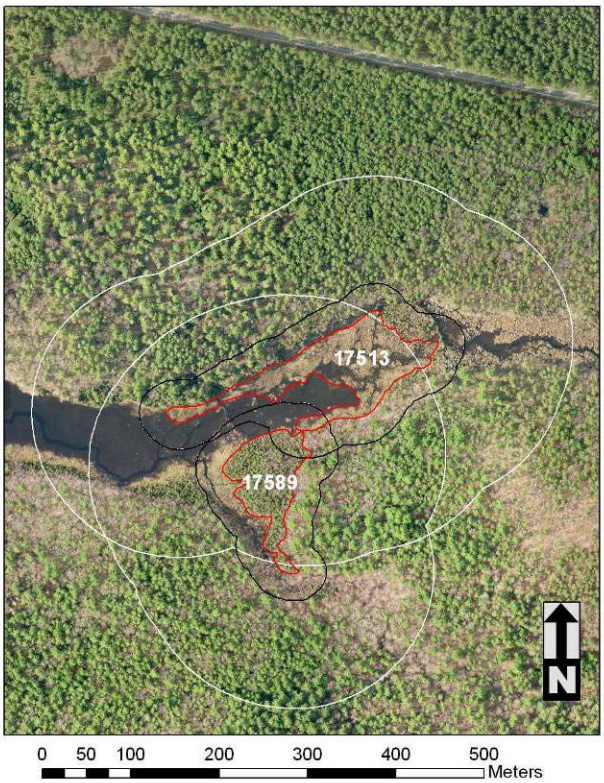

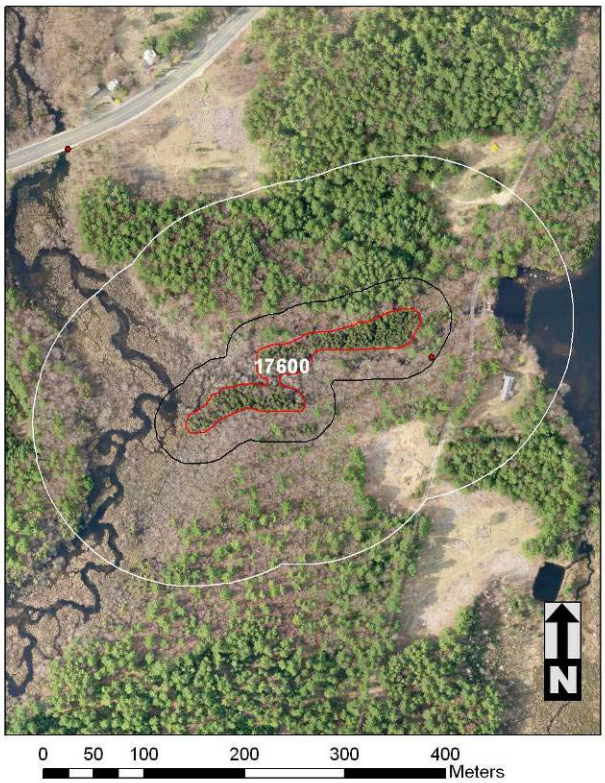

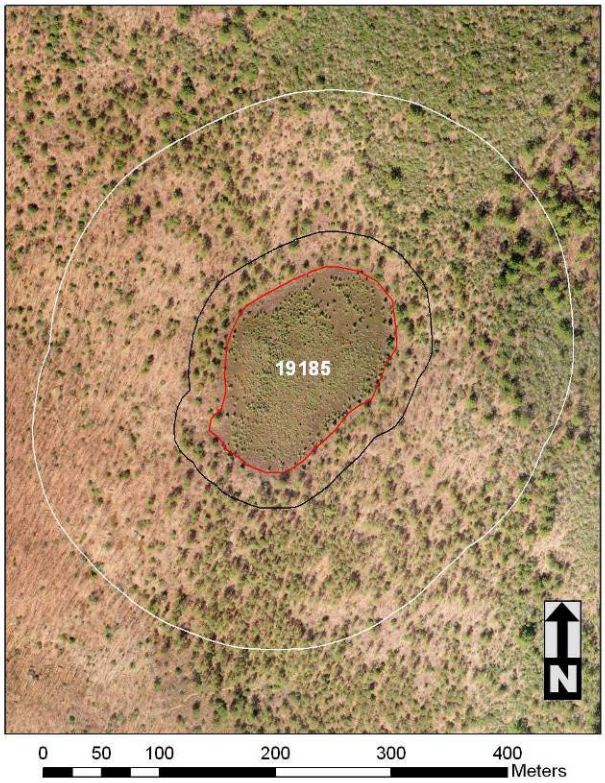

Study Sites 2009

100' Buffer

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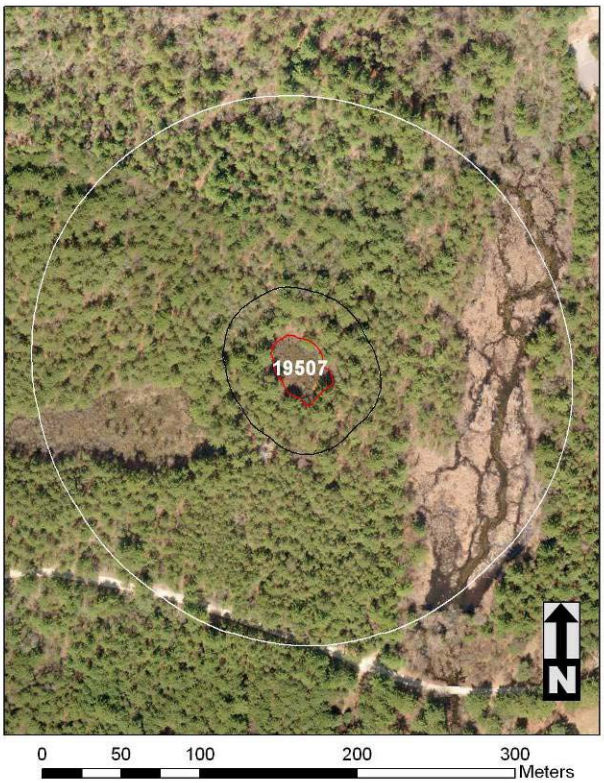

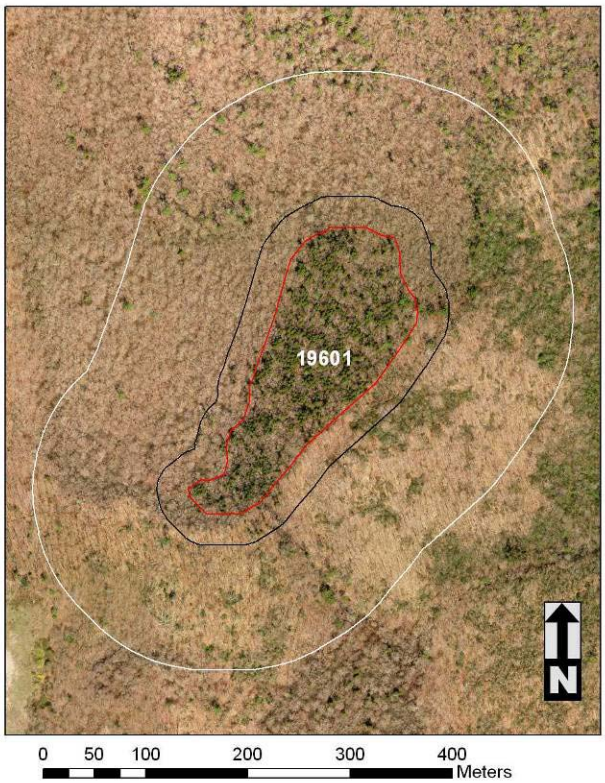

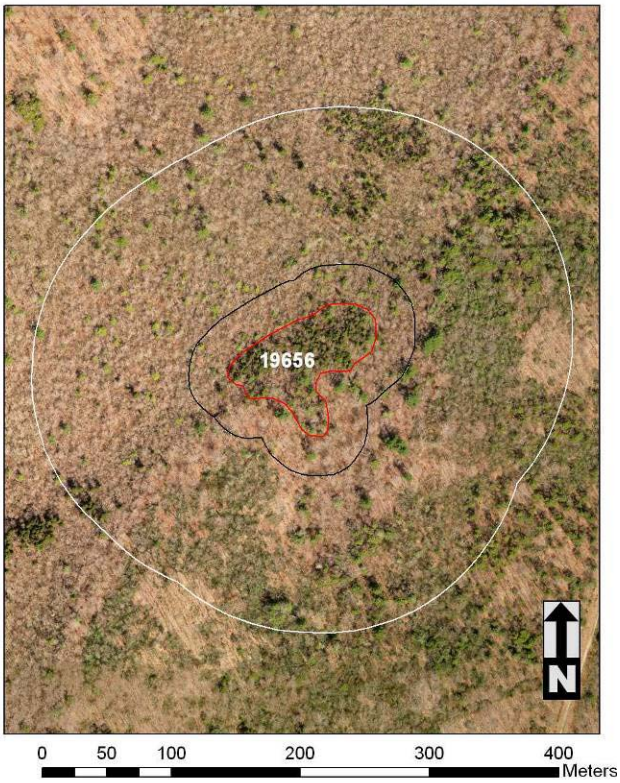

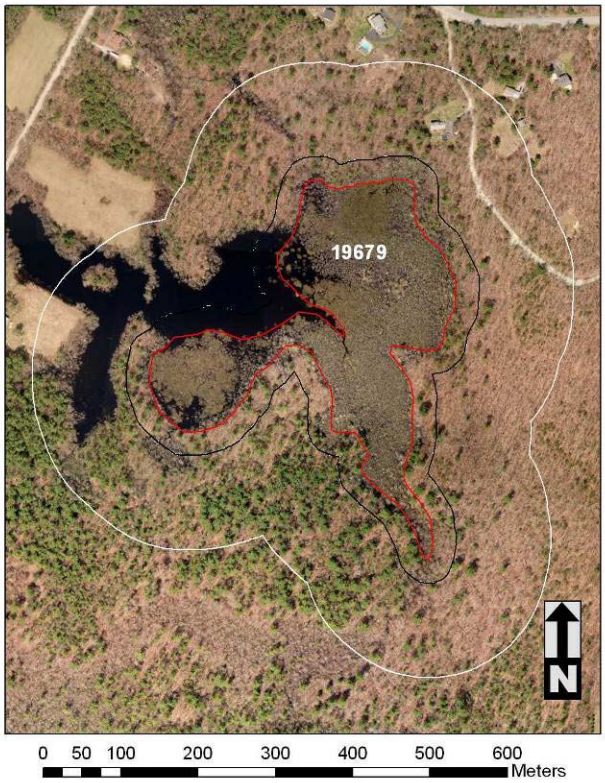

Study Sites 2009

100' Buffer

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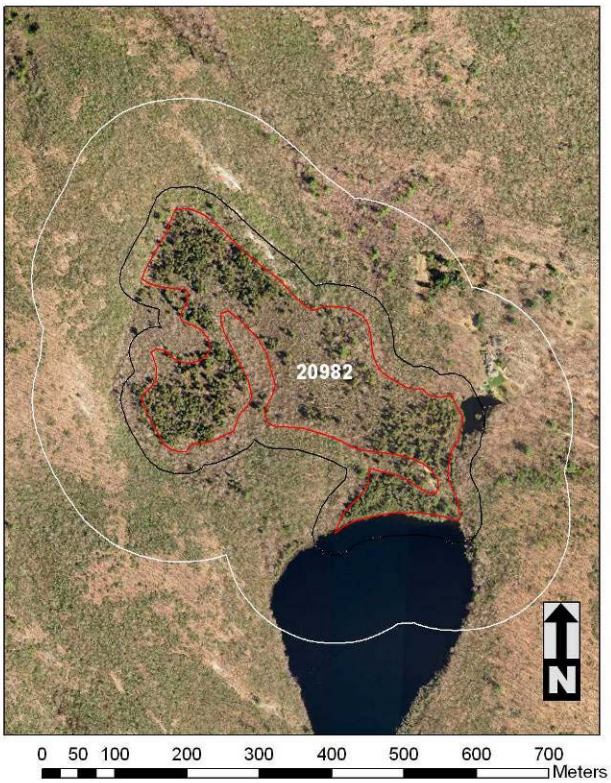

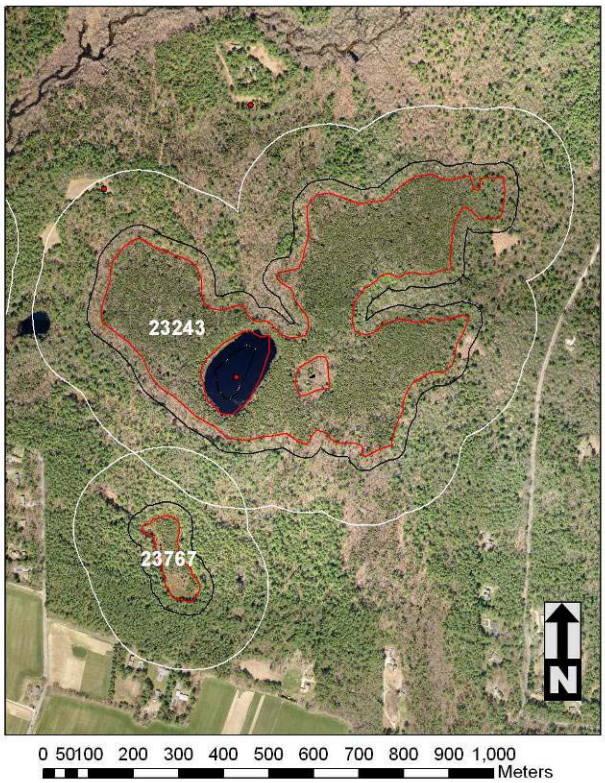

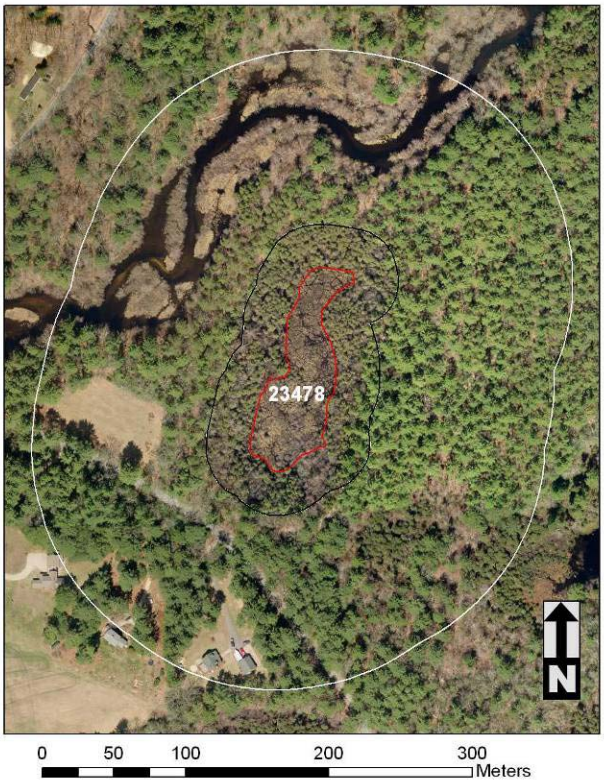

Study Sites 2009

100' Buffer

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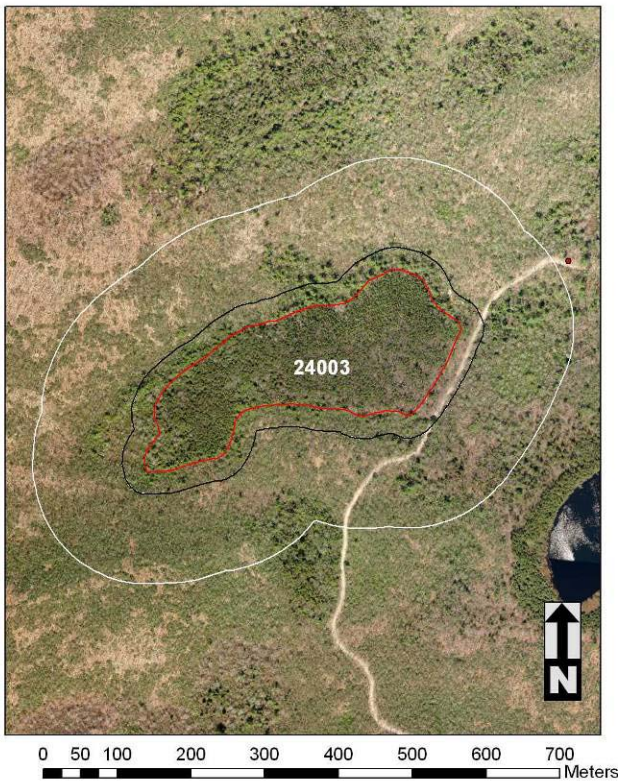

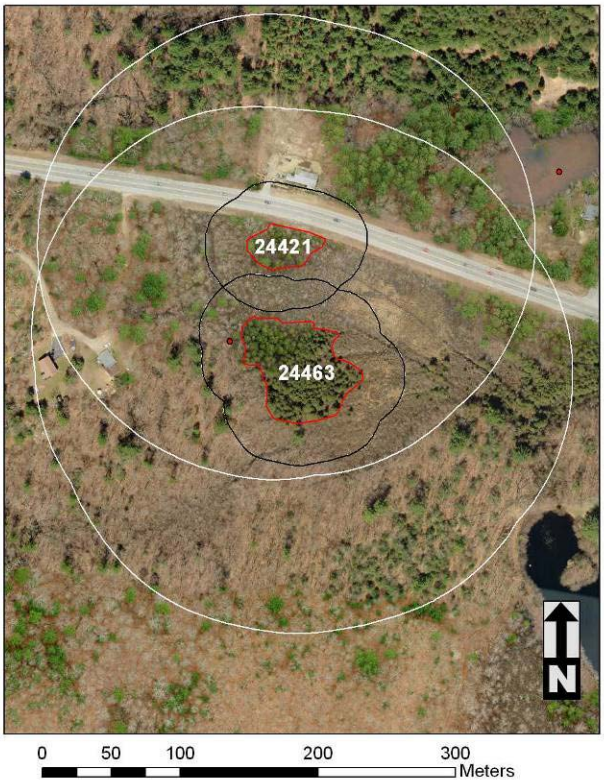

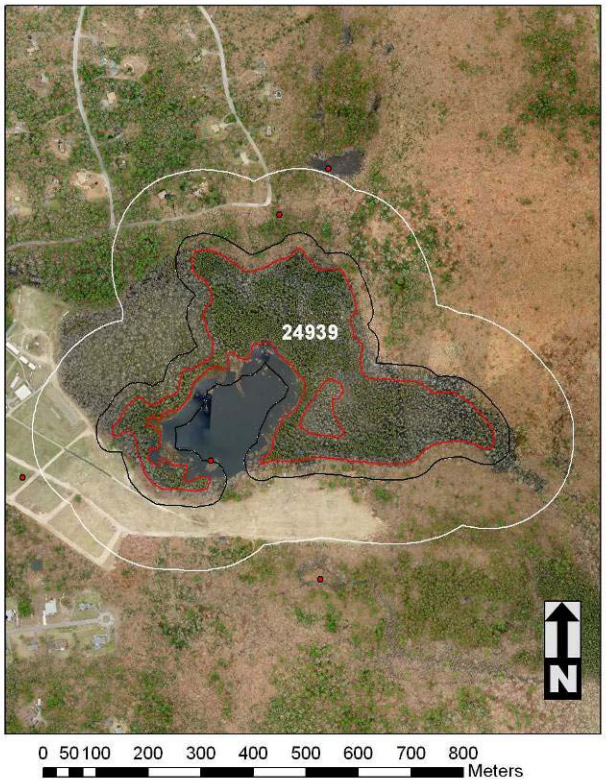

Study Sites 2009

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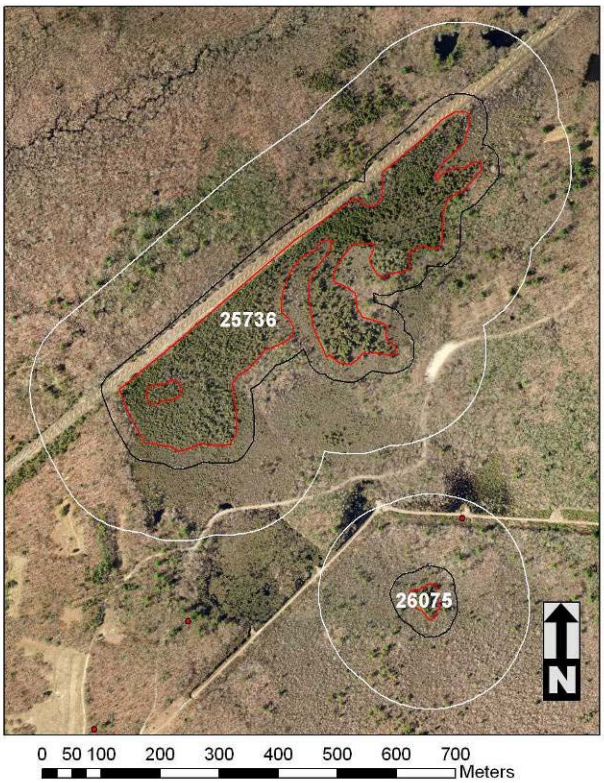

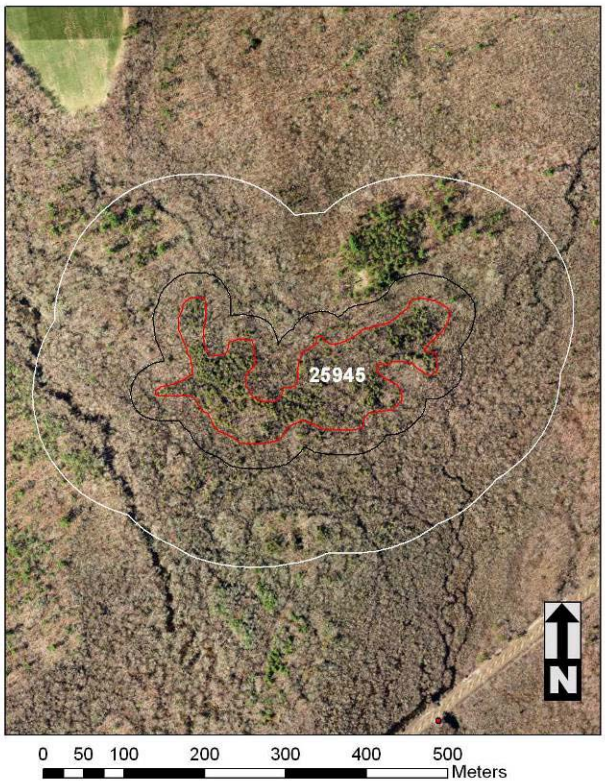

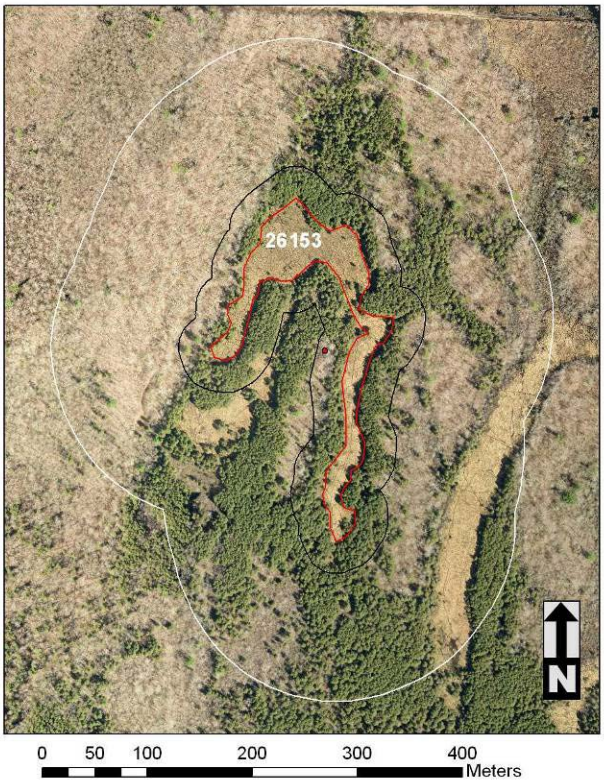

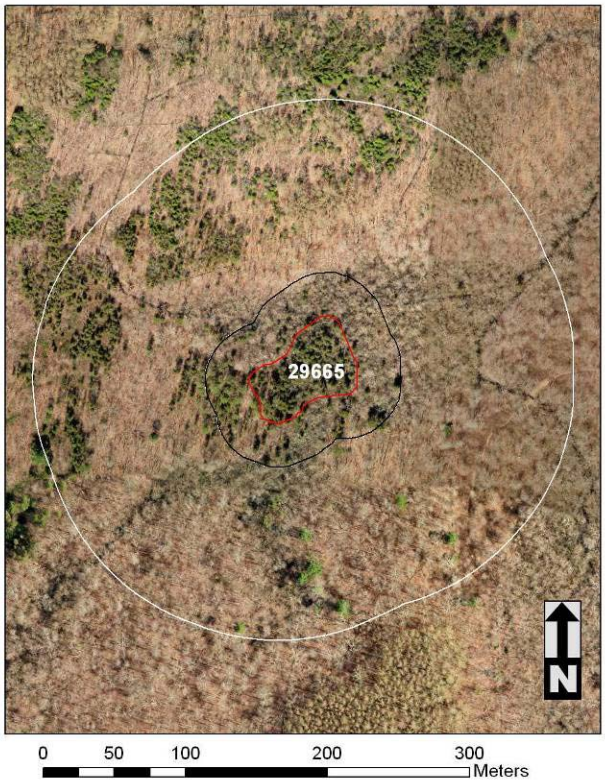

Study Sites 2009

100' Buffer

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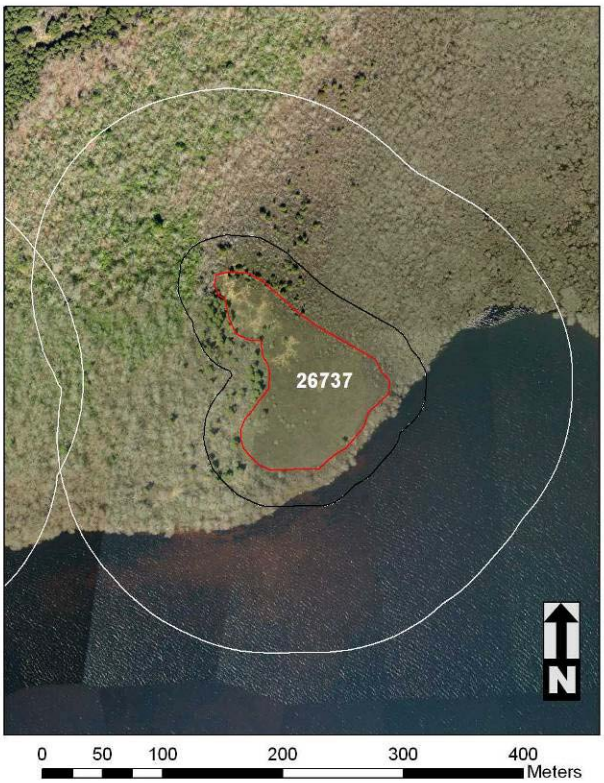

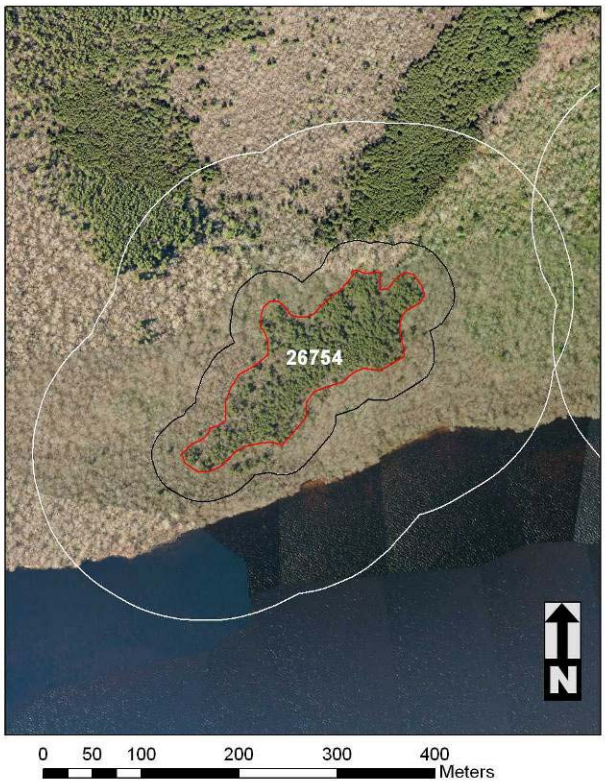

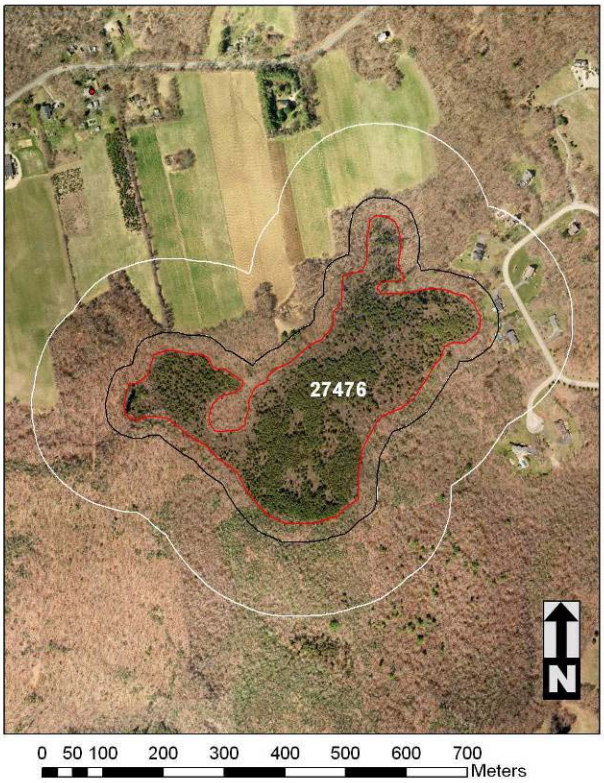

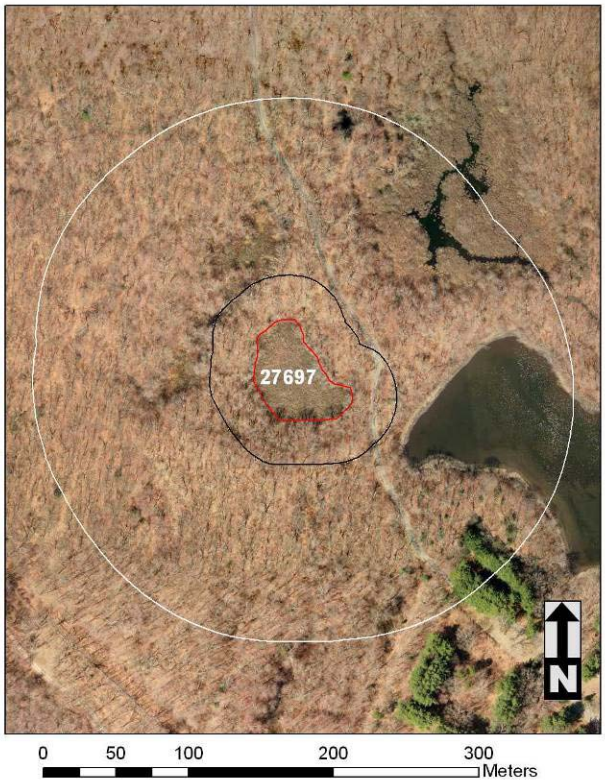

Study Sites 2009

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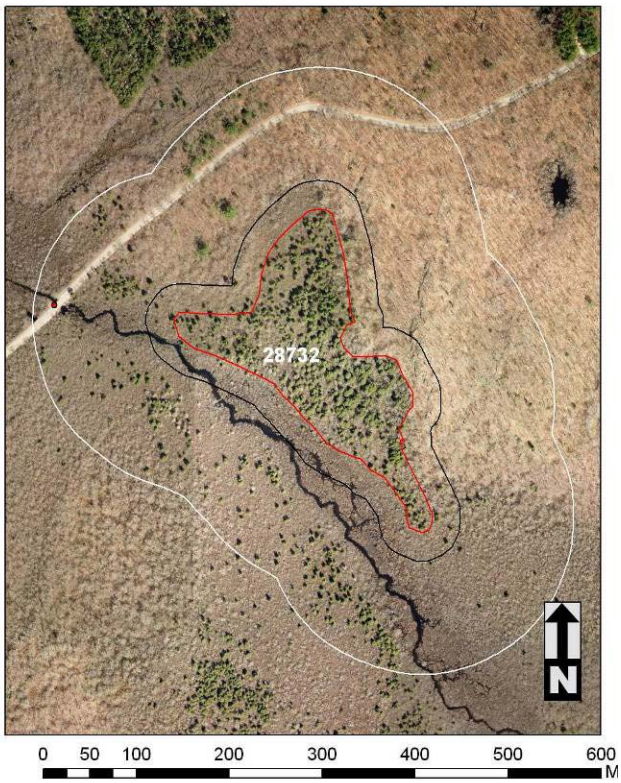

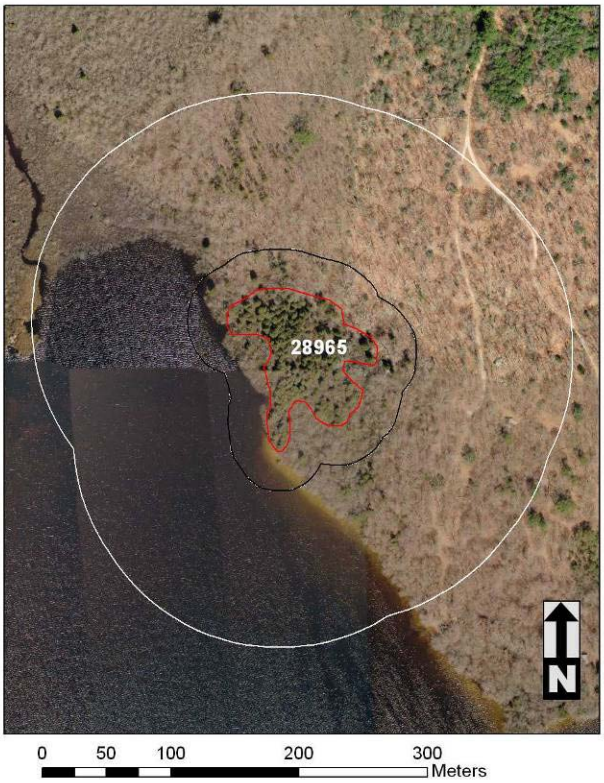

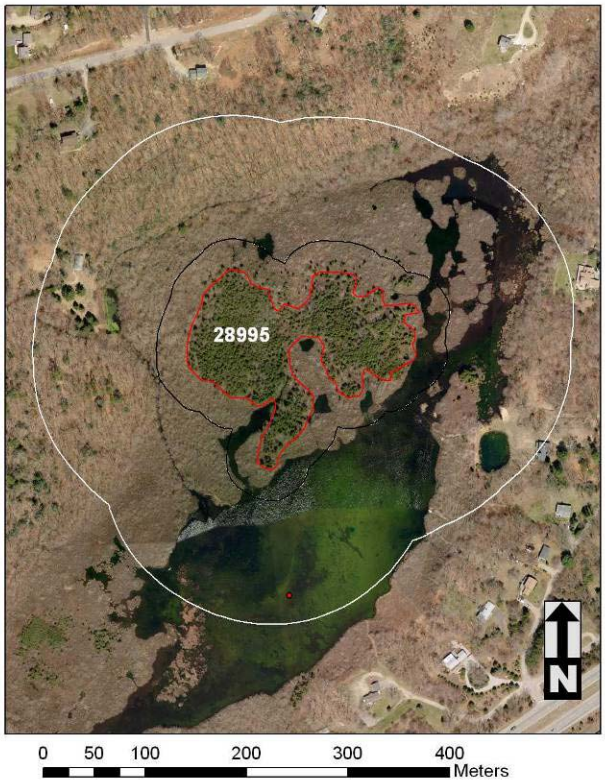

Study Sites 2009

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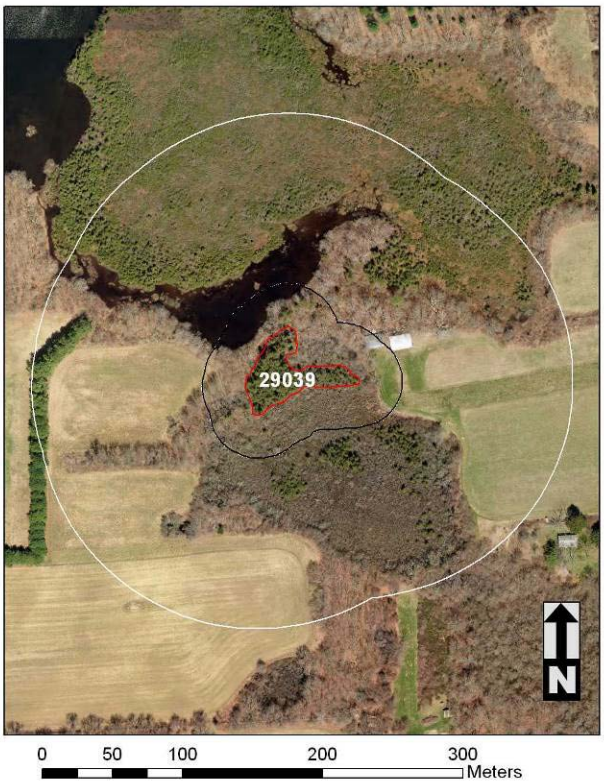

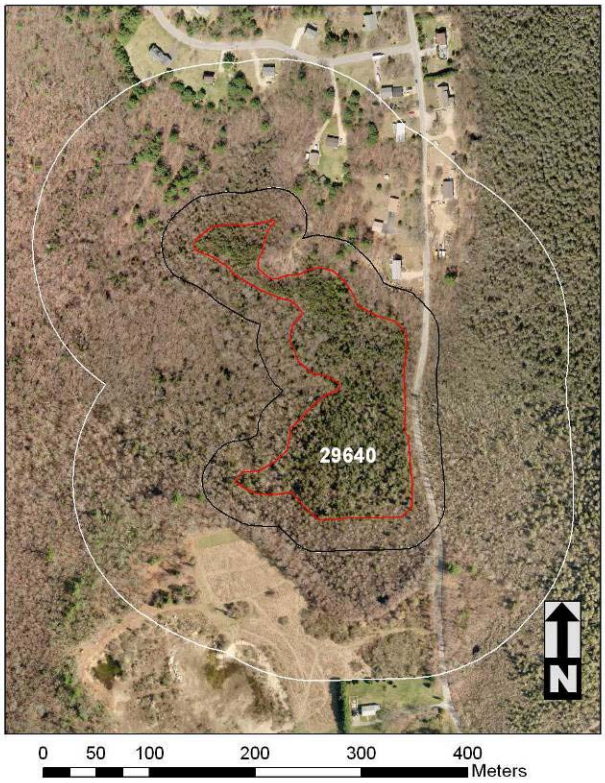

Study Sites 2009

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