



# Permanent Freshwater Wetland Monitoring Protocol for Acadia National Park

## *Northeast Temperate Network*

Natural Resource Report NPS/NETN/NRR—2013/653



ON THE COVER  
Big Heath in Acadia National Park  
Photograph by K. M. Miller

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April 2013

U.S. Department of the Interior  
National Park Service  
Natural Resource Stewardship and Science  
Fort Collins, Colorado

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Please cite this publication as:

Miller, K. M. and B. R. Mitchell. 2013. Permanent freshwater monitoring protocol for Acadia National Park: Northeast Temperate Network. Natural Resource Report NPS/NETN/NRR—2013/653. National Park Service, Fort Collins, Colorado.

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# Acronyms

ACAD: Acadia National Park

APPA: Appalachian National Scenic Trail

BOHA: Boston Harbor Islands National Recreation Area

EPA: Environmental Protection Agency

FOM: Field Operations Manual

IAH: Isle au Haut

MABI: Marsh-Billings-Rockefeller National Historical Park

MDI: Mount Desert Island

MIMA: Minute Man National Historical Park

MORR: Morristown National Historical Park

NCBN: Northeast Coastal and Barrier Network

NETN: Northeast Temperate Network

NHP: National Historical Park

NHS: National Historic Site

NPS: National Park Service

NWCA: National Wetland Condition Assessment

NWI: National Wetland Inventory

ROVA: Roosevelt-Vanderbilt National Historic Sites

SAIR: Saugus Iron Works National Historic Site

SAGA: Saint-Gaudens National Historic Site

SARA: Saratoga National Historical Park

USA-RAM: U.S. Rapid Assessment Methods

USGS: U.S. Geological Survey

WEFA: Weir Farm National Historic Site



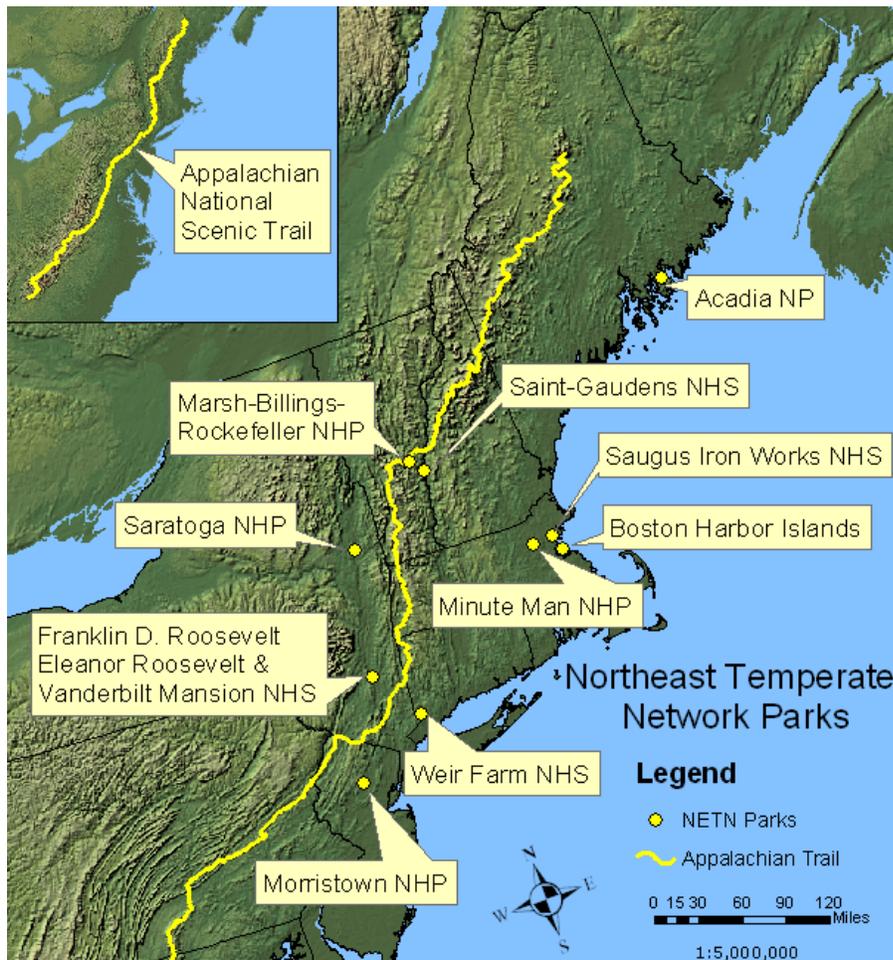


# Background and Objectives

## Introduction

This protocol outlines the justification and methods for long-term monitoring of permanent freshwater wetlands within the National Park Service (NPS) Northeast Temperate Network (NETN; Figure 1) as part of the Inventory and Monitoring Program.

Wetlands in NETN are widespread and diverse, ranging from marine to freshwater habitats. Forested freshwater wetlands are the dominant wetland type in most NETN parks (Table 1). However, marine and intertidal estuarine habitats dominate Boston Harbor Islands National Recreation Area (BOHA). Palustrine scrub/shrub and unconsolidated bottom are the two most dominant wetland habitats in Saint-Gaudens National Historic Site (SAGA), but together they only cover a total of 4.44 ha. The greatest diversity and abundance of wetlands are found in Acadia National Park (ACAD), including considerable coverage of palustrine scrub/shrub and emergent habitats. Vernal pools are present in most, if not all NETN parks, but are not mapped as part of the National Wetland Inventory (NWI).



**Figure 1.** Map of national parks in the Northeast Temperate Network.

**Table 1.** Approximate extent (hectares) of Cowardin wetland and deepwater habitats present within NETN parks based on the National Wetland Inventory. Wetland area was calculated within the fee-owned boundaries of each park. Unconsolidated is abbreviated as Uncons. Marine habitats were not included. Where two classes were listed for a polygon, the area was included in the calculations for the dominant (i.e., first listed) class.

System	Subsystem	Class	ACAD	BOHA	MABI	MIMA	MORR	ROVA	SAGA	SAIR	SARA	WEFA
Estuarine	Intertidal	Aquatic Bed	0.45	0.29	-	-	-	-	-	-	-	-
		Emergent	41.90	39.59	-	-	-	-	-	1.27	-	-
		Reef	-	1.01	-	-	-	-	-	-	-	-
		Rocky Shore	5.04	7.25	-	-	-	-	-	-	-	-
		Uncons. Shore	16.60	59.54	-	-	-	-	-	-	-	-
	Subtidal	Aquatic Bed	0.05	-	-	-	-	-	-	-	-	-
		Uncons. Bottom	28.48	2.24	-	-	-	-	-	-	-	-
Lacustrine	Limnetic	Uncons. Bottom	28.89	-	-	-	-	-	-	-	0.28	-
	Littoral	Aquatic Bed	0.16	-	-	-	-	-	-	-	-	-
		Emergent	1.28	-	-	-	-	-	-	-	-	-
Palustrine		Aquatic Bed	3.06	-	-	-	-	-	-	-	-	-
		Emergent	184.09	3.19	-	14.99	-	1.51	0.59	-	20.56	-
		Forested	644.75	0.42	1.90	28.84	7.24	26.02	0.09	0.32	55.45	3.03
		Scrub/shrub	338.93	0.33	-	5.23	0.72	8.54	2.36	-	4.99	-
		Uncons. Bottom	59.15	5.33	4.97	0.75	0.14	4.21	2.08	-	1.45	1.17
		Uncons. Shore	0.17	3.99	-	-	-	-	-	-	-	-
Riverine	Tidal	Uncons. Bottom / Shore	1.52	-	-	-	-	1.03	-	-	-	-
	Lower Perennial	Uncons. Bottom	-	-	-	3.80	0.40	-	0.04	0.02	-	-
	Upper Perennial	Uncons. Bottom	-	-	-	-	0.79	-	-	-	-	-
	Intermittent	Uncons. Shore	-	-	-	-	0.10	-	-	-	-	-
Total Wetland Area			1,354.52	123.18	6.87	53.61	9.39	41.31	5.16	1.61	82.73	4.20

Estuarine, permanent freshwater and vernal pool habitats are all of significant concern to NETN park managers, but indicators of condition and critical stressors vary considerably across these wetland types. Therefore, separate protocols are necessary for monitoring estuarine, permanent freshwater and vernal pool habitats. This protocol focuses on permanent freshwater wetlands. A protocol for salt marsh and estuarine wetlands is currently being developed for ACAD, BOHA, and Saugus Iron Works National Historic Site (SAIR) in collaboration with the Northeast Coastal and Barrier Network (NCBN) and Maine Maritime Academy (James-Pirri and Roman 2010). This protocol is in review, and is being modified since the salt marsh methods were tested in ACAD in 2011. Time permitting, NETN staff plan to adapt US Geological Survey Amphibian Research Monitoring Initiative (ARMI) methods for vernal pool monitoring. Vernal pools will also be monitored through NETN's phenology monitoring protocol (Tierney et al., in review), and current pilot testing includes acoustic monitoring of vocal anurans (frogs and toads) and breeding birds at vernal pools and other wetland sites.

## **Rationale and Justification**

### ***Importance of Wetland Vital Sign in NETN***

Wetlands provide many important ecosystem functions to NETN parks including habitat for flora and fauna, chemical uptake and nutrient cycling, and erosion and flood control (Keddy 2000 and Mitsch and Gosselink 2000). NETN wetlands are also important sites of biodiversity (Mitchell et al. 2006), and in ACAD nearly 2/3 of the state-ranked rare species in the Mount Desert Island region are found in wetland and aquatic systems (Greene 1990). Wetlands are also particularly vulnerable to a number of stressors including hydrological alteration, invasive species, poor water quality run-off, and sedimentation (Mitsch and Gosselink 2000).

In May 2004, NETN convened a workshop of park staff, academic and government scientists, and other stakeholders to identify key "Vital Signs" or indicators of ecological condition for long-term monitoring in NETN parks. During this workshop, wetlands were identified as a priority vital sign, and climate, hydrology, water chemistry, species composition (both flora and fauna), landuse/landcover, invasive exotic species, acid deposition and stress, contamination and nutrient enrichment were identified as key wetland indicators to monitor. The results of this workshop are summarized in an Appendix to the NETN Vital Signs Monitoring Plan: [http://science.nature.nps.gov/im/units/netn/downloads/Phase3/Appendix\\_Vital\\_Signs\\_Workshop\\_Summary.pdf](http://science.nature.nps.gov/im/units/netn/downloads/Phase3/Appendix_Vital_Signs_Workshop_Summary.pdf).

In March 2009, NETN requested input from park Resource Managers to prioritize the network's commitment to all current and planned long-term monitoring protocols. Based on received input, freshwater wetland monitoring was rated as a secondary protocol. Secondary protocols are protocols that are currently being developed, but that may be implemented on a limited scale due to budget restrictions and limited staff time and may require some cost-sharing with parks or other organizations. Further input from park Resource Managers suggested that vernal pools were of greater management concern and a higher monitoring priority than permanent wetlands in all parks except ACAD. Resource Management staff in ACAD considered both vernal pools and permanent freshwater wetlands to be equally important, and vernal pools were already being monitored by park staff.

### ***Included Vital Signs***

This protocol primarily addresses the NETN Wetland Vegetation Vital Sign in ACAD. However, some measures will address these additional vital signs: Water Chemistry, Water Quantity, Invasive/Exotic Plants, Land Use, and Land Cover.

### ***Existing Research in ACAD***

Considerable research has taken place in ACAD wetlands over the past few decades, and this has provided us with a good understanding of disturbance and vegetation patterns, major threats and stressors, and indicators of condition in ACAD wetlands. The majority of wetland research has taken place on Mount Desert Island (MDI), the main unit of ACAD (Figure 2).

### **Beavers**

Beavers (*Castor canadensis*) are important agents of natural disturbance in wetlands in the eastern U.S., and a number of studies have examined beaver dynamics in ACAD. Since the reintroduction of beaver in 1921 to MDI, spatial and temporal variability of beaver activity have created a mosaic of wetland habitats across the landscape (Cunningham 2003 and Little 2005). Cunningham (2003) described a progression of beaver activity on MDI starting with initial occupation of optimal habitats (i.e., large sites that are low in the watershed) dominated by early successional forests that originated after the large 1947 fire (Figure 2). As beaver populations increased, colonization expanded into marginal and sub-optimal habitats (i.e., small sites with low potential for stream impoundment). By the population peak in 1979, more than 50% of the sites occupied by beaver were marginal or worse habitat, and most of those sites have since been abandoned and remain vacant. Cunningham suggested that without a major disturbance to increase abundance of early successional and beaver-preferred tree species, expansion beyond the current population is unlikely, and therefore marginal sites may return to a shrub-dominated or forested state.

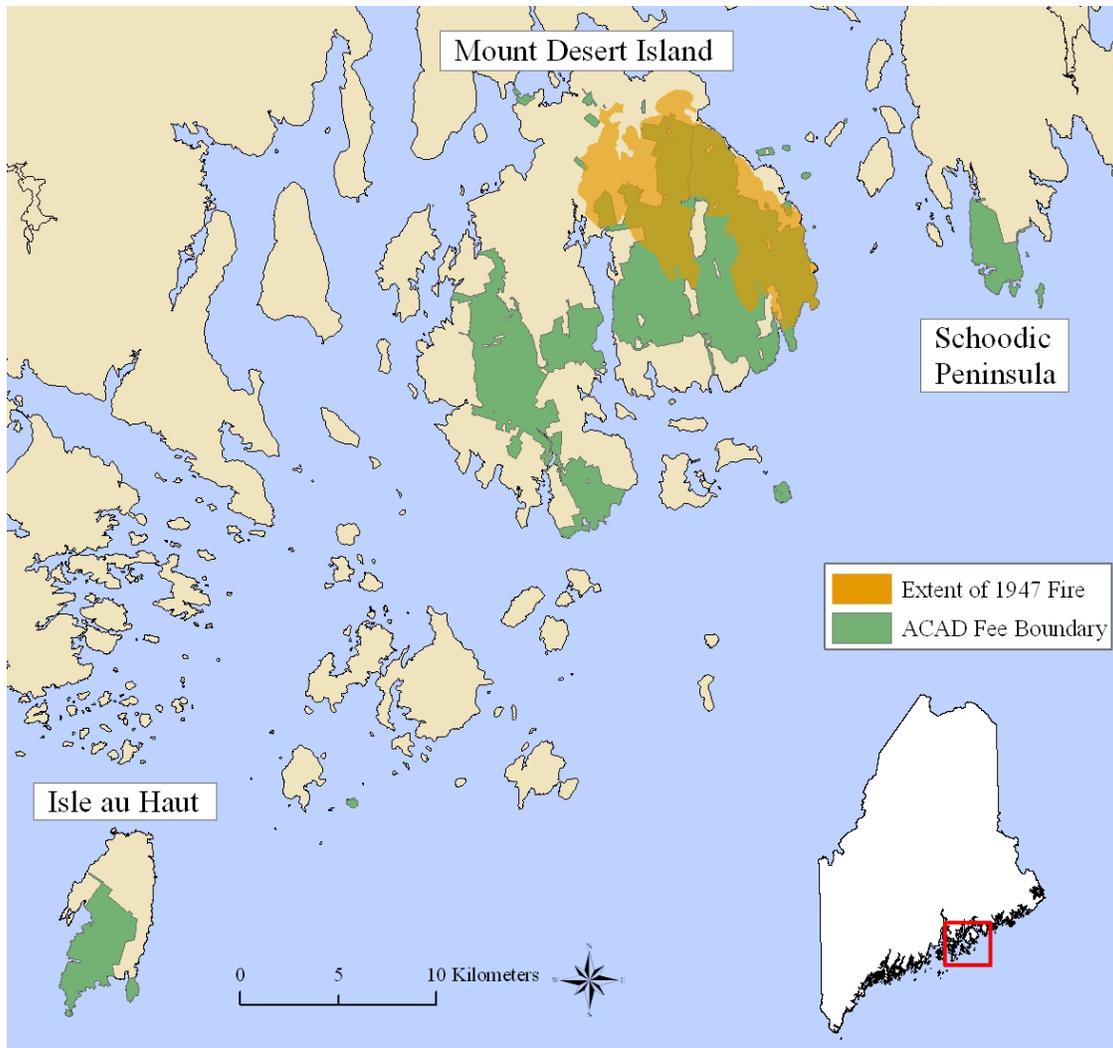
Little (2005) documented a pattern of natural succession in wetland vegetation relative to beaver-caused disturbance. Wetlands that were actively or recently occupied by beaver were dominated by open water and emergent vegetation. In the absence of beaver, wetlands succeeded towards shrub-dominated and forested wetlands.

### **Amphibians**

Amphibian use of wetland habitat in ACAD has been the focus of several studies.

Cunningham (2003) found amphibian species diversity to be positively associated with wetland connectivity and habitat heterogeneity created by beaver. Gahl (2007) examined patterns of amphibian disease in ACAD wetlands, and found amphibians in high catchment (i.e., headwater) ephemeral wetlands to be most susceptible to *Ranavirus*. Gahl suggested that the presence of multiple sub-lethal stressors (e.g., low pH, low calcium, and high total aluminum) may contribute to amphibian disease susceptibility in high catchment wetlands, and recommended disease containment to focus on these higher catchment wetlands.

Kolozsvary (2003) examined the hydrology and landscape setting of wood frog (*Rana sylvatica*) and spotted salamander (*Ambystoma maculatum*) breeding pools. Kolozsvary's research produced an extensive dataset on baseline water chemistry, hydrology, and landscape characteristics for 71 wetland sites on MDI. Many of the sites established and described by Kolozsvary have been used by subsequent studies and the park continues to monitor a number of the vernal pool sites for amphibian breeding success.



**Figure 2.** Map of major park units in Acadia National Park, and the extent of the 1947 fire on Mount Desert Island.

### Human Disturbance

Nearly all wetlands and watersheds in ACAD have been altered to some degree by human activities (Vaux et al. 2008). Logging and sheep grazing were widespread in the region throughout the 1800s, and nearly all of the forests in ACAD are second growth (McLane 1989). Many small and several large wetlands on MDI were dredged, ditched, filled, and/or impounded prior to establishment of the park (Little et al. 2010). Roads and human development continue to impact wetlands through increased runoff from impermeable surfaces and altered hydrologic regimes (Little 2005).

A recent study on the influence of beaver and human disturbance on wetland plant communities found that emergent-dominated wetlands represented an early successional and relatively short-lived stage of natural wetland development that resulted from beaver activity (Little 2005). Only human disturbance had the capacity to force wetlands out of the range of natural variation, and create seemingly permanent emergent wetlands (Little 2005). While small wetlands (< 1.4 ha) were most susceptible to stressors and the resulting shift to a persistent emergent marsh,

excessive disturbance has converted several large wetland complexes in ACAD to permanent sedge-dominated meadows (Little et al. 2010).

Despite human disturbance, many wetlands in ACAD exhibit characteristics of minimally disturbed condition, including absence of invasive plant species, thick peat development, abundance of *Sphagnum* moss, and low groundwater and surface water pH and conductivity (Little 2005).

### **Existing Protocols**

A fair amount of work has been done in ACAD to develop and test wetland monitoring protocols, including an intensive (Level 3) protocol for monitoring emergent wetlands developed by USGS (Neckles et al. 2007), and a GIS and rapid field assessment (Level 1 and 2) framework for assessing wetland condition in all wetlands developed by NatureServe (Faber-Langendoen 2009).

The intensive (Level 3) protocol developed by USGS involved GIS spatial analyses and thorough field testing to identify indicators of disturbance (Neckles et al. 2007). One of the first steps in the protocol development process involved formulating a gradient of anthropogenic stress based on attributes such as distance to roads, condition of buffer, and proportion of human development within each watershed. This stress gradient (called “SumRel” by Neckles et al. 2007) was then used to classify wetlands as reference, undisturbed, or disturbed. Wetlands classified as reference were least disturbed. Undisturbed wetlands fell in the middle of the gradient and represented moderately disturbed sites that, when compared to other wetlands in New England, would probably be considered not disturbed by most wetland ecologists. The disturbed category represented the end of the gradient with the highest degree of anthropogenic stressors. These classes of disturbance were used to develop field methods and identify metrics that varied with the disturbance gradient.

The USGS protocol served as a valuable foundation for protocol development. However, through multiple years of field testing the protocol in ACAD and Saratoga National Historical Park (SARA) and further refinement of our wetland monitoring goals and objectives, NETN staff decided not to implement this protocol for several reasons. First, full implementation of the USGS protocol would require a 2-3 person field crew committed solely to this protocol for much of the growing season, and we do not have the resources to implement this scale of wetland monitoring. Additionally, the protocol was developed only for a narrow subset of wetland types (i.e., emergent-dominated wetlands with no tall shrubs, < 50% *Sphagnum* cover, and < 50% low shrub cover) that are found in ACAD. Our focus is broader than emergent wetlands, and we need a protocol that can be applied across all permanent wetlands in ACAD.

A rapid assessment framework (Level 1 and 2) was developed for NETN by NatureServe for all wetlands in ACAD (Faber-Langendoen 2009). The framework identified 15 metrics and developed assessment points to assess ecological integrity of wetland landscape context, size, biota, hydrology, and soils. This report was the first attempt at devising a rapid assessment method of wetland condition that could be applied across NETN. However, the U.S. Environmental Protection Agency (EPA) has also developed a U.S. Rapid Assessment Method (USA-RAM; U.S. EPA 2011b). The USA-RAM metrics were developed with input from NatureServe wetland scientists and designed to be applicable across wetlands throughout the

U.S. USA-RAM metrics are also very similar to those developed for the NETN rapid assessment framework. To maintain consistency with EPA methods, and to ensure we can benefit from data collected throughout the region, we have chosen to use the USA-RAM for Level 1 and 2 monitoring of wetland condition in ACAD.

In addition to the USA-RAM, EPA has developed an intensive, Level 3 wetland monitoring protocol for the National Wetland Condition Assessment (NWCA). As part of the NWCA, the Level 3 protocol will be implemented, along with the USA-RAM, every 5 years starting in 2011 (U.S. EPA 2011a). Both the USA-RAM and the Field Operations Manual were developed over the course of several years based on feedback from hundreds of wetland scientists throughout the country. Protocols also went through several rounds of field testing and peer review, including by NETN staff. For more information on the peer review process, refer to the NWCA Quality Assurance Project Plan (U.S. EPA 2011c).

The undisturbed (i.e. minimally disturbed) condition of many wetlands in ACAD has provided us with the opportunity to collaborate directly with EPA on the NWCA by collecting data for the assessment. EPA has a randomly selected component of their assessment (about 1,000 sites) and a “targeted” component of their assessment (150 sites) which are potential reference sites. Undisturbed wetlands were chosen for the targeted sites using expert judgment, and include the ten sentinel sites we established in 2011 in ACAD. The data collected at the potential reference sites will be used to make a final determination of whether they are suitable reference sites. The targeted sites that are determined to be reference will then be compared against the full random data set using a variety of approaches to evaluate condition of the nation’s wetlands. By collaborating with EPA, we are able to contribute to a national dataset and we benefit from having a protocol that has been extensively peer-reviewed. EPA also trains NETN staff on the field methods, covers the cost of lab analyses, and manages the associated databases and data collected.

### **Measureable Objectives**

Our overall goal is to monitor status and trends in permanent freshwater wetland vegetation, hydrology, and water quality in ACAD. Specific monitoring objectives include:

- Determine the status and trends in vegetation structure, including changes in herbaceous, shrub, and tree cover, using sentinel sites.
- Determine status and trends in vascular plant species composition, diversity, and abundance using sentinel sites. Special emphasis will be on species of high conservation priority (i.e., vulnerable [S3], imperiled [S2] or critically imperiled [S1] in the state), indicators of wetland condition, and invasive species.
- Determine the status and trends in water chemistry, including pH, conductance, and nutrients, using sentinel sites.
- Determine baseline conditions in soil chemistry, including pH, conductance, and nutrients, using sentinel sites.
- Determine the status and trends of water level, including variability and seasonal patterns of water depth, using shallow wells installed in sentinel sites.

- Determine the status and trends in indicators of wetland condition and stressors, including adjacent land-use, condition of buffer, abundance of invasive species, and hydrologic disturbance, using rapid assessments (Level 1 and 2) of randomly selected wetlands in ACAD.

Note that the NETN list of invasive species is more comprehensive than the FOM, and includes any species considered invasive by NatureServe and/or the Integrated Plant Atlas of New England (IPANE).

## Sampling Design

As described earlier, monitoring permanent freshwater wetlands is a secondary priority for the national historical parks and sites in NETN, and we have chosen to monitor permanent freshwater wetlands in ACAD only. Our definition of permanent freshwater wetlands follows the targeted wetland habitats used by the EPA Field Operations Manual. EPA's list of targeted wetland habitats utilizes a modified version of the Cowardin classification system (Cowardin et al. 1979), and includes palustrine emergent, palustrine scrub/shrub, and palustrine forested wetlands. All of these wetland types are characterized as having rooted vegetation, open water less than 1-m deep where present, hydric soils, hydrophytic plant indicators, and wetland hydrology. Assessment areas may include no more than 10% non-wetland area (e.g., upland habitat, deep water, etc). There are no restrictions on the composition of the 100-m buffer surrounding the assessment area.

Ideally, the target population would be all permanent freshwater wetlands in ACAD. However, staff and funding constraints will not allow us to implement the extensive and randomized sampling frame that would be necessary to achieve that target population. Instead, we will use a combination of intensive monitoring in ten sentinel sites, and rapid assessments in a larger number of randomly selected sites. We will not be able to statistically relate our findings in sentinel sites to all permanent freshwater wetlands in ACAD and results will be specific to undisturbed wetlands. However, our findings can serve as an early warning of threats or changes in wetland condition that may then be examined with follow-up research throughout the park.

### Site Selection and Sampling Frequency

Generalized random tessellation stratified sampling (GRTS: McDonald 2004) will be used to locate sites for rapid assessment (Level 1 and 2) sampling. Sites will be selected to provide a spatially balanced random sample within a merged wetland shapefile that contains polygons from the National Wetland Inventory (NWI) maps and the Acadia vegetation map (Lubinski et al. 2003). The GRTS design was chosen because it provides a probabilistic random sample of mapped permanent wetlands, and because it is compatible with the sampling design of other NETN protocols.

There are drawbacks to using the NWI and ACAD vegetation maps. NWI wetlands were delineated from aerial photos flown in 1983 and the park vegetation map was delineated on aerial photos flown in 1997. Both also have issues of mapping accuracy, particularly with forested and small wetlands misclassified as upland. Both are also limited by their minimum mapping unit, which was 0.5 ha for the park vegetation map, and 1 ha for NWI (unless there were smaller conspicuous wetlands that were easily detected from aerial photography). Despite these limitations, they are the most comprehensive datasets available on wetland extent in ACAD. By combining the two datasets, and verifying their accuracy using current orthophotography and field visits, we improve the overall accuracy of the population of wetlands from which the GRTS sample will be drawn for rapid assessment monitoring. However, we recognize that wetlands that were not mapped by either program will be missed, and forested and small (<0.5 ha) wetlands may be underrepresented in our sample. While our site selection approach is not likely to identify a wetland smaller than 0.5 ha for monitoring, EPA protocols do allow for wetlands between 0.1 ha and 0.5 ha to be sampled. In this case, the boundary of the

wetland becomes the boundary of the assessment area, and the USA-RAM buffer is 100 m outside the boundary of the wetland.

The GRTS sample for this protocol will be drawn park-wide, and the wetland polygons will be layered on top of the park-wide sample. The first 40 GRTS points that fall within wetland polygons and that meet the EPA guidelines for establishing a 0.5 ha assessment area (e.g., no more than 10% non-target habitat) will be the initial sample. The only exception to this approach involves large wetland complexes (e.g., Bass Harbor Marsh, Big Heath, Northeast Creek, etc.), which will have a maximum of three rapid assessment sites to ensure smaller wetlands are adequately represented in the sample. Rapid assessment sites will be centered on the points selected by the GRTS sampling algorithm. As new or updated wetland datasets and technologies for delineating wetlands (e.g., LiDAR and radar) become available for ACAD, we will overlay the new data on top of the GRTS sample and determine if any formerly rejected points should be sampled. Time permitting, the original and new points will be sampled. However, if there are insufficient resources for expanding the sample size, then some of the original points may be dropped in order to recalibrate the monitoring to the most current and accurate wetland information.

Intensive (Level 3) sampling will be conducted in ten sentinel wetlands that have been non-randomly selected to represent minimally disturbed condition. Wetlands were chosen that appeared to be within the natural variation of wetland condition, based on work by Cunningham (2003) and Little (2005), and preference was given to locations that were used in previous studies. To ensure that sentinel wetlands represent a broad range of minimally disturbed habitats in ACAD, they were chosen to include:

1. Large ( $\geq 2$  ha) and small ( $< 2$  ha and  $> 0.1$  ha) wetlands
2. Multiple wetland types (i.e., sedge fen, shrub fen, and forested wetland)
3. A relatively even distribution across the park, including at least one wetland each on Isle au Haut and Schoodic Peninsula.

Within each sentinel wetland, the location of an intensive monitoring site was chosen using GRTS after applying a buffer of 40 m inside the mapped boundary of each wetland. The 40-m buffer ensured that the entire 40-m radius assessment area fell within the wetland, in accordance with the EPA NWCA site selection guidelines. Monitoring of the ten sentinel sites began in 2011. Following the EPA NWCA sampling rotation, sentinel sites will be sampled every 5 years using the NWCA Field Operations Manual (FOM; U.S. EPA 2011a) and USA- Rapid Assessment Method (USA-RAM; U.S. EPA 2011b). The only deviation from the NWCA FOM will involve less intensive soil sampling after the initial survey to ensure our monitoring efforts do not impact wetland condition. The specific methods will be determined after consultation with EPA NWCA scientists and prior to the 2016 sampling effort. In addition, water levels will be continuously monitored in sentinel sites using shallow wells and pressure transducers, and data will be downloaded twice annually. Rapid assessment monitoring of randomly selected wetlands will be conducted in 10 different sites per year during the 4 years between EPA NWCA sampling years (Table 2).

At the scale of 0.5 ha, the sentinel wetlands are relatively homogenous; the assessment areas (AA) are each contained within a single vegetation polygon delineated by the ACAD vegetation map, and there is only one hydrogeomorphic class within each AA. The sentinel wetlands are

**Table 2.** Panel design and number of sites sampled per year. Intensive (Level 3) monitoring occurs in permanent sites in sentinel wetlands. Rapid assessment includes Level 1 and 2 monitoring in a rotating panel of permanent sites in randomly selected wetlands.

		2011	2012	2013	2014	2015	2016
Intensive Sampling		10					10
Rapid Assessment	Panel 1		10				
	Panel 2			10			
	Panel 3				10		
	Panel 4					10	

more complex (e.g., more microtopography, higher species diversity and species patchiness) than the impacted wetlands around the park, which are often monotypic stands of broadleaf cattail (*Typha latifolia*; Little 2005). Considering the differences between minimally disturbed and impacted sites, we are interested in characterizing the variability within minimally disturbed wetlands, as changes in variability may be just as meaningful as changes in species abundance. By allowing for complexity in our monitoring sites, this will allow us to better understand how these systems change over time, and potentially how stressors can force these systems into the impacted, cattail-dominated state.

The EPA FOM involves sampling vegetation in five 100 m<sup>2</sup> plots per AA, which amounts to 500 m<sup>2</sup>, or 10% of the total assessment area. The EPA FOM also samples vegetation using nested plots within the larger 100 m<sup>2</sup> plots (10 m<sup>2</sup>, and 1 m<sup>2</sup>) to characterize structure, diversity and composition at multiple scales. We expect this approach to be adequate for characterizing plant species composition and diversity based on pilot data collected in ACAD by Neckles et al. 2007. Neckles et al. sampled up to 50 1-m<sup>2</sup> quadrats in 20 wetlands that ranged in size from 0.015 ha to 46.16 ha. Quadrats were randomly scattered throughout entire wetland complexes. Based on species accumulation curves, the optimal number of quadrats to characterize vegetation for an entire wetland complex in ACAD was 25 quadrats, and these results were regardless of wetland size (0.015-46.16 ha). Therefore, we expect that sampling 500 m<sup>2</sup> out of the 0.5 ha will be more than adequate to characterize vegetation in the AA. Because the five 100 m<sup>2</sup> vegetation plots are permanent, we will be able to track changes in each of the vegetation plots over time.

### Level of Change that can be Detected

Pre-existing data are insufficient to allow for a power analysis that incorporates temporal variability to determine the appropriate sample size for sentinel and rapid assessment sites. After two sampling cycles are complete, we will conduct power analyses on key variables to determine the level of change that can be detected with the current sample size, and to determine realistic and appropriate levels of Type I and Type II error. At a minimum, we want to detect a 50% decline or increase in any metric after two survey cycles, while controlling both Type I and Type II error at 20%. We use 50% as the target level of change to detect because 1) by only sampling the sentinel plots every 5 years (except for the water level monitoring), we can't expect to detect small changes and 2) a 50% change isn't necessarily large, and depends on the baseline value of each metric. For example a 50% increase in invasive species cover, when it currently is 0 in all of the sentinel wetlands, is very small. Conversely, for metrics that are high, such % TC in the peat-dominated soils, we should be able to detect a 50% change in 5 years, and this change would be significant. By continuously monitoring water level in eight of the 10 sentinel sites, which includes two annual visits, we may also be able to explain some of the changes we detect

between the 5 years of sampling. If, after two sample cycles, power analyses suggest that the current design does not provide adequate power for some or all key variables, more sites may be added to the survey and methods will be reviewed to determine if any metrics should be refined or dropped. Power is also likely to increase over time as multiple cycles of data are collected.

### **Sentinel Wetland Descriptions**

Acadia National Park (ACAD) is located in mid-coast Maine and is comprised of three major park units (Figure 2): Mount Desert Island (MDI), Schoodic Peninsula (Schoodic), and Isle au Haut (IAH). ACAD lies within a transition zone between the boreal spruce-fir forests to the north, and the northern hardwood forest to the south. Topography is rugged and characterized by shallow acidic soils and north-south trending mountains separated by U-shaped valleys. Watersheds are relatively short and steep and contain numerous small brooks and streams that drain to the ocean (Calhoun et al. 1994).

Ten sentinel wetlands were selected in ACAD, with eight wetlands located on MDI and one wetland each on IAH and Schoodic. In each wetland, we established a permanent monitoring site that will be sampled intensively every 5 years for the EPA NWCA, and that follows the standard 0.5 ha design of the assessment area. Wetland sizes vary from 1.35 ha to 20.4 ha, and elevation ranges from 8 to 70 m above sea level (Table 3). Sentinel wetlands represent all three catchment positions described by Gahl (2007), with most wetlands located in middle or lower catchment position. Over half of the wetlands are located in watersheds (i.e., 14 digit hydrologic units) where 98% or more of the watershed area is fee-owned park land. All wetlands are threatened by a suite of anthropogenic stresses including hydrologic alteration, nutrient enrichment, poor water quality run-off, atmospheric deposition, erosion and sedimentation, and invasive species (Mitchell et al. 2006). Detailed descriptions of sentinel wetlands are below in order from largest to smallest, and maps of the wetlands and monitoring sites are included in Appendix A.

#### **Big Heath**

Big Heath in Southwest Harbor, ME is a Coastal Plateau Bog at the southern edge of this community's range (Appendix A: Figure 2). Coastal Plateau Bogs occupy a narrow band of islands and headlands along the eastern coast of Maine and New Brunswick, and feature a surface that is flat or undulating and raised above the surrounding terrain (Calhoun et al. 1994). The Maine Natural Areas Program designated this wetland a state Critical Area in the 1980s because of its condition (minimally disturbed), rarity, and diversity (Calhoun et al. 1994).

The raised, open portion of the bog, which is approximately 20 ha, is acidic (pH ~4.5), saturated for most of the year, and dominated by *Sphagnum* moss (Gawler and Cutko 2010). Characteristic species include black crowberry (*Empetrum nigrum*), dwarf huckleberry (*Gaylussacia dumosa*) deer hair sedge (*Trichophorum caespitosum*), and several species of cottongrass (*Eriophorum* spp.). Other noteworthy species that occur in Big Heath include grasspink (*Calopogon tuberosus*), dragon's mouth (*Arethusa bulbosa*; ranked S3) and cloudberry (*Rubus chamaemorus*; ranked S3). This wetland also harbors Lincoln's sparrows (*Melospiza lincolni*). Surrounding the open bog are approximately 57 ha of woodland and conifer swamps dominated by black spruce (*Picea mariana*) and tamarack (*Larix laricina*).

**Table 3.** Information on sentinel wetlands. All wetlands are classified by the National Wetland Inventory (NWI) as Palustrine. NWI classes are shrub/scrub (SS), emergent (E), and forested (F). Wetlands with two classes have the more dominant class listed first. HGM lists the Hydrogeomorphic Class and Subclass. Elevation refers to elevation at the center of the sentinel monitoring site.

Wetland	NWCA11 Plot #	NWI Class	Park Unit	Area (ha) of wetland	Level 7 HUC Area (ha)	% Watershed in park	Catchment Position	Elevation (m)	HGM
Big Heath	R303	SS/E	MDI-West	20.41	438	64	Low	8	Flats- Organic Soil
Duck Pond Peatland	R301	SS	MDI-West	2.85	74	100	Middle	70	Depression- Open
Frazer Fen	R310	E/SS	Schoodic	2.68	79	62	Middle	35	Depression- Closed
Gilmore Meadow	R304	E	MDI-East	7.98	161	100	Low	70	Depression- Open
Great Meadow	R307	SS	IAH	6.06	119	53	Middle	57	Depression- Open
Heath Brook	R308	SS/E	MDI-West	2.53	242	98	Middle	28	Riverine- Upper Perennial
Hodgdon Swamp	R309	F	MDI-West	1.68	169	100	Middle	37	Slope- Topographic
Little Hunter's Brook	R305	E	MDI-East	1.35	89	94	Low	21	Riverine- Upper Perennial
New Mills Meadow- North	R306	SS	MDI-East	4.49	330	99	Low	65	Depression Open
Western Mountain Swamp	R302	F	MDI-West	1.65	122	99	Upper	50	Slope- Topographic

There are few known historic disturbances that occurred within this wetland complex. A land ownership map of Mount Desert Island from 1887 shows Big Heath subdivided into lots, which may have been for rights to marsh hay (Colby and Stuart 1887; R. Cole-Will, Cultural Resources Specialist, Acadia National Park, 12/30/2009, personal communication). Roads to the north and south have existed since 1887, but no known roads or trails have ever intersected the heath.

Threats to Big Heath include climate change, visitor use impacts, invasive species, and hydrologic alteration. Coastal Plateau Bogs are formed by a unique climate setting characterized by frequent summer fog and low summer temperatures, which restrict evapotranspiration rates during the growing season (Damman 1977). Therefore, changes in climate, such as fog frequency, precipitation and growing season temperatures, all have the potential to greatly impact the dynamics of this wetland community.

The vegetation in Big Heath grows slowly and is sensitive to trampling (Gawler and Cutko 2010). A number of social trails have developed around the southeastern section of the bog and are likely the primary means of visitor access from Route 102A. Increased use or expansion of these trails could impact the local hydrologic regime, serve as a vector for invasive plants, and cause local extirpation of species most sensitive to trampling.

The raised dwarf shrub and sedge lawn portion of Big Heath is the area we expect to be most sensitive to environmental stressors, and of the most ecological significance (Maine Natural Areas Program ranking: State Vulnerable [S3]). Therefore, to monitor this wetland, we used GRTS to locate a permanent monitoring site within the raised portion of the bog that was mapped as Acadian Maritime Bog on the Acadia vegetation map (Lubinski et al. 2003) (Appendix A: Figure 2).

### ***Gilmore Meadow***

Few large wetland complexes on MDI were spared major human disturbance or hydrologic alteration during the 19th and early 20th century. For example, historic patterns of ditching and channelization are still evident on aerial photos of Great Meadow on MDI and Kent Field, and both wetlands have a long history of human disturbance and hydrologic alteration (Little 2005). Gilmore Meadow was selected for monitoring because it represents the least disturbed condition of large, graminoid-dominated wetland complexes on MDI.

Gilmore Meadow is an 8-ha graminoid shallow marsh on the eastern side of MDI (Appendix A: Figure 3). The entire watershed is completely in park ownership and was burned in the 1947 fire (Table 3). The outlet of Gilmore Meadow is a stream water quality and quantity monitoring site, and has been sampled biannually since 2006.

The northern half of Gilmore Meadow is surrounded by carriage roads, and a culvert at the outlet impounds the stream that flows into Aunt Betty Pond. An active beaver colony is also located near the outlet. Historic records indicate that while a smaller version of this wetland may have existed prior to human disturbance, the current size is likely the result of a long history of impoundment near the outlet (circa 1893, R. Cole-Will, Cultural Resources Specialist, Acadia National Park, 1/5/2010, personal communication). The construction of the carriage road and culvert on the north side of Gilmore Meadow in the 1930's was the last major human modification to the hydrologic regime, and the wetland extent has been relatively stable since.

While beaver activity has influenced the hydrologic regime, and likely helped maintain the graminoid vegetation, the culvert impoundment at the outlet has likely had the greatest lasting influence on the extent and hydrology of this wetland.

Gilmore Meadow is dominated by sedges and grasses, including wiregrass sedge (*Carex lasiocarpa*), tussock sedge (*Carex stricta*), Northwest Territory sedge (*Carex utriculata*) and bluejoint (*Calamagrostis canadensis*). Several low shrub species are also common, including leatherleaf (*Chamaedaphne calyculata*) and sweet gale (*Myrica gale*). Broadleaf cattail (*Typha latifolia*) is also present at low levels.

A number of stressors have the potential to impact Gilmore Meadow, including climate change, invasive species, erosion, sedimentation, and hydrologic alteration. Climate models for coastal Maine predict increases in the frequency and intensity of storm events (Jacobson et al. 2009). This is an important concern to park management, as high intensity storm events often cause damage to park infrastructure, including washouts of the carriage roads, flooding and increased erosion and sedimentation. Invasive species, such as species of cattail (*Typha latifolia*, *Typha angustifolia*, and *Typha x glauca*) and reed canarygrass (*Phalaris arundinacea*), are also an important concern to park managers, as they often respond favorably to increases in sedimentation and run-off (Werner and Zedler 2002).

Gilmore Meadow's location within the carriage road system will allow us to monitor impacts from these stressors, and relate our findings to the many other wetlands in a similar situation. We used GRTS to determine the location of the permanent monitoring site within the area delineated on the ACAD vegetation map as Laurentian-Acadian Wet Meadow-Shrub Swamp and Marsh (Appendix A: Figure 3).

### **Great Meadow**

Great Meadow is a 6-ha dwarf shrub acidic fen located on Isle au Haut (IAH), a remote island in mid-coast Maine (Appendix A: Figure 4). The park-administered portion of IAH (roughly the southern half of the island) is the most undeveloped and pristine area in ACAD, and Great Meadow is located near the park boundary in the west-central part of the island. While only 53% of the watershed containing Great Meadow is in park ownership, the land that drains into this wetland is completely undeveloped. Historical records indicate that the interior of IAH was extensively logged in the 19th century, and the existence of a saw mill downstream from Great Meadow on Long Pond suggests that forests within the Great Meadow watershed are predominantly second growth (R. Cole-Will, Cultural Resources Specialist, Acadia National Park, 12/30/2009, personal communication). However, there are no known human disturbances that have occurred within Great Meadow, and the second growth forests have remained largely undisturbed for nearly 100 years.

In the 1980s Great Meadow was designated a state Critical Area by the Maine Natural Areas Program (MNAP) due to the minimally disturbed condition, and the high abundance of dragon's mouth (*Arethusa bulbosa*), a state-listed rare species (S3). Ink-berry (*Ilex glabra*) and twining screwstem (*Bartonia paniculata*), both listed as critically imperiled (S1) by MNAP, are also present in Great Meadow. The occurrence of ink-berry is the only known location in Maine (Greene et al. 2005). Other noteworthy species in this wetland include rose pogonia (*Pogonia ophioglossoides*), grasspink (*Calopogon tuberosus*), spoonleaf sundew (*Drosera intermedia*),

pitcherplant (*Sarracenia purpurea*), dwarf huckleberry (*Gaylussacia dumosa*), sweet gale (*Myrica gale*), leatherleaf (*Chamaedaphne calyculata*) and several graminoid species (e.g., *Carex oligosperma*, *Carex exilis*, *Juncus canadensis*, *Eriophorum angustifolium*, *Eriophorum virginicum*, and *Rhynchospora alba*).

Threats to Great Meadow include hydrologic alteration, climate change, and invasive species. Much of the watershed upstream from Great Meadow is protected from development by the park, but hydrologic alteration downstream and outside of the park could greatly impact the condition and vegetation of this wetland. While infrequent on Isle au Haut and not currently present in Great Meadow, invasive species are an important concern as they could potentially displace rare species and would require considerable effort to control in this remote location. The location of the permanent monitoring site was determined using GRTS and is within the area delineated by the ACAD vegetation map as Laurentian-Acadian Acidic Basin Fen (Appendix A: Figure 4).

#### ***New Mills Meadow – Northwest***

New Mills Meadow – Northwest is a 4.5-ha fen that is part of a larger wetland complex called New Mills Meadow (Appendix A: Figure 5). The graminoid-dominated wetland that follows the main channel of Duck Brook is likely impacted by Duck Brook Road, which runs parallel to Duck Brook on the east side of the main complex. However, the northwest fen, which runs nearly perpendicular to Duck Brook Road, appears to have remained fairly intact and undisturbed. A number of disturbance-sensitive species occur in abundance in this wetland, including dragon's mouth (*Arethusa bulbosa*), rose pogonia (*Pogonia ophioglossoides*), and bog rosemary (*Andromeda glaucophylla*).

Potential threats are similar to those discussed for Gilmore Meadow. Carriage roads surround and drain into the north side of this fen. Sedimentation, run-off and erosion are all potential threats to wetland condition. We used GRTS to determine the location of the permanent monitoring site within the area delineated on the ACAD vegetation map as Laurentian-Acadian Acidic Basin Fen.

#### ***Duck Pond Peatland***

This 2.8-ha wetland surrounds the small, notably acidic Duck Pond, and is near the Long Pond Fire Road (Appendix A: Figure 6). The watershed containing Duck Pond Peatland is entirely in park ownership (Table 3) and primarily composed of second-growth spruce-fir forest. The abundance of standing dead white cedar (*Thuja occidentalis*) among the largely ericaceous shrub and sedge dominated ground layer is suggestive of a major hydrologic disturbance in the recent past. Little (2005) determined beaver activity along Duck Pond Stream to be the cause of the disturbance that killed the trees. This wetland was subsequently abandoned by beaver around 1970, and this site appears to be converting back to a forested wetland.

This wetland was selected for monitoring because it represents the natural variation of wetland disturbance and succession in ACAD, as described by Little (2005), and there is little evidence of human disturbance. This wetland is currently in a transitional stage from a low shrub and sedge dominated fen to a white cedar fen. White cedar seedlings and saplings are relatively common throughout the wetland, and barring major disturbance, it will likely return to a forested state.

Potential threats are similar to those of most similar-sized wetlands in ACAD. The proximity to Long Pond Fire Road, which is a potential source of run-off, sedimentation and erosion, could impact wetland condition and make it more susceptible to invasion of exotic species such as reed canarygrass (*Phalaris arundinaceae*), glossy buckthorn (*Frangula alnus*), and purple loosestrife (*Lythrum salicaria*). The location of the permanent monitoring site was determined using GRTS and is within the area delineated by the ACAD vegetation map as Laurentian-Acadian Acidic Basin Fen.

### **Frazer Fen**

Frazer Fen is a 2.7-ha acidic basin fen located in the headwaters of Frazer Creek on Schoodic Peninsula (Appendix A: Figure 7). While only 62% of the watershed containing this wetland is in park ownership, the watershed is largely undeveloped and composed primarily of second-growth spruce-fir forest. Partial harvesting of large diameter red spruce occurred in the mid-1990s outside of the park (Woodlot Alternatives, Inc. 1996), and skid trails are still visible on 2009 orthophotography. However, only a small portion of the harvested area drains into this wetland, and the perimeter is surrounded entirely by at least a 100-m buffer of forested parkland.

The outer fringe of this wetland is forested and dominated by black spruce and tamarack. The interior portion of the wetland is dominated primarily by shrub/scrub vegetation, with patches of emergent vegetation and stunted trees. Most notably, jack pine (*Pinus banksiana*), which typically occurs in upland habitats in ACAD, is common in this wetland. Other common plant species include tussock sedge (*Carex stricta*), pitcherplant (*Sarracenia purpurea*), leatherleaf (*Chamaedaphne calyculata*), sweet gale (*Myrica gale*) and catberry (*Ilex mucronata*).

Threats to Frazer Fen include climate change, development and/or impairment of the non-park land in the watershed, and invasive species. Jack pine is near its southern range limit in ACAD, and changes in temperature and precipitation regimes may impact this species. Changes in upstream and adjacent land use could contribute excess nutrients and sedimentation, resulting in altered species composition and increased vulnerability to exotic species invasion (Zedler and Kercher 2004). GRTS was used to locate a permanent monitoring site within the area delineated as Laurentian-Acadian Acidic Basin Fen by the ACAD vegetation map.

### **Heath Brook**

This 2.5-ha fen is part of a larger complex of wetlands along Heath Brook (Appendix A: Figure 8). At the outlet of this wetland, Heath Brook flows through a culvert on Seal Cove Road. Seal Cove Road has had roughly the same route since 1887, which suggests that a culvert draining Heath Brook has likely been in place as long. While the area around Heath Brook is currently forested and in park ownership, this area was dominated by farm settlements during the 19th century. Settlements included sheep pastures, agricultural fields, and timber stands (R. Cole-Will, Cultural Resources Specialist, Acadia National Park, 1/5/2010, personal communication). This area has been in park ownership and undisturbed since about 1940 (U.S. Geological Survey 1942).

Despite historic disturbances and its proximity to Seal Cove Road, this wetland exhibits minimally disturbed condition; invasive species are absent, vegetation is dominated by low shrubs and sedge species, and *Sphagnum* moss is abundant. Several active beaver colonies occur

throughout this wetland complex, and damming of the culvert at the output has caused flooding and washouts along Seal Cove Road in the recent past.

We selected this wetland over the larger wetlands in the complex because we expect its smaller size and proximity to the road will make it more vulnerable to stressors. This wetland was also used in a previous wetland study (Little 2005), and a stream water quality monitoring site is located within 50 m downstream of this wetland's outlet.

Threats to wetland condition in Heath Brook are similar to those mentioned for New Mills Meadow and Gilmore Meadow, and include run-off and sedimentation from nearby roads, impounding by the culvert, and invasive species. GRTS was used to locate a permanent monitoring site within the area delineated as Laurentian-Acadian Acidic Basin Fen.

### **Hodgdon Swamp**

Hodgdon Swamp is a 1.68-ha white cedar swamp located upstream from Hodgdon Brook (Appendix A: Figure 9). The watershed containing this wetland is entirely in park ownership and dominated by second-growth spruce-fir forests. The ground layer is composed of *Sphagnum* moss, threeseeded sedge (*Carex trisperma*), cinnamon fern (*Osmunda cinnamomea*), and black huckleberry (*Gaylussacia baccata*), creeping snowberry (*Gaultheria hispidula*), northern bayberry (*Morella pensylvanica*), tamarack (*Larix laricina*) and bristly dewberry (*Rubus hispidus*). Mud sedge (*Carex limosa*) is also present in this wetland.

This wetland was chosen for monitoring because it represents a later stage in wetland succession and we have been monitoring a forest health plot on the northern side of this wetland every four years since 2006. Hodgdon Swamp is more than 400 m from the nearest road, and the entire watershed containing this wetland is owned by the park. Given the level of protection buffering Hodgdon Swamp, monitoring this wetland will allow us to better understand natural variation in small wetlands in the absence of major stressors over time. We used GRTS to locate a permanent monitoring site within the area delineated by the ACAD vegetation map as Laurentian-Acadian Acidic Swamp.

### **Western Mountain Swamp**

This 1.65-ha white cedar swamp is located at the base of Bernard Mountain and north of the Western Mountain Road on MDI (Appendix A: Figure 10). The watershed is dominated by second-growth spruce-fir forest and is 99% park owned. Historic disturbances were probably similar to those described for Heath Brook. However, the Western Mountain Road system has only been in place since about 1940 (U.S. Geological Survey 1942).

This wetland was chosen for monitoring because it represents a later stage in wetland succession and we have been monitoring a forest health plot on the western side of this wetland every 4 years since 2006. The vegetation in this wetland is very similar to Hodgdon Swamp. However, Western Mountain Swamp is less remote and more likely to be influenced by human stressors. We used GRTS to locate a permanent monitoring site within the area delineated by the ACAD vegetation map as Laurentian-Acadian Acidic Swamp.

### **Little Hunter's Brook**

This site is part of an approximately 3-ha fen complex that follows Little Hunter's Brook (Appendix A: Figure 11). Approximately 94% of the watershed that contains this complex is in

park ownership, and the remaining 6% is confined to a privately-owned gravel pit. Extensive logging occurred in the interior uplands around the brook (by *ca.* 1800) and a sawmill was located at the mouth of the brook. However, the surrounding forests exhibit characteristics of mature to late-successional structure, and were not likely disturbed since the initial harvest.

This complex is composed of three smaller wetlands separated by beaver dams and/or constriction by the upland. While this complex is mapped as one polygon in the ACAD Vegetation Map, we will treat these as separate wetlands as in Little (2005). There are active beaver colonies and dams in all three wetlands, and a fair amount of deep water (i.e., > 1 m depth) occurs throughout the two most downstream wetlands. The wetland furthest upstream has the most area (1.35 ha) that can be sampled and a forest health plot (established in 2007) is less than 10 m north of this wetland's boundary. Therefore, the uppermost wetland in the complex will be monitored, and we will use the boundary delineated by Little (2005).

A privately owned gravel pit east of Little Hunter's Brook may be the greatest threat to wetland condition. Currently there are no observed impacts from the gravel pit, but increased use, or removal of forest cover could increase inputs of sediment into the system. Increased sediment could make the wetland more vulnerable to invasion by exotic species. GRTS was used to locate a permanent monitoring site within the area delineated as Laurentian-Acadian Acidic Basin Fen.



## Sampling Methods

Sampling methods will primarily follow EPA National Wetland Condition Assessment (NWCA) protocols, which employ a 3-tier approach to monitoring. Monitoring sites are composed of a 40-m radius assessment area, and a 100-m buffer around the assessment area. Rapid assessment monitoring consists of Level 1 and Level 2 monitoring, and follows the USA-RAM (U.S. EPA 2011b). Level 1 is a GIS-based assessment of landscape context, and focuses on condition of the buffer. Level 2 is a field-based rapid assessment of stress and condition in the assessment area and buffer. Level 3 procedures follow the Field Operations Manual (FOM), and consist of site-based monitoring of vegetation, hydrology, soils, and water chemistry within the 40-m radius assessment area (U.S. EPA 2011a). Level 3 monitoring also further characterizes the condition and habitat in the buffer using twelve 100-m<sup>2</sup> buffer plots that are oriented in the four cardinal directions (N, S, E, and W), and centered at 5 m, 50 m, and 95 m from the assessment area boundary. Detailed methods are described in the USA-RAM (U.S. EPA 2011b) and the Field Operations Manual (FOM; U.S. EPA 2011a). Because our methods follow the EPA FOM and USA-RAM protocols so closely, we will refer to these manuals in this protocol, rather than creating a stand-alone document. Where our methods differ from or are in addition to the FOM or USA-RAM, we provide standard operating procedures (SOPs) following the narrative of this protocol. SOPs for this protocol include detailed instructions for installing shallow wells and using pressure transducers, and data analysis and reporting.

For intensive sampling, the field crew should have copies of the EPA FOM, USA-RAM, EPA guidance memos, site datasheets, and NETN SOPs 1-6 in the field. For rapid assessment monitoring, the field crew should have a copy of the USA-RAM manual, a set of USA-RAM datasheets and NETN SOPs 1-5 in the field. SOPs 7 and 8 are necessary for well construction and maintenance, and deploying and downloading data from the pressure transducers.

### Field Season Preparation

Prior to intensive sampling years for the NWCA (2011, 2016, and every 5 years thereafter), all equipment and supplies will need to be purchased by NETN and/or acquired from EPA and tested to ensure proper functioning (see Equipment and Supply List in U.S. EPA 2011a). A park research permit must be obtained and soil sampling locations must be approved by ACAD's Cultural Resource Specialist. Field maps with sampling locations overlaid on topographic maps and orthophotos should be created, and printed on waterproof paper. Additionally, a seasonal technician or volunteer must be hired and the NETN Plant Ecologist and seasonal technician must attend the week-long EPA protocol training. Field season preparation during the four intervening years of rapid assessments will require renewing a park research permit, determining and mapping sampling locations, and hiring a field technician or volunteer to assist the NETN Plant Ecologist with sampling.

### Field Season Scheduling

Rapid assessment and intensive sampling will be conducted between the beginning of July and end of August, and will mostly occur after the forest monitoring field work is completed in NETN (usually late July). Data collection for Level 1 (GIS-based) monitoring will occur prior to the field season, in late winter or early spring. Shallow wells will be visited twice a year, with one visit in the spring (between ice-out and beginning of growing season) and one visit in the fall (between the end of the growing season and ice-in) to check well status and download data from

the pressure transducers. Wells will be constructed and installed at least one month prior to, or after Level 3 sampling occurs to reduce impacts of trampling in the vegetation plots.

### **Details of Taking Measurements**

The monitoring site design for both the USA-RAM and the FOM consists of a 40-m radius assessment area (0.5 ha) and a 100-m buffer surrounding the assessment area (Appendix B: Figures 1 and 2). The Level 1 component in the USA-RAM quantifies the extent of natural habitat in the 100-m radius buffer surrounding the assessment area in eight 100-m transects. The Level 2 component in USA-RAM evaluates the overall condition and presence of stressors for the assessment area and buffer, and focuses on the hydrology, physical structure, and biological structure of the wetland (U.S. EPA 2011b). The USA-RAM is conducted in the 40 rapid assessment sites, and as part of the NWCA in the ten sentinel sites.

Level 3 monitoring follows the FOM (U.S. EPA 2011a), and is only conducted in the ten sentinel sites. In the assessment area (AA) of each sentinel site, a suite of measures related to vegetation, soils, hydrology, algae, and water quality are monitored (Appendix B: Figure 3; FOM Chapter 3). Vegetation is sampled in five 100-m<sup>2</sup> plots within the assessment area, and each vegetation plot contains smaller nested plots to characterize species composition data at multiple scales (Appendix B: Figure 4; FOM Chapter 5). Level 3 monitoring also involves characterizing the buffer around the AA using thirteen square 100-m<sup>2</sup> buffer plots (FOM Chapter 4). Buffer plots are oriented in the four cardinal directions and centered at 5 m, 50 m, and 95 m from the AA boundary, and one buffer plot is located at the center of the AA. There are no restrictions on the composition of the 100 m buffer surrounding the assessment area. The only major deviation from the NWCA FOM will involve less intensive soil sampling after the initial 2011 survey to ensure our monitoring efforts do not impact wetland condition. The specific methods will be determined after consultation with EPA NWCA scientists and prior to the 2016 sampling effort.

Because EPA selects new sites for each year of the NWCA, permanent plot marking techniques are not covered by the EPA FOM. To permanently mark the sentinel sites, we will install a 60 cm fiberglass stake at the corner of each vegetation plot along the North, East, South or West transect that is closest to the center of the AA. The locations of the fiberglass stakes will help us identify quickly where a vegetation plot is located, so as not to trample it while sampling soils or checking on the shallow wells. This approach puts two of the stakes close to a soil sampling location along the North and West transect. If we find that the close proximity of the North and West vegetation plot markers and soil sampling locations becomes problematic in the future, we will move the stakes further down the transect.

While indicators of wetland hydrology are recorded during the EPA NWCA, the 5-year sampling interval will be inadequate for detecting trends in hydrology and associated changes in wetland structure, function, and composition. Therefore, NETN will establish a shallow well in the center of the assessment area in each sentinel site on MDI (eight sites) to continuously monitor water level (Appendix B: Figure 3). Due to difficult logistics and limited staff time, shallow wells will not be installed in the sentinel sites on Isle au Haut and Schoodic Peninsula. Wells will be installed and/or visited at least a month before the plot will be sampled to allow for trampled vegetation to recover. Pressure transducers will be placed inside the wells for continuous monitoring of water level, and the data will be downloaded twice annually. The standard operating procedures (SOP) which follow this narrative, provide instructions for well installation

and deployment/use of pressure transducers for monitoring wetland hydrology (See SOPs 2, 7, and 8) .

### **Processing of Samples**

Water, algae, and soil samples that are collected for the Level 3 monitoring will be processed and sent to EPA-designated laboratories following the procedures described in the FOM, and will be analyzed according to the NWCA Laboratory Methods Manual (U.S. EPA 2012). Costs associated with lab analyses will be covered by the EPA. Unknown plant specimens and Quality Control (QC) plant specimens will be pressed by the Plant Ecologist or technician. Unknown specimens will be later identified by the Plant Ecologist and/or a contract botanist who is knowledgeable of the local flora. All QC specimens will be identified by a contract botanist. If a QC specimen is also an unknown species on the same plot, a different contract botanist must identify each specimen. NETN will cover the costs of contract botany work.



## **Data Handling, Analysis, and Reporting**

Data will be recorded in the field on datasheets provided by the EPA NWCA or designed by NETN staff. Once datasheets for sentinel sites are verified, scanned, and printed, originals will be sent to EPA staff for entry into NWCA databases. EPA staff will handle initial data management and reporting responsibilities for sentinel sites as part of the NWCA. After NWCA data are made available to NETN staff, the NETN Plant Ecologist and Data Manager will manage and archive a set of ACAD-specific data. The NETN Plant Ecologist and Data Manager will also manage data collected in the shallow wells and the USA-RAM data collected in the 40 rapid assessment sites.

### **Data Quality**

The EPA and NETN both take data quality and accuracy very seriously, and extensive quality assurance / quality control (QA/QC) measures are taken throughout the process of data collection and laboratory analysis. For example, every field team is audited by an EPA staff member within the first week of sampling to ensure the field team is following the protocol. Every Friday during the NWCA field season, EPA holds a mandatory call for the crew leaders of each field team. These calls give everyone a chance to hear important clarifications and ask questions about the protocols. In addition, field teams are required to collect one randomly chosen plant species in each of the five vegetation plots per assessment area. The QA/QC specimens must then be identified by a different botanist than the crew sampling. For more details, refer to the NWCA Quality Assurance Project Plan (U.S. EPA 2011c).

### **Data Analysis**

Data collected in the sentinel sites will be analyzed using an ecological integrity framework and will include a combination of metrics developed in Faber-Langendoen (2009), relevant analyses in the Data Analysis Plan (U.S. EPA in prep), and metrics developed for an index of ecological integrity in ACAD emergent wetlands by Grace et al. (2012). The data collected in 2011 for the NWCA are not currently available, and it is not clear what data will be available for each sentinel wetland. The EPA Data Analysis Plan, which will include indicators of wetland condition for the NWCA, is also currently under development, and a draft version is not available. After the NWCA data for the sentinel wetlands are provided by EPA, and the Data Analysis Plan is completed, we will provide a more detailed list of wetland condition indicators to include in our analyses and reports.

Trend analyses on key measures of wetland condition will be performed after two cycles of NWCA sampling. Initial trend analyses will be quite simple (e.g., paired sample t-tests of metrics for each site). As the data series becomes longer we will employ more sophisticated approaches, such as trend analyses based on a general linear model which partitions spatial and temporal variability to allow assessment of change over time, as is done by the U.S. Forest Service Forest Inventory and Analysis program (Woodall and Williams 2005), and the NETN Forest Monitoring Protocol (Tierney et al. 2011). The USA-RAM data will likely be more amenable to statistical analysis, even though the data collected are more qualitative. This is because the USA-RAM data will be based on a statistical sample with a reasonable sample size. The sentinel wetlands, on the other hand, are not a statistical sample and include only a small number of sites in several distinct wetland types. The strength of these data is in the in-depth site information

they provide and, while statistical models will likely help us explore data trends at each site, they cannot be used for inference to a larger population.

### **Reporting**

The NETN will produce an annual summary report for each year of NWCA sampling after data are made available by EPA. These reports will include results from the soil, water, and algae lab analyses processed by EPA, vegetation data summaries, and an ecological integrity scorecard. NETN will also produce a status report after all 4 panels of rapid assessments are completed. Every 10 to 15 years, NETN will produce a trend report that combines results from the NWCA sampling, rapid assessment monitoring, and continuous water level monitoring and examines change over time.

## Personnel Requirements and Training

Because this is a protocol of secondary priority to ACAD and NETN, NETN will have limited staff time and funding to devote to the implementation of this protocol. The freshwater wetland monitoring protocol will be implemented by the NETN Plant Ecologist and a technician and/or volunteer, and sampling will occur after sampling for primary protocols (e.g. forest health monitoring) is complete. The NETN Plant Ecologist will oversee implementation of the monitoring program. Pre-season tasks include applying for a permit, scheduling field work, hiring and training technicians and/or volunteers, preparing maps of sample locations, coordinating with EPA staff for the NWCA, and purchasing equipment and supplies. The NETN Plant Ecologist will lead data collection in the field, and will be responsible for ensuring accurate data collection, coordinating daily logistics, and ensuring data management practices are met. During years that sentinel sites are sampled for the NWCA, the NETN Plant Ecologist and seasonal technician will attend a pre-season training by EPA on the Field Operations Manual (FOM; U.S. EPA 2011a). For the four years between the NWCA, the NETN Plant Ecologist will train the seasonal technician on USA-RAM (U.S. EPA 2011b) and other protocol methods.

NWCA sampling procedures were designed for a crew of four to six people to sample one wetland site in a day (U.S. EPA 2011a). Because only two staff members are available for sampling in NETN, the NETN Plant Ecologist and seasonal technician will conduct all of the field work for a monitoring site over two days. The vegetation is most prone to trampling, and therefore data collection outlined in chapters 3 through 5 in the FOM for the Vegetation Team will be completed on the first day of sampling. The USA-RAM will also be completed on the first day of sampling. Tasks assigned to the Assessment Area-Buffer Team in chapters 6 through 9 in the FOM will be completed on the second sampling day.

Additional staff may be required periodically to implement this protocol, including:

- NETN Program Manager to help with contracting, hiring, and potentially participate in data collection
- NETN Air and Water staff to train staff and/or assist with water samples



## **Operational Requirements**

### **Annual Workload and Field Schedule**

Field work can be conducted between the beginning of July and end of August. Due to limited staff time, field work will primarily occur in August after the forest monitoring field work is completed in NETN. During NWCA years, we expect the time required to sample all 10 permanent sites will be around 5 weeks for a 2-person crew. This includes travel time for the more remote wetland sites. During rapid assessment years, we expect to complete field data collection for 10 sites in 2 to 3 weeks. The office-based Level 1 data collection will take place prior to the field season, and is expected to take less than a week to complete. Spring and fall visits to check and download data from the shallow wells will require a week of field work for each round of visits.

### **Facility and Equipment Needs**

The NETN Plant Ecologist and technician will be based in ACAD, and the technician may need park housing. If lab space is needed, NETN will coordinate with ACAD staff to use existing lab facilities. Most of the equipment required for the intensive and USA-RAM sampling has already been acquired by NETN for other monitoring protocols. Purchasing pressure transducers and well materials is the largest initial cost to implementing this protocol, but once purchased, long-term costs associated with this aspect of the protocol are much reduced. Due to limited funds, additional supply costs will be minimal, and may include purchasing rite in the rain paper, plastic bags for unknown samples and fiberglass and rebar for plot markers.



## Literature Cited

- Calhoun, A.J.K., J.E. Cormier, R.B. Owen, A.F. O'Connell, C.t. Roman, and R.W. Tiner. 1994. The wetlands of Acadia National Park and vicinity. Maine Agricultural and Forest Experiment Station, Miscellaneous Publication 721.
- Colby, G.N., J.H., Stuart. Map of Mount Desert Island, Maine, 1887. 1:17,820.
- Cowardin, L.M., V. Carter, F.C. Golet, and E.T. LaRoe. 1979. Classification of wetlands and deepwater habitats of the United States.
- Cunningham, J.M., 2003. Pond-breeding amphibian distributions in a beaver-modified landscape, Acadia National Park, Mount Desert Island, ME. M.S.thesis, University of Maine, Orono, Maine.
- Damman, A.W.H. 1977. Geographical changes in the vegetation pattern of raised bogs in the Bay of Fundy region of Maine and New Brunswick. *Vegetatio* 35(3): 137-151.
- Faber-Langendoen, D. 2009. A freshwater wetlands monitoring and assessment framework for the Northeast Temperate Network, National Park Service. Natural Resource Report NPS/NETN/NRR—2009/143. National Park Service, Fort Collins, Colorado.
- Gahl, M.K. 2007. Spatial and temporal patterns of amphibian disease in Acadia National Park wetlands. PhD. thesis, University of Maine, Orono, Maine.
- Gawler, S. and A. Cutko. 2010. Natural Landscapes of Maine: A guide to natural communities and ecosystems. Maine Natural Areas Program, Maine Department of Conservation, Augusta, Maine.
- Grace, J. B., D. R. Schoolmaster, G. R. Guntenspergen, A. M. Little, B. R. Mitchell, K. M. Miller, E. W. Schweiger. 2012. Guidelines for a graph-theoretic implementation of structural equation modeling. *Ecosphere* 3(8): 1-44.
- Greene, C.W. 1990. Rare vascular plants of Acadia National Park and the Mount Desert Island Region of Maine. Technical Report, Northeast Region, National Park Service.
- Greene, C.W., L.L. Gregory, G.H. Mittlehauser, S.C. Rooney, and J.E. Weber. 2005. Vascular Flora of the Acadia National Park Region, Maine. *Rhodora* 107: 117-185.
- Jacobson, G.L., I.J. Fernandez, P.A. Mayewski, and C.V. Schmitt (editors). 2009. Maine's climate future: an initial assessment. Orono, ME: University of Maine. <http://www.climatechange.umaine.edu/mainesclimatefuture/>
- James-Pirri, M.-J., C. T. Roman. 2010 (draft). Northeast Coastal Barrier Network Salt Marsh Vegetation Monitoring: A Protocol for National Park Service's Long-Term Monitoring Program. Natural Resource Technical Report NPS/NCBN/NRTR—2010/XXX. National Park Service, Fort Collins, Colorado.

- Keddy, P. A. 2000. *Wetland Ecology: Principles and Conservation*. Cambridge University Press, Cambridge, UK.
- Kolozsvary, M.B. 2003. Hydroperiod of wetlands and reproduction in wood frogs (*Rana sylvatica*) and spotted salamanders (*Ambystoma maculatum*). PhD thesis, University of Maine, Orono, Maine.
- Little, A. M. 2005. The effects of beaver inhabitation and anthropogenic activity on freshwater wetland plant community dynamics on Mount Desert Island, Maine, USA. PhD thesis, University of Wisconsin, Madison, Wisconsin.
- Little, A. M., G. R. Guntenspergen, and T. F. H. Allen. 2010. Conceptual hierarchical modeling to describe wetland plant community organization. *Wetlands* 30:55-65.
- Lubinski, S., K. Hop, and S. Gawler. 2003. U.S. Geological Survey-National Park Service Vegetation Mapping Program: Acadia National Park, Maine. United States Geological Survey, Upper Midwest Environmental Sciences Center, La Crosse, WI. 110 pp + Appendices.
- McDonald, T. L. 2004. GRTS for the Average Joe: A GRTS Sampler for Windows. [http://www.west-inc.com/biometrics\\_reports.php](http://www.west-inc.com/biometrics_reports.php).
- McLane, C.B. 1989. *Islands of the Mid-Maine Coast, Volume II: Mount Desert to Machias Bay*. The Kennebec River Press, Falmouth, Maine.
- Mitchell, B. R., W. G. Shriver, F. Dieffenbach, T. Moore, D. Faber-Langendoen, G. Tierney, P. Lombard, and J. Gibbs. 2006. Northeast Temperate Network vital signs monitoring plan. Technical Report NPS/NER/NRTR—2006/059. National Park Service, Woodstock, Vermont.
- Mitsch, W. J., and J. G. Gosselink. 2000. *Wetlands*, Third edition. John Wiley and Sons, Inc., New York.
- Neckles, H. A., A. T. Gilbert, G. R. Guntenspergen, N. P. Danz, T. Hollenhorst, A. Little, J. Olker. 2007 (in prep). Protocol for monitoring freshwater wetlands in National Parks of the Northeast Temperate Network. Prepared for the National Park Service. U.S. Department of the Interior. U.S. Geological Survey, Reston, Virginia.
- Tierney, G., B. Mitchell, K. Miller, J. Comiskey, A. Kozlowski, and D. Faber-Langendoen. 2011. Northeast Temperate Network long-term forest monitoring protocol: 2011 revision. Natural Resource Report NPS/NETN/NRR—2010/195. National Park Service, Fort Collins, Colorado.
- Tierney, G., A. Miller-Rushing, B. Mitchell, F. Dieffenbach, A. Kozlowski, T. Donovan, A. Richardson, J. Katz, C. Brauer, O. Sonnentag, C. Teshera-Sterne, and M. Tooney. In review. Northeast Temperate Network Phenology Monitoring Protocol. Natural Resource Report NPS/NETN/NRR – XXXX/XXX

- U.S. Environmental Protection Agency. 2011a. National Wetland Condition Assessment: Field Operations Manual. EPA-843-R-10-001. U.S. Environmental Protection Agency, Washington, DC.
- U.S. Environmental Protection Agency. 2011b. National Wetland Condition Assessment: USA-RAM Manual. EPA-843-R12-001. U.S. Environmental Protection Agency, Washington, DC.
- U.S. Environmental Protection Agency. 2011c. National Wetland Condition Assessment: Quality Assurance Project Plan. EPA-843-R10-003. U.S. Environmental Protection Agency, Washington, DC.
- U.S. Environmental Protection Agency. 2012. National Wetland Condition Assessment: Laboratory Operations Manual. EPA-843-R10-002. U.S. Environmental Protection Agency, Washington, DC.
- US Geological Survey. Mount Desert, Maine Quadrangle. 1942. 1:31,680. 15min Series. US Department of the Interior, USGS, 1942.
- Vaux, P. D., S.J. Nelson, N. Rajakaruna, G. Mittlehauser, K. Bell, B. Kopp, J. Peckenham, and G. Longworth. 2008. Assessment of natural resource conditions in and adjacent to Acadia National Park, Maine. Natural Resource Report NPS/NRPC/WRD/NRR— 2008/069. National Park Service, Fort Collins, Colorado.
- Werner, K.J., and J.B. Zedler. 2002. How sedge meadow soils, microtopography, and vegetation respond to sedimentation. *Wetlands* 22(3): 451-466.
- Woodall, C. and M. S. Williams. 2005. Sampling protocol, estimation, and analysis procedures for the down woody materials indicator of the FIA program. General Technical Report NC-256. U.S. Forest Service, North Central Research Station, St. Paul, Minnesota.
- Woodlot Alternatives, Inc. 1996. An ecological assessment of the 1600 acre parcel at Schoodic Peninsula. Technical report. Woodlot Alternatives, Inc., Topsham, Maine.
- Zedler, J.B., and S. Kercher. 2004. Causes and consequences of invasive plants in wetlands: opportunities, opportunists, and outcomes. *Critical Reviews in Plant Sciences* 23(5): 431-452.



## Appendix A. Maps of sentinel sites in Acadia National Park.

**Table A.1.** GPS coordinates and EPA site numbers for sentinel sites. GPS coordinates are in UTM NAD83 and represent the center of the sentinel site.

Sentinel Site	EPA Site #	X	Y
Big Heath	NWCA11-R303	554269.4900	4898325.525
Duck Pond	NWCA11-R301	549457.8418	4907550.899
Frazer Fen	NWCA11-R310	574781.2155	4912542.806
Gilmore Meadow	NWCA11-R304	558038.9127	4912418.319
Great Meadow	NWCA11-R307	530760.4985	4877379.503
Heath Brook	NWCA11-R308	550295.8216	4902978.343
Hodgdon Swamp	NWCA11-R309	548334.0218	4908555.805
Little Hunter's Brook	NWCA11-R305	562734.6871	4905961.533
New Mills- NW	NWCA11-R306	560565.5447	4915579.552
Western Mtn. Swamp	NWCA11-R302	550431.5484	4903780.792

### Permanent Wetland Monitoring Location Legend

#### Base Layers

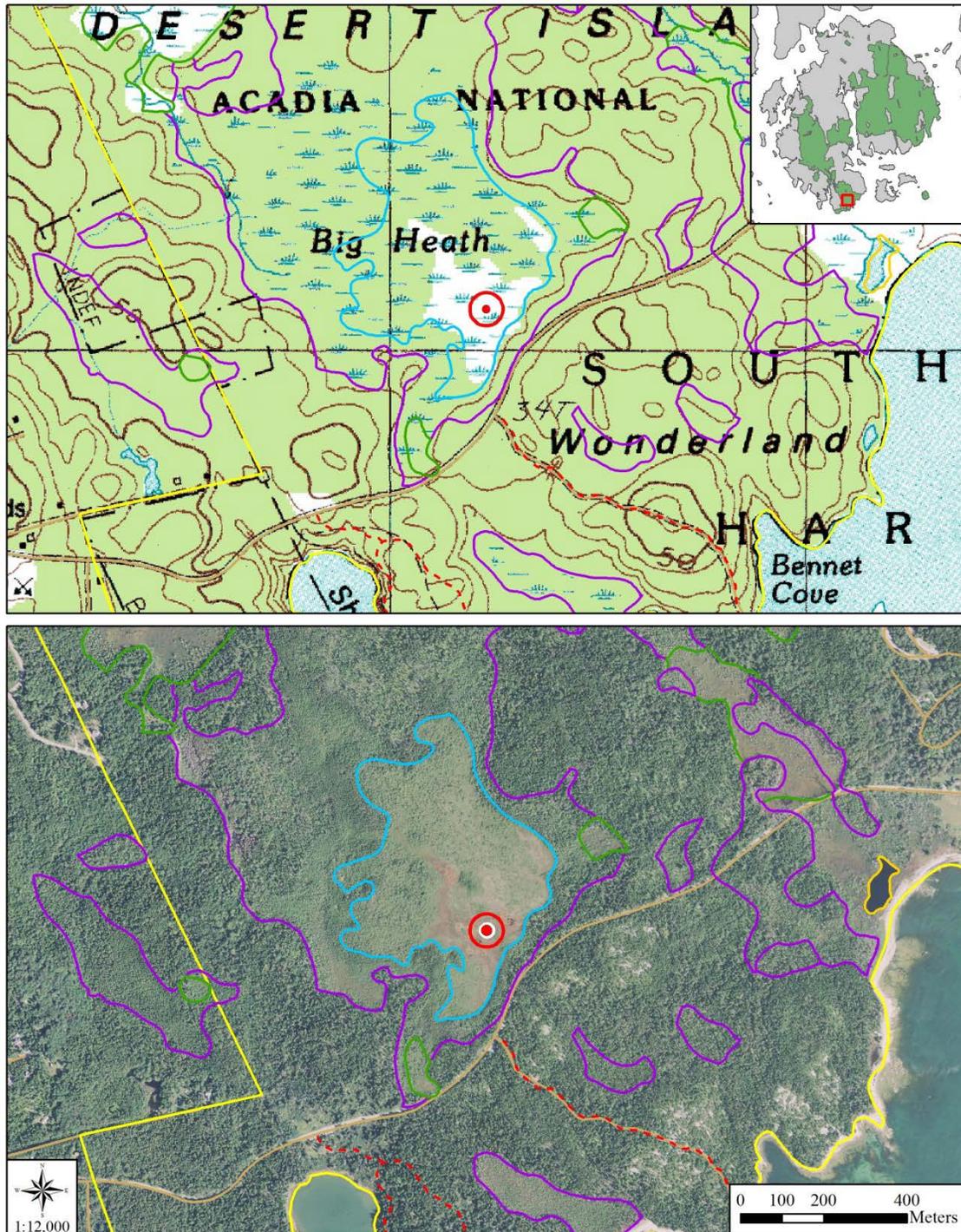
- Paved Road
- Unpaved Road
- Carriage Road
- - - Hiking Trail
- Acadia Fee Boundary
- Assessment Area Boundary
- Assessment Area Center

#### USNVC Ecosystem

- Acadian Maritime Bog
- Laurentian-Acadian Acidic Basin Fen
- Laurentian-Acadian Acidic Swamp
- Laurentian-Acadian Acidic Swamp AND/OR Eastern Boreal Semi-Treed Bog
- Laurentian-Acadian Alkaline Fen
- Laurentian-Acadian Wet Meadow-Shrub Swamp and Marsh

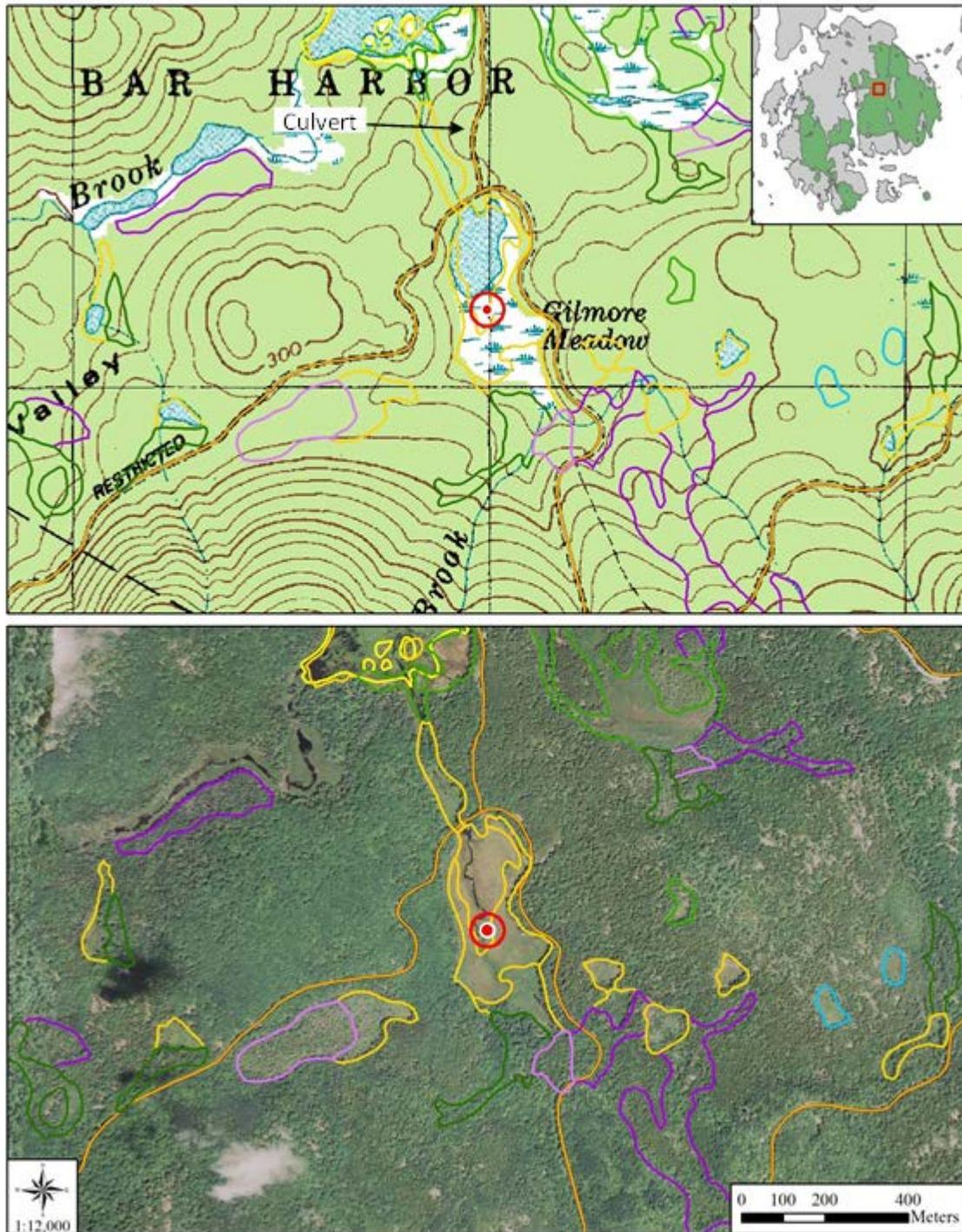
**Figure A.1.** Legend showing base layers and mapped US National Vegetation Classification wetland Ecosystems for following permanent sentinel site maps.

Appendix A. Maps of sentinel sites in Acadia National Park (continued).



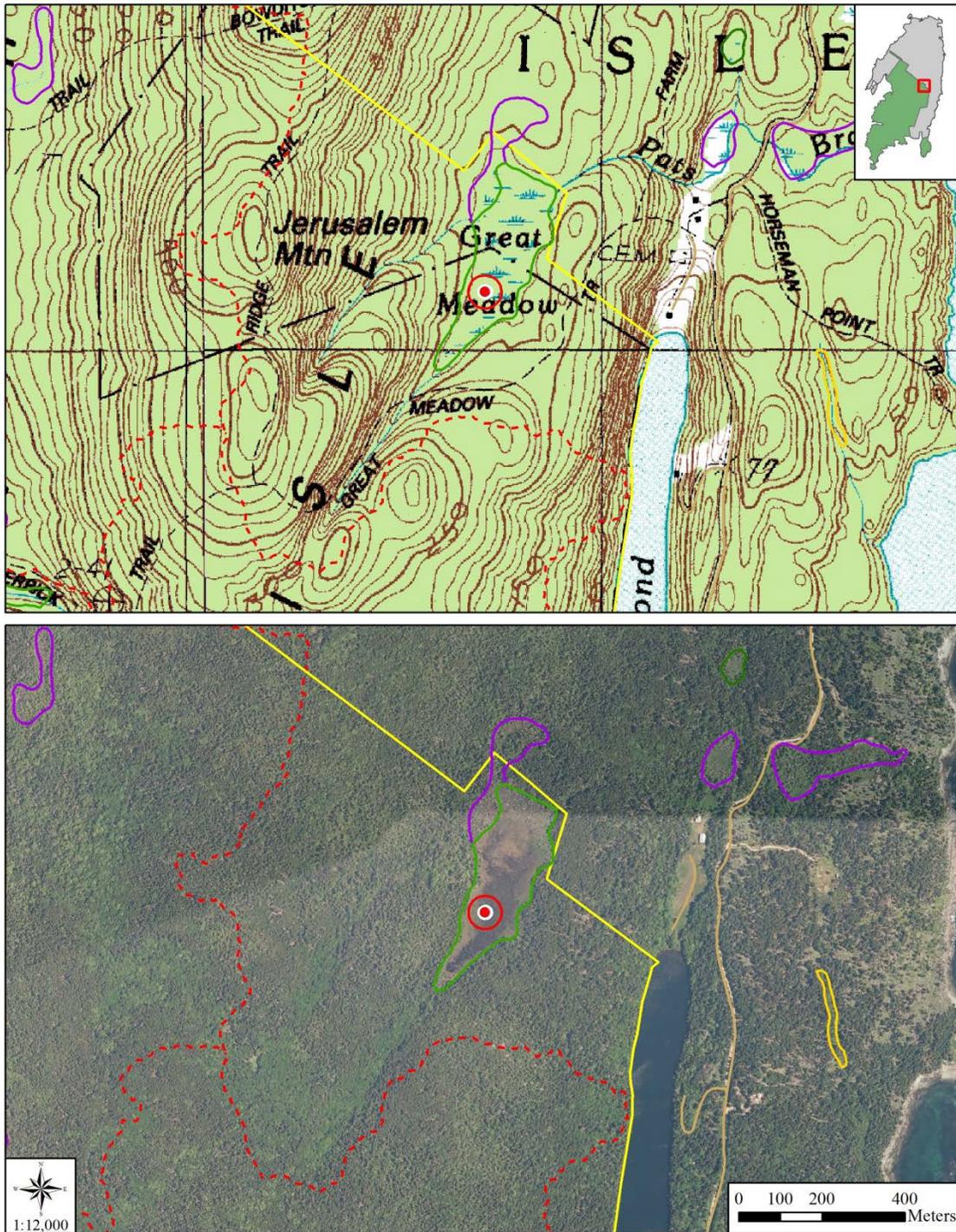
**Figure A.2.** Location of sentinel site with assessment area in Big Heath on Mount Desert Island including wetland boundaries mapped by the Acadia Vegetation Map and overlaid on a USGS topographic map and 2011 leaf-on orthophotography.

**Appendix A.** Maps of sentinel sites in Acadia National Park (continued).



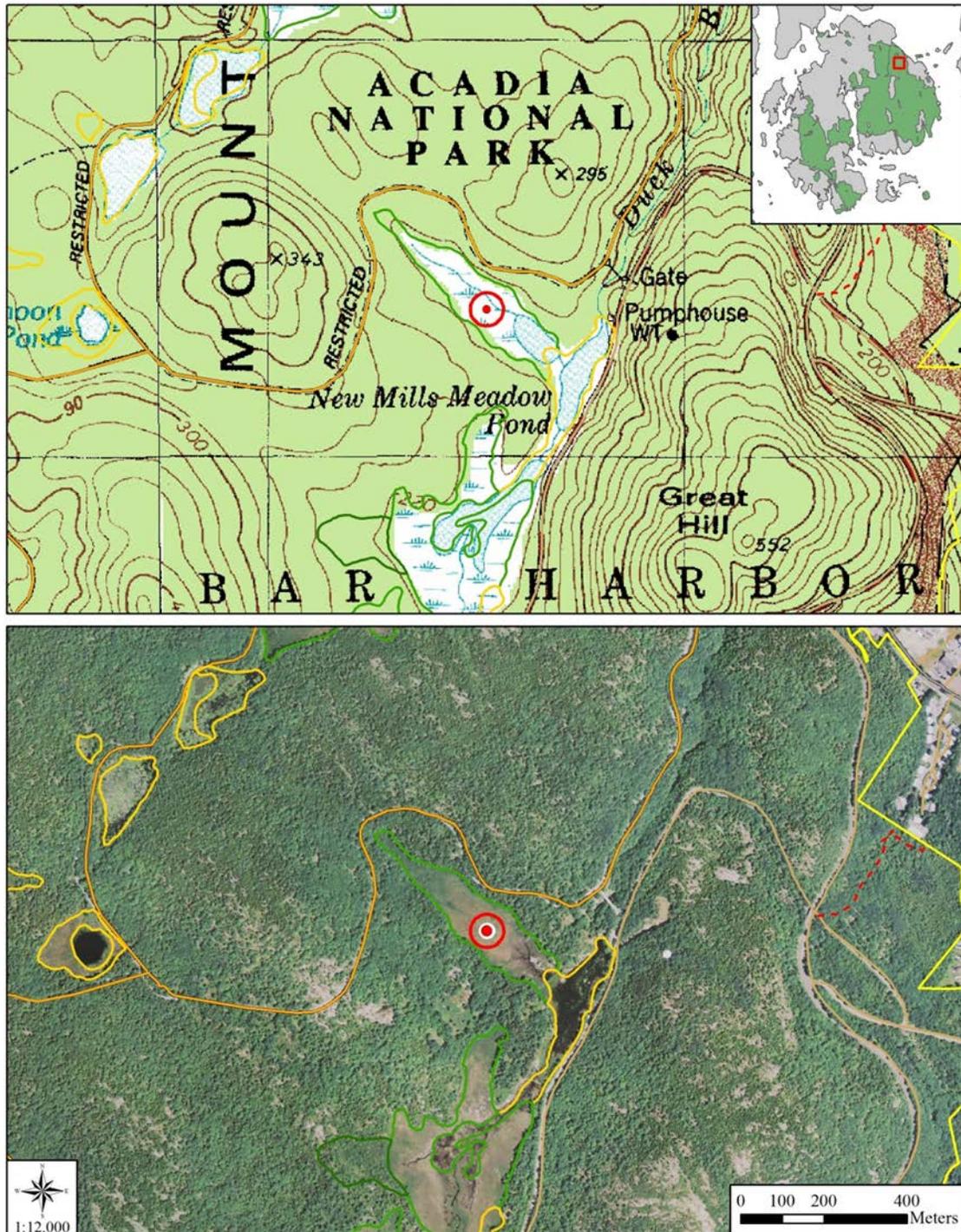
**Figure A.3.** Location of sentinel site with assessment area in Gilmore Meadow on Mount Desert Island including wetland boundaries mapped by the Acadia Vegetation Map and overlaid on a USGS topographic map and 2011 leaf-on orthophotography.

Appendix A. Maps of sentinel sites in Acadia National Park (continued).



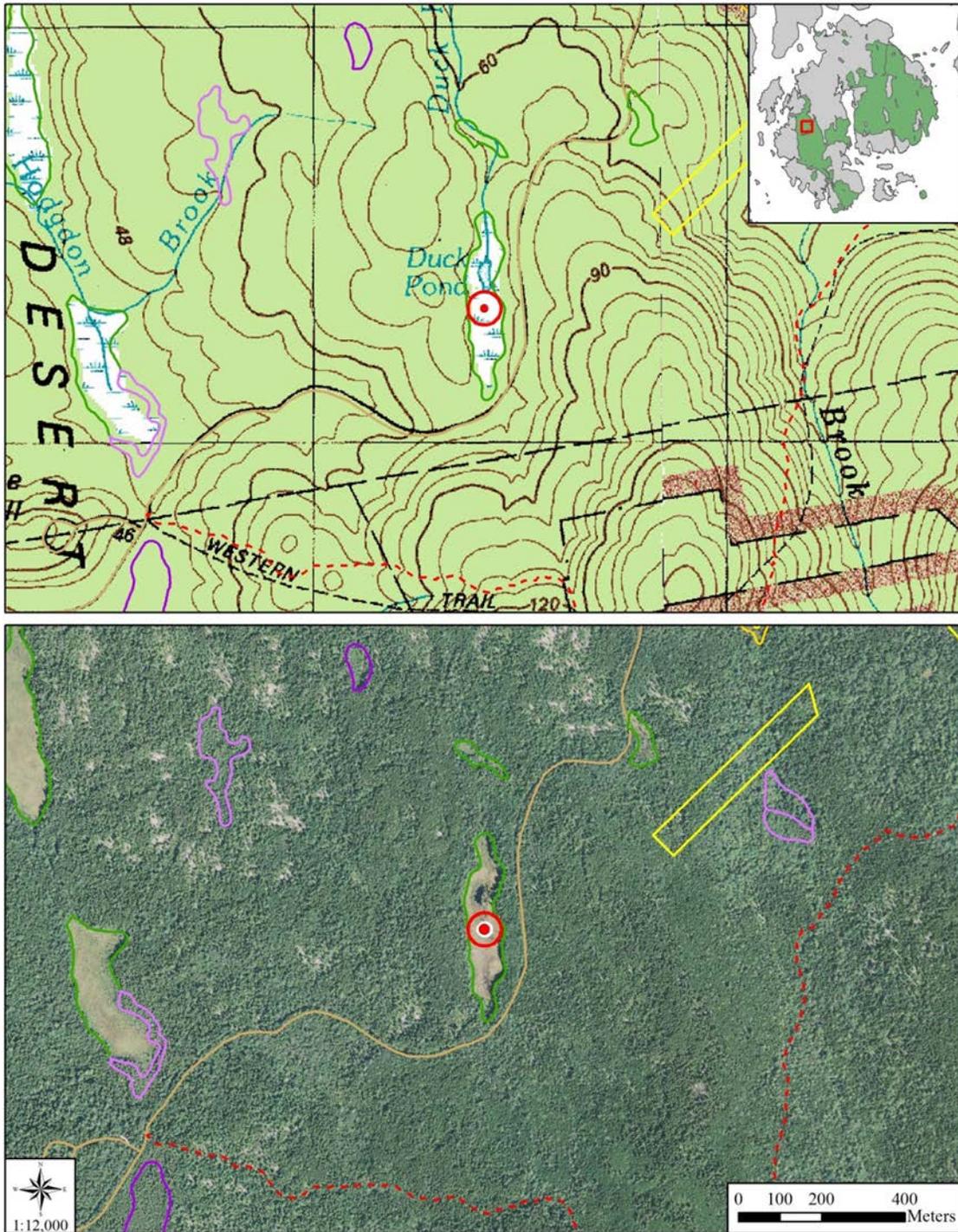
**Figure A.4.** Location of sentinel site with assessment area in Great Meadow on Isle au Haut including wetland boundaries mapped by the Acadia Vegetation Map and overlaid on a USGS topographic map and 2009 leaf-on orthophotography.

Appendix A. Maps of sentinel sites in Acadia National Park (continued).



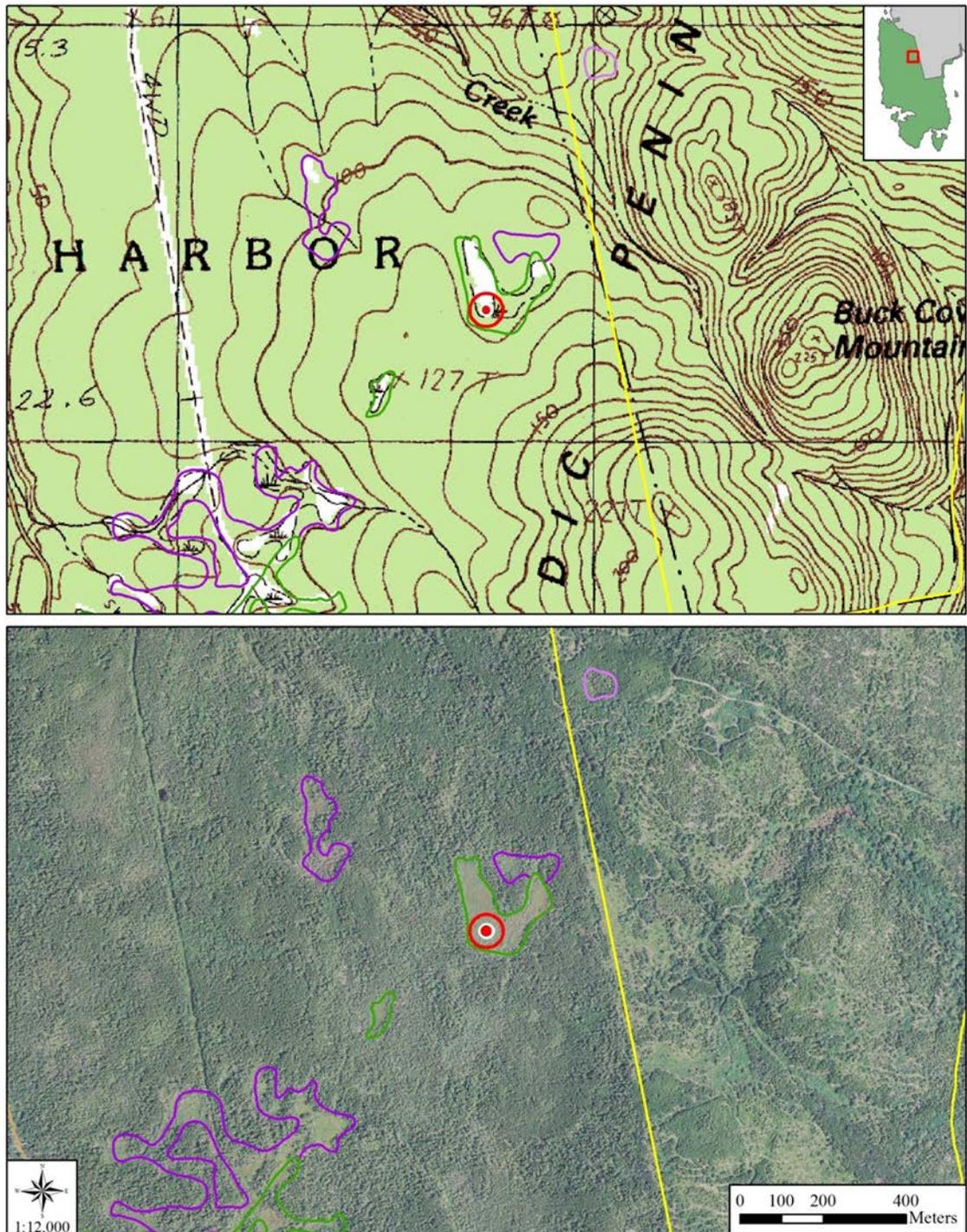
**Figure A.5.** Location of sentinel site with assessment area in New Mills Meadow- NW on Mount Desert Island including wetland boundaries mapped by the Acadia Vegetation Map and overlaid on a USGS topographic map and 2011 leaf-on orthophotography.

**Appendix A.** Maps of sentinel sites in Acadia National Park (continued).



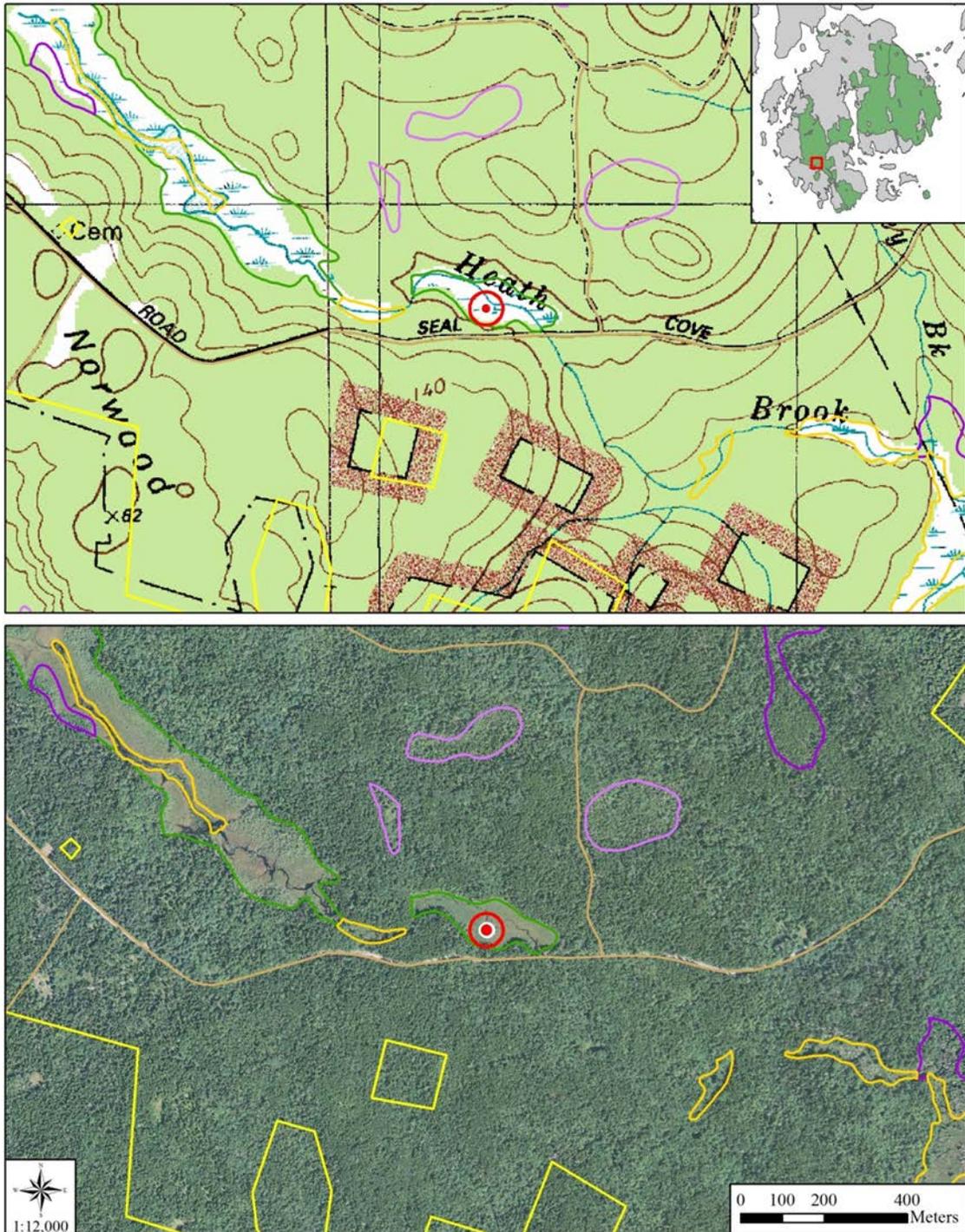
**Figure A.6.** Location of sentinel site with assessment area in Duck Pond Peatland on Mount Desert Island including wetland boundaries mapped by the Acadia Vegetation Map and overlaid on a USGS topographic map and 2011 leaf-on orthophotography.

**Appendix A.** Maps of sentinel sites in Acadia National Park (continued).



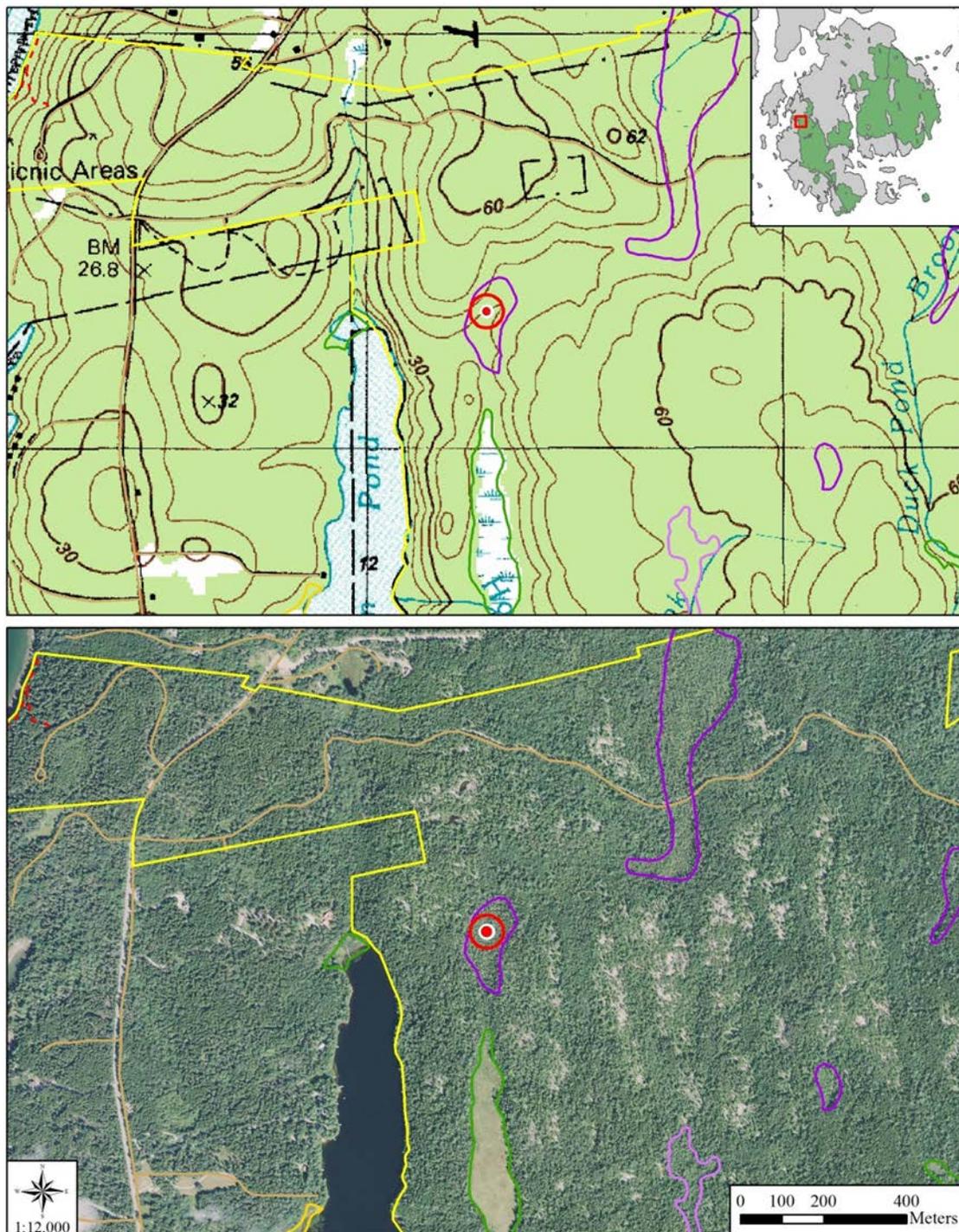
**Figure A.7.** Location of sentinel site with assessment area in Frazer Fen on Schoodic Peninsula including wetland boundaries mapped by the Acadia Vegetation Map and overlaid on a USGS topographic map and 2011 leaf-on orthophotography.

**Appendix A.** Maps of sentinel sites in Acadia National Park (continued).



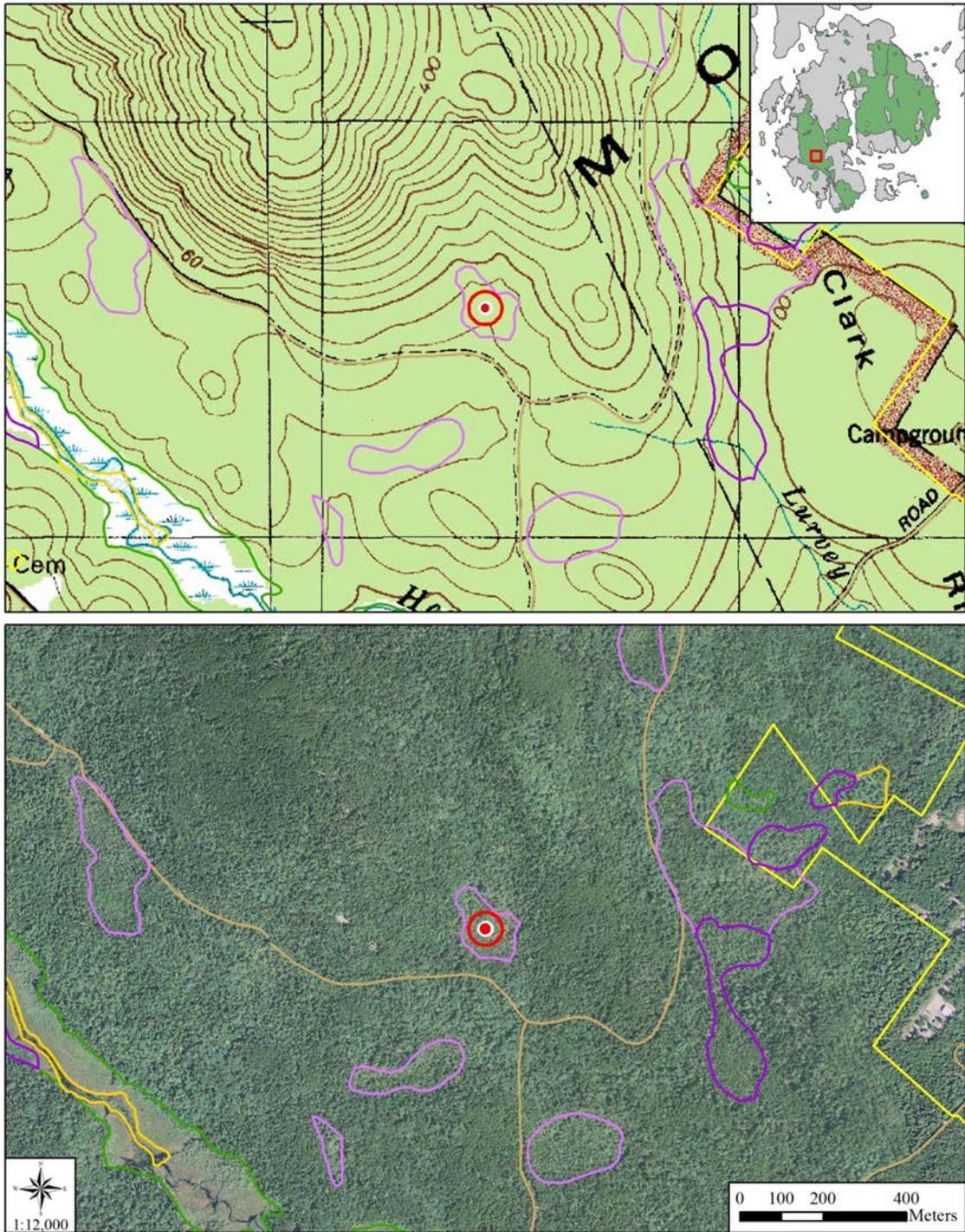
**Figure A.8.** Location of sentinel site with assessment area in Heath Brook on Mount Desert Island including wetland boundaries mapped by the Acadia Vegetation Map and overlaid on a USGS topographic map and 2011 leaf-on orthophotography.

**Appendix A.** Maps of sentinel sites in Acadia National Park (continued).



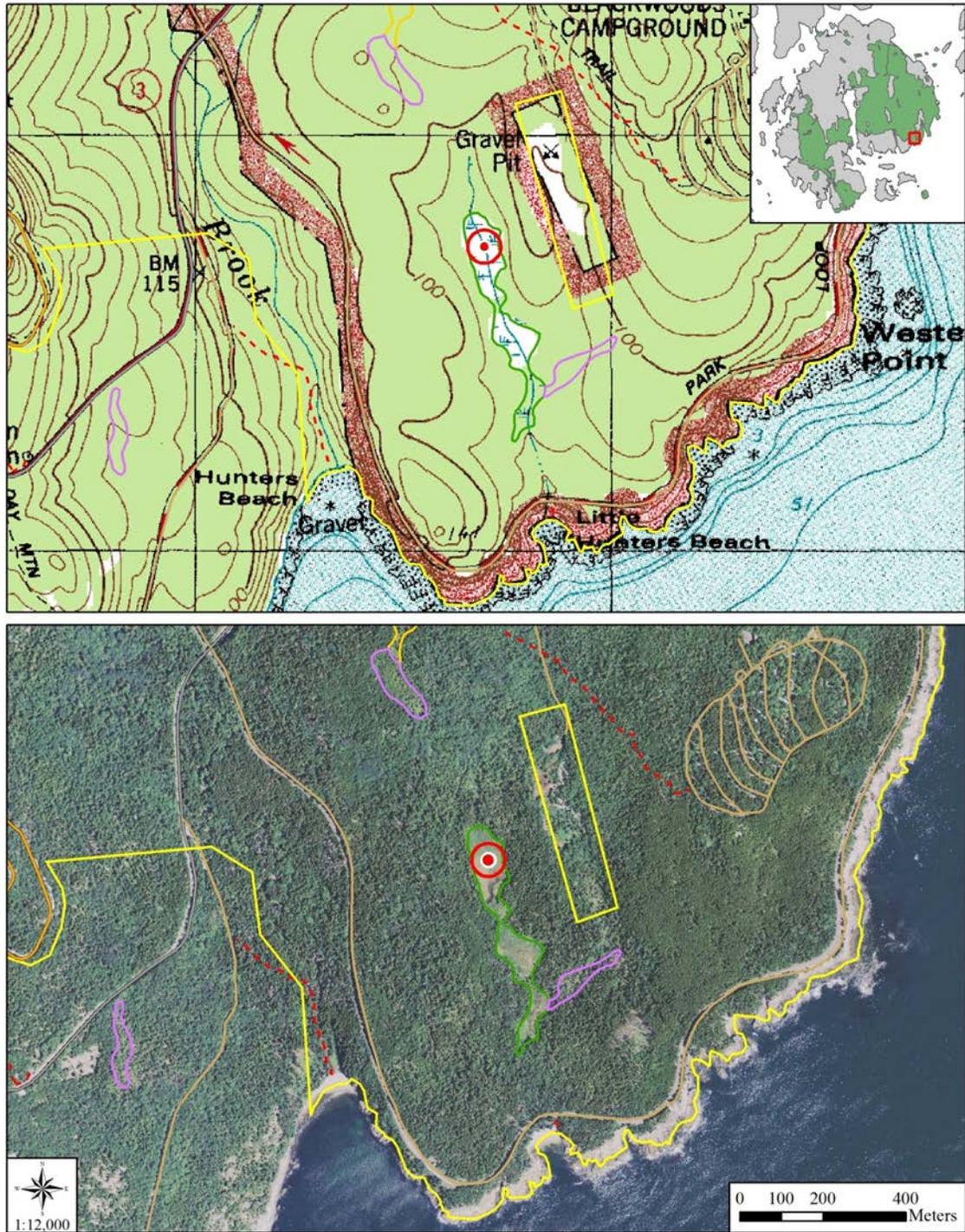
**Figure A.9.** Location of sentinel site with assessment area in Hodgdon Swamp on Mount Desert Island including wetland boundaries mapped by the Acadia Vegetation Map and overlaid on a USGS topographic map and 2011 leaf-on orthophotography.

**Appendix A.** Maps of sentinel sites in Acadia National Park (continued).



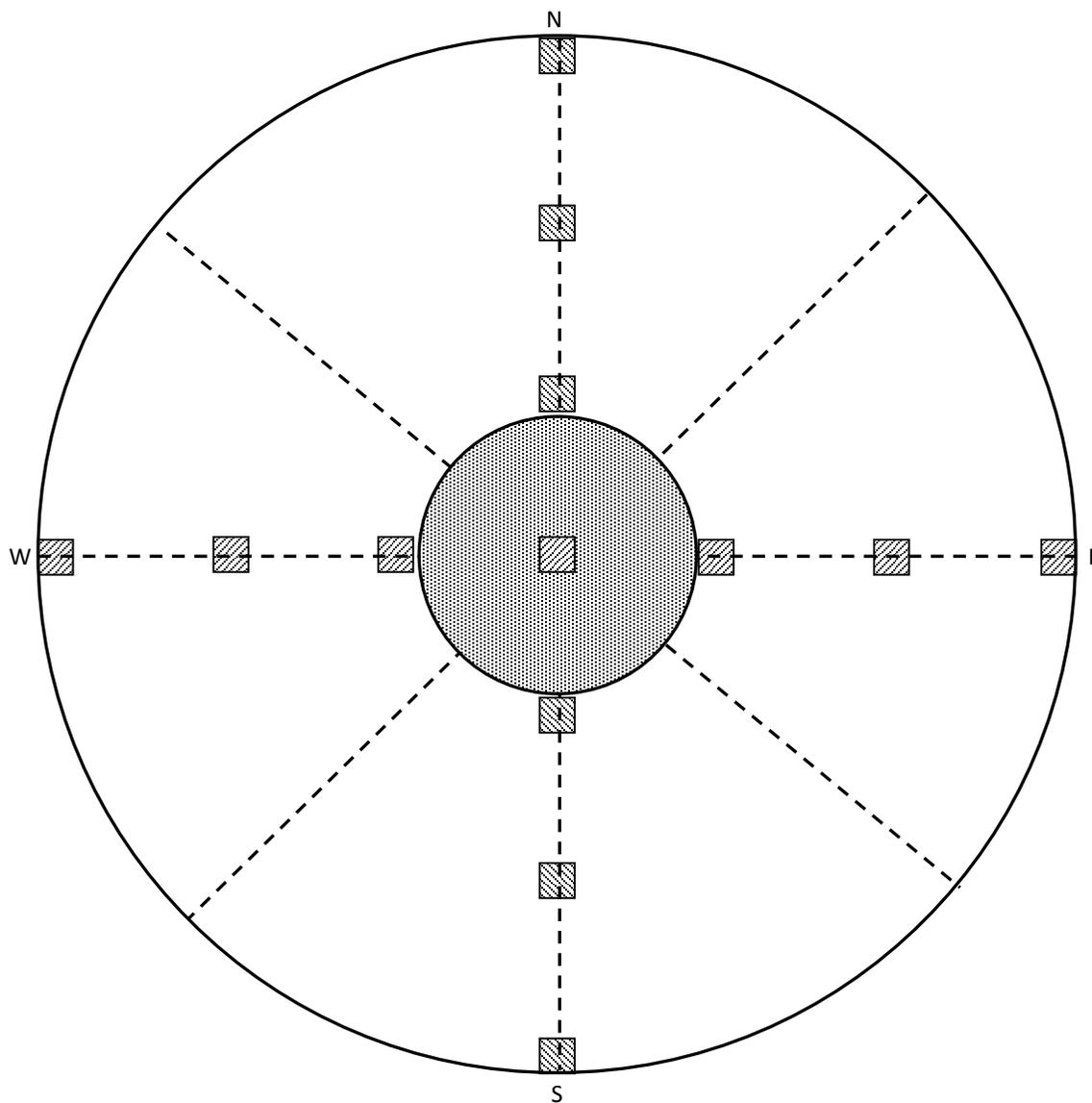
**Figure A.10.** Location of sentinel site with assessment area in Western Mountain Swamp on Mount Desert Island including wetland boundaries mapped by the Acadia Vegetation Map and overlaid on a USGS topographic map and 2011 leaf-on orthophotography.

Appendix A. Maps of sentinel sites in Acadia National Park (continued).



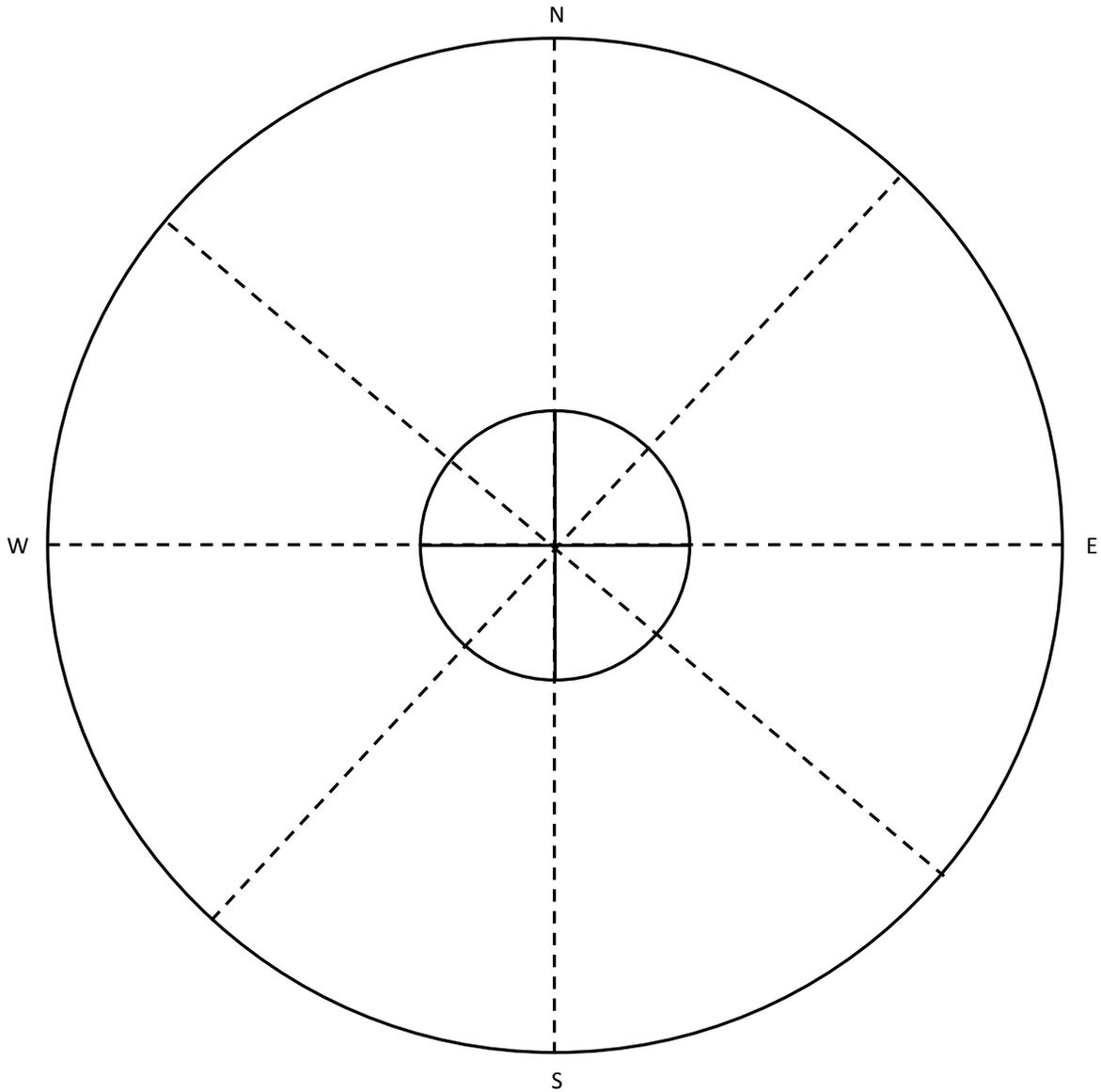
**Figure A.11.** Location of sentinel site with assessment area in Little Hunter's Brook on Mount Desert Island including wetland boundaries mapped by the Acadia Vegetation Map and overlaid on a USGS topographic map and 2011 leaf-on orthophotography.

**Appendix B.** U.S. EPA National Wetland Condition Assessment monitoring site designs.



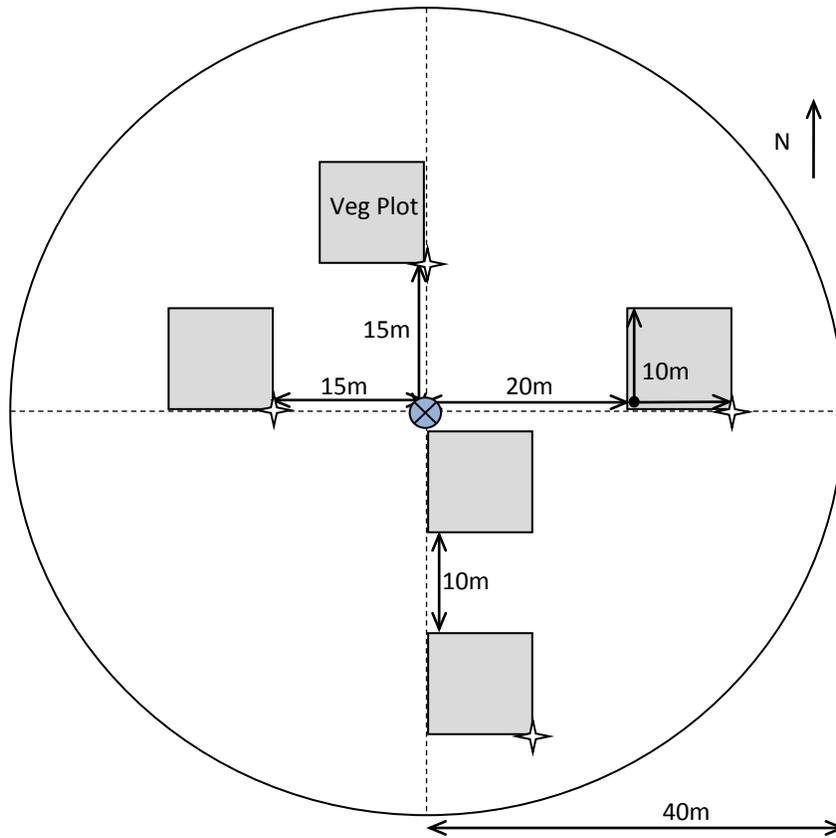
**Figure B.1.** Overall design of a sentinel site, including a 40-m radius assessment area (⊙), 100-m buffer (white) around the assessment area, 13 buffer plots (◻), and eight 100-m buffer transects (dashed lines). Buffer plots are 10 x 10 m and spaced 40 m apart on center.

**Appendix B.** U.S. EPA National Wetland Condition Assessment monitoring site designs (continued).

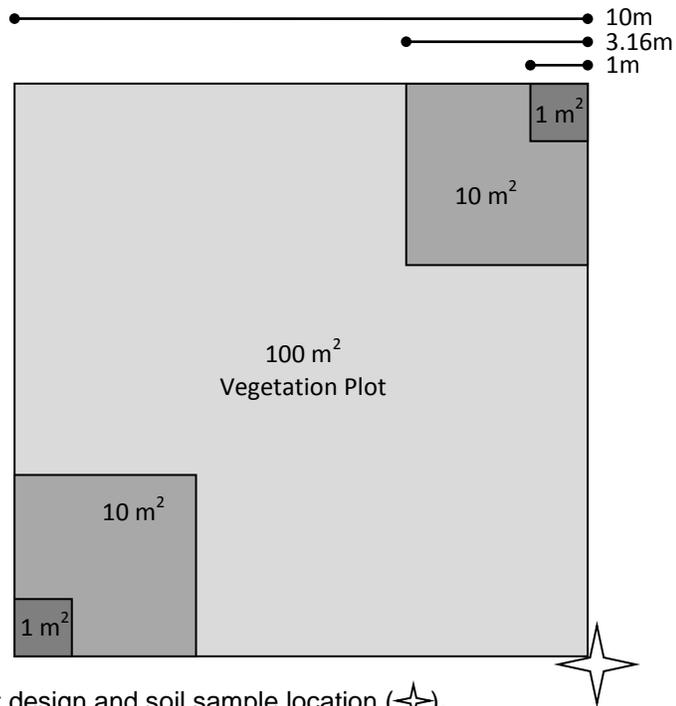


**Figure B.2.** Overall design of a rapid assessment site, including a 40-m radius assessment area (⊙) broken into quarters, 100-m buffer (white) around the assessment area, and eight 100-m buffer transects (dashed lines).

**Appendix B.** U.S. EPA National Wetland Condition Assessment plot designs (continued).



**Figure B.3.** Assessment area design for sentinel sites, including location of shallow well (⊗), vegetation plots (grey boxes), and soil samples (✦).



**Figure B.4.** Vegetation plot design and soil sample location (✦).

# SOP 1 – Safety

## *Northeast Temperate Network*

Version 1.00

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### **Overview**

The Northeast Temperate Network (NETN) considers the occupational health and safety of its employees, cooperators, and volunteers to be of utmost importance, and is committed to ensuring that all seasonal field technicians receive adequate training on National Park Service (NPS) safety procedures, incident reporting, and emergency response prior to field work.

### **Procedures**

For general field safety, NPS guidance, and worker's compensation procedures, follow procedures described in the current version of the Safety SOP of the NETN Long-term Forest Monitoring Protocol. For specific safety guidelines related to implementation of this protocol, refer to Section 2.5.1 of the EPA Field Operations Manual (U.S. EPA 2011a).

### **Revision History**

Version numbers will be incremented by a whole number (e.g., Version 1.30 to 2.00) when a change is made that significantly affects requirements or procedures. Version numbers will be incremented by decimals (e.g., Version 1.06 to Version 1.07) when there are minor modifications that do not affect requirements or procedures included in the protocol. Add rows as needed for each change or set of changes tied to an updated version number.

#### Revision History Log

<b>Version #</b>	<b>Date</b>	<b>Revised by</b>	<b>Changes</b>	<b>Justification</b>
1.00	August 2011	Kate Miller	Initial version	



# SOP 2 – Preparation and Equipment List

## *Northeast Temperate Network*

Version 1.02

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### **Overview**

This SOP delineates preparations for the summer field season and includes a list of necessary field equipment for intensive and rapid assessment sampling. Preparations should be complete by the start of the summer field season in May or early June.

### **Procedures**

Follow procedures described in Chapter 2 of the EPA Field Operations Manual to prepare for intensive sampling in the sentinel sites for the National Wetland Condition Assessment (NWCA). Refer to section 2.9 of the FOM for a complete list of equipment and supplies required to implement the FOM. Additional procedures specific to implementing this protocol in the Northeast Temperate Network are described below.

### **Staff**

This protocol will be implemented by a 2-person team and will include the NETN Plant Ecologist plus a seasonal technician or volunteer. Additional personnel and network staff may be needed for the following tasks:

- NETN Program Manager to help with contracting, hiring, and potentially participate in data collection
- NETN Air and Water staff to train staff and/or assist with water samples and calibrating equipment
- NETN Data Manager to develop and manage databases for storing non-NWCA data

### **Planning and Coordination**

The Plant Ecologist should ensure that the ACAD Natural Resource Manager has a current version of the wetland protocol including all SOPs, as well as a current map of sampling locations. A map clearly showing the location of each site must be provided to ACAD's Cultural Resource Specialist at least one month prior to any soil sampling, to provide time for determination of the presence of cultural artifacts that might be compromised by soil sampling. Site marking procedures must be cleared by the ACAD Natural Resource Manager prior to establishment.

### **Maps**

Prior to each field season, the Plant Ecologist should prepare topographic maps and orthophotos showing sampling locations in the annual panel at scales of 1:24,000 or larger. Maps should clearly show location of the sites in relation to topography, roads, trails and park features, and should display preliminary USA-RAM Metric 1 and 2 layers (includes the assessment area and buffer perimeters, and the eight buffer transect lines), and the buffer plot locations (sentinel sites only). These maps and aerial photographs should be printed on Rite-in-Rain paper using a color

## SOP 2 – Preparation and Equipment List

LaserJet printer. Center coordinates of each site should be exported, printed, and downloaded directly into the network GPS unit. Trails, park boundaries, and topographic maps should also be loaded on GPS units.

### **Training**

During years that sentinel sites are sampled for the NWCA, the Plant Ecologist and seasonal technician will attend a pre-season EPA NWCA training on the FOM (U.S. EPA 2011a). During the four years between the NWCA, the Plant Ecologist will train the seasonal technician on USA-RAM (U.S. EPA 2011b) and additional protocol methods.

Training topics that should be covered by NETN staff every year include:

- Regulations and procedures related to use of NPS vehicles
- Guidelines regarding timesheets, credit leave versus comp time, and requesting leave
- Safety and workers compensation
- Proper use of all NETN equipment including a Garmin 60CSX GPS unit, park radio, and digital camera

### **Equipment**

A list of equipment and supplies required to implement the EPA Field Operations Manual is described in Section 2.9 of the FOM. Additional equipment and supplies required to implement this protocol are listed below by task.

#### ***Well Installation***

PVC threaded cap for 4.2 cm pipe

60 cm of 4.2 cm outside diameter schedule 40 threaded PVC

PVC threaded pipe coupling for 4.2 cm PVC

60 or 120 cm of 4.2 cm slotted schedule 40 PVC pipe with threaded flush joints

PVC threaded point for 4.2 cm PVC

PVC Primer

PVC Cement

1.2 to 1.8 m (depends on length of well) of 15 mm stainless steel cable (1 per well)

15 mm stainless steel crimp (2 per well)

3/8-16 x 2 1/2" stainless steel hex bolt and nut (18-8/ 304) (1 per well)

HOBO<sup>®</sup> U20 Water Level Logger (1 per well)

HOBO<sup>®</sup> U20 Water Level Logger for barometric pressure calibration (1 unit will cover a radius of 15 km)

HOBO<sup>®</sup> Waterproof Shuttle

Lens tissue and water (for cleaning HOBO<sup>®</sup> logger optics)

Heavy duty pliers

Permanent paint pen

Carabiner (must be wider than the inside diameter of the well pipe)

Cordless drill with 0.48 cm and 2 mm drill bits

1.8 m heavy duty U channel fence post (2 per well)

40 cm or longer bubble level

2 m or longer metric carpenter ruler or metric measuring tape

## SOP 2 – Preparation and Equipment List

Water level meter for depth to water measurements in wells  
Panasonic Toughbook laptop with latest version of Hoboware installed

### ***Well Measurement***

A HOBO<sup>®</sup> Waterproof Shuttle  
Lens tissue and water (for cleaning HOBO<sup>®</sup> logger optics)  
40 cm or longer bubble level  
2 m or longer metric carpenter ruler or rigid metric measuring tape  
Water level meter for depth to water measurements in wells  
Permanent paint pen (to re-establish faded calibration marks)  
Carabiner (must be wider than the inside diameter of the well pipe)  
Panasonic Toughbook laptop with latest version of Hoboware installed

### ***Rapid Assessment Monitoring***

USA-RAM and vascular plant datasheets (on Rite-in-the-Rain paper)  
USA-RAM Metric 1 and 2 map for each site  
Enclosed clipboard (2)  
100 m measuring tape (2)  
GPS unit  
Compass (2)  
Flagging and survey flags (5)  
Sharpened pencils and permanent markers  
45 cm long # 4 rebar with secured metal survey cap  
Sealable plastic bags for unknown samples

## SOP 2 – Preparation and Equipment List

### Revision History

Version numbers will be incremented by a whole number (e.g., Version 1.30 to 2.00) when a change is made that significantly affects requirements or procedures. Version numbers will be incremented by decimals (e.g., Version 1.06 to Version 1.07) when there are minor modifications that do not affect requirements or procedures included in the protocol. Add rows as needed for each change or set of changes tied to an updated version number.

#### Revision History Log

<b>Version #</b>	<b>Date</b>	<b>Revised by</b>	<b>Changes</b>	<b>Justification</b>
1.00	August 2011	Kate Miller	Initial version	
1.01	August 2012	Kate Miller	Includes info for USA RAM years and monitoring shallow wells	Update to include both types of sampling events and hydrology monitoring
1.02	January 2013	Kate Miller	Revised site terms	Maintain consistency with NETN and EPA protocols.

# SOP 3 – Using the Global Positioning System

## *Northeast Temperate Network*

Version 1.00

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### **Overview**

This Standard Operating Procedure explains the methods that all observers should follow to learn to use Global Positioning System (GPS) with the Garmin GPSMAP 60CSX unit. The GPS will be used to help navigate to and locate pre-existing plots as well as document the location of new plots.

### **Procedures**

Follow the procedures described in Section 2.5.4.3 of the EPA Field Operations Manual (U.S. EPA 2011b). For specific procedures related to using the Garmin GPSMAP 60CSX, refer to the current version of the Using the Global Positioning System (GPS) SOP of the NETN Long-term Forest Monitoring Protocol. Note that all GPS data collected for this protocol will be reported to EPA in decimal degrees and in NAD83 datum, but will be stored in NETN databases as Universal Transverse Mercator (UTM) and NAD83.

### **Revision History**

Version numbers will be incremented by a whole number (e.g., Version 1.30 to 2.00) when a change is made that significantly affects requirements or procedures. Version numbers will be incremented by decimals (e.g., Version 1.06 to Version 1.07) when there are minor modifications that do not affect requirements or procedures included in the protocol. Add rows as needed for each change or set of changes tied to an updated version number.

#### Revision History Log

<b>Version #</b>	<b>Date</b>	<b>Revised by</b>	<b>Changes</b>	<b>Justification</b>
1.00	August 2011	Kate Miller	Initial version	



# SOP 4 – Data Management and Quality Assurance/ Quality Control

## *Northeast Temperate Network*

Version 1.01

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### **Overview**

Careful, accurate collection of data as directed in these SOPs is critical to the success of Vital Signs monitoring. This SOP describes quality assurance/quality control (QA/QC) procedures for accurate data collection, transcription and stewardship, and assessment of data quality.

### **Procedures**

Data management procedures follow Section 2.5.2 of the EPA Field Operations Manual with the following additions:

- Data collected by pressure transducers will be downloaded twice annually (spring and fall) and stored in a database. For detailed instructions on managing water level and temperature data collected by pressure transducers, refer to SOP 8 – Using the HOBO<sup>®</sup> Water Level Logger and Shuttle.
- Rapid assessment data collected in Panels 1-4 will be recorded on datasheets, and entered by NETN staff into an MS Access database that has been adapted from EPA databases by the NETN Data Manager. All data sheets from the rapid assessments will be scanned and archived with the database.

### **Revision History**

Version numbers will be incremented by a whole number (e.g., Version 1.30 to 2.00) when a change is made that significantly affects requirements or procedures. Version numbers will be incremented by decimals (e.g., Version 1.06 to Version 1.07) when there are minor modifications that do not affect requirements or procedures included in the protocol. Add rows as needed for each change or set of changes tied to an updated version number.

#### Revision History Log

<b>Version #</b>	<b>Date</b>	<b>Revised by</b>	<b>Changes</b>	<b>Justification</b>
1.00	August 2011	Kate Miller	Initial version	
1.01	August 2012	Kate Miller	Well monitoring occurs twice annually. References SOP 8 for managing transducer data.	Revision to minimize loss of growing season data due to well shifting in winter.



# SOP 5 – Rapid Assessment Site Establishment and Data Collection

## *Northeast Temperate Network*

Version 1.01

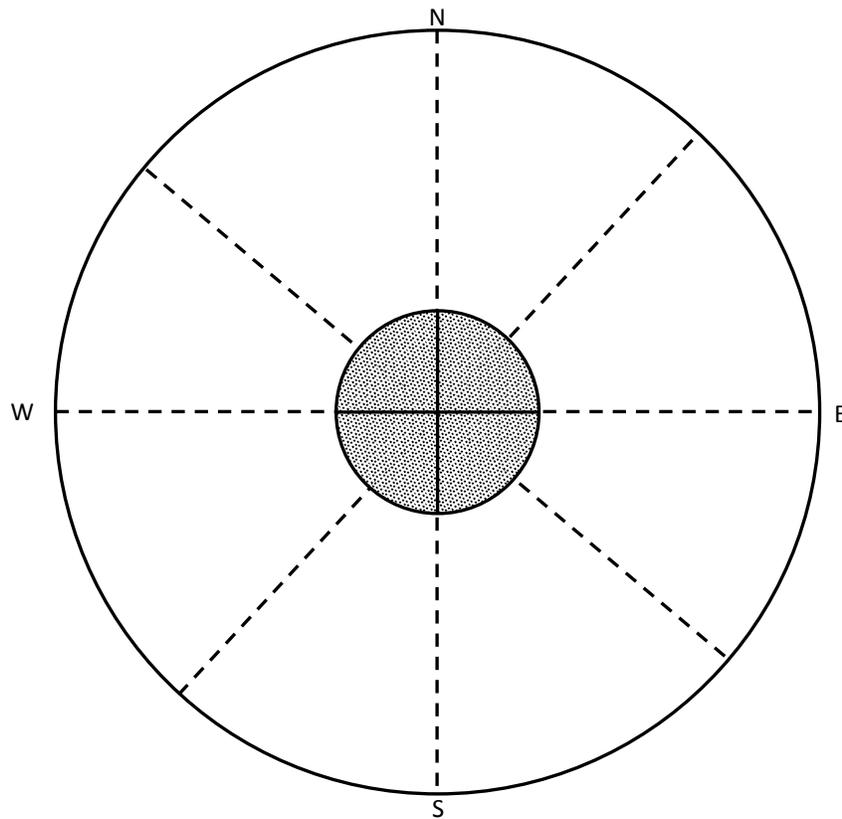
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### **Overview**

This SOP covers procedures that are not covered in the USA-RAM for establishing and sampling the rapid assessment monitoring sites. Prior to the field season, rapid assessment sites will be selected using GIS and the GRTS sampling algorithm to provide a random, spatially balanced sample. It is important that site marking procedures have been approved by the ACAD Resource Manager prior to establishment.

### **Procedures**

Procedures for establishing and sampling a rapid assessment site follow the USA-RAM with a few additions. First, a metal survey cap attached to a 45 cm long, #4 rebar is installed to permanently mark the center of the assessment area (Figure 1).



**Figure 1.** Design of rapid assessment site, including a 40-m radius assessment area (⊙) broken into quarters, 100-m buffer (white) around the assessment area, and eight 100-m buffer transects (dashed lines).

## SOP 5 – Rapid Assessment Site Establishment and Data Collection

Once the center of the assessment area is established, the circle should be broken into quarters by running measuring tapes out 40 m in the four cardinal directions. Starting along the north transect and moving clockwise, photopoints should be taken from the center using a landscape orientation and facing each of the cardinal directions. Photopoints should be taken and named according to guidelines described in Appendix D of the EPA FOM.

After photopoints are taken, and prior to performing the rapid assessment, a 15-minute search is conducted in each quarter of the assessment area, and all vascular species observed in each quarter are recorded. This ensures that all areas of the assessment area have been checked for presence of stressors, including invasive species, and provides a working species list for each site. Upon completing the 15-minute searches in each quarter of the assessment area, ground-truth the eight buffer transects that were delineated for Metric 2 of the USA-RAM and note the presence of any stressors in the buffer.

### Revision History

Version numbers will be incremented by a whole number (e.g., Version 1.30 to 2.00) when a change is made that significantly affects requirements or procedures. Version numbers will be incremented by decimals (e.g., Version 1.06 to Version 1.07) when there are minor modifications that do not affect requirements or procedures included in the protocol. Add rows as needed for each change or set of changes tied to an updated version number.

#### Revision History Log

Version #	Date	Revised by	Changes	Justification
1.00	August 2012	Kate Miller	Initial version	
1.01	January 2013	Kate Miller	Revised site terms and SOP name. Added site diagram Added directions on sampling in the buffer area.	Maintain consistency with NETN and EPA protocols.

# SOP 6 – Sentinel Site Establishment

## Northeast Temperate Network

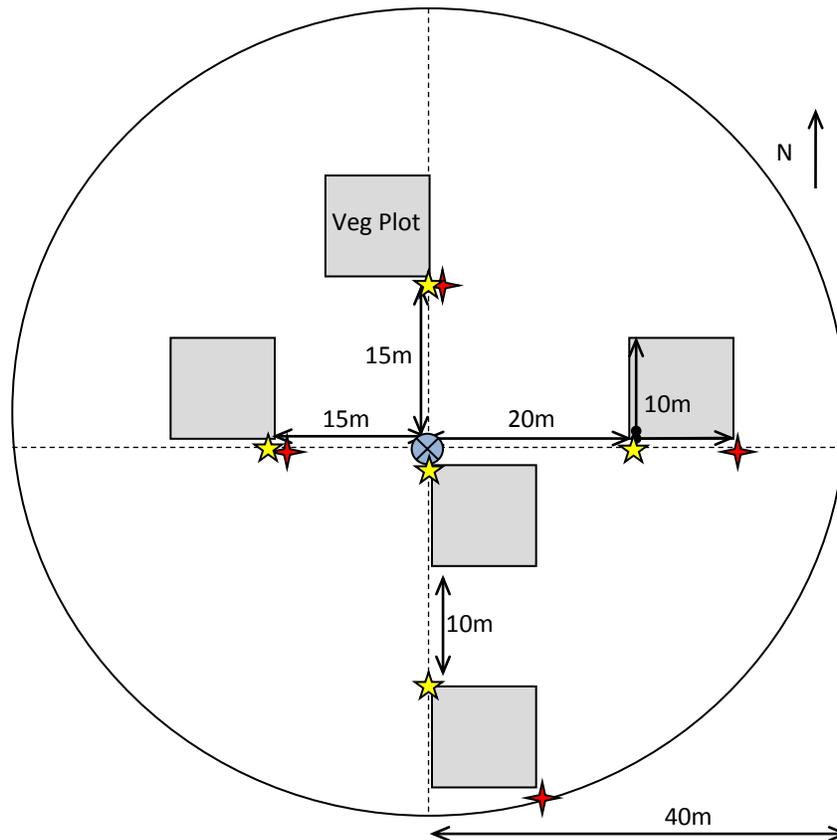
Version 1.01

### Overview

This SOP covers procedures that are not covered in the Field Operations Manual (FOM) for establishing assessment areas in the sentinel sites. Prior to the field season, sampling locations will be selected using GIS and expert judgment (see Sampling Design in the protocol narrative). It is important that plot marking procedures have been approved by the ACAD natural resource manager prior to plot establishment.

### Procedures

Procedures for establishing the assessment area and nested plots are described in Chapter 3 of the FOM. Procedures for establishing buffer plots are described in Chapter 4 of the EPA FOM. In addition to FOM procedures, NETN will install a shallow well at the center of the assessment area (SOP 7 – Shallow Well Construction and Installation), and five 60-cm long fiberglass stakes to mark the vegetation plots in the assessment area (Figure S6.1).



**Figure S6.1.** Plot design of assessment area, including location of shallow well (⊗), vegetation plots (grey boxes), soil samples (→★), and permanent plot markers (★).

## SOP 6 – Sentinel Site Establishment

### Revision History

Version numbers will be incremented by a whole number (e.g., Version 1.30 to 2.00) when a change is made that significantly affects requirements or procedures. Version numbers will be incremented by decimals (e.g., Version 1.06 to Version 1.07) when there are minor modifications that do not affect requirements or procedures included in the protocol. Add rows as needed for each change or set of changes tied to an updated version number.

#### Revision History Log

<b>Version #</b>	<b>Date</b>	<b>Revised by</b>	<b>Changes</b>	<b>Justification</b>
1.00	August 2011	Kate Miller	Initial version	
1.01	January 2013	Kate Miller	Revised site terms and SOP name.	Maintain consistency with NETN and EPA protocols.

# SOP 7 – Shallow Well Construction, Installation, and Maintenance

## *Northeast Temperate Network*

Version 1.03

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### **Overview**

This SOP provides instruction for constructing, installing and maintaining shallow wells for monitoring water level in sentinel monitoring sites.

### **Procedures**

#### ***Well Construction***

The following materials are needed to construct a shallow well in order of assembly from top to bottom (Figure S7.1).

- Riser Cap: polyvinylchloride (PVC) cap for 4.2 cm outside diameter pipe
- Riser: 60 or 120 cm of 4.2 cm outside diameter PVC with threading on one end, and painted in green camouflage colors
- Coupling: PVC threaded pipe coupling for 4.2 cm PVC
- Well Pipe: 60 cm of 4.2 cm slotted PVC pipe with threaded flush joints
- Well Bottom: PVC threaded point for 4.2 cm PVC

All well pieces are composed of schedule 40 PVC pipe. Riser pipe and well pipe should have threads on the ends to allow for the point and coupling attachments. To assemble the well, first make sure the PVC is clean and dust free. Spread PVC primer on the threaded joint of the riser pipe and half of the coupling, and allow to dry. Next spread PVC cement onto the same surfaces and screw the two pieces together. Repeat the same primer and cement process to attach the well pipe to the coupling, and the pointed end to the bottom of the well pipe. Next drill several 2 mm vent holes in the cap, and place cap on the top of the riser pipe.

Once well assembly is complete, the following components of the data logger should be assembled.

- 1.2 m or 1.8 m of 15 mm stainless steel cable (depending on well length)
- 2, 15 mm stainless steel crimps
- 3/8-16 x 2 1/2" stainless steel hex bolt and nut (18-8/ 304)
- HOBO<sup>®</sup> U20 Water Level Logger (logger)

On each end of the stainless steel cable, thread a 15 mm steel crimp through the cable. On one end, make a fold in the cable that is 5 cm long and thread the end of the cable through the other hole in the crimp. Use heavy duty pliers or a crimping tool to tighten the crimp over the cable. Make sure the crimp is tight by tugging on the cable. Repeat the same process for the other end of the cable, but first thread the cable through the hole on the top of the logger (this is the smaller

SOP 7 – Shallow Well Construction, Installation, and Maintenance

black end that easily screws off). Finally, drill two holes through the riser pipe approximately 2 cm below the top of the well cap. The 2 holes made should be straight across from each other and 0.48 cm in diameter. Insert the hex bolt through one of the holes in the riser, through the top loop in the cable, and then through the other hole of the riser. This will allow the logger to hang from the hex bolt in the well. The logger should be suspended about 8 cm above the bottom tip of the well. Verify that the bottom of the logger is higher than the lowest slots in the well. This will ensure that the logger records actual water level, and not the depth of residual water collecting in the bottom of the well.

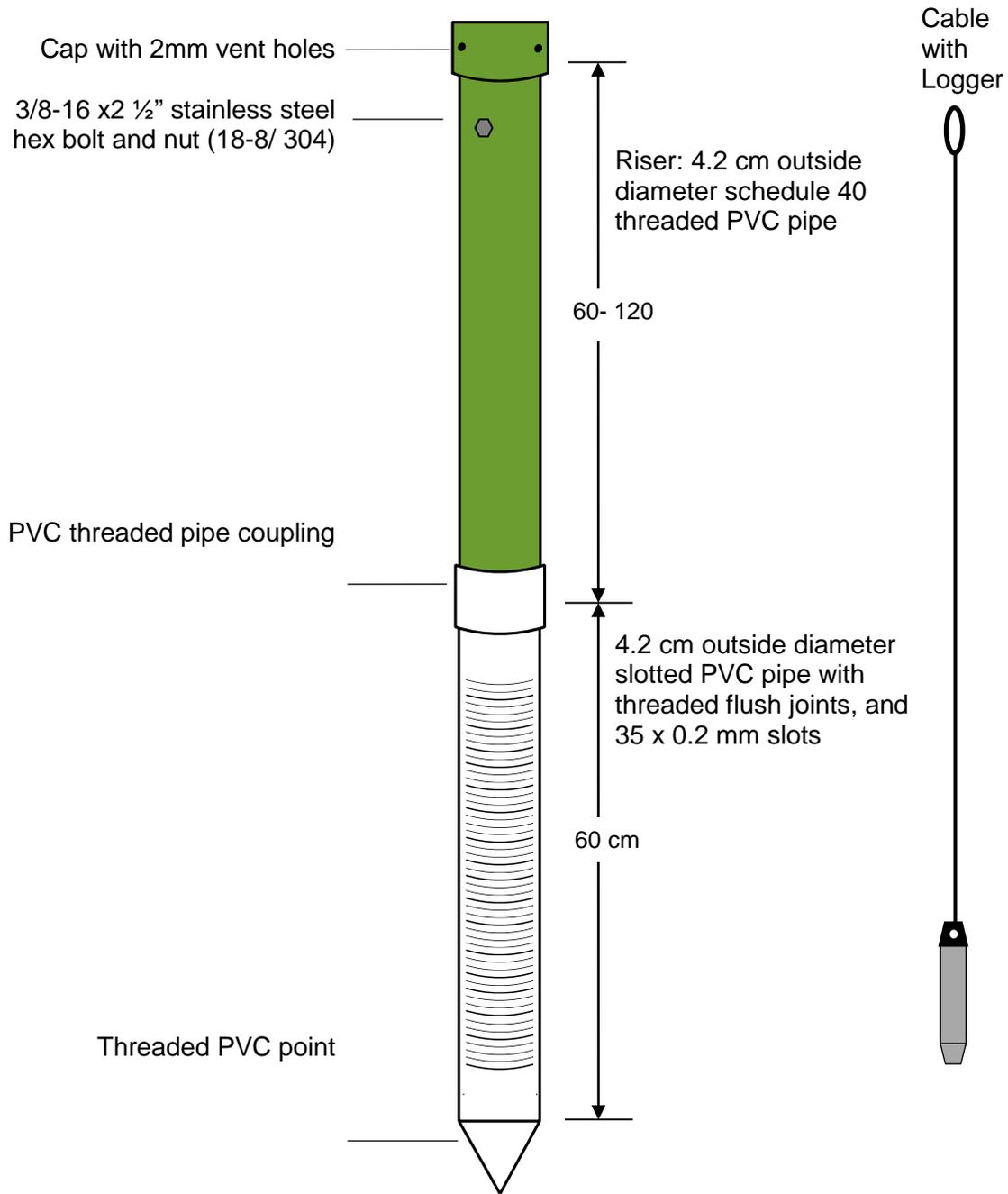


Figure S7.1. Diagram of fully assembled shallow well.

### ***Well Installation***

A well will be installed at the center of each sentinel site located on Mount Desert Island. At sites with a deep layer of Sphagnum peat, wells may be inserted directly into the wetland substrate by applying pressure on the top of the well. In areas without a deep Sphagnum peat layer, use a 4 cm diameter or smaller auger to make an opening deep enough to insert the entire slotted pipe end of the well into the substrate. Insert the well into the opening, and use the extracted soil to fill in and tighten around the pipe. Install the well as vertical as possible. A level may be helpful to insure the well is vertical. Once the well is installed, take measurements of well height, HOBO<sup>®</sup> Water Level Logger (logger) length, and post distances as described below and illustrated in Figure S7.2.

To enable checking if the well has remained at the same height over time, install two 1.8 m heavy duty U channel fence posts. Fence posts should be located approximately 30 cm from the well and at right angles from each post to the well. Insert each fence post into the substrate until it is roughly 20 cm above the top of the well. Use a level (must be at least 40 cm long) to determine the point on each fence post that is level from the top of the closest side of the well to the fence post. Mark the level point on each fence post using a permanent paint pen and wrap the post with electrical tape directly above the level point. Measure the distance between the level point on each fence post and the location used to measure level on the pipe (measure to the inside of the pipe). Assign a “#1” and “#2” fence post, and use a permanent paint pen to write the corresponding number on the fence post, and on the inside of the pipe to denote each location of the level measurement. Attach an ACAD research tag to fence post #1, and write “NETN Wetland Monitoring” on the tag.

To calculate depth to water from ground, several additional measurements must be performed repeatedly on the pipe. Assign one point on the top of the riser pipe that is directly above one of the bolt holes as the water level measuring point (MP), and record this on the inside of the pipe as an arrow. Measure the distance along the riser pipe from the wetland surface to the MP and the distance between the MP and the top of the bolt hole directly below the MP. Use the water level meter to determine the depth of water from the top of the well at the MP. After these measurements are complete, and the logger has been downloaded and/or launched (See SOP 8 – Using the HOBO<sup>®</sup> Water Level Logger and Shuttle), lower the logger down into the well, and make sure the nut on the hex bolt is tight.

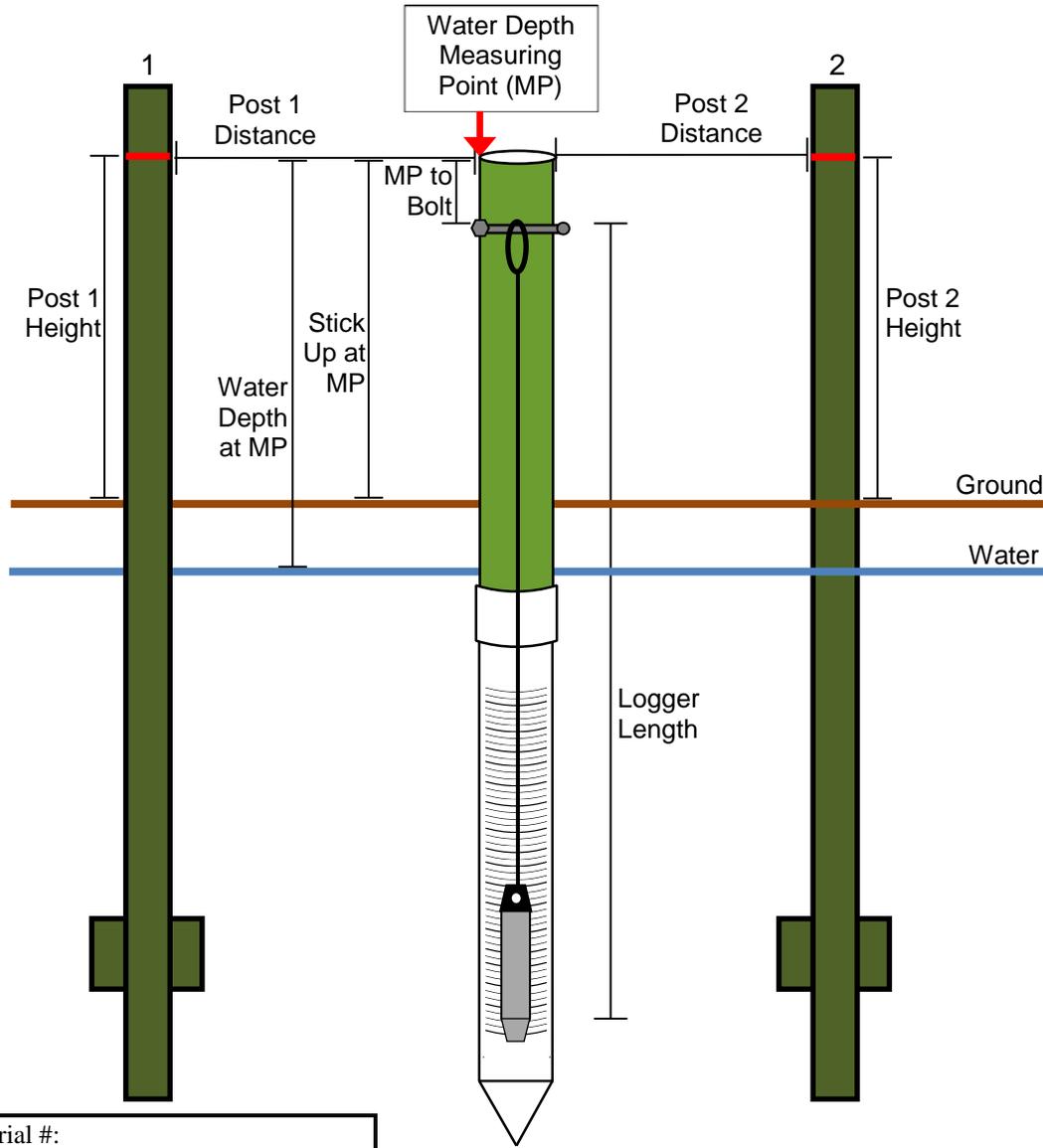
### ***Well Maintenance and Replacement***

Ideally wells will be visited twice a year. The first visit will be in the spring, and the second season will be in the fall. The spring visit should take place after frost heaves are no longer an issue, but before emerging vegetation can be trampled (mid-April to early May). The fall visit should occur between the end of August and before ice-in (November 1). At each visit begin by taking the following measurements:

- Distance from the surface of the ground to the top of the pipe at the water depth measuring point (MP)
- Distance from the ground to the level point on each fence post
- Distance between the pipe and the level point on the fence posts

SOP 7 – Shallow Well Construction, Installation, and Maintenance

Site: \_\_\_\_\_ Date: \_\_\_\_\_ Recorders: \_\_\_\_\_



Logger Serial #:
Launch Date & Time:
Logging Interval:
Battery Status:

**Ground Water Level:** \_\_\_\_\_ - \_\_\_\_\_ = - / + \_\_\_\_\_  
 (Stick Up at MP – Water Depth)

Measurement	Length (cm)	Measurement Notes
Stick Up at MP		Ground to measuring point (MP) on top of pipe
Post 1 Height		Ground to level line on post 1
Post 1 Distance		Shortest distance between edge of post to inside of pipe
Post 2 Height		Ground to level line on post 2
Post 2 Distance		Shortest distance between edge of post to inside of pipe
Logger Length		Top of bolt to bottom line on logger
MP to Bolt		Water depth measuring point to top of bolt.
Water Depth (WD)		MP to top of water surface
WD Meas. Time		Time of water depth measurement

Figure S7.2. Diagram of well and logger measurements and data collected during each field visit.

## SOP 7 – Shallow Well Construction, Installation, and Maintenance

- Depth to water from the MP using the water level meter. Note that the logger may need to be unbolted and secured (via a carabiner) above the well opening before the water level meter can be lowered into the well
- Check level between the top of pipe and the level point on each fence post

Be sure to record the distances even if they have not changed from the original measurements. While large changes in the distance measurements indicate that the well has shifted significantly from the original height, the predominant substrate in these wetlands is a living layer of Sphagnum moss, which shrinks and expands as soil saturation changes. This makes for an unstable measurement surface, and less than ideal measurement accuracy. However, our primary interest is depth of water relative to the wetland surface, rather than absolute water level. Having wetland wells that “float” with changes in the underlying substrate is actually beneficial, provided the wells do not shift or lean relative to the surface. Therefore measurements of level between two independent locations (i.e., fence posts) will be the primary method for checking well status.

To determine if the well has shifted, check if the top of the pipe closest to each fence post is level with the level point marked on the corresponding fence post. If one or both of the fence posts are not level, use the distance measurements from the previous visit to determine which one moved (i.e., the well or the fence post(s)) and record this information in the visit notes. Next, reestablish the level point on each fence post, measure the distance of the new level points from the ground, distance between the well and fence posts, and distance from ground to MP. Finally, check the lean of the well using the level. If wells are leaning more than 10 degrees, or are too loose in the substrate to be stabilized, they will need to be installed in a new location. The well should be installed within 2 m of the original location, and the distance and bearing to the center of the sentinel site (original well location) should be measured. Avoid trampling the first vegetation plot (located 2 m south from the center of the site) during reinstallation. If wells prove unstable over multiple sampling years, consider installing longer posts or rebar to bedrock (if possible) and attach wells to posts.

Once well and post measurements are completed, remove the HOB0<sup>®</sup> logger from the well. Download data from the logger (See SOP 8 – Using the HOB0<sup>®</sup> Water Level Logger and Shuttle). If only one annual visit is possible, then the well checks and data download should take place simultaneously in the spring. If a well has to be reset in the spring, it must be visited again in the fall to check for shifting.

**NOTE:** Trampling is a very important concern in wetlands that are repeatedly visited. Wetlands are often slow to recover from trampling, and repeated use of the same path to the well may permanently impact the site. During each visit, be careful not to form trails to the wells. Extreme care should also be taken while performing well maintenance and taking measurements near the wells, since observers can compact the substrate and force water into or out of the well. Observers must never to step within 0.5 m of wells. If, over time, the area surrounding the well shows impacts of trampling, consider using a platform (e.g., stadium bench), a wire frame, or other equipment to distribute weight more evenly and reduce soil compaction while working near the wells.

## SOP 7 – Shallow Well Construction, Installation, and Maintenance

### Revision History

Version numbers will be incremented by a whole number (e.g., Version 1.30 to 2.00) when a change is made that significantly affects requirements or procedures. Version numbers will be incremented by decimals (e.g., Version 1.06 to Version 1.07) when there are minor modifications that do not affect requirements or procedures included in the protocol. Add rows as needed for each change or set of changes tied to an updated version number.

#### Revision History Log

<b>Version #</b>	<b>Date</b>	<b>Revised by</b>	<b>Changes</b>	<b>Justification</b>
1.00	August 2011	Kate Miller	Initial version	
1.01	August 2012	Kate Miller	Added fence posts to aid in leveling the well and detecting shifts, revised measurements used for leveling. 2 visits per year.	Revised procedures to enhance ability to detect shifting of wells.  Reduce chance of losing growing season data.
1.02	January 2013	Kate Miller	Revised site terms	Maintain consistency with NETN and EPA protocols.
1.03	April 2013	Kate Miller	Minor editorial changes Added that a wire frame may be useful for reducing trampling	Suggestions from external review

# SOP 8 – Using the HOBO® Water Level Logger and Shuttle

*Northeast Temperate Network*

Version 1.01

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## **Overview**

This SOP provides instruction for using the HOBO® Water Level Logger and HOBO® Waterproof Shuttle to monitor water quantity in freshwater wetlands.

## **Procedures**

### ***Launching the HOBO® Water Level Logger***

In order for HOBO® Water Level Loggers (loggers) to begin logging data they need to be launched. To launch a logger, connect the HOBO® Waterproof Shuttle (shuttle) to a computer using the provided USB cable, and open Hoboware. If internet is accessible, allow Hoboware to check for and install updates. Next, connect the logger to the appropriate coupler on the shuttle, and squeeze the coupler lever once. The yellow “Transfer” LED light and the green “OK” LED light will each blink once to signal that the shuttle is on, and Hoboware will indicate that the logger is attached.

Once the shuttle with attached logger is turned on and recognized in Hoboware open the “Device” drop down menu and select “Launch”. Perform the following tasks in the Launch window:

1. Record the serial number and battery status of the logger. Note that if battery is poor, or logger has been deployed for 4 or more years, the logger should be replaced, and the original sent to the manufacturer for battery replacement.
2. Enter a description using the following format:  
Seven digit logger serial number + four-character EPA site code + Launch Date (YYYYMMDD), with each element separated by an underscore (\_).

Ex: 9997197\_R301\_20110912

3. In the “Configure Sensors” section ensure that the temperature (in degree C) and pressure (in kPa) sensors are both checked to log.
4. In the “Deployment” section set logging interval to 1 hour, and select a delayed start. Set deployment time to the next hour and click on delayed start. Be sure to record the exact date and time the logger is set to begin logging.

### ***Downloading data using the HOBO® Waterproof Shuttle***

The preferred method of downloading data from the logger is for the shuttle to be connected to a computer and to perform this process through Hoboware. This reduces the risk of data being lost during the downloading process, and makes it possible to check the battery status of the logger.

When a computer is available for the downloading process, connect the shuttle to the computer using the USB cable and open Hoboware. If internet is accessible, allow Hoboware to check for

## SOP 8 – Using the HOB0<sup>®</sup> Water Level Logger and Shuttle

and install updates. Connect the logger to the coupler on the shuttle, and squeeze the coupler lever once. The yellow “Transfer” LED and then the green “OK” LED will blink once to signal that the shuttle is on, and Hoboware will indicate that a logger is attached.

Once the shuttle with attached logger is turned on and recognized in Hoboware perform the following tasks:

1. Open the “Device” drop down menu and select “Readout”. When the “Stop Logger” window appears, click on the stop button to continue.
2. In the “Save” window, select the appropriate file location and name the file name using the following format:  
Seven digit logger serial number + four-character EPA site code + download date (YYYYMMDD), with each element separated by an underscore (\_).  
  
Ex: 9997197\_R301\_20120912
3. In the “Plot Setup” window ensure the Temp and Pressure boxes are checked. If available select the barometric pressure file and then click on the plot button. Review the plot and verify that the plot contains the entire logging interval.
4. Check that the battery status of the logger is fair or better before placing the logger back into the well. If battery is poor, or the logger has been deployed for 4 years, replace the logger and send the original to the manufacturer for battery replacement.
5. Before lowering the logger back into the well, check the condition of the optics and O-ring on the logger. If the optics shows signs of corrosion, algae growth, or dirt on the surface, clean with a lens tissue and water before replacing back in well. If O-ring appears brittle or cracked, it must be replaced before deployment.
6. After data have been successfully transferred, all files should be backed up on an external hard drive or a different computer.

If a computer is not available to download data from the logger, attach the logger to the coupler on the shuttle and perform the following tasks:

1. Squeeze the coupler level and watch the LED lights. The yellow “Transfer” light will blink up to several minutes (indicates data are being transferred). When the transfer is complete, the green “OK” LED should blink. Once the “OK” LED light blinks, the logger can be removed from the shuttle and placed back into the well.
2. Once back in the office, connect the shuttle to a computer with the USB cable. Open Hoboware and allow Hoboware to check for and install updates. Once updates are complete, perform the following steps:
  - a. Open the “Device” drop down menu and select “Readout”.
  - b. Check the save box in front of the files to be saved to the computer
  - c. Click on “Choose” box and browse to the appropriate location for the data.
  - d. Use the following file name format:  
Seven digit logger serial number + four-character EPA site code + download date (YYYYMMDD), with each element separated by an underscore (\_).  
Ex: 9997197\_R301\_20120912
  - e. Click on the “Save checked box”

## SOP 8 – Using the HOBO<sup>®</sup> Water Level Logger and Shuttle

- f. After the files have been saved from the shuttle, double check that the files were successfully saved to the computer. Next put a check in the box in front of the files to be deleted and click on the “Delete checked” box to clean up the shuttle.
3. Because checking the battery status in the logger is not possible in this scenario, any logger that has been deployed for four years should automatically be replaced with a logger containing a new battery. The original logger should be sent to the manufacturer for battery replacement.
4. Before lowering the logger back into the well, check the condition of the optical sensor and O-ring on the water level logger. If the optical sensor shows signs of corrosion, algae growth, or dirt on the surface, clean with a lens tissue and water before replacing back in well. If O-ring appears brittle or cracked, it must be replaced before deployment.
5. After data have been successfully transferred, all files should be backed up on an external hard drive or a different computer.

### **Quality Control/Quality Assurance and File Management**

Quality Control and Quality Assurance (QA/QC) are important to ensure accurate water level and temperature data. Before examining the water level data, the data must be corrected for barometric pressure, temperature, the difference (if any) in elevation between the barometric logger and the water level logger, and drift (if any) in the water level data between deployments. Two loggers are installed on Mount Desert Island (MDI) to measure barometric pressure for this calibration; one logger is located on the east side of MDI at the McFarland Air Research Station, and one logger is on the west side of MDI next to the well established in wetland NWCA11-R302. The logger closest to each wetland should be used for the calibration. The barometric calibration can be performed through the plot function in Hoboware. We are currently working with Rocky Mountain Inventory and Monitoring Network to develop methods for elevation corrections and detecting/correcting drift.

After water level data have been corrected for barometric pressure, water level and temperature data should be exported as .csv files and inspected in Excel for outliers and data gaps. Outliers should be compared with available weather data (e.g., large precipitation events, timing of spring thaw, etc.) to determine if the two are correlated. If no explanation is found for an outlier, then that data point may be removed from the data series.

After water level and temperature data have been inspected and cleaned, the water level data should be converted to water depth relative to the ground surface by performing the following steps in Excel:

1. Convert kPa pressure data to cm of water above the logger (1 kPa = 10.197 cm of water)
2. Calculate water depth relative to surface using the following formula:

$$\text{Water Depth} = (\text{Step 1 Value}) - [(\text{Logger Length} + \text{MP to Bolt}) - \text{Stick Up at MP}]$$

Note that a negative value indicates water depth is below the ground surface, and a positive value indicates that water depth is above the ground surface. After water level data have been converted to depth relative to ground surface, water level and temperature data files should be imported into a database, along with all well and logger information specific for each site. All original data files and information about any changes to the data (e.g. removal of outliers) must be retained and archived.

## Revision History

Version numbers will be incremented by a whole number (e.g., Version 1.30 to 2.00) when a change is made that significantly affects requirements or procedures. Version numbers will be incremented by decimals (e.g., Version 1.06 to Version 1.07) when there are minor modifications that do not affect requirements or procedures included in the protocol. Add rows as needed for each change or set of changes tied to an updated version number.

### Revision History Log

<b>Version #</b>	<b>Date</b>	<b>Revised by</b>	<b>Changes</b>	<b>Justification</b>
1.00	September 2012	Kate Miller	Initial version	
1.01	January 2013	Kate Miller	Revised site terms	Maintain consistency with NETN and EPA protocols.

# SOP 9 – Data Analysis and Reporting

## *Northeast Temperate Network*

Version 1.02

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### **Overview**

This SOP provides important guidelines related to data analysis and reporting for the Permanent Freshwater Wetland Monitoring Program in Acadia National Park (ACAD). This SOP recommends a multi-tiered approach to reporting, based on the type of data available, and includes a rough schedule for each type of report, potential statistical approaches, and staff responsibilities.

### **General Considerations for Writing Reports**

The NETN will produce a summary status report for each year of intensive sampling for the National Wetland Condition Assessment (NWCA) after data are made available by EPA (once every five years, and approximately 2 years after sites are sampled). NETN will also produce a status report after all 4 panels of rapid assessment sites are completed (i.e., once every five years). The primary functions of the status reports are to archive the data and document procedures for the year(s) of sampling. Every 10 to 15 years, NETN will produce a trend report that combines results from multiple years of intensive sampling, rapid assessment monitoring, and continuous water level monitoring. Reporting will be the responsibility of the Plant Ecologist with assistance from the NETN Program Manager or other designated staff as needed. All reports will be subject to a thorough peer review process that includes park staff.

It is a recent objective of the National Park Service (NPS) Inventory and Monitoring (I&M) Program to streamline annual reporting; best efforts should be made to comply with new policies. Annual reports and trend analysis reports will use the NPS Natural Resource Publications template, a preformatted Microsoft Word template document based on current NPS formatting standards. Both reports should be completed using the Natural Resource Technical Report template. This template and documentation of the NPS publication standards are available at: <http://www.nature.nps.gov/publications/NRPM/index.cfm>.

### **Data Analysis**

#### ***Sentinel Monitoring Data***

Data collected in the sentinel sites have some important limitations. Because these sites were not selected randomly or systematically, they cannot be assumed to be representative of a larger area. Inference from statistical analyses of the sentinel monitoring data is limited to the site level, and the data should not be used to make statements about ACAD freshwater wetlands as a whole. Nevertheless, any highly significant trend between all sites in ACAD or within a wetland type would be suggestive of a larger-scale trend. Additionally, these data may be suitable for correlative analyses to explore potential causes of long-term trends, but those analyses would need to be followed with manipulative experiments to confirm their findings.

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To examine variation in wetland composition, structure and function over space and time, summary statistics (mean and standard error of the mean) describing the vegetation, soil, water and algae for each site and sample period will be calculated and graphically plotted. Initial trend analyses will be quite simple, such as paired sample t-tests of metrics for each site. As the data series becomes longer we will employ more sophisticated approaches, such as a random effects (hierarchical) model, where each sentinel site is considered a random effect and all sites are modeled together. While this approach would still not allow extrapolation beyond sites sampled, it would potentially enable a more complete understanding of the site-level data. Comparisons of the trends in ACAD wetlands can potentially be integrated within the broader sampling efforts of the EPA NWCA. This would provide more power to evaluate local changes in the context of a broader system, and enable consideration of large-scale changes in the environment such as geographic variation in climate.

Continuous water level data collected in the sentinel sites will periodically be plotted and analyzed for correlations with major weather events. In addition we will calculate basic statistics, such as hydroperiod, number of inundations, and annual mean, minimum, and maximum levels. We will initially use the 5-year mean and standard deviation (SD) to establish the baseline for each water level metric, and will assume a normal distribution and consider the “range of natural variation” to be data within 1.96 standard deviations of the mean (i.e., 5% of observations would be outside this range even if there is no change). The end points of the mean  $\pm$  1.96 SD will become our “assessment points,” and results outside of these endpoints will be considered indicative of a problem. This approach assumes that the ecosystem is in its “natural” state during the baseline period, which may not be the case. Therefore, this approach should be considered a “first cut” at hydrology- related metrics of ecological integrity. NETN has not had a chance to review historic data that could be suitable for establishing the range of natural variation for our water level metrics, and the network will conduct this review and adjust assessment points as time permits.

### ***Rapid Assessment Data***

The USA-RAM data will likely be more amenable to statistical analysis, even though the data collected are more qualitative. This is because the USA-RAM data will be based on a statistical sample with a reasonable sample size ( $n = 40$ ). USA-RAM data will be used to assess status and trends in wetland condition, presence of wetland stressors, and potential associations between condition and stressors. If an appropriate floristic quality index (FQI) becomes available, we will calculate FQI scores for each USA-RAM site, and examine how FQI scores relate to other USA-RAM metrics. Trend analyses will be performed using a mixed effects model that will allow for estimation of “fixed” effects (i.e., park subunit, or trend over time), while accounting for “random” effects (i.e., randomly located sites). This model will allow us to examine overall trends in ACAD, as well as trends within a site.

### **Reporting**

The general outline of each report, whether it is a status or trend report, should include:

1. A brief Introduction section describing the project along with the goals and objectives.
2. A Methods section detailing data collection procedures and analytical techniques; this may change little between reports but should still be included as part of each report. The

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section should highlight any changes from previous methods. For status reports, describe any logistic problems that were encountered and provide suggestions for preventing or coping with similar problems in the future.

3. A Results section that describes the content of the summary tables, figures and ecological integrity scorecard (see below; status reports only).
4. For status reports, graphs or tables display current values compared to the average results from previous years. For trend reports, include graphs showing trends in key metrics.
5. A brief Discussion section that highlights and interprets any notable findings, such as detections of unexpected or invasive species, unexpectedly large changes in water quality (> 50% change), or factors such as extreme weather events that might have affected results. Note that the NETN list of invasive species is more comprehensive than the FOM, and includes any species considered invasive by NatureServe and/or the Integrated Plant Atlas of New England (IPANE).
6. An Acknowledgements section thanking individuals and organizations who contributed to the field season or the report.

A sentinel site status report will be completed after every year of intensive sampling for the NWCA. Annual reports will include vegetation data summaries for each site, results from the soil, water, and algae lab analyses processed by EPA, summaries of the water level data, and a description of important protocol concerns and/or changes from the previous survey. In addition, wetland condition will be interpreted using an ecological integrity framework and will include a combination of metrics developed in Faber-Langendoen (2009), relevant analyses in the Data Analysis Plan (U.S. EPA in prep), and metrics developed for an index of ecological integrity in ACAD emergent wetlands by Grace et al. 2012. Where possible, results in ACAD will also be compared with regional EPA data.

A rapid assessment status report will be produced after each cycle of USA-RAM sites are completed. Status reports will include a description of stressors and wetland condition for each site, as well as an overall assessment of wetland ecological integrity in ACAD. Trend reports, which will be completed every 10 to 15 years, will combine results from multiple years of intensive sampling, rapid assessment monitoring, and continuous water level monitoring.

### Literature Cited

Faber-Langendoen, D. 2009. A freshwater wetlands monitoring and assessment framework for the Northeast Temperate Network, National Park Service. Natural Resource Report NPS/NETN/NRR—2009/143. National Park Service, Fort Collins, Colorado.

Grace, J. B., D. R. Schoolmaster Jr., G. R. Guntenspergen, A. M. Little, B. R. Mitchell, K. M. Miller, and E. W. Schweiger. 2012. Guidelines for a graph-theoretic implementation of structural equation modeling. *Ecosphere* 3(8):73. <http://dx.doi.org/10.1890/ES12-00048.1>

U.S. Environmental Protection Agency. 2012 (in prep). National Wetland Condition Assessment: Data Analysis Plan. EPA-xxx-x-xx-xxx. U.S. Environmental Protection Agency, Washington, DC.

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### Revision History

Version numbers will be incremented by a whole number (e.g., Version 1.30 to 2.00) when a change is made that significantly affects requirements or procedures. Version numbers will be incremented by decimals (e.g., Version 1.06 to Version 1.07) when there are minor modifications that do not affect requirements or procedures included in the protocol. Add rows as needed for each change or set of changes tied to an updated version number.

#### Revision History Log

<b>Version #</b>	<b>Date</b>	<b>Revised by</b>	<b>Changes</b>	<b>Justification</b>
1.00	November 2012	Kate Miller	Initial version	
1.01	January 2013	Kate Miller	Revised site terms	Maintain consistency with NETN and EPA protocols.
1.02	April 2013	Kate Miller	Clarified how invasive species are defined. Added that a Floristic Quality Index will be a useful analysis tool for USA-RAM data, once it is available.	Suggestions from external review.

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NPS 123/120495, April 2013

**National Park Service**  
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