



Freshwater Wetland Monitoring in Acadia National Park

Northeast Temperate Network 2011-2016 Summary Report

Natural Resource Report NPS/NETN/NRR—2017/1418





ON THIS PAGE

Sunken Heath Marsh in Acadia National Park
NPS/Kate Miller photograph.

ON THE COVER

Photograph of NPS staff sampling wetland vegetation in Acadia National Park
NPS photograph.

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Executive Summary

Background

As transitional habitats between upland and aquatic environments, wetlands provide many essential ecosystem functions, including habitat for flora and fauna, water quality maintenance, erosion and flood control, groundwater recharge, and carbon storage. With over 60% of the state-listed rare plants in Acadia National Park (ACAD) found in wetland and aquatic systems, they are also important sites for biodiversity. Wetlands are vulnerable to a number of stressors, including altered hydrology, invasive species, run-off from developed and/or agricultural lands, and sedimentation. Impacts from climate change are another important concern. As wetlands degrade, their capacity to provide wildlife habitat and ecosystem services can be severely compromised. Understanding the current status and threats to wetland condition is therefore imperative for ensuring continued protection of these resources.

The Northeast Temperate Network (NETN) began monitoring permanent freshwater wetlands in ACAD in 2011. NETN defines permanent wetlands as those that are saturated or inundated for most or all of the growing season (i.e., not vernal pools) and are dominated by hydrophytic plants. The overall goal of the freshwater wetland monitoring program is to monitor status and trends in vegetation, hydrology, soil and water quality, and indicators of wetland condition and stressors in ACAD's freshwater wetlands. NETN uses a three-tiered approach to wetland monitoring, where level 1 is a GIS-based monitoring of landscape condition, level 2 is a rapid field-assessment, and level 3 is an intensive field-assessment. NETN conducts level 3 monitoring in 10 sentinel sites, which were non-randomly selected to represent the best condition of various wetland types in ACAD, and are sampled following protocols developed by the Environmental Protection Agency (EPA) for the National Wetland Condition Assessment ([NWCA](#)). During the years between the EPA NWCA, NETN conducts rapid assessment monitoring (RAM; Level 1 and 2) following the USA-Rapid Assessment Manual (USA-RAM) at 40 randomly located wetland sites in ACAD. NETN also monitors continuous water level during the growing season in the eight sentinel wetlands on Mount Desert Island (MDI) in ACAD. In addition to the NETN's vital signs monitoring in wetlands, ACAD staff and partners are monitoring wetland condition in Great Meadow for a watershed-level restoration initiative known as "Wild Acadia". The park uses a similar 3-tiered approach as NETN and follows the same protocols to characterize baseline condition in Great Meadow.

This report summarizes results from the first cycle of plot-based sampling in 10 sentinel sites and 40 rapid assessment sites (2011-2015), along with 4 years of water level monitoring in the eight sentinel sites on MDI (2013-2016). The report also includes comparisons with data collected by ACAD park staff and partners in Great Meadow, along with regional data collected by the EPA NWCA.

Results

Results from the first monitoring cycle indicate that wetlands in ACAD are generally in Good condition with the exception of a few impacted wetlands. Monitored wetlands in ACAD (with the exception of the impacted sites of Great Meadow, Marshall Brook, and the Kent Field complex) are largely composed of native species indicative of intact habitats, and invasive species are generally

very low in abundance or absent. In contrast, the sites in impacted wetlands, particularly Great Meadow, are composed primarily of disturbance tolerant native species, and have higher abundances of invasive species (e.g., glossy buckthorn [*Rhamnus frangula*]). Sites rated as Fair for vegetation are primarily beaver-influenced wetlands, and the Fair rating in these sites is more of an indication of the recent natural disturbance caused by beaver, rather than unhealthy ecosystem condition. Many of the sites that are rated Poor for vegetation, including all of the sites in Great Meadow and Marshall Brook, are also influenced by beaver, but additionally have a history of hydrological disturbance and/or are affected by multiple stressors in both the 40-m radius Assessment Area and in the surrounding 100-m buffer.

Wetland hydrology during the study period was strongly influenced by rainfall events and overall rainfall amounts, and followed expected patterns by hydrogeomorphic classes and vegetation type. Water levels were faster to respond to rainfall events in the undisturbed sentinel sites than in Great Meadow, which may be due to a combination of smaller catchment, higher watershed position, and lack of hydrological alterations compared to Great Meadow. These data serve as important baselines to assess how restoration efforts may influence wetland hydrology in Great Meadow. Long-term, these data will also help us understand how climate change impacts wetland hydrology, and the resulting impacts on wetland vegetation composition and function.

Monitoring results indicate that water quality is less impacted in Great Meadow compared to hydrology and vegetation. Our results suggest that restoration efforts in Great Meadow should focus on restoring the natural hydrologic regime and invasive plant management. Reducing buffer stressors, such as undersized culverts or sediment input from roads, will help ensure that intact wetland communities remain stable and healthy which should also improve overall condition of the impacted sites. Continued invasive species management is essential to ensure that invasive species remain absent or at low levels in ACAD wetlands. As restoration efforts continue in Great Meadow and subsequent watersheds, wetland monitoring will help define desired condition and measure the effectiveness of restoration efforts.

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Introduction

As transitional habitats between upland and aquatic environments, freshwater wetlands provide many important ecosystem functions, including habitat for flora and fauna, chemical uptake and nutrient cycling, erosion and flood control, groundwater recharge, and carbon storage (Keddy 2000, Mitsch and Gosselink 2000). Wetlands play key roles in regulating water quality in aquatic systems, including removal of excess nutrients and sediment, and filtration of toxins (Verhoeven et al. 2006). Wetlands are also important sites of biodiversity, with roughly half of the migratory bird species in the US and over 30% of plant and animal species listed under the Endangered Species Act reliant on these habitats (U.S. Fish and Wildlife Service 1996).

The three primary components that define a wetland are hydrology, vegetation, and soils – impacts to any of these components can negatively affect condition and function (Mitsch and Gosselink 2007). Altered hydrology, both from human influence and by beaver, can lead to dramatic changes in wetland vegetation and soils (Little 2005, McLaughlin and Cohen 2013). Hydrologic impacts, such as ditching, channelizing, draining, or damming can dramatically reduce wetland function, such as flood abatement and nutrient cycling, along with altering species composition (Ritcher et al. 1996). Wetlands are particularly vulnerable to invasive plant species, which can form dense monocultures that greatly reduce structure, alter function, and impact habitat for wildlife (Zedler and Kercher 2004). In addition, run-off of sediment and nutrients can increase their vulnerability to invasion of exotic species (Werner and Zedler 2002). Land use and stressors in adjacent uplands can also impact wetland condition, as increased development often leads to higher peak flows, inputs of poor quality water, and increased sedimentation (Schueler 1994). As wetlands are degraded, their capacity to provide wildlife habitat and ecosystem services can become severely compromised (Jansen and Healey 2003, Zedler and Kercher 2005).

Impacts from climate change are an important concern for wetlands (Junk et al. 2013) since their formation and structure result from local climatic patterns and topography. Recent changes in precipitation and warming temperatures have already been documented in Maine, and these climatic changes are expected to continue into the future (Fernandez et al. 2015). For example, extreme precipitation events have increased in frequency across the state and mean annual temperature has risen 1.7 °C (3.0 °F) since pre-industrial times (Fernandez et al. 2015). In addition, since the 1930s the ratio of snow to rainfall has decreased and annual precipitation has increased on the Maine coast by an average of 8.2 cm since the 1930s (Huntington et al. 2004, Huntington et al. 2009). Combined with increased threats associated with human development, climatic change is expected to further exacerbate impacts and threats to wetlands (Tu 2009, Pavri et al. 2013). Understanding the current status and threats to wetland condition is therefore imperative for ensuring continued protection of wetland resources (National Research Council 2001).

Recognizing the importance of monitoring wetland resources, the U.S. Environmental Protection Agency (EPA) initiated a National Wetland Condition Assessment (NWCA) as part of the National Aquatic Resource Surveys program (NARS). The NWCA, which represents the first nationwide and standardized survey of wetlands in the US, was implemented in 2011. The NWCA uses a

combination of probability sites and a smaller set of non-randomly selected reference sites, and collects information on a suite of vegetation, soil, water, hydrology, and site characteristics. The probability sites are randomly located and used to assess wetland condition and extent. The reference sites are hand-picked, based on best professional judgment to be least disturbed, and are used to characterize the natural range of variation of wetland attributes. The overall objectives of the NWCA are to provide regional and national estimates of wetland condition and extent, and to determine stressors most commonly associated with poor condition (EPA 2011a).

Despite occupying only about 7% (988 ha) of the park fee area, nearly 2/3 of the state-listed rare plants that occur in Acadia National Park (ACAD) are found in freshwater wetland and aquatic systems (Greene 1990, Lubinski et al. 2003). Given their importance and the threats posed to these habitats, the Northeast Temperate Network (NETN) of the National Park Service (NPS) began monitoring permanent freshwater wetlands in ACAD in 2011. NETN defines permanent freshwater wetlands as wetlands that are saturated or inundated with freshwater for most or all of the growing season (i.e., not vernal pools) and are dominated by hydrophytic plants (i.e., not open water). The overall goal of the freshwater wetland monitoring program is to monitor status and trends in vegetation, hydrology, soil and water quality, along with indicators of wetland condition and stressors on ACAD's permanent freshwater wetlands.

NETN uses a three-tiered approach to wetland monitoring, where level 1 is a GIS-based monitoring of landscape condition, level 2 is a rapid field assessment, and level 3 is an intensive field assessment (Miller and Mitchell 2013). NETN conducts level 3 monitoring in 10 sentinel sites, which were non-randomly selected to represent the best condition of various wetland types in ACAD (Figure 1), and are sampled following the Field Operations Manual (FOM) developed by the EPA for the NWCA (NWCA; EPA 2011a). The sentinel sites in ACAD also serve as potential reference sites for the EPA NWCA, and this partnership allows us to compare wetlands in ACAD to patterns across a broader region. During the years between each NWCA, NETN conducts rapid assessment monitoring (RAM; Level 1 and 2) following the USA-Rapid Assessment Manual (USA-RAM; EPA 2011b) at 10 randomly located wetland sites per year (i.e. 40 total RAM sites).

NETN also monitors hydrology, which has a strong influence on wetland vegetation and soils, using water level loggers that are deployed during the growing season in the eight sentinel wetlands on Mount Desert Island (MDI) in ACAD. While the influence of hydrology on wetlands is well known, few programs monitor how changes in hydrology affect long-term changes in wetland vegetation and soils (Cole et al. 1997, Steven and Toner 2004). By monitoring continuous water level during the growing season in the sentinel sites on MDI, we can better understand the linkages between hydrology and wetland condition, along with how they change over time.

In addition to the NETN's long-term vital signs monitoring in wetlands, ACAD staff and partners are monitoring wetland condition in a watershed-level restoration initiative known as "Wild Acadia" (Miller-Rushing et al. 2014). Cromwell Brook Watershed, which encompasses Great Meadow (roughly 45 ha), is the first watershed targeted for restoration, and improving the ecological integrity of Great Meadow is a major focus in this restoration effort. The park is using a similar 3-tiered approach and following the same protocols as NETN to characterize baseline conditions in Great

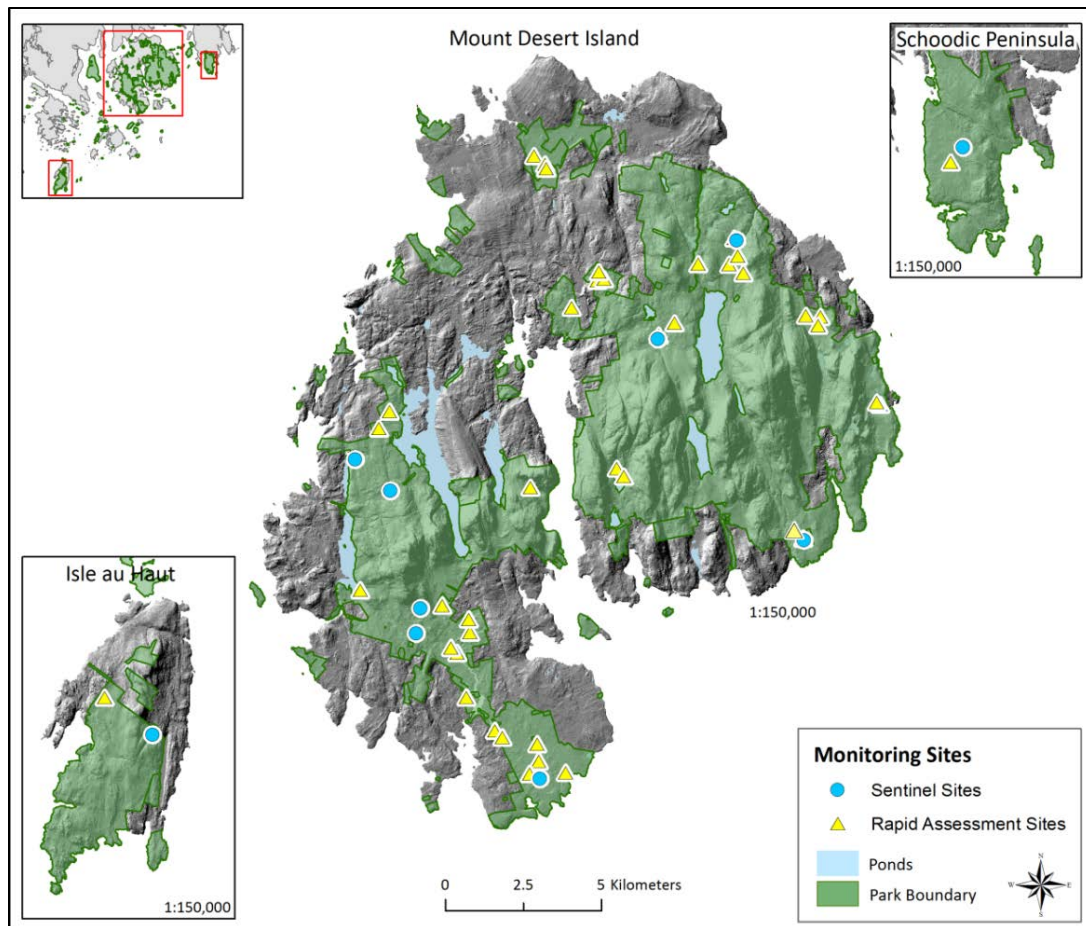


Figure 1. Map of wetland sites that are monitored by NETN in ACAD.

Meadow (Mittlehauser 2016); six sites receive the same level of monitoring as NETN sentinel sites, referred to as intensive sites, and four sites receive Level 1 and 2 rapid assessment monitoring (Figure 2).

This report summarizes results from the first 5-year cycle of permanent freshwater wetland monitoring in ACAD, including summaries from the 2011 EPA NWCA, the 40 rapid assessment sites that NETN sampled between 2012 and 2015, and the sentinel site water level data from 2013 - 2016. We calculated multimetric indicators (MMIs) developed for vegetation, soil and water chemistry to assess the condition of wetlands in ACAD (Miller et al. 2016). In addition, we incorporate data from the EPA NWCA to make comparisons to the broader region, along with data collected from the intensive sites in Great Meadow restoration project area.

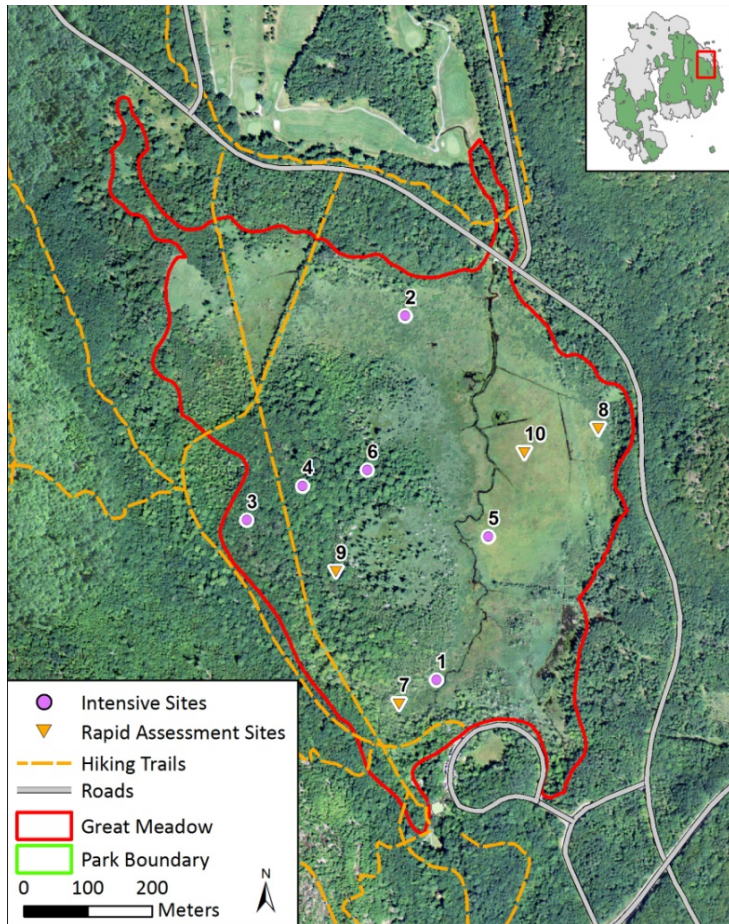


Figure 2. Sites monitored by ACAD in the Great Meadow restoration project area.

Methods

Sample Design and Methods

NETN monitored 50 permanent freshwater wetland sites in ACAD from 2011 to 2016 using a rotating panel design (Table 1; Miller and Mitchell 2013). The first panel contains 10 sentinel sites that are sampled during the EPA NWCA (2011 and 2016) and follow the EPA FOM (FOM; EPA 2011a). The ACAD sentinel sites serve as potential reference sites for the EPA NWCA. EPA screens potential reference sites for indicators of disturbance or poor condition to determine which sites will serve as true reference sites for the NWCA, and these are then used to build indicators and assign Good, Fair, and Poor thresholds for wetland condition. EPA uses the indicators developed from the reference sites to assess condition of the probability sites, which are a larger representative sample of randomly selected sites that are used to assess the overall condition of wetlands in the eastern US.

Table 1. Number of sites sampled per year in each site type and panel. Intensive (Level 3) monitoring only occurred in sentinel sites. Water level monitoring started in the fall of 2012 is continuous in each of the 8 sentinel sites on Mount Desert Island. Level 1 and 2 monitoring was implemented in a rotating panel of permanent sites (RAM) located in randomly selected wetlands.

Site Type	Panel	2011	2012	2013	2014	2015	2016
Sentinel Sites: EPA NWCA	–	10	–	–	–	–	10
Sentinel Sites: Water Level	–	–	8	8	8	8	8
Rapid Assessment	Panel 1	–	10	–	–	–	–
(RAM)	Panel 2	–	–	10	–	–	–
	Panel 3	–	–		10	–	–
	Panel 4	–	–	–	–	10	–

The wetlands where ACAD sentinel sites are located were non-randomly selected by NETN to represent minimally disturbed condition based on best professional judgement and research by Little (2005) and Grace et al. (2012). Selected sentinel wetlands are large (≥ 2 ha) and small (< 2 ha and > 0.1 ha), include multiple wetland types (e.g., topographic slope, organic flats, depression, etc.), and are distributed across the park. Within each sentinel wetland, the location of the sentinel monitoring site was determined using generalized random tessellation stratified sampling (GRTS; Stevens and Olsen 2004). At each sentinel site we implemented the full EPA NWCA sampling protocol, which collects data on vegetation, soils, water chemistry and hydrology in a 40-m radius assessment area (AA), and assesses the landscape context and buffer condition in a 100-m radius buffer that surrounds the AA (EPA 2011a; Appendix A). Starting in 2013, we monitored continuous water level during the growing season in the eight sentinel sites located on MDI. Because wells often shift during the winter, and loggers deployed for the barometric pressure correction are often buried during years of high snowfall (e.g., > 1 m deep snowpack), we are only able to reliably monitor water level relative to the wetland surface during the growing season (i.e., between spring and fall well visits). The timing of spring visits, which depended on the opening of park roads after winter closure, was

typically in late April or early May. However, the spring visit may be later if openings of park roads were delayed due to excessive snow pack and soft road conditions (e.g., 2014). Timing of fall visits typically occurred at the end of October, which was after the end of the growing season but before frost heaves and snowfall can shift wells. While changes in snowfall and rainfall patterns will likely impact wetland hydrology, we are unable to directly monitor these effects because water level monitoring is restricted to the growing season, and the nearest weather stations only collect data on water equivalent precipitation (i.e., no data on precipitation that fell as snow vs. rain).

Because sentinel sites were not selected randomly across the park, sampling data from these sites cannot be used for inference on the larger population of wetlands found in ACAD. However, the importance of the sentinel data comes from in-depth monitoring that occurs at these sites that represent relatively unimpaired conditions for which we can compare status and trends to the larger representative sample of rapid assessment monitoring (RAM) sites (refer to Appendix B for site information).

The four panels of RAM sites were sampled during the years between the EPA NWCA (Table 1). RAM sites were randomly located across ACAD using GRTS to provide a spatially balanced random sample based on a wetland shapefile that contained freshwater wetland vegetation polygons from the Acadia vegetation map (Lubinski et al. 2003). At each RAM site, we implemented the USA-RAM (EPA 2011b), which includes a Level 1 GIS-based assessment of buffer condition and a rapid field assessment (Level 2) of the presence of stressors in a 40-m radius AA and a 100-m buffer that surrounds the AA (Appendix A: Figure 2). The Level 1 assessment involves inspections of orthophotos and GIS data to identify potential stressors in the buffer and AA (e.g., roads, developed lands, etc) of each site, which are then verified in the field during the Level 2 assessment. In addition to implementing the USA-RAM, we conducted a 15-minute timed search of plant species within each quarter of the 40-m radius AA. Because the RAM sites are a representative sample of wetlands in ACAD, results from the RAM sites can be used to assess overall freshwater wetland condition in ACAD. For more details on the NETN monitoring approach, refer to Miller and Mitchell (2013).

The sites sampled for the Great Meadow restoration project were also determined using GRTS within the Great Meadow wetland boundary. To maintain spatial balance, the first six sites based on GRTS priority were designated as intensive sites, and the remaining four sites were designated as RAM sites. All 10 sites were established and sampled by ACAD staff and cooperators for vegetation in 2015, and the soils and water were sampled in 2016. Note that only the vegetation, water chemistry, and water level data were available for inclusion this report. For more details on the sites sampled for the Great Meadow restoration project, refer to Mittlehauser (2016).

Data Analysis

To assess freshwater wetland condition in ACAD, we developed multi-metric indicators (MMI) for vegetation, soil, and water chemistry using the EPA NWCA dataset from 2011 (Miller et al. 2016), following the methods developed by Stoddard et al. (2008) for MMI construction. MMIs (sometimes called IBIs) are common tools for assessing condition of aquatic resources, and are often more responsive to disturbance and a better measure of condition than individual metrics (Stoddard et al. 2008). MMIs are composed of three to four metrics that distinguish between reference and heavily

disturbed sites, are not correlated with each other, and represent different ecological processes or phenomena. To calculate the MMI, each metric is rescaled and combined to calculate an MMI score from 0 (poor condition) to 100 (best condition) to permit assessments of Good, Fair or Poor based on the distribution of MMI scores in reference sites. Using this approach, we calculated and rated the Vegetation, Soil and Water Chemistry MMIs based on data from the sentinel sites, and Vegetation and Water Chemistry MMI for the intensive sites in the Great Meadow restoration project area.

The metrics for the Vegetation MMI were calculated by averaging data collected within five, 100-m² vegetation plots that were sampled following the EPA FOM in each sentinel site AA (Miller et al. 2016). The four metrics in the Vegetation MMI include the mean coefficient of conservatism (C) of all species (range: 0-10), percent cover of bryophytes (range: 0-100%), percent cover of invasive exotic species (range: 0-100%), and percent cover of native disturbance-tolerant species (range: 0-100%). The mean C and percent cover of native disturbance-tolerant species metrics rely on coefficient of conservatism (C) rankings that range from 0 (exotic) to 10 (high fidelity to pristine habitats) and have been assigned to each plant species at the state or ecoregion level in the conterminous US (Lopez and Fennessy 2002, Chamberlain and Ingram 2012). Disturbance-tolerant, generalist species are those with a coefficient of conservatism ≤ 4 . The mean C is the average coefficient of conservatism score of all plant species present, and ranges from 0 to 10, with higher mean values reflecting vegetation of more intact, pristine habitats (Chamberlain and Brooks 2016).

In the RAM sites, we did not implement the EPA FOM to sample five 100-m² vegetation plots. Instead, we implemented the USA-RAM (EPA 2011b), which consists of recording vegetation data across the entire 40-m radius AA, including percent cover of the six most dominant species by vegetation strata (e.g., short emergent plants, tall emergent plants, tall woody plants, etc.) in Metric 7 of the USA-RAM (EPA 2011b), and the presence of all species observed within each quarter of the 40-m radius AA. Because of these differences in sampling, we used an adjusted version of the Vegetation MMI to assess the condition of RAM sites. For the adjusted Vegetation MMI, the mean C for RAM sites was calculated as the mean C of all species observed in the AA. Percent cover of bryophytes (mosses) and exotic species in the RAM sites represent the percent cover estimated for the entire AA. Note that we did not start estimating percent cover of bryophytes in RAM sites until 2015. We estimated the percent cover of bryophytes in sites sampled from 2012-2014 based on detailed knowledge of the site (e.g., all sites in Sunken Heath have > 95% bryophyte cover), review of photopoints, comparisons with sites in the same wetland sampled in years where bryophyte cover data were available (i.e., 2011, 2015 or 2016), and comparisons with sites sampled in Little (2005). We will verify these estimates in the second survey cycle, and will report any deviations in the next report. We estimated percent cover of disturbance-tolerant species using the percent cover of dominant species by strata that are recorded in Metric 7 of the USA-RAM (EPA 2011b).

The individual metrics used to construct the Soil MMI were derived from chemical analyses of the upper 30 cm of wetland soil samples collected at each sentinel site in 2011. The metrics used to calculate the Water Chemistry MMI were derived from chemical analyses of water samples collected at each sentinel site in 2011. We did not collect the necessary soil and water data to calculate the Soil or Water Chemistry MMIs in the RAM sites. However, we did summarize stressor and site-level data

for all RAM, sentinel and Great Meadow restoration project sites to assess the buffer condition for each site. To put the condition of ACAD wetlands into a regional context, we compared the results in ACAD with probability and reference sites that were sampled in the northeastern US for the EPA NWCA in 2011, and that we used to develop the MMIs (Appendix C).

For the hydrological analysis, we calculated summary statistics of water levels by growing season, defined as May 15 to October 1 in each calendar year. Water level change over the growing season was calculated as the difference in the mean June water level to the mean September water level for each year. We estimated hydroperiod as the proportion of the growing season that water level was 1) above the surface (i.e., water level is > 0 cm), 2) within 30 cm of the surface, and 3) more than 30 cm below the surface. These break points are important thresholds that drive vegetation patterns in wetlands, as prolonged surface water often selects for emergent vegetation, and prolonged saturation of the rooting zone (upper 30 cm of soil) selects for wetland species over upland species (Cole et al. 1997, Steven and Toner 2004). Wells and loggers in the sentinel sites were installed in the fall of 2012, and have been monitored continuously during each growing season since 2013. Wells in the intensive sites that are monitored for the Great Meadow restoration project were installed during the 2015 growing season. As indicated by a sharp increase in water level just after the loggers were deployed (Figure 3 in Mittlehauser 2016), water level in the wells in the Great Meadow intensive sites took several days to equilibrate with water level in the wetland. To ensure the water level data represents actual patterns in the wetland, we deleted the initial logging period up to the point where water level stabilized in Great Meadow. This was not an issue for the sentinel site data because wells were deployed the fall prior to the 2013 growing season.

Results and Discussion

Buffer and AA Stressors

Most sentinel sites had at least one stressor present in the 100-m buffer surrounding the 40-m radius AA, and gravel or paved roads were the most common stressor recorded in the buffer (Table 2). In contrast, only one stressor was recorded within the AA of a sentinel site, and this was due to selective cutting of standing dead trees that occurred over a decade ago in Duck Pond (Table 3). Not surprisingly, more stressors in the AA were recorded in RAM sites than in the sentinel sites. Grazing or trampling by native ungulates was the most common stressor recorded in the AA for RAM sites, with impacts primarily restricted to the wetland surface (e.g. deer trails), rather than browse to the vegetation. Gravel roads and presence of invasive species were the most common buffer stressors recorded for RAM sites. While 30% of RAM sites had invasive species present in the AA, the actual cover of the invasive species was very low (i.e., 1-2 seedlings) for all but a few of the sites located in Marshall Brook and Great Meadow. The sites sampled for the Great Meadow restoration project had considerably more stressors recorded in both the buffer and the AA than the RAM and sentinel sites. Every Great Meadow restoration project site had at least one stressor recorded in the buffer and the AA, and 30% of the sites had at least three stressors recorded within the AA.

Table 2. Percentage of sites with stressors observed in the 100-m buffer surrounding the AA for RAM (n=40), sentinel (n=10) and Great Meadow restoration project (n=10) sites.

Stressor Type	Stressor	% RAM	% Sentinel	% Great Meadow
Habitat/ Vegetation	Cover of non-native or invasive species	10.0	0.0	60.0
	Forest - selective cut	2.5	10.0	0.0
	Mowing/shrub cutting	2.5	0.0	10.0
	Sediment input	0.0	20.0	0.0
	Shrub layer browsed	2.5	0.0	0.0
	Substrate disturbance	2.5	0.0	0.0
	Trails	5.0	10.0	50.0
Hydrology/	Culverts	7.5	30.0	20.0
Water Quality	Dikes/dams/levees/roadbed	2.5	0.0	20.0
	Ditches/drains/channelization	5.0	0.0	70.0
	Impervious surface input	0.0	0.0	10.0
	Obvious spills/unusual water color/foam	2.5	0.0	0.0
Residential	Lawn/Park	2.5	0.0	20.0
	Parking lot/ pavement	0.0	0.0	20.0
	Road - 1 or 2 lane paved	7.5	10.0	30.0

Table 2 (continued). Percentage of sites with stressors observed in the 100-m buffer surrounding the AA for RAM (n=40), sentinel (n=10) and Great Meadow restoration project (n=10) sites.

Stressor Type	Stressor	% RAM	% Sentinel	% Great Meadow
Residential (continued)	Road - gravel	17.5	50.0	10.0
	Suburban residential land use	2.5	0.0	0.0
Overall	# of Plots with ≥ 1 buffer stressor	40.0	60.0	100.0
	# of Plots with ≥ 3 buffer stressors	7.5	20.0	60.0

Table 3. Percentage of sites with stressors observed in the 40 m radius AA for RAM (n=40), sentinel (n=10) and Great Meadow (n=10) sites.

Stressor Type	Stressor	% RAM	% Sentinel	% Great Meadow
Habitat/ Vegetation	Cover of non-native or invasive species	30.0	0.0	70.0
	Dumping of garbage or other debris	0.0	0.0	10.0
	Excessive insect herbivory	2.5	0.0	0.0
	Forest - selective cut	2.5	10.0	0.0
	Deer browse or trampling	40.0	0.0	20.0
	Substrate disturbance	2.5	0.0	0.0
	Trails	2.5	0.0	10.0
Hydrology/ Water Quality	Culverts	2.5	0.0	0.0
	Dikes/dams/levees/ roadbed	2.5	0.0	20.0
	Ditches/drains/channelization	2.5	0.0	50.0
Overall	# of Plots with ≥ 1 AA stressor	67.5	10.0	100.0
	# of Plots with ≥ 3 AA stressors	10.0	0.0	30.0

Great Meadow sites also had considerably more stressors affecting hydrology within the AA, such as ditches and channelization, than the RAM and sentinel sites (refer to Appendix D for a complete list of stressors that each site was evaluated for). Stressors within the AA are likely to have a strong effect on wetland condition. The low level of stressors in the AA of the majority of ACAD wetlands is a good sign. However, stressors within the AA were recorded in Great Meadow and Marshall Brook and mitigating for or removing these stressors is a high priority for restoration. Stressors in the buffer (100 m) surrounding wetlands, such as roads, culverts, and invasive species were common across the park, and can also impact wetland condition (Houlahan et al. 2006, Wardrop et al. 2007). Ensuring wetland buffers are intact and reducing stressors, such as replacing undersized culverts that affect wetland hydrology, or abating sources of sediment deposition in wetlands, can help maintain and improve wetland condition (Wilcox and Whillans 1999).

Vegetation

The majority of RAM sites were rated Good for the Vegetation MMI due to low or absent invasive species cover, high bryophyte cover (e.g. Sphagnum moss) and being composed primarily of plant species that occur in intact habitats (i.e. $C > 4$; Table 4). In addition, the median Vegetation MMI in the RAM sites was nearly equal to the median of the EPA NWCA reference sites (i.e., minimally disturbed condition) (Figure 3). The mean Vegetation MMI in RAM sites was also considerably higher than the mean score for the EPA NWCA probability sites, which are a representative sample of wetlands in the region (Figure 3). Based on the analyses in Miller et al. (2016), Vegetation MMI was a strong predictor of soil and water condition. Therefore, our sampling results suggest that wetlands in ACAD are in overall good condition, and excluding a few impacted wetlands in the park, ACAD wetlands are disproportionately in better condition than others in the region.

The distribution of Vegetation MMI scores for sentinel sites was also largely in the Good category, which helps validate their selection as sentinel sites. The sentinel site in Gilmore Meadow (NWCA-R304) was the only sentinel site that rated Fair instead of Good. Gilmore Meadow is a strongly beaver-influenced wetland. Similar to Gilmore Meadow, RAM sites in ACAD that scored in the Fair category were most often in wetlands that were influenced by beaver, which alter wetland hydrology by damming flowing water, and are an important driver of wetland natural disturbance regimes in the northeastern US (Cunningham et al. 2006). Beaver activity in wetlands typically leads to increased surface water and ponding, which reduces cover of bryophytes and woody species and increases the abundance of more disturbance-tolerant species (Little 2005). This in turn will lower the Vegetation MMI compared with wetlands without beaver activity.

Table 4. Mean Vegetation MMI (VMMI) score and individual metrics, along with number of sites in each rating category. Mean C is the mean coefficient of conservatism. % Inv. Cover is the percent cover of invasive species. % Dist. Tolerant is the percent cover of native disturbance tolerant species.

Site Type	Mean VMMI	Individual Metrics				Ratings (no. sites)		
		Mean C	% Inv. Cover	% Bryophyte	% Dist. Tolerant	Good	Fair	Poor
NWCA PROB	46.1	4.4	9.2	22.4	72.6	19	18	75
NWCA REF	70.3	5.6	<0.1	43.7	27.8	26	13	5
NETN RAM	64.1	4.3	<0.1	67.4	59.6	24	5	11
NETN Sentinel	78.4	5.0	0	80.7	17.9	9	1	0
Great Meadow	32.5	3.6	8.3	11.7	100.8	0	0	6

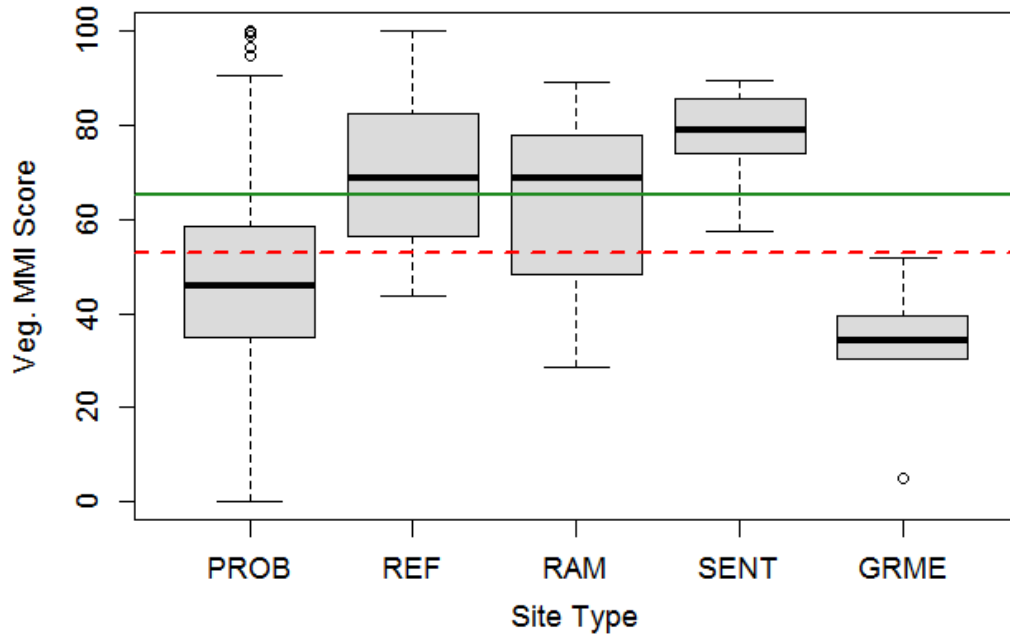


Figure 3. Distribution of Vegetation MMI scores for EPA NWCA probability sites (PROB), EPA NWCA reference sites (REF), and NETN RAM, NETN Sentinel sites (SENT), and Great Meadow restoration project sites (GRME) located in ACAD. The black line in each box plot represents the median of the data. The box around the median represents upper and lower 25% quartiles. Whiskers represent the minimum and maximum of the data excluding outliers, which are indicated by an open circle. The green line distinguishes between Good and Fair MMI ratings, and the red dashed line distinguishes between Fair and Poor ratings.

However, lower Vegetation MMIs in a beaver-impacted wetland is not a big concern in ACAD, as the vegetation typically begins to recover fairly rapidly after beaver abandon a site (Little 2005, and Miller pers. obs.). In addition, the hydrological disturbances caused by beaver contribute to increased wetland heterogeneity across the landscape (Cunningham et al. 2006). We are more concerned about cases where the Vegetation MMI does not improve after beaver abandonment, or where vegetation condition is poor due to impacts from anthropogenic stressors on vegetation. For example, three of 11 RAM sites rated Poor for the Vegetation MMI are located in Great Meadow, which is also a strongly beaver-influenced wetland.

The RAM sites in Great Meadow are rated Poor due to moderate cover of invasive species, low bryophyte cover, and dominance by disturbance-tolerant native species. These sites also have multiple stressors recorded in the buffer and AA that likely impact the vegetation. In addition, all six intensive sites that were sampled for the Great Meadow restoration project rated in the Poor category, with one site (ACAD_GRME-06) scoring as low as 4.93 out of 100 due to prevalence of glossy buckthorn (*Rhamnus frangula*) and dominance of disturbance tolerant native species. Marshall Brook and the Kent Field wetland complex also had more than one site rated Poor for vegetation. Both Marshall Brook and Kent Field are beaver-influenced wetlands, but they are also impacted by anthropogenic stressors, as indicated by multiple stressors, such as roads, culverts, and residential areas, observed in the buffers of the poor-rated sites (Figure 4).

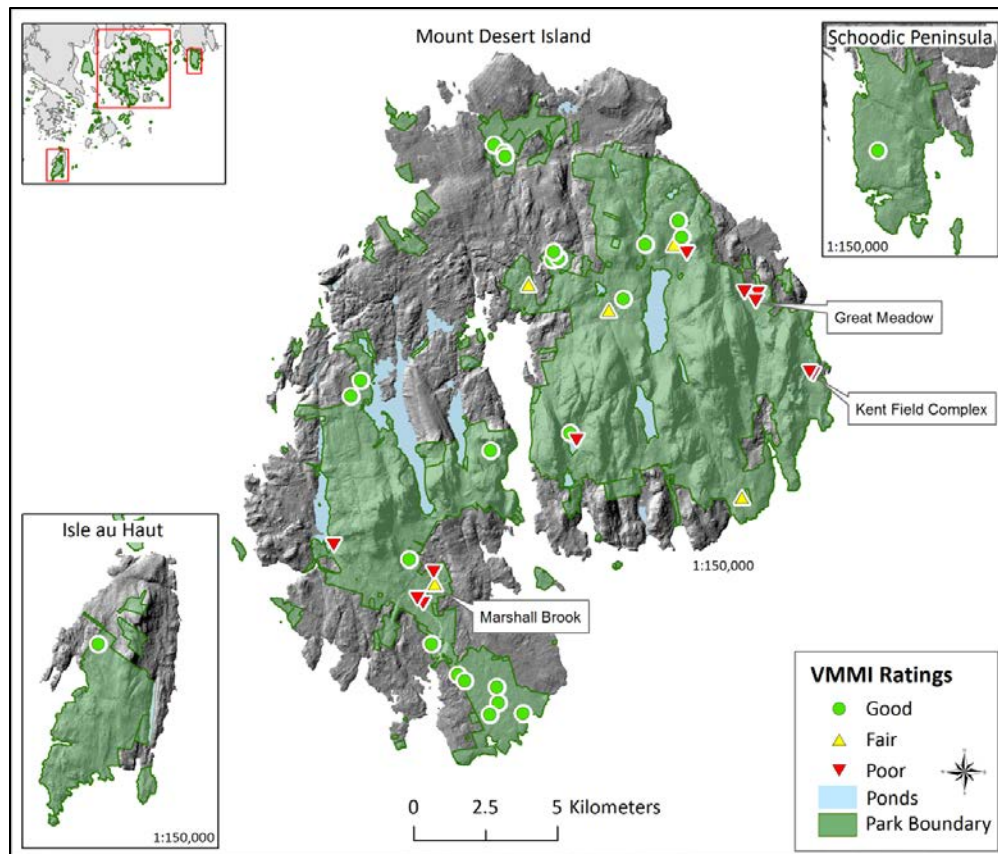


Figure 4. Vegetation MMI rating for the 40 RAM sites in ACAD.

The consistently poor condition of vegetation in sites located in Great Meadow, Marshall Brook, and the Kent Field complex is therefore of higher concern than the beaver-influenced sites that rated Fair and had few anthropogenic stressors (e.g., Gilmore Meadow). Knowing that the three most impacted wetlands in ACAD are beaver-influenced, a Fair rating rather than a Good rating for the Vegetation MMI may be the most appropriate goal for restoration in these sites, as long as they continue to be beaver influenced.

Soils

Similar to vegetation, the Soil MMIs for all but the sentinel site in Gilmore Meadow were rated Good (Table 5). The sentinel site in Gilmore Meadow was rated Poor due to a combination of low Carbon content in the soil, and elevated levels of Phosphorous (P), both of which were likely influenced by beaver activity. The Soil MMI scores for all sentinel sites but Gilmore Meadow were well above the median for EPA NWCA reference sites, indicating that soils in most of the sentinel sites are in good condition (Figure 5). While soil data were not collected in RAM sites, based on the results from Miller et al. (2016), Vegetation MMI is a strong predictor of soil condition in wetlands. Given that most of the RAM sites were rated Good for the Vegetation MMI, we therefore expect soils for most RAM sites to also be in good condition.

Table 5. Mean Soil MMI (SMMI) score and individual metrics, along with number of sites in each rating category.

Site Type	Mean SMMI	Individual Metrics				Ratings (no. sites)		
		% Total Carbon	pH in CaCl ₂	P (mg/kg)	Co (mg/kg)	Good	Fair	Poor
NWCA PROB	50.3	26.1	4.8	367.9	4.8	26	30	55
NWCA REF	73.6	40.9	4.1	183.1	2.3	24	12	5
NETN Sentinel	82.1	47.7	3.8	66.1	2.7	9	0	1

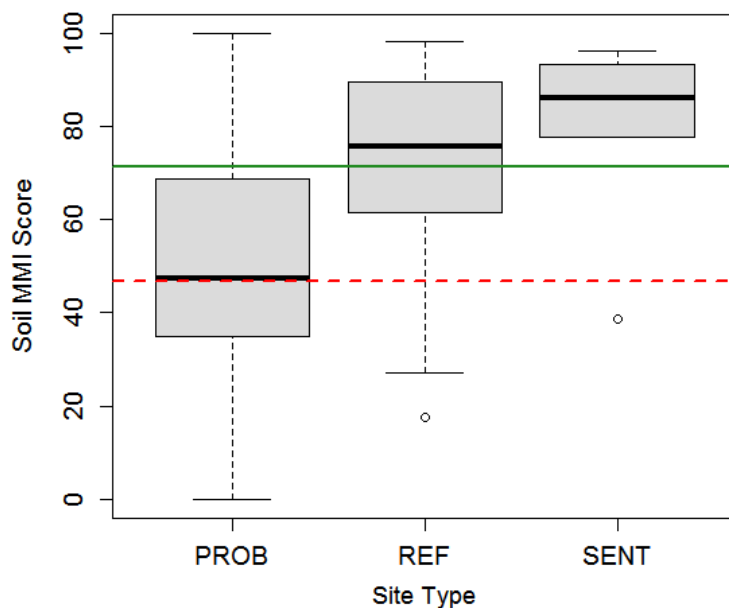


Figure 5. Distribution of Soil MMI scores for EPA NWCA probability sites (PROB), EPA NWCA reference sites (REF), and NETN Sentinel sites (SENT). The green line distinguishes between Good and Fair MMI ratings, and the red dashed line distinguishes between Fair and Poor ratings. See caption of Figure 3 for additional details.

The metrics used to calculate the Soil MMI score for each site reflect a combination of wetland soil processes and indicators of stress. For example, carbon storage is an important wetland function that is often compromised in wetlands that are degraded and is also extremely slow to develop in constructed wetlands (Liao et al. 2007, Moreno-Mateos et al. 2012). Therefore, high %Total Carbon indicates an intact wetland function. Concentration of trace metals, such as Cobalt (Co), can indicate sources of sedimentation and runoff from developed landscapes (Faulkner 2004). High concentration of Phosphorous, which is typically a limiting nutrient in wetlands, can lead to eutrophication in wetlands and resulting loss in species diversity and increased vulnerability to invasive species (Brinson and Malvarez 2002). Finally, high soil pH (measured in CaCl₂ for the Soil MMI) can indicate influence of water from anthropogenic sources and a lack of Sphagnum peat development due to beaver activity or human impacts (Little et al. 2010). Good Soil MMI ratings therefore

indicate that wetland soil processes are intact, and that stressors that often impact soil function or wetland composition are minimal. As the soil chemistry data become available for the intensive sites in Great Meadow, we will examine how the Soil MMIs from impacted sites compare with the sentinel sites.

Water Chemistry

The metrics in the Water Chemistry MMI, which are pH, conductivity and Total P, measure aspects of water quality that are important to wetland condition and function (Brinson and Malvarez 2002, Little et al. 2010). While the mean Water Chemistry MMI score for sentinel sites was higher than the mean score for EPA NWCA reference sites, the range of Water Chemistry MMI scores in sentinel sites was comparatively greater than the range of MMIs based on soil and vegetation. The sentinel site in Gilmore Meadow rated Poor and the sentinel site in Little Hunter Brook (NWCA-R305) rated Fair (Table 6, Figure 6). Both sites had relatively high pH (>6.5) and higher total Phosphorus (Total P) concentrations compared with the other sentinel sites. The remaining four sentinel sites with surface water were rated Good for Water Chemistry MMI. Interestingly, sites in the Great Meadow restoration project had a higher mean Water Chemistry MMI score than the sentinel sites, with three sites in Great Meadow rated Good and two sites rated Fair. These results suggest that water quality is on average in better condition than vegetation in Great Meadow. Restoration efforts such as invasive plant management need to ensure that these activities do not impact water quality.

The Water Chemistry MMI is based on surface water samples of water chemistry. Because surface water was not present at all sites, water chemistry data were only available for about 50% of the sites that were sampled during the 2011 EPA NWCA, in only six of the sentinel sites in ACAD and five out of six intensive sites in Great Meadow. Fortunately, the surface water depth requirements were relaxed for the EPA NWCA in 2016, and we were able to collect samples from all but two of the sentinel sites. When the 2016 data become available, we will have a better understanding of how the Water Chemistry MMI varies across the sentinel wetlands and how it varies over time.

Table 6. Mean Water Chemistry MMI (WMMI) score and individual metrics, along with number of sites in each rating category.

Site Type	Mean WMMI	Individual Metrics			Ratings (no. sites)		
		pH	Conductivity (µS/cm)	Total P (µg/L)	Good	Fair	Poor
NWCA PROB	43.7	6.8	197.4	241.0	7	11	38
NWCA REF	69.6	6.0	58.4	49.7	12	4	5
NETN Sentinel	77.0	5.4	60.7	23.0	4	1	1
Great Meadow	81.6	5.2	55.5	18.8	3	2	0

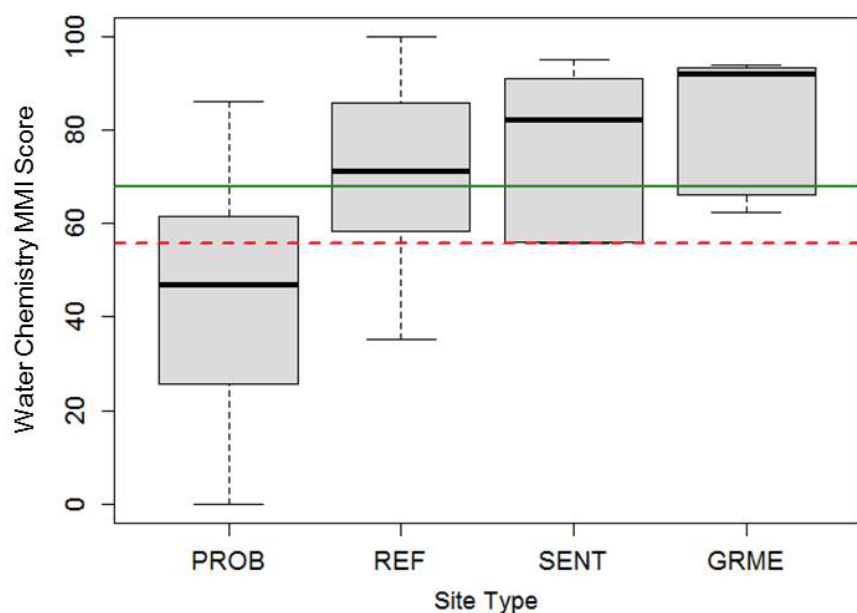


Figure 6. Distribution of Water Chemistry MMI scores for EPA NWCA probability sites (PROB), EPA NWCA reference sites (REF), and NETN Sentinel sites (SENT). The green line distinguishes between Good and Fair MMI ratings, and the red dashed line distinguishes between Fair and Poor ratings. See Figure 3 caption for additional details.

Hydrology

Wetland hydrology varied considerably across sentinel sites and years, and mostly followed expected patterns based on wetland hydrogeomorphic class (HGM) and vegetation type (Table 7). The sentinel sites in Gilmore Meadow, Little Hunter Brook, and Heath Brook, which are riverine upper perennial sites, had a greater range in water level and longer periods of prolonged surface water than Duck Pond and New Mills Meadow- NW, which are depression wetlands. Prolonged surface water selects for herbaceous wetland species (e.g., tussock sedge [*Carex stricta*]) over woody species. Not surprisingly, the riverine upper perennial sites were dominated by graminoids (sedges, grasses and rushes), and the depression sites had a mix of woody and herbaceous species. The topographic slope wetlands, including Western Mountain Swamp and Hodgdon Swamp, tended to have deeper water levels and are white cedar (*Thuja occidentalis*) swamps (Table 8). Similar patterns in water level and vegetation were observed across the intensive sites for the Great Meadow restoration project (Table 9).

Table 7. Summary statistics for growing season water levels (cm) by year and sentinel site. Values are expressed relative to the soil surface. Std.Dev. is the standard deviation. Min. is the minimum growing season water level. Max. is the maximum growing season water level. Max. Inc. is the maximum hourly increase in water level. WL Change is the change in mean water level from June to September of the same calendar year.

Site	Year	Mean	Std.Dev.	Min.	Max.	Max. Inc.	WL Change
Duck Pond	2013	-5.6	1.9	-8.1	-0.5	1.3	-3.2
NWCA-R301	2014	-5.9	1.3	-7.8	-1.7	4.6	-3.2
	2015	-3.0	3.2	-9.6	3.5	9.7	-7.4
	2016	-8.4	7.8	-24.2	3.5	8.1	-18.8
Western Mtn. Swamp	2013	-9.9	4.6	-16.0	7.3	5.5	1.4
	2014	-17.4	4.8	-25.0	3.1	6.7	-7.4
NWCA-R302	2015	-21.4	5.8	-36.1	6.4	5.6	-11.1
	2016	-23.6	4.2	-33.3	-15.3	8.4	-9.5
Big Heath	2013	-1.2	2.8	-7.9	7.5	4.4	-2.4
NWCA-R303	2014	-8.2	4.3	-15.8	4.3	3.6	-8.5
	2015	-14.7	4.9	-24.1	-0.3	6.7	-9.7
	2016	-16.2	3.9	-23.4	-4.7	10.6	-7.0
Gilmore Meadow	2013	29.0	4.7	21.3	56.8	5.3	-1.5
	2014	26.6	7.3	13.5	61.7	14.0	-17.8
NWCA-R304	2015	21.0	9.6	3.1	55.8	18.3	-22.7
	2016	21.7	11.1	1.6	40.0	4.7	-28.7
Little Hunter Brook	2013	-2.7	3.3	-10.1	17.4	5.5	-2.6
	2014	-4.6	4.7	-17.1	17.8	8.8	-1.8
NWCA-R305	2015	14.3	13.1	-15.7	32.2	4.7	19.6
	2016	2.8	13.5	-16.3	26.9	9.9	-31.5
New Mills Meadow-NW	2013	6.6	3.1	-0.3	17.0	2.9	-1.2
	2014	0.8	4.6	-9.9	16.1	4.0	-9.1
NWCA-R306	2015	-0.5	5.2	-15.3	15.6	9.0	-10.7
	2016	-5.6	7.5	-20.6	6.5	7.7	-16.9
Heath Brook	2013	-17.1	4.8	-27.4	4.7	4.3	-0.7
NWCA-R308	2014	-27.4	8.6	-44.6	8.0	7.3	-17.1
	2015	-34.8	8.9	-54.6	9.1	14.5	-18.5
	2016	-41.0	7.9	-55.8	-22.5	11.2	-14.7

Table 7 (continued). Summary statistics for growing season water levels (cm) by year and sentinel site. Values are expressed relative to the soil surface. Std.Dev. is the standard deviation. Min. is the minimum growing season water level. Max. is the maximum growing season water level. Max. Inc. is the maximum hourly increase in water level. WL Change is the change in mean water level from June to September of the same calendar year.

Site	Year	Mean	Std.Dev.	Min.	Max.	Max. Inc.	WL Change
Hodgdon Swamp	2013	-16.2	5.9	-24.8	-1.8	1.4	2.7
	2014	-25.8	5.2	-32.0	-9.1	1.9	-6.5
NWCA-R309	2015	-28.7	6.4	-37.9	0.5	6.4	-11.1
	2016	-32.1	3.1	-39.3	-23.4	1.5	-5.9

Table 8. Proportion of water level observations recorded within each depth class during the growing season in sentinel sites.

Site	Year	Proportion of Water Level		
		> 0cm	-30 to 0cm	>30cm deep
Duck Pond	2013	0.0	100.0	0.0
NWCA-R301	2014	0.0	100.0	0.0
	2015	20.9	79.1	0.0
	2016	18.4	81.6	0.0
Western Mtn. Swamp	2013	5.5	94.5	0.0
	2014	0.5	99.5	0.0
	2015	0.4	93.5	6.1
	2016	0.0	88.8	11.2
Big Heath	2013	30.4	69.6	0.0
	2014	2.4	97.6	0.0
	2015	0.0	100.0	0.0
	2016	0.0	100.0	0.0
Gilmore Meadow	2013	100.0	0.0	0.0
	2014	100.0	0.0	0.0
	2015	100.0	0.0	0.0
	2016	100.0	0.0	0.0
Little Hunter Brook	2013	14.6	85.4	0.0
	2014	12.9	87.1	0.0
	2015	82.4	17.6	0.0
	2016	54.6	45.5	0.0

Table 8 (continued). Proportion of water level observations recorded within each depth class during the growing season in sentinel sites.

Site	Year	Proportion of Water Level		
		> 0cm	-30 to 0cm	>30cm deep
New Mills Meadow-NW	2013	99.5	0.5	0.0
NWCA-R306	2014	64.7	35.3	0.0
	2015	53.4	46.6	0.0
	2016	29.4	70.6	0.0
Heath Brook	2013	1.0	99.0	0.0
NWCA-R308	2014	0.6	66.4	33.0
	2015	0.3	29.8	69.9
	2016	0.0	9.3	90.7
Hodgdon Swamp	2013	0.0	100.0	0.0
NWCA-R309	2014	0.0	85.5	14.5
	2015	0.2	43.5	56.3
	2016	0.0	21.6	78.4

Table 9. Summary statistics for growing season water levels (cm) by year and intensive site in Great Meadow. See caption of Table 7 for additional details.

Site	Year	Mean	Std.Dev.	Min.	Max.	Max. Inc.	WL Change
Great Meadow	2015	-18.0	3.4	-24.4	-7.34	1.2	–
Plot 01	2016	-19.9	4.2	-26.5	-10.6	1.1	-10.3
Great Meadow	2015	-1.0	3.3	-9.2	10.9	2.6	–
Plot 02	2016	-9.7	4.0	-17.6	1.3	2.6	-6.5
Great Meadow	2015	-38.5	10.9	-57.8	0.2	5.5	–
Plot 03	2016	-53.2	15.3	-81.8	-18.4	8.2	-36.3
Great Meadow	2015	-18.9	6.4	-38.7	-4.0	1.2	–
Plot 04	2016	-14.1	7.1	-28.2	1.3	1.4	-17.1
Great Meadow	2015	10.5	4.4	2.5	26.9	1.4	–
Plot 05	2016	8.9	4.0	0.8	17.5	2.7	-2.1
Great Meadow	2015	-43.6	3.7	-50.1	-29.4	1.4	–
Plot 06	2016	-40.7	3.4	-46.6	-32.8	1.1	-7.1

For example, plot 05, which is located in the riverine upper perennial portion of Great Meadow and dominated by graminoids (Mittlehauser 2016), had the highest average water level of the six sites, and had prolonged surface water during most of the 2015 and 2016 growing seasons (Table 10). In contrast, average water levels in Great Meadow plot 03 and plot 06 were greater than 30 cm over the growing season for both 2015 and 2016 -- both sites are hardwood swamps (Table 10).

Table 10. Proportion of water level observations recorded within each depth class during the growing season in Great Meadow.

Site	Year	Proportion of Water Level		
		> 0cm	-30 to 0cm	>30cm deep
Great Meadow	2015	0.0	100.0	0.0
Plot 01	2016	0.0	100.0	0.0
Great Meadow	2015	33.8	66.2	0.0
Plot 02	2016	0.7	99.3	0.0
Great Meadow	2015	0.1	18.3	81.6
Plot 03	2016	0.0	5.6	94.4
Great Meadow	2015	0.0	92.2	7.8
Plot 04	2016	3.6	96.4	0.0
Great Meadow	2015	100.0	0.0	0.0
Plot 05	2016	100.0	0.0	0.0
Great Meadow	2015	0.0	0.3	99.7
Plot 06	2016	0.0	0.0	100.0

Due largely to the steep, narrow watersheds in ACAD, wetland hydrology was strongly and rapidly influenced by precipitation. For example, water levels in all sentinel sites peaked within 1-2 hours following a precipitation event, and then slowly declined over a period of 24-48 hours after rainfall ended (Appendix E). Sentinel sites in riverine upper perennial wetlands were the flashiest after rainfall events, showing maximum hourly increases in water level as high as 18.3 cm in Gilmore Meadow, and 14.5 cm in Heath Brook. Depression and topographic slope wetlands had maximum hourly increases below 10 cm. Water levels in Great Meadow were slower to respond to rainfall events compared to the sentinel sites (Appendix F), with the maximum observed hourly water level increase only 8.2 cm in plot 03, which was at the base of Door Mountain (Table 9). The slower water level response in Great Meadow may be due to a combination of catchment size and watershed position (i.e. Great Meadow has a larger catchment and is lower in the watershed than sentinel wetlands) and likely because of hydrological alterations. For example, the ditching and channelization of the stream in Great Meadow likely drains the wetland faster and reduces the water holding capacity of the wetland while the trails that cross-cut the wetland impede the flow.

Across the 4 years of monitoring, water levels tended to be highest in 2013, which experienced above average precipitation amounts for each month during the growing season (Figure 7). In contrast, 2015 and 2016 received below average precipitation during the growing season, and all but the sentinel site in Little Hunter Brook in 2015 lost considerable water level over both growing seasons (Appendix E: Figure 5). The water level increase in the Little Hunter Brook sentinel site during the study period was due to recolonization of an abandoned beaver dam starting in 2015.

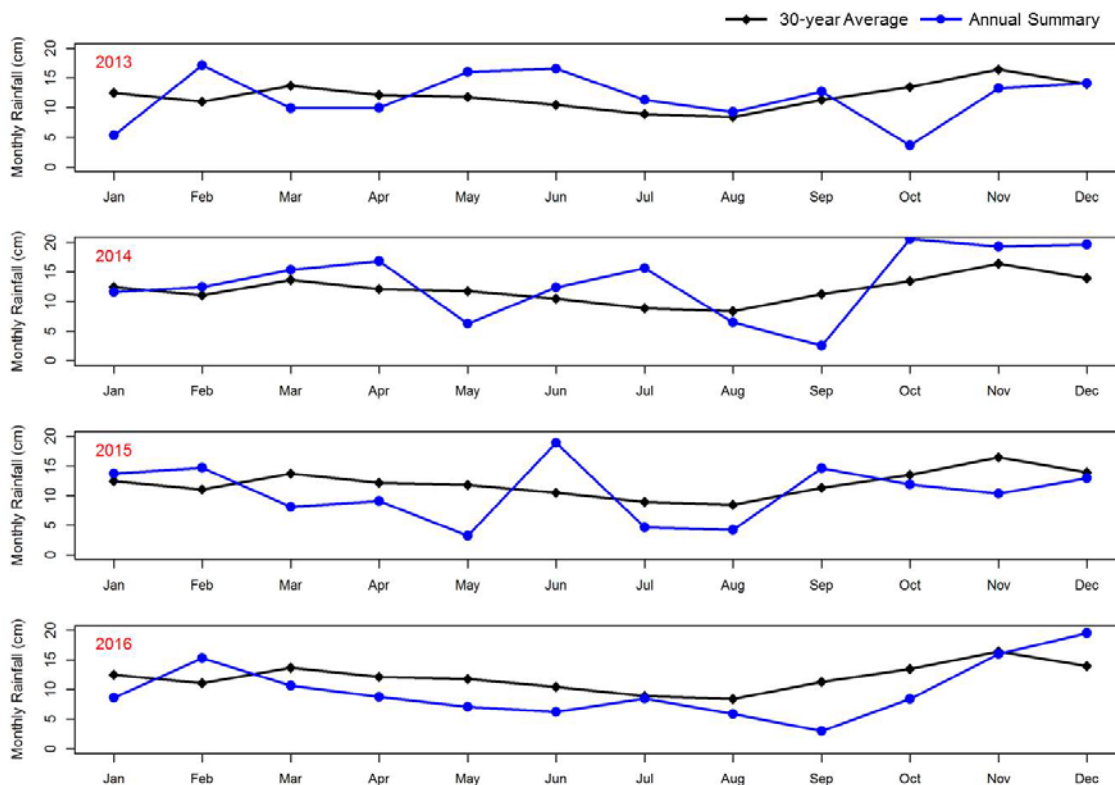


Figure 7. Average monthly precipitation (cm) recorded at the weather station (ME98) in ACAD. Precipitation as snow was converted to the water equivalent and combined with rainfall. 30-year denotes the 30-year average monthly precipitation for 1981-2010.

The beaver dam downstream of the Little Hunter Brook sentinel site not only increased water level over the 2015 growing season, but also appeared to dampen the response in water level typically observed following a precipitation event. During the 2016 survey in the Little Hunter Brook sentinel site, we observed widespread dieback of white cedar and eastern white pine (*Pinus strobus*) seedlings, and this was likely the result of the increased water levels in 2015. While the water level in 2016 started out high, it was comparable to 2013 and 2014 levels by the end of the growing season due to lack of rainfall.

The results of the last 4 years of monitoring offer hints as to how water level may vary under different climate scenarios (e.g. drier vs. wetter growing season). For example, during years with above average precipitation (e.g., 2013), all eight sentinel wetlands maintained water levels within 30 cm of the surface over the entire the growing season (Table 8). The depth of 30 cm is significant as it

represents the lower limit of the rooting zone of wetland plants, and prolonged inundation of this zone will select for wetland-adapted species. In contrast, water levels during years with lower than average rainfall dropped considerably, with several wetlands having prolonged levels more than 30 cm below the surface. Lack of inundation in the vegetation rooting zone may lead to increases in less wetland-adapted species in these sites, such as upland trees and shrubs. Sites that tended to have water levels near or below the 30 cm depth below the surface, including Great Meadow plots 03 and 06, Hodgdon Swamp and Heath Brook, may be most vulnerable if future climate becomes drier, and could lead to loss in wetland area. Over time, it will be important to track how variability in water level due to climate and beaver activity affects long-term wetland condition and vegetation.

Conclusions

With the exception of a few impacted wetlands, including Great Meadow, Marshall Brook, and the Kent Field wetland complex, overall results from the first monitoring cycle indicate that wetlands in ACAD are in good condition. Outside of the three impacted complexes, wetlands are largely composed of native vegetation, including species that are mostly found in intact habitats, and where present, invasive species are generally very low in abundance. Sites rated Fair for the Vegetation MMI are frequently beaver-influenced wetlands, and the Fair rating in these sites is more an indication of the recent natural disturbance caused by beaver, rather than unhealthy ecosystem condition. In general, wetlands are more diverse within complexes and across the landscape because of beaver activity. Many of the sites rated Poor for the vegetation MMI are also influenced by beaver, but they also have a history of hydrological disturbance and/or are affected by multiple stressors in both the 40-m radius AA and in the surrounding 100-m buffer.

Wetland hydrology was strongly influenced by rainfall events and overall rainfall amounts, and followed expected patterns by hydrogeomorphic classes and vegetation type. Water levels were faster to respond to rainfall events in the sentinel sites than in Great Meadow, which may be the result of both landscape position and hydrologic alteration. These data serve as an important baseline to assess how wetland hydrology influences wetland condition, and also to examine how wetland hydrology, composition and function responds to climatic change over time.

Monitoring results indicate that water quality is less impacted in Great Meadow compared to hydrology and vegetation. These results suggest that hydrologic restoration and invasive species management should be prioritized targets for restoration in Great Meadow. Given the strong relationships between wetland hydrology and vegetation, restoring hydrology in Great Meadow will likely also lead to improvements in vegetation condition, such as increases in bryophytes and disturbance intolerant species. Reducing buffer stressors, such as undersized culverts or sediment input from roads, may also improve wetland condition of impacted sites and will help ensure that intact wetlands remain in good condition. Continued invasive species management is also essential to ensure that invasive species remain absent or at low levels in ACAD wetlands. As restoration efforts continue in Great Meadow and the Cromwell Brook Watershed, our monitoring data can help define desired condition and measure the effectiveness of restoration efforts.

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Appendix A. Wetland monitoring plot designs

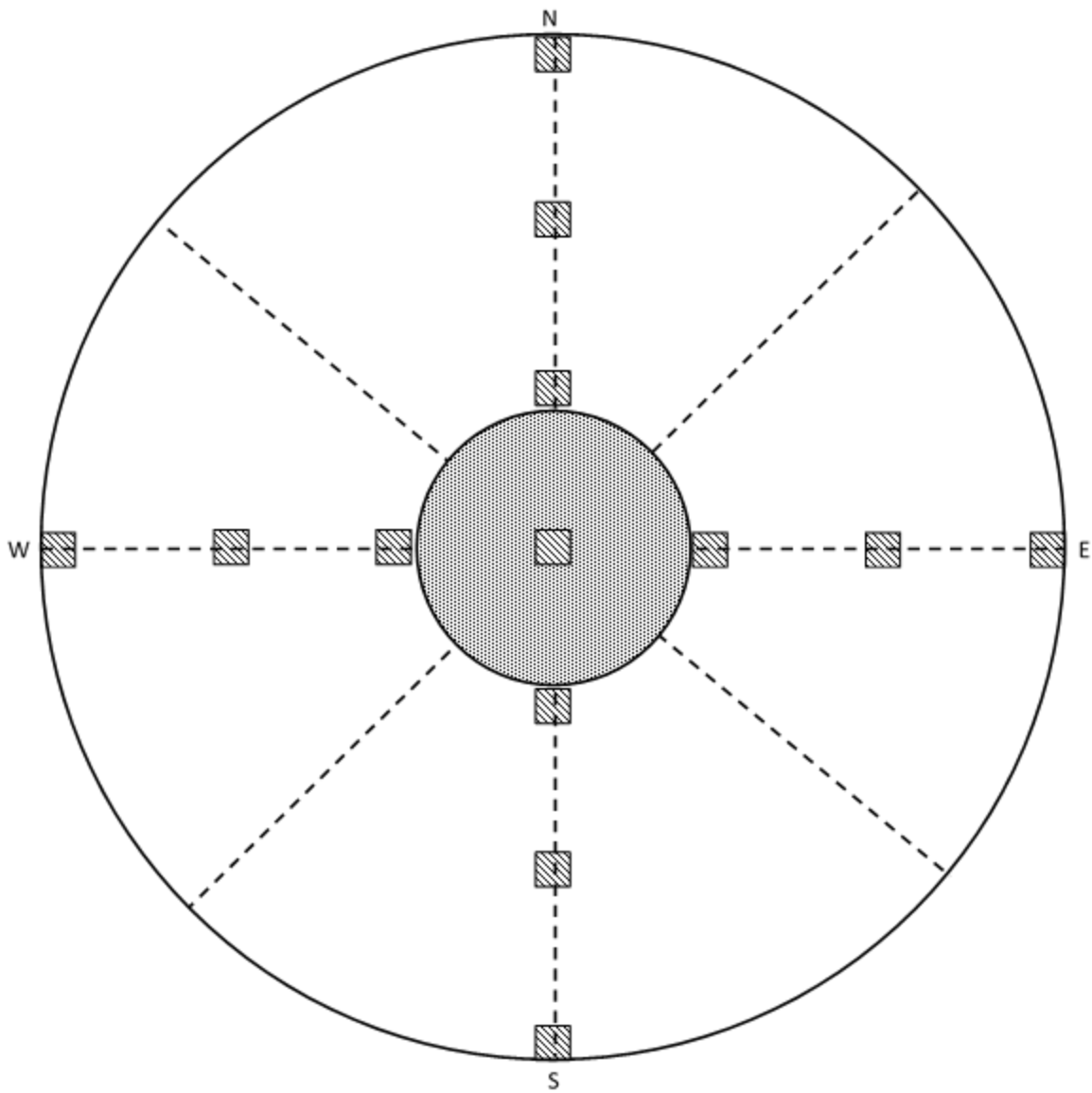


Figure A.1. Overall design of 2011 EPA NWCA site and NETN sentinel site, including a 40-m radius assessment area (●), 100-m buffer (white) around the assessment area, 13 buffer plots (■), and eight 100-m buffer transects (dashed lines). Buffer plots are 10 x 10 m and spaced 40 m apart on center

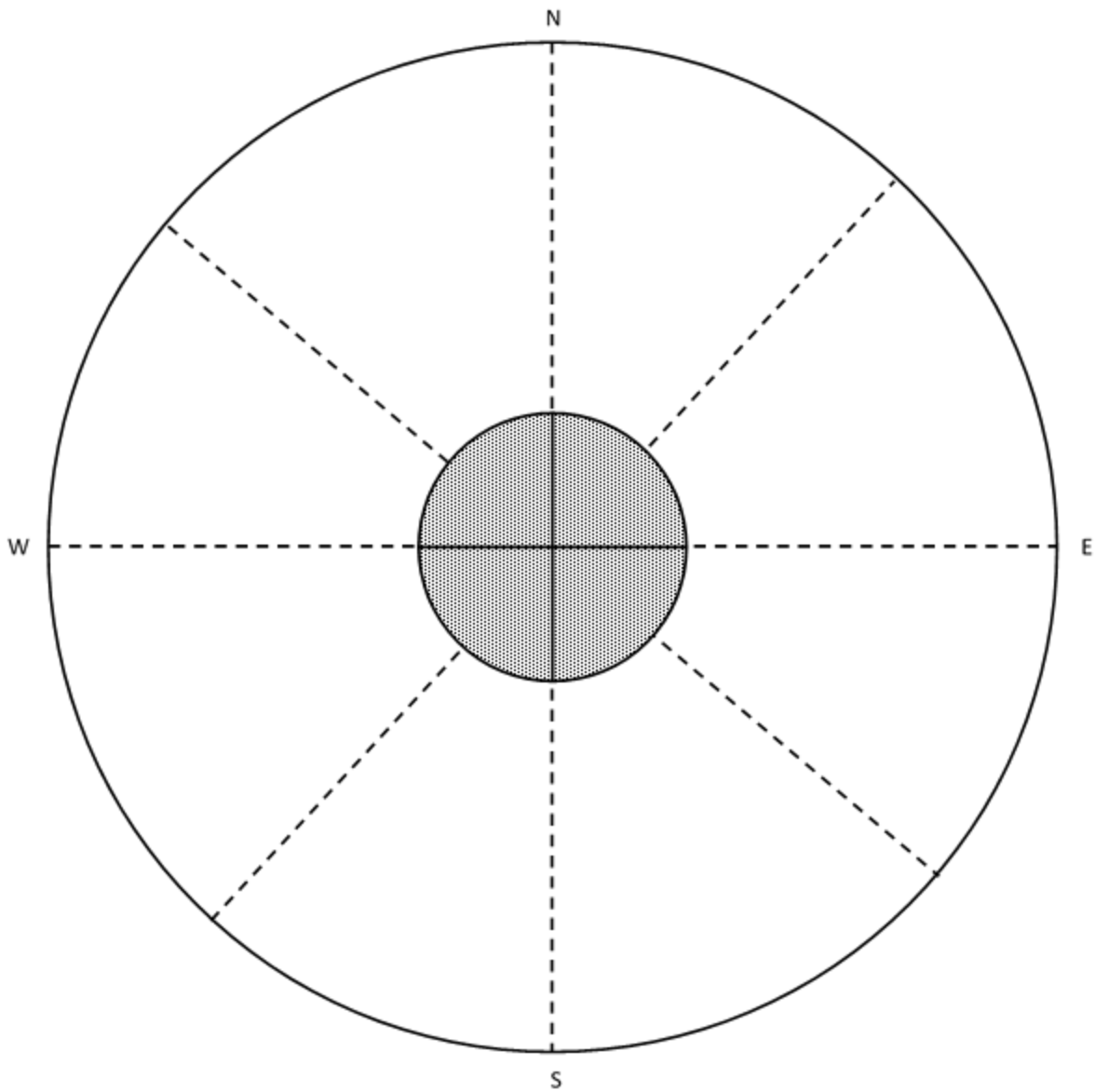


Figure A.2. Overall design of a rapid assessment monitoring (RAM) site, including a 40-m radius assessment area (●) broken into quarters, 100-m buffer (white) around the assessment area, and eight 100-m buffer transects (dashed lines).

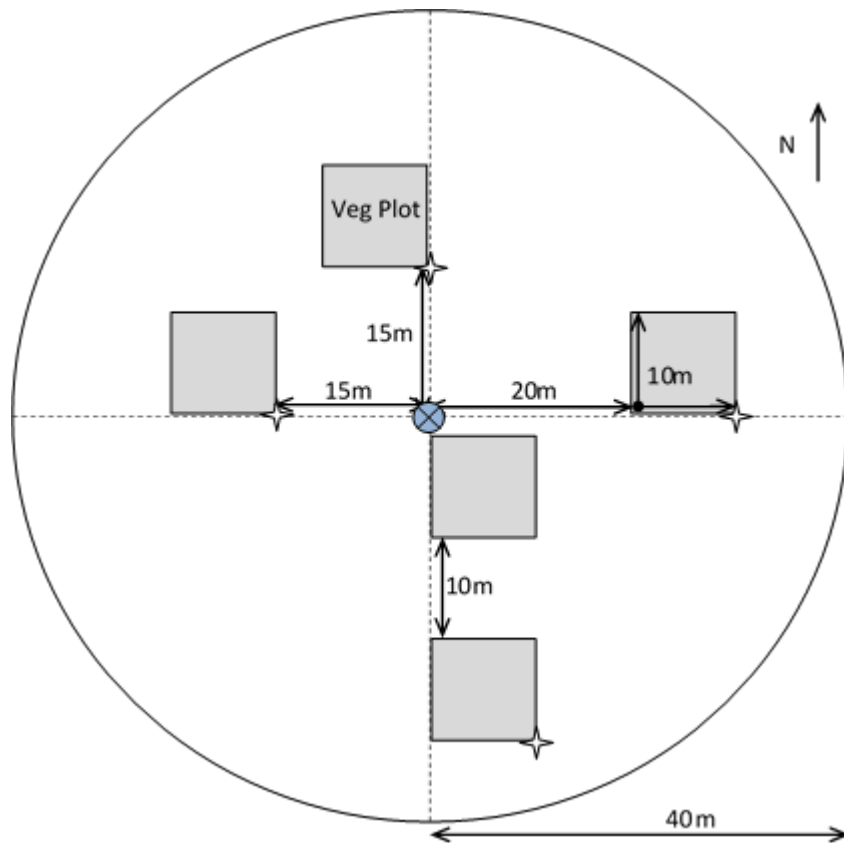


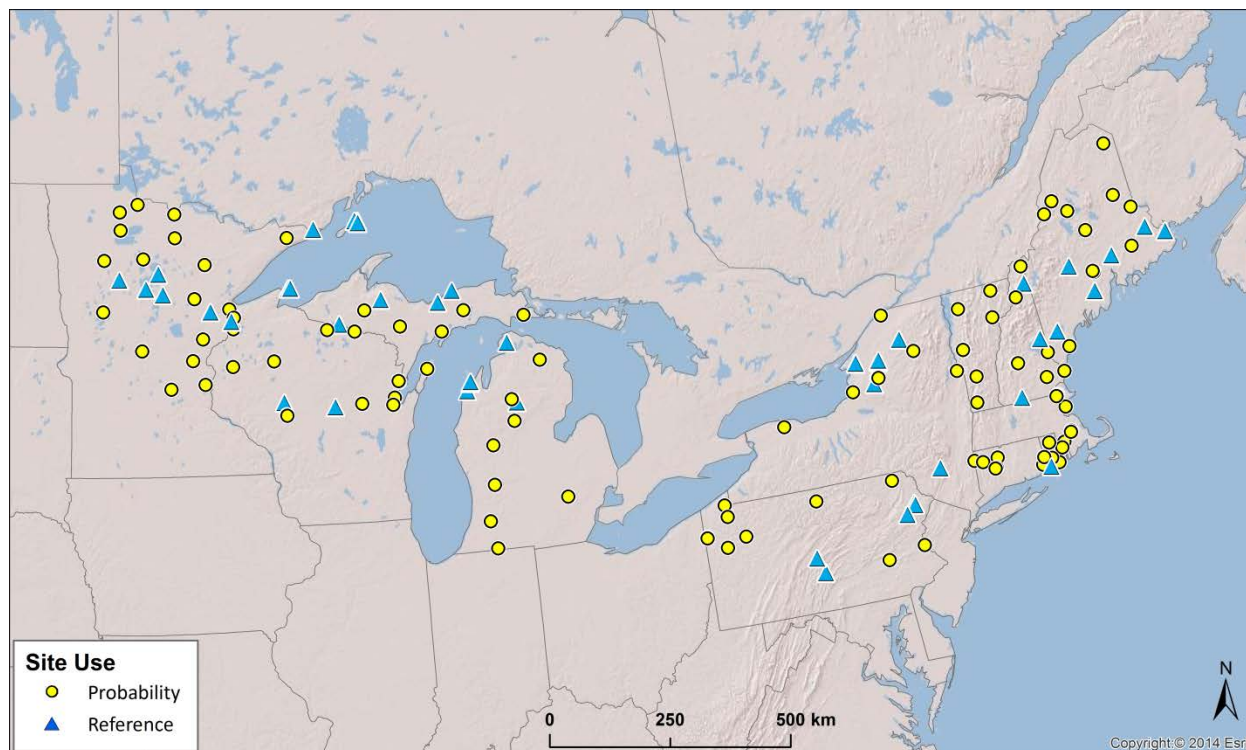
Figure A.3. Assessment area (40-m radius) portion of the design for 2011 EPA NWCA and NETN sentinel sites, including location of shallow well (⊗), vegetation plots (grey boxes), and soil samples (★).

Appendix B. Freshwater wetland monitoring locations in Acadia National Park

Site ID	X Coord	Y Coord	Site Type	Park Unit	Wetland Name
NWCA-R301	549459	4907555	Sentinel	MDI-West	Duck Pond
NWCA-R302	550434	4903783	Sentinel	MDI-West	Western Mtn. Swamp
NWCA-R303	554268	4898328	Sentinel	MDI-West	Big Heath
NWCA-R304	558040	4912422	Sentinel	MDI-East	Gilmore Meadow
NWCA-R305	562726	4905965	Sentinel	MDI-East	Little Hunter Brook
NWCA-R306	560569	4915581	Sentinel	MDI-East	New Mills Meadow- NW
NWCA-R307	530759	4877330	Sentinel	IAH	Great Meadow- IAH
NWCA-R308	550293	4902977	Sentinel	MDI-West	Heath Brook
NWCA-R309	548339	4908557	Sentinel	MDI-West	Hodgdon Swamp
NWCA-R310	574780	4912541	Sentinel	Schoodic	Frazer Fen
NETN_RAM-01	552812	4899853	RAM	MDI-West	Bass Harbor Marsh
NETN_RAM-02	560332	4914806	RAM	MDI-East	–
NETN_RAM-03	553061	4899646	RAM	MDI-West	Bass Harbor Marsh
NETN_RAM-04	563269	4913129	RAM	MDI-East	Great Meadow
NETN_RAM-05	554170	4899429	RAM	MDI-West	Big Heath
NETN_RAM-06	551129	4903869	RAM	MDI-West	–
NETN_RAM-07	554226	4898884	RAM	MDI-West	Big Heath
NETN_RAM-08	553930	4898479	RAM	MDI-West	Big Heath
NETN_RAM-09	554076	4918278	RAM	MDI-East	Northeast Creek
NETN_RAM-10	555277	4913418	RAM	MDI-East	–
NETN_RAM-11	574384	4912059	RAM	Schoodic	–
NETN_RAM-12	554430	4918013	RAM	MDI-East	Northeast Creek
NETN_RAM-13	562797	4913160	RAM	MDI-East	Great Meadow
NETN_RAM-14	554464	4917873	RAM	MDI-East	Northeast Creek
NETN_RAM-15	548496	4904367	RAM	MDI-West	–
NETN_RAM-16	552018	4903002	RAM	MDI-West	Marshall Brook
NETN_RAM-17	5593017	4914819	RAM	MDI-East	Breakneck Pond
NETN_RAM-18	556103	4914280	RAM	MDI-East	Sunken Heath
NETN_RAM-19	563193	4912852	RAM	MDI-East	Great Meadow

Site ID	X Coord	Y Coord	Site Type	Park Unit	Wetland Name
NETN_RAM-20	551903	4900927	RAM	MDI-West	Bass Harbor Marsh
NETN_RAM-21	551611	4902361	RAM	MDI-West	Lurvey Brook
NETN_RAM-22	549091	4909551	RAM	MDI-West	–
NETN_RAM-23	560497	4915640	RAM	MDI-East	New Mills Meadow- NW
NETN_RAM-24	555084	4898515	RAM	MDI-West	–
NETN_RAM-25	551971	4903428	RAM	MDI-West	Marshall Brook
NETN_RAM-26	556721	4908274	RAM	MDI-East	Upper Hadlock Pond
NETN_RAM-27	565180	4910307	RAM	MDI-East	South of Kent Field
NETN_RAM-28	556329	4914323	RAM	MDI-East	Sunken Heath
NETN_RAM-29	549431	4910093	RAM	MDI-West	–
NETN_RAM-30	560785	4914529	RAM	MDI-East	–
NETN_RAM-31	558067	4912529	RAM	MDI-East	Gilmore Meadow
NETN_RAM-32	529214	4878582	RAM	IAH	–
NETN_RAM-33	560609	4915070	RAM	MDI-East	New Mills Meadow
NETN_RAM-34	565063	4910390	RAM	MDI-East	South of Kent Field
NETN_RAM-35	556155	4914559	RAM	MDI-East	Sunken Heath
NETN_RAM-36	551406	4902513	RAM	MDI-West	Lurvey Brook
NETN_RAM-37	556955	4908008	RAM	MDI-East	Upper Hadlock Pond
NETN_RAM-38	553958	4907652	RAM	MDI-West	Man-of-War Brook
NETN_RAM-39	558574	4912925	RAM	MDI-East	–
NETN_RAM-40	562704	4906021	RAM	MDI-East	Little Hunter Brook
ACAD_GRME-01	563119	4912595	Intensive	MDI-East	Great Meadow
ACAD_GRME-02	563071	4913162	Intensive	MDI-East	Great Meadow
ACAD_GRME-03	562824	4912845	Intensive	MDI-East	Great Meadow
ACAD_GRME-04	562910	4912898	Intensive	MDI-East	Great Meadow
ACAD_GRME-05	563200	4912819	Intensive	MDI-East	Great Meadow
ACAD_GRME-06	563011	4912923	Intensive	MDI-East	Great Meadow
ACAD_GRME-07	563061	4912558	RAM	MDI-East	Great Meadow
ACAD_GRME-08	563371	4912986	RAM	MDI-East	Great Meadow
ACAD_GRME-09	562963	4912763	RAM	MDI-East	Great Meadow
ACAD_GRME-10	563256	4912949	RAM	MDI-East	Great Meadow

Appendix C. EPA NWCA sites for regional comparisons



Appendix D. USA-RAM Buffer and AA stressor checklists

FORM USA-RAM 2: STRESSORS IN BUFFER AREA (Front) Reviewed by (initial): _____																	
Site ID: _____			Date: ____/____/____														
METRIC 3: Stressors based on observations of the 100m area surrounding the AA. Data should be collected in all land uses whether or not they count as buffer in Metric 1. Fill in the bubble corresponding to the choice for each stressor indicator that is observed using the guidelines below. Then provide an overall rank for each Stressor Category. <table border="1" style="margin: 10px auto; border-collapse: collapse; text-align: center;"> <thead> <tr> <th style="padding: 5px;">Portion of 100m Buffer Zone surrounding AA Influenced by Stressor</th> <th style="padding: 5px;">Severity Code</th> </tr> </thead> <tbody> <tr> <td style="padding: 5px;">Less than one-third</td> <td style="padding: 5px;">1</td> </tr> <tr> <td style="padding: 5px;">Between one-third and two-thirds</td> <td style="padding: 5px;">2</td> </tr> <tr> <td style="padding: 5px;">At least two-thirds</td> <td style="padding: 5px;">3</td> </tr> </tbody> </table>										Portion of 100m Buffer Zone surrounding AA Influenced by Stressor	Severity Code	Less than one-third	1	Between one-third and two-thirds	2	At least two-thirds	3
Portion of 100m Buffer Zone surrounding AA Influenced by Stressor	Severity Code																
Less than one-third	1																
Between one-third and two-thirds	2																
At least two-thirds	3																
If stressor is present, mark its severity			Field Indicators by Stressor Category							OVERALL RANKING:							
1	2	3	Hydrological Stressors							○ 1	○ 2	○ 3					
☐	☐	☐	Ditches/drains/channelization														
☐	☐	☐	Dikes/dams/levees/railroad or roadbed														
☐	☐	☐	Culverts, pipes (point source discharge) in the buffer zone														
☐	☐	☐	Water level control structure														
☐	☐	☐	Obvious spills, discharges or odors; unusual water color or foam														
☐	☐	☐	Moderate to heavy formation of filamentous algae														
☐	☐	☐	Excavation, dredging														
☐	☐	☐	Fill/spoil banks														
☐	☐	☐	Wall/riprap														
☐	☐	☐	Inlets and Outlets														
☐	☐	☐	Impervious surface input														
1	2	3	Residential/Urban/Commercial Stressors							○ 1	○ 2	○ 3					
☐	☐	☐	Suburban residential land use														
☐	☐	☐	Urban multifamily														
☐	☐	☐	Urban/Commercial buildings														
☐	☐	☐	Road - gravel														
☐	☐	☐	Road - 1 or 2 lane paved														
☐	☐	☐	Road - 4 lane														
☐	☐	☐	Parking lot/pavement														
☐	☐	☐	Lawn/park														
☐	☐	☐	Golf course														
☐	☐	☐	Landfill														
☐	☐	☐	Gravel pit/mining														
☐	☐	☐	Surface mine														
☐	☐	☐	Military land														
☐	☐	☐	Trash/dumping														
USA-RAM 2 Stressors in Buffer Area 06/02/2011 0658179264																	

FORM USA-RAM 2: STRESSORS IN BUFFER AREA (Back) Reviewed by (initial):				
Site ID: Date: / / 				
OVERALL RANKING:				
1	2	3	Habitat/Vegetation Stressors	☐ 1 ☐ 2 ☐ 3
☐	☐	☐	Soil subsidence, scour or surface erosion (root exposure)	
☐	☐	☐	Substrate disturbance (off-road vehicles, mountain biking, logging roads)	
☐	☐	☐	Sediment input (construction, erosion, agricultural runoff)	
☐	☐	☐	Forest - selective cut	
☐	☐	☐	Forest - clear cut	
☐	☐	☐	Removal of large woody debris	
☐	☐	☐	Tree plantation present	
☐	☐	☐	Heavily grazed grasses, excessive grazing	
☐	☐	☐	Tree canopy herbivory	
☐	☐	☐	Shrub layer browsed	
☐	☐	☐	Fire lines (fire breaks)	
☐	☐	☐	Recently burned forest canopy	
☐	☐	☐	Recently burned grassland	
☐	☐	☐	Mowing/shrub cutting (brush hogging)	
☐	☐	☐	Other mechanical plant removal	
☐	☐	☐	Chemical vegetation control (herbicide application)	
☐	☐	☐	Cover of non-native or invasive species	
☐	☐	☐	Presence of power lines or utility corridors (continual maintenance)	
☐	☐	☐	Oil/gas wells	
☐	☐	☐	Offroad vehicle damage	
☐	☐	☐	Trails	
1	2	3	Agricultural Stressors	☐ 1 ☐ 2 ☐ 3
☐	☐	☐	Pasture/rangeland	
☐	☐	☐	Row crops	
☐	☐	☐	Small grains	
☐	☐	☐	Nursery	
☐	☐	☐	Orchard	
☐	☐	☐	Dairy	
☐	☐	☐	Confined animal feeding operations	
☐	☐	☐	Irrigation (irrigated land)	
☐	☐	☐	Fallow field - recent	
☐	☐	☐	Fallow - old	
☐	☐	☐	Rural residential	

USA-RAM 2 Stressors in Buffer Area 06/02/2011

5043179267

● FORM USA-RAM 7: STRESSORS TO WATER QUALITY IN THE AA Reviewed by (initial): ●									
Site ID: 			Date: / / 						
METRIC 8: Indicate water quality stressors observed in the AA Each observed indicator is ranked as: 1 - Not severe - the stressor is present, but does not appear to negatively impact any Attribute of condition in the AA. 2 - Moderately severe - the stressor is present and appears to have moderately negative impacts on one or more Attributes of condition in the AA. 3 - Severe - the stressor is present and appears to have major negative impacts on one or more Attributes of condition in the AA. Each indicator can have only one severity rank. Fill in the bubble corresponding to the choice for each stressor indicator that is observed, then provide an overall rank for each Stressor Category.									
If stressor is present, mark its severity			Field Indicators by Stressor Category						OVERALL RANKING:
1	2	3	Point Sources						○ 1 ○ 2 ○ 3
○	○	○	Point source inputs (discharge from wastewater plants, factories, etc)						
○	○	○	Stormwater inputs (discharge pipes, culverts, sewer outfalls)						
1	2	3	Sedimentation/Pollutants						○ 1 ○ 2 ○ 3
○	○	○	Debris lines on plants, trees or silt-laden vegetation						
○	○	○	Sedimentation (e.g., the presence of sediment fans, deposits or plumes)						
○	○	○	Industrial or domestic spills or discharges (odors, color, oil sheen, foam)						
○	○	○	Turbidity in the water column						
1	2	3	Eutrophication						○ 1 ○ 2 ○ 3
○	○	○	Direct discharges from feedlot manure pits, etc.						
○	○	○	Direct discharges from septic or sewage systems						
○	○	○	Direct application of fertilizer						
○	○	○	Agricultural runoff (drain tiles, etc. discharging to site)						
○	○	○	Formation of heavy algal or <i>Lemna</i> sp. surface mats or heavy benthic algal growth						
1	2	3	Mining Impacts						
○	○	○	Acid mine drainage discharge (excessively clear water (low pH) or presence/accumulation of "yellow-boy" orange precipitate)						
1	2	3	Salinity						
○	○	○	Obvious increases in the concentration of dissolved salts (dead or stressed plants; salt encrustations, etc)						
● USA-RAM 7 Stressors to Water Quality in the AA 06/02/2011 0748273461 ●									

● FORM USA-RAM 8: ALTERATIONS TO HYDROPERIOD IN THE AA Reviewed by (initial): ●			
Site ID: 		Date: / / 	
METRIC 9: Indicators of altered hydroperiod observed in AA. Each observed indicator is ranked as: 1 - Not severe - the stressor is present, but does not appear to negatively impact any Attribute of condition in the AA. 2 - Moderately severe - the stressor is present and appears to have moderately negative impacts on one or more Attributes of condition in the AA. 3 - Severe - the stressor is present and appears to have major negative impacts on one or more Attributes of condition in the AA. Each indicator can have only one severity rank. Fill in the bubble corresponding to the choice for each stressor indicator that is observed.			
If stressor is present, mark its severity			Field Stressor Indicators
1	2	3	
☐	☐	☐	Ditches/channelization within AA
☐	☐	☐	Dikes/dams/levees/berms at AA margin or within AA or roadbed or railroad (acting as block to water flows into or through AA)
☐	☐	☐	Channels have deeply undercut banks and/or bank slumps or slides.
☐	☐	☐	Culverts, pipes (point sources) into AA (<i>change in water quantity</i>)
☐	☐	☐	Water level control structure that impounds water in all or part of the AA
☐	☐	☐	Die-off of trees within AA due to increased ponding (exempting beaver impounded sites)
☐	☐	☐	Tidal restriction in tidal wetlands (restricts flows to and from AA)
☐	☐	☐	Presence of agricultural tiles or culverts at AA margin or within AA
☐	☐	☐	Siphons, pumps moving water in or out of AA
☐	☐	☐	Stormwater inputs from impervious surfaces/flashy flows into AA
Refer to USA-RAM User's Guide for full details.			
● USA-RAM 8 Alteration to Hydroperiod 06/02/2011 8238360235 ●			

● FORM USA-RAM 9: STRESSORS TO SUBSTRATE IN THE AA Reviewed by (initial): ●			
Site ID: 		Date: / / 	
METRIC 10: Indicators of altered substrate observed in AA Each observed indicator is ranked as: 1 - Not severe - the stressor is present, but does not appear to negatively impact any Attribute of condition in the AA. 2 - Moderately severe - the stressor is present and appears to have moderately negative impacts on one or more Attributes of condition in the AA. 3 - Severe - the stressor is present and appears to have major negative impacts on one or more Attributes of condition in the AA. Each indicator can have only one severity rank. Fill in the bubble corresponding to the choice for each stressor indicator that is observed.			
If stressor is present, mark its severity			Field Stressor Indicators
1	2	3	
☐	☐	☐	Soil subsidence, scour or surface erosion (root exposure, etc)
☐	☐	☐	Off-road vehicles, mountain biking, trails cut, etc
☐	☐	☐	Inorganic sedimentation inflow (sediment accumulation around vegetation, deep sediment splays, recent vegetation burial, etc)
☐	☐	☐	Dredging or other prominent excavation at AA margin or in AA
☐	☐	☐	Grazing by domesticated or feral animals in AA (includes trampling, digging, wallowing, etc)
☐	☐	☐	Grazing by native ungulates
☐	☐	☐	Recent farming activity (plowing, disking, etc)
☐	☐	☐	Soil compaction by human activity (parking by cars, heavy machinery, etc)
☐	☐	☐	Filling, grading, or other prominent deposition of sediment
☐	☐	☐	Dumping of garbage or other debris
☐	☐	☐	Mechanical plant removal that disturbs substrate(rutting, grubbing by heavy machinery, etc)
☐	☐	☐	Fire lines (fire breaks) dug in AA or at AA margin
● USA-RAM 9 Stressors to Substrate in the AA 06/02/2011 0662343981 ●			

● FORM USA-RAM 10: COVER OF INVASIVE PLANT SPECIES IN THE AA ● Site ID: Date: / / Reviewed by (initial): 	
Metric 11: Data table to indicate the percent cover of invasive plant species in the AA. Estimate the absolute percent cover of all invasive species in the AA. Information gathered in Metric 7 can be used to inform this metric, but note that this metric is based on an estimate of the invasive species cover for all strata combined over the entire AA. Invasive species include those identified in the NWCA Invasive Species Guide as well as those in any approved state or regional lists. Fill in the bubble corresponding to the choice for the cover class.	
Cover Class	Fill bubble for appropriate cover class:
Absent (none)	☐
Trace (nearly absent): <5% cover)	☐
Moderate: 5 - 25% cover)	☐
Extensive: 26 - 75% cover)	☐
Dominant: >75% cover)	☐
● USA-RAM 10 Cover of Invasive Plants 06/02/2011 7342028129 ●	

FORM USA-RAM 11: STRESS TO VEGETATION IN THE AA Reviewed by (initial): 									
Site ID: 			Date: / / 						
METRIC 12: Indicators of vegetation disturbance observed in AA Each observed indicator is ranked as: 1 - Not severe - the stressor is present, but does not appear to negatively impact any Attribute of condition in the AA. 2 - Moderately severe - the stressor is present and appears to have moderately negative impacts on one or more Attributes of condition in the AA. 3 - Severe - the stressor is present and appears to have major negative impacts on one or more Attributes of condition in the AA. Each indicator can have only one severity rank. Fill in the bubble corresponding to the choice for each stressor indicator that is observed, then provide an overall rank for each Stressor Category.									
If stressor is present, mark its severity			Field Indicators by Stressor Category						OVERALL RANKING:
1	2	3	Human Use and/or Management						☐ 1 ☐ 2 ☐ 3
☐	☐	☐	Mowing within AA (or at AA margin)						
☐	☐	☐	Forest - selective cut						
☐	☐	☐	Forest - clear cut						
☐	☐	☐	Prominent removal of large woody debris						
☐	☐	☐	Mechanical plant removal besides tree cutting or woody debris removal						
☐	☐	☐	Evidence of planting of non-native vegetation						
☐	☐	☐	Farming (recent plowing, disking, etc)						
1	2	3	Excessive Grazing or Herbivory						☐ 1 ☐ 2 ☐ 3
☐	☐	☐	Grazing by domestic or feral animals (cows, sheep, pigs, etc)						
☐	☐	☐	Excessive wildlife herbivory (deer, muskrat, geese, carp, beaver, etc.)						
☐	☐	☐	Excessive insect herbivory of tree canopy, shrub layer						
1	2	3	Fire						☐ 1 ☐ 2 ☐ 3
☐	☐	☐	Evidence of intentional burning at AA margins or in AA (blackened tree canopy, ground cover, etc.)						
☐	☐	☐	Fire lines (fire breaks)						
USA-RAM 11 Stress to Vegetation in the AA 06/02/2011 4617347899									

Appendix E. Sentinel site hydrographs

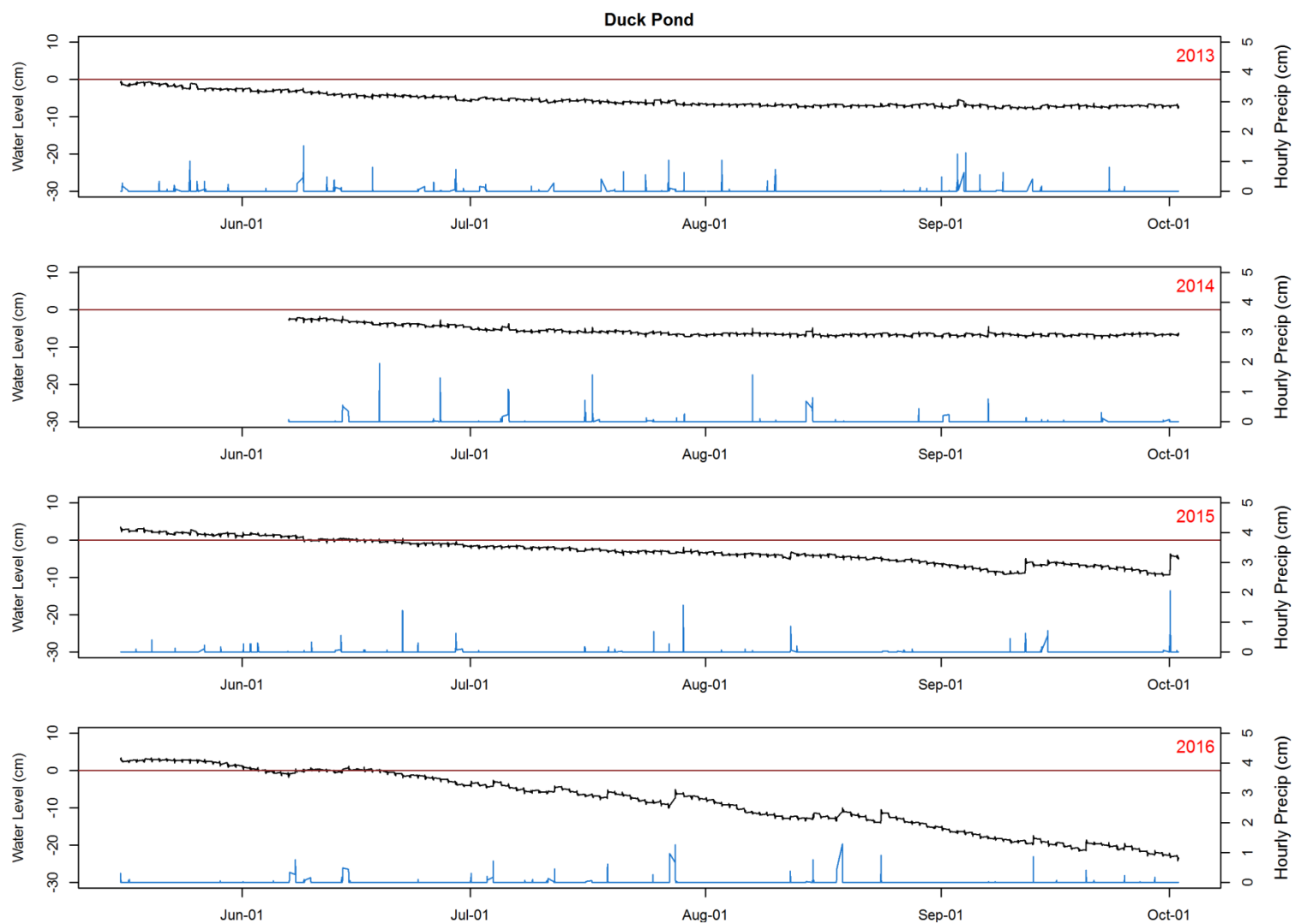


Figure E-1. Hydrographs for Duck Pond (NWCA-R301) by year. Black lines are water level. Blue lines are hourly precipitation. The brown line at 0 is the wetland surface.

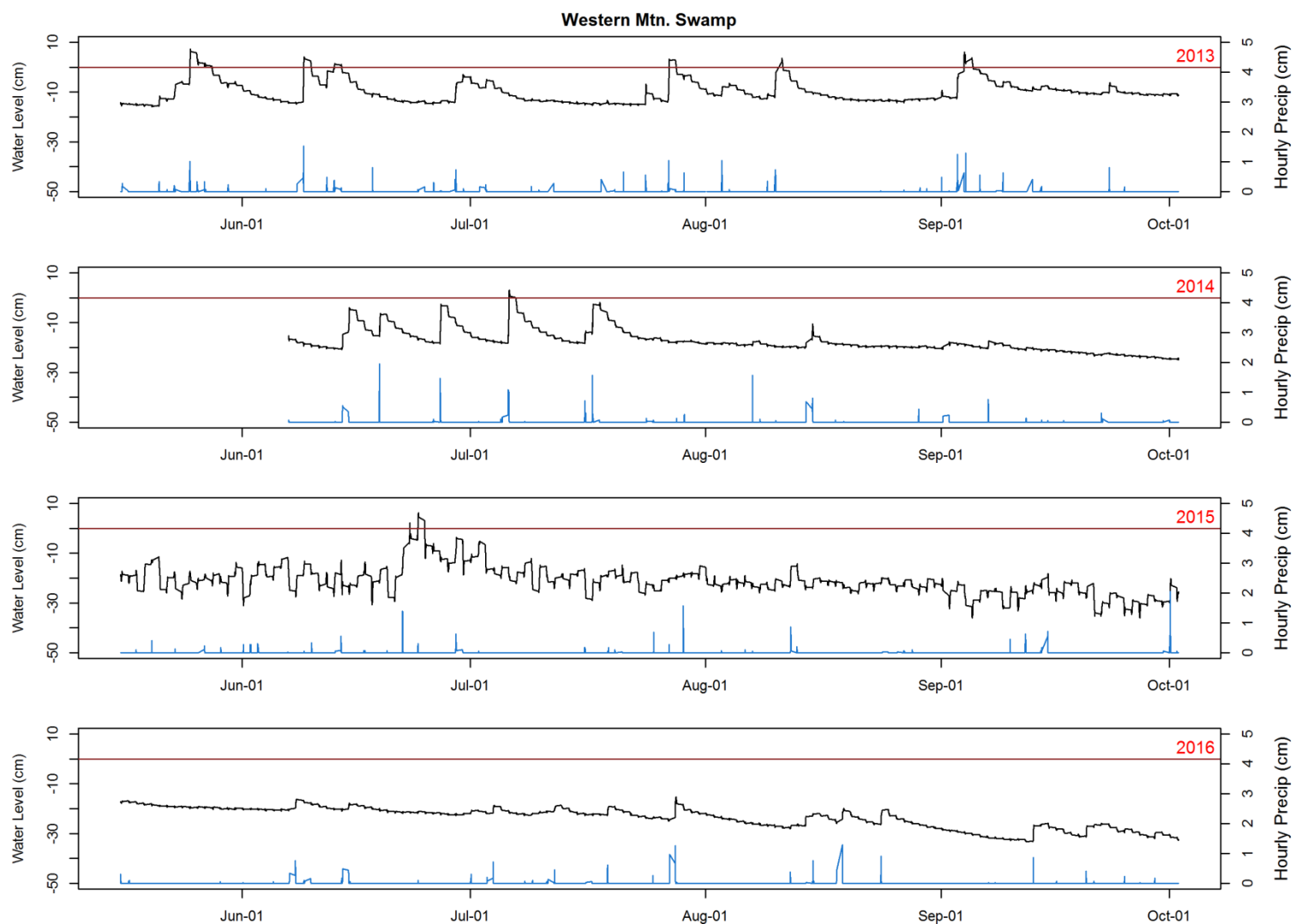


Figure E-2. Hydrographs for Western Mountain Swamp (NWCA-R302) by year. Black lines are water level. Blue lines are hourly precipitation. The brown line at 0 is the wetland surface.

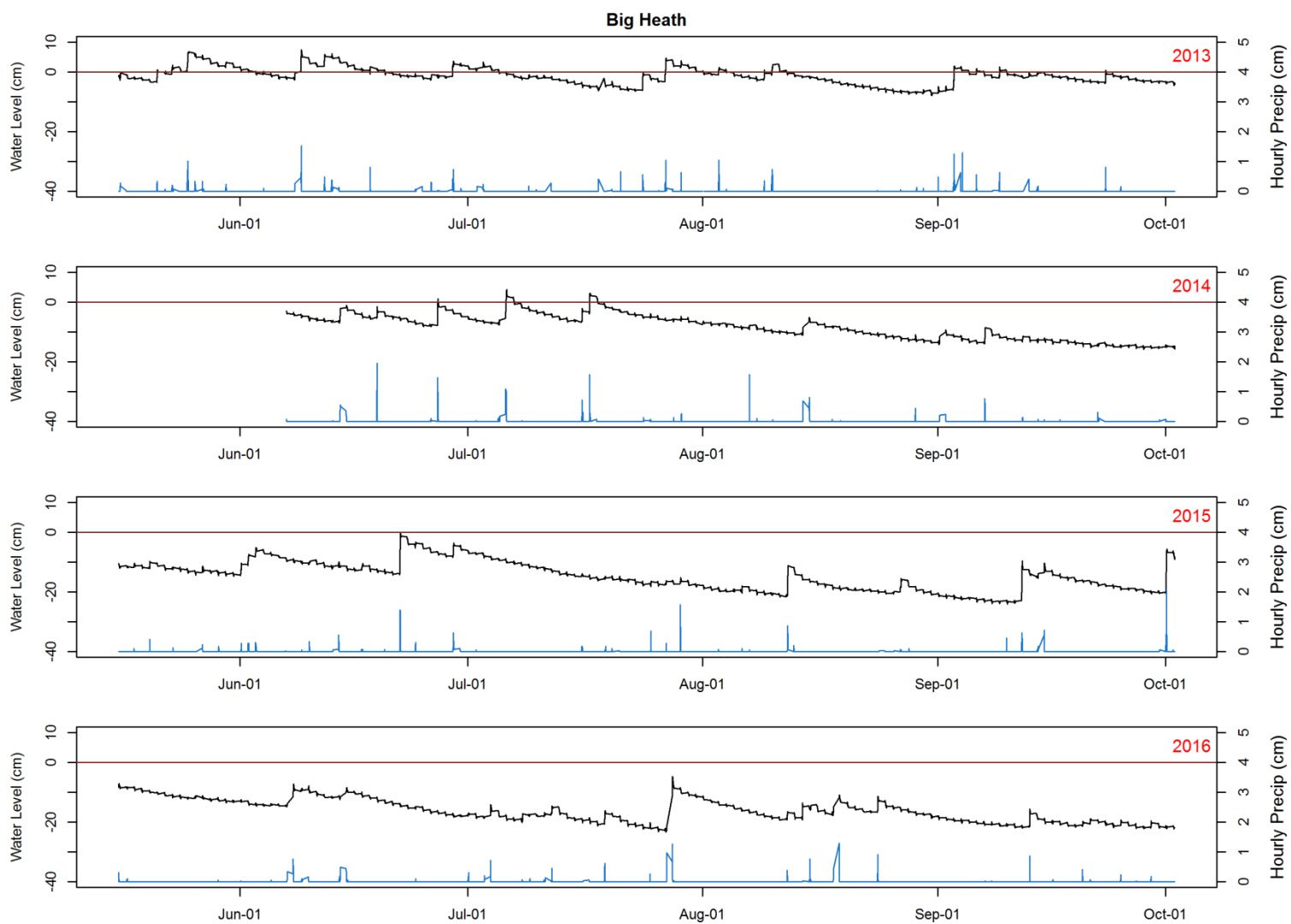


Figure E-3. Hydrographs for Big Heath (NWCA-R303) by year. Black lines are water level. Blue lines are hourly precipitation. The brown line at 0 is the wetland surface.

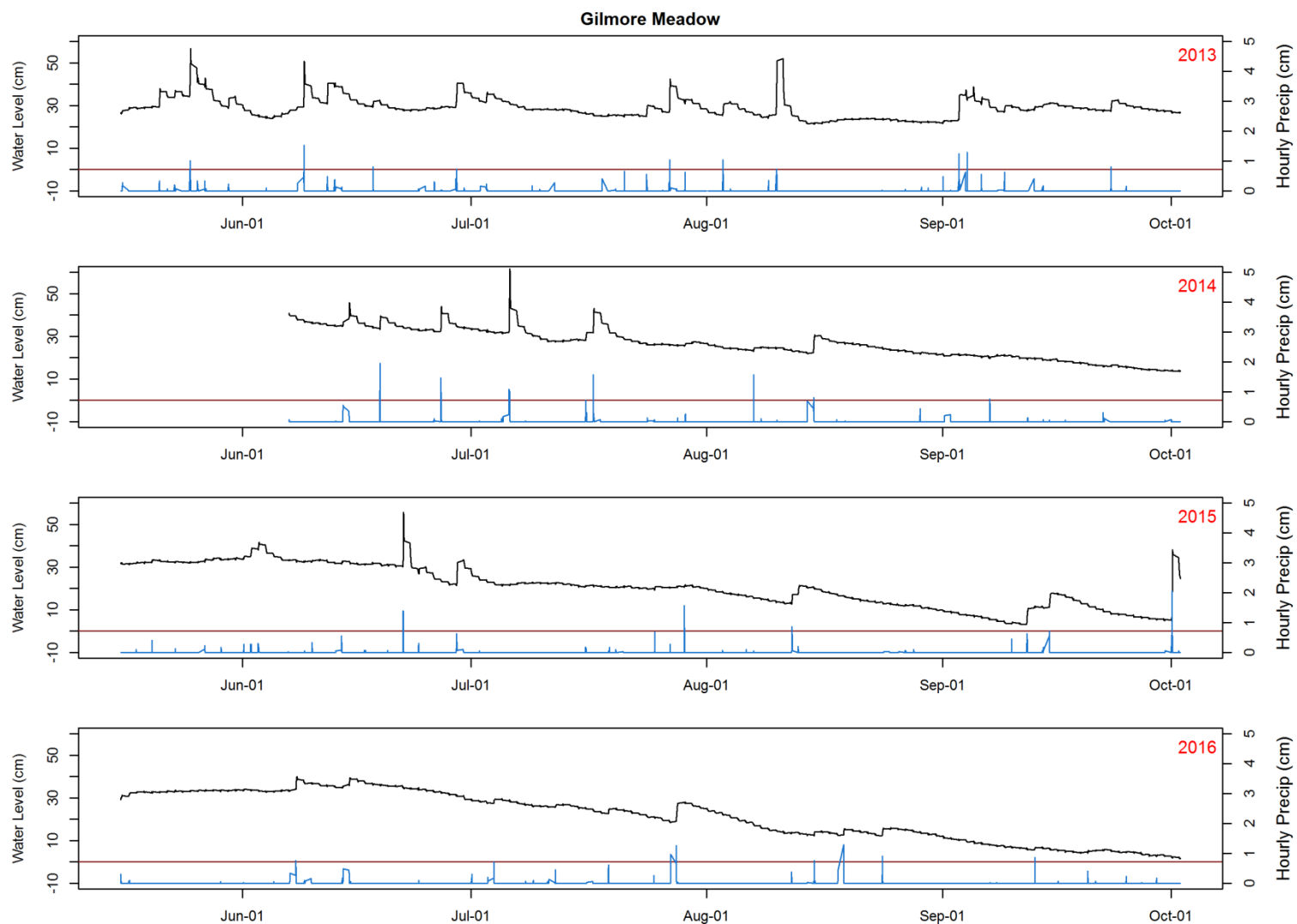


Figure E-4. Hydrographs for Gilmore Meadow (NWCA-R304) by year. Black lines are water level. Blue lines are hourly precipitation. The brown line at 0 is the wetland surface.

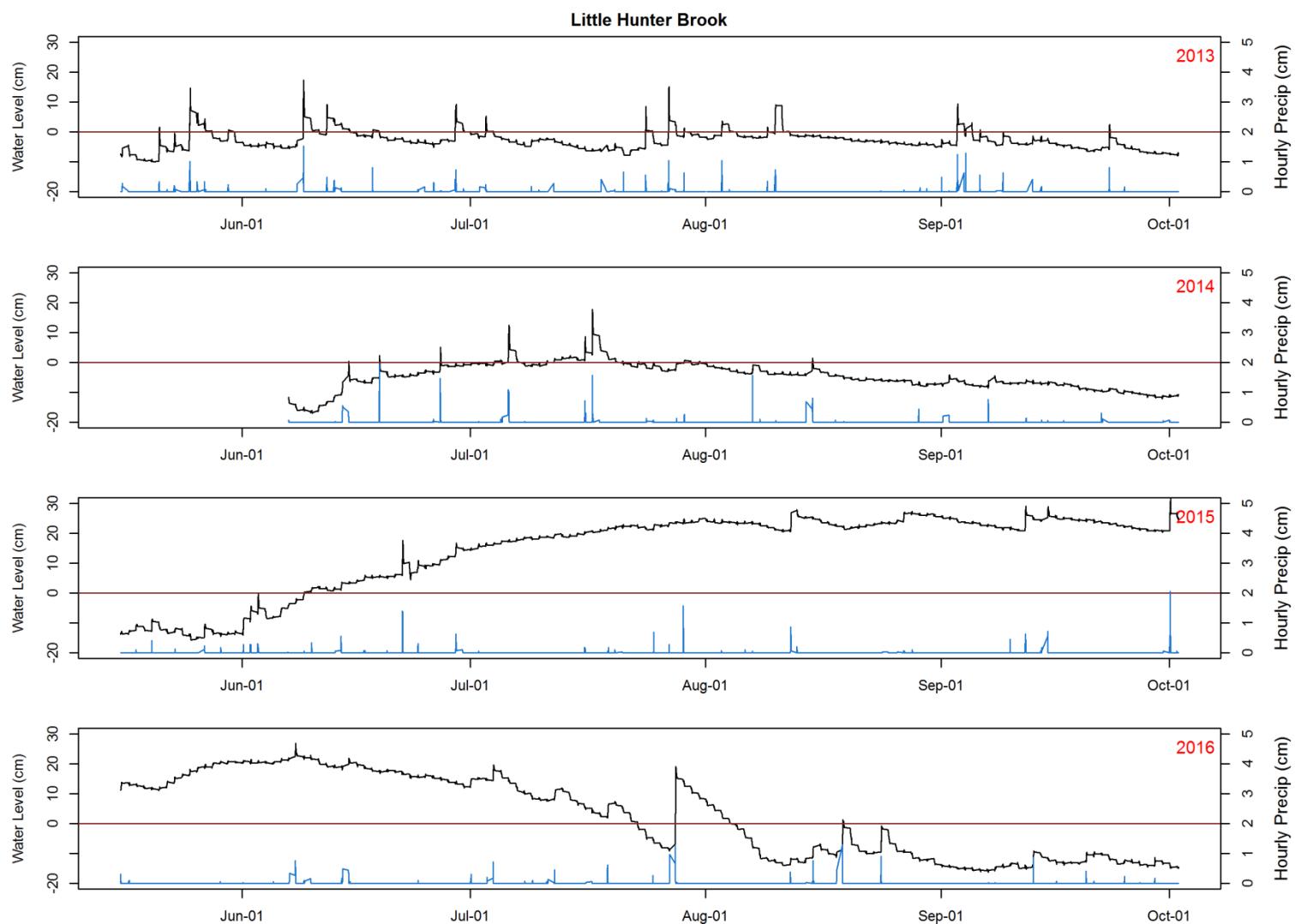


Figure E-5. Hydrographs for Little Hunter Brook (NWCA-R305) by year. Black lines are water level. Blue lines are hourly precipitation. The brown line at 0 is the wetland surface.

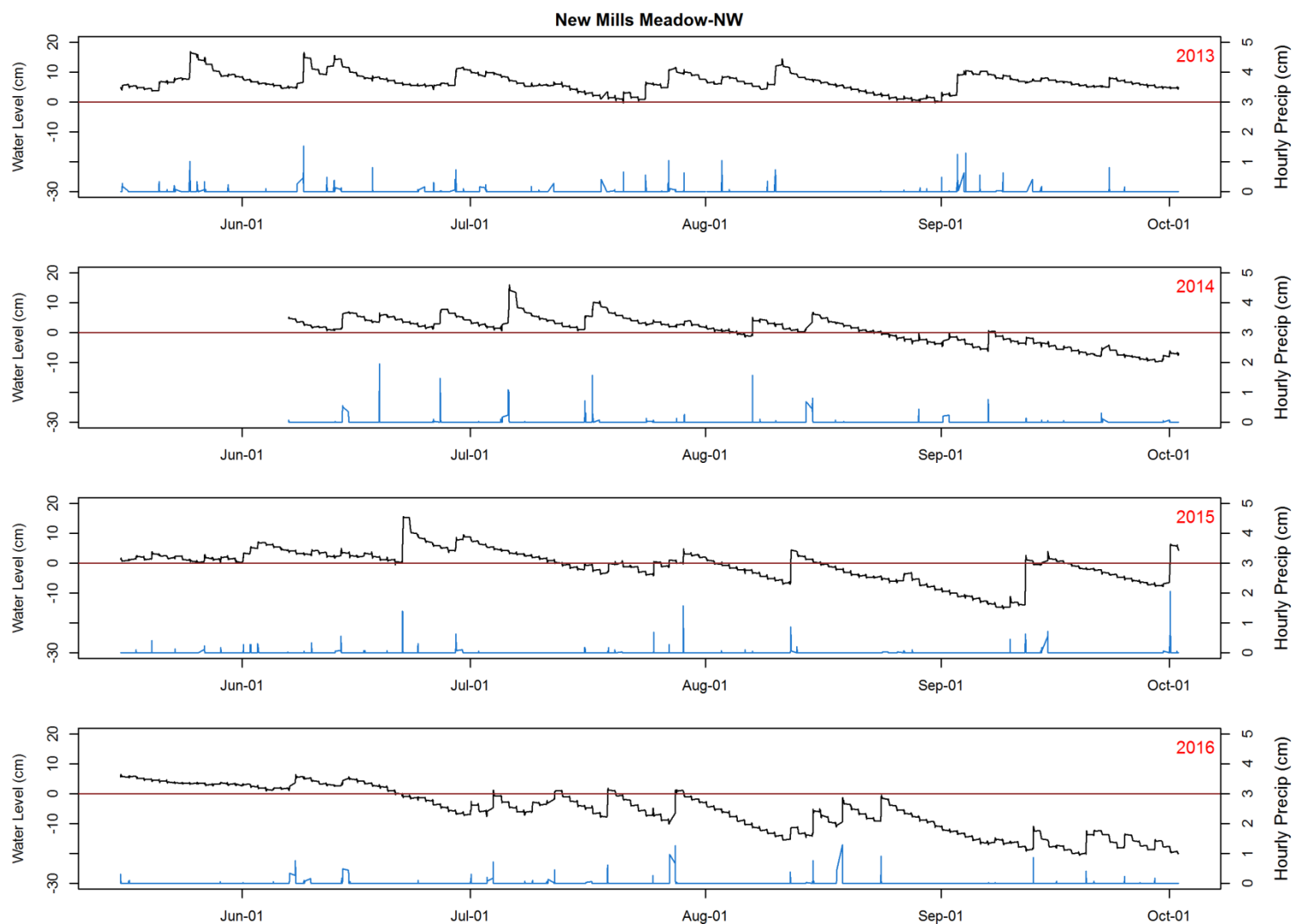


Figure E-6. Hydrographs for New Mills Meadow-NW (NWCA-R306) by year. Black lines are water level. Blue lines are hourly precipitation. The brown line at 0 is the wetland surface.

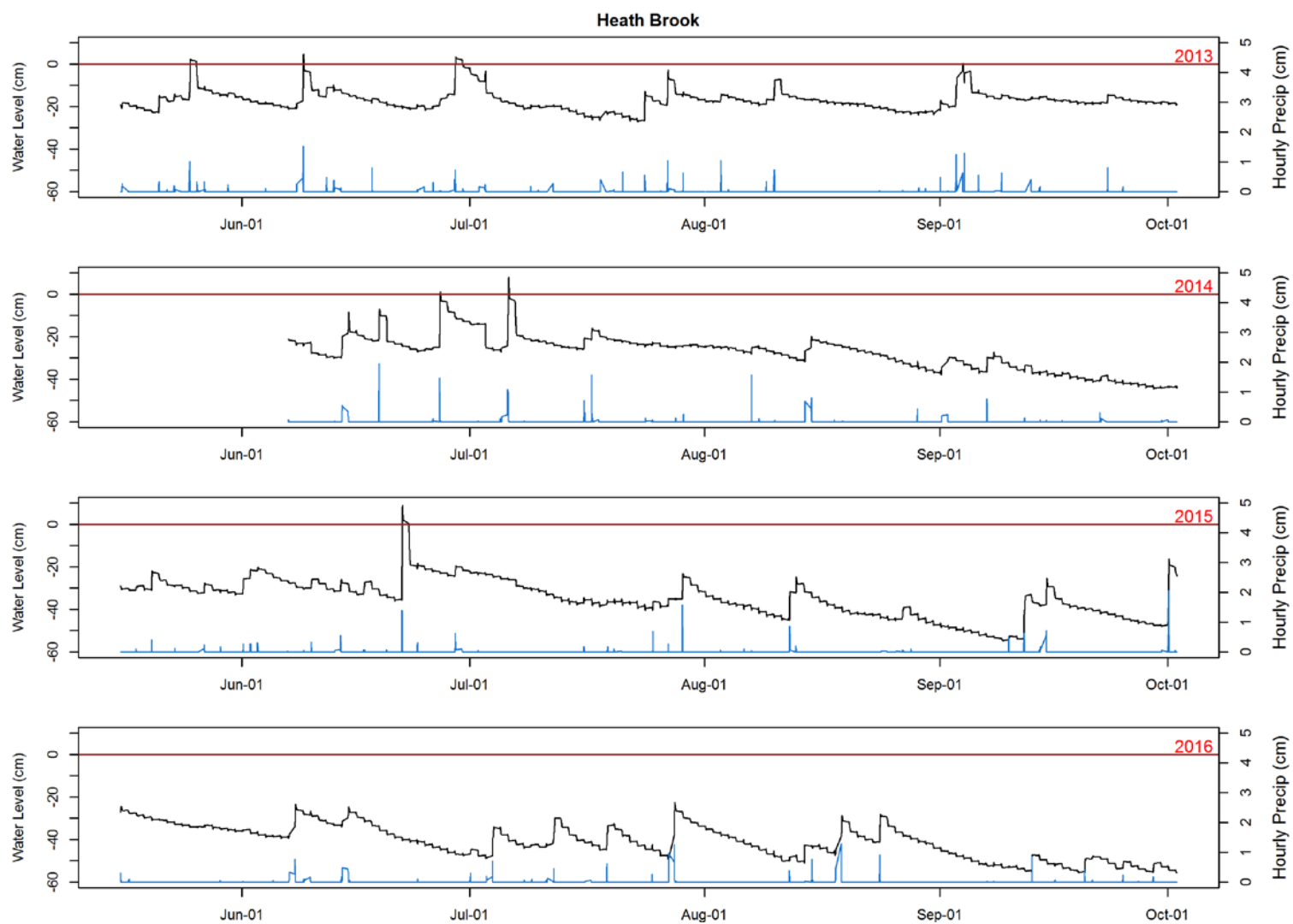


Figure E-7. Hydrographs for Heath Brook (NWCA-R308) by year. Black lines are water level. Blue lines are hourly precipitation. The brown line at 0 is the wetland surface.

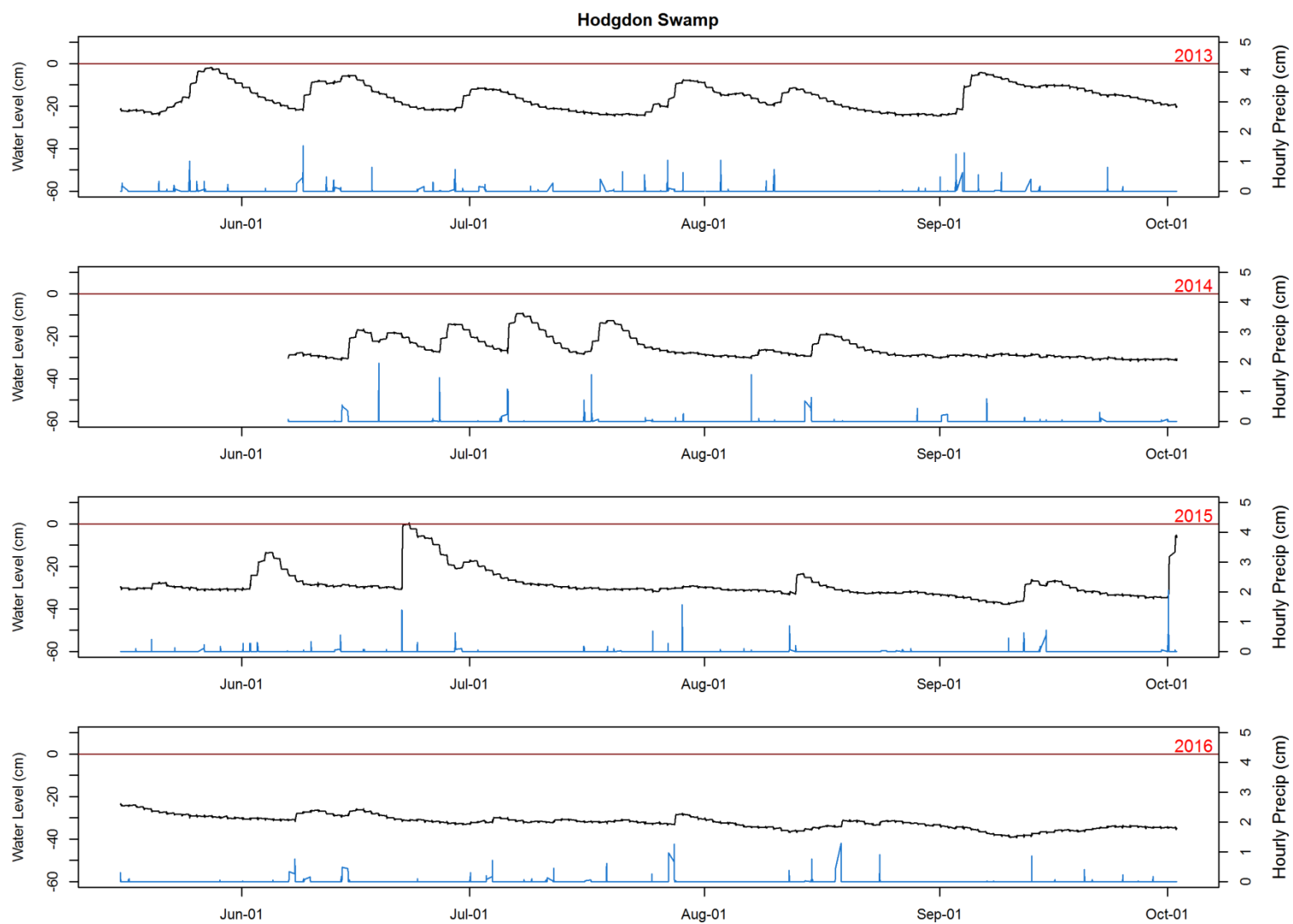


Figure E-8. Hydrographs for Hodgdon Swamp (NWCA-R309) by year. Black lines are water level. Blue lines are hourly precipitation. The brown line at 0 is the wetland surface.

Appendix F. Intensive site hydrographs in Great Meadow

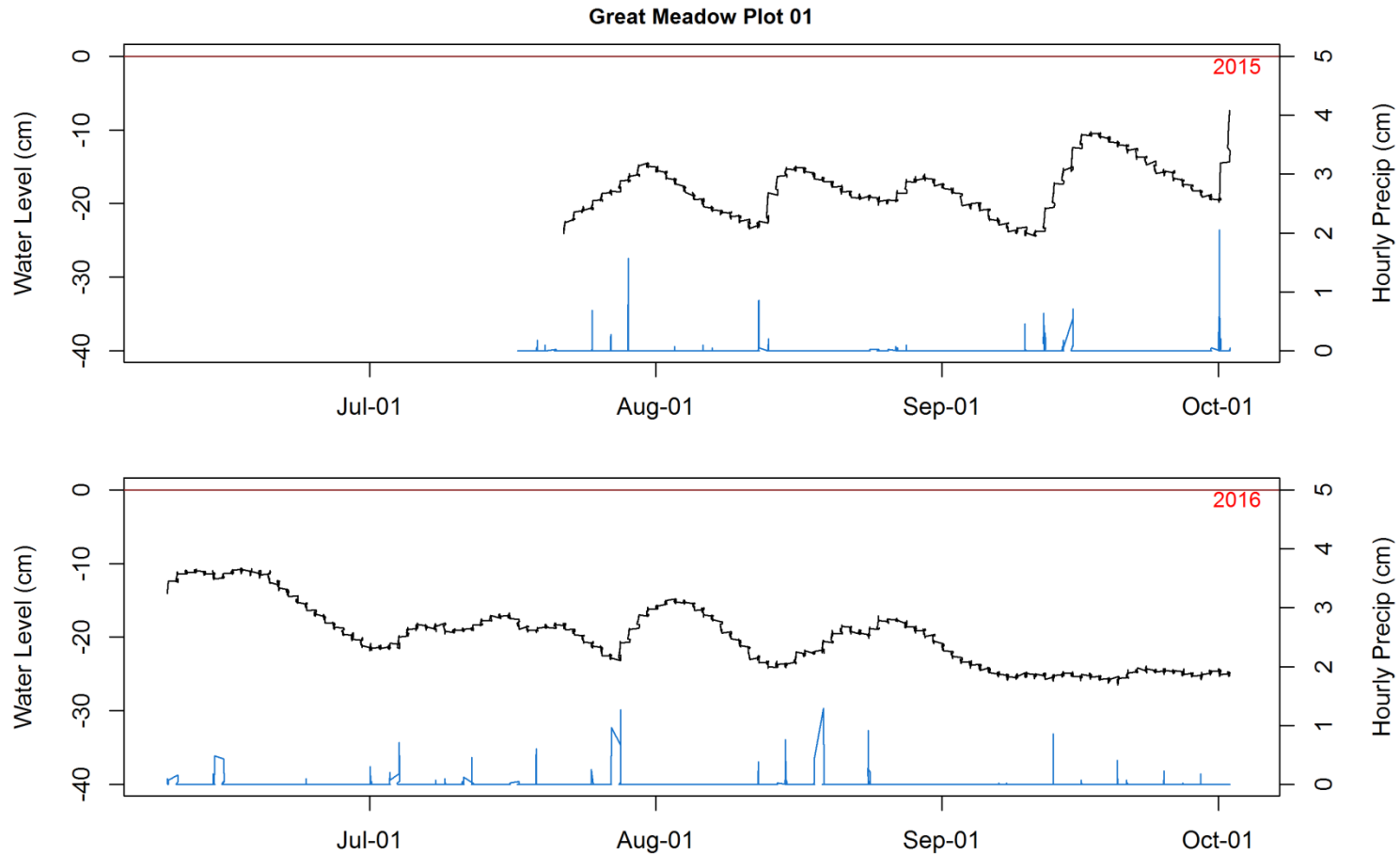


Figure F-1. Hydrographs for Great Meadow Plot 01 by year. Black lines are water level. Blue lines are hourly precipitation. The brown line at 0 is the wetland surface.

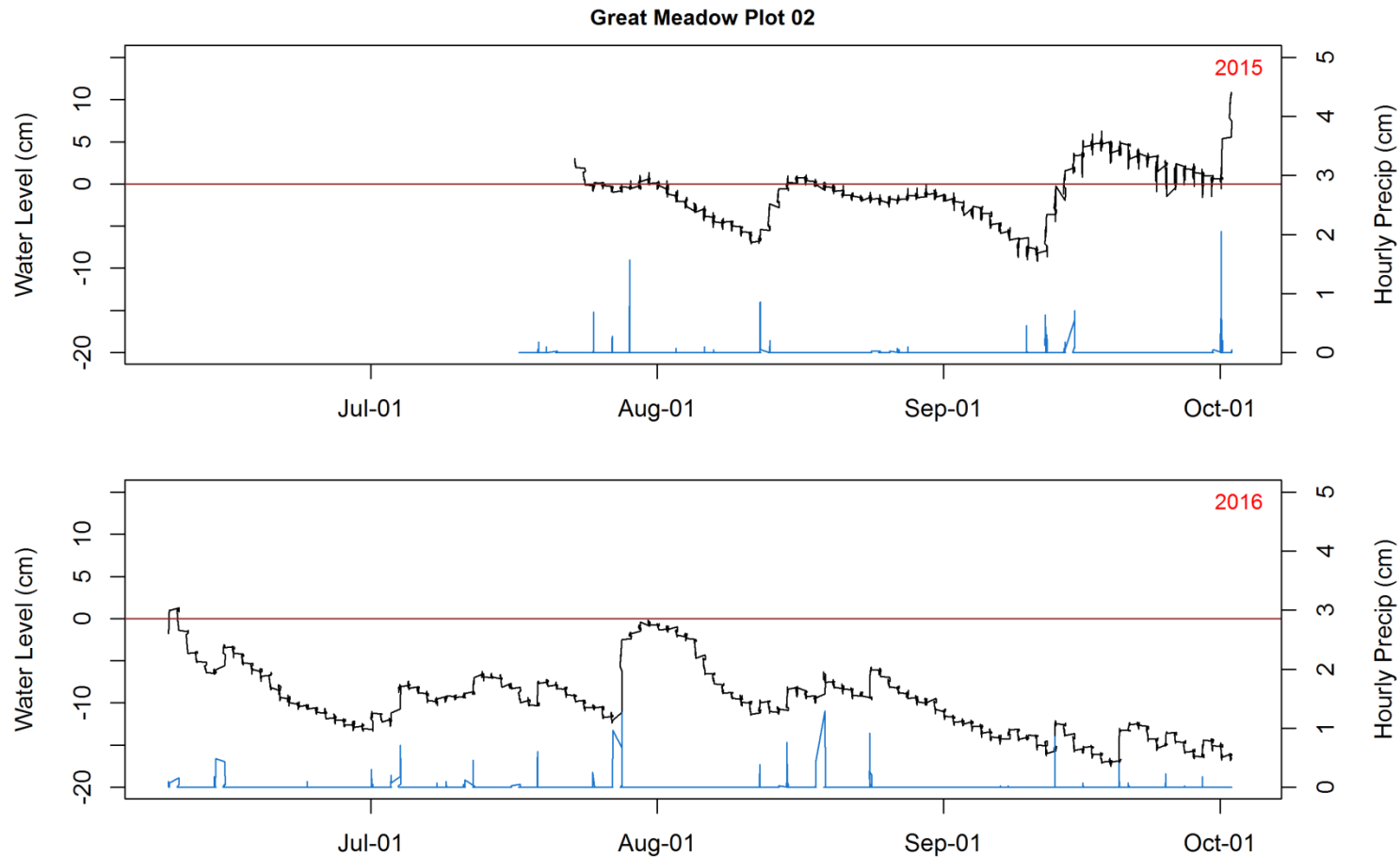


Figure F-2. Hydrographs for Great Meadow Plot 02 by year. Black lines are water level. Blue lines are hourly precipitation. The brown line at 0 is the wetland surface.

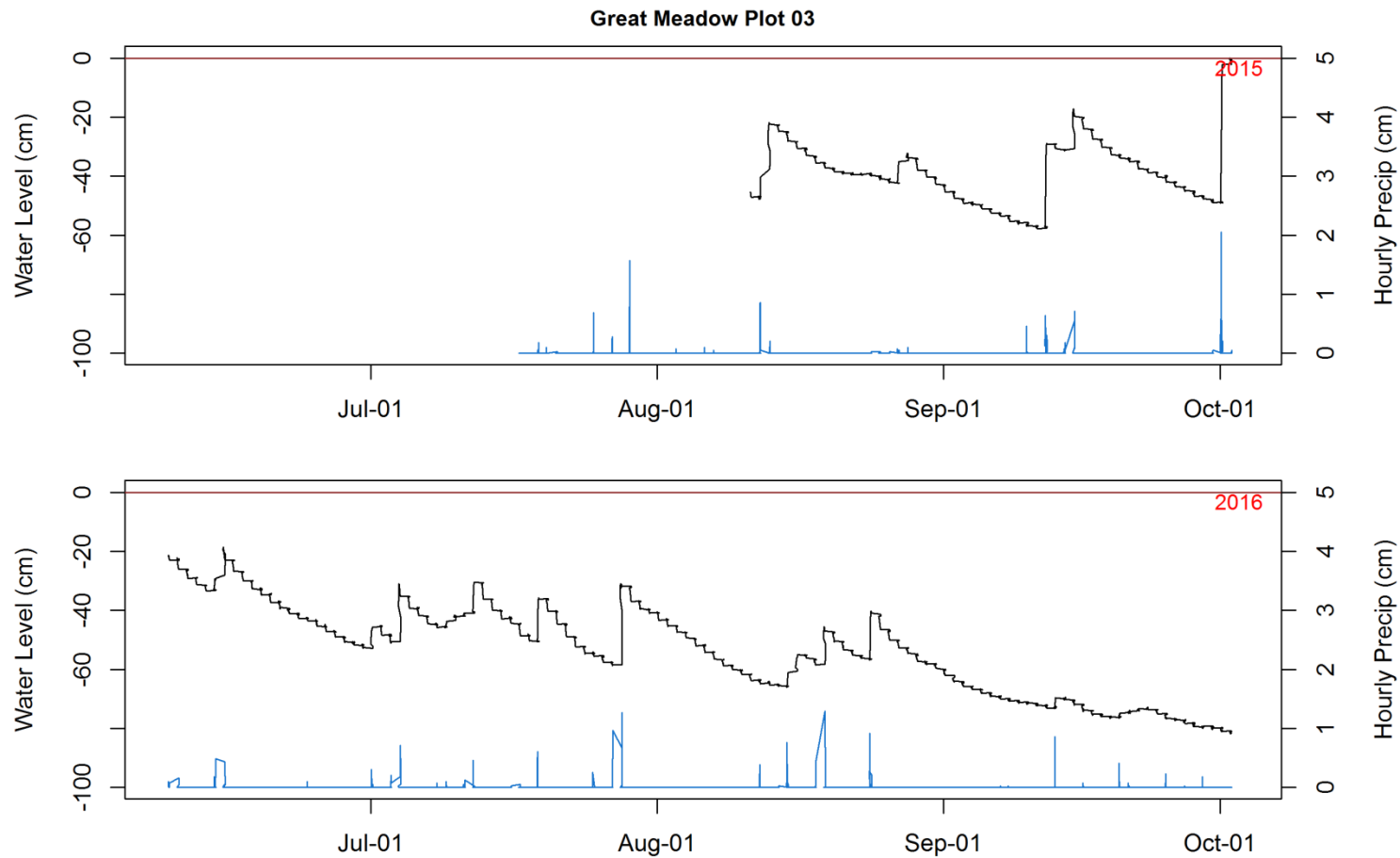


Figure F-3. Hydrographs for Great Meadow Plot 03 by year. Black lines are water level. Blue lines are hourly precipitation. The brown line at 0 is the wetland surface.

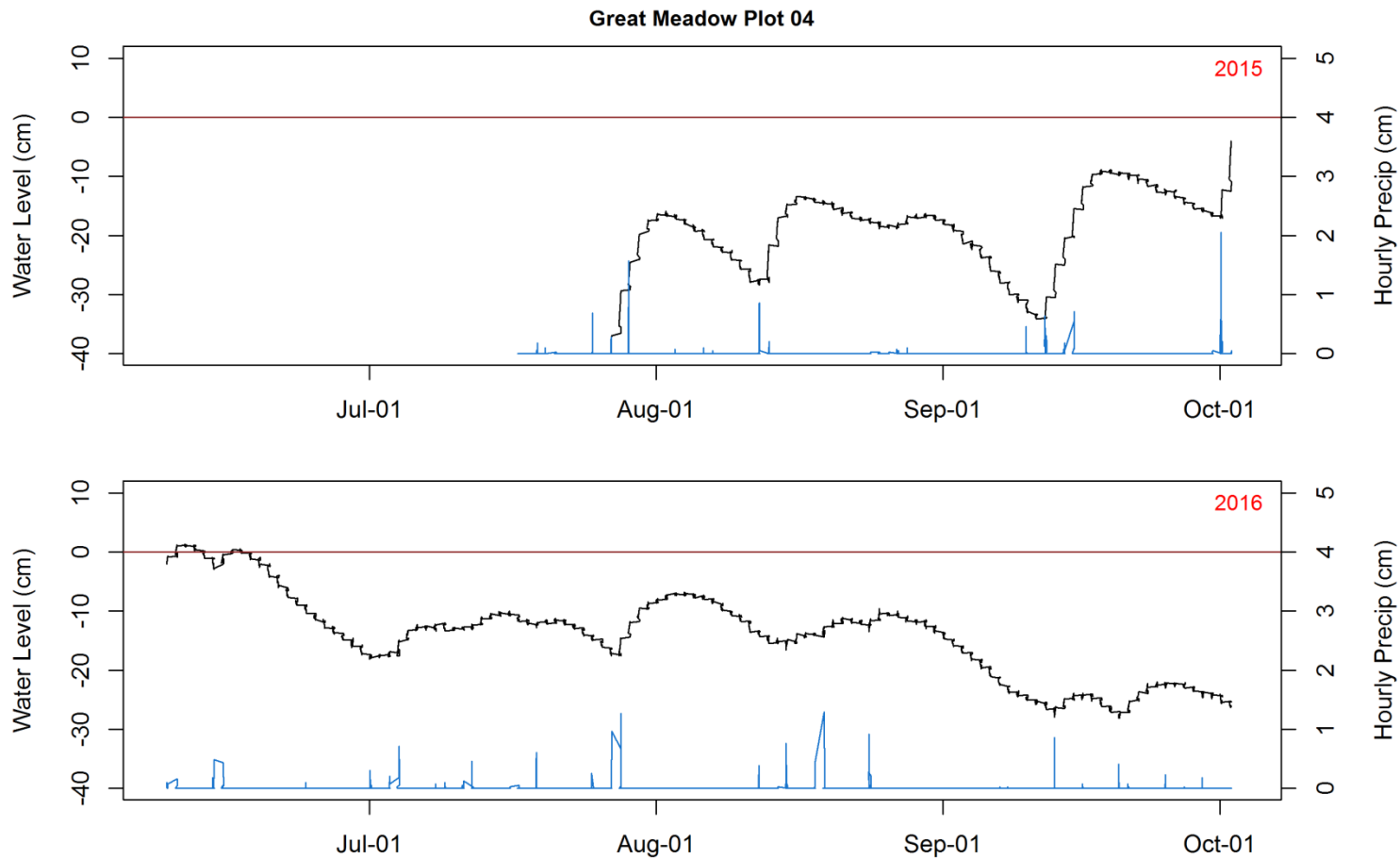


Figure F-4. Hydrographs for Great Meadow Plot 04 by year. Black lines are water level. Blue lines are hourly precipitation. The brown line at 0 is the wetland surface.

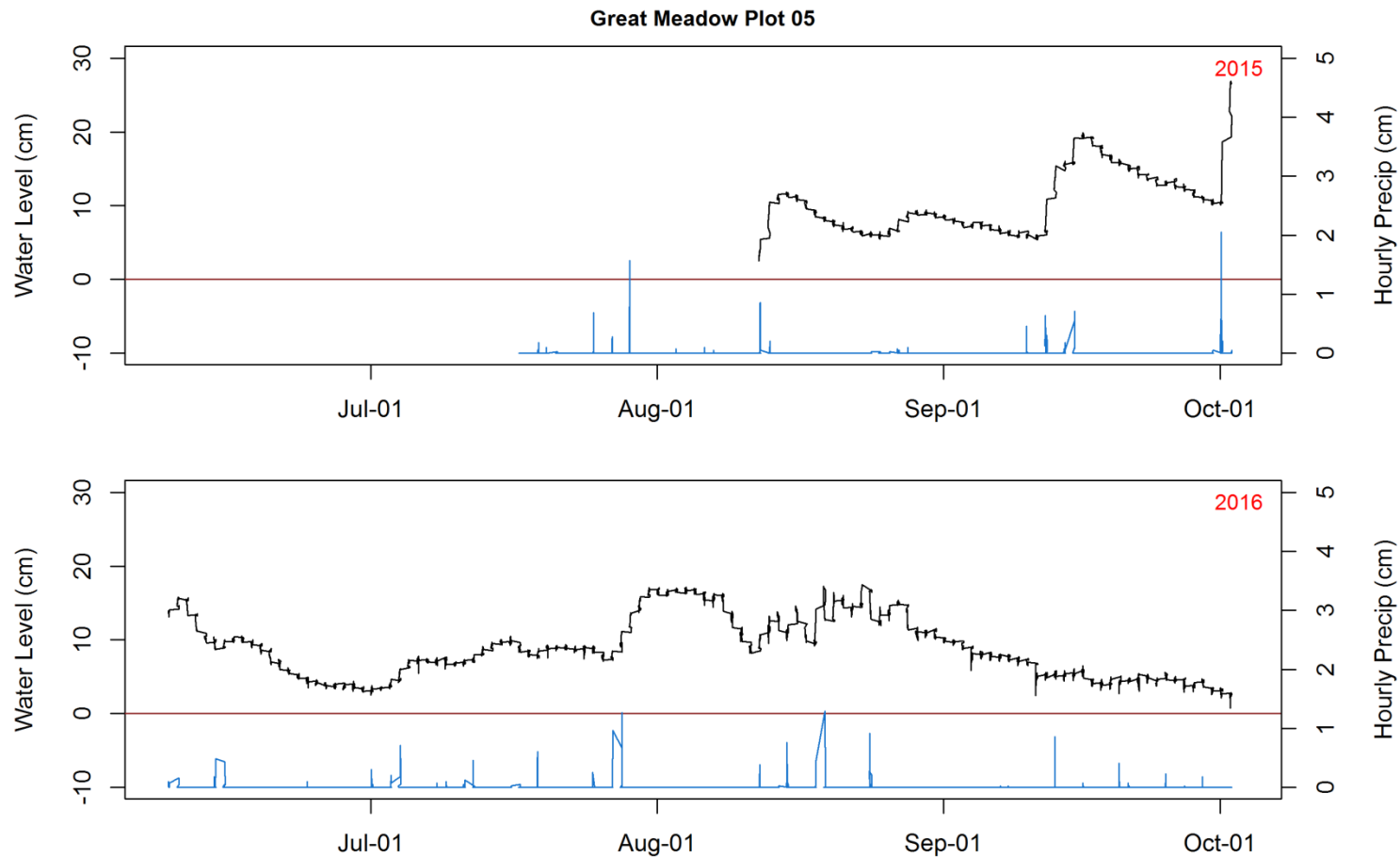


Figure F-5. Hydrographs for Great Meadow Plot 05 by year. Black lines are water level. Blue lines are hourly precipitation. The brown line at 0 is the wetland surface.

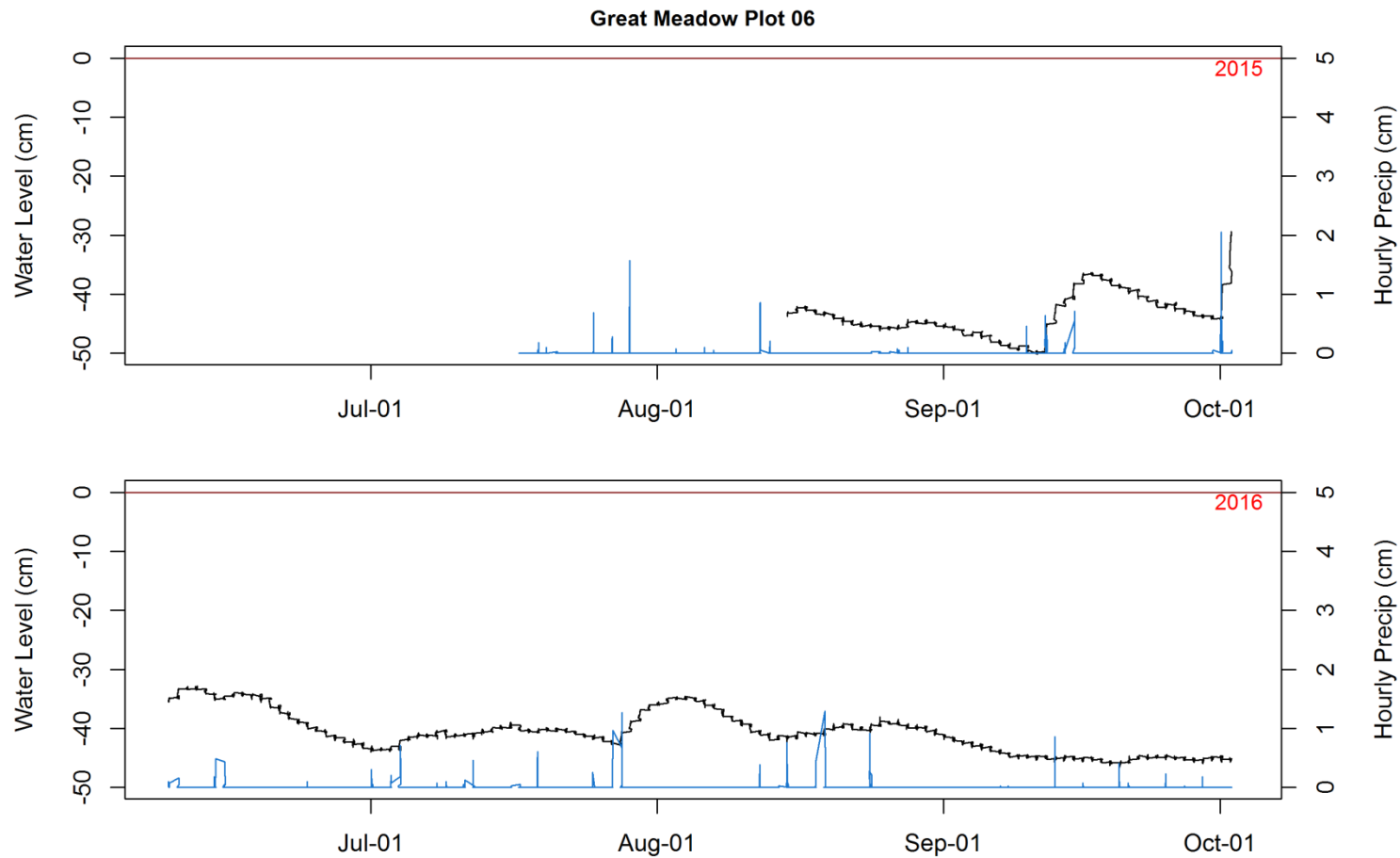


Figure F-6. Hydrographs for Great Meadow Plot 06 by year. Black lines are water level. Blue lines are hourly precipitation. The brown line at 0 is the wetland surface.

The Department of the Interior protects and manages the nation's natural resources and cultural heritage; provides scientific and other information about those resources; and honors its special responsibilities to American Indians, Alaska Natives, and affiliated Island Communities.

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