Wells National Estuarine Research Reserve
Sentinel Site Application Module-1 Plan

Photo Credit: Amelie Jensen

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Primary Reference Materials
The following document outlines and details the Wells National Estuarine Research Reserve (WNERR) plan to establish a National Estuarine Research Reserve System (NERRS) Sentinel Site to monitor climate change impacts in the estuaries of the Reserve. This plan has been guided by the following documents and reports: NERRS System-Wide Monitoring Program (SWMP), Sentinel Site Application Module 1 (SSAM1), Program Plan Development and Review (SSAM-1 Workgroup, 2020), the NERRS Sentinel Sites Program Guidance for Understanding Climate Change Impacts (NERRS 2012), the Coastal Habitat Response to Changing Water Levels NERR SSAM1 (NOAA-OCM 2016), and NERRS Vegetation Monitoring Standard Operating Procedure: Long-term Monitoring of Estuarine Vegetation Communities (NERR Biomonitoring Workgroup 2020). Additional insights for developing this SSAM-1 Plan were drawn from approved plans written by: ACE Basin NERR (Leffler et al. 2013), Delaware Bay NERR (St. Laurent 2017), and South Slough NERR (Schmitt & Helms 2017). This SSAM-1 Plan outlines the rationale for establishing a Sentinel Site and summarizes the methods WNERR will employ for maintaining a long-term monitoring program , which are detailed in the SWMP Program Plan (NERRS 2011), the NERRS SWMP Vegetation Monitoring Protocol (Moore 2013 & NERR Biomonitoring Workgroup 2020), Accurate Elevations for Sea Level Rise Sentinel Sites (NOAA-NOS 2019), The Surface Elevation Table and Marker Horizon Technique (NPS 2015), WNERR Site Profile (Dionne 2006), and the WNERR Tier II Monitoring Plan (Dionne & Tyrrell 2006).

Maps and GIS Data Attribution
Map coordinate system: NAD83 (2011) State Plane Maine West 1802.
Basemaps and Orthoimagery were obtained from Earth Systems Research Institute. State boundaries were obtained from the Maine Office of GIS. Watershed boundaries and NHD flowlines were obtained from USGS. Benchmark and CORS were obtained from NGS. Tidal benchmark locations were obtained from CO-OPS.

Wells National Estuarine Research Reserve
DRAFT Sentinel Site Application Module 1 Plan

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Webhannet River Estuary (Wells Reserve)

I. Introduction

Reserve Overview and Physical Setting

The Wells National Estuarine Research Reserve (Wells Reserve) is positioned at 43°19'N and 70°34'W in the Wells Embayment on the Gulf of Maine (GOM), located in Wells, ME (Fig. 1.1). The Wells NERR lies in the geographic center of the GOM shoreline in a transition area where the sandy beaches of southern New England are interspersed with the dominant rocky shoreline found in mid-coast and eastern Maine. The GOM is a dynamic system with cold ocean waters, deep basins, shallow banks, and dramatic tidal ranges in places. Its waters span 93,240 km^2 (36,000 mi^2) and is innervated by 60 major rivers that flow into it. The GOM is bounded by the Canadian provinces of Nova Scotia and New Brunswick and the U.S. states of Maine, New Hampshire, and Massachusetts. Water in the GOM generally flows counterclockwise, traveling southwestward from New Brunswick and Nova Scotia (reviewed in Pettigrew et al. 2005**,** also see: Dionne 2006, WNERR Mgt. Plan 2019). Cold waters enter the GOM through the Northeast Channel south of Nova Scotia, with an occasional influx of warmer water (and warm-core eddies) from the Gulf Stream. The tidal range in the GOM is large, with the highest tides in the world occurring in the Bay of Fundy. Semi-diurnal tides have a typical range of 2.6 - 3.0 m (8.5 to 9.8 ft.) in the Wells embayment. Strong tidal currents keep the waters of the GOM well mixed, which increases the availability of nutrients to zooplankton and higher-trophic animals.

The Wells Embayment is defined by its arcuate coastline and lies offshore between the Kennebunk River and the Ogunquit River inlets. The embayment has an irregular seafloor dominated by bedrock outcrop and relict deposits of glacial sediments from the last major North American ice sheet. Geophysical technology allows us to visualize the layers below the surface and glimpse the sediments of the seafloor (Kelley et al. 1988). Sand is only a thin cover on the nearshore in most places (Miller 1998). The barrier system at the Wells Reserve comprises two beaches: Wells Beach south of Wells Inlet, and Drake's Island Beach and Laudholm Beach (a single system) to the north, and Crescent Surf Beach, part of the Laudholm/Drakes Island barrier beach system. Wells Beach is a barrier spit, anchored on the till and bedrock outcrops of Moody Point. Drakes Island/Laudholm Beach, located between Wells Inlet and Little River Inlet, is a barrier island anchored on till. The barrier and inlet complex of the Wells Reserve is near the northern end of a semi-continuous chain of barrier islands and spits stretching southwest along the coast of Maine, New Hampshire, and Massachusetts to Cape Ann.

Figure 1.1. *Geographical setting of the Wells Reserve within the larger Gulf of Maine (GOM) ecosystem.*

Hydrology

The Webhannet River watershed has a drainage area of 3,627 ha. (8,964 acres), entirely contained within the Town of Wells. The Webhannet's major tributaries are Depot Brook, Eldridge River, and Blacksmith Brook and flow into the Webhannet River estuary. Extensive wetlands and salt marshes near the Webhannet River mouth empty into Wells Harbor, which flows into the Wells embayment via a 122 m wide dredged channel between two jetties (Argow 2006).

The Little River estuary is formed by the confluence of the Merriland River and Branch Brook. Together, the three waterways have a drainage area of 8,116 ha. (20,057 acres). The Merriland River has its headwaters in the City of Sanford and crosses the Town of Wells. Branch Brook originates from several springs near the Sanford municipal airport and serves as the border between the towns of Kennebunk and Wells. The Kennebunk-Kennebunkport-Wells Water District draws public water from Branch Brook, reducing its flow to the Little River. The Little River estuary flows to the Wells Embayment via a salt marsh protected by an unarmored double-spit barrier beach with an inlet that changes frequently.

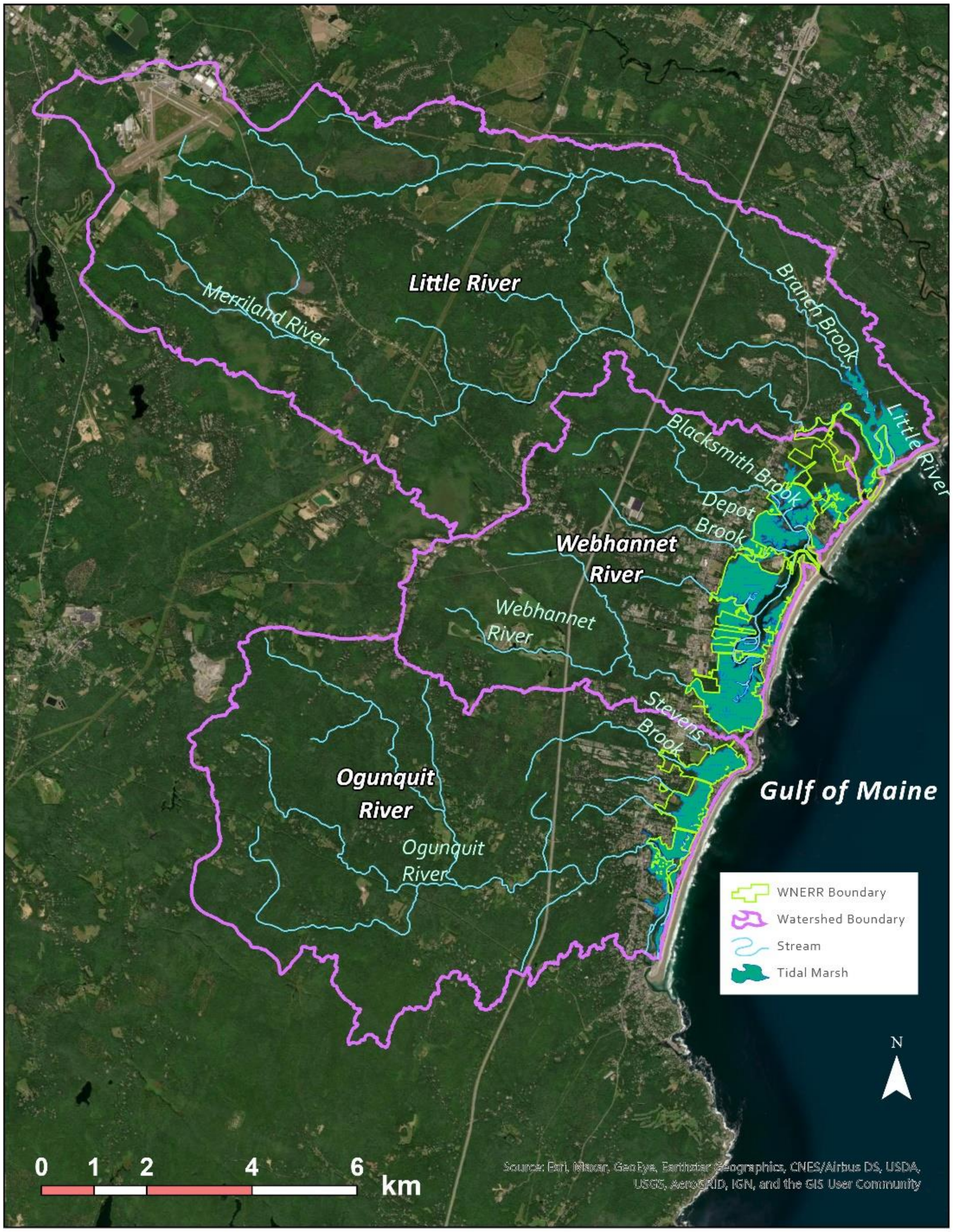

Figure 1.2. *The Wells Reserve includes area in the watersheds of the Ogunquit River, Webhannet River, and Little River, including 1,300 acres of tidal marsh.*

The Ogunquit River watershed covers approximately 5,382 ha. (13,300 acres) within the towns of Wells, York, Ogunquit, and South Berwick. Green Brook and Steven's Brook are major tributaries, with Tatnic Brook and several smaller tributaries also converging with the main stem of the river. The expansive salt marshes of the Moody Division of Rachel Carson National Wildlife Refuge are located behind a 3.2 km-long barrier beach and dune system. The Ogunquit River empties into the GOM in the Town of Ogunquit.

The Wells Reserve also extends support to other watersheds in southern Maine's coastal zone communities from the Salmon Falls River to Casco Bay. Project initiatives and reports for some of these studies can be found on the Wells Reserve website, www.wellsreserve.org.

Habitat Types

The three estuarine systems that comprise the Wells Reserve (Webhannet River, Little River, and Ogunquit River) encompass three broad habitat types: wetlands, upland (natural and developed), and beach (sandy and rocky), each containing a wide range of environmental conditions. The diversity, large size and close vicinity of these habitats makes for an ecologically rich area, a setting which has become exceptionally rare along the coast of New England. The diversity of habitats is actively protected and managed by a consortium of local, state, and federal entities, including the Wells Reserve (see Wells Reserve Mgt. Plan, 2019). The wetlands of the Wells Reserve include salt marsh, red maple swamp, shrub swamp, and brackish marsh, with salt marsh being the dominant habitat type at 1,200 acres (reviewed in Widoff 1986, Short 1988, Dionne 2006). Over the past 3,000-4,000 years, these salt marshes formed behind double spit barrier beaches. Complex plant associations, intricate drainage channels, extensive marsh pools, and regular inundation by a large tidal range mark this high energy habitat. This intertidal zone bears the marks of its diverse geologic history, with mud flats, fine to coarse sands, and cobble and boulder beaches. Resident and migratory fish and birds make their diets of the invertebrates that inhabit this area.

Barrier System

The Wells Reserve barrier system itself is a long, low coastal feature. Stretching a total of 4.7 km (2.9 mi.) in a gently curving arc from its anchor points on Moody Point to the till that forms Drakes Island, the barrier island stands only 2 - 4 m (6.5 - 13 ft) above mean sea level. The Wells barrier beach is heavily developed, and large sections of the beach have been stabilized by sea walls or revetments. Stabilization protects property in the short term but alters the natural evolution of the barrier complex and prevents the island from migrating landward via natural overwash processes under rising sea level scenarios.

Salt Marsh

The extensive salt marshes of the Webhannet River, Little River, and Ogunquit River are among the largest in the state of Maine. These dynamic systems form a broad, flat, vegetated platform deeply incised by tidal channels and creeks. These intertidal environments cover ~ 526 ha (1,300 acres, Short 1988, Dionne 2006) and are the most obviously recognizable ecosystem in the Wells Reserve for many visitors. These systems formed over the last 4,000 years or so during a time of relatively slow sea-level rise (approximately 10 cm per century), but today face a much higher rate of sea level rise (about ~ 25 cm in the last century). Rates of sea level rise are expected to keep accelerating, resulting in the inundation and loss of these salt marshes if they are not able to maintain their position relative to rising sea level (Dionne 2006).

There are two major classifications of salt marsh ecosystems found in the Wells Reserve. Low marsh systems form between mean tide level and mean high water (generally 0.8 - 1.3 m (2.6 - 4.3 ft.) above mean sea level) and are commonly defined in the field by their vegetation. Vegetation communities are typically comprised almost exclusively of the halophyte (salt-tolerant) smooth cordgrass (*Spartina alterniflora*) at lower elevations and salt marsh hay (*Spartina patens*) at higher elevations (see section III.b, Vegetation Monitoring, for more details). Likewise, low marsh ecosystems are restricted to narrow ribbons along tidal creeks and to slumped ramps along the main tidal channels. The high marsh, in contrast, inhabits broad, fairly level marsh platform and makes up the majority of the marsh system in these three estuaries (Dionne 2006). High marsh is formed at elevations around and above mean high tide (1.39 m (4.5 ft.) above mean sea level at Wells Inlet), up to the upland margin ecosystem that begins at the limit of highest spring tidal inundation ~ 2 m (6.5 ft.) above mean sea level).

<u>Tidal Flats and Channels</u>
Tidal flats make up a relatively small percentage of the total intertidal area of the Wells Reserve. This sediment-rich environment is characterized by gentle slopes and sandy or muddy substrate and is home to a diverse population of benthos. Tidal flats may form at elevations from spring low tide (1.45 m (4.7 ft.) below mean sea level) to spring high water (1.45 m above mean sea level), depending on the amount of energy along the shore from waves and tidal currents. A system of tidal creeks and channels incise the salt marshes and tidal flats drain the intertidal region during ebb tides. The tidal network is also the conduit for rising flood tidal waters, until the water level reaches the height of the banks and floods the marsh surface, after which tidal flow in the back-barrier is driven by estuary-wide circulation patterns.

<u>Uplands</u>
Upland soils in the Wells Reserve are developed on the glacial and glaciomarine material that was deposited during and after the last glaciation. These sediments blanketed the pre-existing landscape with a layer of clay and large, often linear mounds of till. This material has developed into a relatively deep, well-drained soil layer rich in mineral material, called a sandy loam (Argow 2006). The Wells Reserve uplands exhibit variations of these soil types, but are generally sandy and well-drained, with low water tables. The excellent hydraulic conductivity of the soils enhances infiltration of rainwater, resulting in less freshwater runoff and fewer streams draining to the lowlands. In relatively low-lying areas near the salt marsh, waterlogged wooded areas have a lacustrine (lake) soil type or are covered by freshwater peats.

In January 2007, the Wells Reserve published a comprehensive Site Profile, a 326-page document that details the Reserve's physical and biological resources. The Site Profile includes plant and animal species lists, past research and monitoring projects, and current and future research needs. The Site Profile is a comprehensive reference document; it is targeted at researchers and resource managers carrying out projects in south coastal Maine. This document is available online at: https://www.wellsreserve.org/project/site-profile.

Sea Level Rise

Sea level rise (SLR) is a systemic, complex, and often pronounced issue for our planet's oceans and coastlines. Globally, ongoing satellite altimetry measurements suggest that sea levels are rising at a rate (3.3 ± 0.4 mm/year, NASA 2021) that, within the next century, will inundate much of our coastal infrastructure and coastal plain, making communities and habitats more vulnerable to storm surge and wave action (FitzGerald and Hughes 2019, Sweet et al. 2019, Frederikse et al. 2020). Of particular importance is our ability to monitor and quantify SLR in our local salt marshes which provide a natural buffer and support key ecosystem services to adjacent communities.

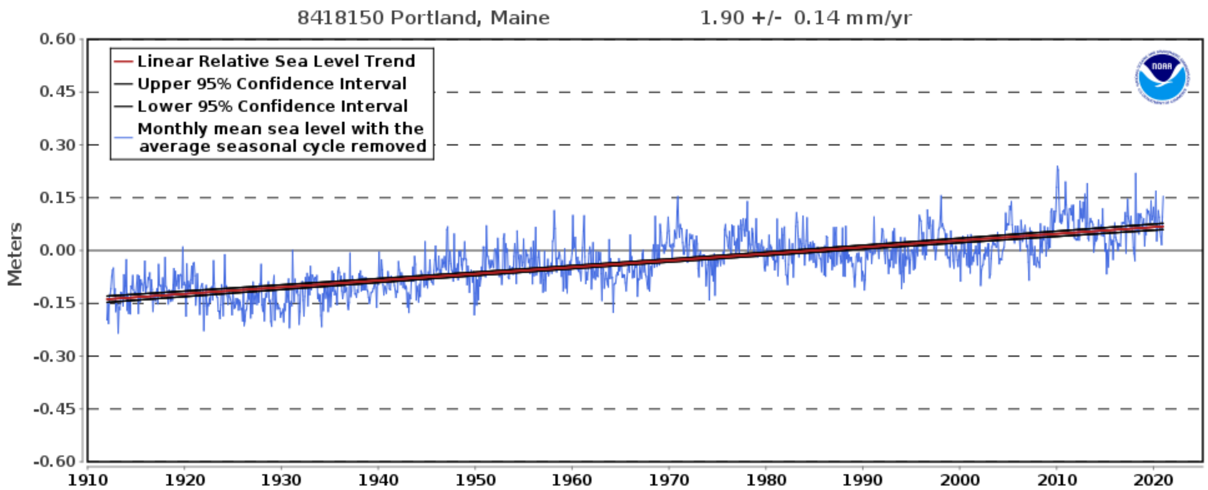

Figure 1.3 *The relative sea level trend is 1.9 millimeters/year with a 95% confidence interval of +/- 0.14 mm/yr based on monthly mean sea level data from 1912 to 2020 (Portland, ME; Station ID: 8418150) which is equivalent to a change of 0.19 meters in 100 years (NOAA 2020).*

Throughout the country, salt marshes are being increasingly impacted by SLR, resulting in shifting vegetation communities, creation of water-logged pannes, expansion of salt pools, and upland migration of salt marsh habitat (Wilson et al. 2014, FitzGerald and Hughes 2019). In areas where the salt marsh cannot migrate inland due to adjacent development, marshes will be submerged, resulting in the removal of this critical ecosystem and buffer to neighbouring communities. As a result of SLR, the frequency and magnitude of flooding events along U.S. coastlines are projected to continue to increase on a decadal scale (Sweet et al. 2019). On a regional scale, salt marshes in Maine and within Wells Reserve, are also being inundated on a more frequent basis by seawater, and this is exacerbated during storm events (Gehrels et al. 1996, Weston 2014). By coupling long-term observations from NOAA tide gauges with a national set of flood threshold estimates, the National Ocean Service has quantified high tide flooding (HTF) occurrences and has predicted a substantial trending increase (5-15 fold) in HTF events by 2050 (Sweet et al. 2019). However, even prior to this time, changing conditions in many locations, including Wells Reserve, will be apparent.

The nearest National Water Level Observation Network (NWLON) primary control tide station to the Wells Reserve is located in Portland, Maine, approximately 64 km (40 mi) distant, and has been monitoring water level since 1910.Sea level trends for the Portland, ME tide station have been calculated by NOAA CO-OPS. The historic rate of sea level rise for this station is 1.9 mm/yr +/- 0.14 mm/yr (95% confidence) (Fig. 1.3, NOAA 2021). Localized sea level rise predictions are available from the U.S. Army Corps of Engineers (USACE) online Sea-level Change Curve Calculator. Based on the alternate model developed by NOAA et al. 2017 the calculator shows that the Portland, ME station can expect between 0.37 m (highest probability) and 3.32 m (lowest probability) of sea level rise above local mean sea level by the year 2100 (Fig. 1.4, USACE 2021).

Scenarios for PORTLAND
NOAA2017 VLM: 0.00000 meters/yr
All values are expressed in meters

Year	NOAA2017 VLM	NOAA2017 Low	NOAA2017 Int-Low	NOAA2017 Intermediate	NOAA2017 Int-High	NOAA2017 High	NOAA2017 Extreme
2000	0.03	0.03	0.03	0.03	0.03	0.03	0.03
2010	0.03	0.07	0.08	0.10	0.13	0.16	0.17
2020	0.03	0.11	0.13	0.18	0.24	0.28	0.30
2030	0.03	0.15	0.18	0.27	0.37	0.45	0.49
2040	0.03	0.18	0.23	0.37	0.52	0.68	0.75
2050	0.03	0.22	0.28	0.48	0.69	0.93	1.06
2060	0.03	0.27	0.34	0.61	0.88	1.22	1.43
2070	0.03	0.30	0.39	0.74	1.09	1.53	1.83
2080	0.03	0.33	0.43	0.89	1.33	1.85	2.26
2090	0.03	0.35	0.47	1.05	1.59	2.25	2.78
2100	0.03	0.37	0.50	1.20	1.86	2.69	3.32

Figure 1.4 *Sea level rise scenarios for Portland, ME tide station computed with the USACE Sea-level Change Curve Calculator based on models from NOAA et al. 2017.*

One of the primary design goals for this SSAM-1 plan is to be able to accurately and consistently evaluate long- and short-term changes in water level and seawater inundation of local salt marshes, and the associated changes in vegetation community structure, elevation, and marsh hydrology. Having the ability to gather, summarize, and disseminate these types of data products will allow emergency management personnel (e.g., local Fire Department), coastal managers, and other end-users to be fully informed so they can appropriately respond to local flooding issues and develop adaptation strategies for future resilience decision-making efforts.

SSAM-1 Primary Goals: Environmental stressors and users

The overarching goal of the Wells Reserve SSAM-1 Plan is to provide a design and methodological foundation to assess the impacts of changing climate conditions on emergent marsh habitat and provide a basis for comparing these impacts within New England NERRs and across the entire NERR system. To achieve this goal our focused objectives are to:

1) Establish a network of permanent monitoring sites to assess a range of wetland characteristics (vegetation, wetland surface elevation, water level, salinity, crab use);
2) Establish a network of local geodetic benchmarks to tie monitoring sites to local tidal datums and the National Spatial Reference System;
3) Quantify changes in vegetation patterns, hydrology, and wetland surface elevation across spatial gradients and over different timescales;
4) Determine relationships between these wetland characteristics and changing environmental factors;
5) Communicate our findings to coastal communities and decision-makers to help inform coastal resource planning and;
6) Create opportunities to demonstrate marsh monitoring techniques and foster research to end-users including educators, students, and members of the public.

The primary objective of this SSAM-1 Monitoring Plan is to detect and quantify long-term changes in Reserve tidal marshes in response to natural as well as anthropogenically-induced stressors such as climate related changes in precipitation and sea level, spread of invasive species, landscape development, and altered hydrology. To fully and comprehensively understand the changes observed in our salt marshes, we incorporate a suite of monitoring metrics into our plan, including core SWMP and SSAM-1 metrics (vegetation cover and community structure, wetland surface elevation, water level, abiotic water quality, nutrients, and weather) and elective metrics (pore water salinity, groundwater level, sediment bearing capacity (as a proxy for below-ground biomass), and crab abundance and habitat use).

Figure 1.3. *The encroachment of Phragmites spp. in select upland reaches of our Webhannet marsh system. One goal of our SSAM-1 plan is to better understand marsh landscape change due to climate change. Photo credit: Chris Peter, GBNERR.*

<u>Core metrics will allow us to address the following questions:</u>

1. How do vegetation cover and community structure change over time in response to sea level rise and other stressors?
2. How does the response to these stressors vary spatially across different marsh habitats and elevation zones (e.g., low marsh vs. high marsh vs. upland)?
3. How is wetland surface elevation changing in response to changes in sea level over decadal timescales, and how do those changes influence sediment accretion and vegetation community structure?
4. Is wetland surface elevation increasing, and is it keeping pace with sea level rise?
5. As sea level rises, do we observe landward movement of marshes with conversion of upland habitat into salt marsh habitat, and a conversion of low elevation marsh to unconsolidated shoreline?

<u>Elective metrics will allow us to further evaluate:</u>

1. How are crab abundance and species composition changing in our salt marshes, particularly with the arrival of invasive species and range expansions of other species?
2. Does the arrival and spread of invasive decapods (e.g., green crabs) or range expansions (e.g., blue crabs, fiddler crabs) affect salt marsh vegetation or sediment composition (e.g., via bioturbation or herbivory)?
3. How do sea level rise and altered hydrology affect pore water salinity over time and how do these effects influence vegetation community structure in different elevation zones?
4. How do hydrologic changes at the upland edge (pore water salinity, water level, groundwater level) translate to subsequent changes in vegetation composition (e.g., transition from upland to salt marsh species)?

5. How does sediment bearing capacity, used as a proxy for belowground biomass, change over time, and how do changes in bearing capacity correlate with changes in above-ground biomass (stem height, density, cover), vegetation species composition, and/or crab burrow distribution?

In addition to the monitoring metrics described in this SSAM-1 Monitoring Plan, other parameters may also be explored in the future to more thoroughly understand the changes occurring in our salt marsh systems. For example, we may incorporate the use of Unmanned Aerial System (UAS, or drones) based remote sensing for mapping salt marsh habitats, assessing vegetation community composition, or tracking salt pool expansion (Fig. 1.5). The Wells Reserve UAS program has purchased a Sentera Normalized Difference Vegetation Index (NDVI) camera mounted to a DJI Mavic II quadcopter and is currently exploring methods for collecting and analyzing near infrared imagery in tidal marsh habitat.

Figure 1.5. *A DJI Matrice drone (pictured) was used to collect high resolution aerial orthoimagery in the Little River marsh, as part of a field training exercise by industry partner AirShark. These preliminary data can be used to begin mapping marsh pool expansion and could have additional application for SSAM-1 monitoring.*

This long-term monitoring program design and strategy will provide us with the opportunity to not only track long-term changes at the local level, but also to make comparisons in salt marsh dynamics across regional and national scales as evidenced by past success stories involving marsh crabs and the synthesis of vegetation communities (see references herein). The protocols described here conform to methods used throughout the NERR system and were developed with frequent input and feedback from researchers at other NERRs, partner resource agencies, and universities. This synergistic approach to developing and implementing our monitoring program will facilitate comparisons across reserves and collaborative research efforts. Additionally, this document includes our plans for disseminating our research findings and sharing environmental monitoring techniques with regional decision-makers, natural resource managers, local community members and businesses, educators, and students via the Wells Reserve Education and Coastal Training Programs (CTP).

Research and Management Initiatives

The Wells Reserve maintains and operates as a public-private partnership with oversight vested in the Reserve Management Authority (RMA), an independent state agency established in 1990. The RMA comprises a board of directors (BOD), with individuals representing organizations that have a property, management, or programmatic interest in the Reserve. These individuals currently represent the U.S. Fish and Wildlife Service (USFWS), Town of Wells, Laudholm Trust, Bureau of Parks and Lands (Maine Department of Agriculture, Conservation and Forestry), the Maine Coastal Program (Maine Department of Marine Resources, MEDMR), and the National Oceanic and Atmospheric Administration (NOAA). The RMA BOD is also composed of a Governor-appointed coastal/marine/estuarine scientist.

The Wells Reserve Research Program investigates coastal food webs, the species of interest that depend on them, the habitats that support them, and the human-mediated and natural disturbances that alter them. In addition, we continue to actively promote the development and implementation of regionally coordinated ecological monitoring of coastal habitats along a gradient of least disturbed, to restored, to most disturbed. These activities are met through committee work, meetings, workshops, presentations, reports, and peer-reviewed publications.

The Wells Reserve acknowledges climate-driven disturbance as an underlying force that needs to be measured and assessed in the natural and altered habitats that we study. The impacts of a changing climate on coastal areas will be expressed across a diverse number of ecosystem variables (e.g., changes in air, water and soil temperatures; water chemistry; the quantity, timing and intensity of precipitation; the intensity of storm events; sea-level rise, species distributions and movements, among others). As part of meeting these research and monitoring initiatives, a primary goal for the Wells Reserve is to fully integrate the NERRS Sentinel Site Application Module 1 (SSAM-1) and its monitoring program (e.g., vegetation monitoring, vertical control of water quality stations, surface elevation tables, etc.) and is committed to establishing and maintaining a NERRS SSAM-1 Site, as described in the '*Sentinel Sites Guidance for Climate Change Impacts as part of its ongoing System Wide Monitoring Program*'. We also work closely across the NERR System (e.g., NERRS Science Collaborative Program) and with our CTP, Education, and Stewardship sectors to assess and communicate the needs and questions of local communities relative to climate-driven changes in coastal habitats including socio-economic impacts from marsh flooding and storm events.

Climate change has had a recent and pronounced effect on the coastal waters of the Gulf of Maine (GOM) (Nye 2010, Mills 2013, Pershing et al. 2015, Staudinger et al. 2019, MCC 2020). For example, changes in the thermal structure coastal areas, including estuarine systems are already having profound and adverse effects on water quality, circulation features, sea level rise, and the flora and fauna in these ecosystems. As we expect a changing ocean climate to persist, stressful environmental perturbations will likely continue to impede estuarine function and associated biological processes. Ecosystem services such as flood protection, water filtration and blue carbon make it critical to focus on research themes that reflect these issues as well as the Wells Reserve mission ***"to understand, protect, and restore coastal ecosystems of the Gulf of Maine through integrated research, stewardship, environmental learning, and community partnerships".*** As such, our thematic research and monitoring initiatives include the following:

- Estuarine water quality and degradation
- Climate change impacts on salt marsh habitats and communities
- Salt marsh degradation and restoration
- Invasive species monitoring
- Aquatic resource restoration
- New technologies for environmental monitoring
- Academic and institutional partnerships
- Student mentoring and academic study
- Science translation for best management practice and policy development
- Communication and information dissemination

Examples, details, and case studies for each of these themes are detailed in the WNERR 2019-2024 Management Plan, and are available on our website: http://wellsreserve.org

The Wells Reserve is an active participant in ongoing NERR Science Collaborative funded projects that will integrate with and improve upon future implementation of this SSAM-1 Plan, including applications for UAS, marsh inundation monitoring, and habitat mapping. These projects include:

- History and Topography to Improve Decision-making for Estuary Restoration (HiTIDER) (Wasson, 2020)
- Transfer of a low-cost tidal wetland water level monitoring system: hyperlocal calculations of inundation and tidal datums for understanding change and restoration planning (Sheremet, 2020)
- Bridging the Gap between Quadrats and Satellites: Assessing Utility of Drone-based Imagery to Enhance Emergent Vegetation Biomonitoring (Puckett, 2020)

II. Communication and Outreach

a. Education Program

The Wells Reserve is a regional center for education, training, and outreach on coastal, estuarine, and watershed ecology. Reserve interpretive education programs inform and engage audiences in learning about coastal ecosystems. Audiences include thousands of regional residents and visitors of all ages, including K-12 school groups, families, day campers, and teachers. Education programs translate research into readily available information, increase environmental literacy, and help promote stewardship of the environment.

The Wells Reserve's research and education sectors will work collaboratively to integrate Sentinel Site data into the informal and formal education programs offered throughout the year. Details on how the data will be utilized are provided below.

Informal Education

The Wells Reserve holds an annual National Estuaries Day event in September and an Earth Day Celebration in April for families in the community. Research staff will have a table at these events to share Sentinel Site data and information in an interactive way. The two events draw a combined total of close to 2,000 visitors to the Reserve, making them ideal opportunities for reaching a large audience.

For several years, the Reserve has offered "*Meet the Scientist*" programs during the summer months. These informal offerings allow visitors to get a 'behind the scenes' look inside the research lab while learning about current projects from the scientists themselves. Sentinel Site research will be spotlighted in future Meet the Scientist programs.

The Reserve has a long history of offering monthly "*Lunch & Learn*" programs for the community. They feature a speaker sharing information on a topic for an hour in the auditorium at noontime. While the research staff have been highlighted speakers in the past on numerous occasions, the Sentinel Site program has not yet been in the spotlight. This is a new opportunity that will be integrated into the Lunch & Learn program in future months.

The Reserve's education program includes a phenology citizen science monitoring program. A team of volunteers checks various plants each week throughout the year and documents their findings in the USA National Phenology Network's Nature's Notebook database. Participating educators will seek guidance from Reserve researchers to integrate Sentinel Site data collection into the existing phenology monitoring program.

In 2018, the Reserve used sea level rise models and GIS mapping to develop interpretive signage at several locations along the Barrier Beach Trail. These signs provide visitors with the opportunity to envision how future tidal flooding might affect the landscape, getting a sense of the magnitude of these changes while walking the trail.

Formal Education

The Wells Reserve offers annual Teachers on the Estuary (TOTE) workshops for middle and high school science teachers. TOTE aims to give high school teachers a research and field-based experience in our nation's estuaries (Fig. 2.1). During these three-day in-person workshops, the SWMP Program Manager does a two-hour presentation on the System-Wide Monitoring Program (SWMP), enabling teachers to access water quality and weather data and create graphs. The teachers also conduct water quality monitoring in the field while kayaking on the Little River estuary and exploring the salt marsh on foot. Researchers are on hand at the marsh as well, sharing the seining technique with teachers and exploring the fish species that inhabit these tidal waters. The teachers then share this newfound knowledge with their students back in the classroom and facilitate student-led projects throughout the school year using a $200 stipend received during the TOTE workshop to purchase necessary equipment. The education and research sectors will continue this ongoing TOTE workshop collaboration and will integrate additional Sentinel Site data and monitoring techniques as they become available.

Figure 2.1. *A Teachers On The Estuary (TOTE) Workshop held at Wells Reserve.*

One of the Reserve's field trip offerings for school groups is "Microscopic Marvels." This three-hour program takes middle and high school students out to the salt marsh for water quality testing and then back to the laboratory for plankton identification. Reserve educators will continue to integrate water quality monitoring into this program, as well as the mention of it in the Exploring Estuaries program for grades 2-5. They will also seek research staff assistance in securing preserved larval fish specimens to share with students during these two programs.

In addition to the three-day TOTE workshops that are currently offered, Reserve educators would like to also offer a two-hour in-person mini workshop for teachers, facilitated by the SWMP Program Manager, that focuses solely on SWMP data. This would be held after school or during the summer months, and specifically geared towards teachers who bring their students to the Reserve for the Microscopic Marvels program. This workshop would enable participating teachers to use the SWMP data confidently with their students as a post-visit activity following their field trip experience. During the COVID pandemic, the SWMP Program Manager and Reserve educators collaborated to offer a shortened virtual TOTE workshop for teachers, with SWMP data and analysis featured for two hours. This was a successful pilot, and lessons learned will assist in the development of future mini workshop offerings for teachers. More information on TOTE is available at: https://coast.noaa.gov/estuaries/teachers-on-the-estuary/

b. Coastal Training Program

The Coastal Training Program (CTP) acknowledges and respects the critical role that local and regional decision-makers, natural resource providers, businesses, and citizens play in determining the character and condition of Maine's coastal areas. Decisions about land use, infrastructure, development and maintenance, and public health and safety are influenced by regulations, policy, planning processes, scientific findings, and best management practices. Developing effective CTP activities requires awareness that underlying the seemingly pragmatic decision-making process is a complex system of human values, attitudes, and motivational forces. Municipal decision-making is heavily influenced by economic factors. Scientific findings that 'tell a story' about the economic impacts of climate induced ecological change are valued by decision makers. The path leading to the application of scientific findings, including SSAM-1, must navigate through these aspects of decision making.

Figure 2.2. *The Drakes Island tide gate restricts tidal exchange north of Drakes Island Road, as illustrated by the difference in the snow cover removed from the marsh surface by the previous high tide, clearly visible in this drone orthoimage from March 8, 2020.*

The CTP provides science based training and technical assistance to governments, communities and organizations in coastal watersheds in southern Maine and coastal New Hampshire. CTP works in partnership with academic institutions and is involved in select Maine and New Hampshire state-wide initiatives and projects. One target audience for the CTP is municipal decision-makers, including elected officials, paid professionals, and professionals and community members serving on volunteer town boards whose decisions affect local land use. Paid professionals include Town Managers, Planners, Code Enforcement Officers, Public Works, Town Engineers, Water and Wastewater Managers, and Harbor Masters. Included in the municipal audience are those volunteers serving on Planning Boards, Site Plan Review Boards, Conservation Commissions, Town Councils or as Select Board members. Volunteer boards are in many cases the backbone of the decision-making process at the local level. In addition to municipal audiences, the CTP Market Analysis and Needs Assessment (2002) identified land trusts, watershed and river associations, open space planning committees, and state and federal employees as audiences for CTP, and they continue to be part of the CTP target audience.

Intersections for SSAM-1 data and CTP include:

- Data integration with Maine Climate Council recommended initiatives (e.g., marsh migration planning, integrated beach management plan) identified in the new report Maine Won't Wait (MCC, 2020).
- Emergency management preparedness for flooding and storm surge for the town of Wells (technical assistance is ongoing, as needed)
- Reference for future watershed-wide initiatives (e.g., Merriland, Branch Brook, Little River Management Plan)
- Use SSAM-1 reports and analysis such as the SWMP report cards and SETr to share the story that the data tell over time.
- Work with NERRs partners to develop and communicate an ecosystem services conceptual model for salt marsh to mangers and stakeholders (NSC proposal submitted 2020).
- Transfer the SSAM-1 story to managers and climate change adaptation workgroups:
    - Maine Climate Change Adaptation Providers' Network Annual Meeting *Maine Won't Wait* -- Climate Action Plan Coastal and Maine Working Group
    - *Better Safe than Sorry* -- Annual Meeting (10 coastal communities in southern Maine, including the town of Wells)
    - 1-year funded project: *Tides, Taxes, and New Tactics*: Planning for Adaptation and Impacts of Sea Level Rise and Storm Surge on Coastal Property and Municipal Budgets through GIS-Driven Vulnerability Assessments and Community Dialogues in Southern Maine (including the town of Wells)
    - 2-year funded project: Developing a Regional Coastal Resilience Plan for Southern Maine
    - Maine Blue Carbon Working Group
    - Building our National Capacity to Protect Coastal Wetland Migration Pathways

- Project integration with system-wide NSC-funded collaborations, for example:
    - Leverage biomonitoring data with multi-metric indices (e.g., MARS Marsh Resilience to Sea Level Rise; Raposa et al. 2016) to measure relative salt marsh health and resilience.
    - "Synthesizing Monitoring Data to Improve Coastal Wetland Management Across New England" (2018-2019) produced a suite of analytical and data management tools to facilitate comparisons of marsh vegetation communities within and between New England NERRs.
    - "A National Synthesis of Tidal Marshes to Detect Impacts of Climate Change across Multiple Scales" (2021-2024)
    - Annual SWMP Report Cards use NERRS system-wide data analysis scripts to synthesize and summarize water quality and meteorological data to communicate short-term variability and long-term trends to a variety of audiences including stakeholders and members of the general public.
    - Publish annual reports on marsh elevation change utilizing statistical analysis developed in the NERRS Science Collaborative Catalyst grant titled *"Is marsh surface tracking sea level change? Developing tools and visualizations for NERRS Sentinel Site Data" aka "SETr"* (Cressman et al., 2020)
    - A Landscape Scale Assessment of NERRS Marsh Resilience: Creating a Framework for Effective Monitoring Program and Tool Implementation (Stevens et al., 2021).

III. Site-Based Monitoring Plan

Figure 3.1. *Top left: Surface elevation table set up for measuring marsh accretion and erosion. Top right: Laura Crane and Amanda Giacchetti measure sediment compaction with a penetrometer. Bottom left: Brianna Fischella and Jason Goldstein monitor vegetation using the Point Intercept method while Laura records data. Bottom right: Quadrat set up for monitoring vegetation cover and community composition using the Point Intercept method. Center: Jacob Aman measures marsh elevation with an RTK GNSS.*

a. Location of Infrastructure

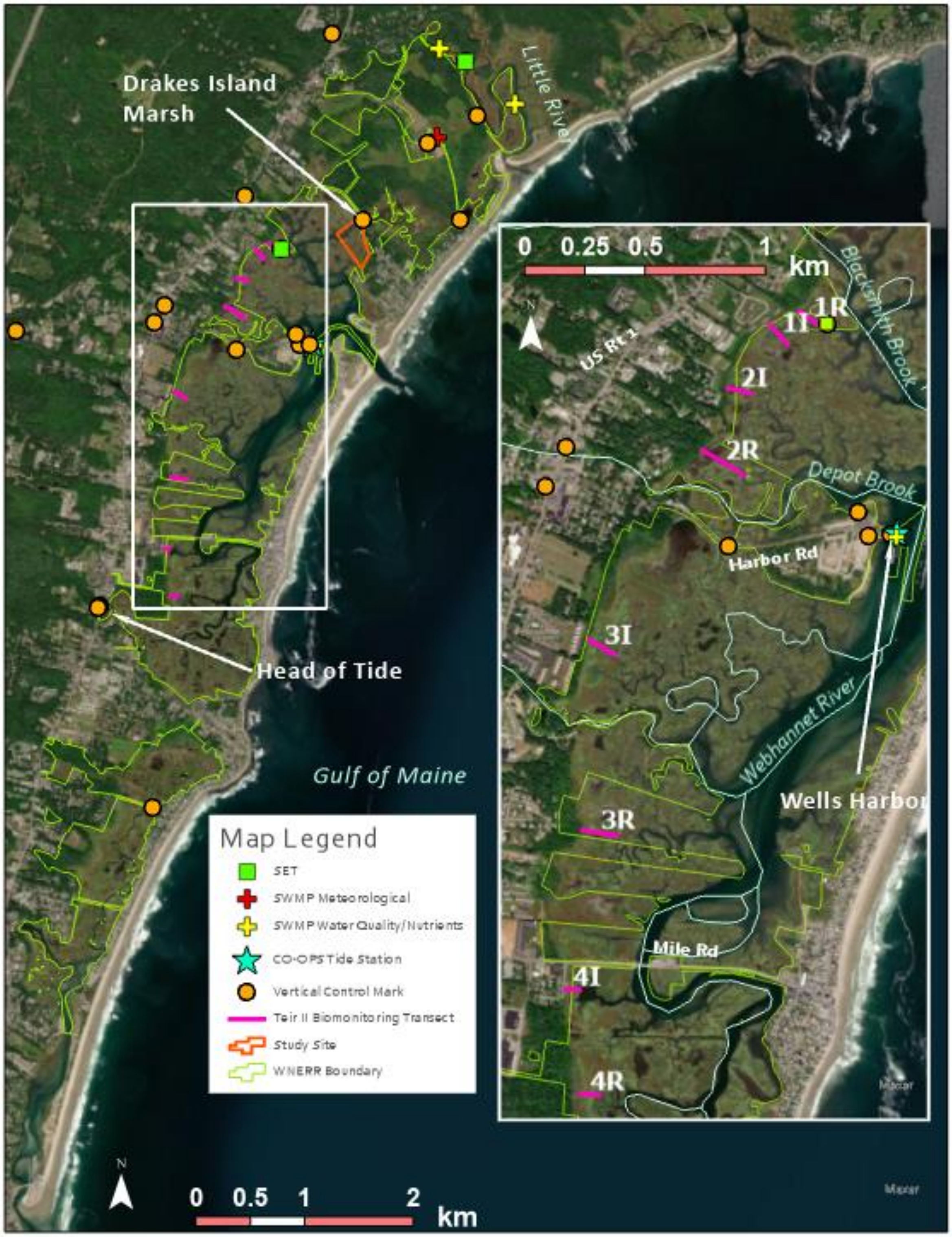

Figure 3.2. *Location of SSAM-1 Infrastructure. New infrastructure is planned at the Head of Tide and Drakes Island Marsh sites.*

b. Vegetation Monitoring

The suite of biological monitoring attributes described here represents a sentinel for gauging change in local salt marsh ecosystems. The long-term monitoring of vegetation communities allows us to detect responses to sea level, climate, nutrient loading, and alternations to marsh hydrodynamics. Our vegetation monitoring activities leverage our ability to address key questions about local salt marsh change, variability, and resiliency including, but not limited to:

1) Overall changes in vegetation cover and community structure over decadal timescales;
2) Response of vegetation communities to the spread of invasive species;
3) Responses of different marsh habitats (e.g., low versus high marsh) to environmental change and;
4) Factors that may contribute to observed vegetation changes (e.g., altered hydrology, nutrients, salinity, etc.). Long-term changes detected in salt marsh vegetation can additionally be compared to elective monitoring metrics (e.g., sediment compaction, pore water salinity, etc.; see section III. g. Elective Monitoring) to better understand observed trends.

Location
All vegetation monitoring transects, Tier II (Legacy) and Drakes Island (SSAM-1), are located within the Webhannet River estuary marsh system. This estuary receives saltwater input from the Gulf of Maine to the east via the Wells Inlet (near the northern end of the estuary), and freshwater inputs from the Webhannet River on the southern end and from Blacksmith and Depot Brooks at the northern end (Fig. 1.2). This approximately 1,000-acre salt marsh is characterized by complex plant assemblages, intricate drainage channels, extensive marsh pools, and a large tidal range (average 8.79 feet) (reviewed in Dionne et al. 2006). Over the last 15 years of monitoring, 34 vegetation species have been documented within our monitoring plots (Appendix A). A unique feature of northern New England salt marshes—and a common feature of the Webhannet marsh—is the presence large waterlogged pannes containing a high diversity of salt marsh forbs, which may be due to either ice disturbance or a lack of extensive ditching (Dionne et al. 2006). Another feature of northern temperate salt marshes is the presence of salt pools. These 'mesocosms' are dispersed throughout the Webhannet marsh and are characterized as water-filled depressions that remain flooded throughout the tidal cycle.

<u>Tier II Transects:</u> Our Tier II (Legacy) transects (8 transects, 40 plots), established in 2005, extend along the western side of the estuary. Two of the eight transects (4I, 4R) are located south of Mile Road, two transects (3I, 3R) are located between Mile Road and Harbor Road, and four transects (1I, 1R, 2I, 2R) are located north of Harbor Road (Fig. 3.2). Each transect contains five monitoring plots, with the first plot (Plot 1) located near a tidal creek and the last (Plot 5) at the upland/marsh edge. The remaining plots in each transect (Plots 2-4) fall within low marsh, high marsh, and transitional zones. The Tier II transects consist of 4 pairs of transects, with each pair including a "Reference" transect and an "Impacted" transect (e.g., transects 1R and 1I) based on the land use within the 75 m-wide upland buffer zone (forested vs. developed) (as described in Dionne and Tyrrell 2004).

The primary goal of the Tier II monitoring transects was to examine the relationship between upland land use, marsh elevation, and vegetation community structure within the Webhannet River Estuary (Dionne and Tyrrell 2004). Additionally, the Tier II monitoring provided baseline data that was valuable in planning and assessing the effectiveness of a restoration project in the Webhannet River which would increase tidal flooding upstream of a tidal restriction (Dionne and Tyrrell 2004). In addition to providing substantial baseline and long-term monitoring data for this site, findings from this project have revealed elevated nitrate levels and shifts in vegetation community structure—particularly an increase in *Triglochin maritimum*—in areas adjacent to developed upland (Fitch et al. 2009). Because these transects were designed to meet these specific goals, they do not follow the same stratified random sampling design required of SSAM-1 plots and therefore are not categorized as SSAM-1 plots. Additionally, the transects do not extend all the way to a major tidal channel; rather, they traverse across narrow creeks and large pools, and do not exhibit a continuous elevation gradient from upland to creek edge. Transects were arranged based on recommendations of the NERRS Vegetation Biomonitoring Proposal (Moore and Bulthuis 2003). Although they are not compliant with SSAM-1 requirements, we will continue to monitor the Tier II transects as they allow us to monitor long-term changes in marsh community structure over a relatively large geographic scale and we have collected over 15 years of cumulative data from these sites.

<u>Drakes Island (SSAM-1) Transects:</u> In 2021, we installed new long-term biomonitoring plots in another section of the Webhannet marsh that conform with the most updated SSAM-1 protocols. These new transects (5 transects, 29 plots total) were established on the northern end of the estuary, east of Depot and Blacksmith Brooks and just south of Drakes Island Road (Figs. 3.2, 3.3). Each transect includes one plot located in the upland area (100% upland vegetation) and one plot located adjacent to the creek edge. The remaining plots in each transect fall between these two plots, within high marsh, low marsh, or transition zones. Plots and transects are at least 15 m apart to ensure independence.

The locations of these newly established biomonitoring transects and plots are shown in Figure 3.3. Proposed transect locations were selected in Google Earth by delineating the monitoring site into 5 equal sections, avoiding any intersection with the artificial dyke, unnatural upland edges (i.e., manicured lawns), major pool complex, private property areas, and to prevent transects from crossing creeks (other than the artificial ditch that runs parallel to the upland edge). A random number generator was used to place a transect within each section, so it ran perpendicular with the main channel and parallel to the other transects and was at least 15 m apart from the other transects. Plots were then equally spaced along each transect (distances excluding water): 3 plots each along transects D1 and D2, 7 plots each along transects D3 and D5, and 6 plots along transect D4, based on relative transect lengths.

Exact plot placement along each transect was decided in the field by: (1) randomly placing the first plot (Plot 1) within the low marsh zone adjacent to the creek edge (or within 10 m of the creek bank if no low marsh was present); (2) randomly placing the last plot within the first 3 m of upland edge (100% upland species); and (3) placing all subsequent plots at regular intervals between these two plots (distances excluding water). In the field, we also ensured that the upland plot was within 100% upland vegetation and plots were at least 15 m apart. This spatial design follows guidance described in Moore et al. (2020) and Roman et al. (2001). Additionally, since high marsh-upland transition zones were not represented by these 26 established plots, one "transition" plot each was established along transects D1, D3, and D5 by randomly placing the plot within the part of the transect cohabitated by a mix of high marsh and upland species. This resulted in the establishment of 29 total plots representing all marsh habitats present: low marsh, low-high marsh transition, high marsh, high-upland transition, and upland.

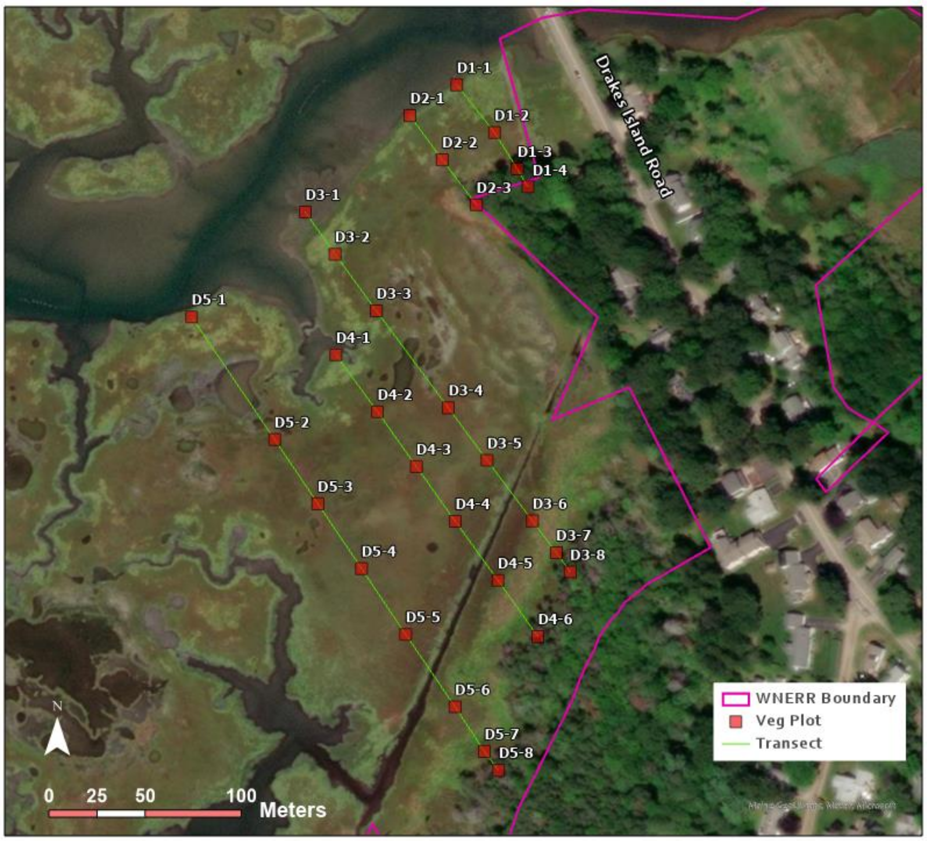

Figure 3.3. *Map of the locations of the newly established Drakes Island transects and monitoring plots.*

Unlike the Tier II project area, this project area is not heavily intersected by complex drainage channels and marsh pools, allowing the transects to traverse a relatively continuous elevation gradient from creek edge to upland. Transects D3, D4, and D5 traverse several small pools, depressions, and a single ditch that runs parallel and adjacent to the upland edge (Fig. 3.3); regardless, initial RTK elevation surveys demonstrate that, overall, all 5 transects traverse an elevation gradient from creek to upland edge (Fig. 3.4). This study design is important because it minimizes spatial variability of our plots, allowing us to make basic assumptions about the nature of our plots when analyzing our data. This will allow us to compare the community composition changes occurring at different points along the elevation gradient and determine if the marsh is migrating upland along this gradient. Additionally, the land use within the 75 m upland buffer is mostly forested with some residential use (similar to the transects designated "Reference" in the Tier II design).

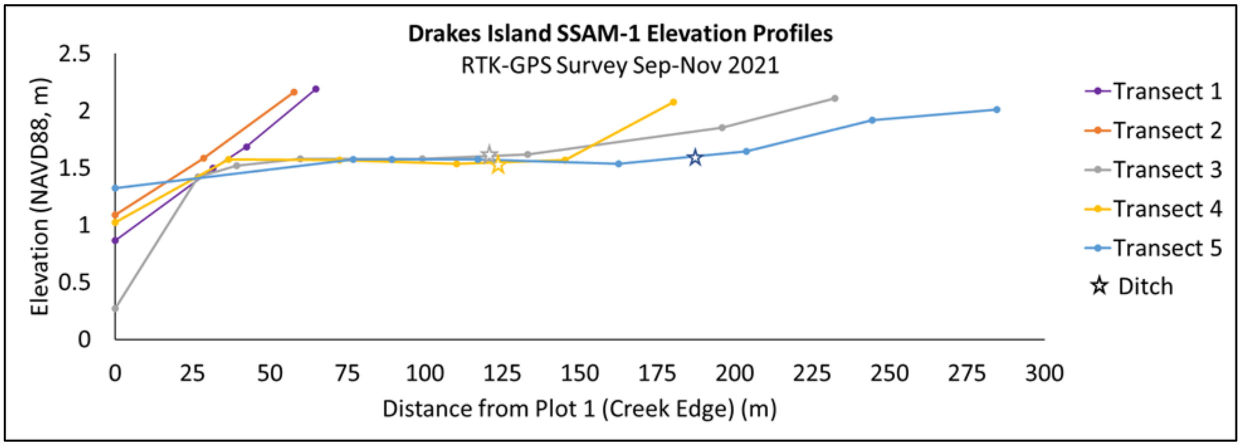

Figure 3.4. *Marsh surface elevations measured along the 5 new SSAM-1 transects, where each point is a biomonitoring plot at Drakes Island SSAM-1 stie. The approximate location of the artificial ditch as it intersects each transect (Transects 3-5) is indicated with a star of the same color. Surveys were conducted September-November 2021 with an RTK-GNSS.*

As is the case in many other regions, salt marshes in Wells, ME were heavily used for salt hay farming, ice production, and animal grazing during the 1700-1800s. In 1848, Drakes Island farmers built a dike (parallel to present-day Drakes Island Road) so the marsh upstream of the dike could be used as pasture (Burdick et al. 1997). After the dike broke in 1915, a road and box culvert with a water control structure were installed in 1920 (Burdick et al. 1997). In the 1950s, a culvert was installed with a flap gate that prevented salt water from entering the marsh (Burdick et al. 1997). In 1988, the flap gate fell off, inadvertently providing partial tidal restoration upstream of the culvert (Burdick et al. 1997). In 2004, a new self-regulating tide gate was installed to control tidal flooding upstream of Drakes Island Road. We have established our new monitoring site downstream of this tide gate.

Biological and hydrological monitoring has occurred at Drakes Island marsh on several occasions between 1988-2010, both upstream and downstream of the culvert. Burdick et al. (1997) describes monitoring that was conducted 1992-1995 in the impacted (upstream) marsh and the reference (downstream) marsh; data was collected on water level, marsh elevation, vegetation community structure, pore water salinity, water table depth, and nekton diversity. A final report to the Gulf of Maine Council/NOAA Habitat Restoration Partnership (2010) describes hydrological monitoring conducted 2009-2010. Additionally, Moore et al. (2009) includes raw data from the Drakes Island reference marsh collected in 1988-2007 including vegetation, pore water, nekton, and tidal data. These resources provide us with valuable historical reference data to which we can compare future long-term monitoring trends. Additionally, historical information regarding the vegetation and hydrology of Drakes Island marsh can help inform the spatial design of our transects and monitoring plots.

Our Drakes Island site has clearly defined high and low marsh zones reflecting distinct elevations and is primarily composed of high marsh habitat (Burdick et al. 1997; pers. obs.). According to historical monitoring data from the 1990s, the high marsh was 90% vegetated and dominated by *Spartina patens*, with *S. alterniflora* short form dominating waterlogged depressions of the high marsh (Burdick et al. 1997). Meanwhile, the low marsh was 60% vegetated and dominated by *S. alterniflora* tall form; a wide band of low marsh extended along the main creek bank, with narrower bands along minor creek banks and drainage paths throughout the marsh (Burdick et al. 1997). In 2009, Moore et al. described our monitoring site as having high species richness of halophytes possibly due to "(1) persistent forb pannes spanning much of the marsh (pers. obs.) and (2) absence of invasive species." While there were no invasive species found in 2003, 2005, or 2006, "a stand of common reed on one of the reference marsh transects [was] determined to be native (*Phragmites australis* subspp. a*mericanus*)" (Moore et al. 2009). In 2006, about 97% of the marsh was found to be inundated during spring tides while only 10% was inundated during neap tides (Moore et al. 2009). Similarly, Burdick et al. (1997) found that spring tides submerged the high marsh while neap tides only submerged most of the low marsh. This historical record of marsh vegetation composition and hydrology provides further evidence that this will be an optimal site for establishing long-term monitoring transects that extend from low marsh adjacent to a creek bank, across high marsh platform, and ending at the upland edge.

Methods

Emergent vegetation monitoring at the Wells Reserve is based on the protocols described in Moore et al. 2020. The following describes monitoring methods that have been used in the past at our Tier II transects and that we plan to continue at both the Tier II and the new Drakes Island transects. Metrics include vegetation cover and community structure, canopy height, stem density, and plot elevation. Three PVC or wooden stakes are used to permanently mark the locations of each vegetation plot (2 PVC/stakes) and transect line (1 PVC/stake) from which the site of the pore water well installation is deduced (Fig. 3.5).

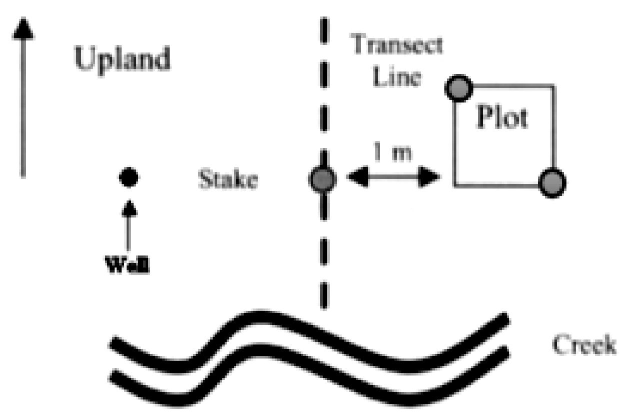

Figure 3.5. *Sampling plot and pore water well orientation along each monitoring transect (modified from Roman et al. 2001).*

Vegetation Cover and Community Structure: Immediately prior to conducting vegetation monitoring, a photo is taken of the plot using a digital camera held above the plot. These photos provide a visual record of how the plots change over time and a valuable resource during data QA/QC. Next, all vegetation species present within the plot are recorded (identified according to Tiner 2009), indicating if *Spartina alterniflora* is short- or tall-form (as recommended in Dionne et al. 2007). Presence of visible bare ground, dead plants, or seaweed (macroalgae) are also recorded (wrack is not recorded but is removed from the plot and replaced after monitoring is complete). Plant communities are surveyed using the point intercept method at all vegetation monitoring plots (ocular cover was additionally monitored in 2019 to compare the results of the two methods as part of an NSC marsh vegetation catalyst Grant; findings described in Burdick et al. 2020). The point intercept method involves laying five marked dowels across a 1 m^2 quadrat to create a grid of 49 marked points (+ 1 random point = 50 total points per quadrat; Fig. 3.1; Roman et al. 2001). A vertical dowel is placed at each of these points and each species directly touching the dowel at each point receives a tally. Bare ground or dead plants are only tallied if there are no living plants touching the vertical dowel at that point; otherwise only the living species touching the dowel are tallied. Seaweed (macroalgae) is treated the same as other living plant species. Any species present but not captured using point intercept are recorded as present ("P") and receive a value of 0.5. Tally numbers are doubled before entering into the spreadsheet to get the percent cover number (P = 1% cover). Marsh vegetation ID guides are utilized to accurately identify vegetation to the species level (or at least to the genus), and marsh vegetation experts are consulted when needed for species that are rare or difficult to identify.

Canopy height and stem density: Stem density is surveyed within a subplot of the 1 m^2 quadrat, placed in the corner closest to the transect and creek. Subplot dimensions are 25 x 25 cm for *Spartina alterniflora*, 10 x 10 cm for *S. patens*, and the whole 1 m^2 plot for *Phragmites* spp. and *Typha* spp. Stem density is determined by counting the number of stems of each species present within their respective subplot. Canopy height is determined for each of these four species by measuring the three longest plants (full plant height when standing upright) of each species present within the whole 1 m^2 quadrat.

Plot elevations: The elevation is measured at each corner of the vegetation monitoring plot and at the center of the plot. A Leica Total Station was used in 2005-2016, while an RTK GNSS was used in 2019-2021 to measure plot elevations. We plan to use an RTK GNSS or Digital Level for monitoring elevation going forward. See Table 3.1 for information regarding the years each transect was monitored.

Table 3.1. *Method used to monitor plot elevation at each of the vegetation transects in each year. Xs indicate the transects at which plot elevation was monitored in each year.*

	Tier II Transects								Method
	1I	**1R**	**2I**	**2R**	**3I**	**3R**	**4I**	**4R**	
2005				X	X	X	X	X	Leica Total Station
2006	X	X	X			X	X	X	Leica Total Station
2010		X		X		X			Leica Total Station
2011	X	X	X	X	X	X	X	X	Leica Total Station
2014		X	X	X	X	X	X	X	Leica Total Station
2016	X	X	X	X	X	X	X	X	Leica Total Station
2019	X				X	X		X	RTK GNSS
2020		X	X	X			X		RTK GNSS

Frequency

The eight Tier II transects were established and first monitored in Oct 2005. Since then, vegetation was monitored during peak biomass (Aug-Sept) during the years shown in Table 3.2. We established 5 new transects and initiated monitoring in 2021. Beginning Summer 2021, we plan to monitor each transect (Tier II and Drakes Island) every 3 years, alternating which transects will be monitored each year (see Table 3.2). The transects (13 total) will be divided into the three "groups" described below, with one group monitored each year:

- Group A: Drakes Island Transects D1, D2, D3, D4, and D5
- Group B: Tier II Transects 1I, 1R, 3I, and 3R
- Group C: Tier II Transects 2I, 2R, 4I, and 4R

The Tier II transects were divided in this way so that pairs of transects (Impacted and Reference; see Dionne and Tyrrell 2004) would be monitored together and to maximize spatial extent monitored each year (Fig. 3.2).

Data was submitted to the Centralized Data Management Office (CDMO) for the 2011 monitoring season. Beginning with 2019 monitoring data, all non-elective monitoring data will be submitted annually to CDMO by April 15 following collection. Data will be submitted using the NERRS system-wide spreadsheet template, along with associated metadata for that year using the required metadata template (Moore et al. 2020).

Table 3.2. *Transects monitored each year between 2005-2021 and transects we propose to monitor in 2022-2026, indicated with an "X". "E" indicates the year the transect was established.*

	Tier II Transects								Drakes Island Transects				
	1I	**1R**	**2I**	**2R**	**3I**	**3R**	**4I**	**4R**	**D1**	**D2**	**D3**	**D4**	**D5**
2005	E	E	E	E	E	E	E	E					
	X	X	X	X	X	X	X	X					
2008		X		X		X							
2009		X		X		X							
2010		X		X		X							
2011	X	X	X	X	X	X	X	X					
2014	X	X	X	X	X	X	X	X					
2016	X	X	X	X	X	X	X	X					
2017	X	X			X	X							
2019	X				X	X		X					
2020		X	X	X			X						
2021									E	E	E	E	E
									X	X	X	X	X
2022	X	X			X	X							
2023			X	X			X	X					
2024									X	X	X	X	X
2025	X	X			X	X							
2026			X	X			X	X					

Data Archiving

Vegetation monitoring data is collected in the field by a team of at least two trained individuals. Any unknown vegetation species are identified in the field using standard and proven identification guides (e.g., Tiner 2009). However, if the species still cannot be identified, a sample is taken back to our lab for further investigation; experts in salt marsh plant identification are also consulted as needed. Whenever plot markers are missing in the field and need to be replaced, this will be recorded so that any changes in the locations of plots can be accounted for when analyzing the data.

Raw point intercept data is multiplied by two to get a "percent cover" for each species. This is entered into a spreadsheet saved in a data folder for that given year on the Wells Reserve Research network drive. Additionally, these data are copied into the Reserve database which contains a compilation of data from all monitoring years. There is a separate Reserve database for: vegetation, pore water (see Elective Monitoring), plot elevations, crab data (see Elective Monitoring), and sediment bearing capacity (see Elective Monitoring) (R:\Sentinel Site Adaptation Module 1 (SSAM1)\VEG MONITORING\DATA). The Wells Reserve vegetation database is nearly identical to the New England NERRs database created by Great Bay NERR (as a result of the NSC Sentinel Site Data Synthesis Project) so regional analyses can be easily conducted and comparisons can be made across New England Reserves. This data is transferred into the NERRS system-wide spreadsheet template for submission to CDMO.

At the end of each monitoring season, details about what was done that year are recorded in a metadata document using the required template for submission to CDMO. All data are QA/QC'd by looking for outliers, ensuring proper and up-to-date scientific names were used, total "percent cover" in each plot is at least 100%, and identifications make sense based on data collected in that plot in previous years. Species names are checked annually against the ITIS database (www.itis.gov/) and updated as needed, documenting any species name changes in the metadata tab of the data workbook. QA/QC recommendations from CDMO will also be followed each year as outlined in the CDMO "Vegetation Biomonitoring QAQC Guideline and Tips" document and "Veg QAQC Checklist" spreadsheet. QA/QC flags will be assigned accordingly to each row in the CDMO database prior to data submission. Details about any suspect data will be described in the metadata document. At the end of each monitoring season, field datasheets are scanned into the computer and stored in a metal filing cabinet. In 2019, a "QAQC Veg Monitoring Data" spreadsheet was created that highlights suspect data from 2005-2019 that should be addressed before conducting any data analyses.

Habitat Mapping

The purpose of the Habitat Mapping and Change Project is to provide coordination and consistency in the implementation of the land use and habitat change component of the System Wide Monitoring Program (SWMP). Its goals are to help the NERRS track and evaluate short-term variability and long-term changes in the extent and type of habitats within the Reserves and examine how these changes are related to anthropogenic- and climate-stressors. The task of the Wells Reserve Habitat Mapping and Change Plan was to map land cover and land use within the Reserve boundary and surrounding uplands, and to model elevation and compute tidal datums within that same area. This will enhance the capacity within the NERRS to map, model, and disseminate information on habitat trends and associated linkages to anthropogenic- and climatic-stressors across the nation. Change detection mapping projects are scheduled for every ten years. The initial project was completed in 2018 and it was accepted by NOAA in 2019. We also produce data mapping products in land use classification to address: **1) High Resolution Mapping Areas** that include all of the land within the Reserve's boundary as well as adjacent beaches, wetlands, and uplands from the coastline to Route One. This area is mapped down to a 0.15 ha. habitat block and **2) Habitats of Perpetual Concern** that will include high and low marsh, forb pans, pools, areas of *Phragmites, Typha, S. alterniflora, and Juncus*, as well as developed areas and a 250' riparian buffer zone around marshes. These areas will be mapped down to a 0.01 ha. habitat block. In 2019, the Wells Reserve ''baseline habitat maps" were approved by the Habitat Mapping and Change Technical Committee (see Appendix B). Wells Reserve is currently exploring the steps to conduct a 10-year change analysis and will be updating this plan in the future to reflect the methods and products of for the analysis once they are developed.

c. Wetland Surface Elevation Change Measurements

Surface elevation influences the period and duration of tidal inundation in tidal marshes and is a critical factor in determining the composition of plant community structure. Surface elevation is a function of several processes including surface accretion, shallow subsidence and expansion of the root zone, deep subsidence between the root zone and underlying bedrock, and vertical motion of the bedrock itself. To quantify each of these processes we will use a combination of deep and shallow surface elevation tables (SET), marker horizons, digital leveling, and GNSS observations.

Using these methods will enable us to 1) quantify the marsh elevation characteristics and how they are changing over time, 2) determine the contribution of surface and subsurface processes in wetland surface elevation, 3) to relate surface elevation changes to local hydrology, 4) assess the ability of the marsh to maintain adequate elevation to keep pace with local sea level rise.

Location
The Wells Reserve maintains two surface elevation monitoring stations, WR8 and LR21, which were established in 2011. These stations each consist of a deep rod SET and a single marker horizon.

Station WR8 is located in the Webhannet River marsh north of Harbor Road, in the vicinity of Tier II monitoring transect 1R (Fig. 3.2). This station consists of a deep rod SET and one feldspar marker horizon (0.25 m^2 plot) installed 1 m due north of the SET plot edge. The station is located in *Spartina patens*-dominated high marsh vegetation within approximately 20 m of the tidal channel, and approximately 915 m from SWMP station welinwq and CO-OPS Tide Station 8419317, Wells, ME.

Station LR21 is located in the Little River marsh near the confluence of the Merriland River and Branch Brook (Fig. 3.2). One feldspar marker horizon (0.25m^2 plot) was installed 1 m due north of the SET plot edge. This station is approximately 268 m downstream of SWMP station WELSMWQ, and approximately 599 m from SWMP station WELLMWQ near the river mouth. The SWMP stations in the Little River Marsh do not currently report water level. The closest water level station to LR21 approximately 2,900 away in the adjacent Webhannet River at the CO-OPS tide station. The station is located in *S. patens* dominated high marsh vegetation approximately 18 m from the tidal channel.

The ellipsoidal heights of these SETs were measured using static GNSS occupations and orthometric heights were calculated using the NOAA OPUS Projects online tool. Due to the remote location of these SETs, leveling from a benchmark is not currently feasible. We will measure the long-term stability of these stations using static GNSS surveys at a minimum interval of 5 years. See the Vertical Control Plan section for more details on transferring vertical control to SETs.

Table 3.3. *Status of Surface Elevation monitoring stations.*

Station ID	SET Type	# Of Marker Horizons	Date Installed	# Of Monitoring Events	Habitat	Distance to Tidal Channel
LR21	Deep rod	1	2011	10	High Marsh	18 m
WR8	Deep rod	1	2011	9	High Marsh	19 m

The Wells Reserve will install six new sampling stations within the new sentinel marsh study area in the vicinity of the new vegetation monitoring transects (see Vegetation Monitoring section). The location of sampling stations will be determined through stratified random sampling. The study area will be divided into 2 sections based on the elevation and proximity to the tidal channel. Half (3) of the stations will be randomly located in a 30 m wide zone adjacent to the main tidal channel and at an elevation between 1.0 m and 1.5 m. The other three stations will be randomly located in the interior of the marsh at an elevation between 1.5 m and 2.0 m. This configuration will focus on capturing essential variability of the study site and enable an intra-site comparison of surface elevation change between low to high elevation and between low/transitional marsh species and high marsh species. To maintain the independence of our stations they will be located no less than 60 m apart from each other. In order to avoid variability due to hydrology, we will locate all sites within a contiguous marsh unit that is not bisected by a tidal creek. Finally, all stations will be located within the interior of the marsh boundary, as defined by a 3 m buffer from the edge of the tidal channel or the upland boundary, to avoid edge effects such as erosion.

Methods

The Wells Reserve will monitor shallow subsidence, surface accretion, root zone expansion and compaction, and local deep subsidence following methods outlined in “The Surface Elevation Table and Marker Horizon Technique” (Lynch et al. 2015) and “Procedures for Connecting SET Benchmarks to the NSRS” (Geoghegan et al. 2009) which are the standard protocols adopted for wetland surface elevation monitoring within the NERR system.

New monitoring stations will be established in the immediate vicinity of the new vegetation plots. Each sampling station will include a deep rod SET driven to refusal, and three marker horizon plots. Each station will be oriented in the configuration recommended by Lynch et al. (2015) for paired deep/shallow SETs (Fig. 3.6). Plots will be configured with ample room for maneuvering and will be delineated with PVC markers to avoid trampling within the plots. Due to the occurrence of ice on the marsh surface during winter months it may not be possible to maintain shallow SETs as part of the monitoring station. Ice could freeze around the aluminum and shift the SET when high tides cause it to float and move. Use of the shallow SETs is preferred as the combination will enable us to assess the contribution of root-zone expansion or subsidence to marsh surface elevation. One or two shallow SETs will be installed and monitored over the course of 2-3 winter seasons to assess stability and the impact of ice. Digital leveling will be used to evaluate the degree to which the SETs move. It may also be possible to reinstall the shallow SET to the correct height using the digital level to help position the pipes and reader mount. If these deployments can be maintained without the need to replace equipment shallow SETs will be installed at the remaining stations. New shallow SETs and marker horizons will be added to the WR8 and LR21 stations as resources and site conditions allow.

Measurements will be taken annually in the fall (September – November) during dry weather and within 2 hours of low tide. This consistency with the timing of sampling will minimize the variability of our measurements due to seasonal climatic factors and daily tidal compression of marsh peat. A double arm rod SET instrument will be mounted on the shallow and deep SETs to enable simultaneous readings at two compass positions per setup. The compass bearings of the four arm positions (A, B, C, D) will be standardized across stations during installation. A compass bearing will again be taken at each arm position when they are measured. Fiberglass pins will be numbered according to position on the double arm (1-18) and used consistently in the same position to avoid error from variable pin length. Measurements of pin height will be taken using a 0.5 m steel zero-edge ruler. It is intended that the same staff person will take measurements each year for consistency. In the event of staff turnover, efforts will be made to conduct double readings at all stations to calibrate measurement error. Marker horizons will be sampled by cutting and removing a small (20 cm x 20 cm) wedge marsh plug approximately 15-20 cm deep, or as deep as necessary to expose the feldspar layer. The depth of the feldspar layer will be measured on three sides of the plug, and a photo of the plug will be taken on a dry erase board with date/time and station/plot information recorded.

To assess the stability of our SET stations we will conduct annual digital leveling surveys of deep and shallow SET vertical reference points to tie them to the local geodetic network. A subset of SETs will also be surveyed using static GNSS measurements for the first three years after establishment of the stations, after which GNSS surveys will be conducted at a minimum frequency of every 5 years. See Vertical Reference Plan section for more details.

Frequency
All surface elevation stations will be monitored annually between September and November. Measurements will be taken within 2 hours of low tide to allow the marsh surface adequate time to decompress from tidal inundation. Sampling will be conducted in dry weather conditions, with no significant rain during the preceding 24-hour period.

Digital leveling will be conducted annually for all SETs in the new sentinel marsh site, and GNSS static surveys will be conducted annually for three years after installation and then every 5 years at a minimum.

Data Archiving
Field datasheets will be digitized by scanning and all data and metadata will be entered into our MS Excel database following formatting developed by Cressmen et al. in 2020. All digital files including photos of marker horizons and plots will be archived on our physical and cloud servers. Field data collection could move to a digital format in the future using field data collection apps as resources allow.

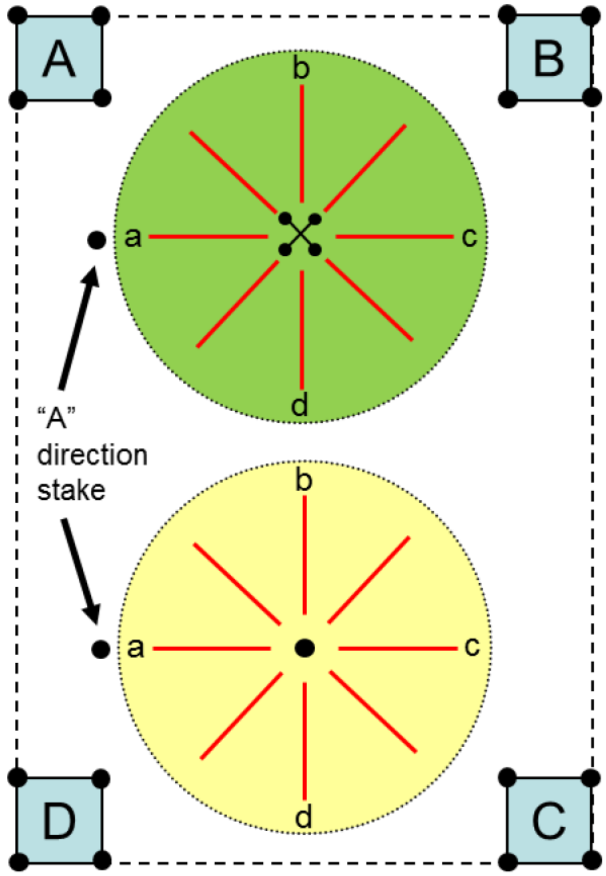

Figure 3.6. *The recommended configuration of paired deep and shallow SETs with four marker horizons from Lynch et al. 2015.*

Data Dissemination
In 2020, analyses of NERR system wide SET data were produced in R programming language as part of a NERRS Science Collaborative Catalyst grant titled *"Is marsh surface tracking sea level change? Developing tools and visualizations for NERRS Sentinel Site Data" aka "SETr"* (Cressman et al. 2020). Data analysis and outreach reports were distributed to participating Reserves covering data from 2011 to 2018. Each Reserve was also provided with a guide to the SETr workflow and the necessary scripts to produce the analysis and reports in R programming language. This analysis and reporting will be updated annually to include new data, and reports will be shared via the Wells Reserve website.

d. Vertical Reference Plan for SSAM-1 Infrastructure

The sentinel site vertical control network will cover three different areas that are within the Webhannet Marsh and are separated from each other by long distances or open water: Drakes Island, Wells Harbor, and Webhannet Head of Tide. This means that separate local vertical control networks will be needed in each area with at least three stable marks each to monitor the relative stability of the local network, and at least one designated Local Control Mark (LCM) with which to anchor the local network to the National Spatial Reference System (NSRS). The local vertical control networks will be located in close proximity to the local study plots (vegetation, SETs, etc.) and the LCM for each local network will be positioned to maximize visibility of GNSS satellites to enable quality static GNSS measurements.

NOAA Continuously Operating Reference Station Network (NCN)

In order to connect the local vertical control networks to the NSRS and track vertical movement of the network we will measure high accuracy positions of our local control marks with static GNSS observations and post-process GNSS data with observations continuously recorded at the NOAA CORS Network (NCN) stations. The CORS data will include local and distant stations to provide corrections for atmospheric effects on the GNSS signals during post-processing.

Table 3.4. *CORSs closest to the Wells Reserve Sentinel Site.*

CORS ID	Frequency	Distance km	Operator/Agency	Installed
NHUN	1 second	37.2	University of New Hampshire	8/27/2004
MEGO	1 second	41.1	Maine Department of Transportation	2/12/2008
MASA	1 second	57.4	Massachusetts Department of Transportation	10/6/2009
P776	15 seconds	70.5	UNAVCO-PBO	5/28/2008
NHCO	5 seconds	78.6	New Hampshire Department of Transportation	2/10/2010

There are five CORSs within 100 km of the Sentinel Site (Table 3.4, Fig 3.6). The best available data from these stations will be used during post-processing of static observations in the Online Positioning User Service Projects tool (OPUS Projects) in addition to a distant CORSs.

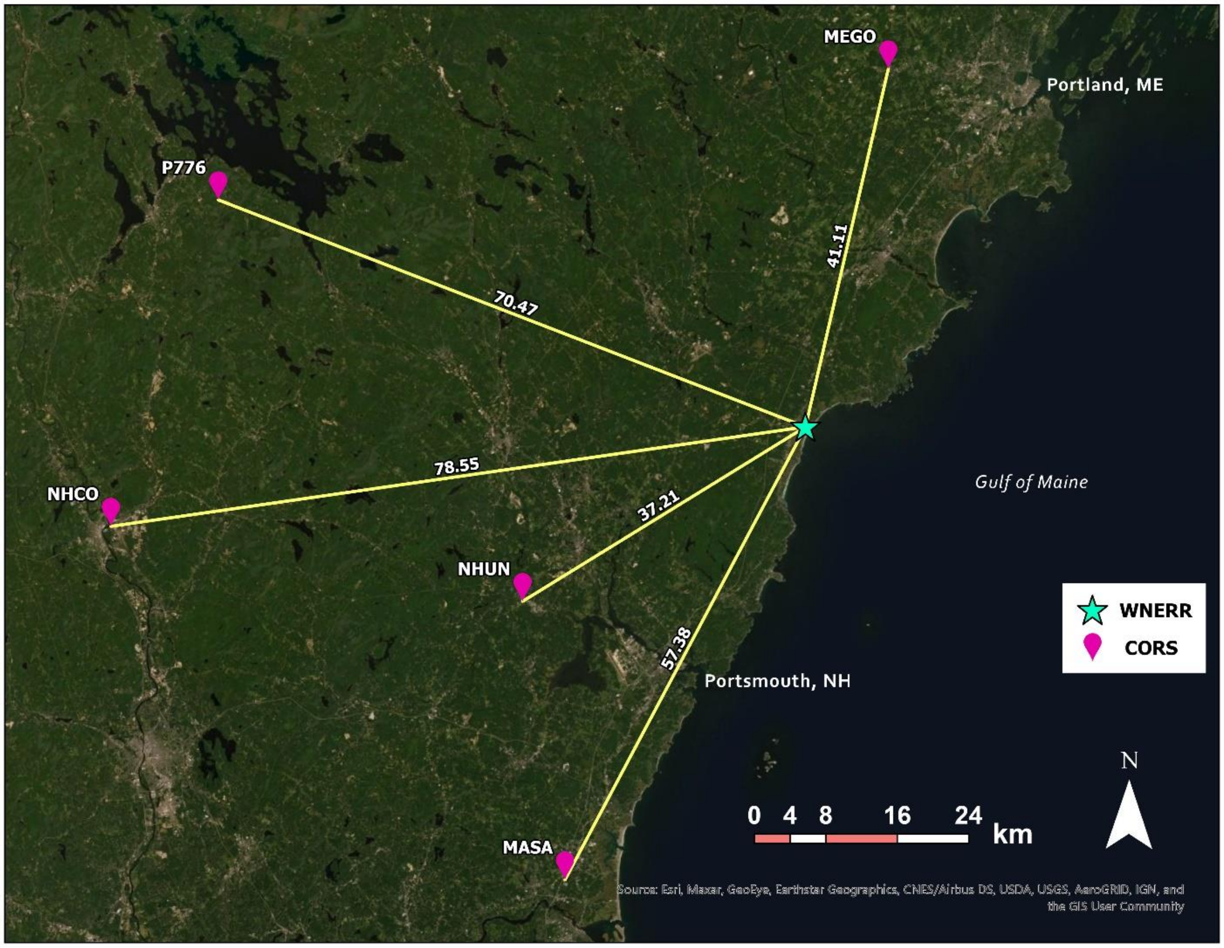

Figure 3.7. *CORS stations (5) located within 100 km of the Wells Reserve that can provide atmospheric corrections for static GNSS observations. Numbers on each line indicate the distance in km between the CORS station and the Wells Reserve.*

NGS Benchmarks

To create the most accurate connection to NAVD88 it would be ideal to tie into one or more existing NGS leveling runs. The National Geodetic Survey (NGS) data explorer identifies five First Order Class I vertical control marks in the vicinity of the sentinel site, all of which were last adjusted in 1991 (Table 3.5, Fig. 3.8). There is a more recent Second Order Class II vertical control mark in the vicinity of the sentinel site that was leveled and adjusted in 2017. If funding allows it may be possible to connect the LCM in each local vertical control network via a leveling line that includes two or more of the existing NGS marks.

NGS will be implementing a modernized NSRS sometime in the near future. A new vertical datum (North American Pacific Geopotential Datum of 2022 [NAPGD 2022]) will replace NAVD 88. The primary method of tying to this new vertical datum will be through GNSS connections to the NCN and the use of a new Gravimetric Geoid (Geoid 2022). As such, more emphasis will be put on high accuracy GNSS surveys tied to the NCN through OPUS. Additionally, NGS has recommended that existing NAVD 88 benchmarks be observed with static GNSS, and that the data be uploaded to OPUS and shared as part of the NGS' GNSSonBM campaign (https://geodesy.noaa.gov/GNSSonBM/index.shtml). The deadline for these submissions is December 31, 2021.

Table 3.5. *National Geodetic Survey published benchmarks in the vicinity of the Wells Reserve Sentinel Site. Two are suitable for GNSS static observations.*

Name	NGS PID	Stability	Vertical Order/Class	Year Adjusted	GNSS
C 161	OC0370	C	First Class I	1991	No
X 5	OC0374	B	First Class I	1991	No
B 161	OC0368	C	First Class I	1991	No
A 161	OC0367	C	First Class I	1991	No
B 158	OC0366	A	First Class I	1991	Yes
FURBISH	DQ2576	B	Second Class II	2017	Yes

Tidal Benchmarks

In addition to the NGS benchmarks, there is also a network of tidal benchmarks associated with the NOAA Center for Operational Oceanographic Products and Services (CO-OPS) Tide Station 8419317 Wells, which includes two of the NGS marks (Table 3.6, Fig.3.8). The tidal benchmark network is conveniently located in the vicinity of one of the SWMP water level stations, which is adjacent to the tide station. These marks will enable running a level line to connect the SWMP station to the NSRS. Unfortunately, because the tide station is located across open water from the sentinel site, it is likely not feasible to run a level line from the tidal benchmarks to the sentinel site LCMs and we will need to rely on simultaneous GNSS observations to establish a vertical positional relationship between these LCMs. Shared OPUS solutions are available for two of the tidal benchmarks and historic observations and associated files will be requested from CO-OPS to enable long term comparisons.

Table 3.6. *Tidal benchmarks for CO-OPS tide station 8419317 Wells. All marks were included in the most recent CO-OPS level run from 2016.*

Name	NGS PID	OPUS PID	Stability
841 9317 PUMP		BBCF81	B
841 9317 C		BBHK75	C
841 9317 A		BBCC03	C
LORD	OC2106		C
B 161	OC0368		C
A 161	OC0367		C

Other Marks
The Wells Reserve maintains a number of other marks that have been used to provide an NSRS tie for past projects via GNSS observations (Fig 3.6, Table 3.7). Many of these are either deep rod style marks or in one case attached to a concrete tide gate abutment. Some of the marks are less stable, consisting of nails in pavement or buried concrete posts.

Table 3.7. *Wells Reserve benchmarks are dispersed to provide GNSS derived vertical control to SWMP stations and Tier II vegetation transects. In 2019 and 2020 new static GNSS observations were taken at most of the benchmarks. Network adjustment in OPUS Projects improved coordinate accuracy considerably.*

Mark ID	Stability	Mark Type	GPS DATE	GPS DURATION	OBS_ USED	FIXED _AMB	REF FRAME	ELIPS_ HGT	ELIPS_ RMS	ORTHO_ HGT	ORTHO _RMS	GEOID
FLAGPOLE	C	Concrete post	5/8/2019	4:24	94%	100%	NAD_83(2011) @ 2010.0000	20.229	0.002	20.229	0.021	GEOID18
HT31	D	Nail in pavement	9/1/2011	3:49	82%	83%	NA	-22.541	0.047	3.897	0.08	GEOID09
HT32	D	Water main access	4/24/2019	4:40	83%	80%	NAD_83(2011) @ 2010.0000	-22.526	0.014	3.928	0.038	GEOID18
LR21	B	Deep rod mark	5/8/2019	4:10	95%	100%	NAD_83(2011) @ 2010.0000	-24.717	0.002	1.715	0.021	GEOID18
LR25	B	Deep rod mark	4/25/2019	4:32	79%	100%	NAD_83(2011) @ 2010.0000	-24.525	0.019	1.901	0.027	GEOID12B
OLDFARMLANE	B	Deep rod mark	1/23/2020	6:56	98%	100%	NAD_83(2011) @ 2010.0000	-24.015	0.001	2.413	0.021	GEOID18
WR8	B	Deep rod mark brass disc	8/24/2011	4:58	99%	100%	NA	-22.5	0.005	1.228	0.014	GEOID09
PAD2	B	Mark in concrete structure	11/5/2020	6:37	98%	100%	NAD_83(2011) @ 2010.0000	-24.151	0.002	2.289	0.021	GEOID18

Survey Plan
As was mentioned above, NGS will be releasing new horizontal and vertical datums in the near future. NGS has recommended that older/archived GNSS observations be reprocessed through OPUS, and “shared” using the OPUS share option. By doing this, the data for LCM’s will be available to NGS for additional processing prior to the release of the new datums, ensuring that new coordinates will be generated for any LCM that has been shared. Any static observation taken on the LCM’s in the future will be shared through OPUS allowing NGS to compute future coordinate updates.

Local control networks will be established or improved in the vicinity of all new and existing monitoring plots and water level stations. This will entail the installation of new benchmarks with suitable stability, either affixed to exposed bedrock, stable infrastructure, or deep rod marks, which may include new SETs.

Figure 3.8. *Inventory of geodetic benchmarks in the vicinity of the Wells Reserve sentinel site.*

The connection to the NSRS will be maintained for each of the local vertical control networks using static GNSS occupations of the LCM for each network. Static GNSS surveys on LCMs will be recorded simultaneously with observation on other LCMs in each local vertical control network at least every 5 years to reestablish the connection with the NSRS and to monitor vertical movement of the local network. Surveys will be conducted more frequently when GNSS equipment is deployed for other tasks (during RTK surveys for example). Marks will be surveyed on two separate dates for 4-7 hours each. A quality control check will be performed post-deployment to determine if the GNSS data are suitable for use in a network adjustment. Data will be uploaded to OPUS static after 24 hours, and solutions will be evaluated. If data is not within quality specifications, new observations will be taken. GNSS observations will be simultaneous for at least two LCMs during a given static session and ideally static occupations will occur simultaneously at all the LCMs if enough GNSS units are available to enable this. All static observations will be post-processed using the OPUS Projects software and network adjustments will be calculated for each LCM. A weighted average orthometric height will be calculated for each LCM using the inverse of the orthometric RMS error as the weight for each static occupation. Static GNSS observations will be recorded simultaneously on LCMs in each local vertical control network every 5 years to reestablish the connection with the NSRS and to monitor vertical movement of the local network. The elevation of benchmarks not associated with the primary local vertical control networks will be measured every 5 years using static GNSS observations.

The relative heights of marks within each local vertical control network will be measured with a level line to monitor the stability of the local marks. Leveling of each local network will be conducted on an annual basis using a Leica Sprinter 150m digital barcode level and telescoping aluminum barcode staffs with bipods. If funding allows, fixed height barcode staffs may be purchased to improve leveling accuracy.

For orthometric height measurements at monitoring plots, such as vegetation plots or groundwater wells, that cannot be levelled to with a reasonable amount of effort, RTK GNSS will be used instead. The GNSS base station will be set up on the highest quality mark within radio range of the plots to be measured. Individual plot elevations, including vegetation plots, groundwater wells, and SETs, will be measured on the same frequency and in the same year as the associated data is collected. In most cases, this will be annually, with the exception of the Tier II vegetation plots and SETs.

Installation of benchmarks, line leveling, RTK GNSS, and static GNSS observations will conform to methods outlined in the manual “Accurate Elevations for Sea Level Rise Sentinel Sites” (Hensel et al. 2019). Installation of SETs will conform to the methods outlined in the manual “The Surface Elevation Table and Marker Horizon Technique” (Lynch et al. 2015).

Connection to Tidal Datums

NOAA CO-OPS has published tidal datums for the tides station, including the North American Vertical Datum of 1988 (NAVD88) height. This will enable us to tie all of the sentinel site components to the local tidal datums through local vertical control network connections to the NSRS. The CO-OPS tide station will be levelled on an annual basis. CO-OPS requires an annual First Order Class II level run to maintain vertical control at the tide station, however the equipment and level of survey expertise required to carryout this leveling are prohibitive. The methods we intend to employ will follow those for differential leveling outlined in Hensel et al. (2019). See the Water Level section for more details.

Harbor Study Site

The existing CO-OPS tidal benchmark network will be sufficient for maintaining vertical control at the SWMP WELINWQ water level station. The primary tidal benchmark (9317 PUMP) will serve as the LCM and provide a tie to the NSRS. Annual measurement of the sensor height will be accomplished using a line level which includes the LCM and at least one of the other nearby tidal benchmarks. Additional leveling will occur after any alterations to the station or major disturbances. A “quick check” measurement will be made at least every 3 months at the start of a new sensor deployment to monitor the stability of the well, consisting of a visual comparison of a mark on the sonde cable with a mark on the top of the well.

Drakes Island Study Site

An existing Wells Reserve benchmark (PAD2) will serve as the LCM for the local vertical control network and provide the tie to the NSRS. Additional benchmarks will be installed in exposed bedrock (if available) or more likely on deep rod style marks. If funding is a constraint the additional benchmarks will be located at two of the six new SETs to be installed at the study site. Orthometric height measurements will be taken at vegetation plots, groundwater wells, and SETs in any year that data is collected at the plots. Line leveling will be the preferred method for measuring relative height when time and staff capacity allow. Those plots that cannot be leveled with a reasonable amount of effort will be monitored with RTK GNSS.

Figure 3.10. *Existing local vertical control marks at the Head of Tide study site are not suitable for long term vertical control. Three new marks will be installed in the vicinity of the SWMP station to facilitate leveling of the water level sensor.*

Head of Tide Study Site

The existing local benchmarks at this site are not of suitable stability to provide ongoing vertical control of the SWMP station welhtwq water level sensor. Additionally, the area surrounding the site is not ideal for GNSS observations, with limited southern sky exposure. However, steps will be taken to install new benchmarks and create a tie to the NSRS for at least one mark using static GNSS observations. Static GNSS observations of the LCM should be taken either during a time of year when leaves have dropped to maximize satellite visibility. The water level sensor will be leveled on an annual basis as well as after any physical alterations or disturbances to the station. A “quick check” measurement will be made at least every 3 months at the start of a new sensor deployment to monitor the stability of the well, consisting of a visual comparison of a mark on the sonde cable with a mark on the top of the well.

Legacy Vegetation Plots

There are currently no plans to establish local vertical control networks in the vicinity of the legacy vegetation transects. Wetland surface elevation will be measured using an RTK GNSS during years that the vegetation plots are monitored. RTK surveys will be conducted in late fall or early winter after leaves have fallen to maximize satellite visibility and improve the precision of the measurements. Local control marks may be established in the future to facilitate use of the digital level as funding permits.

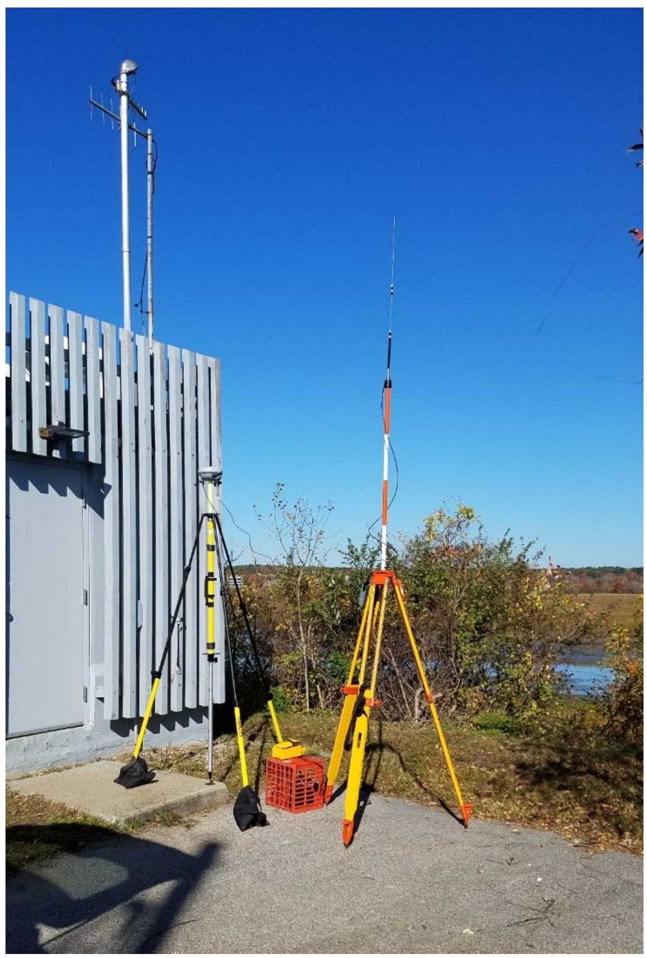

Figure 3.11. *A GNSS base receiver and radio is setup on the primary tidal benchmark at Wells Harbor to provide real time corrections for RTK measurements of the wetland surface at Tier II*

vegetation plots in 2019. The 9317 PUMP benchmark is not ideal for static GNSS occupations due to increased chance for multi-path error from the nearby sewer pumping building.

Legacy SETs
There are currently no plans to establish local vertical control networks in the vicinity of the legacy SETs. The vertical reference point of these SETs will be surveyed with static GNSS observations every 5 years (Figure 3.11).

Data Archiving
For static GNSS occupations, field data sheets will be filled out for each session at each benchmark and will include information on the reference frame and ellipsoid model used. Datasheets will be digitized and archived. Digital files, including raw GNSS files, RINEX files, and OPUS Projects files will be archived on both cloud storage and the local server drives. Updated benchmark coordinates will be entered into a database to track and assess changes over time and to provide a single location for referencing benchmark coordinates for control surveys such as for UAS or RTK GNSS.

Figure 3.12. *GNSS observations are collected on the vertical reference point of deep rod SET LR21 in 2019.*

Line leveling data and metadata will be recorded on field datasheets or entered into a cloud based digital platform such as ESRI Survey123. Field datasheets will be digitized and archived. Digital archives will be stored on both cloud storage and local server drives. Measured heights will be entered into the respective databases for each data type (wetland surface, benchmark, groundwater well, etc.).

Training Needs

Staff training in the use of Translev and WinDesc will be considered to improve archiving and data analysis of leveling lines as. Staff will continue to attend relevant webinars and training hosted by NERRS and partner organizations. Other training topics could include the use of real time networked GNSS (RTN) and post processing of RTN data with OPUS.

e. Water Levels

Tidal hydrology is the primary factor driving biological and physical processes in estuarine habitats including the distribution of wetland species, sediment dynamics, inundation depth and duration, and salinity. The Wells Reserve will monitor water level in association with other biomonitoring parameters included in this plan.

The Wells Reserve collects water level data at two SMWP stations in the Webhannet River (see Section f. Water Quality and Meteorological Data), at the inlet (welinwq) and head-of-tide (welhtwq). Water level data are also available for the Webhannet River from a NOAA CO-OPS Tide Station (station #8419317). This tide station has only been collecting verified 6-minute water level data since 2005, so tidal datums are computed using the Portland, ME Tide Station 8418150 as a control. Tidal datums are based on a data series length of 9 years including three time periods: 12/05-11/08, 12/09-11/10, and 7/11-6/16. In 2017, the Wells Reserve established a 5-year cooperative agreement with the NOAA Center for Operational Oceanographic Products and Services (CO-OPS) to maintain, service, and manage the tide gauge at Wells Harbor, which expires in 2022. As of 2022 CO-OPS has decided to no longer support real-time data for the station due to a lack of annual leveling. However, Wells Reserve will continue to operate and maintain the station. The gauge permits the Reserve to maintain local, accurate, and vertically controlled water level data for research, monitoring, and management as part of our Sentinel Site development. Station information, including tidal and orthometric datums and historic data, are available online at https://tidesandcurrents.noaa.gov/stationhome.html?id=8419317.

We will continue to collect water level data at the two SWMP stations located in the Webhannet River estuary for comparison of methods, to check data accuracy, and to provide potentially higher resolution data in the upstream reaches of the estuary. Past efforts to collect vertically controlled water level data at two additional SWMP stations (wellmwq, welsmwq) in the nearby Little River estuary, which is distinct hydrologically from the Webhannet River, have been hindered by a lack of stable infrastructure from which to deploy a stable data collection platform. Installation of steel helical anchors in the stream bed was attempted in 2018 but was unsuccessful. Stable benchmarks have been installed and surveyed in the Little River marsh and could enable an NSRS tie for future water level monitoring if a stable permanent deployment solution can be found.

Location

The CO-OPS tide station is located at the inlet of the Webhannet River and is mounted to the Town Pier at 70.5634189°W, 43.3202447°N. The Inlet SWMP station (welinwq) is also mounted to the pier, adjacent to the tide station. The Head-of-Tide SWMP station (welhtwq) is mounted to the bridge abutment of the State Route 1 crossing of the Webhannet River just below the natural head of tide (a waterfall), at 70.5870935°W 43.2983381°N (see Fig. 3.2).

Methods

Water level data are collected at SWMP stations in accordance with CDMO guidelines for deployment and maintenance of long-term water quality monitoring stations (see SWMP section). The YSI EXO-2 data sondes are deployed in schedule 40 PVC wells affixed to permanent structures (either driven pilings or concrete abutments), with substantial stainless-steel brackets that are not subject to significant motion.

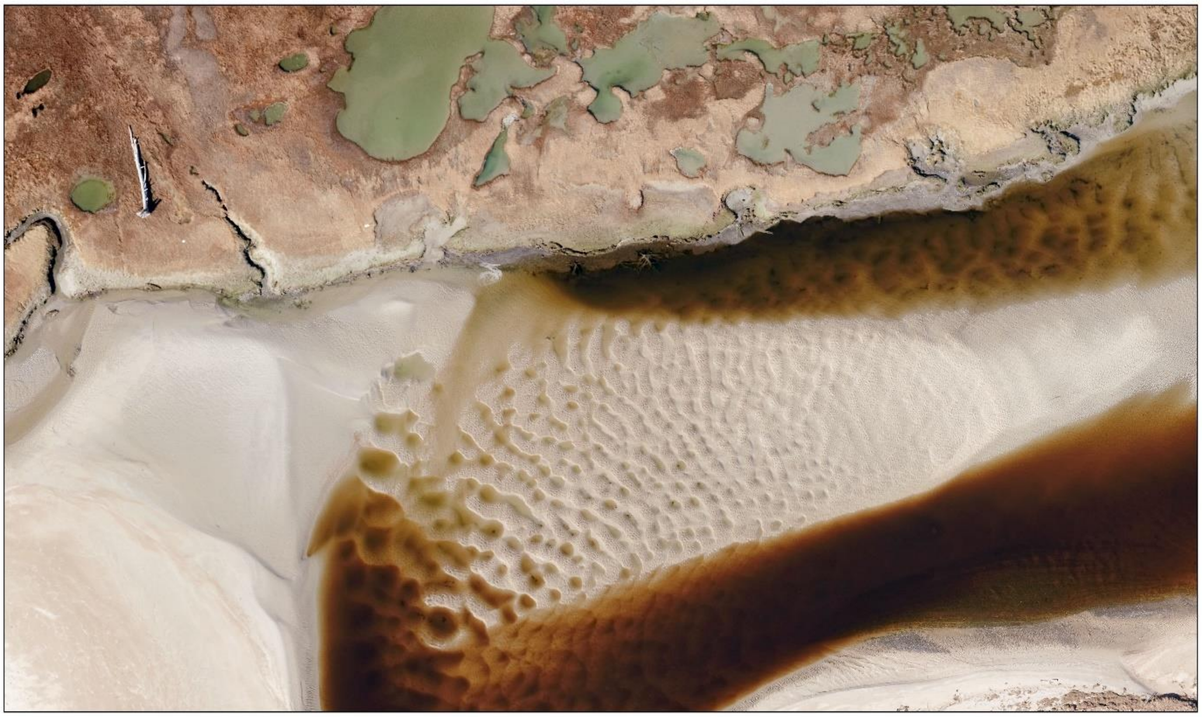

Figure 3.13. *Shifting sediment and remote location create challenges for deployment of stable water level stations in the Little River estuary.*

Staff at the Wells Reserve will continue to maintain the station per the standard operating procedures set forth in the Standing Project Instructions For CO-OPS Observing (CO-OPS 2020). This includes monthly site visits to inspect all connections, power supply, station hardware, as well replacement of desiccant inside station. Reserve staff will also conduct annual dives on the station to clean and inspect underwater components and hardware. Local vertical control benchmarks have been installed in the vicinity of each SWMP station collecting water level data, and sensor orthometric height is measured with a Leica Sprinter 150 digital level (see Vertical Reference Plan section).

Tidal datums will be computed for SWMP station water level data using the CO-OPS Tidal Analysis Datum Calculator (https://access.co-ops.nos.noaa.gov/datumcalc/index.jsp). We will calculate the First Reduction Datum to assess recent trends as well as the National Tidal Datum Epoch equivalent datums (NTDE), selecting the Portland, ME tide station as a control station, to compare water level data with longer term trends.

Vertically controlled water level data are available for the WELWQIN and WELWQHT SWMP stations for part of 2018 and 2019 seasons. Initial tidal datum calculations have been made and datum values are stored in a datum database for easy tracking and comparison, in addition to published datums for Wells, ME and Portland, ME tide stations.

We will estimate the depth and duration of tidal inundation at each of our biomonitoring plots (see vegetation monitoring section) over the course of the annual growing season in order to assess how inundation patterns influence species distribution and how this changes over time as sea level rises. To do this we will use the CDMO Inundation Tool (Buck 2019) to analyze water level data relative to each plot elevation and estimate the frequency and duration of tidal flooding.

Our new study site is located approximately 1.7 km upstream of the Wells Harbor tide station. A temporary water level station was deployed near the study site to determine if there was any delay in the tidal phase between the study site and the water level station in the harbor. In addition, water level was measured with an RTK GNSS and compared with simultaneous measurements from the tide station. Based on these comparisons it appears that within the 6-minute data interval there is no discernable difference in the hydrograph with respect to the timing and elevation on the flood and eb tides. These results indicate that the water level measurements collected at the tide station will be suitable for measuring water level at the study site, which is preferable to the use of temporary, and less stable, stations closer to the study site.

Frequency

The orthometric height of water level sensors at SMWP stations will be measured one to two times per year and updated as needed due to station maintenance or other periodic activities that result in movement of the station infrastructure or deployment regime.

Orthometric height will be measured for the Tide Station water level sensor at least once per year and updated as needed for maintenance and other activities that may alter sensor position.

Tidal datums will be calculated for SWMP station water level on an annual basis with provisional water level data, and datums will be updated for approved water level data as they become available from CDMO.

Vertically controlled water level data are available for the WELWQIN and WELWQHT SWMP stations for part of 2018 and 2019 seasons. Initial tidal datum calculations have been made and datum values are stored in a datum database for easy tracking and comparison, in addition to published datums for Wells, ME and Portland, ME tide stations.

Tidal datums for the Tide Station will be updated by CO-OPS at the conclusion of the current tidal epoch (2002-2020). Annual tidal datums will be calculated to evaluate annual variation and track sea level rise.

Data Management and Dissemination
Orthometric height for SWMP sensors will be reported in the annual SMWP metadata documents required with all data submissions, and survey files will be in a dedicated database. Orthometric heights for the Tide Station will be submitted as part of the annual E-Site report to NOAA CO-OPS and survey files will be archived in a dedicated database. Hard copy field sheets will be scanned and archived along with survey field notes.

Water level data for the welinwq SWMP station and the 8419317 Wells Tide Station are telemetered and available through the CDMO and CO-OPS websites, respectively. Data from the welhtwq SMWP station will be transmitted for real time delivery starting in the summer of 2020 and are also submitted to CDMO on a quarterly basis with provisional and approved data available on the CDMO website.

In 2020, CO-OPS ceased verifying the realtime water level data from the Tide Station. At some point soon the station page will no longer provide the realtime data. The Wells Reserve will continue to collect data and broadcast it to the Hydrometeorological Automated Data System (HADS) server. Discussions are currently taking place as to where and how data will continue to be made available through an online user portal.

Additional water level products such as tidal datums and inundation analysis may be made public through the Reserve website.

f. Water Quality and Meteorological Data

Figure 3.14. *<u>Left:</u> The NOAA tide gauge at the Wells Harbor inlet site. <u>Top Center</u>: Jeremy Miller deploys a data sonde at the Skinner Mill site. Bottom Center: J. Miller downloads data from the weather station at Laudholm Farm. <u>Top Right</u>: J. Miller downloads data from the water quality station at Skinner Mill. <u>Bottom Right:</u> J. Miller and L. Crane deploy a data sonde in the Little River during the pandemic.*

Location

The Wells Reserve started collecting core SWMP water quality and weather parameters in 1995. Currently the Wells Reserve has all water quality and weather monitoring infrastructure in place and collecting data according to the CDMO standard protocols (NERRS, 2017). These stations are located in the Webhannet and Little River Estuaries (Fig. 3.2)

There are two sampling sites in the Webhannet River estuary, located at the Head of Tide (welhtwq) and at the Webhannet Harbor Inlet (welinwq). The Webhannet Head of Tide site is located 4 miles south of the Wells Reserve campus, just downstream of the Webhannet Falls (freshwater) and affixed to the western bridge abutment of the U.S. Route One bridge. Depths at this site range between 0.5 m during dry periods and 3 m on exceptionally high tides and during heavy runoff events. The salinity range here is 0-31 psu (practical salinity units), with a mean of 3.6 psu.

The Webhannet inlet site is located 2.4. km south of the Wells Reserve campus, at the mouth of the Webhannet River. The maximum depth range of the Inlet site is 2.38- 6.74 m. The salinity range here is 7-35 psu, with a mean of approximately 31 psu. This site is also home to our diel nutrient sampling program using an automated water sampler (ISCO) to collect 12 grab samples over the course of a full tidal cycle, for nutrient and chlorophyll-a analysis. The Webhannet estuary forms an extensive wetland/salt marsh area, and the entrance to the harbor is through a jetty. This site is also home to a NOAA Co/Ops tide gauge (Station # 8419317, https://tidesandcurrents.noaa.gov/) which provides accurate local water level data for use in our sea level rise assessments. The Wells Inlet site also houses a variety of monitoring and research projects throughout the year including an ongoing larval fish monitoring project, marine invasive species monitoring and research, and the recent addition of a pCO_2 sensor to begin looking at parameters associated with ocean acidification.

The Little River Estuary is located 0.64 km from the Wells Reserve campus and is a smaller and less impacted system than the Webhannet. There are two sites in the estuary: one located near the mouth of the system (wellmwq), and one near the head of tide (welsmwq). The Little River site exists in a shallow and relatively pristine system with a sandy to mud bottom and a salinity range of 0-32 psu. There are two major freshwater inputs, the Merriland and Branch Brook Rivers, which converge to form the Little River. The tidal range of the Little River estuary is 2.6-3.0 m (Mariano and FitzGerald 1989). Depth typically ranges from 0.24-2.39 m, with greater range seen at during spring tides and storm events. At this point, we do not have any active vegetation plots in the little river system.

Figure 3.15. *Location of the welhtwq data sonde deployed in a PVC tube attached to the Route 1 bridge, along with the associated telemetry station constructed in 2020.*

In both estuaries, water quality sondes are located along a salinity gradient, designed to capture long-term changes in salinity due to sea level rise, as well as short-term variability due to storm surge or spring tides. The Laudholm Farm weather station (wellfmet) is located in an open field just behind the Maine Coastal Ecology Center (Fig. 3.2), and in between the two estuaries being monitored, allowing for connectivity between the weather, water quality, and vegetation monitoring data. Four of our stations (welinwq, welhtwq, welsmwq, and wellfmet) are equipped with GOES satellite telemetry equipment providing near real-time data to the CDMO and NOAA HADS (https://www.goes.noaa.gov/).

Methods
All water quality, weather, and nutrient data are collected, QA-QCed, and processed according to protocols in place by the System-Wide Monitoring Program (SWMP) (NERRS 2017). Meteorological parameters collected include air temperature, relative humidity, barometric pressure, wind speed and direction, photosynthetically active radiation, and precipitation. Water quality parameters include water temperature, specific conductance, salinity, water level, pH, dissolved oxygen, and turbidity.

Water samples are collected for nutrients and chlorophyll-a analysis on a monthly basis, per SWMP protocol. Duplicate grab samples are taken from the four water quality stations (excluding the time period when associated data sondes are removed due to ice), and an automated ISCO water sampler is deployed at our welinwq site, allowing for nutrients and chlorophyll to be assessed over a complete tidal cycle each month. Nutrients include orthophosphate, combined nitrate/nitrite, ammonium, dissolved inorganic nitrogen, and silicate.

Frequency
All SWMP weather and water quality stations collect abiotic data over a 24-hr. period, at a 15-min. frequency, over the course of the entire year. The exception to this is three water quality sites (welsmwq, wellmwq, and welhtwq) that must be removed during winter due to ice. One weather station (wellfmet) and three water quality stations (welinwq, welsmwq, and welhtwq) are connected via telemetry to the GOES satellite system to provide near real-time data to the CDMO. Data from the remaining water quality station (wellmwq) are downloaded and published quarterly.

Data Archiving
All SWMP data collected at the Wells Reserve are submitted to the CDMO, a centralized repository that can have data queried by anyone at any time located anywhere. All SWMP data is also backed up on the reserve's internal servers and on the SWMP laptop located in the Maine Coastal Ecology Center.

Data Dissemination
Data is available online through the CDMO (www.nerrsdata.org) and can be downloaded at any time by a variety of end users. Near real-time data from our telemetered stations are available online at http://cdmo.baruch.sc.edu/pwa/index.html. The Wells Reserve has a long history of working with state, federal, regional, educational, and academic partners, allowing for SWMP data to have a wide dissemination and a variety of uses. Wells Reserve SWMP data is integrated into regional monitoring efforts like the Northeast Regional Association of Coastal and Ocean Observation System (NERACOOS), as well as the Maine Department of Environmental Protections internal databases. SWMP data is accessed and used by local Emergency Management Officials to help in the response to flooding events and extreme weather events and is also being used to help inform a number of research and monitoring projects occurring at the Wells Reserve.

g. Elective Parameters and Protocols

The following describes elective monitoring methods that have been used in the past at our Tier II vegetation transects and that we plan to continue at both the Tier II transects and the new Drakes Island transects: Crab and Burrow Abundance and Discrete Pore Water Sampling. Potential new elective metrics are also described, including Continuous Pore Water Monitoring, Marsh Migration and Ecotone Assessment, and Sediment Bearing Capacity.

Crab and Burrow Abundance

Crab assessments were added to the Vegetation Monitoring Protocol in 2017 as part of a NERRS synthesis project with 22 other Reserves to better understand the distribution of crab species within salt marsh habitats and their impacts on marshes, such as via bioturbation (e.g., Fig. 3.16) and herbivory. The Wells Reserve is continuing this monitoring at all transects to detect long-term changes in crab species distributions in our marshes. The current focus is on the invasive green crab, *Carcinus maenas*, which is abundant in Maine's salt marshes (Raposa et al. 2019). Continued monitoring will allow us to detect future invaders or range expansions (i.e., by the fiddler crab *Uca* spp. or blue crab, *Callinectes sapidus*). At each vegetation monitoring plot, the following are recorded: crab presence/absence and species, number of crab burrows, distance to the nearest creek, and signs of crab herbivory (Wasson et al. 2019). Additionally, crab pitfall traps constructed of tennis ball canisters are installed 1 m north of each plot. 22-24 hr. after the traps are set, the abundance, species, sex, and carapace width of crabs present in each trap are recorded (Wasson et al. 2019).

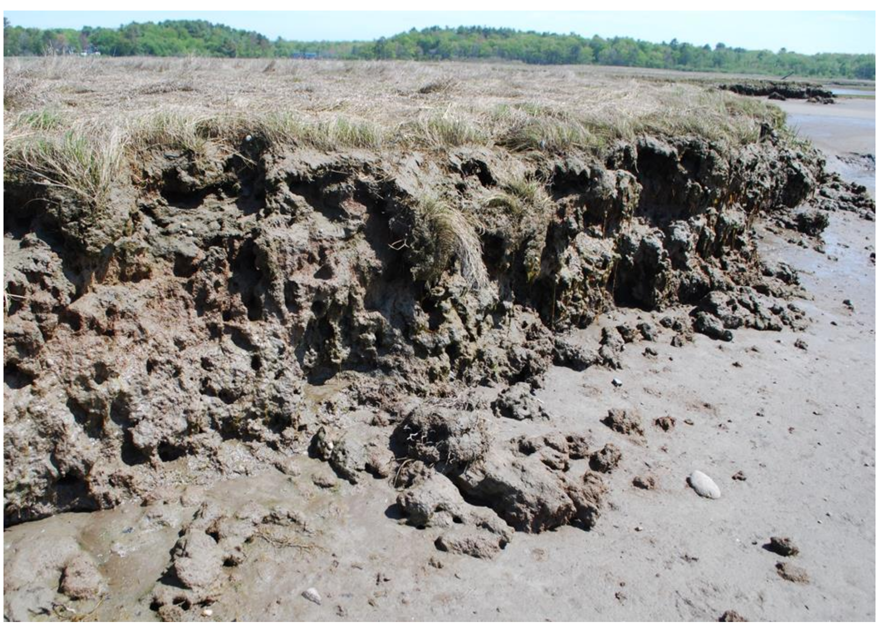

Figure 3.16. *Green crab burrowing activity in a WNERR marsh.*

Discrete Pore Water Sampling

Hydrology and salinity are two of the most important environmental factors influencing plant species distribution in tidal wetlands. In order to document spatial and temporal variations in subsurface hydrodynamics, at each vegetation monitoring plot, shallow pore water wells are installed 1 m south of the PVC marking the transect at least 1-2 weeks before the first pore water sampling event. Once per month (June – September) and within 2 hours of low tide, the following are measured and recorded: outside well height (top of well to ground), inside well height (top of well to water), well salinity (extracted from well), and sipper salinity (water extracted from the ground using a marsh sipper/soil probe). Pore water depth is calculated by subtracting inside well height from outside well height. Methods are adapted from Roman et al. (2001), though well construction differs slightly; our pore water wells are constructed of 0.5-inch interior diameter PVC Schedule 40, 60 cm in length and driven 45 cm into the ground so water is collected closer to the root zone. Analyses should ideally be run on the sipper salinity data since this is collected directly from the ground/root zone, but well water salinity can be used when sipper samples come up dry.

Continuous Pore Water Monitoring

While the methods described above for monitoring pore water are limited to discrete points in time, the collection of continuous pore water data (e.g., using HOBO or In-Situ Aqua Troll data loggers) would improve temporal coverage and detect changes in pore water across tides and changing weather patterns. A preliminary study was conducted in July-September 2020 to pilot the use of HOBO Conductivity loggers for continuous monitoring of pore water salinity in conjunction with discrete sampling. Three wells were constructed that were similar in design to the traditional wells used for discrete sampling, but slightly wider to hold a HOBO Conductivity data logger at a fixed depth of 45 cm (the same depth at which discrete pore water samples are collected). These wells were installed ~ 1 m apart from the discrete pore water wells at 2R1, 2R3, and 2R5 and loggers collected conductivity and temperature data every 30 min. This pilot study demonstrated the importance of collecting continuous conductivity data to improve understanding of long- and short-term fluctuations. While the discrete salinity measurements somewhat agreed with the continuous measurements collected simultaneously ($\pm$ 5 psu), the discrete measurements provided no evidence of the drastic changes in salinity that were observed over time. Additionally, when discrete measurements create outliers in the data, continuous data can help explain these sudden changes in salinity. Discrete salinity measurements are heavily influenced by recent weather patterns and tidal ranges which can be difficult to fully account for in monthly sampling. Therefore, the incorporation of continuous pore water monitoring will allow for more accurate—and complete—analyses of long-term pore water trends.

Each year, we propose to install a continuous pore water well containing a HOBO Conductivity logger (model U24-002-C, Onset Computer Corp., Onset, MA) at each of three plots (1, 3, and 5) along a transect with a relatively continuous elevation gradient from creek to upland edge (3R or 2R depending on which set of transects is being monitored that year; see Table 3.2 in the Vegetation Monitoring section). Continuous wells will be installed ~ 0.5 m apart from adjacent traditional pore water wells to minimize spatial differences in hydrology between the two wells.

A calibrated handheld YSI will measure pore water conductivity at the start and end of each HOBO deployment to calibrate the HOBO loggers. Loggers will be deployed June-September to encompass discrete pore water sampling and vegetation monitoring. Discrete measurements collected from the pore water wells will be compared to the measurements collected simultaneously by data loggers, and SWMP data will also be incorporated into analyses to better understand observed fluctuations. An SOP and R script (R Core Team, 2020) were created in 2020 for HOBO logger deployment, post-deployment data processing, and data visualization based on the pilot study. While we currently plan to continue simultaneous continuous and discrete pore water monitoring, data comparisons over the next few years will allow us to reassess the value of collecting both types of pore water data and whether continuous pore water monitoring alone may be sufficient for analyzing long-term trends in salinity.

Marsh Migration and Ecotone Assessment

While the vegetation monitoring conducted at the permanent monitoring plots (see Vegetation Monitoring section) will allow for detection of long-term vegetation changes over decadal timescales—and plot 5 in particular will detect marsh migration into the upland after migration has reached a certain point—they will not be able to detect shorter-term fluctuations in the marsh-upland boundary, nor at the marsh-creek boundary. Therefore, a pilot study will be conducted in 2022 in which a highly accurate GNSS point will be taken at several locations along each transect line: 1) the boundary between 100% salt marsh vegetation and marsh-upland transition zone, 2) the boundary between the marsh-upland transition zone and 100% upland vegetation, and 3) the boundary between unvegetated creek bank and vegetated low marsh near permanent monitoring plot 1. During vegetation monitoring conducted during peak biomass, these boundary points will be marked with flags based on vegetation composition. During elevation surveys conducted in late fall, an RTK GNSS (10-30 mm horizontal accuracy) will be used to record the location of each flag. This pilot study will allow us to assess the feasibility and accuracy of this method for long-term monitoring of marsh migration.

Sediment Bearing Capacity

In 2020, we piloted the use of a soil penetrometer designed and constructed by researchers at Bates College (Dr. Beverly Johnson, Phillip Dostie) to measure sediment bearing capacity, which includes loading response and penetration depth. Loading response is a measure of how deep a given weight sinks when placed on the marsh surface and is an indicator of the level of decomposition in the upper layer of sediment (Mansfield & Grady 2015). Penetration depth is a measure of how deep that same weight penetrates with five successive blows and is an indicator of belowground biomass, where penetration depth is inversely related to bearing capacity and belowground biomass (Bertness & Miller 1984; Mansfield & Grady 2015). Changes in belowground biomass have been found to precede changes in aboveground vegetation communities (Twohig & Stolt 2011). Methods are adapted from monitoring protocols by TNC NJ (2015) and DE DNREC (2010). The penetrometer designed by Bates College consists of a 2 kg brass weight that slides freely over a metal rod attached to a capped PVC base (as shown in Fig. 3.1). At each vegetation monitoring plot, the capped PVC will be placed within 25 cm outside a corner, in a spot that is representative of the vegetation monitoring plot (Fig. 3.17). Any vegetation will be gently shifted out of the way of the PVC to maximize contact with the sediment surface. Without applying force, the depth to which the PVC penetrates the sediment (initial depth) will be recorded as the Loading Response. Holding upright, the brass weight will be dropped free-fall five times. After each drop, the depth to which the PVC penetrates the soil will be measured. Penetration depth will be calculated by subtracting initial depth from final depth. The first monitoring at each plot will occur outside the corner facing the upland and transect line; each time a plot is monitored, the corner measured should rotate clockwise to minimize disturbance (Fig. 3.17). Measurements should be taken within 2 hr. of low tide (when possible) to reduce variability in soil saturation. Any observations about surface water on the plot or sediment composition (organic, anoxic, texture, etc.) will also be recorded. This elective monitoring data will be analyzed to detect changes in bearing capacity as a proxy for belowground biomass over time. Additional analyses may include correlations with vegetation composition, aboveground biomass (stem height, density, cover), and/or crab burrow distribution.

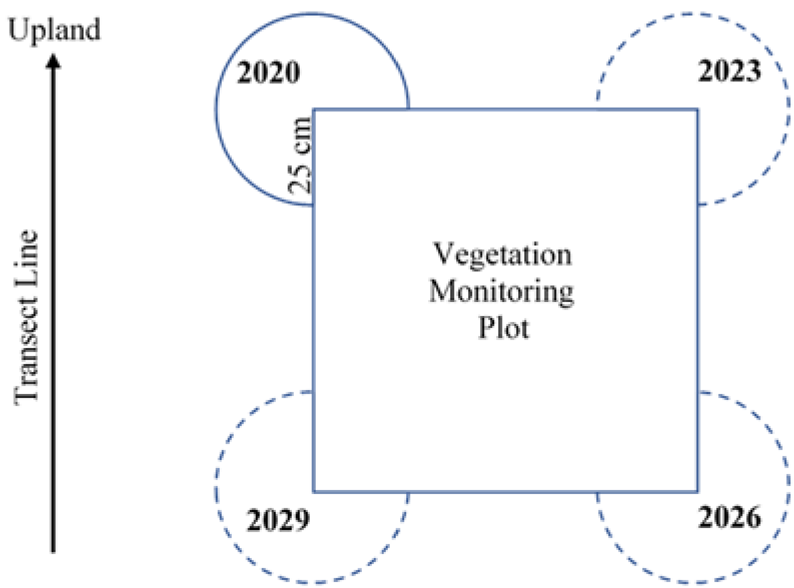

Figure 3.17. *Placement of the penetrometer within 25 cm of the corner of the vegetation monitoring plot. Years indicate when each corner would be monitored, for a plot that is monitored every 3 years with the first sampling occurring in the corner closest to the upland and the transect line.*

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V. Appendices

Appendix A. Plant species recorded within the Tier II vegetation monitoring plots 2005-2020.

Scientific Name	Common Name
Agalinis (Gerardia) maritima	seaside/saltmarsh gerardia
Alnus spp.	alder tree
Atriplex patula	marsh orach
Carex palacea	chaffy sedge
Calystegia (Convolvulus) sepium	morning glory / hedge bindweed
Cuscuta spp.	dodder
Distichlis spicata	spike grass
Festuca rubra	red fescue
Juncus balticus	Baltic rush
Juncus gerardii	saltmarsh rush
Limoneum carolinianum (nashii)	sea lavender
Lonicera japonica	Japanese honeysuckle
Lysimachia (Glaux) maritima	sea milkwort
Persicaria sagittata	arrow-leaved tearthumb
Phragmites australis	common reed
Plantago maritima	seaside plantain
Potentilla (Argentina) anserina	silverweed
Puccinellia maritima	seaside alkaligrass
Salicornia spp.	glasswort
Salix spp.	weeping willow
Schoenoplectus (Scirpus) americanus	chairmaker's bulrush
Solanum dulcamara	bittersweet / nightshade
Solidago sempervirens	seaside goldenrod
Spartina alterniflora	smooth cord grass
Spartina patens	salt hay / salt meadow cord grass
Spartina pectinata	prairie cordgrass
Suaeda linearis	sea blite
Symphyotrichum novi-belgii	New York aster
Symphyotrichum tenufolium	perennial salt marsh aster
Thinopyrum (Agropyron) pungens	tick quackgrass
Toxicodendron radicans	poison ivy
Triglochin maritimum	seaside arrow grass
Typha angustifolia	narrow leaf cattail
Typha latifolia	broad leaf cattail

Appendix B. NOAA-OCM Habitat Mapping Approval Letter 2019

U.S. DEPARTMENT OF COMMERCE
National Oceanic and Atmospheric Administration
Office for Coastal Management
Silver Spring Metro Center, Building 4
1305 East-West Highway
Silver Spring, Maryland 20910

March 13, 2019

Dear Paul,

This letter is to formally acknowledge that the Habitat Mapping and Change Technical Committee has approved the baseline habitat maps of the Wells National Estuarine Research Reserve. We would like to thank you and your staff, particularly Sue Bickford, for submitting the map and responding to the Committee's comments. The map has been forwarded to the CDMO for upload and should be available very shortly.

Sincerely,

Nina Garfield

Nina Garfield and Saundra Upchurch, HMCTC Co-Chairs

Cc: Jason Goldstein
Sue Bickford
Adrianne Harrison
Erica Seiden

Update 01/26/22: As of this update the Rachel Carson National Wildlife Refuge has not received funding for the proposed restoration in the vicinity of the SSAM-1 study site. It is likely however that this project will go forward in the future. Installation of veg plots went forward in summer 2021. The Wells Reserve will continue to coordinate with the Refuge to avoid any impacts to monitoring infrastructure within the SSAM-1 study site.

Wells National Estuarine Research Reserve
Sentinel Site Application Module 1 Plan Addendum
February 22, 2021

The Wells Reserve has recently completed drafting a plan for implementing the Sentinel Site Application Module 1 (SSAM-1). This plan includes the context for our site as well as the rationale and protocols for implementing these various monitoring components. Our SSAM-1 plan also identifies a study site in the Drakes Island Marsh where new biomonitoring transects (with associated vegetation study plots), and new SETs are to be installed. This site location was chosen from several candidate locations that would lend themselves well to the study design and monitoring procedures specified in related SSAM-1 guidance documents. Some key considerations towards this goal included: 1) a more or less continuous elevation gradient from the tidal channel to the upland edge uninterrupted by the sinuous tidal creeks that riddle most of the marsh; 2) proximity to the NOAA Tide Station in the Webhannet River; 3) proximity to an existing vertical control network and potential for establishing an NSRS tie through a leveling run along adjacent roads and; 4) preliminary data collected for elevation as well as pore water salinity.

Most of the tidal wetland within the Wells Reserve boundary (including a majority of the Webhannet River marsh), is owned and managed by the Rachel Carson National Wildlife Refuge (RCNWR). As such, any monitoring activities within these areas are subject to the approval of the Refuge. The Refuge is generally supportive of long-term ecological monitoring, and there is already a Cooperative Agreement established between the Wells Reserve and the Refuge that encompasses monitoring activities under SWMP, Tier II vegetation transects, and two SETs. As part of our SSAM-1 Plan development, Wells Reserve consulted with RCNWR in 2019 to discuss the proposed location for new monitoring infrastructure and identify any obstacle to plan implementation. At that time no significant obstacles were identified and a revised Special Use Permit for working in the new area was approved in spring 2020 for Wells Reserve.

During the course of finalizing the draft SSAM-1 Plan in January 2021 it was discovered that a new marsh restoration initiative on the part of the Refuge had the potential to negatively impact new SSAM-1 study site. A meeting was convened between Wells Reserve and the Refuge to discuss these developments and reconcile potentially conflicting management goals. Since the initial planning meeting in 2019 and subsequent approval of the revised SUP, the Refuge had been developing plans for a demonstration marsh restoration project in the Webhannet River marsh that would seek to prevent marsh loss through proactive alterations to marsh hydrology and the addition of sediment sourced from harbor dredging activities that take place every 10 years or so.

After examining potential locations for a restoration project, a location very close to our chosen SSAM-1 study sites was identified for the restoration project (Figure A.1). RCNWR has also since submitted a grant proposal to NAWCA and if approved, restoration planning and implementation would begin in 2021 and 2022 at the Drakes Island site. A restoration plan has not yet been developed, so at this time it is not possible to accurately assess the potential impacts to any monitoring infrastructure, but there is the possibility that monitoring plots could be impacted either from foot and vehicular traffic during the restoration, plots could end up in the area to be restored, or the addition of large volume of sediment adjacent to the study plots could influence marsh processes being monitored making it difficult to distinguish between long term change and artificial enhancement effects.

Figure A.1 *USFWS Rachel Carson National Wildlife Refuge proposed restoration site. Actual location of restoration activities will be determined during the restoration planning phase to be initiated by the Refuge.*

Due to the uncertainty that this situation has created, and the need to move our SSAM-1 Plan into the next phase, we are proposing to continue with development of monitoring procedures, while acknowledging that the physical location of some monitoring infrastructure may be subject to change pending further development of restoration planning by the Refuge. A site walk with Reserve and RCNWR staff is planned for spring/summer 2021 to further assess the potential for restoration activities to impact this SSAM-1 study site. As previously mentioned, several alternative locations have been identified that could meet the needs of the SSAM-1 Plan but would require more effort and additional preliminary work to implement. If necessary, the draft plan could be revised to reflect a change in location of monitoring infrastructure, but which would not necessitate changes to monitoring procedures. For example, the ability to connect biomonitoring plots to local tidal datums and the NSRS is not heavily dependent on the location of the study site since alternate locations are within the Webhannet River, and still in proximity to local geodetic control marks.

We feel that this approach is the best way to continue to move forward with development of the SSAM-1 Plan while also accommodating some uncertainty around the Refuge restoration activities.