1. PROJECT MANAGEMENT

1.1. Title and Approval Page

Quality Assurance Project Plan for
Long-term salt marsh vegetation and elevation monitoring in Buzzards Bay
Pursuant to Buzzards Bay NEP Workplan Task 12, EPA Cooperative Agreement CE-00A00456-0

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1.2. Acknowledgments

The principle authors of this plan are Joseph Costa of the Buzzards Bay National Estuary Program and Rachel Jakuba of the Buzzards Bay Coalition. Some sections were taken in their entirety from "Quality Assurance Project Plan for Long-term Monitoring of Tidal Marshes in Massachusetts" (March 20, 2018 version) prepared by Cristina Kennedy, Marc Carullo, and Adrienne Pappal of Massachusetts Coastal Zone Management.

1.3. Table of Contents

1.4. Distribution List

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1.5. Project Organization

The organizational chart in Fig. 1 shows the lines of communication among these individuals and the U.S. EPA. Below is a description of the positions.

Project Manager: Joseph Costa, Buzzards Bay National Estuary Program (NEP) Executive Director, is the overall project manager, lead principal investigator for the GIS components of project, and is responsible for analysis and integration of datasets, communication, project management, maintenance, and distribution the QAPP, and project reporting. He will develop GIS spatial coverages based on interpretation of aerial photographs and corresponding field collected data from GPS and traditional surveying techniques over installed monuments.

Quality Control Officer, GIS work: Kevin Bartsch, Buzzards Bay NEP, Stormwater Specialist/GIS Analyst, is the quality control officer for the GIS and data analysis elements project, and will ensure that the protocols described here are adopted. He will review the GIS spatial features to ensure they meet MassGIS data standards, and accurately represent physical boundaries of salt marsh units. He will also provide oversite on the collection of field elevation data and ensure that the theodolite is operated according to the manufacturer's specifications.

Subaward Project Manager: Rachel Jakuba will oversee the Buzzards Bay Coalition (BBC) elements of the project including tasks funded through a sub-award from the Buzzards Bay NEP, overseeing BBC staff collecting field data on vegetation and habitat features, and undertaking QC evaluations on that data. She will also oversee the contractor of an aerial survey being funded by a private donation.

BBC Field Intern(s): Under their subaward, the Buzzards Bay Coalition will hire an intern familiar with coastal fieldwork.

Mass Maritime Academy Summer Intern(s): Under a separate ISA subaward with Mass Maritime Academy (MMA), the Buzzards Bay NEP will fund one or more summer interns to assist with monitoring in this project.

Buzzards Bay Coalition Science Advisory Committee (SAC) salt marsh monitoring subcommittee: A subcommittee of the SAC will meet quarterly to review progress on this project and suggest course corrections where needed. Dr. Ann Giblin will also provide training to the interns and other participants on salt marsh plant identification.

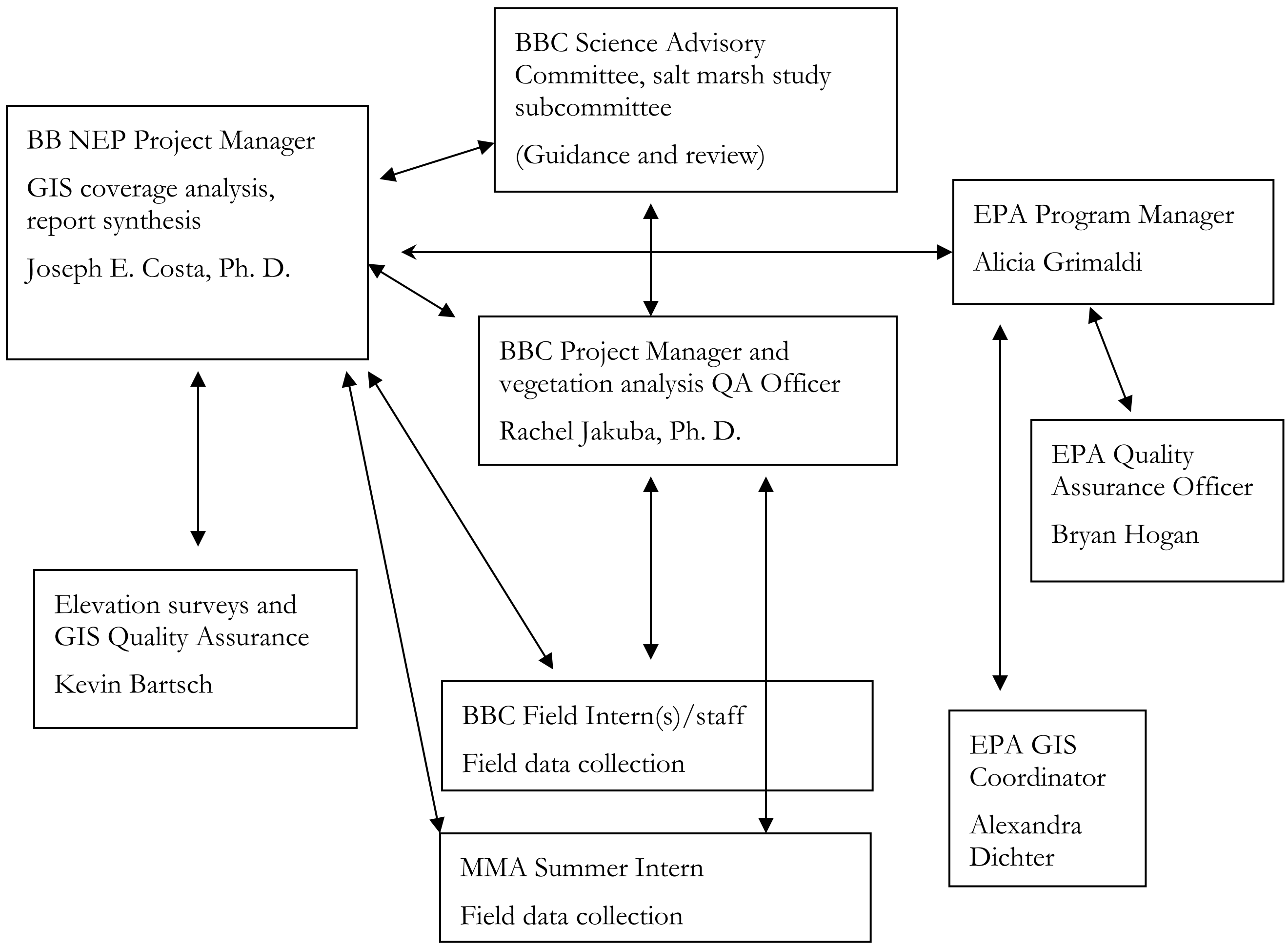

Fig. 1. Project organizational chart.

1.6. Problem Definition/Background

1.6.1. Problem Definition

Coastal salt marshes are an important habitat and nursery for many coastal marine species of plants, aquatic and terrestrial vertebrates, and invertebrates (Nixon, 1982; Redfield, 1972). Other functions provided by salt marsh ecosystems include storm damage prevention, prevention of pollution, protection of marine fisheries and wildlife habitat, and a source of primary production of carbon that is the basis of coastal food webs. Salt marshes also contribute to aesthetic values of the coast. Conserving and protecting this valuable resource and habitat fulfills important goals of the 2013 update Buzzards Bay Comprehensive Conservation and Management Plan.

Historically, many salt marsh areas in Buzzards Bay and elsewhere have been filled or otherwise adversely affected by human activities(Bertness et al., 1992, 2002; Costa, 2013a; Deegan et al., 2012; Donnelly and Bertness, 2001). More recently, the Buzzards Bay NEP and Buzzards Bay Coalition have received numerous reports of rapid salt marsh loss around Buzzards Bay[1]. Over geologic time, as sea level has risen hundreds of feet since the last ice age, coastlines and salt marshes have migrated. During recent centuries, with appreciably lower rates of sea level rise, some protected marsh systems with sufficient sources of terrigenous sediments, have nearly kept pace with sea level rise (10 inches per century relative rise in sea level in Southern New England). However, with greater rates of sea level rise and increased frequency of more intense coastal storms, increased climate-related salt marsh losses are a concern. In addition to these physical stressors, other identified threats to salt marshes have included excessive grazing by crabs, and adverse effects of coastal eutrophication from excessive nitrogen inputs, which can cause accelerated decomposition of salt marsh peat and subsidence of marsh channels where nitrogen concentrations are elevated.

This QAPP defines two classes of activities. First, the QAPP defines the process of establishing and implementing a long-term monitoring network of salt marsh reference sites and permanent transects at selected reference salt marsh study sites around Buzzards Bay. At these long-term monitoring sites baseline vegetation, land elevation, and tidal elevation conditions will be documented for studies in future years and decades. Second, the data collected at the long-term transect sites will help inform an effort to map saltmarsh boundaries in Buzzards Bay based on an November 2018 high resolution four band aerial survey of salt marsh vegetation. The interpretation of aerial photographs will include assessments of boundary changes at the transect sites based on historical photographs. The delineation of the upper boundaries of salt marshes around Buzzards Bay will be based in part on defining the geodetic elevation of the high tide line at the transect sites, and applying this information to available LiDAR data for the watershed.

The establishment of permanent monitoring stations or sites in particular habitats, and the implementation of long-term monitoring programs to gather essential information about conditions and changes in those ecosystems, has long been recognized as a valuable approach to inform environmental policies, laws, and regulations for managing those habitats. Data collected from long-term monitoring efforts also inform scientists of site-specific changes, and help address ecological questions that cannot be resolved with short-term observations or experiments. With respect to salt marshes, long-term data of vegetation type, tidal inundation, and elevation from a network of representative salt marsh reference sites and permanent transects can inform both scientists and managers about the spatial distribution and relative impacts of stressors causing changes to salt marshes in Buzzards Bay. By selecting sites that are representative of different marsh types, and with apparent different causes and rates of loss, the collected data would have greater utility.

This document defines the selection of representative and accessible marsh sites, the installation of permanent survey benchmark monuments in adjacent upland areas, the establishment of permanent transects, the collection of tidal and land elevation, and vegetation cover data along those transects. This QAPP also details the process of generating GIS coverages defining marsh boundaries (high tide line and vegetated low banks) and vegetation ecotones within those marshes. The monitoring of marsh ecotone boundaries and baseline vegetation and elevation data by the Buzzards Bay NEP and Buzzards Bay Coalition will foster future comparative surveys by government agencies and scientists in future years and decades. Long-term data of marsh bank erosion, time series of vegetation succession, sediment accretion, or loss within different portions of each marsh transect, and the documentation of tidal levels, will provide essential data for assessing, conserving, and managing these valuable ecosystems, and promoting future salt marsh research in Buzzards Bay. This QAPP also supports measurements of marsh vegetation and elevation in companion studies, including experiments to evaluate the benefit of creating drainage runnels, and the use

[1] See http://buzzardsbay.org/reports-salt-marsh-loss-buzzards-bay/

of thin film deposition to help restore marsh vegetation and function.

1.6.2. Background

New England salt marshes are typically classified into three intertidal zones: low, middle, and high marsh based on the assemblage of plant species found in each (e.g., Bertness et al., 1992; Donnelly and Bertness, 2001; Nixon, 1982; Redfield, 1972). The plant species assemblage in each of these zones is defined by the frequency of tidal flooding and the average inundation time. In Buzzards Bay, the low marsh is dominated by cord grass, *Spartina alterniflora*, and begins roughly at mean sea level (MSL). The middle marsh area, occurring roughly between mean high water (MHW) and mean higher high water (MHHW) is dominated by *Spartina patens*, *Salicornia* spp., *Distichlis spicata*, and *Juncus gerardii*. The high marsh environment occurs above MHHW, and vegetation includes mid-marsh species as well as the invasive *Phragmites australis*. The transition between the high salt marsh and upland areas include certain characteristic species such as the high tide bush *Iva frutescens*, and switch grass, *Panicum virgatum*. Salt marshes may also grade into freshwater wetlands. The elevation of all these boundaries with respect to local tidal datums depends on numerous factors ranging from fresh water inputs to levels of eutrophication (Bertness et al., 2009, 2002; Silliman and Bertness, 2002). Fig. 2 shows Buzzards Bay marsh boundary elevations relative to tidal datums.

In salt marshes, the elevation of the lower marsh boundary is not at a fixed elevation and varies with many factors including tidal range, coastal erosion, wave exposure, winter icing, storms, grazing, and other physical and biological factors, and can vary within different areas of the marsh. Generally, the lower boundary of the salt marsh is stated to coincide with the local mean sea level (LMSL; McKee and Patrick, 1988), but occasionally the lower edge is referenced to other tidal datums like the "mean high water at neap

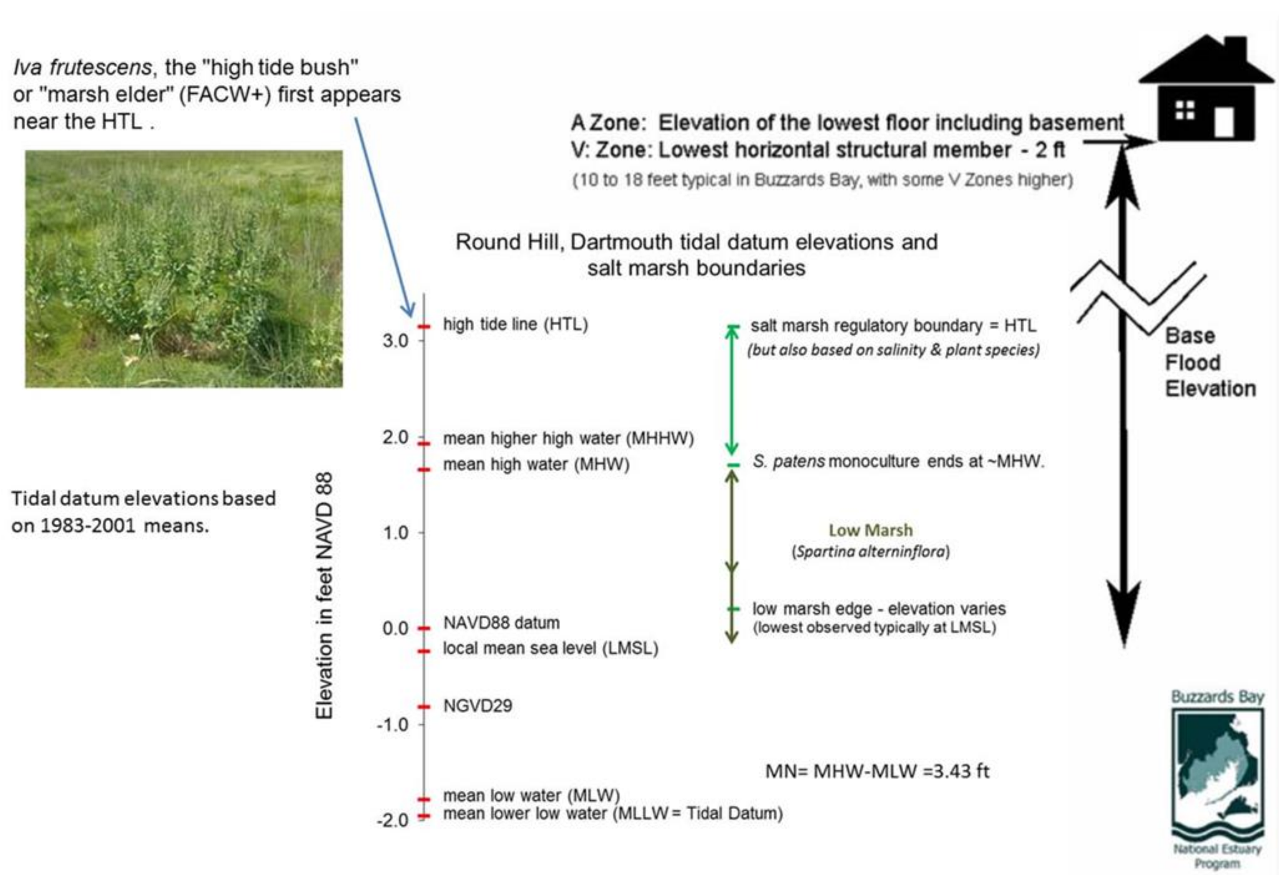

Fig. 2. The relationship between tidal datums, land elevation datums, and salt marshes in Buzzards Bay. From buzzardsbay.org/technical-data/tidal-datums-ma/.

tide" line as described in Ranwell (1972) and at the Sea Level Rise in CT Salt Marshes website.

Under the Massachusetts Wetlands Protection Act regulations (310 CMR 10.0), a salt marsh is defined as "a coastal wetland that extends landward up to the highest high tide line, that is, the highest spring tide of the year, and is characterized by plants that are well adapted to or prefer living in, saline soils. Dominant plants within salt marshes are salt meadow cord grass (*Spartina patens*) and/or salt marsh cord grass (*Spartina alterniflora*)."

In federal regulations (33 U.S.C. 1344, Regulatory Program of the U.S. Army Corps of Engineers, Part 328.3), the "high tide line"(sometimes called the annual high tide) is defined as "the line of intersection of the land with the water's surface at the maximum height reached by a rising tide. The high tide line may be determined, in the absence of actual data, by a line of oil or scum along shore objects, a more or less continuous deposit of fine shell or debris on the foreshore or berm, other physical markings or characteristics, vegetation lines, tidal gauges, or other suitable means that delineate the general height reached by a rising tide. The line encompasses spring high tides and other high tides that occur with periodic frequency but does not include storm surges in which there is a departure from the normal or predicted reach of the tide due to the piling up of water against a coast by strong winds such as those accompanying a hurricane or other intense storm." Not explicit in the state and federal regulations is the fact that the high tide line refers to the current high tide line during the recent year, and not an average for the current tidal epoch. The tidal definitions used in tidal studies and various regulations are summarized in Table 1, which also shows Newport tidal datum elevations. Most of Buzzards Bay has tidal characteristics similar to that of the Newport tidal station.

In a study of salt marsh island loss in Westport, MA, Costa and Weiner (2017) found that the loss in area on most islands was relatively constant throughout the 20th century (Fig. 3), although there appeared to be acceleration of losses on many islands during the last fifteen years. The Buzzards Bay Coalition (2017) noted that these more recent losses could have been due to rising sea levels, nutrient loading, increased grazing by invasive crabs, recent storms and erosion, increased water temperature, or other factors. With global warming, the rate of sea level rise may increase. If vertical accretion within salt marshes cannot keep pace with rising sea levels, and if they cannot migrate inland, they will be lost. Many marshes are impaired from migrating inland because of barriers created by road construction, raised fill areas with steep grades, bulkheads, and seawalls.

Elsewhere in Buzzards Bay, rapid marsh loss has been reported to the Buzzards Bay NEP and Buzzards Bay Coalition[2]. At some of these sites, the pattern of loss of marsh vegetation (vegetation loss near creek banks) was consistent with impacts caused by crab grazing (**Error! Reference source not found.**).

Knowing the precise geodetic elevations of the upper and lower boundaries of salt marshes, and the elevation of the high marsh -low marsh transition zone has utility in both the management of salt marshes, and in understanding the potential impacts of accelerating sea level rise, nutrient loading, and crab grazing. Salt marsh vegetation helps trap sediments suspended in the water column during storms and other conditions. In the case of marshes that are receiving sufficient sediments to keep up with sea level rise (currently about 2.5 cm per decade), the geodetic elevations of the marsh will increase with time. For marshes receiving little new sediments, and are being inundated by sea level rise, their elevations will remain nearly static over time. In contrast to these scenarios, in the case of marsh loss caused by nutrient loading, elevated inorganic nitrogen concentrations are thought to result in net accretion rates half of sea level rise in nutrient enriched marshes (Turner et al., 2009) to actual decomposition of salt marsh peat, causing marsh subsidence, particular near marsh boundaries and creek banks (Deegan et al., 2012). The geodetic elevations of these areas will decline with time. Similarly, the denuding of marsh vegetation and increased burrowing by

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[2] See buzzardsbay.org/reports-salt-marsh-loss-buzzards-bay/

crabs along the banks of marshes may preclude sediment trapping near the edges of marshes, increase sediment loss, or contribute to bank subsidence. These outcomes will result in the selective loss of elevation near the marsh borders over time. By installing permanent horizontal and vertical control monuments, and documenting elevations based on established transects with high precision, baseline information will be gathered at the reference study sites that can be revisited by future investigators to document salt marsh loss and elevation changes in subsequent years or decades.

Table 1. Elevations of Newport Tidal Datums converted to NAVD88 GEOID 12a (1)

Datum Abbreviation	Range Ft	Elev. Ft NAVD88	Description
HTL for 2013 (salt marsh reg. boundary)		3.06	high tide line (aka annual high tide)
MHHW (typ. *S. patens* monoculture)		1.81	mean higher high water
MHW		1.57	Mean High Water
DTL		-0.11	Mean Diurnal Tide Level
MTL		-0.16	Mean Tide Level
LMSL (typ. *S. alterniflora* edge)		-0.30	Local Mean Sea Level
MLW		-1.90	Mean Low Water
MLLW		-2.04	Mean Lower Low Water
GT	3.85		Great Diurnal Range(MHHW-MLLW)
MN	3.47		Mean Range of Tide (MHW-MLW)

(1) As reported at: tidesandcurrents.noaa.gov/datums.html?id=8452660, Accessed 24 May 2013.

There are other ancillary benefits of documenting the MHW and HTL line in this study. Over the years, the Buzzards Bay NEP has received requests from Conservation Commissions and planners to review the accuracy of land and tidal elevations specified on engineering plans submitted with local permit applications. While land surveyors have long-established practices for tying land elevations on a property to local benchmarks, tying tidal datums like the "high tide line" and "mean high water" (two very different elevations) to land elevations is complicated and nuanced. Geodetic elevations of tidal datums differ all around Massachusetts, and can even differ appreciably between the upper and lower reaches of a large tidal estuary. Survey firm estimates of these elevations are sometimes based on an arbitrary high tide on a given date. Exactly where a tidal datum lies on a property can affect the cost of a project, or even whether an activity is permittable under state or local regulations. Disputes over the location of these tidal datums have been the subject of lawsuits about property ownership and regulatory jurisdiction. Because tying tidal datums to land elevations is complicated, many municipal boards and their staff often accept at face value tidal datums specified on site plans. However, these lines may be wrong, or the elevation definition applied by the surveyor may not match the definition used in an applicable regulation.

In Connecticut, the state agencies were so frustrated by inconsistent high tide line elevations reported by surveyors and engineers, the state legislature passed a law defining its own coastal jurisdiction based on predefined geodetic elevations (in NAVD88) for each municipality and water bodies in the state3.

This study will define geodetic elevations of the HTL in the Buzzards Bay estuaries and marshes examined, as well as the geodetic elevation of specific marsh ecotones around Buzzards Bay. This elevation information, when combined with available LiDAR data, will also facilitate defining the upper marsh boundaries of salt marshes, which are sometimes difficult to discern in aerial photographs. The information will also provide for a better understanding of the capacity of marshes to accommodate sea level rise.

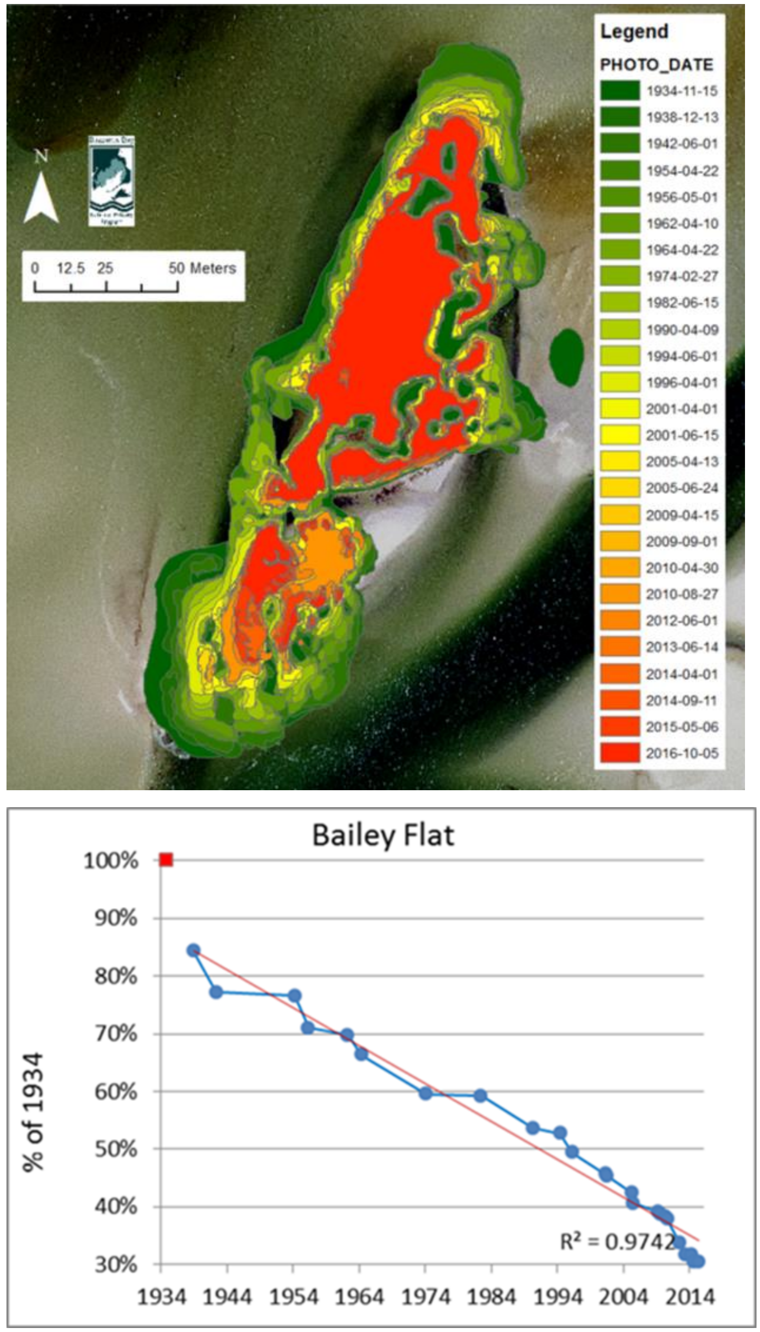

Fig. 3. Composite of estimated vegetated salt marsh boundaries for Bailey Flat for 1934-2016 (ltop), and change in area from 1934 (bottom). From Costa and Weiner (2017).

In Buzzards Bay, when LiDAR data is compared to the NOAA VDatum tidal elevation model, the lower boundary of salt marshes seems to be mostly bounded between near LMSL and a few inches to a foot above. However, using LiDAR to estimate boundary elevations in marshes in this way is challenging because of numerous confounding issues. These issues include the fact that LiDAR imagery may not be precisely georeferenced to aerial imagery, LiDAR does not precisely measure bare earth in salt marshes, LiDAR point data is aggregated across salt marsh banks, and it can be difficult to distinguish between living and dead marsh peat in aerial photographs. Even making field observations of salt marsh vegetation elevation along marsh banks can involve value judgments. For example, *Spartina alterniflora* grows to a general elevation, but some clumps of vegetation grow lower, and individual shoots may grow lower still. Sometimes vegetation may be observed to grow down a marsh creek bank during a growing season if the site was altered by storms or winter icing, so the time of observation can be important. Because marsh grass precludes the measurement of bare earth elevation in LiDAR

[3] See www.ct.gov/deep/cwp/view.asp?a=2705&Q=511544&deepNAV_GID=1622

analysis, the grass canopy height must be accounted for to effectively interpret LiDAR data.

The Buzzards Bay NEP has already calculated the HTL around Buzzards Bay using VDATUM (Fig. 7, and additional information and data posted at buzzardsbay.org/BB NEP-posts-tidal-datums/). We have previously adopted this approach to estimate marsh migration using LiDAR data (Fig. 5).

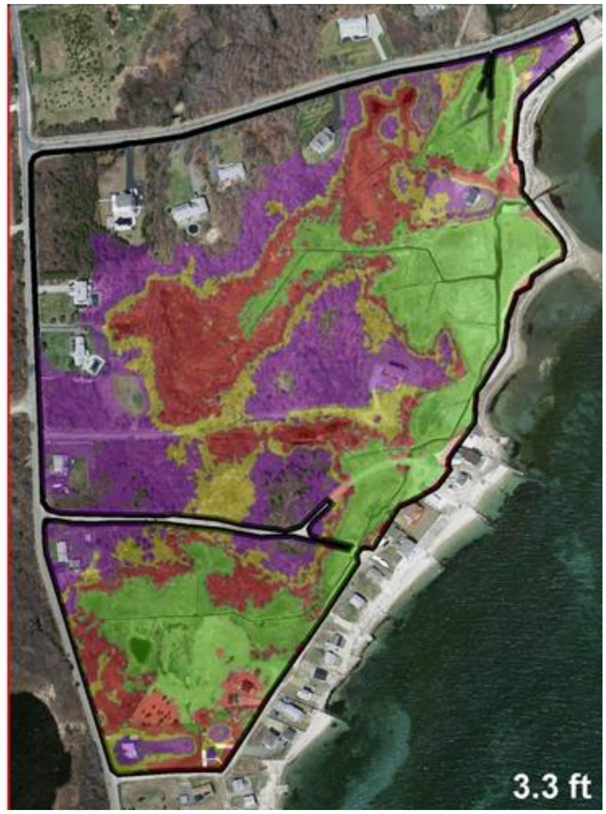

Fig. 5. An existing salt-marsh (green, based on a HTL elevation of 3.3 ft NAVD88 from VDATUM), and projected 1,2, and four feet increases in sea level rise (red, yellow, and purple respectively. From climate.buzzardsbay.org/marsh-migration-methods.html

Geodetic elevations of tidal datums can vary within an estuary because tides can be damped. Thus, in the uppermost regions of large local estuaries like the Westport River and Acushnet River, the elevation of specific tidal datums at the heads of these estuaries may occur at slightly different geodetic elevations than at the mouth of these estuaries. Furthermore, on any specific date, weather conditions (especially pressure, wind speed, and direction) can cause tides to be higher or lower than predicted. This behavior is illustrated in Fig. 6, which shows actual high tides versus predicted high tides for Newport, RI during all of 2017. This data illustrates several important relationships.

First, mean high water during 2017 (Fig. 6, left, red line) is about 10 cm higher than published predicted tide elevations. This is expected because the tidal datum (MLLW) was based on water elevations from the last tidal epoch (1983-2001, mid-date = 1992), and sea level rise has nearly been that amount. Second, deviations from predicted are greater in the winter and spring because of storms (as confirmed by barometric pressure (right), and lowest during the summer, when deviations were typically +/- 10 cm. Because real time tidal elevation data is available for Newport (the station on which Buzzards Bay tides are based), then site visits during summer on specific dates that coincide with specific tidal datums can be used to determine geodetic elevations of tidal datums and allow for a characterization of marsh species composition at that tidal datum. Table 2 shows convenient upcoming summertime dates and times where the predicted tide is within 2 cm of the MHW datum. Other dates exist that coincide with MHHW and other datums. The targeted King Tide is on Monday morning, September 30, 2019.

Fig. 4. Loss of vegetation along a salt marsh bank in Mattapoisett, MA observed June 21, 2017. This pattern of loss (heavy grazing near the bank), is consistent with damage caused by the purple marsh crab, *Sesarma reticulatum*. Photo credit: Dave Janik.

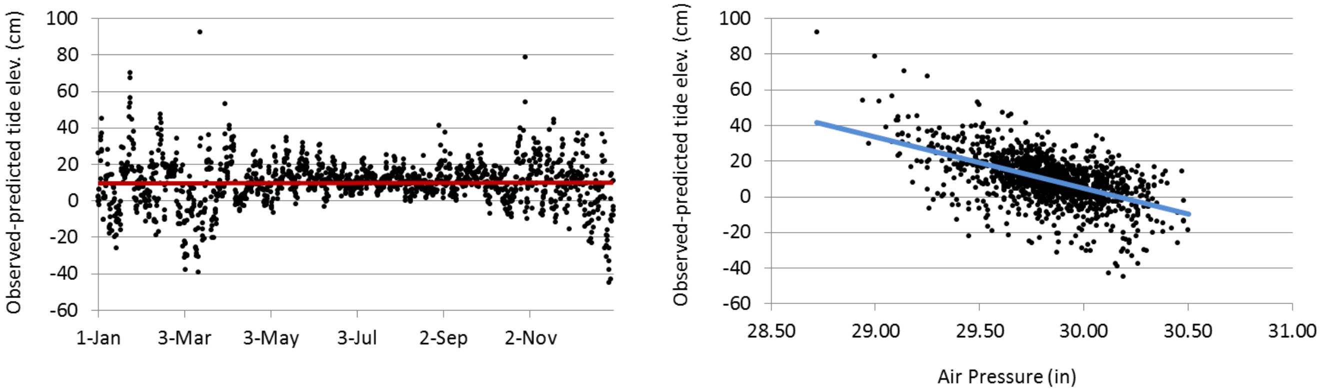

Fig. 6. Left: Observed -predicted tide elevations in Newport for all high tides during 2017. Right: the same data plotted against air pressure. Data from NOAA Coops and National Weather Service.

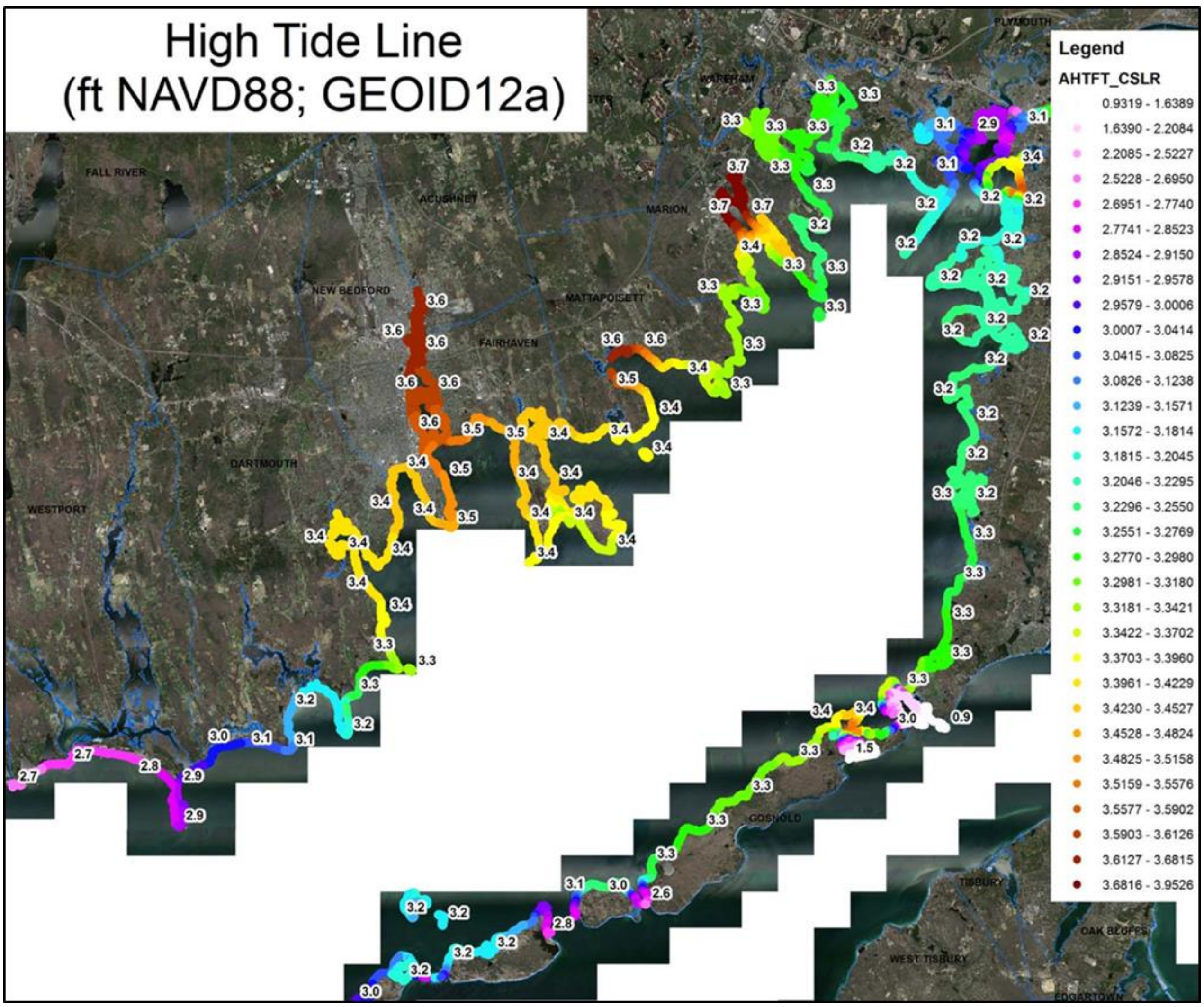

Fig. 7. The high tide line geodetic elevation for Buzzards Bay estimated from the NOAA VDATUM model. Data and additional information at buzzardsbay.org/BB NEP-posts-tidal-datums/.

Table 2. Convenient summertime dates and times where the predicted high tide is within 2 cm of the MHW tidal datum (=110 cm).

Date	Day	Time	Elev (ft)	Elev (cm)	Tide
2019-06-03	Mon	8:26 AM	3.58	109	H
2019-06-04	Tue	9:13 AM	3.68	112	H
2019-06-16	Sun	7:49 AM	3.69	112	H
2019-06-17	Mon	8:36 AM	3.69	112	H
2019-06-18	Tue	9:21 AM	3.64	111	H
2019-06-19	Wed	10:06 AM	3.53	108	H
2019-06-20	Thu	11:08 PM	3.68	112	H
2019-07-16	Tue	8:16 AM	3.58	109	H
2019-07-17	Wed	8:59 AM	3.59	109	H
2019-07-18	Thu	9:41 AM	3.55	108	H
2019-07-27	Sat	4:18 PM	3.56	109	H
2019-08-14	Wed	7:55 AM	3.57	109	H
2019-08-15	Thu	8:35 AM	3.63	111	H
2019-08-16	Fri	9:13 AM	3.65	111	H
2019-08-17	Sat	9:50 AM	3.61	110	H
2019-08-25	Sun	3:47 PM	3.61	110	H
2019-09-08	Sun	4:40 PM	3.60	110	H
2019-09-09	Mon	5:41 PM	3.61	110	H
2019-09-12	Thu	7:30 AM	3.62	110	H
2019-09-17	Tue	10:23 AM	3.68	112	H
2019-09-18	Wed	11:00 AM	3.60	110	H
2019-09-19	Thu	11:42 AM	3.53	108	H
2019-09-22	Sun	2:21 PM	3.54	108	H
2019-09-23	Mon	3:24 PM	3.66	112	H
2019-10-05	Sat	2:08 PM	3.69	112	H

1.7. Project/Task Description and Schedule

The primary focus of this project is to characterize salt marsh vegetation cover, vegetation ecotone boundaries from aerial photographs and along permanent field transects, and to document the locations and elevations of marsh boundaries and vegetation ecotones in up to ten salt marshes around Buzzards Bay, including some marshes where rapid marsh loss has been reported or is evident from recent aerial photographs. Permanent transects with high precision bare earth elevation measurements to 0.1 cm) will allow future monitoring efforts at these sites to document precise changes and geodetic elevations relative to sea level rise. This data will also help define the relationship between elevation and vegetation types, which is expected to change around Buzzards Bay and within embayments. This information will be used as a baseline for repeated surveys of the same sites in futures years and decades. A secondary focus of this study will be an investigation of crab burrow density, and how those densities relate to patterns of salt marsh loss observed. During field investigations, ancillary observations of other physical or apparent biological disturbances will be documented as well.

Documentation of changes in salt marsh boundaries over time will be based on the interpretation of historical and recent aerial photographs. Interpreting marsh boundaries on more recent surveys will be informed by LiDAR data sets (locally available for 2006, 2011, and 2015 surveys) and informed by recent studies on ecotone migration (e.g., Wasson et al., 2013). Boundaries of different vegetation types will primarily focus on the interpretation of a privately funded baywide aerial survey of Buzzards Bay salt marshes completed in fall 2018. The findings of detailed field surveys will be used to validate vegetation types for a baywide interpretation of habitat types, and also document geodetic elevations of low marsh, high marsh, and MHW, MHHW, and annual high tide or high tide line (AHT or HTL) geodetic elevations in each marsh.

The salt marsh study sites selected for this project, and monument locations, will be located principally in publically owned or permanently protected conservation lands so that the data will define baseline conditions for surveys undertaken in future years or decades. Monuments will be sited in upland areas with permission of the landowner and with wetland permit filings.

Activities for this project will involve principally these five tasks:

1) Establishing permanent vertical and horizontal control monuments for field survey vegetation and elevation transects. Detailed elevation and horizontal positions of the monuments will be evaluated using traditional survey techniques (from known benchmarks) and GPS.

2) Post hoc photointerpretation of salt marsh boundaries in an November 2018 aerial survey, and to the extent possible, marsh vegetation types, as discerned in historical aerial photographs.

3) Field surveys will be undertaken to a) verify the signature of marsh species evident on aerial photographs and coordinates of transition zones to inform vegetation boundaries interpreted from a privately funded aerial survey of Buzzards Bay salt marshes, b) define baseline summertime vegetation composition along permanent transects, and c) conduct counts of crab burrow and ribbed mussel (Guekensia demissa), and d) characterize dead grass canopy during seasons that coincide with previous LiDAR surveys. The 4-band aerial photography survey flown in November 2018 to evaluate the use of color shifts during fall senescence to assist in species diagnosis and defining plant phenology.

4) Field surveys of the precise geodetic elevations of vegetation types and transition zones(e.g., low and high marsh, high tide bush, etc.), and the geodetic elevations of predicted tidal datums such as mean high water (MHW), mean higher high water (MHHW), and high tide line (HTL; highest annual tide). Volunteers will assist in documenting these tidal datums on specific dates by placing flags at the location of maximum tidal inundation. This effort will include a September 2019 King Tide event.

5) Development of a report and a GIS dataset that defines 2019 baseline conditions at both the long-term monitoring sites, and a more generalized baywide analysis. The baywide analysis will use the new aerial survey, and incorporate data of marsh vegetation cover, elevation surveys, and LiDAR data, to define boundaries for the salt marsh jurisdictional area and transitions zones.

A finer breakdown of tasks with organizational leads and estimated schedules are shown in Table 3.

Table 3. Summary of tasks, organization leads, and schedule.

Task	Lead	Sep-18	Oct-18	Nov-18	Dec-18	Jan-19	Feb-19	Mar-19	Apr-19	May-19	Jun-19	Jul-19	Aug-19	Sep-19	Oct-19	Nov-19	Dec-19
Baywide aerial survey of Buzzards Bay marshes (undertaken with private funding; not part of this QAPP)	BBC			X													
Selection of long term monitoring sites (desktop analysis, discussions with municipalities and partners) and transects	BBC & BB NEP	X															
Installation of concrete monuments and permanent transect markers (PVC pipe)	BB NEP									X	X	X					
Preliminary interpretation of vegetation signatures in new survey	BBC											X	X				
GIS analysis of historical changes at long term monitoring sites	BB NEP										X	X	X	X			
GIS analysis of November2018 survey	BB NEP										X	X	X	X			
Use volunteers to set out markers for specific tidal events (BBC), follow-up survey of geodetic elevations	BBC & BB NEP										X	X	X	X			
Vegetation survey along transects (field data, percent cover, and photography of quadrats). March date just for dead grass canopy height on one transect in three representative marshes.	BBC											X	X	X			
Elevation surveys off monuments with three technologies along permanent transect at each long-term monitoring site (surveys initial fall and spring to establish baseline, biannually thereafter.)	BB NEP												X	X	X		
Conduct crab burrow counts and ribbed mussel (*Guekensia demissa*) counts	BB NEP											X	X	X			
Preparation of draft and final reports	BB NEP & BBC															X	X

The Buzzards Bay Coalition will be the lead in the collection of vegetation species composition along transects and in identifying different vegetation types evident from aerial photography. Fieldwork will be undertaken by Buzzards Bay Coalition staff to confirm plant species that coincide with features evident on aerial photographs. Locations will be confirmed using GPS units with a nominal 0.5-meter horizontal accuracy. The Buzzards Bay NEP will be the lead in the installation of benchmark monuments, field survey work, modeling elevations using VDatum, collecting elevation data along the established transects, interpreting LiDAR data composition, and generating GIS coverages. The two project leads will prepare the final project report, maps, and geodatabases.

For this study, we will use modeled tidal datum elevations in NOAA's VDatum model to estimate local tidal datum elevations that approximate the existing high marsh boundaries around Buzzards Bay4. Real time and predicted tidal data for Newport and Woods Hole will be used to confirm the actual elevations of geodetic datums within an estuary, and inform the analysis of tidal elevations on specific dates. The geodetic elevations of the high tide line and vegetation transition zone (low marsh, low/high marsh, high tide bush, and MHW and MHHW will be documented with elevations calculated from the installed field monuments using three technologies: a barcode laser level, precision pressurized hydrostatic altimeter, and a pair of survey grade GPS units (one used as a base station over the monument, and one used as a rover, with the two data streams evaluated with a post-processed kinematic (PPK) solution.

1.8. Quality Objectives and Criteria for Measurement Data

This section describes the general objectives of the project and defines the measurement performance needed to meet program objectives. The program consists of two classes of data generated under the QAPP. First, elevation and vegetation is collected in the field to define vegetation and elevations along permanent transects established at a minimum of 10 salt marsh sites. These data will help inform a second effort to generate GIS coverages of salt marsh vegetation through Buzzards Bay based on recent and historical aerial photographs at a precision near the resolution aerial photography (mostly 1 to 4 m). This latter effort includes estimates of the upper jurisdiction boundary of salt marshes (the high tide line), which will be based on field collected land and tidal elevation data collected in the long-term salt marsh study sites.

The QA/QC is laid out in the assessment sampling protocol as a system of audits, standard procedures, and training for each section of the data collection. These activities and procedures begin with the assessment protocol conceptualizations, where the data requirements are determined, and continue through sampling, measurement of function, and data management to ensure the data quality meets those standards and are overseen by the Quality Assurance Manager and Project Manager. The data quality objectives of the monitoring program are described below, with definitions of terminology summarized also below, and the criteria for key parameters summarized in Table 4. Specific details are included in the Standard Operating Procedures (Appendix A-C).

Precision - is a measure of mutual agreement among individual measurements of the same variable, usually under prescribed similar conditions. Data precision of the assessment protocol can be checked with replicate field measurements and standard procedures.

Accuracy - is the degree to which a measurement reflects the true or accepted value of the measured

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[4] VDatum 3.2 (2013) uses GEOID12a/b, whereas the FEMA 2006 LiDAR uses GEOID3 and the 2010 Northeast LiDAR data GEOID09. Because the upper portions of Buzzards Bay are higher by 3.5 cm in GEOID12a, grading to less than 1 cm in lower Buzzards Bay, these differences in the NAVD88 elevations will need to be accounted for.

parameter. It is a measure of the bias in a system. Accuracy depends on the technique used to measure a parameter and the care with which it is executed. Standard procedures and QA audits are used to maintain data accuracy.

Completeness is a measure of the amount of valid data actually obtained compared to the amount expected under normal conditions. Ideally, 100% of the data should be collected. Data may be incomplete due to incomplete data collection, lost, or damaged data forms, or errors in data transcription. Through careful documentation, management, and timely entry of data the QA/QC manager will make every effort to avoid these human errors.

Representativeness - expresses the degree to which data accurately and precisely represent a characteristic of the parameter measured. Representativeness is established by proper site selection and appropriate spatial arrangement of sampling areas (i.e. site selection stratified by frequency distribution of selected metrics).

Comparability - expresses the confidence with which one data set can be compared to another. Collection of data by different investigators is the primary cause of variability in the data. Standardized procedures, internal QA audits, and training minimize variability in the data. Field protocols are based on accepted, regional methods that will increase comparability with other salt marsh studies.

1.8.1. Objectives and Project Decisions

The Project will pursue collecting data of sufficient quality to characterize vegetation signatures at long-term monitoring transects to assist in the post hoc interpretation of late seasonal aerial photograph taken November 2018, and to characterize vegetation habitat boundaries relative to field monuments, and their precise elevation (to 0.5 cm). For LiDAR period surveys, average canopy height above bare earth will be documented. Volunteers will place flags to document the extent of King Tides, MHW, MHHW, and other NOAA model tidal datums. Crab burrow densities will be quantified in and out of areas that have strong crab grazing signatures.

1.8.2. Action Limits/Levels

Because the field work in this project principally involves documenting baseline conditions, and mostly small changes in condition, no action limits or levels are defined to help decision makers target a course of action, as well as to support selection of analytical operations and field measurements.

1.8.3. Measurement Performance Criteria/Acceptance Criteria

Because the principal focus of the monitoring effort is to document long term changes in vegetation, certain fauna, and elevations at permanent stations along permanent transects, and because changes at most of these sites is expected to be small from year to year, a principal data quality indicator (DQIs) is consistency of observations with past measurements. If data at any given station is inconsistent with past measurements, data sheets, recent photographs, notes, storm history, and recent known activities at the site will be reviewed to identify causes for changes, and whether similar changes were observed at nearby stations and transects. If changes were outside of the normal range of variation previously recorded, or if one elevation is inconsistent with other elevation methodologies and past measures, then the dataset will be rejected, or the site reevaluated after apparent errors are discovered.

Table 4. Data quality objectives.

Parameter	Units	MDL	Expected Range	Accuracy (+/-)	Precision
Location along transects, ecotone boundary along transects (from steel tape measure)	Meters (m)	0.05 m	0-0.2 m	0.01 m	Relative Percent Difference (RPD) less than 10% for repeat measurements
Vegetation: species presence (or genus if species ID is not possible); Percent cover	NA; %	NA	0, 1; 0-100%;	95% accuracy of identification at the species level for salt marsh species; 95% accuracy of the identification at the genus level for upland species	Percent cover within 5% among separate observers
Vegetation: stem density for select species	Stems per m^2	0	S. alterniflora: 0-4000 per m^2; S. patens: 0- 10,000 per m^2		
Tidal Inundation (Hobo water level data logger)	Meters (m) referenced to NAVD88	0	0-9 m	+/- 0.2 %	
Elevation: (RTK GNSS)	Meters (m) referenced to NAVD88	NA	NA	+/- 0.03 m	Repeated readings to verify positions essentially the same
Elevation: barcode laser level		NA	NA	+/- 0.0025 to 0.005 m	0.0025 m
Elevation: precision pressurized hydrostatic altimeter		NA	NA	+/- 0.001 to 0.003 m	0.001 m
Location by coordinates (RTK GNSS)	MA State plane referenced to NAD83 (2011)	NA	NA	+/- 0.02 m Dependent upon a variety of environmental factors	Repeated readings to verify positions essentially the same
Physical condition: crab burrow count	Burrows per m^2	0	0-100		
Physical condition: ribbed mussel count	Individuals per m^2	0	0-1000		

MDL = Method Detection Limit

1.9. Special Training Requirements/Certification/Safety

1.9.1. Training Requirements/Certification

No formal certifications are required to undertake any task contained within this QAPP. However, field crewmembers will have sufficient previous training and experience to collect field data reliably, or they will receive training from the BB NEP QA Manager, BB NEP Project Manager, BBC Project Manager, and/or other project scientists with relevant expertise.

1.9.2. Safety Considerations

- Sampling will always be conducted by two or more persons, unless otherwise approved by the field manager.
- Flagging tape will be used to mark access point locations for safe exit, in instances where such locations could be difficult to find as deemed appropriate by field crew.
- Fieldwork will not be conducted during heavy rain events, storms, or unsafe conditions such as electrical storms or high wind events. Please practice "safety first."
- All persons must carry cell phones or other emergency communication devices while sampling. It is recommended these be waterproof or stored in a waterproof case or zip-lock bag.
- If for any reason access to permanent transects is deemed continuously unsafe after establishment, these will either be moved if feasible or sampling will be discontinued for that site if such a location is unavailable.
- If a transect survey is deemed unsafe on a date because of weather, tidal conditions, or other factors, data collection should be suspended on that date. Attempts to access a transect by boat when there are “small craft warning” by the National Weather Service, or where there are atypical tide conditions, safety should be assessed prior to sampling. Should the incoming tide not recede as predicted (i.e. tide is still in flood stage when it should be in ebb stage), monitoring shall be suspended, particularly if access to the site depends upon a low tidal state.
- If a boat, canoe, or kayak is used to access a transect, all persons must wear personal flotation devices while on the water.
- All motored watercraft used must comply with USCG required safety equipment per 46 U.S.C, Chapter 43. Vessel Safety Check information is available at cgaux.org/vsc/
- Good judgment will be used in selecting clothes and personal protection items. Common carried items include extra clothing, sunshade, sunscreen, hats, insect repellent, and boots (knee, hip waders, chest waders) suitable for highest anticipated depths. Staff not dressed appropriately should not participate in field work. Proper footwear is necessary (e.g., no “flip-flops” for field work).
- Good judgment will be used in walking on marsh surfaces; mosquito ditches will be circumvented, or when deemed possible, crossed with caution.
- Fieldwork will take place on public lands or open space parcels with public access granted, and with property manager approval. If access through private property is needed, permission will be sought in advance.

1.10. Documents and Records

The QAPP, including any revisions and updates, as well as data and reports, will be posted on the Buzzards Bay NEP website buzzardsbay.org. Data sheets and databases will be archived at both the Buzzards Bay NEP and Buzzards Bay Coalition offices. All data collected will be maintained in raw form (field data forms) and electronic form for at least ten years in the Buzzards Bay Coalition offices at 114 Front St, New

Bedford, MA 02740. The QAPP and Standard Operating Procedures (SOP) will be dated in their running heads to distinguish among different versions in case there are revisions made over the course of the project. The Project Manager will include all reports of the project status on the annual report, including any problems and the proposed recommended solutions. Annual status reports and final reports will be provided in electronic form to everyone on the distribution list. Hard and soft copies of reports, as well as all electronic data records, will be maintained at BB NEP for at least five years, and posted at http://buzzardsbay.org. Electronic data records, including results of the assessments and analyses, as well as GIS data generated over the course of the project, will also be maintained BB NEP for at least five years, and baywide maps of salt marsh boundaries will be provided to MassGIS.

1.10.1. Quarterly and/or Final Reports

Under the Buzzards Bay NEP's subaward to the Buzzards Bay Coalition, the Buzzards Bay Coalition will prepare quarterly and a draft and final report on the results of the vegetation, ribbed mussel, and crab surveys. The Buzzards Bay NEP will prepare a draft and final report on the baseline elevation data for all surveyed sites, and an analysis of the accuracy and precision of the three elevation measuring devices used (barcode laser leveler, hydrostatic elevation, and PPK GPS elevations, and summary data of any pressure data loggers for documenting tidal elevation.

2. DATA GENERATION AND ACQUISITION

This section addresses aspects of project design and implementation to ensure that appropriate methods for the collection of existing datasets are used in this study.

2.1. Sampling Design, Long Term Monitoring Transects

This study principally involves documenting vegetation, certain fauna, and elevation at stations along permanent transects. This section describes site selection and transect placement of the study marshes and transects.

2.1.1. Marsh Site Selection

Sites will be selected based on consultation with the Buzzards Bay Coalition Science Advisory Committee after considering factors like marsh size, magnitude of past losses, the presence of a tidal restriction, the presence of a tidal creek, degree of wave action, degree of ditching, soil type, proximity to long-term water quality monitoring sites, and through consideration of the following criteria:

- Access and ownership: as we will be placing and revisiting permanent elevation benchmarks and transects for this project, the sites will need to be reliably accessible. Thus, preference will be given to salt marshes located within protected public lands. Primary consideration in the selection of potential sites was to identify upland and salt marsh sites owned by government entities (preferred), or land trusts, where access could be ensured in perpetuity and available public parking including within road shoulders of public roads (private roads or private driveways were not acceptable)(sites that required travel across private property, across extensive wooded areas or thick brush, travel down active rail lines, or crossing of tidal creeks were excluded).
- Restoration status: at least two study areas will include a salt marsh that has a tidal restriction, and at least on site will be included where the tidal restriction has been mostly removed.
- Representativeness: salt marshes and estuaries will be selected that have a limited level of disturbance/degradation whenever possible. Areas where the salt marsh is actively hayed will be avoided.

- Sites where there might be safety considerations for personnel (remote sites) were excluded.
- Marshes no smaller than 5 acres were considered to accommodate needed transects

Tentative salt marsh study sites are shown in Fig. 9.

2.1.2. Elevation Benchmark Site Selection

- Elevation markers must be installed at least 1 foot above the high tide line.
- Monuments cannot be installed in the area immediately behind a barrier beach, in the path of migrating dunes or beach overwash area.
- Elevation markers must be placed where there is a clean line of sight to the marsh transect site (the marker should not be enclosed by dense high brush, *Phragmites*, or tree cover.
- Elevation markers housing must be installed at ground level and any excavated materials must be removed from the immediate site.
- Because the accuracy of elevation measurements decreases with distance for some technologies, benchmarks need not always be located near the start of the transect for transects that run parallel to the high tide line.

2.1.3. Benchmark Installation

Before installation of a benchmark, written permission must be obtained by the property owner, and necessary wetlands permits must be obtained (see sample Request for Determination in Appendix F, and the Abbreviated SOP in Appendix G, which should be included in the local permitting application. Because the monument is installed in uplands, and because there are no permanent structure installed in the marshes, a Request for Determination will be sufficient to comply with state and local permitting. If an area includes Rare or Endangered species, the Natural Heritage and Endangered Species Program should be notified.

The installation of NGS 3-D rod type benchmarks and disk benchmarks (Fig. 8) shall follow NGS Bench Mark Reset procedures (Smith, 2010). This survey marker is recognized as stable for most sites and environmental conditions. A 17 millimeter (9/16 inch) diameter, stainless steel rod driven into the ground, using a gasoline powered reciprocating hammer driver, until refusal (defined as penetration greater than 60 seconds per foot at a driving force of 24 joule or 17.7 foot-pounds and approximately 2,500 blows per minute (not an NGS specification). The rounded top center of the rod is the

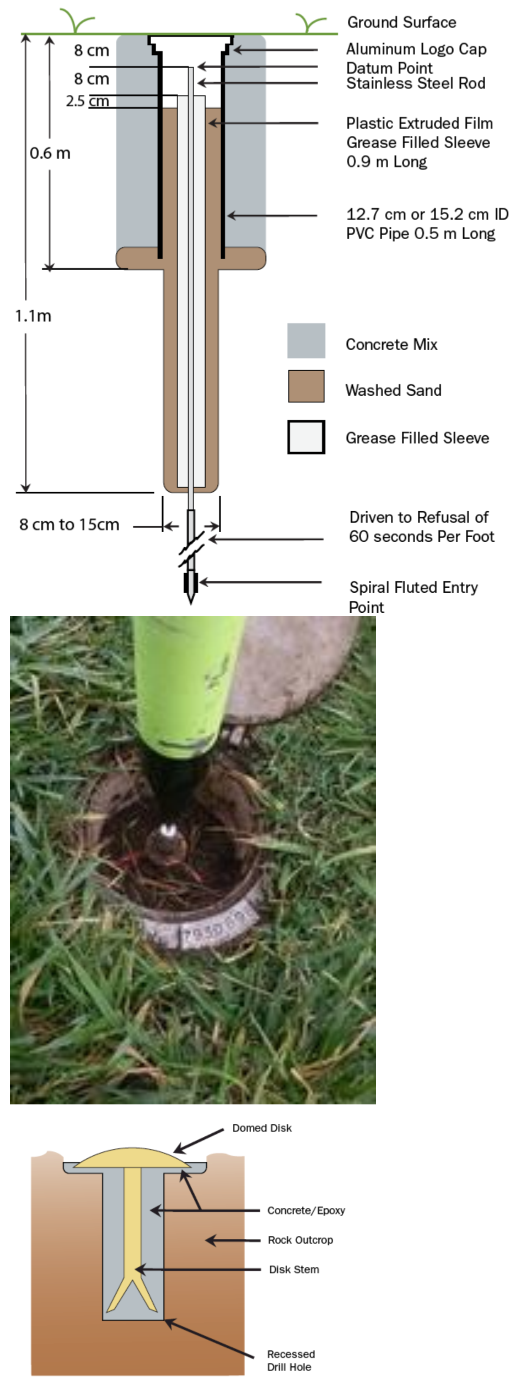

Fig. 8. Top: Schematic of the monument (from NGS (2010), Bench Mark Reset Procedures). Middle: finished installation. Bottom: Optional disk marker for existing structure.

survey datum point. The upper 1.0 meter (3 feet) of the rod is encased in a 2.5 centimeter (1 inch) food-grade non-toxic grease filled PVC or plastic extruded fin sleeve that is held horizontally stable by the surrounding, back-filled, washed sand. Effects of up and down ground movement during freeze and thaw are isolated from the anchored rod in this design. The benchmark is covered with aluminum hinged security cap with identifying information. Details of benchmark installation as developed by Smith (2010) are copied (with some modifications) in Appendix A. Elevation measurements in salt marshes will be made relative to these benchmarks. The actual elevations of each benchmark will be determined later using NOAA OPUS shared solutions (geodesy.noaa.gov/OPUS/) and in some cases, tie-ins to other survey monuments.

2.1.4. Permanent Transects

For this study, we will establish three to six permanent transects within each salt marsh system included the study (Fig. 10). The number of transects will depend on marsh size and complexity. The placement of these transects will be defined upon consultation with the Buzzards Bay Coalition Science Advisory Committee salt marsh subcommittee.

The beginning and ending of the transects will be marked by permanent PVC markers. The position of these permanent transects will be defined by 18" plastic surveyor stakes hammered into the marsh with a rubber mallet. A 12-inch length of rebar will be similarly hammered immediately next to the stake to one inch below the surface. This rebar will be used to find the end of the transect with a metal detector should the plastic stake be removed or lost. These markers will generally not be spaced more than 200 feet apart, and longer transects may require placement of additional markers at 200 feet intervals. Upland transect

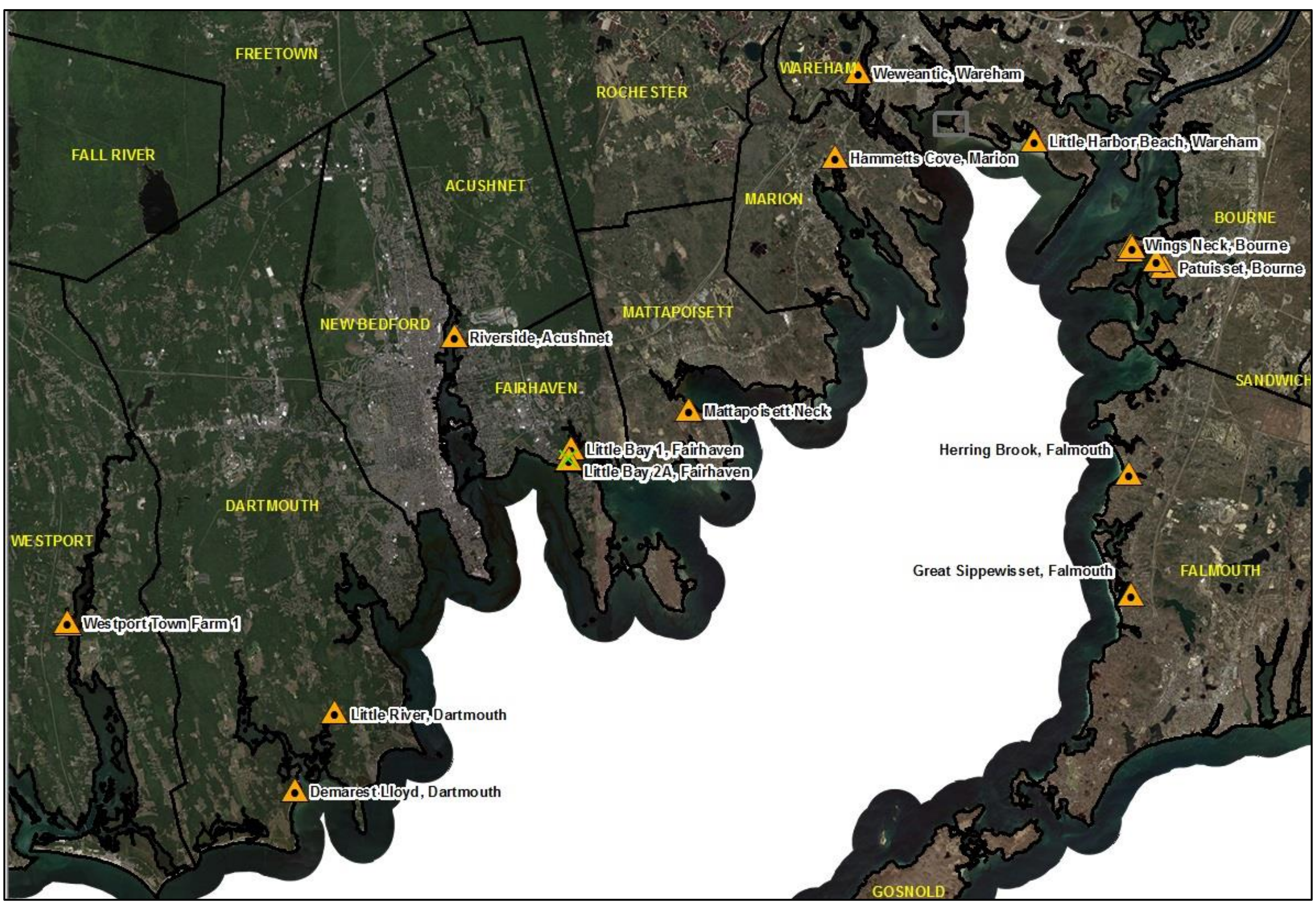

Fig. 9. Tentative long term salt marsh monitoring sites

markers should be established at least one foot above the high tide line and between 15 to 30 feet from the high tide line depending upon bank slope. Low marsh markers should be placed near the low marsh bank, but not closer than five feet from the bank, or at a greater distance if historical photos suggest rapid rates of marsh loss at the edges. Stations along these transects refer to a specific distance from the upland location station using a steel tape measure. These stations will not be marked by permanent markers.

Transects will intersect a variety of plant communities, and will extend from the low marsh at the bank of salt marsh creeks to typically 15 feet into the upland. The number of communities analyzed will vary per site. Typically four communities and the boundaries between them will be evaluated: low marsh (S*partina alterniflora* zone), high marsh (*Spartina patens* or short form *Spartina alterniflora* zone), marsh border (Iva frutescens, Juncus gerardii, etc.) and upland (upland grasses, woody plants and trees).Baseline vegetation and elevation surveys will be undertaken at specific stations (distances) along these transect in the first year. Baseline elevation surveys will be undertaken using three technologies on the same date. These measurements may be repeated during different seasons. Study areas will be established and sampled in 2019 for baseline conditions and will be monitored annually in 2020 and 2021, thereafter anticipated for at least

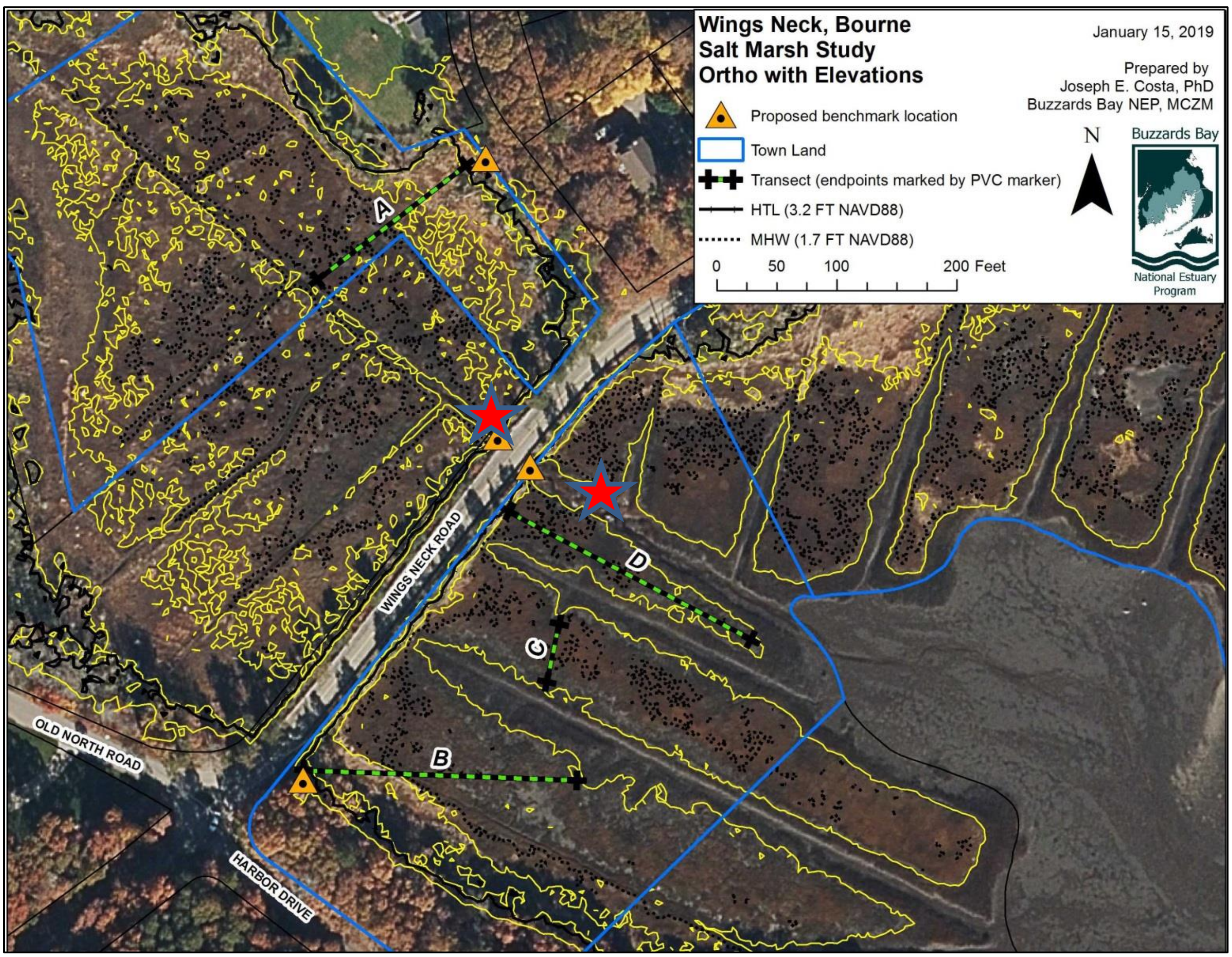

Fig. 10. Proposed placement of permanent benchmarks, salt marsh transects (green dashed lines) and water level logger (red star). The markers along Wings Neck Road are disks atop concrete culverts that will act as secondary elevation reference points to both rod markers at the edges of the marshes.

every three to five years.

Data collected in the baseline year will include vegetation, elevation, and hydrologic data. Vegetation parameters will include salt marsh plant species, general habitat characterization, upland plant species composition and percent cover. The ecotone boundaries will be documented to establish baseline points to measure over time.

A water level logger will be placed at a single subtidal station on a staff with an elevation established from the elevation benchmark and placed for a minimum of two weeks at the site. Logged tidal depths will be used to measure geodetic elevations of specific tidal datums, inundation frequency, inundation duration, percent of time flooded.

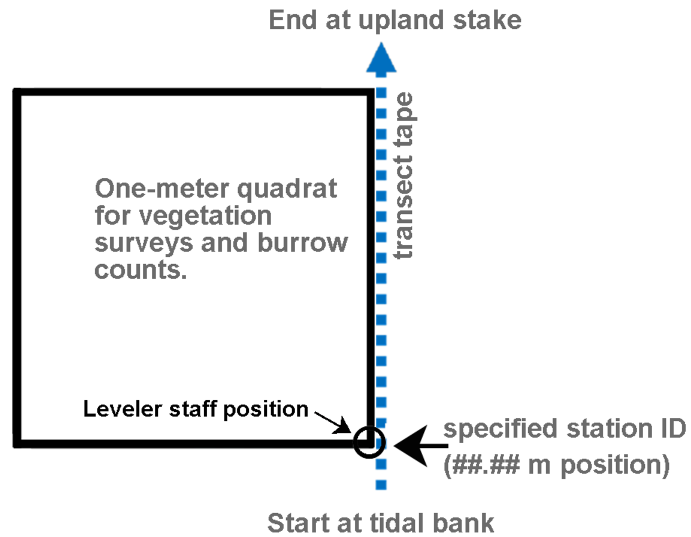

Fig. 11. One meter quadrat placement along transect tape between transect stake markers. Affix the start of the tape measure to the upland marker. Proceed to the bank in line with the low marsh marker keeping well to the left so there is no chance of walking on the transect area. Affix the tape to the low marsh stake, and extend the tape to near the marsh bank. Proceed to each Station ID. Keep the transect tape on left when moving from creek bank to upland. Modified from Kennedy et al. (2018).

2.1.5. Locating Permanent Transects in Subsequent Years

In the field, static transects will be demarked by 18-inch plastic survey stakes at the transect start and endpoints. Survey sites will be defined as precise positions along a steel tape measure stretched between the two stakes, and extend the tape measure to the marsh bank. The zero position of the tape shall always be the survey stake located closest to the benchmark. While most of the transects will be located close to the benchmarks, handheld GPS, sighting compass, and GIS maps may also be used to locate more remote transects, with recommended approaches. Field staff will consult the GIS map before walking out to the site to ensure they choose a path that does not trample vegetation to be sampled. The plastic survey stakes marking the start of the transect will be located and the sighting compass will be used to lay out measuring tape along the survey stakes marking the transect line, taking care to walk on the left side of the transect so that vegetation to be assessed on the right side is not disturbed.

2.2. Sampling Methods

This study principally involves documenting vegetation cover and canopy height, wrack depth, crab and ribbed mussel burrow densities, and elevation at stations along permanent transects (Fig. 10) provides an overview of the sampling methods used. The following sections contain a more detailed description of each method.

2.2.1. Vegetation and Faunal Surveys

Methods used for vegetation surveys shall be informed by monitoring studies of salt marsh condition and loss (Carlisle et al., 2002; Neckles et al., 2013; Raposa et al., 2018; Roman et al., 2001). Vegetation and faunal surveys will occur in July through September when the tide level is low enough that there is no standing water within the vegetation (Table 2). Vegetation and fauna will be quantified in 1 m^2 plots along the permanent transects. For each marsh site, ~20 plots will be monitored. Permanent quadrat locations will be selected such that at least 1 quadrat will be placed in each of the following habitats along the transect: low marsh; *S. patens/Distichlis spicata/Juncus gerardii* dominated high marsh; short form *S. alterniflora* dominated high marsh; *Phragmites australis*; and the salt marsh to upland ecotone. Where there is sufficient distance along the transect, quadrats will be placed at least 10 m apart.

Transect markers will have drilled holes and clips to the end of the steel measure tape. Attach the end of the measuring tape to the upland transect marker. Run a measuring tape along transect from the beginning upland station proceed to the creek bank boundary marker. Attach the tape with a clip to the low marsh marker, so that the tape is taught. The low marsh marker should be about a meter from the creek bank. Station ID beyond the stake can be documented with a meter stick, or extending the tape further. Record the distance of the low marsh marker to the nearest cm, and confirm the distance approximately equals past surveys. When working along transects, walk on the right side of the transect line when beginning at the marsh tidal bank and facing the upland (left determined when looking along transect towards the upland) or on the right side of the transect when facing the ocean and monitor the vegetation community or elevation on the opposite side of the transect (Fig. 12). For any transects that is roughly parallel to shore (for example, a transect between two low marsh markers, walk only on the upland side of the transect line. This procedure will ensure that that monitored vegetation community is not disturbed during sampling. To mark the transect line, clip the end of the steel tape measure to the center of the upland PVC marker, and proceed to a point right of the anticipated location of the lower marsh transect marker. Sweep in to the low marsh transect marker and clip tape measure to it. Continue to extend the tape measure to the low marsh bank, taking care not to get too close or disturbed the marsh bank.

Proceed to the established site-specific station locations (distance intervals) along each given transect and place the meter quadrat to the right side of the tape measure with the lower left quadrat placed to the designated distance mark of the tape measure. Record distance positions, percent covers, and species on the data sheet and take photos where appropriate, take a picture of the quadrat and record the time the photo was taken on the datasheet.

2.2.2 Fauna observations

First, record organisms present in the quadrat – make a quick visual assessment as placing the quadrat to observe if crabs or other organisms flee the area. Count the number of crabs by species.

Take a photograph of the quadrat straight-down using tripod, with marker in the frame that indicates the distance in meters and centimeters from the start of the transect. Record the time that the photo was taken on the data sheet.

Record soil compressibility as either: Very firm = researcher foot sinks < 2.5 cm; Moderately firm = foot sinks 2.5-7 cm; Soft = foot sinks 7-13 cm; Very squishy = foot sinks >13 cm)

Count the number of snails. If fewer than 50 individuals total in the quadrat, record number of each species. If greater than 50 individuals, estimate the total number of individuals and record the estimated percentage of each species.

Count the number of ribbed mussels present in the quadrat. If mussel is obviously dead, indicate that on data sheet.

Count the number of crab burrows greater than 5 mm in diameter and estimate the percentage of burrows

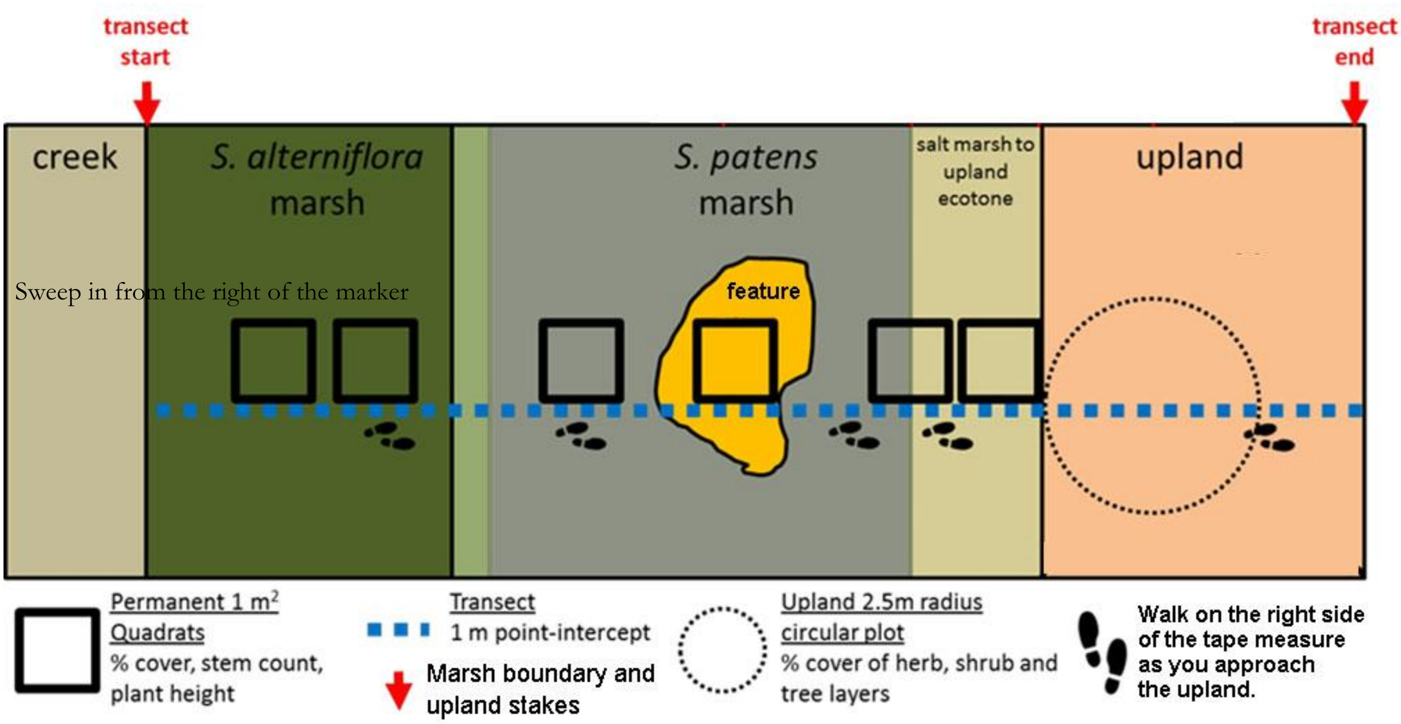

Fig. 12. Conceptual design of vegetation sampling (not to scale). From Kennedy et al. (2018).

that are small (5-20 cm diameter) and the percentage that are large (>20 cm).

During spring tides, five pit traps will be set at each marsh site. Three traps should be located in the vegetated creek bank portion of the marsh (in the tall-form *S. alterniflora* zone) and two traps should be located on the marsh platform (in the short-form *S. alterniflora* zone). Traps will be constructed from tennis ball cans that have had drainage holes drilled into their sides. Around low-tide, at each trap location, a sediment core of 8 cm wide and 20 cm deep will be removed and the sediment plug placed in a labelled plastic bag and placed in a cooler. The pit trap will be placed in the hole such that the top is flush with the marsh surface. The time of trap placement and the GPS coordinates of the trap location will be recorded. Sediment plugs will be refrigerated overnight. 24 hours later, the traps will be removed and the sediment plug replanted. The crabs in each trap will be removed, identified to species, measured (carapace width), and released.

2.2.3 Vegetation observations

List all plant species (differentiate between short-form and tall-form *S. alterniflora*) and habitat types (e.g., bare ground, wrack, pool) found within quadrat. Make a note if any of the plant species are flowering.

If necessary, specimens of unknown species will be collected for offsite identification. Place each species in a separate plastic collecting bag labeled with date, plant ID (e.g. "Unknown #1, etc.), transect/plot ID, collector name, and any comments (see Vegetation Sample Label Sheet in Appendix B). Take digital photographs on site as needed. If longer-term storage is required before an ID can be made, use a plant press to preserve the specimen. Label the archived specimen with time, date, location where sample was taken, and collector's initials.

Estimate the percent cover of each species and bare ground using the point-intercept method. The point-intercept method was selected over a visual cover estimate based on the recommendation in James-Pirri and Roman (2004) for monitoring programs that will be ongoing for several decades and include different teams of field personnel. The point-intercept method is based on dividing the sampling quadrat into a grid and using a vertical rod to record what species is intercepted by each point on the grid (Roman et al., 2001). The $1m^2$ quadrat is divided into a grid of 50 evenly spaced points. At each point, a thin rod (3 mm diameter) is held vertically and dropped straight through the canopy to the sampling point on the ground. For each of the 50 sampling points, all species that touch the thin rod are recorded.

Use two thin rods to separate the quadrat into four equal quadrants. Where the marsh is dominated by *Spartina alterniflora* and/or *Phragmites australis*, count number of stems of each species in the quadrant nearest to the creek edge and transect line. In each quadrant, measure the height in centimeters of the 3 tallest *Spartina alterniflora* and *Phragmites australis* plants (i.e., 12 measurements total of each species). If the quadrat includes *Spartina patens*, leave the plant fallen over and measure the maximum height of the *Spartina patens* canopy in each quadrant (i.e., 4 measurements total).

Where wrack is contained within the quadrat, record wrack depth to the nearest centimeter from five randomly selected points.

2.2.1.1. Ecotone Positions

While proceeding along the transect line from the low marsh edge to the high marsh, record the distance position of the unvegetated marsh bank, the vegetation edge near the marsh bank if different, the low marsh ecotone (100% alterniflora), estimated 50-50 alterniflora/patens, and 100% high marsh (patens or other species) start of high tide bush (if applicable), and the upland boundary (100% upland habitat). Exact ecotone boundaries will be determined by examining the vegetation community, referring to the National Wetland Plant List.

Table 5. Sampling Methods

Monitoring parameter	Method	Protocol followed
Vegetation		
Species composition & percent cover	Point intercept	Roman et al. (2001)
Average canopy height (*dominant vegetation*)	Measurement of plants	Roman et al. (2001)
Photos of veg plots	Digital photography	(Raposa, 2008; Raposa et al., 2017)
Fauna		
Crab burrow density	Burrow counts	(Raposa, 2008; Raposa et al., 2017)
Ribbed mussel density	Burrow counts	
Crab abundance		
Sediment Elevation & Accretion		
Elevation surveys	Bar code level, Ziplevel, GPS measurements	GPS: Messaros et al. .(2012) Manufacturers protocols
Ecotone boundary	The distance and location of 100% upland plants and 100% high salt marsh plants will be measured at each transect for each estuary	
Vegetation: species presence (or genus if species ID is not possible); Percent cover, canopy height, wrack depth (if present)	Species presence and percent cover will be measured in 0.5 m2 quadrats placed at specified distances (stations) specific to each transect	

Table 6. Principal habitat categories

Major Category	Secondary	Definition
Low marsh		Regularly flooded by daily tides, dominated by tall form (75cm+) dominated by *Spartina alterniflora*.
High marsh	Dominant species	Flooded by mean tide or greater, dominant species (>25% cover): *Spartina patens, Distichlis spicata, Juncus gerardii,* can include short form *S. alterniflora* as well as solitary forbs.
Terrestrial border		Infrequently flooded by spring and storm tides, could include areas of higher elevation on marsh platform commonly islands or linear patches next to excavated ditches.
Brackish border		Rarely flooded by tides, but often tidal influenced fresh/brackish, could include fresher areas of high water table on marsh plain, Most common: *Typha angustifolia, S. pectinata.*
Invasive	Species	*Phragmites australis* or *Lythrum salicaria*
Ditch	Open or plugged	
Creek		
Pool	Cover type	Depression not connected to creeks/ditches, filled with water even in summer. Bottom covered by rooted vascular vegetation, algae or no vegetation.
Panne	Cover type	Wet, high salinity depression not connected to creeks/ditches, little water unless recently flooded. Bottom covered by short form *Spartina alterniflora*, *Salicornia*, microalgae or no vegetation.
Impoundment		Standing water over area that has dead salt marsh vegetation. Impoundments with algal mattes covering dead salt marsh, potential indication of impairment.
Open water		
Upland	Cover type	Non-wetland areas of upland. Cover type: forbs and grasses, trees.
Bare ground	Cover type	Unvegetated (except for benthic algae film) ground that is at same elevation as surround area (i.e. not a panne).
Wrack/litter		Area covered by dead plant matter or debris.
Rare species	Species	Category in the event of an unusual or rare species that was not documented in the point intercept.
Other		Fill in for unusual or noteworthy habitat types not captured by above categories.

2.2.2. Salt Marsh Habitat Map

Use the data sheet to record the dominant habitat in salt marsh plant communities at each transect station using the categories in Table 6. Only include habitats that cover greater than 50% or are the predominant habitat type.

2.2.3. Photo-documentation of Vegetation Characteristics

Take digital photographs of the quadrat at pre-defined stations along each transect in four directions (along transect towards upland, along transect towards creek, and to either side of transect). Stations should include at a minimum: the start of transect, in the middle of salt marsh platform at recorded distance, at salt marsh/upland ecotone at recorded distance, and at center of upland circular plot.

2.2.4. Vertical positioning data

As with the vegetation surveys, when working along transects, walk on the left side of the transect when facing and walking toward the upland or on the right side of the transect when facing the ocean and monitor the vegetation community or elevation on the opposite side of the transect (Fig. 12). For any transect that is roughly parallel to shore (for example, a transect between two low marsh creek markers, walk only on the upland side of the transect line. In general, you left hand will be closest to the tape when walking a transect.This procedure will ensure that that the marsh is not compressed from repeated samplings.

Fig. 13. One Juniper Systems Geode™ unit installed on a tripod over the benchmark, and another rover GPS on a monopod (not shown), to allow for differential GPS calculations.

2.2.4.1. Elevations from GPS using post-processed kinematic survey analysis

For this study, the post-processed kinematic survey approach was selected because of lower equipment costs and simpler logistics, but at the same time documenting high precision horizontal and vertical positions. Methods and protocols will otherwise generally be informed by Kennedy et al. (2018), Rydlund Jr. and Densmore (2012) and University of Connecticut and Connecticut Department of Transportation (2013). In this study, two Juniper System Geode™ GPS units are used, coupled with effigis EZSurv® post processing software to achieve a sub-meter GNSS solution. In brief, one unit is placed on a tripod over the study site benchmark at a precisely measured recorded height above the benchmark, and a second GPS unit is used as a rover held on a two-meter staff gently placed on the marsh surface. The unit used as a rover is controlled by EZTagCE™ software application installed on a Windows-based tablet. The tablet can be attached to the rover staff by a clip if desired. PPK surveys collect continuous, static signals at the base station and short, 60-second occupation signals with the rover. Additional details of operation are specified in Appendix C and the GPS and survey software manuals.

The data from both units is subsequently downloaded and then data streams from both units are processed on a computer in order to calculate and apply elevation corrections from the data streams. Horizontal data is corrected to the North American Datum 1983 (NAD83, 2011 realization) referenced to the Massachusetts State Plane Coordinate System Mainland, in meters(MASPC), and vertical elevations corrected to the North

American Vertical Datum of 1988 (NAVD88), GEOID 12B. This technique is expected to achieve a vertical precision of three to seven centimeters, and is the least accurate of the three elevation technologies used. Regular stations along each transect shall be defined in advance, with additional elevations collected at ecotone boundaries and specific tidal events and conditions.

2.2.4.2. Elevations from Leica Sprinter 250m digital bar-code laser level

Measurements using the Leica Sprinter 250m digital bar-code laser level will be informed by various studies (e.g., Cain and Hensel, 2018). The laser level operator and bar code staff operator communicate by walkie-talkie or cell phones. The laser level operator shall keep a note sheet to record position identification (PID) and distance along the tape measure of the staff operator. The digital bar-code laser level is set up on a stable upland location with a clear line of site to the benchmark and transect line.

Fig. 14. Leica Sprinter unit with barcode staff.

Generally, the first measurement will be made by placing the barcode staff atop the survey benchmark steel rod. The staff operator shall proceed along the steel tape measure (walking on the left side, and carefully placing the staff about one foot to the right side of the tape at the designation distance marks for that survey. When placing the staff on the marsh surface, apply no downward pressure (other than the weight of the staff). If wrack is accumulated at the designated transect location, measure, and record the depth of the wrack, then carefully push aside wrack material to reveal bare earth or vegetation. Report wrack depth to the nearest cm.

Care should be taken to hold the staff vertical as indicated by the bubble level on the staff. The staff operator will call off the distance and "mark" to the operator, who will then press the red button to record elevation and position information into the unit's memory, make note of PID and reported distance position along the tape measure, then call back "done," so that the staff operator can proceed to the next station. Additional details of operation are contained in the user manual titled "Using the Leica Sprinter Digital Level" in Appendix D.

2.2.4.3. Elevations from precision pressurized hydrostatic altimeter (ZIPLEVEL)

Set the ZIPLEVEL on the platform used for the study. The platform

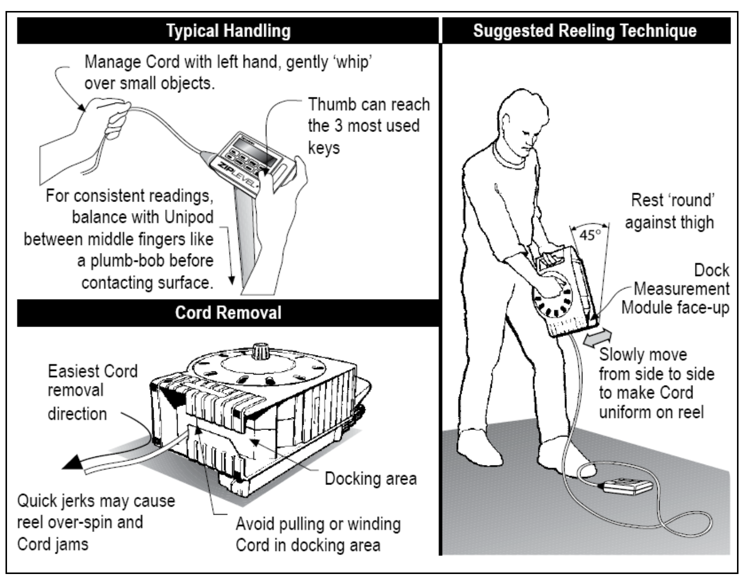

Fig. 15. ZIPLEVEL operation.

should be located within the length of the cord (50 feet) of the elevation bench. For greater distances, carry a suitably sized thin stone paver to place on the marsh (not on or within the transect study area), and use the carry and leapfrog technique described in the manual. In this study, elevations will be recorded by placing the measuring device on bare earth or vegetated surface.

To operate, switch the measuring module on with the ON/OFF-key and put the unit with its back or base on the reference platform. When the display is ready, you will hear 2 short audible bleeps. Make sure the resolution is set to 0.2 cm: press the RES-key for 2 seconds and keep it pressed in order to choose the required resolution. Release the RES-key once the display shows RES,2. Your choice is stored. Begin by placing the measuring device of the top of the steel rod elevation marker, keep the device level. Press the ZERO-key for 2 seconds. Keep the measuring module steady until the figure zero appears on the display. The appliance has now been set to the benchmark, and this reference elevation is defined as zero. Proceed to each designated distance position along the transect tape; place the measuring device about one foot on the opposite side of the line, and record elevations for each designated location on your datasheet. If wrack is accumulated at the designated transect location, first measure and record the depth of wrack to the nearest centimeter then carefully push aside wrack material to reveal bare earth. Gently push aside any living snail or empty shell loosely resting on the surface. For each designated location along the transect or reference plots, lace the measuring unit on the bare or vegetated surface. Observe and record the elevation on the data sheet.

2.2.5. Hydrology

One water level recording system consisting of two Hobo water level loggers will be installed in each estuary to measure inundation frequency, inundation duration, % time flooded and mean water level.

2.2.5.1. Setup of Water Level Loggers

Before deployment the loggers will be tested using the "bucket method" where loggers are set in water in a bucket, the water level is manually measured, some water is removed and the water level is measured again, and the manual measurements are compared with the data recorded on the logger. See Curdts (2017)and Rasmussen et al. (2017) for detailed description of method.

One Hobo water level logger will be installed within the main stem of the tidal creek, so that all vegetation transects are found upstream of the water level logger. The water level logger will be installed on the creek bottom, but as close to the edge as possible for ease of access and to avoid damage from boats or vandalism (Fig. 16A). Water level logger setup and monitoring will be conducted at low tide when creek bottom is accessible. An additional Hobo logger will be installed in the upland or located in a building nearby (within a 10 mile radius per manufacturer's recommendations) to record barometric pressure for correction of the water level data (Fig. 16B).

The water level loggers will be installed using a setup based on the protocols in Curdts 2017. A 40-inch earth anchor will be driven into the creek bottom at low tide. A soil auger will be used to dig a hole next to the anchor for a two-foot length of PVC pipe that will house the logger. The PVC pipe will be partially driven into the ground and secured to the earth anchor using cable ties. The water level logger will be attached to the PVC pipe connection point using a nylon thread.

The precise elevation of the sensor from the top of the staff and the elevation of the top of the sensor staff will be measured from the installed survey elevation benchmark. Elevations will be calculated using the three technologies used in this study. If possible, elevation will be measured again at the middle and end of the water level monitoring period to document any movements.

In the event that there is not a building nearby where the barometric logger can be kept, it will be installed in the upland where it will remain dry even on the highest spring tides (Fig. 16B). If there is a suitable structure present (e.g. small tree) the PVC housing containing the barometric pressure logger will be attached to it, if not a wood stake will be driven into the ground. The elevation of this logger doesn't need to be recorded as it is measuring atmospheric pressure, but it should be mounted in a shaded area to minimize extreme temperature fluctuations.

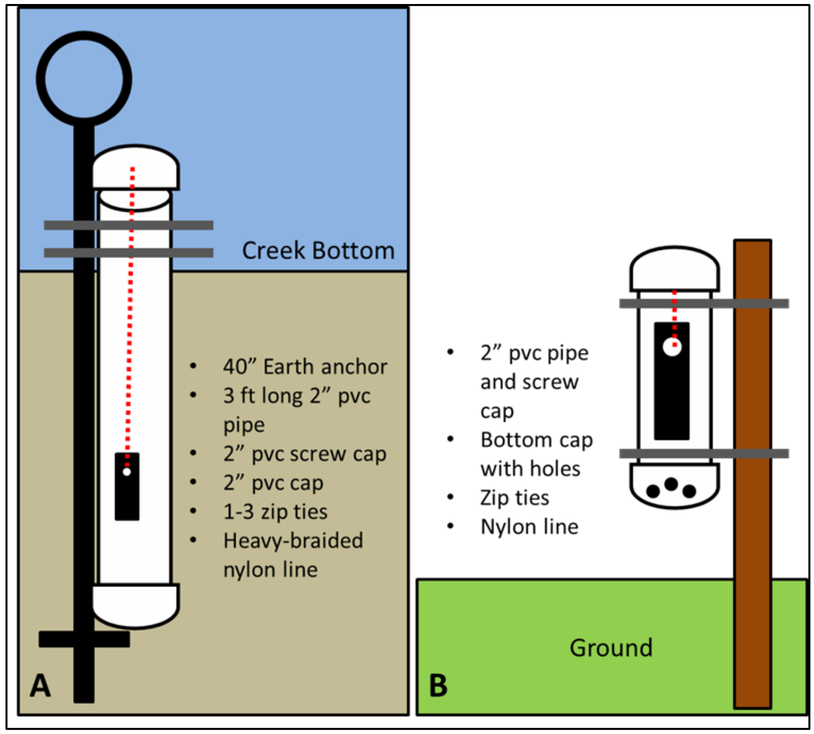

Fig. 16. (A) Water level setup and (B) barometric pressure setup. From Kennedy et al. (2018).

2.2.5.2. Water Level Monitoring

Water level recorders will be deployed for 2-3 months during the growing season (within the months of August, September, and October) to measure local tidal regimes at each monitored estuary, informed by research studies (e.g., Curdtz, 2017). A manual reference measurement will be made at a minimum of two times to check for sensor drift. The water level logger and corresponding barometric pressure logger will be programmed to simultaneously record data in fifteen minute intervals. If possible, water level loggers will be periodically inspected for biofouling/change in position and data will be downloaded and inspected in the field to check for any problems with the recorders. Any biofouling or debris found on the recorders will be cleaned using soapy water and pipe cleaner/syringe to clean the pressure port.

2.2.5.3. Water Level Data Download and Analysis

At the end of the monitoring period, the level loggers and housings will be retrieved during low tide, and water level and atmospheric data will be downloaded using the Hoboware™ software and base station or data shuttle. The raw data will be corrected for atmospheric pressure using Hoboware software and water level data will be exported into Excel™. The elevation will be corrected to meters in NAVD88 using elevation information. Plots of data will be visually inspected in excel to identify any outliers, unusual data points or shifts in data. Any unusual data will be flagged and removed from subsequent analysis.

Elevation data will be imported into an Excel structured database. Calculations will include summary statistics for sites of interest based on site elevation: inundation frequency (number of times reference level is inundated), average inundation duration (average length of time that reference level was inundated in hours), and % time flooded over monitoring period. Examples of sites of interest are ecotone boundaries or vegetation quadrats.

2.2.5.4. Calculation of the High Tide Line

Using the high tide line elevation already calculated by the Buzzards Bay NEP as outlined in section, and from actual observed elevations during King tides, these data will be applied to LiDAR data after any appropriate geoid and estimated canopy elevation corrections using the methodology contained in Costa (2013b). ArcView™ GIS has all the necessary functions to manipulate and intersect the datasets (3D Analyst and Spatial Analyst extensions needed for some steps). The GIS data can also be used in an ArcView environment for simple applications such as calculating the amount of area in the expansion zones. No field collection of data or ground truthing is required for this analysis.

All data files, input and output files, spreadsheet, database, and word processing files will be stored in an appropriate format for the software used. Current and widely used software packages will be used for electronic spreadsheets (Excel, various databases, and word processing (MS Word™). Intersected datasets will primarily be analyzed in Excel spreadsheets using built in pivot table functionality. If necessary, files for these software packages can be converted back and forth between formats without a loss of data.

2.2.6. Transect Physical Condition

To complement the vegetation sampling, observations about the physical condition of the transects and the creek bank will be made using the Physical Condition Datasheet found in Appendix B. General observations about the condition of the area surrounding each transect will be made including signs of human disturbance, slumping, hummocks, holes, fissures, excess water saturation, invasive species, and grazing activity.

Staff will walk fifty-foot section along the creek bank from either side of the transect terminus location to record observations on creek bank physical condition and vegetation condition including signs of slumping, undercutting, erosion, plant lodging, and areas devoid of vegetation.

2.2.7. Protocol for Decontamination of Field Equipment

Inspect all equipment for debris and remove before leaving a site. Dispose of debris in a trash bag or on dry, high ground. Rinse with freshwater or wipe with a freshwater soaked rag, any surfaces exposed to salt water. When possible, leave equipment to air dry and inspect to remove any remaining plant fragments.

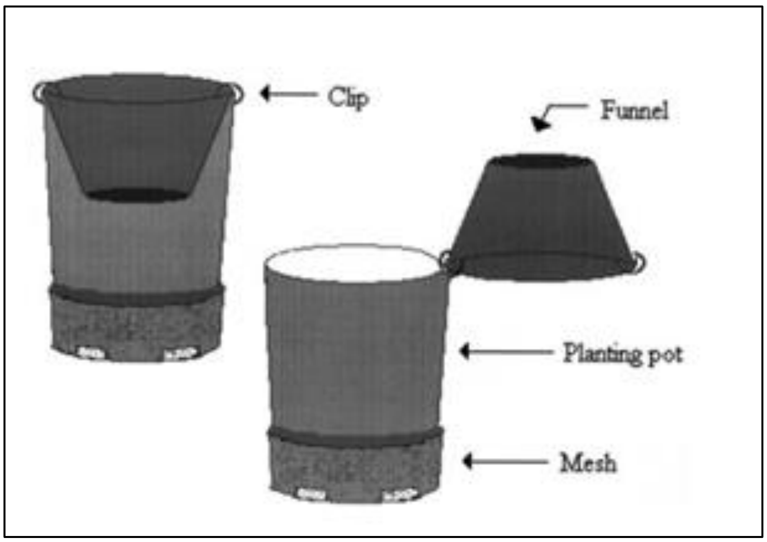

Fig. 17. Crab pitfall trap after Kent and McGinnis (2018)

2.3. Quality Control

Compliance with procedures are described below. See sections 3.1 and 3.2 of the QAPP for additional QA/QC measures.

- Use of standardized sampling procedures (precision, accuracy, representativeness)
- Prompt review and documentation of any changes to the SOPs (precision, accuracy, comparability)

- Use of highly qualified field personnel (precision, accuracy, comparability)
- Rigorous training and mentoring of less experienced technicians in both structured and informal settings, the latter on an as needed basis (precision, accuracy, comparability)
- Daily checks to ensure that data forms are completely filled out (completeness)
- The Quality Assurance Manager will review field data, identify inconsistencies, and if possible, take corrective action. Any significant changes in protocols will be made in coordination with EPA.

2.3.1. Interferences

Inclement weather (heavy rain) may interfere with our ability to collect representative data on a variety of parameters. Severe weather may delay field data collection due to safety concerns. Tidal elevations are affected by weather conditions, and differences between predicted and actual tidal elevations at the NOAA Newport, RI and Woods Hole, MA real time tidal gauges will be used to evaluate and interpret tidal elevations documented in this study.

2.3.2. Corrective Actions

Data quality control ensures high quality data, however we are prepared to re-measure any plots within the same season or period of monitoring as needed (e.g. data are missing, samples are lost or compromised, etc.). Any plots that contain data that cannot be resolved will be removed from the data set.

2.3.3. Waste Minimization and Pollution Prevention

Care will be taken to avoid transport of vegetation and soil to other sites. This will be done by thorough inspection of all equipment and clothing prior to departure from a site. Invasive plant samples will be disposed of in a way to avoid accidental release into the environment. No litter will be left at the study sites. No chemicals will be used at the study sites.

2.3.4. Sample Handling and Custody

Field samples will not be routinely collected, and most data collected will be based on visual observations and enumeration. The collection of vascular plants will be limited to species that cannot be identified in the field. Guides and keys will be made available for training (e.g., Carlisle et al., 2002; Gleason and Cronquist, 1991; Tiner, 2009). For species that cannot be positively identified in the field samples will be collected for lab identification and photographed for digital preservation. Taxonomic identification at the species level (preferred) or genus level (if species identification is not possible) will be achieved in the laboratory with field guides, technical keys, and reference to regional herbaria. Samples will be labeled in the field with the plant ID (e.g. “unknown sedge #1”) site location, date, and person who collected the sample, and assigned a code in the laboratory for use in digital preservation.

Any enumeration of crabs and ribbed mussels, and any physical measurements of those species will be undertaken in the field, with no permanent collection of animals. Crab burrows will be enumerated, and at selected sites crab populations will be estimated using pitfall traps (Kent and McGuinness, 2006).

2.4. Field Measurement Instruments and Equipment Checklist

Before leaving for the field the Field Manager will confirm the appropriate equipment and supplies are brought into the field for the specific tasks to be undertaken as per the Field Measurement Instruments and Equipment Checklist in Appendix B.

2.4.1. Instrument/Equipment Testing, Inspection, Calibration and Maintenance

Field equipment will be inspected by the BBC staff each day before going out to collect field data. At the field site, equipment will be tested prior to data collection to ensure that it is working properly. Equipment will be subject to regular maintenance as needed and as recommended by the manufacturer. Instruments will be calibrated regularly as recommended by the manufacturer. Table 7 summarizes the equipment calibration, inspection, testing, and maintenance schedule.

2.4.2. Field Sampling Supplies and Consumables

Few supplies and consumables will be used in this study. It will be the responsibility of the field managers to ensure that all items in the equipment checklist are available on each monitoring date.

2.5. Data Acquisition Requirements for Indirect Measurements)

2.5.1. Collection and processing of existing data

Historical and recent aerial survey imagery will be acquired in this study. The quality and specifications of those surveys are not under the control of this QAPP. The LiDAR GIS data for this study has already been obtained from USGS (also available through MassGIS) and FEMA. Although the two LiDAR datasets were taken at different times, and use different Geoids (which are corrected for as described above) the data sets are of comparable quality and positional accuracy, and where they overlap, show good agreement. Any discrepancies between the two data sets will be discussed in the project reports. Most datasets will be obtained by direct downloads from publically accessible websites, or by email or drop-box links from agency contacts.

Electronic documentation and data will be stored on individual computers with weekly full backups and daily incremental backups. The backup data will be hosted on USB drives with additional monthly archiving on CDs stored offsite. Upon completion, data will be posted online in final form, including shapefiles with appropriate metadata.

2.6. Data Management

Data will be collected in the field and entered onto field data sheets. Field data sheets will be inspected and approved by the field team leader before leaving each site. At the end of each sampling day, the field team leader will review all field sheets to ensure all required data is accounted for. In the event that significant errors or omissions are detected during on-site inspection, the field team leader will consult with samplers to rectify the situation. Data sheets will be returned to the BBC Project Manager and stored for data entry weekly. A data entry system will be developed in Excel and formatted to resemble the field data form to reduce data entry errors. One person will be designated to enter data for consistency and all data will be reviewed for quality control by the BBC QA Manager. The database (MS Excel) will be stored in a private directory on a secured network server and will be backed-up regularly. Only the BBC Project Manager and Administrative Assistant will have access to the master database. The BBC QA Manager will maintain a database copy in a separate private directory on the same secured network for purposes of review only. Once review is complete, the BBC QA Manager will delete his copy of the database. All supporting documents and ancillary data (e.g., photos, maps, etc.) will be stored in a private directory managed by the BBC Project Manager on the previously mentioned, secured network server, with backups secured at an offsite location.

GIS data will be maintained by the Buzzards Bay NEP Director (project manager for this study).

Table 7. Instrument/equipment calibration, inspection, testing, and maintenance.

Equipment	Calibration	Inspection/testing	Maintenance
Hobo water level data logger	NA (factory calibrated)	Perform "bucket test" prior to deployment according to manufacturer's recommendation; Inspection of housing prior to and at the end of deployment period for biofouling; download data and inspect in the field on a laptop to ensure instrument is recording at the correct time interval and values look correct.	The water level logger will be maintained according to manufacturer's recommendations (see attached manual, Appendix C)
ZIPLEVEL	Check vertical accuracy in the office before each use.	Place the base unit on its back, turn on, and raise the measuring unit 4 ft on GPS unipod, or office shelf and measure precise elevation. If inconsistent, follow the calibration procedures on page 13 of the manual.	Check battery level and cord regularly for damage. Return unit to factory every three years for recharge of pressure sensing liquid or sooner if error light appears.
Leica Barcode Level	After setting up the level in the field test, and confirming the device is level, rotate the level 180 degrees. If the bubble does not remain level, adjust as shown on page 17 of the manual. Also test collimation.	Inspect the field adjustment parameters as per the user manual before using the product.	Dry the product, the transport container, the foam inserts, and the accessories at a temperature not greater than +40°C / +104°F and clean them. Do not repack until everything is completely dry. For prolonged storage, remove the batteries.
PPK survey-grade GNSS	NA	Units will be inspected daily for damage or other problems; units will be tested monthly using known locations	Keep batteries charged and in good condition; clean as needed
Various digital cameras	NA	Daily inspection for damage or other problems	Recharge, replace, and clean batteries as needed

3. ASSESSMENT AND OVERSIGHT

3.1. Assessments and Response Actions

Quality assessment and response will be the responsibilities of the field team leader and Quality Assurance Manager. All corrective actions or changes to field sampling and data management protocols will be recorded.

The field team leader will train and accompany any other staff during field sampling and review data sheets at the end of each day. Equipment will be checked before and after each field day.

Any inconsistencies in sampling technique, equipment malfunctions and data entry errors will be addressed as they occur and recorded.

The Quality Assurance Manager will review all field data and all data entry. Any systemic collection or entry errors will be discussed by the project team and if necessary changes to the sampling methods will be recorded.

3.2. Reports to Management

The Project Manager will include all reports of the project status on the annual report, including any problems and the proposed recommended solutions. Any deviations to the QAPP will be reported.

4. DATA REVIEW, VERIFICATION, AND VALIDATION

All field and laboratory data are reviewed by the BB NEP Project Manager and QA Manager to determine if the data meet QAPP objectives. They will make the ultimate decisions to reject or qualify data. If outside expertise is need, the expert scientists from the BBC Science Advisory Committee salt marsh subcommittee.

4.1. Verification and Validation Methods

Validation and verification methods for field sampling will occur as previously described. All raw data will be submitted to the BB NEP Project and QA Managers for quality assurance review and data entry. Sample readings out of the expected range will immediately be reported to the field team leader, upon which they will take a second sample to verify the condition. All validation records will be retained.

Only one person (the BB NEP Project Manager) will manage the data sets. Comparison of the raw data sheets with data in the database will be conducted to confirm proper transfer of data as well as any qualification or censoring of data. Once the sampling period has closed, the QA Manager and BB NEP Project Manager will graph and review the water level data to look for outliers and anomalous data, will plot and review RTK GNSS data and review vegetation data.

Elevation data based on the three techniques will be compared and validated against each other, given the precision of the methodologies. Outlier data will be will be flagged in the database for measurements outside 2 standard deviations pre- and post- values for that station unless justified by field observations (e.g. sand overwash after a storm). Describe the methods or procedures to be used for verifying and validating data, as well as documenting the process. Describe how accepted, qualified, and rejected data will be identified. Include data qualifiers if appropriate.

4.2. Reconciliation with Data Quality Objectives

After the data has been compiled, verified, and validated, the project team will review the results and compare the data quality to the original data quality objectives. If some of the data do not meet the original data quality objectives, the team will determine whether to discard this data or to change the data quality objectives. All changes and decisions will be recorded.

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Appendix A. University of Rhode Island - National Park Service Guidelines for Installation of Backbone Survey Monuments on NPS Lands

This text was taken from, and directly quotes, edc.uri.edu/Monumentation/Protocols/URI_NPS_Guidelines_for_monument_install.pdf, last accessed May 10, 2019, with edits (revisions and deletions) applicable to the work undertaken in Massachusetts and in this study.

1 Introduction and Background

The University of Rhode Island and the National Park Service collaborated to create a network of stable and permanent survey monuments in ten coastal parks in the northeastern U.S. (Fig. 18). This effort is part of a larger project to assess risk from sea level rise and storm surge at these coastal parks utilizing high accuracy geodetic control (August et al., 2010). These monuments (hereafter referred to as backbone monuments) would serve as reference points on the landscape from which to measure elevation typically using geodetic GPS or survey equipment (see NPS, 2011). The most accurate method of determining the elevation of critical natural or cultural resources is by on-the-ground measurement using GPS or other survey equipment (NOAA, 2010).

This document covers the installation of two types of backbone monuments: steel rods driven to depth into the ground, and brass disks affixed to a solid substrate (typically a concrete pad or bedrock outcrop; Fig. 19 and Fig. 20 respectively). Concrete pillar monument installation procedures can be found in NOAA, 2011 and Smith (2010). This document is intended to be a primer in monument installation for managers and practitioners. NOAA, 2011; Smith (2010); and Floyd (1979) provide more detailed discussions of the subject. Procedures documented here are adapted primarily from Smith (2010) and Bernsten.com.

2 Establishing New Elevation Monuments

The principals of this study decided new elevation backbone monuments at each reference salt marsh study sites were needed to facilitate the collection of data and analyses needed to achieve the goals of this study. The elevation and position of these monuments can be established through the submission of data to NOAA's This Online Positioning User Service (OPUS) service. Elevations and positions can also be established by tying into existing survey monuments with traditional survey techniques. The most robust and up-to-date database of survey markers or benchmarks is managed and maintained by the National Geodetic Survey (NGS). This database of over 700,000 monuments along with continuously operating GPS base stations are the backbone of the National Spatial Reference System (NSRS) (www.geodesy.noaa.gov). Other agencies including the NPS – Lands Office and U.S. Army Corps of Engineers may also have information and data on existing monuments. Information on Massachusetts specific benchmarks can be found at the MA DOT website docs.digital.mass.gov/dataset/massgis-data-survey-control. To find old benchmarks, data posted by geo-caching hobbyists may be helpful (see www.geocaching.com). Additionally, DSWorld, a Google-based software package can be downloaded from www.geodesy.noaa.gov for a comprehensive all-in-one package of recent geocaching findings and recent additions to the NGS benchmark database.

The main function of a backbone monument is to serve as a known location for a kinematic GPS survey (see Henning, 2011) and as a reference point for other elevation survey techniques, like laser levels, and hydrostatic altimeters. There are many considerations for the field-identification of a site suitable for monument installation (NOAA, 2011; Smith, 2010, and Floyd, 1978), but the primary factors for either a brass disk installation or a deep steel rod monument are (in no particular order):

1. topographically high (above predicted storm surge) and sufficient to support a tripod with a GPS receiver
2. clear view of the sky (e.g., minimal trees, buildings, topography, or other obstructions that might cause multipath of the GPS signal)

3. no above ground utility lines immediately overhead that might interfere with GPS signals
4. on approved National Park Service property
5. relatively secure and safe location

3 Supplies, Equipment, and Tools

There are extensive lists of supplies found in NOAA, 2011 and Smith, 2010. Comprehensive lists of supplies, equipment, and tools are difficult because of slight variations during installation procedures, site conditions, and personal preferences. However, minimal supplies are shown in Fig. 21 and Fig. 22

There are many places on the Internet where supplies can be found (www.surv-kap.com, www.stakemill.com, www.forestry-suppliers.com, www.benmeadows.com and www.survey-marker.com) however we found most of what we needed at www.bernsten.com. By searching on part numbers or keywords (given in parenthesis) at Bernsten.com in the steps below, more details, part photos, and specifications on parts can be found.

4 Monument Installation Steps

Installation of survey disk set in bedrock or concrete (adapted from Smith, 2010)

1. The disk (or survey marker) we chose (CD2BL at Bernsten) was one that is designed specifically for setting in a drill hole with concrete. Our disks are pre-labeled "BBNEP-". Add a unique station ID with year, so the Benchmark reads BBNEP-YYYY-##. Stamp station identification on brass disk before heading to the site or after installation.
2. Select a site to drill a hole. Bedrock is the best substrate, but concrete in a bridge abutment, abandoned infrastructure (i.e., foundations of old buildings, radio towers, and aircraft landing strips) should be stable as well (Smith, 2010). Avoid concrete that is excessively cracked or crumbling or looks like it has moved due to soil moisture conditions (e.g., shrinking and swelling or frost heaves), or a structure recently installed.
3. Drill a hole. Using eye and hearing protection, drill a hole using a hammer drill and masonry bit suitable for stone and concrete with a drill bit shank that is compatible with the drill's chuck (our drill used a SDS Plus shank designed for stone and concrete). A 36V cordless drill is adequate for this work (Fig. 23). An extra drill battery and an 800W power inverter connected to the car battery can be used to re-charge drill batteries in remote locations. The size of the hole (as well as the size of the drill bits) will be determined by the brass disk that is purchased. Disks with flared stem require a drill bit that matches the max diameter of the flared stem, such as a 1 1/4 inch diameter masonry bit suitable for stone and concrete (Hitachi 728946). A drill bit may last through the installation of 4 brass monuments in granite before wearing out. The depth of the hole should be equal to the length of the disk stem (2 1/4 inches for the RT35DB) plus the depth to which the disk head will be countersunk (1/4 inch) for a total depth of 2 1/2 inches.
4. Recess (countersink) the disk into the substrate. Using eye and hearing protection and a hammer, chisel away enough rock or concrete so that disk is flush (even) or below the substrate (see Figures B-3 and B-4 from Smith, 2010) (Fig. 24). It may take about ½ hour to countersink the RT35DB by hand.
5. Flush the drilled hole with water to remove any debris from the hole. Extract excess water with a turkey baster or blow out with compressed air. Clean the hole with a dry rag.
6. Mix the hydraulic cement with water in a one quart mixing bowl. Using latex gloves, follow the manufactures' directions for mixing. It should be thick but workable. We used a quick setting (3-5 minutes) hydraulic cement used for filling cracks and preventing water seepage.
7. Prepare the disk. Clean and rinse the disk thoroughly to remove any dirt or grease. Turn the disk upside down and fill the stem or shank of the disk with cement and tap gently to remove any air bubbles. Also place cement on the underside of the disk
8. Setting the disk. Fill the drill hole with cement and insert the cement-filled stem of the disk into the drilled hole. Rotate the disk back and forth with your fingers until the disk sets in place.
9. Finishing. With a damp rag, clean the excess cement around the edge of the disk but leave a slight overlap making sure that the edge of the disk is covered with smooth cement. Cement should fill any other voids in the rock or concrete pad that was left during chiseling.

10. Clean up. Leave the area as close to undisturbed as possible keeping in mind that the lime in cement can burn skin and kill vegetation if tools are rinsed and the water dumped on the ground.

Installation of NGS type steel rod (adapted from Smith, 2010; and Bernsten.com). Installation requires a minimum of two personal and takes one to two hours. Ear protection and gloves are required.

1. Call DigSafe or use their online service to schedule an inspection to verify there are no buried utility lines at the site you plan to install rod (go to **digsafe.com/** to obtain a ticket). The request must be made at least three business days before commencing work, and you must have a flag where you intend to dig. Specify a within a 10 ft radius of that location.
2. Before going into the field, stamp an ID on the aluminum access cover (the covers are pre-stamped BB NEP-, add -YYYY-## to the designation. Thus BB NEP-2019-3 is the third benchmark installed in 2019 by the BB NEP). Wearing nitrile gloves, using PVC cement and a rubber mallet, attach a 2-foot length of 6-inch PVC pipe to the cover. Make sure the cover sets for at least 2 hours before installation
3. Before going into the field, prepare the security sleeve by gluing with PVC cement one of the yellow endcaps. While wearing nitrile gloves, glue the endcaps with PVC cement on the security sleeve and fill with the sleeve with the entire contents food grade grease cartridge (e.g., Belray no-tox clear grease) dispensed from a grease gun (Fig. 28.). The sleeve will fill with one complete cartridge of grease. Gently tap the sleeve and use gravity to distribute the grease evenly throughout the sleeve. After its filled, place stoppers at each end and set aside until it is ready to be inserted over the installed rod.
4. Assemble all needed equipment, supplies, and tools as specified in the checklist in Appendix B.
5. Dig a hole with either a 42-inch deep hole with a power auger (Fig. 25), posthole digger, or spade shovel. The top two feet of the hole should be 12-14 inches, the bottom 18" need only be about 6 to 8 inches diameter as achieved by a post hole digger or auger (Smith, 2010, and Fig. 26). Place a tarp or plastic cover on the ground and place soil from hole in a five-gallon bucket placed on top of the tarp to facilitate soil disposal in an upland area. If desired or warranted, use a 24' segment of 12" Sonotube® to maintain the stability of the upper hole. Note that if refusal is less than ten feet, consider abandoning this hole and relocating the monument a few feet in another direction and starting again.
6. Prepare two 9/16” x 4’ rods by cleaning off any grease from the threads with a rag and solvent (e.g., denatured alcohol or acetone). Apply a generous amount of thread adhesive (e.g., LOCTITE) to the thread of the first rod and attach a drive point. Tighten with vice grip pliers. Each successive segment will be connected by applying thread adhesive ½ of the threaded insert. Screw the insert ½ way into one of the rods. Apply thread adhesive to the exposed thread and screw on the other rod section. Lock the two segments with a pair of vice-grips to each of the rod section. All rods should be firmly tightened taking care not to break or strip the threads. These steps are repeated as each segment is driven with the jackhammer. DO NOT EVER APPLY THREAD ADHESIVE TO THE DRIVE PIN. The drive pin is repeatedly removed and subsequently attached to the next 4-foot segment. This means that during installation of subsequent segments, apply thread adhesive only to the bottom half of the threaded connector, then loosely attach the drive pin.
7. Driving the rods: As described above, assemble two 4-foot steel rods with a drive point to the bottom of the first steel rod, and a steel drive pin loosely attached to the top of the second steel rod.. The drive pin protects the top of the rod from mushrooming and damaging the thread. Hand place the rod from step 6 into the hole (drive point should be at the bottom) so that the rod is in center. Place a piece of plywood with a 9/16” hole in the middle over the top of rod and slide it down so that it rests on top of and covers the hole (Fig. 25. Keeping the rod vertical, and standing on a three foot stepladder, use a small sledgehammer or lead mallet the rod into the ground to at least several feet (if possible; Fig. 10). Unscrew the drive pin from the top, add additional rods as necessary, using Loctite on half connector segments, and moving the drive pin to the top. . Make frequent checks for verticality with a bubble level (e.g. a 9-inch magnetic torpedo level) while driving and after each rod is attached. Move the plywood as necessary to maintain vertical.
8. Adding rods. Once manual driving with a short sledgehammer becomes too difficult (typically after 2 rods depending on soil type), use a gas powered jackhammer. Performance of the jackhammer should be set as close to these specifications: USACE Spec-driving force of 26.9 foot-pounds/blow and an average of 2,500

blows per minute, NGS Spec-driving force (24 joule or 17.7 Foot-Pounds), Yescom spec-impact frequency: 1700-2230 per minute, max power and speed: 900W (1.2HP) /6500r/min = 900/60 = 15 Joules =11 foot-pounds; see also Smith, 2010). Using a stepladder and help from another person(s), lift and guide the jackhammer onto the top of the rod. Start the power jackhammer and drive rod into the ground (Fig. 29) adjusting throttle as necessary. Drive rods until prescribed depth is reached (see Smith, 2010; Floyd, 1979; and Bernsten.com [NGS Three Dimensional Rod Monument Installation Instructions] (last accessed May 20, 2019). Generally, at least 3 rods at a minimum must be used. Due to cost, abandonment of sites may be considered if 20 rods do not achieve refusal.

9. Finishing the datum point. A drive pin should be used during rod installation to protect the inner threads of the topmost rod. If possible, drive the rod to beyond refusal so that the top of four-inch drive pin is about one inch below ground level. This depth will allow about three inches of rod to rise above the protective sleeve, and for the datum to be two or three inches below the cover if it is to be placed flush with ground level. When this depth is achieved, remove the four-inch drive pin and replace it with the two-inch long stainless steel spherical datum point. Remove the red protective cap from the datum point, apply thread adhesive to the threads, and tighten it to the topmost rod with vice grip pliers. If the rod was driven to substantial resistance (you hit a boulder), so that the top of the last rod cannot be driven to about ground level, then the rod must be cut with either a hack saw, a cutoff wheel attached to a drill, or a cutoff tool.. The cut must be made about three or four inches below ground level if the cap is to be placed flush with ground level. The cut steel rod is then rounded on top with a file or grinding bit attached to a portable drill or grinding wheel tool (Fig. 31). Afterwards, use a steel punch to create a dimple, then a small pointed grinding bit to create a dimple like that on the prefabricated spherical datum points.
10. Confirm that the top of the finished rod is about 39 inches (use a meter stick) above the bottom of the hole. Add a little soil to the bottom of the hole or tamp down soil to achieve the depth. Slide the grease-filled sleeve over the steel rod, and continue until the top of the sleeve is about 3 inches below the datum point. If you encounter resistance, do not force the sleeve. Make sure the top- edge of the rod is ground and beveled. Be prepared to catch and wipe away excess grease discharging from the end of the sleeve as it is inserted over the datum point.
11. Cover and tape the top of the sleeve and datum point with a plastic bag and using **Error! Reference source ot found.** as a guide back-fill the hole with clean sand to about 24 inches from the surface.
12. Place the cap and PVC pipe assembly over the datum point and sleeve making sure the datum point is centered and that the cap is at or near the surface of the ground (Fig. 32). Fill the inside of the PVC pipe with clean sand to within 7" of the top of the PVC pipe but not more than within 1" from the top of the sleeve.
13. Adding the concrete collar. Mix concrete in a 5-gallon bucket or plastic mixing tub. To keep the top of the access cover free of concrete, cover with a wastebasket size trash back cut so it extend about six inches below the top of the cap. Pour the mixed concrete in the hole and around the PVC pipe to about the base lip of the cover or about 1 inch from the ground surface (Fig. 33). Remove bag and tamp down the concrete. Rotate the access cap and PVC pipe assembly to remove any air voids or air bubbles that might have formed during the pouring of the concrete.
14. Clean up. Leave the site in the condition in which it was found. Dirt from the hole should be disposed in a discreet upland area in a diffused manner.
15. Record approximate GPS coordinates. At a later date, more precise GPS coordinates and elevations will be established (see Coops website).

5 Other Considerations

1. Rod depth and costs. Rod stability is a vital consideration when installing this type of monument. The NGS recommends driving rods until the rate into the ground slows to one foot/minute with a 55-lb jackhammer (see Smith, 2010). This is known as 'substantial resistance'. When installing these monuments in coastal areas with sandy Holocene deposits that in some cases may be many hundreds of feet thick, substantial resistance may not be reached until several hundred feet of rods have been used. In addition, with a cost of about $7/foot (as of January 2012) it could cost several thousand dollars for a monument in these coastal areas. For our project, we consulted with a state NGS advisor and determined that a depth of 80 feet (or substantial resistance whichever came first) would give us a mark that would be stable enough to withstand

instability caused by freeze-thaw or other surficial factors.

2. Permits and Paperwork. Because the installation of these monuments involves some ground disturbance and work near wetlands, file a Request for Determination with the municipal Conservation Commission (mass.gov/how-to/wpa-form-1-request-for-determination-of-applicability).
3. Wait 30 days before measuring location with a geodetic GPS to let concrete dry and monument to settle.

6 References

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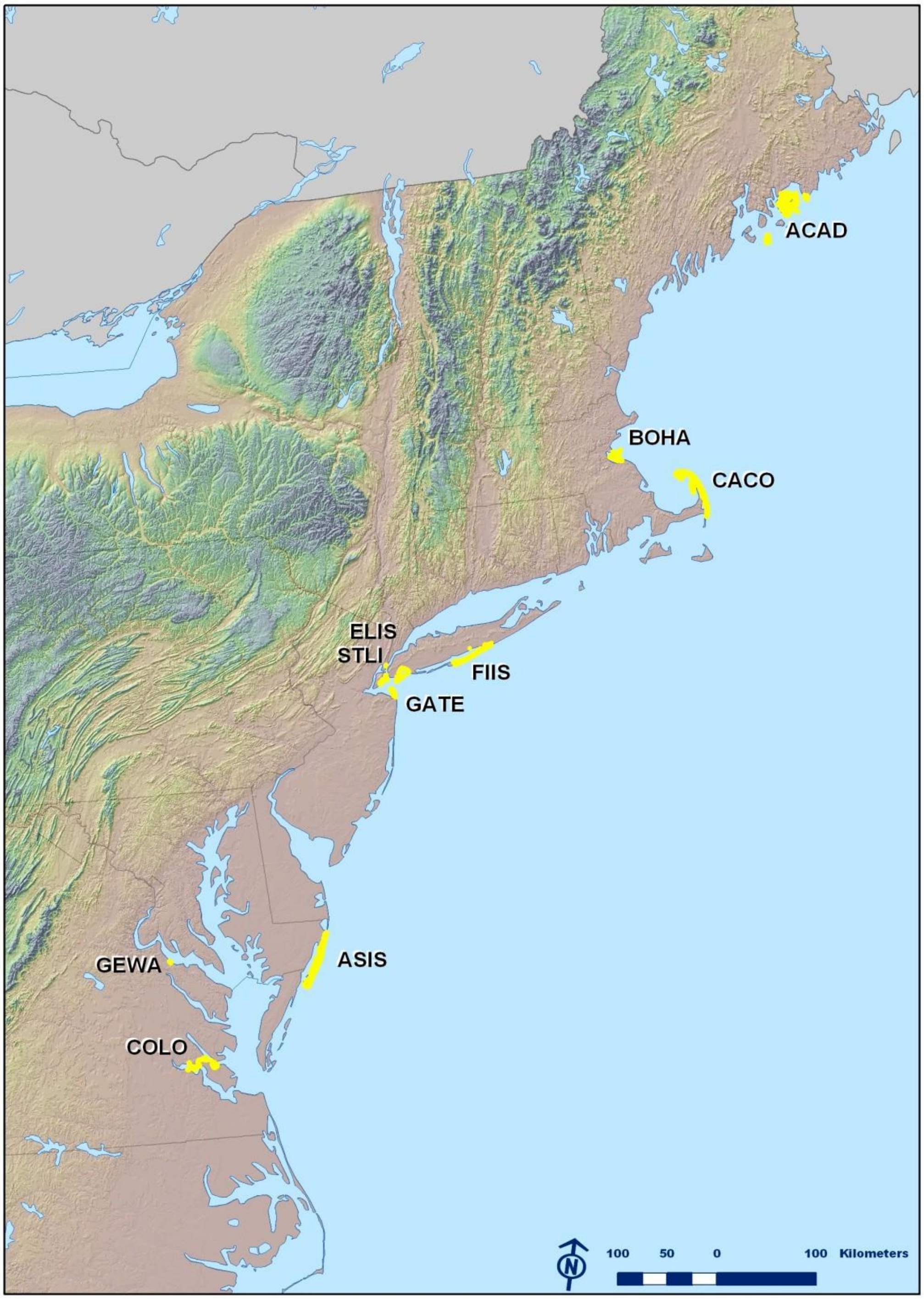

Fig. 18. There are ten coastal parks that were part of the URI/NPS study.

Fig. 19. A steel rod monument driven to depth with a security sleeve.

Fig. 20. Figure 3. A brass disk drilled into bedrock.

Fig. 21. Figure 4. Basic materials necessary for a brass disk drilled into bedrock or concrete. This is not a comprehensive list. Please see text for details and model numbers (where appropriate). 1. Water bottle; 2. Brass disk; 3. Disposable quart container for mixing cement; 4. Cordless battery for drill; 5. Hammer drill; 6. Eye protection; 7. Ear protection; 8. Rag; 9. Disposable face mask; 10. Water bottle; 11.Drill bit; 12. Work gloves; 13. Sledge hammer; 14. Disposable latex gloves; 15. Rock chisel; 16. Hydraulic cement.

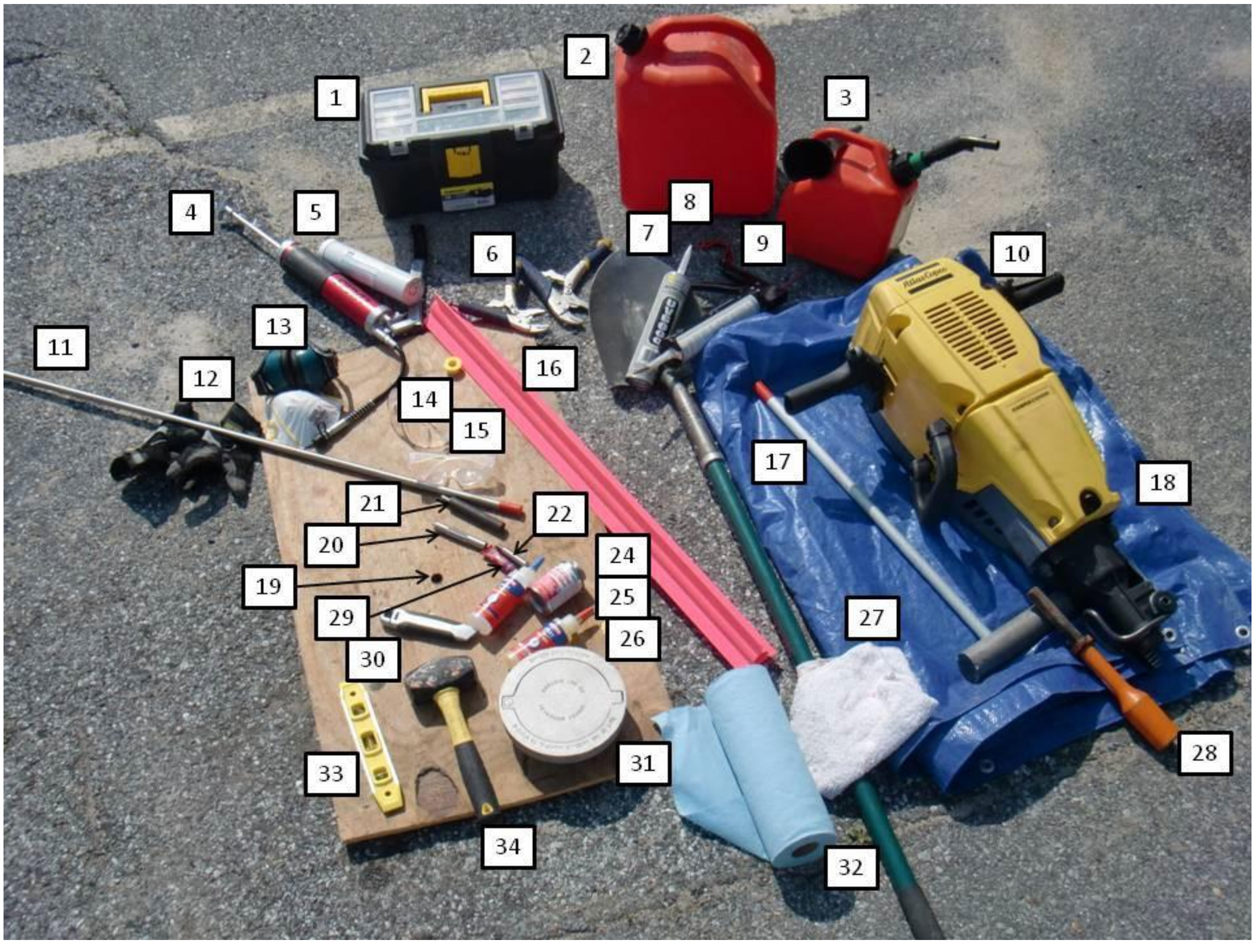

Fig. 22. Basic materials necessary for a steel rod monument. This is not a comprehensive list. Please see text for details and model numbers (where appropriate). Not shown: 6” diameter PVC and measuring tape. 1. tool box; 2. water jug for mixing concrete; 3. mixed gas and oil with funnel; 4. grease gun; 5. non-toxic biodegradable grease tube; 6. vice grips; 7. spade; 8. UV resistant industrial strength adhesive for aluminum cap – PVC bond; 9. caulking gun for adhesive; 10. jack hammer; 11. 3/8” threaded steel rod 4’ section; 12. work gloves; 13. ear protection; 14. security sleeve cap; 15. eye protection; 16. security sleeve; 17. manual drive assembly; 18. tarp; 19. 3/8” plywood with 3/8”drill hole to support steel rod (arrow); 20. drive point; 21. drive pin; 22. datum point; 24. epoxy hardener ; 25. PVC cement (can) for security sleeve caps; 26. epoxy resin for datum point attachment; 27. rag; 28. power drive adapter; 29. Loctite; 30. box cutter; 31. aluminum cap with stamping; 32. paper towels; 33. bubble level; 34. small sledge hammer. Not shown: 5 gallon buckets and mixing tub for cement mixing

Fig. 23. Figure 6. Drill a hole using a cordless hammer drill. A sharp drill bit and extra batteries are essential (video).

Fig. 24. Figure 7. Using a hammer and a chisel, chip away at the substrate to recess the disk (video 1, video2).

Fig. 25. Using a power auger (pictured) or spade, dig a hole 42” deep.

Fig. 26. The hole after it is finished.

Fig. 27. Figure 10. Use a grease gun to fill the security sleeve.

Fig. 28. Figure 11. The plywood helps stabilize the rod in the hole during manual and power driving.

Fig. 29.   Using a gas powered jackhammer, drive the rods into the ground (video).

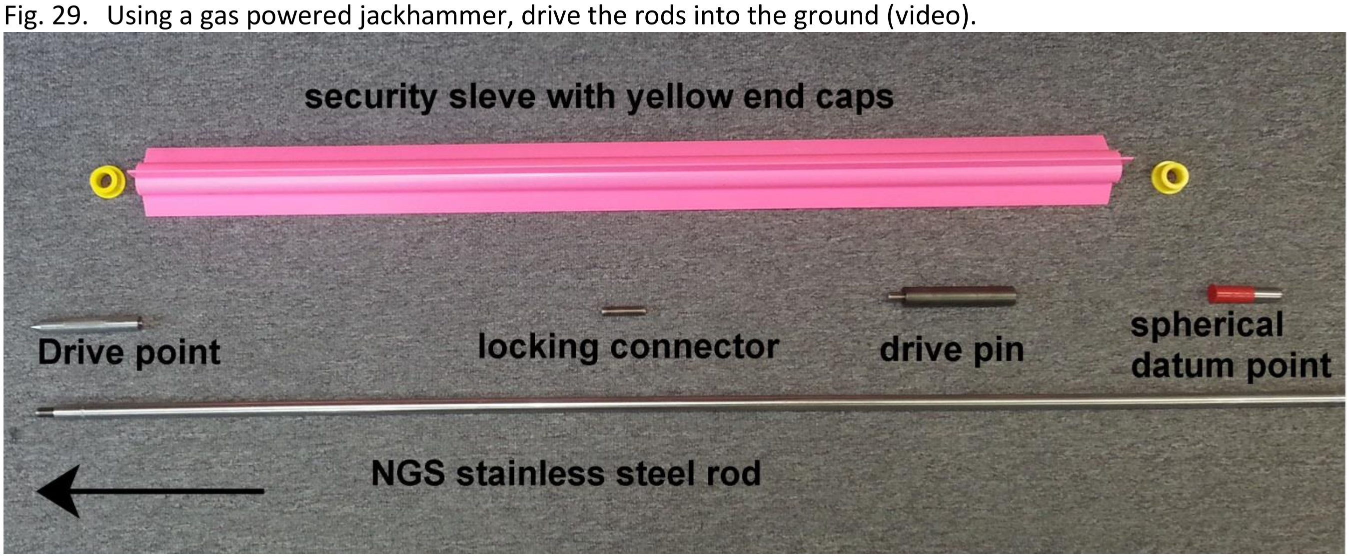

Fig. 30. Key components of rod installation.

Fig. 31. If necessary, a portable band saw (a) can be used to cut the rod (b) if it has been driven to refusal. A portable power grinder (c) can then be used to round the datum point.

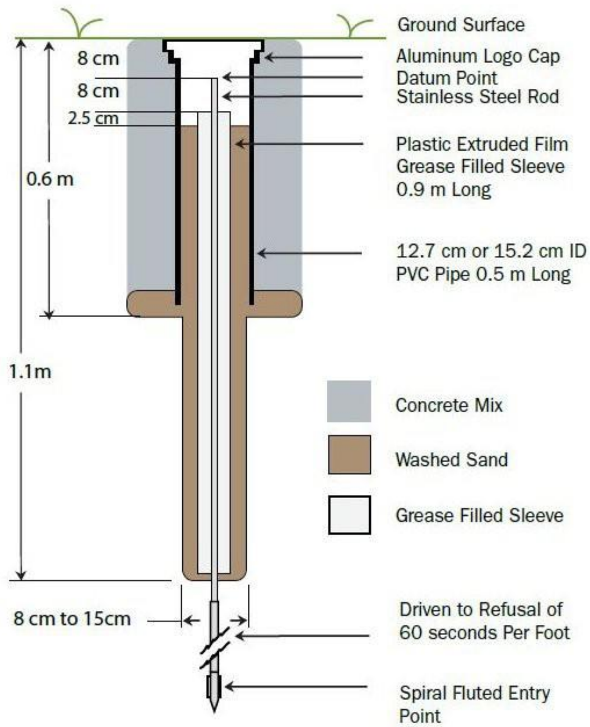

Fig. 32. Diagram of rod installation (from Smith, 2010; to convert cm to inches, multiply by 0.394). Total hole depth is 42 inches. The depth of upper 12-14" wide hole is 24 inches.

Fig. 33. Use a plastic bag to protect the access cover from the poured concrete.

Appendix B. Data Sheets

Field Measurement Instruments and Equipment Checklist

Benchmark Monument Installation Data Sheet

Permanent Transects Establishment Data Sheet

PPK GPS Elevation Survey Data Sheet

Hobo Pressure Logger Data Sheet

Permanent Transects Ecotone Boundary Elevation and Position Data Sheet

Vegetation Quadrats Percent Species Cover Data Sheet

Vegetation Quadrats Point Intercept Data Sheet

Field Measurement Instruments and Equipment Checklist

Site(s): ____

Planned Work: ____

Date: _____________ Staff: _________________

Comments issues during field work

GENERAL SUPPLIES ALL FIELD WORK

___Clipboard and datasheets
___Sighting Compass
___Data sheets
___Cellphone, car charger
___Field notebook
___First aid kit
___Maps of study areas and transect locations
___Steel measuring tapes (50-meter, 100-meter)
___Waterproof pens, pencils, permanent markers
___Scissors or jack knife
___SOP and study field manuals
___Drinking water
___Meter stick
___Marker flags or flagging tape
___Surveyor stakes

VEGETATION SURVEYS

___Labels
___Bayonets for point-intercept, dividing quadrat
___Field guides and technical keys
___Plastic collecting bags [g]
___Plastic stakes (500)
___Quadrat frame (1 m x 1 m)
___Digital camera (if not using cell phone)

ELEVATION SURVEY

___2 GPS units (rover and base station)
___Digital bar-code laser level
___Precision pressurized hydrostatic altimeter
___Steel measuring tapes (50-meter, 100-meter)

CRAB SURVEY

___Pitfall trap
___Core shovel
___ Cooler and icepack for core overnight storage

TIDAL STUDY

___Hobo water level loggers
___PVC housing for barometric with top cap
___2 PVC pipes housing for water level loggers w/ caps
___Nylon line
___Large cable ties
___Hammer
___Slide hammer and protective PVC cap
___Wrench and pliers

Benchmark Installation Checklist

Site(s): ____

Planned Work: ____

Date: ________________ Staff: ____________________

Comments issues during field work

General materials for installation

___9/16" 4-foot stainless steel rods (20 per BM)
___Access cover epoxy to 6-in PVC 2 ft) (per BM)
___Cement mixing tub
___Concrete (one 60-lb. bag per BM)
___Cylindrical post hammer
___Fiberglass rod as probe (reflector marker)
___Fine-grain play sand (one 50-lb. bag per BM)
___Grease gun, one tube of non-tox grease per BM
___Hoe/hand shovel for mixing concrete
___Meter stick
___Pink sleeve (1 per install + 1 extra. (preglue both yellow caps and prefill with grease and stopper before going into the field)
___Post driver with blue bag of supplies, 2 cycle oil, extra gas (small container)
___Posthole digger
___Plywood platform + short 2x4
___Sonotube (2 ft length, 1 per BM)
___Spade shovel
___Two 5-gallon buckets, 1 filled with water w/ lid

Green Toolbox:

__Brass BM (1 per BM + 1 extra)
__Drive pin (flat top; only 1 needed)
__Drive points (1 per BM + 1 extra)
__Exacto knife
__File (1 skinny + 1 fat)
__Flat head screwdriver
__Kitchen knife
__Locking threads (20 per BM + 20 extra)
__Loctite (2 oz. bottle)
__Security tool and security screws for covers
__Small scissors
__Spherical datum points (1 per BM + 1 extra)

Safety Toolbox:

__Bug Spray
__Ear Muffs or other sound protection
__First Aid Kit
__Nitrile gloves (2 pair per BM+1 extra)
__Safety glasses (3 pairs)
__Sunblock
__Work gloves (4 pairs)

General Supplies (Other Orange Toolbox):

__Battery power drill
__Cable screw eyes
__Mini trash bags (cover while pouring cement)
__Plastic bag to cover pipe during pour
__Small claw hammer
__Vice grip pliers (2)

Black Box with Yellow Lid:

__Bag of rags
__Contractor trash bags
__Extra Loctite (2 oz. bottles)
__Foot stool
__Rubber mallet
__Sledgehammer
__Small tarp
__Stamping tool set

Miscellaneous

__Indelible marker
__PVC cement
__Grinding cut off wheel+ arbor, var. wheels
__Pruners
__Masonry drill

Benchmark Monument Installation Data Sheet

Site: __________________ Date Set: ________________ Staff: ____________________

Type: ___ NGS rod with cover or benchmark disk set in ___ rock outcrop __bridge abutment ___other

Exact Stamping of New Disk or Monument Cover: _________________

General description of location and monument:

To reach the monument:

For Rod Mark Driven to Refusal (specify distance units; designated slow time = 60 seconds per foot)

Depth of Rod Driven: ______ Check one: ___To physical refusal __Slow time met

Monument cover relation to ground: __Flush ___Projecting __Recessed:

Depth of grease filled sleeve: _______Distance of top of rod below cover ________

Other Notes/Explanations, including reference photo numbers:
(It is recommended to take photo of hole before installation to show the soil profile.)

Permanent Transects Establishment Data Sheet (pg 1)

Site: ___________________ **Date:** ________________ **Staff:** ____________________

General Site Observations: Record any observations on the condition of the salt marsh and upland habitat such as signs of human disturbance, excess water saturation, invasive species, grazing activity, depth to soil layers and horizons, obstructions, monitoring considerations, etc. Attach aerial map showing estimated transect start and stop of each permanent transect. Use a cellphone maps app to inform creating of sketch.

Transect creation guidance: Insert surveyors stake to mark the start and end of the transect. Where possible, the start stake should be 1 ft above the high tide line and the end stake about 1 meter from the bank. If GPS unit not available, use GPS cellphone coordinates app to estimate preliminary position to 5 decimal places. Use a cellphone compass app to show bearing from true north (area declination is about 14.5° W). Add a two-letter mnemonic for site transect (e.g. Herring Brook Transect #1 is HB-1). Positions are considered preliminary, and will be more precisely surveyed later.

Coordinates from: ___Cellphone app (cell phone model:____________ reported accuracy:_______)

___GPS (Model:____________ Serial number:_______)

_ _ ##	**Transect Start - bearing (degree)** --------- **dist. from BM**	**Transect end - bearing and distance from start**	**Length (m)**	**Lat** ----------- **Long**	**Notes, photo chart number**
_ _ 1	----------	----------	----------	42. ----------- -71.	
_ _ 2	----------	----------	----------	42. ----------- -71.-	
_ _ 3	----------	----------	----------	42. ----------- -71.	
_ _ 4	----------	----------	----------	42. ----------- -71.	
_ _ 5	----------	----------	----------	42. ----------- -71.	

Permanent Transects Establishment Data Sheet (pg 2)

Transect position and Photo Station Records: Attach the steel tape measure to the upland stake. Head to a point 10 to 20 feet left of the tidal bank stake in order not to walk along the permanent transect line. Clip the steel tape measure to the stake near the tidal bank. Stretch the tape measure close to the end of the tidal bank taking care not to collapse it. Record the distance on the tape measure for each of the features below), photos chart ID taken at each station. These data are for the preliminary site assessment, and will be superseded by more precise transect surveys. Enter as xx.xx m. When taking photos, make sure flip chart matches tape position. Extra lines for miscellaneous features.

Feature	**T1**	**T2**	**T3**	**T4**	**T5**
Tidal Bank	/	/	/	/	/
Low Marsh stake	/	/	/	/	/
Tall / short form *S. alterniflora* transition	/	/	/	/	/
patens/alterniflora 50-50	/	/	/	/	/
Upper S paten dominance start	/	/	/	/	/
Lower bound of Iva	/	/	/	/	/
Upper Bound of *Iva*	/	/	/	/	/
Base of coastal bank (if applicable)	/	/	/	/	/
Lower bound of Phragmites (if applicable)	/	/	/	/	/
Upper bound of Phragmites (if applicable)	/	/	/	/	/
Upland stake	/	/	/	/	/
	/	/	/	/	/

Notes:

PPK GPS Elevation Survey Data Sheet (pg 1)

Site: ______________________ Transect ID:______________

Date: ________________ **Staff:** ____________________

Both GPS units must be turned on and receiving satellites at least 10 minutes before the first station data is collected. The base station must record data for 10 minutes before and 10 minutes after the survey, with a goal of 2 hours total data collection.

	Time start:	Time End:
GPS Base	Model / Serial number	Geode/
	Elev. above monument (m)	
GPS Rover	Model / Serial	Geode/
	Unipod Elev. (m)	

Set up base station over the Benchmark on a tripod, and the rover GPS on a monopole as described in Appendix C. The monopole should have a flat disk base installed. Elevations of both GPS units should be measured from the base of the Geode unit to the nearest millimeter to the pole base or monument. Station ID should for transects should be in the form AA#-##.##. For example, HB1-9.58 would be an elevation measurement at Herring Brook Transect 1 at position 9.58 meters from the start stake. The start stake is always set to zero. Affix the tape measure to the start stake , and sweep in to the last stake from the non-survey side of the tape measure. Record corresponding point ID from the GPS, description of feature and/or comments, and coordinate quality indicators from RTK rover. Record elevations to nearest millimeter. For non transect locations, create a station ide using the same two-letter code for the site. For example HB-A is Herring Brook site A (define in comments). Continue on reverse if needed.

Station ID	Point ID	Description/Comments

PPK GPS Elevation Survey Data Sheet (pg 2)

Station ID	Point ID	Description/Comments	CQ1	CQ2

General Comments:

Hobo Pressure Logger Data Sheet

Site: _______________ Hobo Serial #: __________________

Programmed sampling interval: _________________

Launch Date/time: ______________ Deployment Staff: ______________

Retrieval Date/ time: ______________ Retrieval Staff: ______________

Barometric reference station location: _____________________________

Last Bucket Method Calibration Test before deployment **Date:________ Staff:_______________________ Pass/Fail**		
Reference Level (m)		
Manual Level (m)	**Logger Level (m)**	**Difference (m)**

Comments:

At time of deployment, and at time of retrieval, elevation of sensor should be recorded with barcode level (record units). Record salinity and temperature as well.

Start Elevation: __________ Salinity: _______ Temperature: _______

End Elevation: __________ Salinity: _______ Temperature: _______

Deployment site description or sketch (attach aerial photo with approximate Hobo position):

Permanent Transects Ecotone Boundary Elevation and Position Data Sheet

SITE: ________________ TRANSECT ID: ___________ DATE: _________

STAFF: __________ Quadrat size: ______ m^2 Elevation Method: ________________

Use a different datasheet for each transect survey. Transect ID should be in the format AA-#, as in HR-3 for Herring River Transect 3. Record the position (xx.xx m) of each feature along the tape. Affix the start of the tape to the upland stake, then head to a point 10 to 20 feet left of the tidal bank stake in order not to walk along the permanent transect line. Clip the steel tape measure to the stake near the tidal bank. Stretch the tape measure close to the end of the tidal bank taking care not to collapse it. When taking photos, make sure flip chart matches tape position. Extra lines for miscellaneous features. Elevations on this data sheet is by ZipLevel or Barcode Level (generally only one). Lines for extra features like start of panne/end of panne.

Comments:

Feature	**Position (##.## m)**	**Elev. (m)**	**Comments**
Tidal Bank			
Low Marsh stake			
Tall / short form *S. alterniflora* transition			
patens/alterniflora 50-50			
Upper S paten dominance start			
Lower bound of Iva			
Upper Bound of *Iva*			
Base of coastal bank (if applicable)			
Lower bound of Phragmites (if applicable)			
Upper bound of Phragmites (if applicable)			
Upland stake	00.00		
	/		

Notes:

Vegetation Quadrats Percent Species Cover Data Sheet (pg 1)

SITE: ________________ TRANSECT ID: __________ DATE: _________ STAFF: __________ Quadrat size: ______ m^2

Use a different datasheet for each transect survey. Transect ID should be in the format AA-#, as in HR-3 for Herring River Transect 3. Station ID is the quadrat position, and should be in the form of ##.## m along the tape measure, bottom right corner of transect. In the database, HR-3-23.67 is the quadrat position at 23.67 meters on Herring River Transect 3. Station positions are often predefined for each transect, and wherever possible, record in advance.

Comments:

		Species Percent Cover, counts, heights																								
Station ID. ##.## m	**Note**	***Tall S. alterniflora***	***S. patens***	***Short S. alterniflora***	***D. spicata***	***J. gerardii***	***L. carolinianum***	***I. frutescens***	***Salicornia sp.***	***S. sempervirens***	**Bare**	**Wrack cover**	**Wrack depth (mn cm)**	**# Crab burrows**	**# G. demissa**	**Canopy Height (cm)**										

(Continue on reverse.)

Vegetation Quadrats Percent Species Cover Data Sheet (pg 2)

Quadrat Pos. ##.## m	Note	***Species Percent Cover***																								
		Tall S. alterniflora	***S. patens***	***Short S. alterniflora***	***D. spicata***	***J. gerardii***	***L. carolinianum***	***I. frutescens***	***Salicornia sp.***	***S. sempervirens***	***Bare***	**Wrack cover**	**Wrack depth (m cm)**	**# Crab burrows**	**# G. demissa**	**Canopy Height (cm)**										

Buzzards Bay Coalition/Buzzards Bay National Estuary Program SALT MARSH MONITORING PROGRAM

Vegetation Quadrats Point Intercept Data Sheet (pg. 1)

SITE: ________________ DATE: __________ STAFF: __________________

TRANSECT ID: __________ Station ID: ________

This data sheet is for a single quadrat. Transect ID should be in the format AA-#, as in HR-3 for Herring River Transect 3. Station ID is the quadrat position, and should be in the form of ##.## m along the tape measure, bottom left corner of quadrat. Place a check mark for each species that intercepts the point.

Tape measure position	Point #	Tall Spartina alterniflora (TSA)	Short Spartina alterniflora (SSA)	Spartina patens	Distichlis spicata	Juncus gerardii	Lycium carolinianum (sea lavender)	Iva frutescens	Salicornia sp.	Solidago sempervirens (seaside goldenrod)	Phragmites	Wrack	Peat	Sand					
	1																		
	2																		
	3																		
	4																		
	5																		
	6																		
	7																		
	8																		
	9																		
	10																		
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	12																		
	13																		
	14																		
	15																		
	16																		
	17																		
	18																		
	19																		
	20																		

(continue on next page)

Comments:

Vegetation Quadrats Point Intercept Data Sheet (pg. 2)

Tape measure position	Point #	Tall Spartina alterniflora (TSA)	Short Spartina alterniflora (SSA)	Spartina patens	Distichlis spicata	Juncus gerardii	Lycium carolinianum (sea lavender)	Iva frutescens	Salicornia sp.	Solidago sempervirens (seaside goldenrod)	Phragmites	Wrack	Peat	Sand					
	21																		
	22																		
	23																		
	24																		
	25																		
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	27																		
	28																		
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Appendix C. Post-Processed Kinematic (PPK) Survey Methodology and SOP

1 Introduction and Background

For this study, the post-processed kinematic survey approach was selected because of lower equipment costs and simpler logistics, but at the same time documenting high precision horizontal and vertical positions comparable to RTK setups. In this study, two Juniper System Geode™ GPS units are used, coupled with effigis EZSurv® post processing software to achieve a sub-meter GNSS solution. In brief, one unit is placed on a tripod over the study site benchmark at a precisely measured recorded height above the benchmark, and a second GPS unit is used as a rover held on a two-meter staff gently placed on the marsh surface. The unit used as a rover is controlled by EZTag CE software application installed on a Windows-based tablet. The tablet is attached to the rover staff by a clip. PPK surveys collect continuous, static signals at the base station and short, 60-second occupation signals with the rover. The data from both units is subsequently downloaded and then data streams from both units are processed on a computer in order to calculate and apply elevation corrections from the data streams. Horizontal data is corrected to the North American Datum 1983 (NAD83 , 2011 realization) referenced to the Massachusetts State Plane Coordinate System Mainland, in meters(MASPC), and vertical elevations corrected to the North American Vertical Datum of 1988 (NAVD88), GEOID 12B. This technique is expected to achieve a vertical precision of three to seven centimeters, and is the least accurate of the three elevation technologies used. Regular stations along each transect shall be specified in advance, with additional elevations collected at ecotone boundaries and specific tidal events and conditions.

Fig. 34. Using the Juniper Systems Geode™ unit in the field (image from the Geode™ owners manual, ©Juniper Systems.

The SOP here describes general operations and procedures. Detailed operation of the software is contained in the Geospatial Data Acquisition User Guide // Version 2.99 (available at onpoz.com/Documentations/OnPOZ_2.99/en/EZTagCE_UserGuide.pdf).

2 Base station field setup and data collection

1. Locate the benchmark, monument, or landmark to be used as the base station.

2. Set up the tripod on top of the benchmark. Center the tripod and level the antenna mount. Anchor legs so they will not move throughout the survey. Adjust the tripod plate so that it is level using a bubble level.

3. Attach the Juniper Systems Geode unit to the leveled tripod plate

4 Using a meter stick, measure and record the distance between the bottom of the Geode unit to the top of the NGS benchmark. Record to the height to nearest millimeter on the field datasheet, and any other pertinent site conditions such as weather (wind and rain). Take care to not move the tripod while data is being collected. Doing so will affect the precision of positioning.

5. Power up the receiver and turn on the corresponding tablet or laptop, and load the EZTagCE app. Verify the Bluetooth connection between the receiver and laptop. Click on the GNSS capture button to start the

capture of a GNSS average point and leave in this mode for the duration of the survey. Two hours of continuous data or more is best.

3 Rover field setup and data collection

1. Attach Geode GPS and tablet controller to the monopod,

2. With a tape measure, measure and record to the nearest millimeter the antenna height (from the base of the Geode to the base of the pole).

3. Turn on the Geode and tablet and load the EZTagCE app. Verify the blue tooth connection between the units.

4. In EZtag, set and verify the occupation time, sampling rate, antenna height, elevation mask.

Fig. 35. The Juniper Systems Geode™ unit installed on a tripod.

4 Conducting the Survey

Once the base station and rover are functional, and both have been in operation for at least five minutes, begin surveying. In the software, begin a new project and verify the survey settings. In general, four or more satellites should be available to undertake a survey. To collect a data point:

1. Move to the location you wish to measure gently placing the pole on the land surface of the designated survey side of the transect within 1cm of the tape measure.

2. Name the point on the controller (typically the precise location along the transect tape measure). In the software, take a photo of vegetation adjacent to the transect line. Verify satellite availability and reasonable PDOP. A PDOP of less than 5 is required for precise measurements, and values of 2-3 are preferred.

3) Level the pole using the manual bubble level on the pole. Bracing your body in a tripod stance with feet shoulder width and ranger pole braced in front is a stable position.

4. Click on the GNSS capture button on the screen to start the capture of a GNSS average point. Maintain a steady, level orientation for the receiver for the duration of the occupation time (generally 1 minute for this study).

5. After a point is collected move to the next location. Continue steps 1–5 until complete. Allow GPS units to collect data for several more minutes after the last station is recorded. When complete, stop the survey. Check to verify the data file is complete and of appropriate size.

6. Once verified, you may power down the receiver and tablet. Before disassembling, measure the antenna's height again and record on your data sheet. There should not be a change in height. If so, you must be aware of this when processing results.

7. Disassemble and pack the rover and bases station units.

5 Data processing workflow

After returning to the office, download files from the Rover and base station Geode units. EZSurv® Post-Processing software. Ensure that antenna heights, equipment models, site description have been properly recorded. Create baselines from base station to rover positions. Transform and project data if necessary. Export your data in the appropriate format for further analysis and processing..

Appendix D. Leica Sprinter 250m Digital Level SOP

(Selected images and text taken from brochures and webpages at leica-geosystems.com, (c) Leica Geosystems AG - Part of Hexagon and Cain and Hansel (2016).)

1 Overview

For the Buzzards Bay salt marsh loss study, a Leica Sprinter 250 M digital level was chosen based on low cost, reported simple operation, and reported small errors as claimed by the manufacturer (0.1 mm precision; 1.0 mm accuracy per kilometer, double-run), which were generally confirmed by Cain and Hansel (2016). Additional equipment used includes an aluminum slip-leg tripod to hold the level and a telescoping aluminum barcode level rod (Fig. 36). While manufacturer brochure highlights the ease of use of the equipment (Fig. 1), this SOP describes specific protocols and procedures to ensure accuracy when using the device.

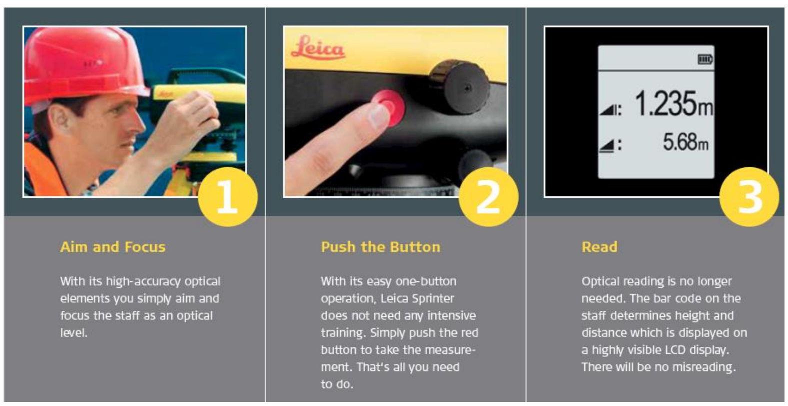


Fig. 1. Leica Sprinter 250m operation overview (from a brochure © Leica Geosystems AG Part of Hexagon).

Fig. 36. Leica Sprinter leveler as used by Cain and Hensel (2018), © Estuaries and Coasts, Springer.

2 Operation

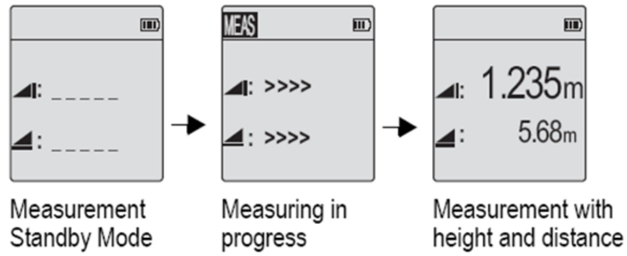
The principal function used on the Sprinter Leica level is the height and distance function. In brief, the operational steps are as follows:

Device Levelling: Set up the tripod either just on the upland side of the benchmark, or at a stable site where a view of the benchmark and the entire length of the transect are in view and unobscured.. Extend the legs to a suitable length and ensure that the tripod head is approximately level. Tread the tripod shoes firmly into the ground to ensure stability. Mount the instrument on the tripod by screwing the tripod screw onto the base of the instrument. Use the three levelling foot screws to center the circular bubble in order to level the instrument.

Eyepiece Adjustment and Target Focusing: Point the telescope to a uniform light surface such as a piece of paper. Turn the eyepiece until the cross hairs are sharp. Use the gunsight to aim the objective lens at the barcode staff. Turn the horizontal fine motion screw until the staff is centered in the field of view, then turn the focusing knob to focus on the staff. Ensure that staff image and reticle are both sharp.

Power the unit on, level, and take measurements: Press the power switch on the back to turn on the level. Level the unit as per the manual.The first measurement should be the relative elevation of the benchmark. Open the bench mark cover and gently rest the staff on the top of the top of the benchmark steel rod. Press the red record button on the side until measuring in progress indicator is shown. Record its height and distance on the datasheet. Proceed to each designated station along the transect, or other features of interest, including secondary reference sites if any.

6.1 Height and Distance Measurement



Step	Key	Description
1.	⏻	Press to switch on the instrument, Leica logo is displayed follow by the default measurement standby mode.
2.	(red button)	Aim at staff and focus. Lightly trigger the measurement key to activate measurement.
3.		Height and distance measurement is displayed.

Fig. 37. Operation of the Leica Sprinter leveler to record relative elevations.

Method 2: Using Memory to Record Values Recommended

The above method is the simplest, but for this study it is recommended that the data be recorded to memory. In the menu, and turn on Recording – select Memory. With this method, we can record values and download them later to a computer using the serial cable. The data will need to be processed later with a spreadsheet, but the format is simple.

1. Start by going to the menu, and turn on Recording (6) – select Memory. This button is also used to turn the unit off.

2. Now at the main screen will be displayed a new field: PtID, which will initially be set to 1. You can use the menu to change this value, and it can include alphabetic as well as numeric characters. The id will be automatically incremented numerically (5 increments to 6, C1 increments to C2, etc.).

3. At the main screen, with the unit focused on the staff (barcode side), press the red measure button and wait for the values to display. You should eventually see the PtID, vertical and horizontal distance values, with vertical from the base of the staff, and horizontal distance to the staff. If you're starting at a benchmark, you might want to give it a special ptID, so you can process this later (the next method will allow you to enter a reference.)

4. Repeat for other measurements.

For all measurements, the barcode staff must be held precisely vertical, and the bubble level should remain centered when the level head is rotated (see the manual for recalibration of the device).. The user manual contains more sophisticated approaches such as the use of turning points, backsights, and automatically calculating elevations relative to a benchmark.

3 Downloading and processing data (for Sprinter 250M)

1. The cable with the 250M goes into a telephone-tab port inside the battery compartment. Plug it in and turn it on – it gets power from your computer.

2. Start Sprinter DataLoader, and press the USB Connect button. Wait a few seconds. If all goes well, you'll see the serial number and other stuff displayed on the left part of the screen.

3. In the Data Export area, select EXCEL Data Listing to request data to be exported to Excel format. Save the file into the appropriate directory on the computer using site name and date in the file name.

Appendix E. Laserliner® ZipLevel, a professional precision altimeter SOP

(Selected images and text taken from brochures and webpages at leica-geosystems.com, (c) Leica Geosystems AG - Part of Hexagon and Cain and Hansel (2016).)

1 Overview

The third elevation technique used in this study is the Laserliner® ZipLevel, a professional precision altimeter that enables elevation with accuracy of within 3 mm within an elevation change of 6 m, and a working distance of 50 m, with extended measurements possible through relayed measurements. The cable with patented gas-liquid-system reliably works through extreme temperatures (-30 °C to +70 °C).

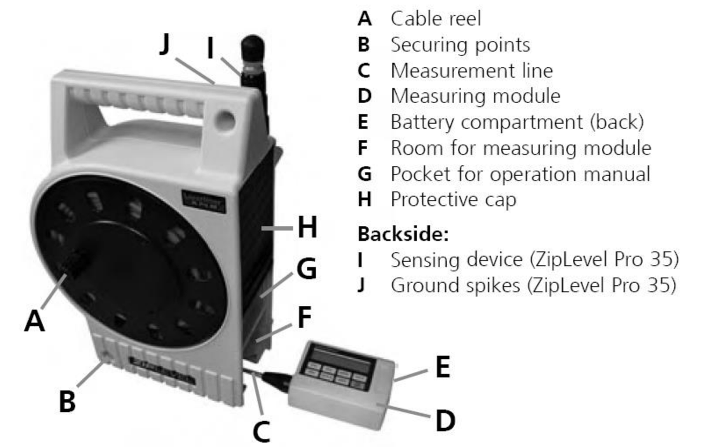


Fig. 38. Leica Sprinter leveler as used by Cain and Hensel (2016) (image (C) Estuaries and Coasts, Springer.

2 Operation

1. Open the bottom protective cap of the basic unit and remove the measuring module. Lay the basic unit on a cinder block between the transect and the NGS benchmark, with the back facing down. Slowly pull a sufficient length of line off the cable reel. The altitude will be transferred from the basic unit to the measuring module.

2. Switch the measuring module on with the ON/OFF-key and put the unit with its back or base on the required place of reference. When the display is ready, you will hear 2 short audible bleeps. Place the measurement module atop the benchmark within the housing (alternatively place the measuring module atop the benchmark housing with the lid on after you have precisely measured the distance between the housing rim and the top of the NGS rod). (note that elevation can be made with either the base or back of the measuring module, but measurements should remain consistent for use at a site (Fig. 39). Press the ZERO-key for 2 seconds. Keep the measuring module steady until the figure zero appears on the display. The appliance has now been set. (Note: if the basic unit is moved, the measuring module needs to be set at the place of reference again).

3. Proceed to each successive station and record location and elevation on the datasheet.

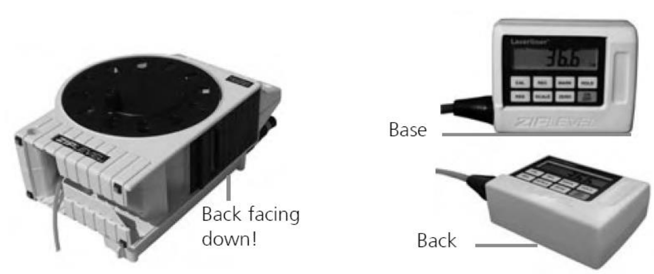


Fig. 39. Orientation of zip level basic unit (left), and measuring module (right) when in use.

Appendix F. Sample Wetlands permit

Massachusetts Department of Environmental Protection
Bureau of Resource Protection - Wetlands

WPA Form 1- Request for Determination of Applicability

Massachusetts Wetlands Protection Act M.G.L. c. 131, §40

City/Town

A. General Information

Important: When filling out forms on the computer, use only the tab key to move your cursor - do not use the return key.

1. Applicant:

Buzzards Bay National Estuary Program, MCZM — Name
joe.costa@mass.gov — E-Mail Address
2870 Cranberry Highway — Mailing Address
East Wareham — City/Town
MA — State
02538 — Zip Code
508.291.3625 x11 — Phone Number
508.291.3628 — Fax Number (if applicable)

2. Representative (if any):

same as above — Firm
Joe Costa — Contact Name
same as above — E-Mail Address
same as above — Mailing Address
City/Town
State
Zip Code
Phone Number
Fax Number (if applicable)

B. Determinations

1. I request the Marion (Conservation Commission) make the following determination(s). Check any that apply:

☐ a. whether the **area** depicted on plan(s) and/or map(s) referenced below is an area subject to jurisdiction of the Wetlands Protection Act.

☐ b. whether the **boundaries** of resource area(s) depicted on plan(s) and/or map(s) referenced below are accurately delineated.

☒ c. whether the **work** depicted on plan(s) referenced below is subject to the Wetlands Protection Act.

☒ d. whether the area and/or work depicted on plan(s) referenced below is subject to the jurisdiction of any **municipal wetlands ordinance** or **bylaw** of:

the Town of Marion — Name of Municipality

☐ e. whether the following **scope of alternatives** is adequate for work in the Riverfront Area as depicted on referenced plan(s).

Massachusetts Department of Environmental Protection
Bureau of Resource Protection - Wetlands
WPA Form 1- Request for Determination of Applicability
Massachusetts Wetlands Protection Act M.G.L. c. 131, §40

City/Town

C. Project Description

1. a. Project Location (use maps and plans to identify the location of the area subject to this request):

0 Creek Rd	Marion
Street Address	City/Town
8	20
Assessors Map/Plat Number	Parcel/Lot Number

b. Area Description (use additional paper, if necessary):

All activities are within a town-owned parcel containing salt marsh at 0 Creek Rd at the top of Hammetts Cove (northwest), behind the sewer line pump station. This parcel contains upland, beach, coastal bank, BVW, and salt marsh. The site is within the 100-year flood plain (V zone). The site of the benchmark is in upland above a shallow coastal bank (photo attached). Permanent monitoring transects would extend from just above the marsh high tide line to the low marsh areas as per the attached plans.

c. Plan and/or Map Reference(s):

Hammetts Cove Salt Marsh Monitoring Study Locus Map	2/11/2019
Title	Date
Hammetts Cove Salt Marsh Monitoring Study Ortho Map with Elevations	2/11/2019
Title	Date
Title	Date

2. a. Work Description (use additional paper and/or provide plan(s) of work, if necessary):

The Buzzards Bay NEP, a unit of MA Coastal Zone Management, in partnership with the citizen group, the Buzzards Bay Coalition, are collaborating on a long-term study of salt marsh loss, sea level rise, and habitat change around Buzzards Bay. The Marion Board of Selectmen approved (Nov. 20, 2018 meeting) the inclusion the town-owned marsh at Hammetts Cove in the study. At the site, we will conduct six activities: 1) install one NGS 3-D deep driven elevation marker above the high tide line (a 9/16" stainless steel rod driven to refusal); 2) install approximately eight to ten, 1-inch diameter PVC pipes (capped) in upland and low marsh sites to define permanent transects, 3) conduct elevation and vegetation surveys along these transects up to three times per year for two years, then once per year (or less) thereafter, 4) conduct a crab population survey to quantify the presence of an invasive species of crab known to damage salt marshes, 5) install a temporary staff with sensors in a tidal creek to document tidal elevation, and 6) periodically document elevations of the High Tide Line near the benchmarks. A summary of methods are contained in the attached document "Abbreviated SOP for WPA Form 1, Revision Number: 3, 1/15/2019 Standard Operating Procedures: Survey Marker Installation and Monitoring." Elevation markers are installed below ground (cover at ground level). The PVC sleeve around the top two feet of the steel rod within the benchmark housing is filled with food-grade non-toxic grease (to isolate the elevation marker from frost heaves). The approximately one to two cubic feet of soil removed during the installation of the benchmark will be dispersed in a nearby upland area.

Massachusetts Department of Environmental Protection
Bureau of Resource Protection - Wetlands

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Massachusetts Wetlands Protection Act M.G.L. c. 131, §40

City/Town ______________

C. Project Description (cont.)

b. Identify provisions of the Wetlands Protection Act or regulations which may exempt the applicant from having to file a Notice of Intent for all or part of the described work (use additional paper, if necessary).

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3. a. If this application is a Request for Determination of Scope of Alternatives for work in the Riverfront Area, indicate the one classification below that best describes the project.

- ☐ Single family house on a lot recorded on or before 8/1/96
- ☐ Single family house on a lot recorded after 8/1/96
- ☐ Expansion of an existing structure on a lot recorded after 8/1/96
- ☐ Project, other than a single family house or public project, where the applicant owned the lot before 8/7/96
- ☐ New agriculture or aquaculture project
- ☐ Public project where funds were appropriated prior to 8/7/96
- ☐ Project on a lot shown on an approved, definitive subdivision plan where there is a recorded deed restriction limiting total alteration of the Riverfront Area for the entire subdivision
- ☐ Residential subdivision; institutional, industrial, or commercial project
- ☐ Municipal project
- ☐ District, county, state, or federal government project
- ☐ Project required to evaluate off-site alternatives in more than one municipality in an Environmental Impact Report under MEPA or in an alternatives analysis pursuant to an application for a 404 permit from the U.S. Army Corps of Engineers or 401 Water Quality Certification from the Department of Environmental Protection.

b. Provide evidence (e.g., record of date subdivision lot was recorded) supporting the classification above (use additional paper and/or attach appropriate documents, if necessary.)

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City/Town

D. Signatures and Submittal Requirements

I hereby certify under the penalties of perjury that the foregoing Request for Determination of Applicability and accompanying plans, documents, and supporting data are true and complete to the best of my knowledge.

I further certify that the property owner, if different from the applicant, and the appropriate DEP Regional Office were sent a complete copy of this Request (including all appropriate documentation) simultaneously with the submittal of this Request to the Conservation Commission.

Failure by the applicant to send copies in a timely manner may result in dismissal of the Request for Determination of Applicability.

Name and address of the property owner:

Town of Marion Board of Selectmen
Name

2 Spring St
Mailing Address

Marion
City/Town

MA
State

02738
Zip Code

Signatures:

I also understand that notification of this Request will be placed in a local newspaper at my expense in accordance with Section 10.05(3)(b)(1) of the Wetlands Protection Act regulations.

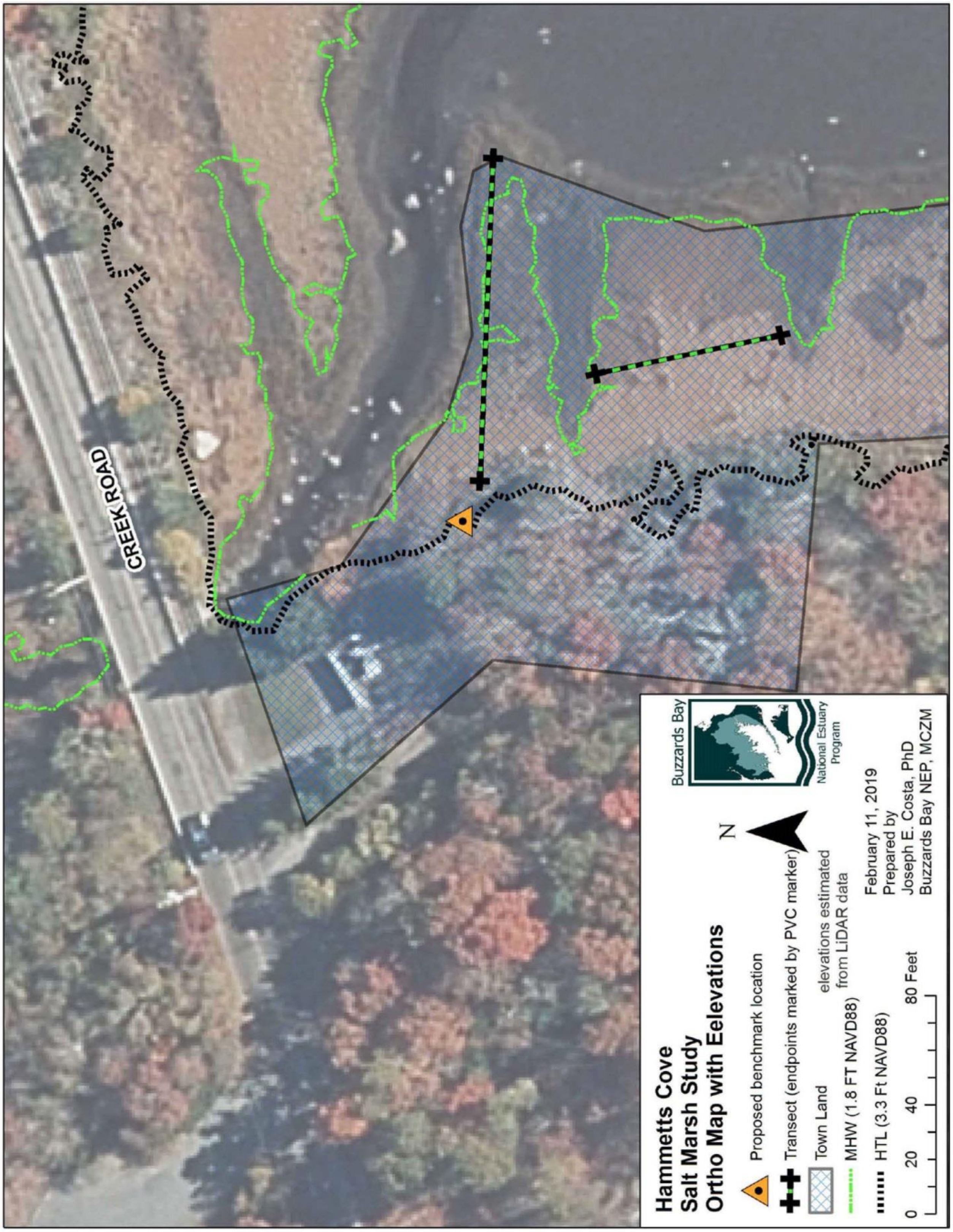
Joseph E Carter
Signature of Applicant

February 12, 2019
Date

Signature of Representative (if any)

Date

WPA Form 1: Request for Determination of Applicability Plans
Long-term salt marsh vegetation and elevation monitoring, Hammetts Cove, Marion, MA --- Page **1** of **3**


CREEK ROAD
Hammetts Cove
Salt Marsh Study
Ortho Map with Eelevations
Proposed benchmark location
Transect (endpoints marked by PVC marker)
Town Land
MHW (1.8 FT NAVD88)
HTL (3.3 Ft NAVD88)
elevations estimated from LiDAR data
0 20 40 80 Feet
N
February 11, 2019
Prepared by
Joseph E. Costa, PhD
Buzzards Bay NEP, MCZM
Buzzards Bay
National Estuary Program

January 3, 2019 photograph of proposed benchmark site (flag labeled 1).

Appendix F-7

Appendix G. Abbreviated Standard Operating Procedures and Study Overview

1 Introduction

The Buzzards Bay NEP and the Buzzards Bay Coalition are collaborating on a long-term study of salt marsh loss, sea level rise, and habitat change around Buzzards Bay. Monitoring the selected sites will help improve our understanding of the causes of marsh loss around Buzzards Bay and help develop possible mitigation strategies. This summary provides an overview of the monitoring approach. Details that are more specific will be contained in an EPA-approved Quality Assurance Project Plan that will be provided to municipal conservation commissions prior to survey work and posted online. Protocols will be put in place to minimize impacts and disturbance to the marsh.

2 Work to be undertaken

Six activities are planned as part of this long-term salt marsh loss monitoring study:

1) Install a NGS rod type survey benchmark in an adjacent upland area (Fig. 1, top and middle; disk marker optional),
2) depending on the site, install four to ten 18" plastic survey stakes (2 to 5 transects) within the marsh to establish permanent transect lines,
3) monitor elevation, vegetation, and other features along these transects up to 3 times per year for the first two years, then once per year thereafter (some *Phragmites* or vegetation trimming may be required around the benchmark to allow line of sight),
4) conduct a crab population survey with pitfall traps,
5) install a temporary staff with sensors in a tidal creek to document tidal elevation, and
6) periodically document the elevation of the High Tide Line during different tidal and weather conditions.

Elevation Benchmark Monument Installation

Factors in the selection of elevation benchmark sites include:

- Sites 1-2 feet above the high tide line are preferred.
- Avoid installing monuments behind active barrier beaches, migrating dunes, or areas prone to overwash.
- Elevation markers must be placed where there is a clean line of sight to the marsh transect site (the marker should not be enclosed by dense high brush, *Phragmites*, or tree stands).

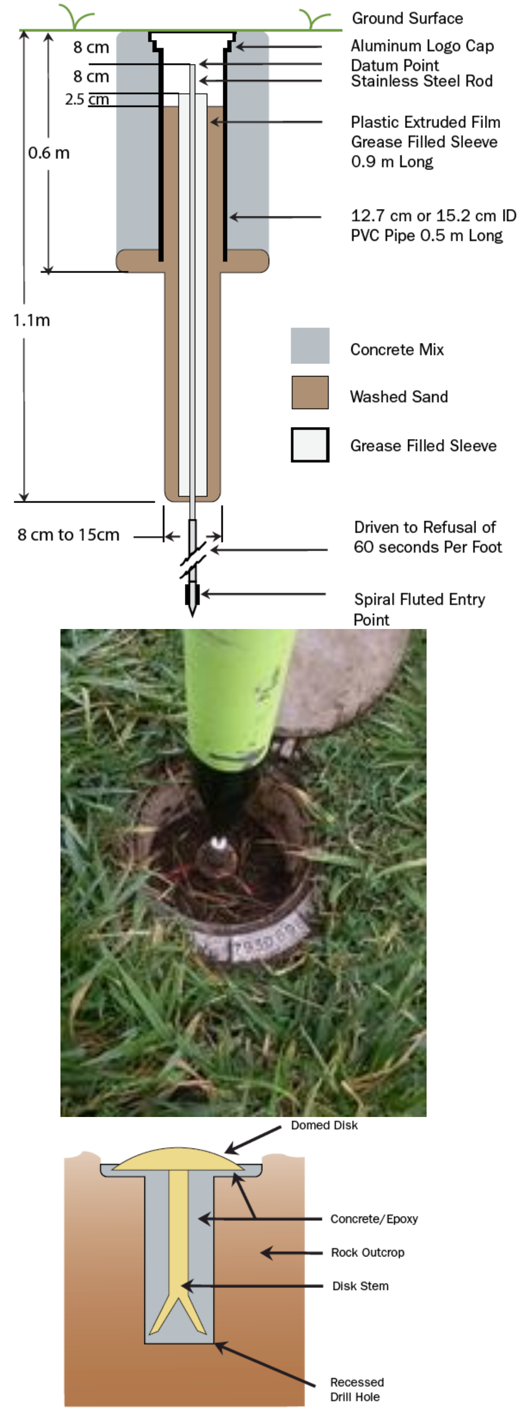


Fig. 1. Top: Schematic of the monument (from NGS (2010), *Bench Mark Reset Procedures*). Middle: finished installation. Bottom: Optional disk marker for existing structure.

Elevation benchmark monuments will be installed in uplands adjacent to selected marshes within 500 feet of monitoring work. The survey markers will be NGS 3-D deep driven rod markers made of 9/16" stainless steel (Fig. 1), driven to refusal. The steel rod is driven with a gas-powered hammer as shown in Fig. 2. The top 2.5 feet of the steel rod is surrounded by a 1-inch PVC pipe containing food-grade non-toxic grease. This design prevents movement of the ground due to frost heaves from affecting the elevation of the marker, and this benchmark type meets the highest government standards for benchmark elevation stability. The housing for elevation markers must be installed at ground level and any excavated materials must be removed from the immediate site.

Transect Marker Installation

To establish permanent monitoring transects in the marsh, 4 to 10 capped one-inch PVC pipe (about two-foot lengths) will be hammered into upland and low marsh within 4 inches of the marsh surface. The number of markers will depend on marsh size and other factors.

Pairs of these markers will establish permanent transect lines across the marsh. One of these marker pairs will be located in an upland area at an elevation about one foot higher than the upper marsh boundary (the high tide line; HTL). The low marsh marker will be installed near the low marsh boundary, but no closer than five feet from the low-marsh edge of the marsh (greater if there is evidence of rapid marsh loss). A surveyor's 300-foot steel blade measuring tape will be used to define quadrat placement between transect markers.

Fig. 40. Fig. 2. Using a gas powered jackhammer to drive the steel rods into the ground (from a URI guide for installing elevation monuments on National Park Lands).

Transect Monitoring Protocols

Monitoring surveys will document elevation, vegetation, and mussel and crab burrows along transects. To minimize human impacts, investigators will walk on only one side of the transect lines, and make measurements on the other. Vegetation within monitoring quadrats will be with field data sheets supplemented by digital photography. Surveys will be undertaken along these transects up to three times per year for the first two years, then once per year thereafter.

Elevation measurements along transect lines will include a comparative analysis of three technologies: 1) a digital bar-code laser level (2.5 mm expected accuracy), 2) a precision pressurized hydrostatic altimeter (e.g. ZIPLEVEL; 1 to 5 mm expected accuracy), and 3) a survey grade GPS with a base station establish on the benchmark (5 to 20 mm expected accuracy).

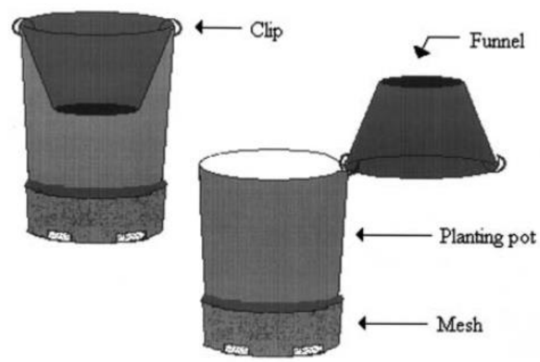


Fig. 41. Fig. 3. Crab pitfall trap after Kent and McGinnis (2018)

Additional measurements

Tidal range and elevations will be documented at least once in each marsh using HOBO™ pressure sensing data loggers. These data loggers will be installed on a temporary PVC pipe set in a tidal creek for two to three weeks. Researchers will also periodically document the high tide line near the benchmarks using small flags, and measure elevations of the high tide line.

A crab population survey will be undertaken at least once during the study using pitfall traps. Up to six pitfall traps will consist of 18 cm diameter black plastic potting containers, with a screen mesh around the drainage holes, and with a funnel made from cutting another planting pot (Fig. 3). In this method, a plug of salt marsh peat is removed and replaced with a trap and set out overnight. The next day, crabs are counted and measured and released, and the original peat plug is returned to fill the hole. If traps are needed for longer use (e.g. a capture-recapture study), when traps are not in use, screens will staked down over the pitfall traps to prevent crabs or other animals from entering.