



Quality Assurance Plan for the Northeast Temperate Network Permanent Freshwater Wetland Monitoring Protocol for Acadia National Park

Natural Resource Report NPS/NETN/NRR—2021/2277



ON THE COVER

Photograph of NETN staff sampling Big Heath in Acadia National Park. NPS photo
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Quality Assurance Plan for the Northeast Temperate Network Permanent Freshwater Wetland Monitoring Protocol for Acadia National Park

Natural Resource Report NPS/NETN/NRR—2021/2277

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Contents

	Page
Figures.....	v
Tables.....	v
Northeast Temperate Network Protocol Package Documents.....	vii
Revision History	ix
Acronyms/ List of Terms	xi
Abstract.....	xiii
Introduction.....	1
Protocol Overview, Objectives, and Sampling Design	2
Protocol Activities	5
Data Quality Objectives.....	9
Data Quality Values	9
Data Quality Standards.....	10
Measurement Quality Objectives	10
Taxonomic Standards	17
Accreditation Standards.....	17
Policy and Protected Data Standards.....	17
Quality Assurance Procedures	19
Hiring.....	19
Training	19
Oversight and Communication.....	19
Data Collection.....	20
Observer Error	28
Operational Review	28
Data Entry, Verification, and Management.....	28

Contents (continued)

	Page
Quality Control Procedures.....	33
Data Validation.....	33
Observer Bias	36
Documentation.....	37
Data Certification	37
Archive of Records.....	38
Metadata	38
Information Dissemination.....	38
Communicating Data Quality.....	39
Protocol Quality Assessment	41
Roles, Responsibilities, and Qualifications.....	43
Forest Crew Leader	43
Plant Ecology Technician.....	44
Contract Botanist.....	44
Literature Cited	47

Figures

	Page
Figure 1. Workflow of protocol activities for Sentinel wetland sites and RAM wetland sites.	3
Figure 2. EPA NWCA plot design.	4
Figure 3. Design of RAM site, including a 40-m radius assessment area broken into quarters, and 100-m buffer around the AA with eight 100-m buffer transects.	5
Figure 4. Data flow for sentinel sites sampled for the EPA NWCA, Sentinel site water level data, and RAM site data.	30

Tables

	Page
Table 1. Panel design and number of sites sampled per year for the NETN Permanent Freshwater Wetland Monitoring Protocol.	4
Table 2. Project activity matrix for the NETN permanent freshwater wetland monitoring protocol.	6
Table 3. Measurement quality objectives for measures collected and derived by NETN in the implementation of this protocol.	12
Table 4. Quality assurance procedures implemented by NETN when collecting and entering data for the Permanent Freshwater Wetland Monitoring Protocol.	21
Table 5. Quality control procedures implemented by NETN when collecting, entering, or deriving data for the Permanent Freshwater Wetland Monitoring Program in ACAD.	34
Table 6. Data quality evaluations to be conducted as a part of implementing the NETN Permanent Freshwater Wetland Monitoring Protocol.	41
Table 7. Roles, responsibilities and contact information for persons affiliated with implementation of the NETN Permanent Freshwater Wetland Monitoring Protocol.	43

Northeast Temperate Network Protocol Package Documents

This is one of a series of documents that collectively describe the objectives, procedures, and data quality of NETN's Permanent Freshwater Wetlands monitoring program at Acadia National Park. Please visit NETN's Freshwater Wetlands Program on the US NPS's Data Store ([IRMA Reference Code #2208704](#)) for links to all supporting protocol documents and products associated with this program, including but not limited to:

- Protocol Narrative
- Standard Operating Procedures (SOPs)
- Safety Plan
- Summary of Major Protocol Changes

Revision History

As part of the National Park Service (NPS) Inventory and Monitoring Program, the Northeast Temperate Network (NETN) Permanent Freshwater Wetland Monitoring Protocol consists of a narrative (Miller et al. 2021) that describes the monitoring objectives and sampling design, Standard Operating Procedures (SOPs) that outline specific data collection details of the monitoring protocol, a Summary of Major Protocol Changes and Deviations, a Safety Plan and a Quality Assurance Plan (QAP; this document) that describes the standards and procedures used in the collection, processing, storage, analysis, and publication of monitoring data. The latest version of the narrative, SOPs, QAP, Safety Plan, Summary of Major Protocol Changes and Deviations, and additional supporting information can be accessed online at the NETN website (<https://www.nps.gov/im/netn/freshwater-wetlands.htm>), or the NPS Data Store (<https://irma.nps.gov/Datastore/Reference/Profile/2208704>).

The narrative, each SOP, and the QAP have respective revision history logs to document changes in the protocol. The following revision history log is for the QAP. Version numbers will be incremented by a whole number (e.g., Version 1.3 to 2.0) when a change is made that significantly affects requirements or procedures. Version numbers will be incremented by decimals (e.g., Version 1.3 to Version 1.4) when there are minor modifications that do not affect requirements or procedures included in the protocol. Rows are added to the log 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	January 2020	–	Initial version	–

Acronyms/ List of Terms

AA: Assessment Area, a 40-m radius circular monitoring plot uses by the EPA NWCA and for RAM monitoring.

ACAD: Acadia National Park

EPA: Environmental Protection Agency

FOM: Field Operation Manual – manual used to sample sentinel sites for the EPA NWCA

IMD: Inventory and Monitoring Division

LOM: Laboratory Operations Manual – manual that documents all lab analysis procedures conducted for the EPA NWCA, including

MDI: Mount Desert Island, Maine

NETN: Northeast Temperate Network

NPS: National Park Service

NWCA: National Wetland Condition Assessment – is implemented by EPA every 5 years

QA: Quality assurance procedures – typically occurs before or during data collection.

QAP: Quality Assurance Plan – documents the quality assurance and quality control procedures for a protocol.

QAPP: Quality Assurance Project Plan – EPA's version of the QAP for the EPA NWCA.

QA/QC Visit: Quality Assurance/Quality Control visit – involves NETN staff resampling a RAM site to assess observer bias and sampling error.

QA Visit: Quality assurance visit conducted by EPA staff during NWCA.

QC: Quality control procedures – typically conducted after data have been collected.

RAM site: Rapid Assessment Monitoring site – one of 40 randomly selected sites in ACAD that are sampled using level 1 & 2 monitoring.

Sentinel site: Sites that were hand-picked as minimally disturbed, and that are sampled intensively (Level 3 monitoring) during the EPA NWCA.

SOP: Standard Operating Procedures – detailed descriptions of the methods used for this monitoring protocol.

USA-RAM: USA Rapid Assessment Methods developed by the EPA for Level 1 and 2 monitoring

Abstract

In accordance with guidelines set forth by the National Park Service Inventory & Monitoring Division, a quality-assurance plan has been created for use by the Northeast Temperate Network in the implementation of the Permanent Freshwater Wetland Monitoring Protocol (Miller et al. 2021). This QAP documents the standards, policies, and procedures used by the Northeast Temperate Network for activities related to the collection, processing, storage, analysis, and publication of monitoring data. This QAP was largely adapted and greatly benefited from the Eastern Rivers and Mountains QAP for Vegetation Monitoring (Perles et. al 2018). The policies and procedures documented in this QAP are consistent with the quality assurance plans for other monitoring activities conducted by the Northeast Temperate Network and supplement National Inventory & Monitoring Division Quality Management Plan (DeVivo in preparation).

Introduction

The National Park Service (NPS) Inventory & Monitoring Program was established by an act of Congress in 1999 to provide more than 270 national park system units a core suite of baseline scientific information (inventories) and to identify and implement long-term monitoring of high-priority measurements of resource condition in those units (Fancy et al. 2009). The overarching purpose of natural resource monitoring in parks is to develop scientifically sound information on the current status and long-term trends in the composition, structure, and function of park ecosystems, and determine how well current management practices are sustaining those ecosystems.

Policies and procedures were designed to ensure that all scientific work conducted by or for the NPS Inventory and Monitoring Division (IMD), including data, reports, and associated decision support tools, is appropriate for its intended use and of documented quality. Transparently communicating information about data quality also ensures continuity and comparability of data over time.

The IMD is responsible for developing a quality management plan (DeVivo in preparation) that documents the policies, procedures, memoranda, Director's orders, training requirements (e.g., Department of Interior Scientific Integrity Training) etc. that apply to all IMD activities Service-wide. Data quality standards and procedures for each monitoring protocol are detailed in a protocol-specific quality assurance plans (QAP).

This QAP outlines data quality standards for permanent freshwater wetland monitoring in Acadia National Park (ACAD) by the Northeast Temperate Network (NETN) – one of 32 ecoregional “networks” of parks that were grouped by geography and shared natural resource characteristics (Fancy et al. 2009). In addition to the QAP, the NETN Permanent Freshwater Wetland Monitoring Protocol consists of a narrative (Miller et al. 2021) that describes the monitoring objectives and sampling design, Standard Operating Procedures (SOPs) that outline specific data collection details of the monitoring protocol, a Summary of Major Protocol Changes and Deviations, and a Safety Plan. The latest version of each of these documents, EPA manuals, and additional supporting information can be accessed in the Permanent Freshwater Wetland Monitoring Project in the NPS Data Store (available at: <https://irma.nps.gov/Datastore/Reference/Profile/2208704>).

The intent of the QAP is to provide all potential end-users of protocol data with adequate information to understand what data are being collected and how, as well as what standards those data are being collected to, so that they can independently determine whether or how those data may be interpreted and used. In addition, the Summary of Major Protocol Changes and Deviations document summarizes any major protocol changes that affect data comparability and/or availability across years that may influence data analysis.

This QAP outlines the quality assurance and quality control procedures implemented during all levels of data collection and processing as detailed in the protocol SOPs. Data that have undergone all quality assurance and quality control procedures and either meet stated data quality standards or are appropriately identified as not meeting the standards, are considered “certified” by the NPS. All data and reports disseminated for general (public) use will be based on certified data. Data certification

and the processes entailed by that designation (as documented in this QAP) is the primary means by which data quality is communicated to end users.

Protocol Overview, Objectives, and Sampling Design

Preserving the condition of park resources, including freshwater wetlands, unimpaired in perpetuity is the fundamental management objective of the NPS. Indeed, this “anti-degradation” or “no decline in condition” management objective captures the essence of the NPS mission and forms the underpinnings of the NPS ecological monitoring program. The purpose of the NETN Permanent Freshwater Wetland Monitoring Protocol is to collect and analyze data and report information that will help park management maintain or improve the ecological condition of the freshwater wetland resources in Acadia National Park (ACAD). Specific monitoring objectives for this protocol include:

1. Determine the status and trends in vegetation structure, including changes in herbaceous, shrub, and tree cover, using sentinel sites.
2. 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, indicators of wetland condition, and invasive species.
3. Determine the status and trends in water chemistry, including pH, conductance, and nutrients, using sentinel sites.
4. Determine baseline conditions in soil chemistry, including pH, heavy metals and nutrients, using sentinel sites.
5. Determine the status and trends of water level, including variability and seasonal patterns of water depth, using shallow wells installed in sentinel sites.
6. 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 of randomly selected wetlands in ACAD.

General workflows for sentinel site and rapid assessment monitoring (RAM) sampling efforts are presented in Figure 1. NETN uses a three-tiered approach to permanent freshwater 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 least disturbed condition of various wetland types in ACAD (Table 1). Sentinel sites are sampled every five years following the Field Operation Manual (FOM; U.S. EPA 2016a) that was developed by the EPA for the National Wetland Condition Assessment (NWCA). The FOM is implemented at each sentinel site, and includes collecting detailed site, vegetation, soil, water and hydrology data in a 40-m radius Assessment Area (AA; Figure 2A). Vegetation is sampled in five 100 m² plots, where presence of all vascular species is recorded at 1 m², 10 m² and 100 m² scales, and percent cover is estimated for the full 100 m² vegetation plot (Figure 2B). Additionally, percent cover by strata and ground layers are estimated for the whole 100 m² vegetation plot. Soils are characterized by horizon in a soil pit that is dug to a depth of 1 m, and each horizon is collected for later chemical analysis in an EPA-designated lab. Where present, surface water is described and collected for later chemical analysis in an EPA-designated

lab. Buffer condition is assessed in twelve 100 m² buffer plots located in a 100-m buffer surrounding the AA, along with a checklist of stressors present within the full 100-m buffer surrounding the AA. Note that there is an additional 100 m² buffer plot located at the center of the AA.

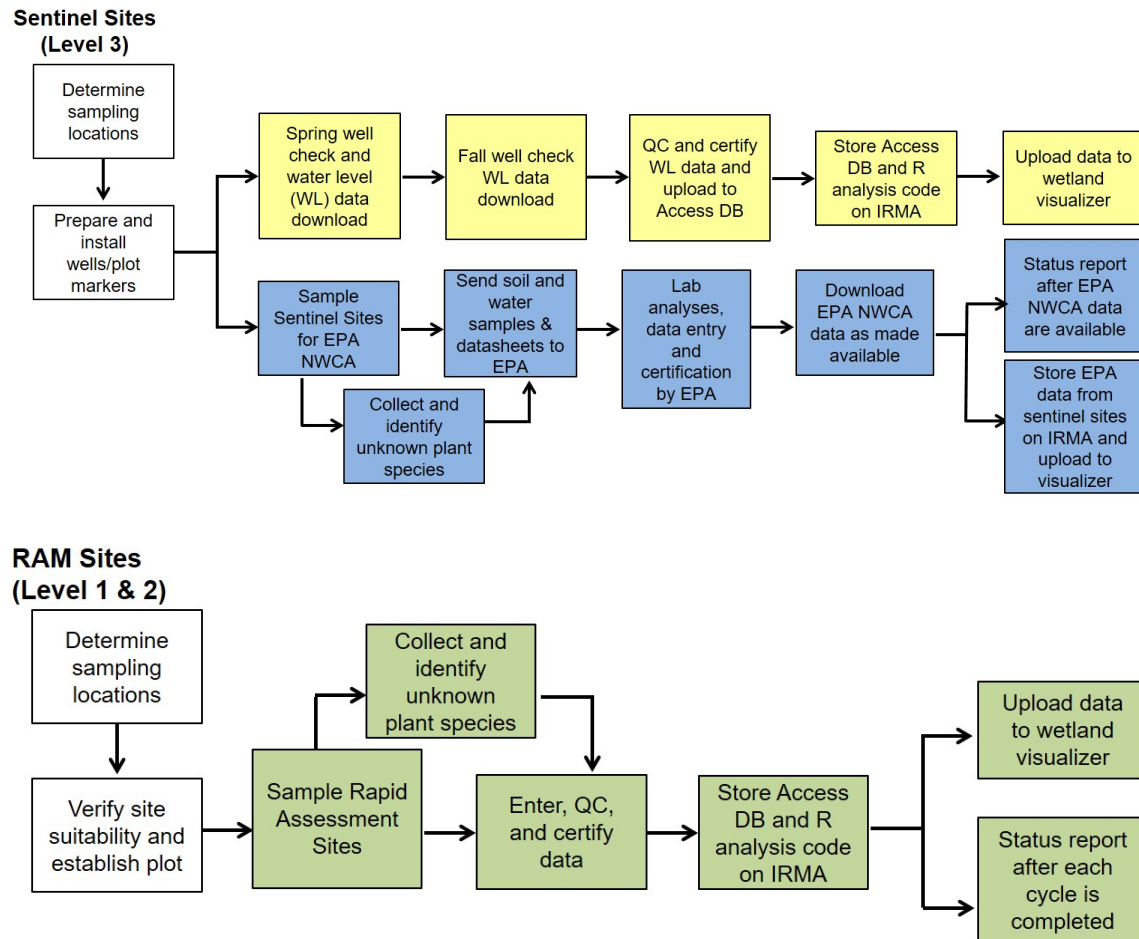


Figure 1. Workflow of protocol activities for Sentinel wetland sites (n=10) and RAM wetland sites (n=40). Tasks in white are only implemented during the initial site visit. Yellow tasks are for water level (WL) monitoring in the sentinel sites and occur every year. Blue tasks are implemented in the sentinel sites every 5th year the EPA NWCA is implemented (e.g., 2011, 2016, etc.). Green tasks are implemented annually between the EPA NWCA (2012–2015, 2017–2020, etc.). Data collected for yellow or green tasks are managed by NETN. Data collected for the blue tasks are managed by EPA.

Table 1. Panel design and number of sites sampled per year for the NETN Permanent Freshwater Wetland Monitoring Protocol. Sentinel sites are monitored intensively every 5 years for the EPA NWCA. Water level monitoring started in the fall of 2012, and is continuous in each of the 8 sentinel sites on Mount Desert Island. Rapid assessment monitoring occurs in a rotating panel of permanent sites in randomly selected wetlands.

Site/Activity Type	Panel Design	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	–	–	–	–
	Panel 2	–	–	10	–	–	–
	Panel 3	–	–	–	10	–	–
	Panel 4	–	–	–	–	10	–

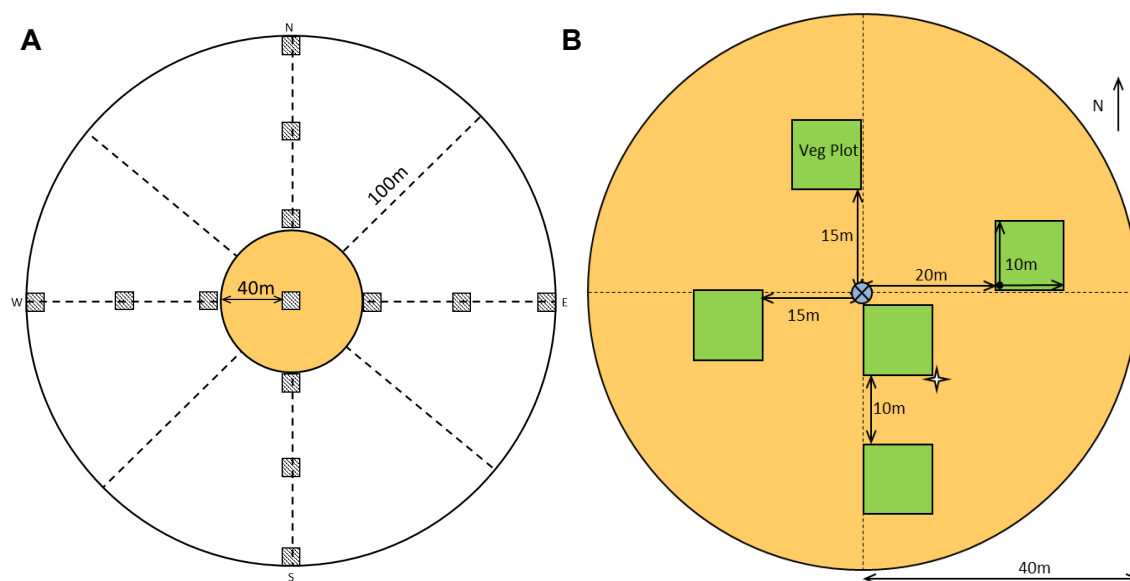


Figure 2. EPA NWCA plot design showing A) overall site including 40 m Assessment Area (orange) 100 m radius buffer (white), and 100 m² buffer plots (grey boxes) and B) Assessment Area design including vegetation plots (green), shallow well location for water level monitoring (blue circle with X), and soil sampling location (yellow star).

The data collected in the sentinel sites during the NWCA meet objectives 1–4. All data collected in sentinel sites during the EPA NWCA are entered, verified, certified, and managed by EPA. Lab samples collected in sentinel sites for the EPA NWCA are analyzed by EPA-designated labs, and associated data are managed by EPA. In addition to implementing the FOM in each sentinel site, a shallow well is located at the center of each of the eight sentinel sites on Mount Desert Island (MDI) to monitor hourly water level during the growing season, meeting objective 5.

During the four years between the EPA NWCA, NETN conducts rapid assessment monitoring (RAM), which includes Level 1 and 2 monitoring. RAM monitoring follows the USA-Rapid

Assessment Manual (USA-RAM; U.S. EPA 2011), and is conducted at 10 randomly located wetland sites per year in ACAD. RAM locations were determined using generalized random tessellation stratified (GRTS) sampling (Stevens and Olsen 2004). Each RAM site consists of a 40-m radius Assessment Area (AA) and a surrounding 100-m buffer (Figure 3). RAM monitoring follows the

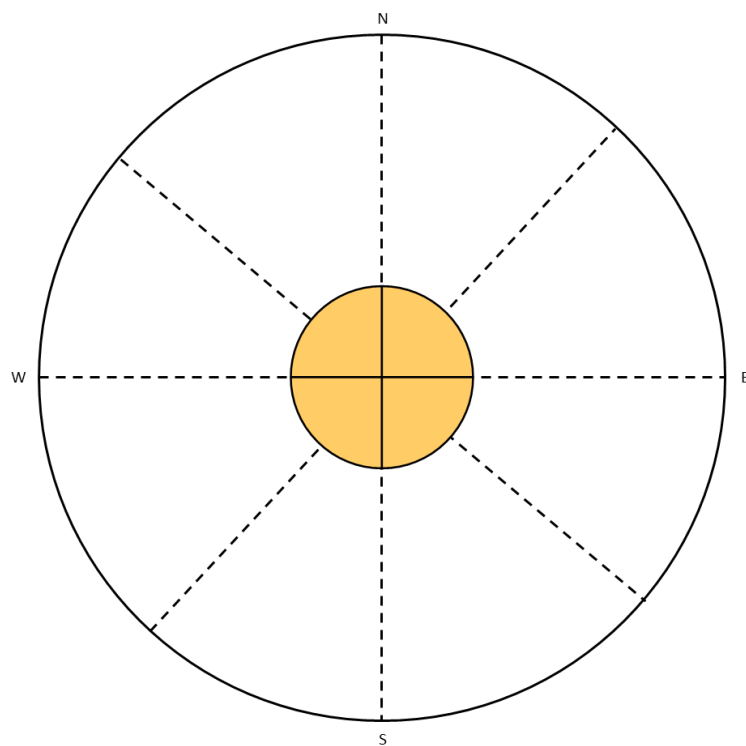


Figure 3. Design of RAM site, including a 40-m radius assessment area broken into quarters (orange circle), and 100-m buffer (white) around the AA with eight 100-m buffer transects (dashed lines).

USA-RAM (EPA 2011), and focuses on documenting the presence of stressors in the Assessment Area (AA) and buffer that could impact wetland condition, and characterizing dominant plant species by strata. In addition to the USA-RAM, NETN conducts a 15-minute timed search for plant species in each quarter of the AA (See SOP 4 – Rapid Assessment Site Establishment and Data Collection).

The RAM sample frame is a spatially balanced random sample (i.e., GRTS) of permanent freshwater wetlands that were delineated by the ACAD vegetation map (Lubinski et al. 2003). The sampling frame for both RAM and sentinel sites follows the EPA FOM, which requires a site to be largely comprised of wetland habitat with less than 10% combined non-target habitat in the 40-m radius AA. Non-target habitat includes both upland habitat and deep water (> 1 m deep).

Protocol Activities

Data are collected or derived as a part of the NETN Permanent Freshwater Wetland Monitoring Protocol in ACAD (Miller et al. 2021) in seven modules and 19 total activities (Table 2). Because protocols and quality control/quality assurance procedures are specific to each site type, activities are separated by whether they are performed in sentinel sites or in RAM sites.

Activities in sentinel sites collect data related to the site, hydrology, vegetation, soil, and surface water in the 40-m radius AA and assess condition of a 100-m buffer surrounding the AA. In addition, hourly water level is collected continuously during the growing season in the eight sentinel sites on MDI. Field methods for water level monitoring are described in detail in the NETN Permanent

Table 2. Project activity matrix for the NETN permanent freshwater wetland monitoring protocol (Miller et al. 2020). Activities are separated by sentinel site and RAM monitoring.

Activity Type	Activity #	Activity	Site Type	Description
Site Establishment	1	Site Establishment	Sentinel	Investigate suitability of site and install permanent plot markers (SOP 5), and shallow wells in sentinel sites (SOP 6).
	2	Site Establishment	RAM	Investigate suitability of site and install permanent plot markers (SOP 4).
Site Maintenance	3	Site Maintenance	Sentinel	Perform annual spring and fall well checks to download sensor data, check logger battery, and check if well shifted. If shifted, reset if necessary. and remeasure well and post height/distances (SOP 6).
Field Observations	4	Site Info and Hydrology	Sentinel	Document site (e.g., Cowardin wetland type) and hydrology info (e.g. Hydrogeomorphic class and water sources) and presence of stressors in a 40-m radius Assessment Area (AA; EPA FOM).
	5	Vegetation sampling	Sentinel	Collect vegetation data in five 100 m ² plots, including percent cover of all vascular species, percent cover by strata, percent cover by ground layer, and tree stem tallies by species and size class (EPA FOM).
	6	Soil sampling	Sentinel	Characterize soil horizon texture, color, and presence of wetland soil indicators to a depth of 1 m in a soil pit located within the AA (EPA FOM). Collect soil samples according to the EPA FOM (see activity 15 for related lab activity)
	7	Surface Water measurements	Sentinel	Where present, record characteristics, measure depth, and collect a sample according to the EPA FOM (see activity 16 for related lab activity).
	8	Site buffer assessment	Sentinel	Characterize buffer habitat and stressors in buffer plots and record presence of stressors in 100 m buffer surrounding the AA (EPA FOM.)
	9	Site Info and Hydrology	RAM	Document site and hydrology info and presence of stressors in a 40-m radius Assessment Area (USA-RAM).

Table 2 (continued). Project activity matrix for the NETN permanent freshwater wetland monitoring protocol (Miller et al. 2020). Activities are separated by sentinel site and RAM monitoring.

Activity Type	Activity #	Activity	Site Type	Description
Field Observations (continued)	10	Vegetation sampling	RAM	Conduct timed plant species search in all quarters of 40-m radius AA (SOP 4), and estimate percent cover of dominant strata, along with the 6 most dominant species per strata (USA-RAM Metric 6 & 7).
	11	Site buffer assessment	RAM	Record stressors present in 100 m buffer surrounding the AA (USA-RAM Metric 3).
Sensor Data	12	Raw water level measurements	Sentinel	Hourly pressure measurements are continuously recorded during the growing season (May 15 to September 30) using HOBO U20 pressure transducers deployed in shallow wells. Data are downloaded each spring and fall (SOP 6 & SOP 7).
	13	Photopoints	Sentinel	Photograph site conditions along each transect and AA center (EPA FOM).
	14	Photopoints	RAM	Photograph site conditions along each transect and AA center (SOP 4).
Lab Samples	15	Soil Chemistry laboratory analysis	Sentinel	Soil samples collected for chemical and bulk density analysis are collected by horizon to a depth of 1 m (EPA FOM). Samples are handled and analyzed by EPA-designated labs and follow the EPA Laboratory Operations Manual.
Lab Samples	16	Water Chemistry laboratory analysis	Sentinel	Surface water grab samples are collected for chemical analysis (EPA FOM). Samples are handled and analyzed by EPA-designated labs and follow the EPA Laboratory Operations Manual.
Data Processing	17	Water Level	Sentinel	Raw pressure data are exported as .csv files for each logger in HOBOWare, compiled into one table using the wetlandACAD R package, stored in MS Access database, and converted to water level relative to the surface using the wetlandACAD R package. Data are then checked for completeness and outliers in the R-based visualizer (SOP 7).
Quality Control Data	18	Plant ID verification	Sentinel	5 randomly selected plant species (a.k.a. "QC specimens") are collected and sent to a separate botanist per sentinel site to quantify accuracy of plant identification (EPA FOM)
	19	Observer Error Data Calculation	RAM	Every other year, 1 RAM site is resampled by separate observers to assess observer error (SOP 3).

Freshwater Wetland Monitoring Protocol standard operating procedures: SOP 6 – Shallow Well Construction, Installation, and Maintenance and SOP 7 – Using the HOBO Water Level Logger and Shuttle. All other field methods for sentinel site monitoring are described in detail in the EPA FOM (EPA 2016a).

Activities in RAM sites collect data related to site, hydrology, and vegetation in the 40-m radius AA and assess condition of a 100-m buffer surrounding the AA. Field activities related to RAM data collection are described in SOP 4 – Rapid Assessment Site Establishment and Data Collection of the the NETN Permanent Freshwater Wetland Monitoring Protocol, and follow the USA-RAM (EPA 2011). All field manuals and SOPs that are used for this protocol, including the EPA FOM and USA-RAM, are available in NETN’s Permanent Freshwater Wetland Monitoring Protocol project on IRMA (<https://irma.nps.gov/Datastore/Reference/Profile/2208704>).

Data Quality Objectives

The data quality objectives of the NETN Permanent Freshwater Wetland Monitoring Protocol is to consistently produce: 1) data of sufficient quality to meet protocol objectives outlined in Miller et al. (2020a), and 2) data of known and documented quality for all potential end-users of data and information generated by this protocol.

Data Quality Values

Several qualitative descriptors are used to help interpret and document the degree of acceptability or utility of the data to the user. These are variously referred to as “data quality indicators” (U.S. EPA 1997) and “data quality values” (DeVivo in preparation) and include the representativeness, completeness, comparability, and timeliness of the protocol dataset.

The concept of *representativeness* within the context of this monitoring protocol refers to the ability of the protocol to precisely estimate metrics of interest for the specified target population within ACAD permanent freshwater wetlands. Sampling frame and target populations, along with the methodology used to specify the sampling frame and site selection (and appropriate scope of statistical inference) are summarized above and discussed in detail in the protocol narrative sections dealing with this topic (Miller et al. 2020a). Briefly, we use a combination of intensive monitoring in ten hand-picked sentinel sites, and rapid assessments in a larger number of randomly selected RAM sites. The RAM sites are a representative sample of mapped permanent freshwater wetlands in ACAD, and are used to assess overall status and trends in wetland condition in the park. Because sentinel sites were non-randomly selected, data from these sites cannot be used for inference to the larger population of wetlands 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 RAM sites.

Sampling *completeness* is defined following Stanley and Verner (1985) as “a measure of the amount of data collected from a measurement process compared to the amount that was expected under the conditions of measurement.” The number of sampling sites and required data measures at each site were carefully planned and piloted over a period of years to achieve a balance among protocol objectives, available budget, and field season length (phenological as well as logistical constraints). Quality assurance procedures ensure that all required data are collected in the field and entered in their corresponding database. Where possible (e.g., RAM sites), all required data are entered directly into a database in the field, which ensures that all required data are checked for completeness before leaving the site. As of 2019, greater than 99% of data values required each year have been collected and entered into their associated database (i.e., EPA vs. NETN databases). For the water level data, some data may be excluded during the QC process, if anomalies are detected. In addition, wells often shift over the winter due to frost heaves, ice, and other conditions. Water level relative to wetland surface cannot be calculated on a shifted well until the distances and heights for the well and posts are remeasured during the spring check. If a well is not stable after it shifted, it is also extracted and reset. Occasionally, spring well visits are delayed because of late park road openings due to winter storm damage or otherwise undriveable conditions. Given these constraints, water level analyses for

this protocol focus on the growing season, and will aim for 90% completeness of water level data during the growing season to generate hydrology statistics.

Data *comparability* refers to the confidence with which one data set can be compared to another. To achieve maximum utility, this protocol must yield data that are consistent and comparable from one year to the next, and to the extent possible with other NPS, state and Federal programs, particularly the EPA. Comparability among years is achieved through strict adherence to the standard operating procedures (available at: <https://irma.nps.gov/Datastore/Reference/Profile/2208704>), including thorough documentation of any changes or revisions to procedures in the revision section at the end of each SOP. Protocol changes and/or deviations from the protocol that could affect data comparability among years are also documented in the Summary of Major Protocol Changes and Deviations (Miller 2020). In addition, sites are monitored within two weeks of previous sampling dates to ensure phenological consistency. To assess data comparability among years for the RAM sites, one RAM site is remeasured by different observers within the same season (called a QA/QC visit). However, because wetlands are extremely sensitive to trampling, QA/QC visits are only conducted every other year in one RAM site per panel. In addition, the NETN Permanent Freshwater Wetland Monitoring Protocol closely follows methods developed by the EPA for the NWCA, allowing for regional and even national comparisons with sites sampled for the EPA NWCA.

Timeliness refers to the length of time required to collect, process, and certify data relative to the intended uses of the data. Data collection in the sentinel sites for the NWCA occurs every five years. Data entry, checking and processing of NWCA data are handled entirely by the EPA. NWCA data are made available as they are certified by the EPA, and are typically disseminated publicly as .csv flat files before the next NWCA commences. Data collection for RAM monitoring occurs during the four years between the NWCA, with all field work completed by NETN staff by the end of August of each sampling year. Because most of the RAM data is collected digitally in the field, the time requirements for post-field data entry, verification, validation, and processing are relatively minimal. RAM data are therefore certified by the end of September of each sampling year. Growing season water level data are downloaded every fall (after October 1). Water level data are compiled, validated, and certified by the end of each calendar year.

Given the relatively short turn-around for RAM and water level data certification, and that EPA only distributes certified data, the use of provisional data will not routinely occur and will be limited to rare circumstances. See the Data Certification and Dissemination section below.

Data Quality Standards

To meet the data quality objectives above, four data quality standards are defined and documented below: 1) measurement quality objectives, 2) taxonomic standards, 3) accreditation standards, and 4) policy and protected data standards.

Measurement Quality Objectives

Measurement quality objectives are data quality requirements specifying the level of bias and precision (and in some cases resolution, sensitivity, etc.) of equipment, sensors, or observers to reliably measure characteristics of the target population. Bias is a systematic difference between a

measured value and the true value and represents an estimate of systematic measurement error. Precision is the degree of mutual agreement among repeated measurements and represents an estimate of random measurement error. Collectively these data characteristics provide an estimate of the total uncertainty surrounding any measurement (typically referred to as accuracy). In many cases, however, assessing bias in vegetation data is not meaningful because true values are not measurable/known. Therefore, we primarily focus on measurements of precision to assess data quality for this protocol.

The measurement quality objectives for permanent freshwater wetland monitoring activities (see Table 2) are presented and summarized in Table 3 and are based largely on standards developed by EPA for the NWCA as detailed in their Quality Assurance Project Plan (QAPP; U.S. EPA 2016c). Note that because lab analyses for activities 15 and 16 are performed entirely by the EPA, measurement quality objectives for these lab analyses are not included in this QAP, but can be found in U.S. EPA (2016c).

Training is conducted prior to the field season to ensure that field personnel are capable of collecting data that meet the measurement quality objectives. Field personnel are also assessed on their ability to collect data that meet the measurement quality objectives throughout the field season (see Observer Error section under Quality Assurance Procedures below).

Table 3. Measurement quality objectives for measures collected and derived by NETN in the implementation of this protocol. In sentinel sites, the field crew is visited by trained EPA staff for a Quality Assurance Visit (QA Visit). Quality objectives for EPA NWCA are based on results of the QA Visit, which are handled by EPA staff. RAM sites, in contrast, are resampled periodically for QA/QC. Quality objectives for RAM sites are based on comparisons between the field crew and the QA/QC visit to calculate precision. Quality objectives for soil and water lab analyses are managed by EPA and reported in the EPA QAPP (U.S. EPA 2016c) and not listed here.

Activity Type	Activity #	Activity	Site Type	Measure	Quality Objective	References
Site Establishment	1	Site Establishment	Sentinel	Record UTM X and Y Coordinates at plot center	<5 m location error on GPS unit	SOP 2
	2	Site Establishment	RAM	Record UTM X and Y Coordinates at plot center	<5 m location error on GPS unit	SOP 2
Site Maintenance	3	Site Maintenance	Sentinel	Check for well shift with bubble level	The measuring point at the top of well and the level line marked on each of 2 posts should be level. Bubble must be within the 2 lines to be considered level.	SOP 6
	3	Site Maintenance	Sentinel	Well and post heights and distances	All height/distance measurements should be within 10% of previous measurement if not shifted.	SOP 6
Field Observations	4	Site Info and Hydrology	Sentinel	Hydrogeomorphic Class	100% agreement during EPA QA Visit	EPA FOM ; EPA QAPP
	4	Site Info and Hydrology	Sentinel	Cowardin Habitat Classification	100% agreement during EPA QA Visit	EPA FOM ; EPA QAPP
	4	Site Info and Hydrology	Sentinel	Water sources present in AA	90% agreement during EPA QA Visit	EPA FOM ; EPA QAPP
	4	Site Info and Hydrology	Sentinel	Stressors present in AA	90% agreement during EPA QA Visit	EPA FOM ; EPA QAPP
	4	Site Info and Hydrology	Sentinel	Wetland Indicators present	90% agreement during EPA QA Visit	EPA FOM ; EPA QAPP
	5	Vegetation	Sentinel	Taxonomic resolution	≥ 90% of observations are identified to species	EPA FOM ; EPA QAPP

Table 3 (continued). Measurement quality objectives for measures collected and derived by NETN in the implementation of this protocol. In sentinel sites, the field crew is visited by trained EPA staff for a Quality Assurance Visit (QA Visit). Quality objectives for EPA NWCA are based on results of the QA Visit, which are handled by EPA staff. RAM sites, in contrast, are resampled periodically for QA/QC. Quality objectives for RAM sites are based on comparisons between the field crew and the QA/QC visit to calculate precision. Quality objectives for soil and water lab analyses are managed by EPA and reported in the EPA QAPP (U.S. EPA 2016c) and not listed here.

Activity Type	Activity #	Activity	Site Type	Measure	Quality Objective	References
Field Observations (continued)	5	Vegetation	Sentinel	Taxonomic accuracy	≤ 15% taxonomic disagreement between field crew and QC botanist for the 5 QC specimens collected in each plot, derived by Activity 18.	EPA FOM; EPA QAPP
	5	Vegetation	Sentinel	Percent cover by species, strata, and ground layer type	±10% precision during EPA QA Visit	EPA FOM ; EPA QAPP
	5	Vegetation	Sentinel	Tree stem counts by size class	±10% precision during EPA QA Visit	EPA FOM ; EPA QAPP
	6	Soil	Sentinel	Hydric Indicators present	90% agreement during EPA QA Visit	EPA FOM ; EPA QAPP
	6	Soil	Sentinel	Water saturation and inundation level	±10% precision during EPA QA Visit	EPA FOM ; EPA QAPP
	6	Soil	Sentinel	Number and characterization of horizons	90% agreement during EPA QA Visit	EPA FOM ; EPA QAPP
	6	Soil	Sentinel	Horizon depths	±10% precision during EPA QA Visit	EPA FOM ; EPA QAPP
	7	Surface Water	Sentinel	Water depth	±10% precision during EPA QA Visit	EPA FOM ; EPA QAPP
	8	Buffer	Sentinel	Percent cover by strata in Buffer Plots	±10% precision during EPA QA Visit	EPA FOM ; EPA QAPP
	8	Buffer	Sentinel	Number and type of stressors in Buffer Plots	±10% precision during EPA QA Visit	EPA FOM ; EPA QAPP
	8	Buffer	Sentinel	Number and type of stressors in 100-m buffer	±10% precision during EPA QA Visit	EPA FOM ; EPA QAPP
	9	Site Info and Hydrology	RAM	Hydrogeomorphic Class	100% agreement between field crew and NETN QA/QC visit	EPA FOM ; EPA QAPP

Table 3 (continued). Measurement quality objectives for measures collected and derived by NETN in the implementation of this protocol. In sentinel sites, the field crew is visited by trained EPA staff for a Quality Assurance Visit (QA Visit). Quality objectives for EPA NWCA are based on results of the QA Visit, which are handled by EPA staff. RAM sites, in contrast, are resampled periodically for QA/QC. Quality objectives for RAM sites are based on comparisons between the field crew and the QA/QC visit to calculate precision. Quality objectives for soil and water lab analyses are managed by EPA and reported in the EPA QAPP (U.S. EPA 2016c) and not listed here.

Activity Type	Activity #	Activity	Site Type	Measure	Quality Objective	References
Field Observations (continued)	9	Site Info and Hydrology	RAM	Cowardin Habitat Classification	100% agreement between field crew and NETN QA/QC visit	EPA FOM ; EPA QAPP
	9	Site Info and Hydrology	RAM	Water sources present in AA	90% agreement between field crew and NETN QA/QC visit	EPA FOM ; EPA QAPP
	9	Site Info and Hydrology	RAM	Stressors present in AA	90% agreement between field crew and NETN QA/QC visit	EPA FOM ; EPA QAPP
	9	Site Info and Hydrology	RAM	Wetland Indicators Present	90% agreement between field crew and NETN QA/QC visit	EPA FOM ; EPA QAPP
	10	Vegetation	RAM	Taxonomic resolution	≥ 90% of observations are identified to species	SOP 4
	10	Vegetation	RAM	Taxonomic accuracy	≥ 90% of species in common between field crew and QA/QC visit	SOP 4
	10	Vegetation	RAM	Percent cover by species, strata, and ground layer type	±10% precision between field crew and NETN QA/QC visit	SOP 4; USA-RAM
	11	Buffer	RAM	Number and type of stressors in 100-m buffer	±10% precision between field crew and NETN QA/QC visit	SOP 4; USA-RAM
Sensor Data	12	Raw Water Level	Sentinel	Seasonal timing of well visits	Spring and fall well visits must occur every year. Spring well visits should occur before May 15 if possible, and no later than June 1. Fall well visits occur between October 1 and November 1.	SOP 7
	13	Photopoints	Sentinel	Image	Transect centered in photo, and contains 90% of the same area as the photograph from the previous visit.	EPA FOM

Table 3 (continued). Measurement quality objectives for measures collected and derived by NETN in the implementation of this protocol. In sentinel sites, the field crew is visited by trained EPA staff for a Quality Assurance Visit (QA Visit). Quality objectives for EPA NWCA are based on results of the QA Visit, which are handled by EPA staff. RAM sites, in contrast, are resampled periodically for QA/QC. Quality objectives for RAM sites are based on comparisons between the field crew and the QA/QC visit to calculate precision. Quality objectives for soil and water lab analyses are managed by EPA and reported in the EPA QAPP (U.S. EPA 2016c) and not listed here.

Activity Type	Activity #	Activity	Site Type	Measure	Quality Objective	References
Sensor Data (continued)	14	Photopoints	RAM	Image	Transect centered in each photo, and contains 90% of the same area as the photograph from the previous visit.	SOP 4
Lab Samples	15	Soil Chemistry	Sentinel	–	–	See U.S. EPA (2016c)
	16	Water Chemistry	Sentinel	–	–	See U.S. EPA (2016c)
Data Processing	17	Water Level	Sentinel	Growing season water level	Changes that are >1 SD (based on growing season water level) from previous and/or following hourly measurement are all explainable by a precipitation event, and not due to logger error.	SOP 7 ; Miller and Weed 2017
	17	Water Level	Sentinel	Variability in water level among years	Large shifts (>15 cm) in average water level among years are all explainable by changes in hydrology (e.g., beaver occupation) or varying rainfall, and not due to well height measurement error.	SOP 7 ; Miller and Weed 2017
	17	Water Level	Sentinel	Growing season hydrology statistics	≥ 90% water level data complete for each site per year sufficient for calculating growing season statistics.	SOP 7 ; Miller and Weed 2017
Quality Control Data	18	Vegetation	Sentinel	–	–	Used to assess taxonomic accuracy for activity 5.

Table 3 (continued). Measurement quality objectives for measures collected and derived by NETN in the implementation of this protocol. In sentinel sites, the field crew is visited by trained EPA staff for a Quality Assurance Visit (QA Visit). Quality objectives for EPA NWCA are based on results of the QA Visit, which are handled by EPA staff. RAM sites, in contrast, are resampled periodically for QA/QC. Quality objectives for RAM sites are based on comparisons between the field crew and the QA/QC visit to calculate precision. Quality objectives for soil and water lab analyses are managed by EPA and reported in the EPA QAPP (U.S. EPA 2016c) and not listed here.

Activity Type	Activity #	Activity	Site Type	Measure	Quality Objective	References
Quality Control Data (continued)	19	Observer Error Data Calculation	RAM	–	–	Used to assess performance standards for activities 9, 10, 11, 14

Taxonomic Standards

All plant taxa observations specify both the taxon name and the reference used for making the identification. The taxonomic standard for all species data collected for this protocol is Flora Novae Angliae (Haines 2011), and we will continue to follow this standard until an updated or more appropriate standard becomes available. Plant nomenclature follows the master plant list in the NETN RAM database table (tlu_Plant), which is based on the Integrated Taxonomic Information System (ITIS.gov). The master plant list is updated every 5 years to be consistent with the latest ITIS nomenclature designations.

Accreditation Standards

No professional or lab accreditations are required for this protocol that are not already handled through EPA-designated labs for the NWCA.

Policy and Protected Data Standards

According to federal policy, data collected by NETN are to be made public. However, there are limited cases in which data may be withheld from release to protect park resources. Dissemination of certain information could put particular resources at risk, and some cultural and natural resource information is protected from public disclosure by resource confidentiality laws. These laws prohibit agencies from releasing protected information except in limited, specified circumstances.

The process of identifying protected data, including which data are protected, the degree of protection warranted, and if/how data will be disseminated was completed by NETN and ACAD staff, and signed by the park Superintendent in 2019.

As a general rule, NETN provides as much monitoring data as possible to the public to facilitate communication and collaboration. NETN therefore does not generally protect location data, such as coordinates of monitoring sites. However, a number of species that are rare in the state of Maine and/or vulnerable to poaching could potentially occur in our freshwater wetland monitoring sites. The locations of these species, if found, will be redacted from all publicly available datasets. The redacted data will be available upon request, but all requests will be reviewed by NETN and ACAD staff to ensure that providing these data will not result in unwanted resource impacts. The permanent freshwater wetland database does not store personally identifiable information or any other data that would require legal protection.

Quality Assurance Procedures

This section describes the quality assurance procedures implemented during all levels of data collection and processing for the Permanent Freshwater Wetland Monitoring Protocol. Quality assurance procedures are employed to minimize errors in data collection and ensure that data are collected according to established and documented standards (to the greatest extent possible). Achieving the data quality objectives for this protocol is a continuous process that follows an annual cycle, including: hiring, training, oversight and communication, data collection, operational review, data entry, and data verification.

Hiring

The experience, dedication, and temperament of field staff are likely the most important factor in obtaining quality field data. This protocol is implemented by the Plant Ecologist and a Plant Ecology Technician. The Plant Ecology Technician must be a qualified candidate who has demonstrated experience with vegetation data collection in the field and in the identification of woody and herbaceous plants in New England. As part of the interview process, all applicants take a plant identification quiz to assess their identification proficiency with a variety of northeastern plant species ranging from trees to forbs. There is no minimum score required to be considered for hiring, rather the intent is to provide information to the protocol lead on applicants' observation skills, interest in plant identification, and strengths/weaknesses with different taxonomic groups. In addition, the Plant Ecologist should have a strong background in wetland ecology, including knowledge of soils and hydrology, and either have advanced wetland plant identification skills, or rely on a contract botanist for plant identification.

Training

During EPA NWCA years, the Plant Ecologist and Plant Ecology Technician are both required to participate in a week-long training that includes classroom and field-based sessions on the Field Operations Manual, which contains all of the procedures used during the EPA NWCA. During the years between the EPA NWCA, the Plant Ecologist will train the Plant Ecology Technician on the RAM protocols, which includes reading all of the RAM-related SOPs, practicing data entry with the FileMaker app, and field-based training on plant ID, sampling methods and proper use of a compass and GPS unit. The Plant Ecologist is responsible for ensuring that the Plant Ecology Technician gains the skills needed to implement the protocol, and is responsible for ensuring that the Plant Ecology Technician and any additional staff and volunteers are accurately following the procedures in the protocol. The Plant Ecology Technician also participates in forest crew training, an intensive week-long training that is held at the beginning of the field season. Forest crew training covers many topics in detail that are relevant to permanent freshwater wetland monitoring, including estimation of percent cover, plant identification, use of a compass, and field safety.

Oversight and Communication

This protocol is implemented by the Plant Ecologist and a Plant Ecology Technician. Because the Plant Ecologist samples every site alongside the Plant Ecology Technician, oversight and communication are straightforward, and the Plant Ecologist can oversee data collection and provide feedback to the Plant Ecology Technician on every plot.

Data Collection

The procedures listed in Table 4 highlight important activities that assure data quality during data collection. Additional guidance (e.g., proper field procedures) on every step of the protocol is described in detail in the EPA FOM for sentinel site monitoring, and the USA-RAM and protocol SOPs for RAM and water level monitoring (available at: <https://irma.nps.gov/Datastore/Reference/Profile/2208704>). Before preparing to complete a module of the FOM (sentinel sites) or before leaving a RAM site, all data must be checked for completeness and quality. Data on datasheets should be checked for missing or unusual values, and any identified errors or omissions detected are corrected before moving on to another FOM module and/or before leaving a site. All data collected using the electronic database (FileMaker app) for RAM sites must be checked for completeness and quality using the checker tool. Field staff cannot pull up the transect tapes and prepare to leave a RAM site until the checker clears and the reviewer records their initials in the "Verified by" box.

Table 4. Quality assurance procedures implemented by NETN when collecting and entering data for the Permanent Freshwater Wetland Monitoring Protocol (Miller et al. 2020a).

Activity Type	Activity #	Activity	Site Type	Measures	QA Procedures	When implemented	Reference(s)
Site Establishment	1	Site Establishment	Sentinel	Permanent plot markers installed	Training and oversight in the field; verified by EPA QA Visit.	Establishment of new plot	EPA FOM; SOP 5
	2	Site Establishment	RAM	Permanent plot markers installed	Training and oversight in the field.	Establishment of new plot	SOP 6
Site Maintenance	3	Site Maintenance	Sentinel	Well shift	Training and oversight in the field; detailed datasheets including a well diagram detailing measurements taken each visit; strict adherence to SOP.	Every spring and fall well visit	SOP 6
Field Observations	4	Site Info, Hydrology, and Stressors	Sentinel	Site characteristics, wetland classification and indicators, and presence of stressors	EPA NWCA training and EPA QA Visit; oversight by protocol lead, and strict adherence to guidance and definitions in EPA FOM to characterize each site.	During the EPA NWCA	EPA FOM
	5	Vegetation	Sentinel	Taxonomic accuracy and resolution	EPA NWCA training and QA Visit; training and oversight by protocol lead on plant ID; strict adherence to guidance and definitions in EPA FOM to sample vegetation plots; hiring qualified staff with plant ID skills.	During the EPA NWCA	EPA FOM

Table 4 (continued). Quality assurance procedures implemented by NETN when collecting and entering data for the Permanent Freshwater Wetland Monitoring Protocol (Miller et al. 2020a).

Activity Type	Activity #	Activity	Site Type	Measures	QA Procedures	When implemented	Reference(s)
Field Observations (continued)	5	Vegetation	Sentinel	Percent Cover by species, strata, and ground layer type	EPA NWCA training and QA Visit; training and oversight by protocol lead on plant ID, percent cover estimation and definitions of strata and ground layers; strict adherence to guidance and definitions in EPA FOM to sample vegetation plots.	During the EPA NWCA	EPA FOM
	5	Vegetation	Sentinel	Tree stem counts by size class	EPA NWCA training and QA Visit; training and oversight by protocol lead on plant ID and measuring diameter at breast height; strict adherence to guidance and definitions in EPA FOM to sample vegetation plots.	During the EPA NWCA	EPA FOM
	6	Soil	Sentinel	Hydric Indicators and depth of inundation and saturation	EPA NWCA training and QA Visit; staff read and carry Field Indicators of Hydric Soils manual (USDA-NRCS 2018); training and oversight by protocol lead on hydric indicators; strict adherence to guidance and definitions in EPA FOM to classify wetland soils.	During the EPA NWCA	EPA FOM; Field Indicators of Hydric Soils

Table 4 (continued). Quality assurance procedures implemented by NETN when collecting and entering data for the Permanent Freshwater Wetland Monitoring Protocol (Miller et al. 2020a).

Activity Type	Activity #	Activity	Site Type	Measures	QA Procedures	When implemented	Reference(s)
Field Observations (continued)	6	Soil	Sentinel	Number, depth, and characterization of horizons	EPA NWCA training and QA Visit; oversight and training by protocol lead on soil sampling and classification; strict adherence to guidance and definitions in EPA FOM to sample soil horizons.	During the EPA NWCA	EPA FOM
	7	Surface Water	Sentinel	Water depth	EPA NWCA training and QA Visit; training and oversight by protocol lead on surface water sampling and classification; strict adherence to guidance and definitions in EPA FOM to sample surface water.	During the EPA NWCA	EPA FOM
	8	Buffer	Sentinel	Percent cover by strata and number and type of stressors in buffer plots	EPA NWCA training and QA Visit; training and oversight by protocol lead on buffer sampling and stressor definitions; strict adherence to guidance and definitions in EPA FOM to sample buffer plots.	During the EPA NWCA	EPA FOM
	8	Buffer	Sentinel	Number and type of stressors in 100-m buffer	EPA NWCA training and QA Visit; training and oversight by protocol lead on 100-m radius buffer sampling and stressor definitions; strict adherence to guidance and definitions in EPA FOM to identify buffer stressors.	During the EPA NWCA	EPA FOM

Table 4 (continued). Quality assurance procedures implemented by NETN when collecting and entering data for the Permanent Freshwater Wetland Monitoring Protocol (Miller et al. 2020a).

Activity Type	Activity #	Activity	Site Type	Measures	QA Procedures	When implemented	Reference(s)
Field Observations (continued)	9	Site Info and Hydrology	RAM	Site characteristics, wetland classification and indicators, and presence of stressors	Training and oversight on site characteristics and definitions by protocol lead, field staff read and carry USA-RAM manual; strict adherence to guidance and definitions in the USA-RAM and SOP 5; data entry and QA in FileMaker app.	Each RAM sample event	SOP 4; USA-RAM
	10	Vegetation	RAM	Taxonomic accuracy and resolution	Training and oversight by protocol lead on plant ID; strict adherence to SOP 4 and the USA-RAM; hiring qualified staff with plant identification skills; data entry and QA in FileMaker app.	Each RAM sample event	SOP 4; USA-RAM
	10	Vegetation	RAM	Percent Cover by species, strata, and ground layer type	Training and oversight by protocol lead on plant ID, percent cover estimation and definitions of strata and ground layers; strict adherence to guidance and definitions in USA-RAM and SOP 4; data entry and QA in FileMaker app.	Each RAM sample event	SOP 4; USA-RAM
	11	Buffer	RAM	Number and type of stressors in 100-m buffer	Training and oversight by protocol lead on buffer sampling and stressor definitions; strict adherence to guidance and definitions in USA-RAM and SOP 4 to identify buffer stressors; data entry and QA in FileMaker app.	Each RAM sample event	SOP 4; USA-RAM

Table 4 (continued). Quality assurance procedures implemented by NETN when collecting and entering data for the Permanent Freshwater Wetland Monitoring Protocol (Miller et al. 2020a).

Activity Type	Activity #	Activity	Site Type	Measures	QA Procedures	When implemented	Reference(s)
Field Observations (continued)	4–12	Data recording error or omission	All sites	All fields on datasheets	Measurer will call out value and recorder will repeat value to ensure data are recorded correctly and not missed.	When one person is measuring and the other is recording on the plot.	SOP 3
	4–8	Data recording error or omission	Sentinel	All fields on datasheets	Field personnel must review all sections of the field datasheets to ensure all fields are complete and no obvious errors exist. The reviewer should not be the recorder.	After each module (e.g., soil, buffer plots) of the FOM is complete at a given site.	EPA FOM
	9–11	Data recording error or omission	RAM	All fields in FileMaker App	Field personnel must run the checker in the FileMaker app to ensure that all data are complete, and add their initials in the verified by box. If the app is not available, datasheets should be reviewed by the person who was not the recorder. Initials indicate quality assurance is complete.	At the end of each RAM sample event, and before transect tapes are removed.	SOP 3; SOP 4

Table 4 (continued). Quality assurance procedures implemented by NETN when collecting and entering data for the Permanent Freshwater Wetland Monitoring Protocol (Miller et al. 2020a).

Activity Type	Activity #	Activity	Site Type	Measures	QA Procedures	When implemented	Reference(s)
Sensor Data	12	Raw Water Level	Sentinel	Hourly water level	Spring and fall visits ensure that well shifts, which often happen in winter, are caught and that loggers are replaced (if needed) before the growing season starts; protocol lead downloads, processes and manages water level data; strict adherence to guidance in SOP 6 and SOP 7.	Every spring and fall well visit	SOP 6; SOP 7
	13	Photopoints	Sentinel	Photo-document site conditions	Training and oversight on camera use; strict adherence to EPA FOM	During the EPA NWCA	EPA FOM
	14	Photopoints	RAM	Photo-document site conditions	Training and oversight on camera use; strict adherence to SOP 4	Each RAM sample event	SOP 4
Lab Samples	15	Soil Chemistry	Sentinel	Complete and accurate sample documentation	EPA NWCA training and QA Visit; training and oversight by protocol lead on collection and post-collection procedures for soil samples; weekly validation of soil sample datasheets by EPA.	During the EPA NWCA	EPA FOM
	16	Water Chemistry	Sentinel	Complete and accurate sample documentation	EPA NWCA training and QA Visit; training and oversight by protocol lead on collection and post-collection procedures for water samples; weekly validation of water sample datasheets by EPA.	During the EPA NWCA	EPA FOM

Table 4 (continued). Quality assurance procedures implemented by NETN when collecting and entering data for the Permanent Freshwater Wetland Monitoring Protocol (Miller et al. 2020a).

Activity Type	Activity #	Activity	Site Type	Measures	QA Procedures	When implemented	Reference(s)
Data Processing	17	Water Level	Sentinel	Hourly water level	All raw data are compiled and converted to water level relative to the surface using R scripts and functions in the wetlandACAD package to ensure repeatability, transparency and minimize errors due to manual compiling and conversions in Excel.	After every fall well visit	SOP 7

Observer Error

Every other year of RAM sampling, NETN resamples one randomly selected site to determine observer error and the repeatability of field data collection. Resampling is completed within two weeks (preferably within 1 week) of the original sampling. Field personnel for re-measurement must include a separate botanist from the Plant Ecologist to sample and identify all plant species for QA/QC. The QA/QC botanist must have strong plant identification skills and thorough knowledge of wetland classification and stressor definitions. The Plant Ecologist compares all data from both sampling visits, and data are flagged if there are any inconsistencies that do not meet the performance standards (Table 3).

Operational Review

At the completion of the field season, NETN conducts operational reviews of the Permanent Freshwater Wetland Monitoring Protocol (Mitchell et al. 2018). This review includes the Plant Ecologist meeting with the Plant Ecology Technician soon after the field season is completed to identify lessons learned in terms of operational efficiencies, logistical or technical challenges, unexpected field conditions, etc. Data from QA/QC visits are also compared with the initial visit to identify measurements that need fine-tuning or require additional training to ensure repeatability. Identifying unusual data collection circumstances that are not adequately addressed in the SOPs is a key component of the operational review. In addition, the Plant Ecologist will hold an operational review during the off season with NETN staff, including the Program Manager, Data Manager, and Forest Crew Leader, to discuss any proposed protocol changes or issues. Based on these discussions, the SOPs are revised as needed to provide better guidance to future field crews.

Data Entry, Verification, and Management

Data collected for the EPA NWCA in sentinel sites are recorded on paper datasheets, and each datasheet is assigned to a specific staff member for the entire field season (e.g., Plant Ecologist is in charge of V-1 forms; Plant Ecology Technician is in charge of W-1 form) to ensure that each datasheet is filled out correctly and consistently. Datasheets are then verified in the field by field staff not assigned to that datasheet, and this should occur before moving on to a different module of the FOM and before preparing to leave the site. All data collected for the EPA NWCA in the sentinel sites are entered, verified and certified by EPA staff and are managed in EPA databases. NETN is therefore only responsible for ensuring that all datasheets are accurate and complete before sending the datasheets to EPA (Figure 4A).

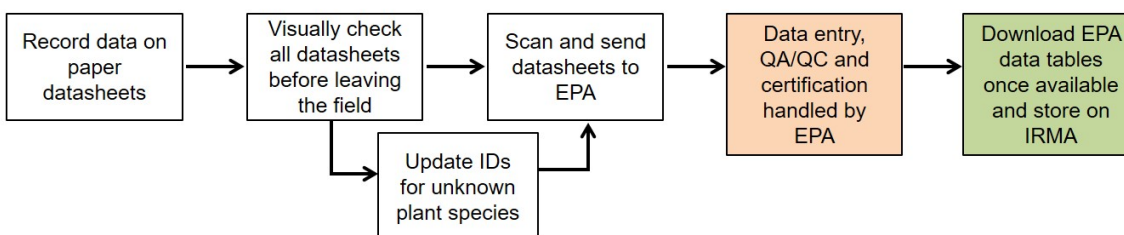
Water level monitoring in the sentinel site is not part of the EPA NWCA. Therefore, NETN staff are responsible for performing all data entry, QA/QC procedures, and data management tasks (Figure 4B). For each fall well visit, well measurement data, such as well height and in situ water level, are recorded on datasheets in the field, and raw water level data are downloaded from Hobo loggers. After each fall well visit, well measurement data are entered and verified in the `tbl_Well_Visit` table in the NETN RAM database (see 100% and 10% verification process below). The well measurement data are then imported into R using functions in the [wetlandACAD R package](#) for later use in the water level conversion process. The raw water level data files are exported from .hobo files to .csv files in HOBOWare, and then imported into R using functions in the

wetlandACAD R package. The raw water level data is then converted to water level relative to the surface using functions in the wetlandACAD package, and then exported to a .csv for further Quality Control checks (see Quality Control Procedures below). The water level and well measurement data are considered "provisional" at this stage. Note that because Quality Control procedures for the water level data are performed in R, and because each growing season produces over 30,000 hourly water level records, the water level data are not imported into the NETN RAM database until after the certification process has been completed in R (See Data Certification section below).

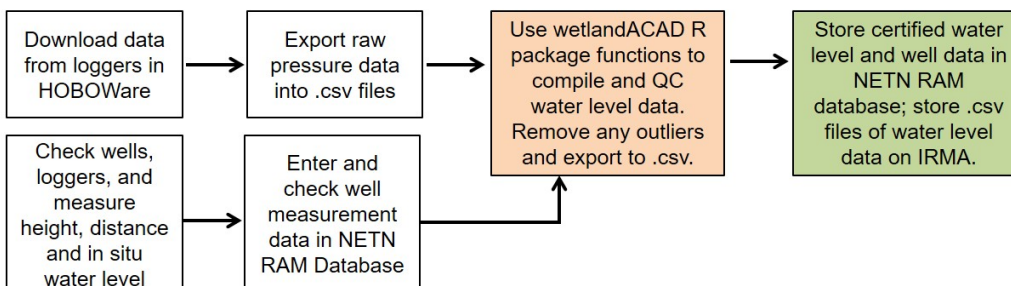
Data collected in the RAM sites are digitally collected in the field using a FileMaker app installed on an iPad (Figure 4C). By using the FileMaker app, data entry errors are minimized through the use of automated methods within the forms (e.g., range limits, pick lists, and calendars) and scripts that check for logical inconsistencies (e.g., a stressor recorded as present, but with a severity rank of 0 instead of 1–3). The app also includes a checker tool that verifies that all required fields are complete and displays any missing data points that are required for a visit. The checker must be cleared in the field before pulling up transect tapes in preparation of leaving the site. Once the checker clears, QA tasks are complete for that site, and all but unknown species data are considered "provisional" (See Data Certification section below). Additional Quality Control checks are then performed during the certification process (see Quality Control Procedures below).

If the FileMaker app is not available for data entry, RAM data are recorded on datasheets and verified in the field using the same approach as for the sentinel sites. RAM data that were recorded on datasheets are then entered into the FileMaker app and follow a two-step verification process. Data entry is first verified with a 100% check of records to the original datasheets. After the 100% check is completed, a random 10% check is conducted. In the 10% check, 10% of datasheets are randomly selected and the data in the app are checked against the datasheet. If any data entry errors are detected during the 10% check, another 100% check must be conducted, followed by another

A) Sentinel Sites: EPA NWCA



B) Sentinel Sites: Water Level Data



C) RAM Sites

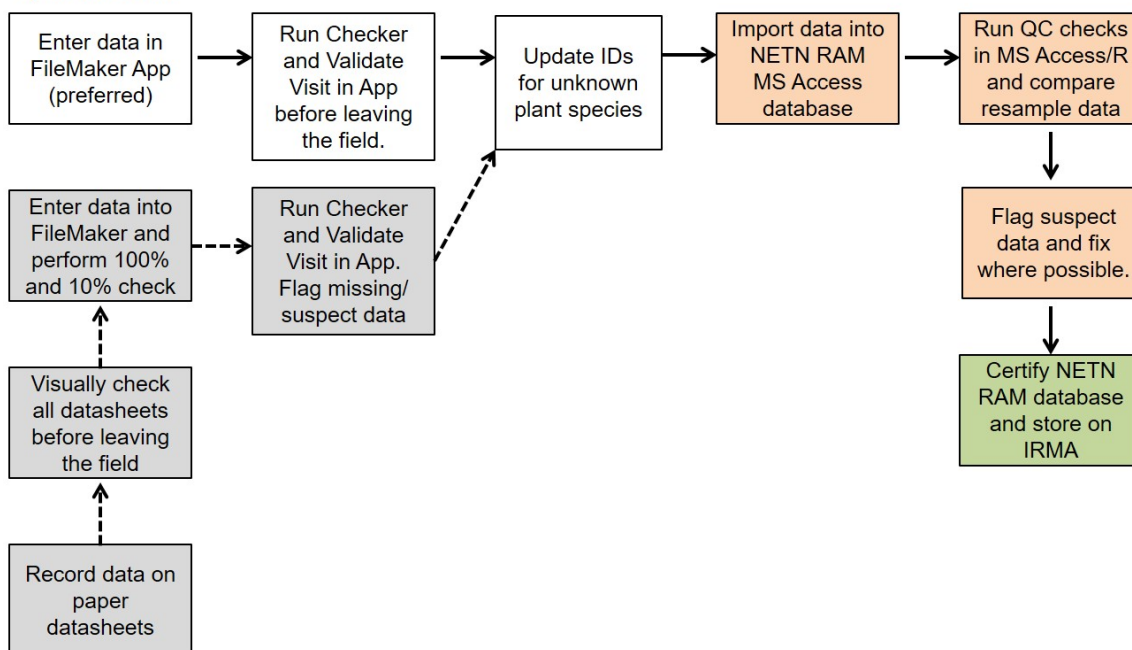


Figure 4. Data flow for sentinel sites sampled for the EPA NWCA, Sentinel site water level data, and RAM site data. Tasks in grey are only performed if an iPad is not available for data entry in the field. Quality assurance occurs in white boxes. After all tasks in white boxes are complete, data are considered provisional. Quality control procedures are performed in orange boxes. After all tasks in orange boxes are complete, data are certified. Green boxes reflect the final data product that is certified and stored on IRMA.

random 10% check. This process is repeated until no data entry errors are detected during the 10% check. After the data in the app are verified to accurately reflect the original field data, the paper forms are archived and the electronic version is used for all subsequent data activities. After the 10% check is accepted, the checker is run for each visit to identify any data omissions or errors. Errors identified in the check that can be resolved are corrected on the paper data sheets and in the app. If these errors can not be resolved, they are documented in the location-level notes field for the site, so the data can be checked during the next visit. After the data are verified for a given site, the person verifying records their initials on the top margin of the datasheets for that site. At this stage, the data for each site are considered provisional (See Data Certification section below). After all RAM data entry (including all unknowns being identified) and checking are complete for a given year in the FileMaker app (i.e., all records in the "provisional" stage), tables are exported to .xlsx files using the Export Tool in the FileMaker app. An MS Access Import Database then loads the exported .xlsx files and appends them to the associated tables in the NETN RAM backend database. Once the RAM data are appended to the NETN RAM backend, further quality control checks are performed to complete the certification process (See Quality Control Procedures).

The tables and data fields in each table of the NETN RAM database are defined in a data dictionary which is populated from the project database and seamlessly integrated with the current data. The data dictionary is a separate document that is stored alongside the QAP. The database schema in the NETN RAM database also matches the database schema in the FileMaker app. For each table in the database, the data dictionary provides a description of the table and explains when data are collected. For each field within the table, the data dictionary provides the field name and description, accepted values, and whether the field is required.

Quality Control Procedures

Quality control (QC) procedures evaluate data to ensure they meet documented standards. Any data that do not meet those standards are rectified through correction, or flagged using documented annotation.

Data Validation

Following data verification, additional quality control steps are conducted on key data components for data validation (Table 5). However, because much of the data collected for this protocol are either entered digitally in the FileMaker app, which has thorough quality assurance measures, or managed by EPA staff (see EPA QAPP; U.S. EPA 2016c), the list of quality control steps for this protocol is fairly limited and only covers a few of the activities in Table 2.

Errors identified through data validation for the RAM sites are corrected on paper field forms (if not recorded in FileMaker app) and in the database. Errors recognized through data validation that cannot be corrected are identified in the Notes field at the record, table, or location-level, as appropriate. These errors are revisited during next sampling of the plot. Based on assessments of data collected from 2010 – 2019, errors identified during data validation that cannot be corrected occur on <0.001% of the data collected per year.

Errors identified through validation of the water level data are either removed or corrected in the dataset prior to importing the water level data into the NETN RAM database. This includes removing water level measurements recorded while water levels were stabilizing after a well was reset, and removing outliers that are >1 standard deviation, based on growing season water level, from the previous and following water level measurement that cannot be explained by a precipitation event. In addition, hydrographs and growing season statistics are compared among years within a site to identify water level shifts that cannot be explained by hydrological changes (e.g., beaver occupation, culvert replacement), or varying rainfall, and that may be the result of well height measurement error. If an error is suspected in the well height measurement and the well was reset, the well must be revisited and the height remeasured. If the well was not reset, the well height from the previous year can be used in the conversion to water level relative to surface. Most of the water level QC checks are conducted in the wetland visualizer, an R-based web application that can be run internally using provisional data for this process. Based on assessments of data collected from 2013 – 2019, water level outliers that had to be removed occurred in <0.001% of the data collected per year, and no well measurement errors have been identified.

Table 5. Quality control procedures implemented by NETN when collecting, entering, or deriving data for the Permanent Freshwater Wetland Monitoring Program in ACAD (Miller et al. 2020a).

Activity Type	Activity #	Activity	Site Type	Measure	QC Procedures	Corrective Action	When Implemented	Implementation Environment
Site Establishment	1	Site Establishment	Sentinel	Plot Location	Compare plot location coordinates entered in database with coordinates collected by GPS unit.	Correct coordinates in database to match GIS file coordinates.	Establishment of new plot	ArcGIS
	2	Site Establishment	RAM	Permanent plot markers installed	Compare plot location coordinates in database with coordinates in GIS files from GPS unit.	Correct coordinates in database to match GIS file coordinates.	Establishment of new plot	ArcGIS
Field Observations	9, 11	Site Info and Hydrology & Buffer	RAM	Presence of stressors in AA and buffer	Compare stressors to previous visit and aerial photos to check if any were potentially missed	Update stressor list for current site	All RAM sample events	NETN RAM Frontend
	10	Vegetation	RAM	Vascular plant identification	Query for duplicate species records within a site	Combine presence by quarter, then remove duplicate values. If duplicates are due to unknown species, assign unique taxa identifiers (e.g., Carex-1, Carex-2)	All RAM sample events	NETN RAM Frontend
	10	Vegetation	RAM	All species identifications	Generate species list for each RAM site, and review for possible plant ID errors.	Investigate unusual species IDs and correct any erroneous IDs. Record change in Notes field of table.	All RAM sample events	NETN RAM Frontend

Table 5 (continued). Quality control procedures implemented by NETN when collecting, entering, or deriving data for the Permanent Freshwater Wetland Monitoring Program in ACAD (Miller et al. 2020a).

Activity Type	Activity #	Activity	Site Type	Measure	QC Procedures	Corrective Action	When Implemented	Implementation Environment
Derived Data	17	Water Level	Sentinel	Outlier check	Plot water level on hydrographs to visually check for outliers unexplained by precipitation events. Outliers are records that are >1 SD from previous and following record that cannot be explained by precipitation.	Remove outliers.	After each fall well visit for every site	Internal ACAD wetland visualizer
Derived Data	17	Water Level	Sentinel	Major water level shift	Plot water level on hydrographs to visually check for large shifts in water level between years that could be due to incorrect well height measurement	If a shift in water level cannot be explained by hydrological changes (e.g., beaver occupation), and well was reset, revisit well and take new measurement. If well was not reset, use previous year's well height measurement and recalculate water level.	After each fall well visit for every site	Internal ACAD wetland visualizer
	17	Water Level	Sentinel	Water level acclimation	Plot water level on hydrographs for wells that were reset in the spring to identify the measurements that were recorded before water level stabilized in a given well.	Remove data collected while water level was stabilizing.	After each fall well visit for every site that was reset	Internal ACAD wetland visualizer

Observer Bias

We use repeated visits (called QA/QC visits) to randomly selected RAM sites within the same year to quantify sampling bias and evaluate the performance of important measures, like the vegetation multimetric indicator. Because wetlands are very sensitive to trampling, QA/QC visits are only conducted every other year of RAM sampling, and only occurs in one RAM site per year. Data from resampled visits are entered as QA/QC visits and excluded from standard queries and analyses (e.g., rating overall park MMIs). Due to limited staff and funds, QA/QC events will be sampled by an independent contract botanist and the Plant Ecology Technician. The contract botanist must have thorough knowledge of wetland plants in coastal Maine, but is unlikely to know the full protocol. Therefore, the Plant Ecologist can be present for sampling to help set up the site and answer questions about the protocol, but cannot influence or be involved in data collection.

In addition to QA/QC in RAM sites, taxonomic accuracy of the Plant Ecologist is measured during the EPA NWCA. Taxonomic accuracy is assessed from 5 randomly selected species per sentinel site that are sent to a separate botanist for identification. Results can be used to update past identifications and/or to flag suspect species identifications or noteworthy changes in nomenclature.

Documentation

Data Certification

Data that have undergone all quality assurance and quality control procedures described above are considered “certified” by the NPS. Data certification is the process confirming that:

- Data have been through all QA/QC procedures as outlined above.
- Data either meet specified quality standards, or data that do not meet those standards are appropriately identified and communicated at the record level.
- Data are suitable for general use.

The levels of data processing are:

Raw: Data in their state of original collection, either in the form of paper or electronic field forms, electronic sensor files, or digital media (photo, video, or audio). These data generally have been collected following some QA procedures, but have not undergone any QC procedures.

Provisional: Data that have undergone incomplete QA/QC procedures as defined in the QAP and are not suitable for general use. Provisional data may be used in some cases, however, depending on the amount of QA/QC completed, and the intended use.

Accepted: Data that have undergone all QA and QC procedures as defined in a published protocol and associated SOPs. Used in cases where a Quality Assurance Plan has not been developed and approved.

Certified Data. Data that a) have been through all QA/QC procedures as outlined in the Quality Assurance Plan, b) meet expected quality standards, or are appropriately identified and annotated at the record level in cases where they do not meet those standards, c) have documented procedures for data collection, processing, and transformation in appropriate metadata formats, and d) are suitable for use.

The data processing level is documented in the NETN RAM database at the visit level for RAM sites (i.e., in tbl_Visit) and well data (i.e., in tbl_Well_Visit). In both tables, data processing level is documented in a Certification_Level field, where raw data are recorded as "R", provisional data are recorded as "P", accepted data are recorded as "A", and certified data are recorded as "C". Note that because RAM data already undergo thorough quality assurance in the FileMaker app, the lowest data processing level recorded for RAM visits in the NETN RAM database is P, provisional. In addition, water level data are not stored in the NETN RAM database until the certification process is completed using R software scripts; the lowest data processing level recorded for water level data in the NETN RAM database is therefore C, certified.

The certified level is the final data processing level (i.e., all data in the database application are considered *provisional* while they undergo the various QA and QC procedures). All subsequent changes to certified data are documented in the tbl_Visit_Metadata table in the NETN RAM database

where a description of the change is provided along with the date of change and the individual who made the change.

Data certification will occur within one month of data collection for the RAM sites and by the end of the calendar year for well visits. The Plant Ecologist is responsible for certifying that all processes described above have occurred.

Archive of Records

Once data from a field season have been certified, the following files are archived on the NETN Server:

- NETN RAM database containing the most recently certified and all previously certified data.
- Version of all the NETN Permanent Freshwater Wetland Monitoring Protocol documents, EPA manuals, blank field data sheets used for data collection, and the latest version of the FileMaker app.
- Electronic copies of all completed field data sheets, scanned after data validation.
- The most recent shapefile of all sites monitored for this protocol, if updated since last sample.
- Labelled photopoints from both sentinel and RAM sites.

In addition, a database containing most recent year's certified data and all previously certified data is posted yearly to the NPS Data Store, with references linking the database to the NETN Permanent Freshwater Wetland Monitoring Protocol documents and EPA manuals.

For all reports generated from the NETN Permanent Freshwater Wetland Monitoring Protocol, the following files are archived on the NETN Server:

- Final manuscript with manuscript submittal form (if NPS NRR/NRTR series), both of which are also posted to the respective NPS Data Store reference.
- Draft of report submitted for peer review, along with peer review comments and author responses to those comments.
- Database containing the data and queries used in the creation of the report.
- Analytical code (e.g., R script) and flat data files (e.g., csv files) used for data analysis presented in the report.

Metadata

At the time of writing in 2020, IMD has convened a working group that will ultimately issue guidance on required metadata and its dissemination.

Information Dissemination

All data reports, analyses, and dissemination of data for general (public) use will be based on accepted or certified data. In general, data will be certified prior to internal use for supporting park-, regional-, or national-level resource management decisions. However, in some cases the use of provisional data (data that have not undergone complete QA/QC as defined in this QAP) may be warranted to base decisions on best-available science.

Communicating Data Quality

Data certification and the processes entailed by that designation (as documented in this QAP) are the primary means by which data quality is communicated to end users. A descriptive paragraph or document for each report or data set will include the following link

(<https://irma.nps.gov/Datastore/Reference/Profile/2208704>) to the NETN Permanent Freshwater Wetland Monitoring Project in the NPS Data Store to ensure that data can be traced to the latest version of the protocol, all associated standard operating procedures and documents, and this QAP.

Protocol Quality Assessment

This section outlines a series of periodic reviews and evaluations to be conducted as part of the implementation of this protocol (Table 6). These quality checks promote a cyclic process of continuous feedback and improvement of both the data and the quality planning process. The protocol lead is responsible for organizing and conducting the reviews and assessments and for ensuring that summary information, deviations from SOPs, data nonconformities, new ideas and methods, etc. are properly documented (revisions to the protocol narrative, SOPs, QAP and/or Safety Plan).

Table 6. Data quality evaluations to be conducted as a part of implementing the NETN Permanent Freshwater Wetland Monitoring Protocol (Miller et al. 2020).

Evaluation	Purpose & Description	Frequency
Field Season Review	Protocol lead meets with field crew members to identify lessons learned in terms of operational efficiencies, logistical or technical challenges, unexpected field conditions, safety issues, etc. Based on these discussions, the SOPs are clarified or updated as needed to provide better guidance to future field crews. See QA Procedures above.	Annually at completion of field season.
Data Quality Evaluation: Data Completeness	Evaluate the number of sites sampled as compared to the number of sites previously sampled in the panel.	Annual as data are certified.
Data Quality Evaluation: Data Timeliness	Measure of time required to certify data.	Annual as data are certified.
Data Quality Evaluation: Data Quality Assessment	Measure the number of data points that do not meet performance standards based on observer error sampling.	Annual as data are certified for every year that QA/QC revisits are performed
Annual Operational Review	Protocol lead obtains feedback from staff and supervisor on protocol implementation. Ensures that the protocol remains in sync with annual monitoring activities. Documents changes in procedures and equipment. Captures lessons learned as changes to be made going forward. Provides NETN staff with an opportunity to discuss the state of the science of the protocol. Based on these discussions, protocol documents are clarified or updated as needed.	Annually at completion of field season.
Scientific Review	Does the protocol meet its stated objectives and produce the best available science? A targeted scientific review addresses one or two specific facets of the protocol (e.g., sampling frequency, field procedures). A full scientific review takes a holistic, in-depth look at the protocol, due to multiple potential areas of concern about the protocol's ability to meet its objectives (Mitchell et al. 2018).	Periodically.

A separate protocol review (which includes a full scientific review and overall assessment of whether the collected data are sufficient to meet protocol objectives) occurs periodically. These should occur when substantial changes are made to protocol objectives or processes, concurrent with a significant data analysis/trend detection report, or as requested by a supervisor. Based on these criteria, protocol reviews should occur approximately every five years.

Roles, Responsibilities, and Qualifications

This section identifies the reporting relationships between all organizations involved in the project, including the lead organization and all contractors and subcontractors. Summaries of staff roles are provided in Table 7. Current names and contact information for these staff are available at:

<https://www.nps.gov/im/netn/who-we-are.htm>.

Table 7. Roles, responsibilities and contact information for persons affiliated with implementation of the NETN Permanent Freshwater Wetland Monitoring Protocol (Miller et al. 2020a).

Position	Role
Regional Program Manager	QAP approval, protocol approval & ensuring that data meet quality objectives
Network Program Manager	Program coordination; oversight of development and implementation of monitoring protocols; ensure protocol implementation meets NPS scientific integrity standards and all data meet DQOs; conduct appropriate peer review of all published products
Plant Ecologist/ Protocol Lead	Protocol implementation; oversee staff training and operation; coordination with EPA NWCA; coordination of all data collection, entry, validation, verification and certification; ensure all data meet DQOs; organize and conduct protocol quality assessment reviews; data analysis and reporting
Protocol Data Manager	Manage FileMaker app, import function to MS Access, and NETN RAM database
Forest Crew Leader	Assist Plant Ecologist with spring and fall well visits
Plant Ecology Technician	Complete mandatory training; collect field data accurately as described in the Standard Operating Procedures; identify plants accurately and/or process unknown plants for later identification; ensure that all field-based QAP procedures are followed; enter data accurately into the project database and follow data entry QAP procedures
Contract Botanist	Sample for RAM QA/QC visits and identify EPA NWCA QC specimens

Plant Ecologist

The Plant Ecologist is the protocol lead and is responsible for coordinating and implementing all aspects of the project, including leading the field work, training field staff, data management, implementation of the QAP, and analysis/reporting. S/he is responsible for developing and revising the protocol and the protocol documents. This person is also responsible for coordinating with EPA for the NWCA and maintaining relationships and participating in periodic conference calls with EPA staff. During NWCA years, the Plant Ecologist must participate in the weeklong NWCA training on the FOM. The Plant Ecologist will ensure that all training and permit requirements are met and that project supplies and equipment are in order. The Plant Ecologist must have a solid background in wetland ecology and thorough knowledge of wetland plants in the Acadian region of Maine.

Forest Crew Leader

The Forest Crew Leader will assist with spring and fall well visits to the 8 sentinel sites on Mount Desert Island to download data from the loggers and reset any wells that shifted.

Plant Ecology Technician

One Plant Ecology Technician will be required to sample sentinel and rapid assessment sites. Depending on funding and year (i.e., NWCA or RAM year), this position can vary from a GS-4 Biological Science Technician for NWCA years, to a cooperator (e.g., Student Conservation Association Intern) for RAM years. During NWCA years, this position will attend EPA NWCA training on the FOM. During the RAM years, the Plant Ecologist will provide all necessary training. The Plant Ecology Technician will work closely with the Plant Ecologist, and will be responsible for data collection in the field and data entry into the project database. The Plant Ecology Technician may be graduate or undergraduate students who have strong interest or experience in wetland ecology and/or botany. S/he must be able to learn and identify common plants found in Acadia wetlands, and all identifications will be verified by the Plant Ecologist. Specific tasks that the Plant Ecology Technician will be responsible for include:

- complete mandatory training
- collect field data accurately as described in the Standard Operating Procedures
- identify plants accurately and/or process unknown plants for later identification
- ensure that all field-based QAP procedures are followed
- enter data accurately into the project database and follow data entry QAP procedures.

Contract Botanist

The contract botanist will sample RAM sites during QA/QC visits, and will be the lead on plant identification during these QA/QC visits. This can be the same botanist that identifies QC specimens collected during the EPA NWCA in the sentinel sites. The contract botanist must have a thorough knowledge of wetland plants in the Acadian region of Maine.

Protocol Data Manager

The Protocol Data Manager will be responsible for maintaining both the FileMaker app for entering data in the field, along with the MS Access database where the data are ultimately stored. S/he will also maintain the import functions in MS Access that transfer the data from the FileMaker app to MS Access. The Protocol Data Manager will develop and maintain the wetlandACAD R package, scripts used for QA/QC and analysis, and the R-based wetland visualizer. S/he will also ensure that all individuals involved in the project are aware of their data management responsibilities and that the QAP is implemented. Currently, this role is filled by the Plant Ecologist, with assistance from the NETN Data Manager, where needed.

Network Program Manager

The Program Manager will be responsible for overseeing the development and implementation of the Permanent Freshwater Wetland Monitoring Protocol and the other vital sign protocols. S/he will ensure that this protocol is aligned with and contributing towards network goals. The Program Manager will also provide support in budget, personnel, and logistical matters. S/he is responsible for reviewing and ensuring publications derived from protocol implementation meet NPS scientific integrity standards, that data and reports are released in a timely fashion, and that the QAP is implemented as written and approved.

Regional Program Manager

The Regional Program Manager will be responsible for responsible for approving this QAP, and accountable for ensuring that data being collected under approved protocols meet stated quality objectives.

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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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