Project Management and Objectives Elements

1.1 Quality Assurance Project Plan Approval Sheet

Program Title: Intensive Monitoring and Assessment Program for Tidal Wetlands of Delaware, New Jersey and Pennsylvania, Version 1.0 (MACWA SSIM Umbrella QAPP V1.0)

Project Title: Development and Implementation of an Integrated Tidal Wetlands Monitoring and Assessment Program in the Barnegat Bay and Delaware Estuaries (New Jersey – Coastal Plan Region.) (MACWA SSIM R2 QAPP 1.1)

Note: QAPP Nomenclature. Any future modifications to the Version 1.0 Umbrella QAPP for MACWA SSIM (site specific intensified monitoring) efforts will require approval and necessitate renaming as new versions (e.g. 2.0, etc.) Addendum QAPP's for projects will be sequentially referenced as Version 1.1, 1.2, etc. in line with the most current version of the umbrella QAPP. The QAPPs for MACWA SSIM efforts (Tier 4 studies) are not to be confused with separate QAPPs for MACWA Rapid Assessment Methods (Tier 2 studies.)

Organization names: Partnership for the Delaware Estuary & Barnegat Bay Partnership

Effective date: September 1, 2010[1]

Approval:

Project Start Date: September, 1, 2010

Project End Date: December 31, 2013

Project Manager &: QA Officer

_________________________ Date: ________
Danielle Kreeger, PhD, Science Director
Partnership for the Delaware Estuary

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Martha Maxwell-Doyle, Project Coordinator
Barnegat Bay Partnership

EPA Project Officers:

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Kathleen Drake
EPA Wetland Protection Team, USEPA Region 2

EPA QA Officers:

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Donna Ringel
EPA Region 2

NJ DEP

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Mark Ferko
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[1] Effective date may be changed to reflect the date of signature of agreement between EPA HQ, EPA Region 2, and the Partnership

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1.3 Project/Task Organization

The relationships of the principal investigators and project managers below are summarized in Figure 1.

Project Managers

Martha Maxwell-Doyle, Project Coordinator of the Barnegat Bay Partnership (BBP) will be responsible for overall organization and implementation of projects that are funded by this grant received by the BBP. This organization will coordinate various subawardees to BBP as well as maintain the official approved QA Project Plan for BBP and any addendums deemed necessary. In the small National Estuary Program we cannot afford to provide a separate Project Manager and QA manager. Therefore Martha Maxwell-Doyle will serve as both the QA officer as well as the Project Manager for this project.

Danielle Kreeger, PhD, Science Director of the Partnership for the Delaware Estuary (PDE) will be responsible for the helping to organize and implement the various metrics of the MACWA SSIM. Dr. Kreeger will take a direct hand in working on biomass metrics as well as bivalve work. Dr Kreeger will also coordinate various subawardees to PDE as well as maintain an officially approved QA Project Plan.

Collaborator - Subawardee

David Velinsky, PhD, Vice President and Director of the Patrick Center for Environmental Research, Academy of Natural Sciences of Philadelphia is a subawardee for this project and will help choose fixed sites, determine data to be collected at the fixed sites and will be the lead steward on some fixed sites.

Tracy Quirk PhD, Patrick Center for Environmental Research, Academy of Natural Sciences of Philadelphia (ANSP) is expected to assist in coordinating various data streams and operations among the fixed stations to ensure consistency of methodologies and to help the NEPs meet quality assurance goals, contingent on funding.

David Bushek, PhD, Haskin Shellfish Research Laboratory, The State University of New Jersey; Rutgers is expected to coordinate with PDE on the southern NJ Delaware Estuary site. Dr. Bushek and his team will be the local "steward" of the site with help from ANSP for consistency.

Collaborators - Associates

Nathaniel Weston, PhD, Villanova University, is expected to collaborate with the Academy of Natural Sciences of Philadelphia on permanent monitoring stations, specifically in the upper NJ site in the Delaware Estuary, and provide advice to PDE for other monitoring needs.

State Partners

Thomas Belton, New Jersey Department of Environmental Protection (NJDEP), and Dorina Frizzera, New Jersey Coastal Zone Program (NJCZP) will work with PDE and BBP to coordinate with other monitoring in New Jersey and help with any state-specific needs of the project.

Federal Partners

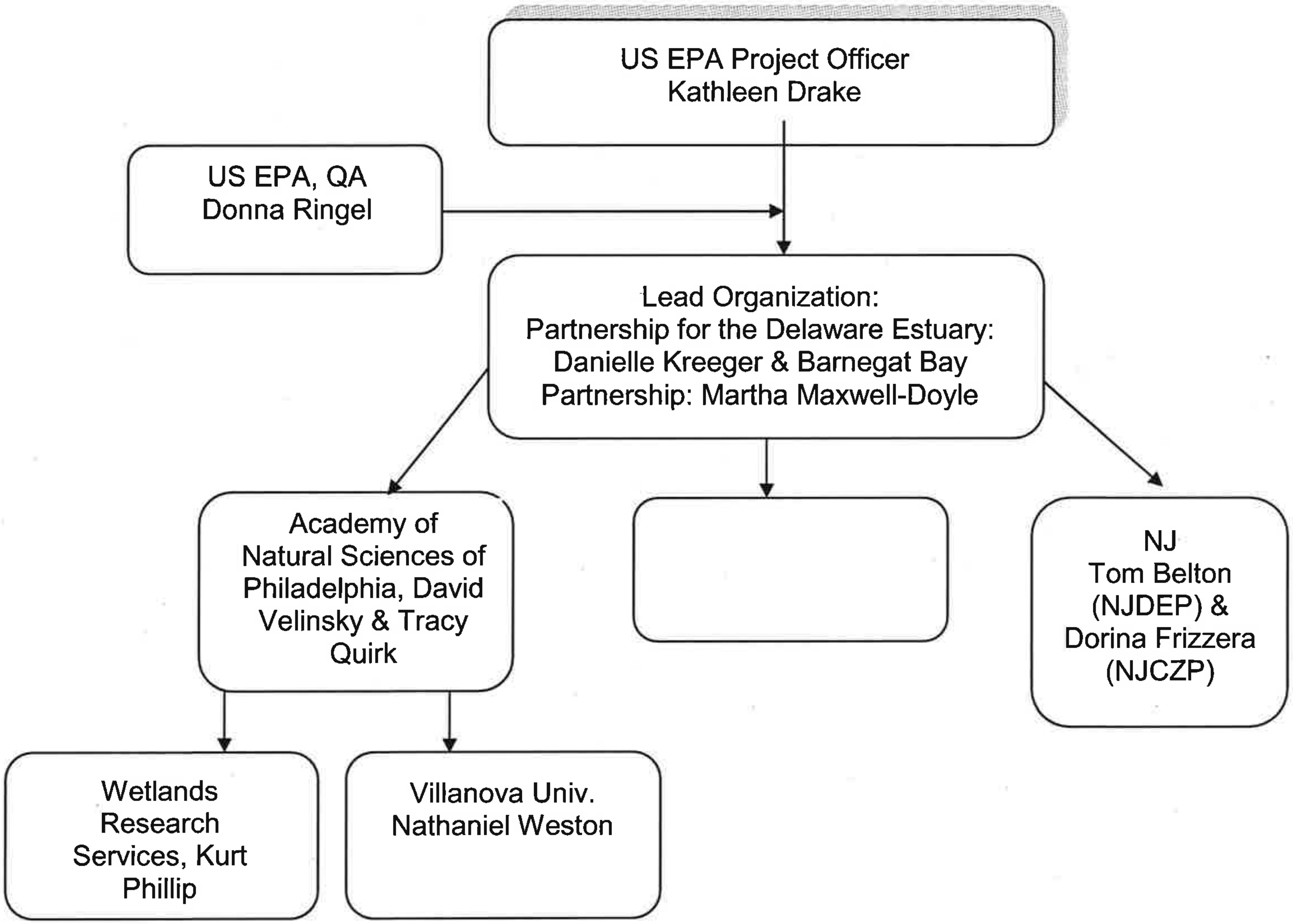
US EPA Quality Assurance Officer: Donna Ringel, EPA Region 2, will perform the responsibilities as Quality Assurance Officers for the US Environmental Protection Agency.

US EPA Project Officer: Kathleen Drake Wetland Protection Team, USEPA Region 2, will perform responsibilities as Project Officers for wetland assessment grants administered to BBP through US EPA Region 2.

US EPA Region 2: Kathleen Drake, Wetlands Protection Team, will facilitate regional interagency coordination between Region 2 and Headquarters, within Region 2, and between Regions 2 and 3. This coordination will facilitate implementation of MACWA, including QAPP review, data sharing, and reporting with regard to rapid assessment outcomes to groups such as the Mid-Atlantic Wetland Workgroup, National Wetland Monitoring and Assessment Work Group, and other federal resource managers.

US Fish and Wildlife Service: Edwin B. Forsythe National Wildlife Refuge; Kevin Holcomb, will help to coordinate monitoring within the refuge.

Figure 1: Organizational Chart for this Project.



1.4 Problem Definition/Background

1.4.1 Problem Definition

To date, no single entity has been able to assess and track both the extent and condition of tidal wetlands across the Delaware Estuary and New Jersey. Consequently only patchy, obsolete or inconsistent data on current wetland status and trends are available, despite the importance of such data to decision makers. This lack of information has hampered our collective abilities to produce periodic "State of the Estuary" reports (*e.g.*, BBNEP 2005; PDE, 2002, 2008) and provide watershed-scale guidance to managers about protecting and enhancing wetland "natural capital" on a long-term basis.

For these and other reasons, the BBNEP and PDE have prioritized tidal wetland assessment, protection, and research as a core component of our strategic plans governing our activities in the next 5+ years. Our combined objectives are to facilitate regional coordination of tidal wetland science and management programs across New Jersey and the mid-Atlantic region, help other entities with resource leveraging, and promote education and outreach about the national importance of the region's coastal wetlands. Perhaps more importantly, the collaborative approach proposed herein helps ensure that all existing activities are complimentary and yield high quality data that can be shared across the region in support of diverse watershed- and ecosystem-scale analyses and management needs.

Outcomes will include new data on current tidal wetland condition and functioning along natural and stressor gradients, a basis for future monitoring and assessment programs, and important planning information for regional restoration and climate adaptation planning. A network of fixed monitoring stations is envisioned covering a range of marsh types, conditions, and stressor exposures in both estuaries. A subset of the chosen stations will represent "reference" stations that are representative of prevailing wetland conditions across the estuary (i.e., for sea level rise stress) rather than highest quality conditions. "Indicator" stations will be those stations that may experience both local stresses and prevailing conditions.

Intensive monitoring of geomorphology, biota, and water quality will be performed at these locations. Results of this project will begin to yield widespread condition data covering the diversity of marsh types across the two estuaries, thereby assisting local and regional decision-making, priority-setting, and the developing of future survey designs throughout the mid-Atlantic and possibly other regions, such as southern New England.

1.4.2 Background

Coastal wetlands are a hallmark feature of the Atlantic Coastal and Delaware Bayshore regions of New Jersey (Fig. 2.) The Barnegat Bay is a shallow lagoonal estuarine system, typical of estuaries along the Atlantic coast of New Jersey. In the Barnegat Bay estuary, most tidal wetlands have experienced significant human impacts and modifications over the last 100 years. For example, over 28% of Barnegat Bay's marshes have been lost to development; most of those wetland loss occurring between 1940 and 1970. Approximately 950 kilometers (590 miles) of parallel grid mosquito control ditches occur throughout roughly two-thirds of Barnegat marshes. Additionally, 45% of Barnegat Bay's shoreline is impacted by bulk-heading, and 71% (10,729 acres) of Barnegat buffer zones is presently developed and/or altered, leaving only 29% (4,406 acres) in natural land cover (Lathrop *et al.* 1999, 2007; Figure 2).

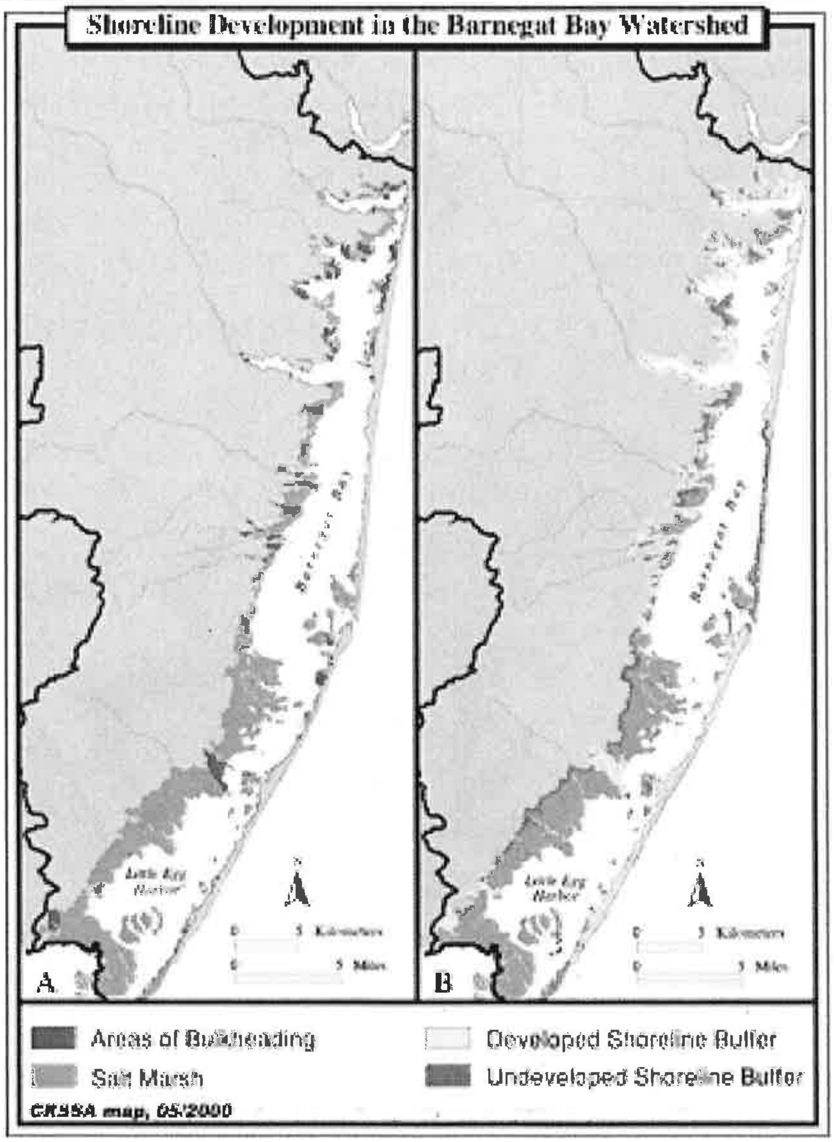


Figure 2. Salt marshes and development in the Barnegat Bay, NJ.

A similar situation exists in the Delaware Estuary where much of the pre-settlement acreage of tidal wetlands have been lost, degraded or otherwise altered by myriad factors. Less than 5% of the natural freshwater tidal wetlands remain in the upper estuary, for example. These wetlands are rare nationally because few estuaries have the broad salinity gradient that is characteristic of the Delaware Estuary, which contains one of the largest freshwater tidal prisms of any estuary in the world. Along with the freshwater tidal wetlands, the Delaware Estuary has expansive brackish and salt marshes that form nearly a continuous fringe around the middle and lower estuary (PDE, 2006; Figure 3).

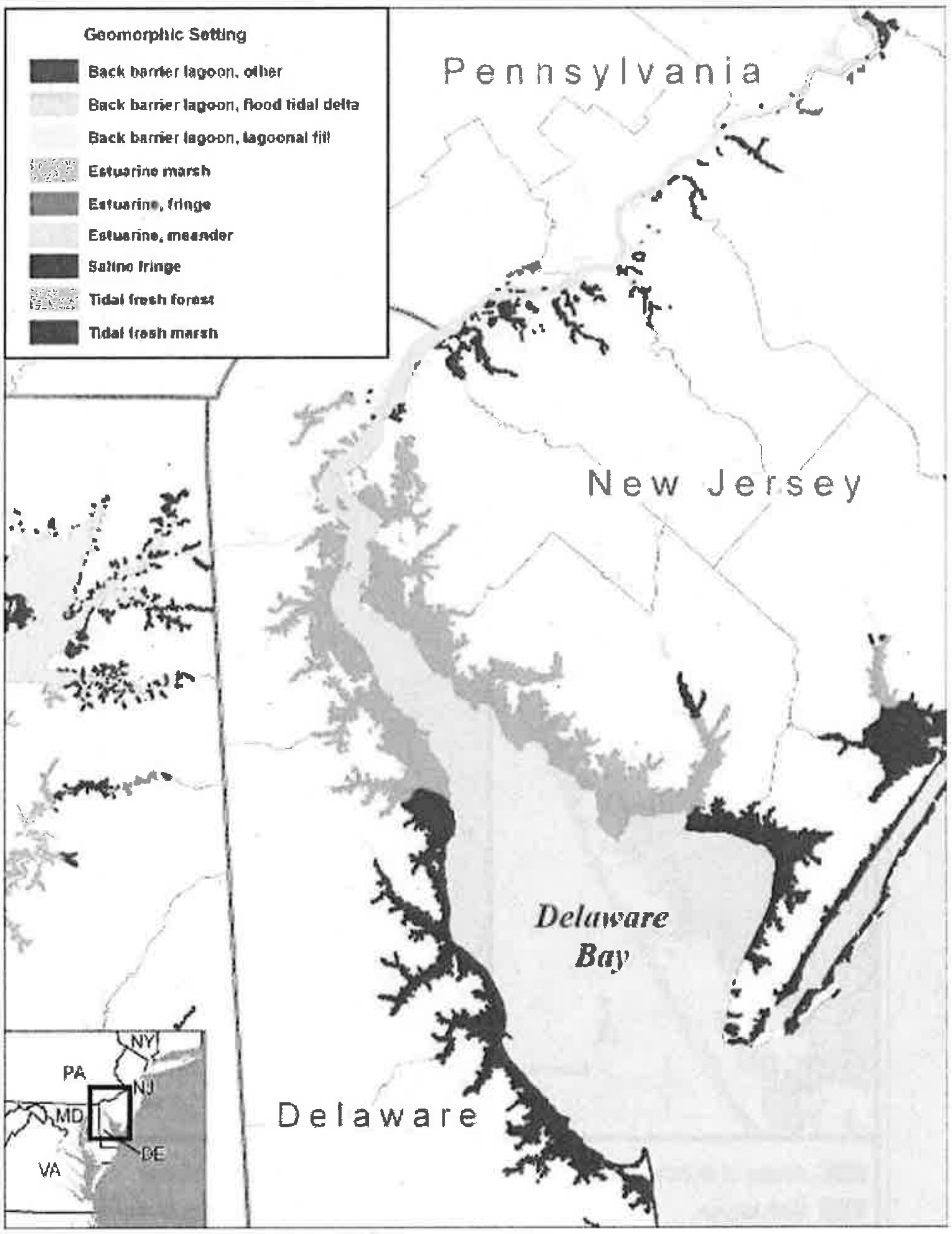


Figure 3. Tidal Wetlands of the Delaware Estuary (Reed et al. 2007.)

Tidal marshes provide biogeochemical cycling, flood protection, water quality improvement, and many other ecological (and economic) services (Costanza *et al.* 1997). They provide nursery, forage, and nesting habitats for fish and wildlife. Tidal wetlands also represent critical transition zones in estuarine landscapes through which there are substantial flows of materials and energy between adjacent terrestrial uplands and aquatic ecosystems (Ewel *et al.* 2001, Levin *et al.* 2001). The edges of tidal marshes are particularly rich 'hotspots' where food webs are complex and primary and secondary production are high (Kreeger and Newell 2000). The habitat values and ecological functions of marshes are changing as a result of sea-level rise (*e.g.*, Erwin *et al.* 2004); such changes emphasize the need for regular monitoring.

Sitting at the nexus between the land and the sea, tidal wetlands are also subject to considerable direct anthropogenic alteration (*e.g.*, development, dikes, bulkheads, mosquito ditching, and roadways). Runoff from human activities (*e.g.*, agriculture, forestry practices, urbanization, *etc.*) in adjacent areas can also impact tidal marshes through surface water and groundwater, affecting the vegetation, invertebrates and fishes therein (*e.g.*, Lerberg *et al.* 2000, Wigand *et al.* 2003, Kirby-Smith *et al.* 2003, Holland *et al.* 2004). Anthropogenic alterations near tidal wetlands have been associated with shifts in the vegetation composition and facilitation of the spread of invasive forms of wetland plants, such as the common reed *Phragmites australis* throughout the mid-Atlantic and northeastern coast of the U.S. (Burdick and Konisky 2003).

Despite the importance of tidal marshes to both ecosystems, the environmental integrity of tidal marshes in the Barnegat Bay and the NJ portion of the Delaware Estuary is difficult to assess at present. Anecdotal and other available information suggests that these tidal wetlands continue to be lost and are increasingly threatened by ongoing development, degradation, sea level rise, sudden marsh dieback, and other factors (Lathrop 2007, PDE 2008). In addition to losses in acreage, perhaps just as importantly more than half of the marshes are believed to be in a degraded state (Kearney *et al.* 2002). A recent climate adaptation report predicts that a minimum of 25% of the tidal wetlands in the Delaware estuary will be lost by 2100 without substantial efforts to stem losses (Kreeger et al., 2010). Better information on wetland condition and trends will lead to more strategic investment in wetland protection and restoration, targeting areas that are more likely to be sustainable and high functioning.

Because of the apparent declines in tidal wetlands and their important role in the integrity of the region's estuaries and for coastal hazards protection (*i.e.*, storm surge protection), the science and management communities of the Delaware River Basin and the Barnegat Bay Estuary have elevated tidal marsh condition and extent as a critical priority for monitoring (*e.g.*, Kreeger *et al.* 2006; DRBC 2008, PDE 2008).

1.5 Project/Task Description

Orientation to MACWA Multi-Tier Design.

Working with the latest national guidance from USEPA (http://www.epa.gov/owow/wetlands/monitor/,) the Mid-Atlantic Wetland Workgroup (http://www.mawwg.psu.edu/overview/meetings_held.asp), and wetland program leaders from each of the states in the region, we developed a multi-tiered design that would monitor and/or determine the following: 1) the extent and condition of tidal wetlands in the sub-region between coastal NJ and coastal DE, 2) changes in the sub-region's tidal wetlands over time in response to major physical, chemical and biological stressors (including anthropogenic alterations in the watershed such as sea level rise, shoreline modification, channel deepening, nutrient balance, and invasive species), and 3) how changes in wetland condition affect the ecosystem services.

In following the EPA national guidance and subsequent workgroup activities, the design is structured as a 4-tier monitoring and assessment program that includes:

- Tier 1: landscape census surveys of extent and condition (to be performed through other efforts of PDE and partners),
- Tier 2: probabilistic sampling on-the-ground across the study region to assess condition and ground-truth Tier 1 surveys (initiated in this study), and
- Tier 3: intensive studies across the study region to ground-truth *Tier 2 analyses, and*
- Tier 4: intensive studies and monitoring at a network of fixed stations that are representative of tidal wetlands in the study area, also helping to ground-truth Tier 2 as well as to track change. *[note: Nomenclature for these tiers is evolving, we consider repeated measures at fixed locations as Tier 4, whereas Tier 3 is reserved for intensive studies that may be probabilistic and not be repeated.]*

As described in the Umbrella QAPP for this project (version 1.0), this work will address Tier 4 of the MACWA design and is referred to as Site Specific Intensive Monitoring (SSIM).

The overall goal of SSIM is to establish a tidal wetland monitoring and assessment framework, initiated in Barnegat Bay and Delaware Estuary but potentially expanded. The sites will be located over a range of tidal heights and salinities. Geomorphic, biotic and water quality data will be obtained to describe both structural and functional properties and integrity at each of fixed monitoring station in the network, representing different tidal wetland types (freshwater tidal, brackish, salt marsh) and stressor conditions. Contingent on funding and partnering resources, our aim is to maintain Tier 4 activities into the future and begin to build long-term and networked monitoring data for broad applications in coastal planning and natural resource management.

Network of Fixed Stations. To represent the various subpopulations of tidal wetlands, a network of fixed MACWA stations must contain a sufficient number to span the broad salinity gradient in the Delaware Estuary as well as represent variation in stressor conditions in both estuaries (e.g. ranging from reference conditions to impaired conditions). On the other hand, to ensure that intensive monitoring addresses core data needs with best possible technology and scientific staffing, available resources will likely constrain the number of stations that can be afforded.

PDE and BBP expect to receive sufficient resources for this project to establish four fixed stations as part of Tier 4 of MACWA. Two will be situated in the Barnegat Bay estuary and two in the New Jersey portion of the Delaware Estuary (final locations to be selected after field reconnaissance.) Some of these sites will be more intensely monitored or studied based on available budgets but the best effort will be given to monitor each station exactly the same to better compare them against each other.

Overview of Fixed Station Layout (see Sections 2.1 and 2.2 for more details as well as Umbrella QAPP v 1.0). Establishment of fixed stations will consist of reconnaissance visits and installation of 3 sediment elevation tables (SETs) per station. Following 30 days of settling, SET measurements will begin to be collected.

The exact location of each of the four stations will be chosen involving multiple stake holders as well as local factors such as land ownership, accessibility and likelihood of being sustained into the future. Additional factors to be considered when choosing a site include; ability to link with pre-existing or planned data and monitoring efforts, wetland condition and historical practices on the site (e.g., whether it has ever been impounded), etc.

Following establishment of a fixed station, thereafter the principal series of core intensive monitoring metrics will be assessed once per year during the peak of the growing season (mid-July to mid-September.) Some core metrics may also be collected at other times of the year (e.g. spring, fall) along fixed transects and study plots, such as sediment elevation and biotic community. More details of the core metrics and sampling to be undertaken at each fixed station are described below and in Sections 2.1 and 2.2.

As a general rule, each station will be situated within 3 km of the main estuary proper (i.e., Delaware Bay, Barnegat Bay, tidal Delaware River) and adjacent to a tidal drainage creeks >30 m wide. Site locations have the following criteria taken into consideration;

1) Distance from creek bank
2) Elevation change between creek bank and high marsh

3) Vegetation community and density (e.g., *Nuphar luteum* versus *Typha* spp.)
4) Tributary network (primary to tertiary; i.e., what level tributary is selected?)

Please reference Intensive Monitoring and Assessment Program for Tidal Wetlands of Delaware, New Jersey & Pennsylvania, Version 1.0 (SSIM Umbrella QAPP) for further general information for this section, including definitions.

Example watershed areas for possible location of the new fixed monitoring stations are shown in Figures 4-7. At each station, an assessment area (AA) will be established that is tailored to site-specific geomorphology and within which all measurements will be taken. Three replicate surface elevation tables (SETs) will be installed within the AA, typically placed at 50, 150, and 300 m from the main channel or water >30m wide. Associated with each SET will be a linear transect (referred to as the "main" transect) that extends to the waterbody such that the transect is generally perpendicular to the main axis of the shoreline. SETs will allow long-term monitoring of sediment dynamics per station. SETs will be accessed using boardwalks to prevent trampling effects.

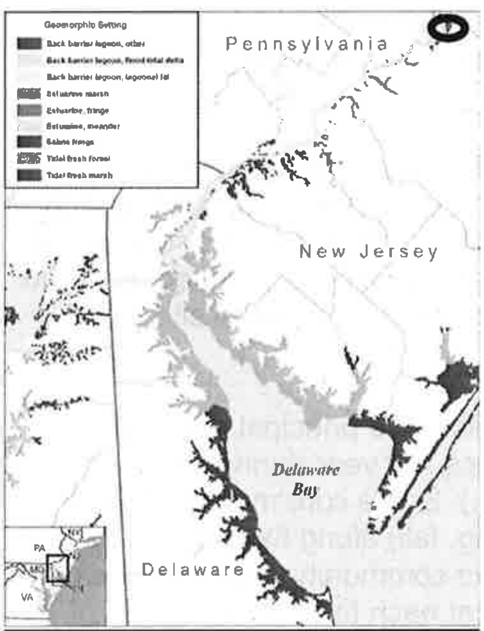


Figure 4. Crosswicks Marsh site, Delaware Estuary, NJ.

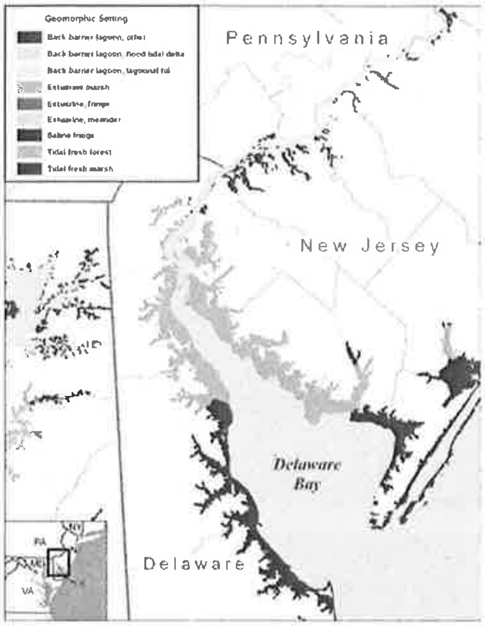


Figure 5. Dennis Marsh site, Delaware Estuary, NJ.

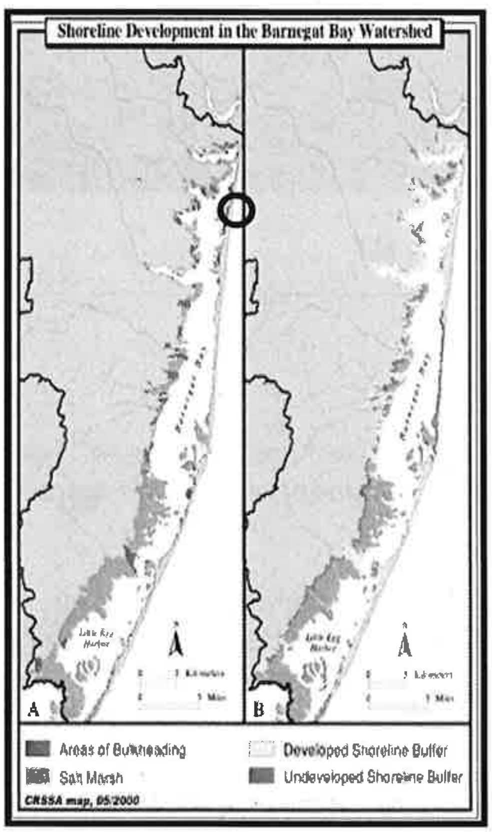


Figure 6. Barrier
Island site, Barnegat Bay, NJ.

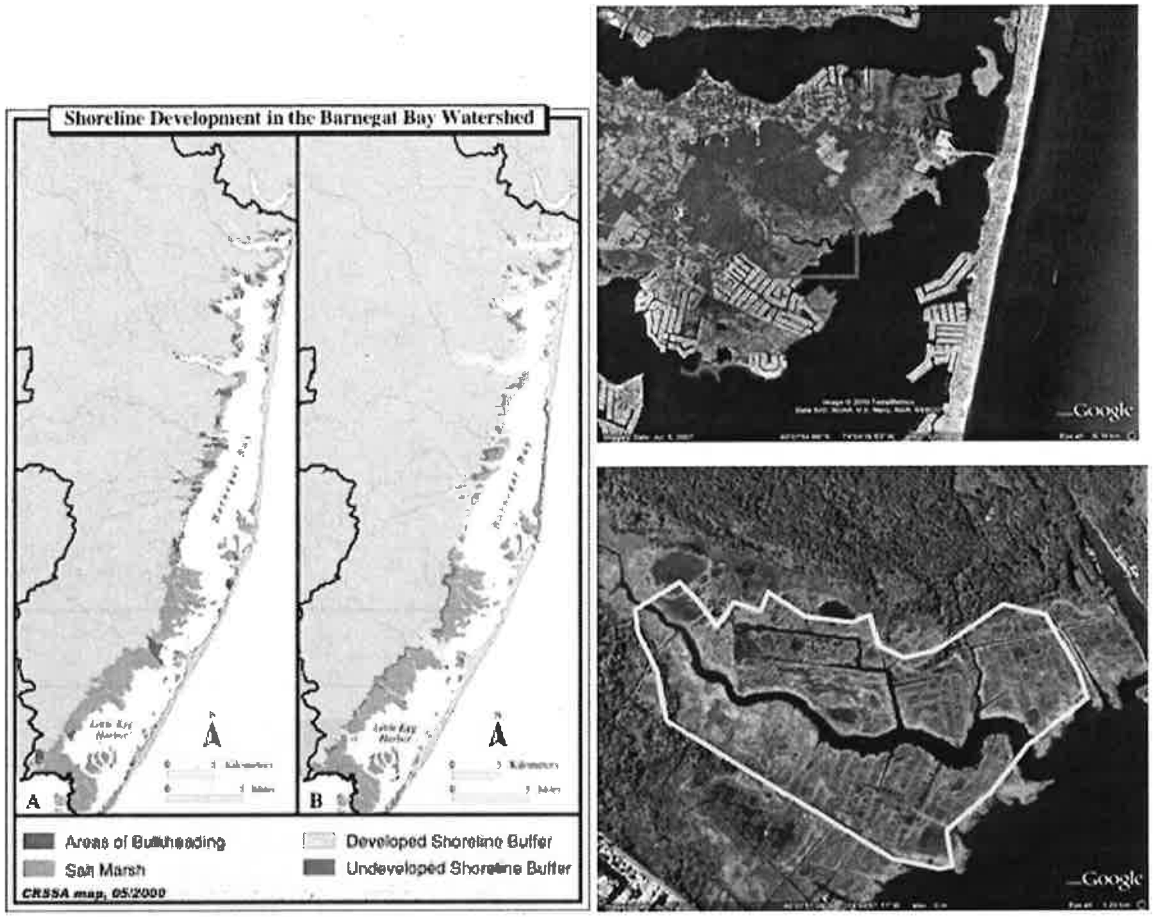


Figure 7. Mantoloking site, Barnegat Bay, NJ.

Terminology

Station (a.k.a., Reference Station): the location of a fixed monitoring site. The exact location for GPS will be the center of the assessment area (see Figure 4a below).

Assessment Area (AA): the area enclosed within a polygon that bounds the outer 50 m buffer surrounding the array of fixed monitoring transects at a station (see Figure 4a below) within which most intensive studies occur.
Marker Horizon (MH): a layer of feldspar (or comparable substance) added to the marsh surface to quantify surface accretion rates.

Biomass Plots: A fixed area of the marsh surface, often 0.25 - 0.5 m^2, within which sampling occurs for aboveground and belowground biomass.

High Marsh: High marsh is a zone located generally above the mean high water Mark (MHW) which is inundated infrequently during periods of extreme high tide and storm. The high marsh is between the low marsh and the uplands, with high marsh flora found such as *Spartina patens* and *Distichlis spicata*.

Low Marsh: The low marsh is found between the high marsh and open water. Low marsh is flooded each tide (twice daily) and has low marsh flora such as *Spartina alernifora*.

Marker Horizon: An area of the marsh surface that is coated with feldspar or a similar substance for the determination of surface accretion rates as new sediments are deposited.

Quadrat: A fixed area of the marsh surface, often 1 m^2, within which qualitative and quantitative sampling occurs. "Systematic quadrats" are repeatedly sampled using non-destructive methods in the same location and are marked by GPS or with stakes to facilitate repeat visitation. Random quadrats" are sampled haphazardly with destructive and/or non-destructive methods.

Reference: For the purposes of MACWA, a "reference" station refers to a station location that is most representative of prevailing conditions for a given subpopulation, but is not unduly affected by specific local stressors such as point-source pollution or hydrological alterations. This use of the term "reference" differs from some other studies that consider a reference site to consist of the best possible (most pristine) example. For MACWA, the intent is to characterize widespread status and trends in tidal wetlands across the estuary, without local stressor bias and also without bias toward best conditions.

Soil Cores: An area of the marsh surface which is sampled using a bottom core for determining sediment chemistry and chlorophyll.

Surface Elevation Table (SET): a permanent monitoring structure consisting of a set of steel rods installed into the marsh to the point of first refusal and used to detect changes in marsh elevation relative to the tidal datum and nearest standard benchmark.

Study Area: the descriptive tract that encompasses a station (e.g., name of Wildlife Management Area, name of estuarine reserve, etc.)

Study Plot: The portion of the AA encompassing one set of three transects (1 main, 2 secondary), a SET, and associated MHs as depicted in Figure 4b. Hence, there are typically three study plots per station and collectively they comprise the AA.

Study Watershed: HUC 8 or HUC 12 name for a sample point (or array of points), station, or study area

Transect: a linear fixed monitoring construct extending perpendicular to the nearest >30 m wide water body and from the contiguous vegetated edge of the wetland nearest the water body (origin, 0) landward into the high marsh (terminus.) The “main transect” denotes the central transect of an array of three (see Figure 4a) and which has a SET at the terminus. “Secondary transects” refer to the lateral two transects that are situated parallel to the main transect per array of three transects.

Station Layout

Transects will be established in each MACWA wetland monitoring site with surface elevation tables paired with marker horizons (SET-MHs) and MHs alone (See Figures 8 and 9). Study plots will be established that extend by three different distances from a major water body and within each a set of three transects will be delineated where SET-MH and MHs will be established. The distances selected for SET-MH and MH placement are dependent on the size of the wetland site as well as the logistics of field work. SET-MH and MH locations (and hence the location of main and secondary transects) in an individual wetland will likely vary in hydrology and sediment availability (distance to water body) and may also vary based on elevation and plant community. MHs alone (secondary transects) are established as replicates to SET-MHs (main transect) to confirm the assumption that sub-surficial processes such as compaction vary similarly at that particular distance from the water body.

Although the distance between the SET and nearest water body will likely vary among the three study plots per station (with corresponding differences in the transect lengths), in general the length of the transects in the three different study plots will be at near, mid-, and far distances (e.g., 50, 150, 300 m) from the main channel or water >30m wide (Fig. 8). As noted above, the distances will vary depending on several factors, including the size of the wetland and the logistics of accessing the site. The placement of transects and SETs for study plots at a station may be modified due to the unique physical constraints of each marsh. Any and all changes to this protocol will be carefully documented why and where the new sites are to be found.

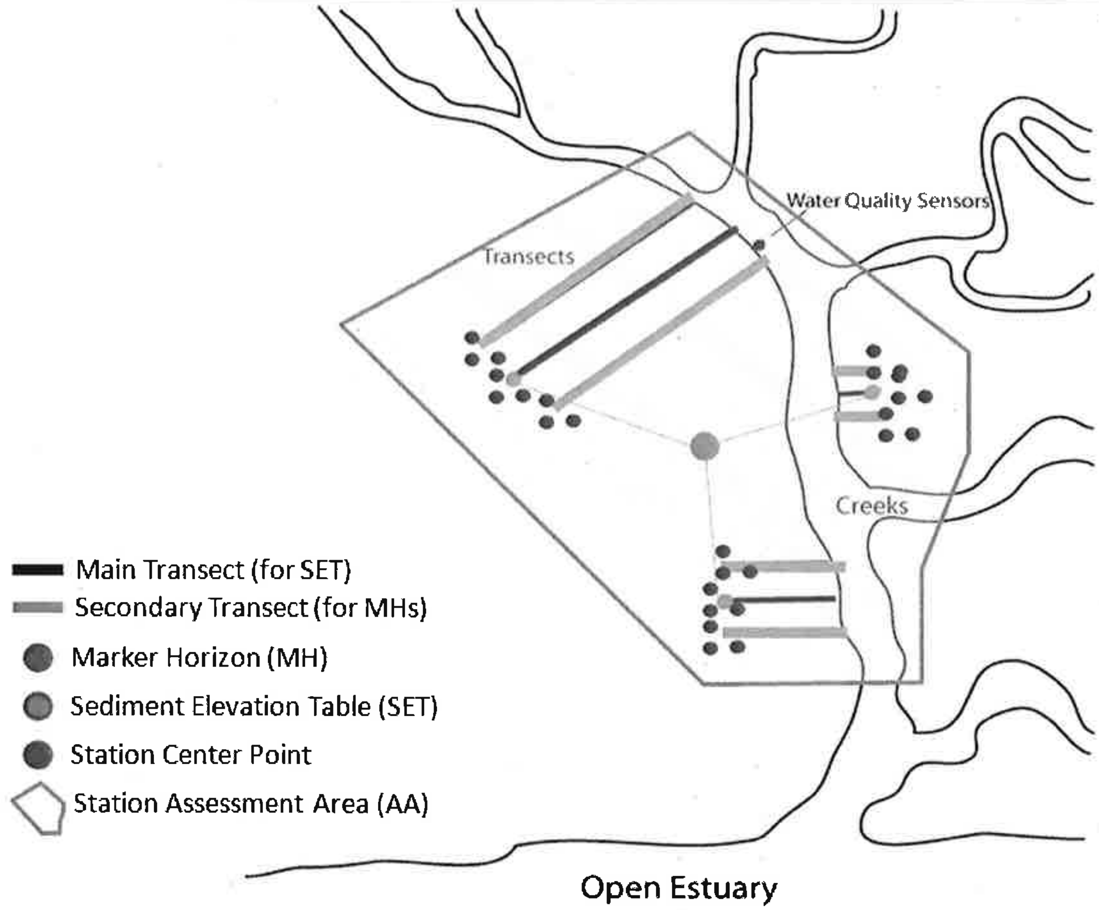


Figure 8. Typical station orientation in reference to tidal creeks and the open waters of the main estuary (not drawn to scale; main estuary will be <3 km from the station.) Up to three study plots (sets of parallel transects) will be situated within the assessment area of each station. The exact positioning of transects and surface elevation tables will be adjusted to local conditions. See text for definitions and details.

The location of each main transect (with a SET at the landward terminus, see Fig. 8 below) will be recorded with GPS and marked with stakes to facilitate repeated sampling at the same locations. Supplemental transects will be situated on either side of the main transect to be used for establishing marker horizons (MHs) and for additional monitoring (see sections 2.1 and 2.2.) These secondary "marker horizon" transects will be to the left and right in parallel to the main transect, thereby also oriented perpendicular to the main axis of the shoreline. The MH transects will be 50 m from the main transect.

The location of each of the three permanent transects will be recorded with GPS and marked with stakes to facilitate repeated sampling at the same locations. The triangulated center of the three SETs will be considered as the center point for the fixed monitoring station for reporting purposes.

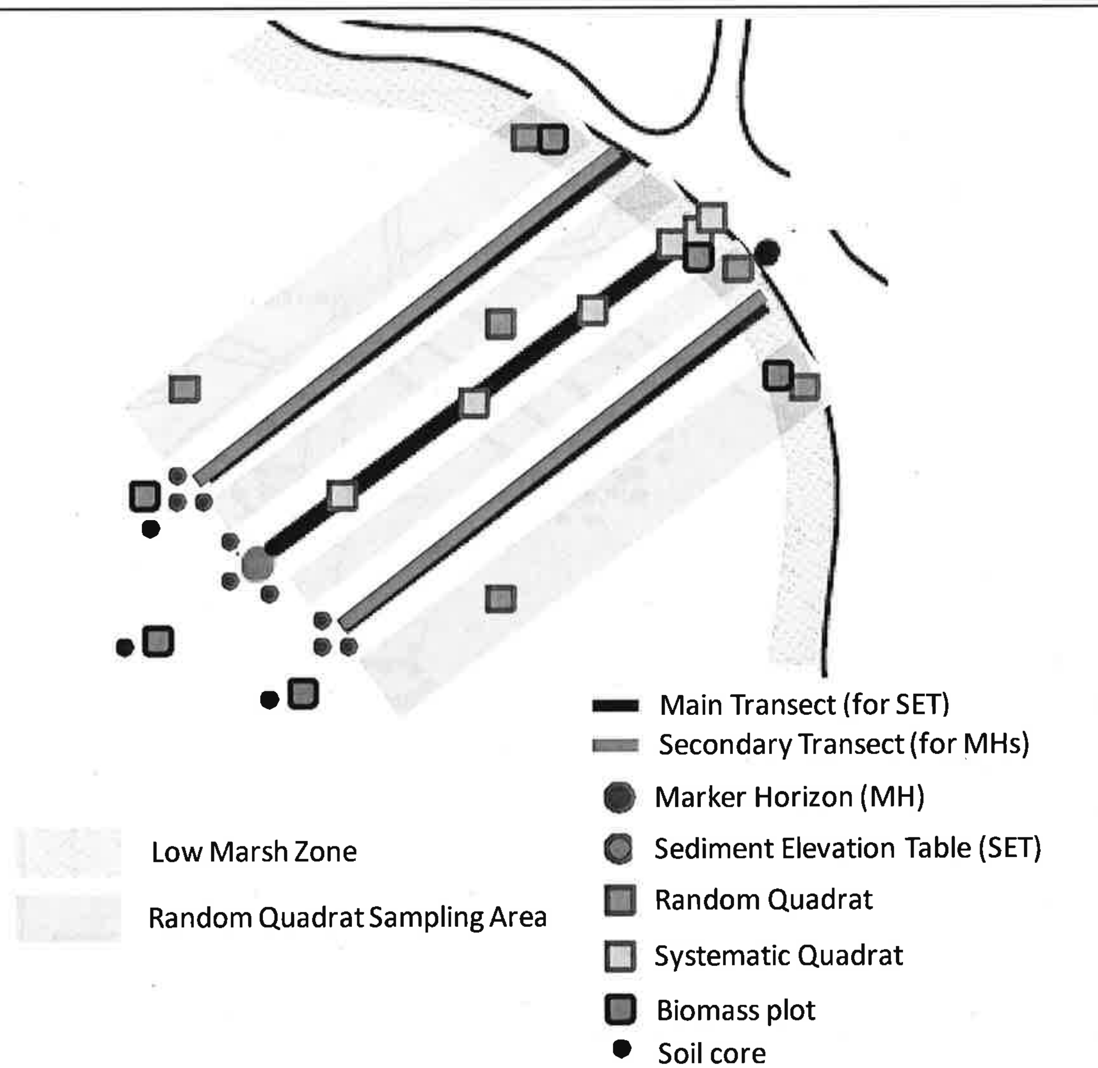


Figure 9. Typical orientation of one of the (up to) three plots per station. Each plot will consist of one main transect and two secondary transects. Systematic quadrats, random quadrats, and biomass plots will occur in both the low and high marsh (replication adjusted to project budgets); whereas, soil cores will occur only in the high marsh. The exact positioning of plot elements will be adjusted to local conditions. See text for definitions and details.

Each main transect (transect where a SET is located) will be a linear transect where once per year at peak biomass the species that intercept the line will be documented (line intercept method). This "line transect" will be done in conjunction with RTK GPS so that a map of the different plant communities and elevation can be developed. A GPS and elevation point will be collected at every major change in plant community as well as at every 25 m.

Along the length of each main transect, at least three systematic monitoring quadrats will also be established and marked with stakes (Fig. 8). Quadrats will be 1 m^2. Plant species richness, percent cover, peak canopy height, and light intensity at the surface will be documented within each quadrat. Sufficient replicate systematic quadrats will be established per station to characterize the main vegetation occurring across the tidal zones of each transect (See Section 2.5 for details). Routine repeated monitoring within these systematic quadrats will use non-destructive measures.

The exact positioning of the quadrats along each transect will be adjusted based on local conditions to characterize the vegetation near each SET, and where possible to also add value to line transect data on vegetation patterns that vary by tidal zonation. Therefore, a minimum of three systematic quadrats will be positioned in the vicinity of each SET, and where resources permit additional quadrats might be positioned at the marsh edge, between the marsh edge and the SETs, and/or between SETs when SETs are along a single transect).

Systematic quadrats will be visited at least once per year. Depending on resources, the positioning and density of systematic quadrats may be increased along a transect to account for different vegetation patterns from different tidal zones. Figure 9 shows one example for how six systematic quadrats might be positioned along a main transect to characterize vegetation zonation.

In addition, once per year each station will be assessed intensively involving destructive sampling. This will consist of measurements of aboveground and belowground biomass within "biomass plots" that vary between 0.25 and 1 m^2 as well as faunal sampling in random quadrats that are typically 1m^2 (Section 2.5.) The location of biomass plots and random quadrats will be randomly determined within the AA, except that none will be within 15 m of permanent transects. Per station, there will be a minimum of 3 biomass quadrats and random quadrats in the high marsh zone and 3 of each in the low marsh zone during each year's assessment. If resources permit, additional biomass plots and random quadrats will be included to further characterize spatial heterogeneity of biomass and fauna e.g., Fig. 9 shows 3 biomass plots and 3 random quadrats per low and high marsh zones in one study plots.

Intensive Monitoring at Fixed Stations. Fixed stations will be sampled with intensive measurements of tidal wetland function and condition using an array of environmental parameters, which are broadly summarized in Table 2. Monitoring will consist of a variety of biological, chemical and physical parameters and metrics (see also Sections 2.1 and 2.2); however, not all parameters envisioned in the "ideal" monitoring plan will be used in each project. Each specific project will be designed to address project goals within cost and feasibility considerations.

Baseline characterization of each station will be performed by contour mapping of elevation data using a kinematic GPS unit, especially along the permanent transect(s). In Year 1 (for a station), MHs will be deployed in selected areas within the assessment area (AA) for monitoring sediment accretion and erosion rates. In Year 1 or 2, up to 3 surface elevation tables (SETs) will be installed for long-term monitoring of sediment dynamics within the AA per station. SETs will typically be deployed in higher marsh areas that are landward of tidal creeks (Figure 8), and these will be accessed using boardwalks to prevent trampling effects.

Table 2. Indicator categories and example metrics to be examined at fixed MACWA monitoring stations.

Indicator	Metrics
Carbon Storage	Carbon sequestration in belowground biomass; litter and wrack accumulation
Elevation and Sediment Budget	Surface Elevation Table (SET), elevation relative to sea level
Plant Community Integrity	Vegetation robustness (percent cover, canopy height; per species)
Functional Dominant Fauna Integrity	Invertebrate species richness and relative abundance along elevation zones
Water Quality (contingent on other funding sources)	Spot monitoring or a monitoring station in adjacent second order tidal creek (e.g., temperature, conductivity, pH, turbidity, DO); grab samples in tidal creek for dissolved nutrients and seston quantity and quality, ebb and flood tides (TSS, chlorophyll, proximate biochemistry and stoichiometry)
Biogeochemical Cycling (contingent on other funding sources)	Sediment porewater nutrient concentrations, forms, stoichiometric ratios; denitrification rates

Dominant flora and fauna will be studied during the peak of the growing season in each year, and additional rapid measures may be collected in other seasons as projects warrant (e.g., spring, summer and fall.) The condition of vegetation on the high marsh and adjacent low marsh (intertidal edge) will be assessed along the permanent transect(s) for systematic and repeated analyses of marsh condition along the landward-seaward axis. To minimize trampling effects, temporary boardwalks will be used if warranted along transect(s), and they will always be used around SETs. As noted above, transects and systematic quadrats will be situated from the littoral edge through the high marsh plain, and their exact locations will be marked with permanent wooden stakes. Systematic quadrats will be situated along the main transect on the clockwise side of the transect line facing from the high marsh plot center (origin) to the low marsh seaward terminus.

The plant community assemblage will be characterized within quadrats and along transects by assessing the species present (including invasives,) percent cover by species, and peak canopy height by species (see Sections 2.1 and 2.2 for details.) Light intensity at the sediment surface, and the presence/absence of aboveground tidal wrack will also be recorded in each quadrat.

As data accumulate from SSIM activities and also from separate rapid assessment efforts from MACWA (RAM), the database of species prevalence within different tidal marsh types should enable Coefficients of Conservatism to be calculated per species. These will in turn be used to perform floristic quality assessments by calculating a floristic quality index (FQI) for each station in SSIM (see Section 2.5.) Since these measures will depend on the array of species actually encountered over the first few years of MACWA, standard methodologies for FQI will need to be developed and provided in future amendments to this Umbrella SSIM QAPP.

If funding and logistics allow, aboveground plant biomass (standing stock), belowground plant biomass, aboveground tidal wrack, and sediment organic content (weight-on-ignition) will also be assessed in randomly placed quadrats >3 m away from any transect and with equal numbers in high versus low marsh areas of the AA. Aboveground measures will entail clipping of vegetation and collection of wrack across the entire quadrat (0.25-1 m^2); whereas, belowground measures will be sampled in cores. Annual sampling will occur at peak growing season (late July / early August).

Metazoan infauna and epifauna such as burrowing fiddler crabs, large worms and bivalve suspension-feeders will be characterized in study plots using various non-destructive (in both systematic and random quadrats) and destructive (only in random quadrats) measures using established sampling and analysis approaches (e.g., Colby and Fonseca 1984, Grace 1984, Bertness 1985; SSIM Umbrella QAPP SOP#28). These analyses of fauna and flora will ascertain whether typical marsh trophic assemblages are present and sufficiently abundant to perform critical functions such as filtration, degradation/remineralization and trophic services (e.g., Dove and Nyman 1995, Kreeger and Newell 2000).

Funding permitting, benthic microalgae (the "microphytobenthos") will also be examined periodically by quantifying chlorophyll concentrations in the upper 1 cm as a surrogate for benthic microalgal biomass (*e.g.*, as described by Williams *et al.* 2001).

Limited water quality metrics will also be assessed when field crews are visiting each site. These might include grab samples to analyze dissolved nutrients and

and TSS. Contingent on funding from other sources, additional water quality measurements might be included as described in the SSIM Umbrella QAPP.

In principle, all work on this wetland assessment will utilize approaches and methods that are well-established and consistent with other tidal wetland monitoring and assessment programs to facilitate data comparability. At least some indicators and metrics will be treated as "core" measures, and any additional measures that are needed to assess condition in various marsh types or watershed regions (e.g. low salinity, narrow fringe marshes) may also require development and use of "supplemental" measures.

Beyond the data mentioned above, additional data is likely to be collected through the synergistic activities of our various MACWA partners. They may include, but are not limited to, Surface Elevation Table (SET) data from DNREC, USFWS, and the Center for the Inland Bays (as previously described in section1.3). Data will also be shared with other researchers in the region who are conducting complimentary research such as Nat Weston of Villanova University and Kurt Phillip of Wetlands Research Services.

Table 2. Example timeline for station establishment and initiation of ongoing monitoring at each fixed station. Only the months are depicted since the year (2010 versus 2011) depends on logistics and funding.

	Delaware Estuary		Barnegat Bay	
TASKS	**Crosswicks**	**Dennis**	**Mantoloking**	**Barrier Island**
SET and MH Installation elevation/accretion	**Aug**	**Aug**	**Aug**	**Sept**
RTK GPS (Line Transects, LT) digital elevation/mapping	**Sept**	**late Sept**	**mid-Aug**	**Oct**
SET data collection (2x's/yr and 2 tidal cycles)	*January and July of following year*	*January and July of following year*	*January and July of following year*	*January and July of following year*
YSI (August, possibly quarterly)				
Biomass /Fauna (in quads, 1X per yr)	*July-Sept 1X per yr for 2 yrs*	*July-Sept 1X per yr for 2 yrs*	*July-Sept 1X per yr for 2 yrs*	*July-Sept 1X per yr for 2 yrs*

Work Flow

The Site Specific Intensive Monitoring (SSIM) will span two years or more. Per new station and project scope of work, Phase 1 will consist of initial orientation and organization, including site selection and reconnaissance visits. Fixed monitoring stations will be established as soon as possible as Phase 2 so that baseline data can begin to be captured before the end of the growing season. Phase 3 will consist of preliminary testing before the end of the first growing season. Phase 4 will consist of regular, routine monitoring at fixed stations. Continued testing and refinement of metrics and methodologies will represent Phase 5. Finally, Phase 6 will consist of data analysis, interpretation and dissemination.

Expected Products

Besides the primary data collected from our group, as well as secondary data shared from our partners various reports and material will be produced from these projects. Some, but not all include;

- Formulation of training materials for future Tier 4 sampling. A report will be prepared describing procedures for how to continue monitoring the fixed reference stations.

- Identification of key decision-making materials and tools to assist local and regional managers in integrating wetland protection and enhancement into watershed planning. By integrating preliminary data on the condition of marshes in different areas of the system (from this study) with census data (from synergistic studies), our final report will begin to identify the greatest challenges and opportunities for tidal wetland protection and enhancement across this estuary. This report will be furnished to watershed organizations, restoration practitioners, agencies that make decisions on mitigating for natural resource damages, and partners working with BBNEP and PDE to advance a regional restoration framework. Hence, our results will help guide regulatory and management actions such as land acquisition, habitat improvement, regional sediment management, and environmental protection.

- Identification of methods and criteria to assess the success of a mitigation site. Wetland mitigation is an important activity in the region, however there is little information available on the relative value and appropriate restoration goals for different types of tidal wetlands (*e.g.*, freshwater tidal marsh versus salt marsh). Little information is available regarding long-term success of restoration sites (Balzano *et al.* 2002). By establishing a network of fixed reference sites, documenting baseline conditions, and developing approaches for rapid condition assessment, we will clarify key metrics to assess when evaluating candidate restoration sites as well as whether projects meet success criteria following mitigation. Therefore, data from the reference network can be used as design criteria and to develop performance standards for mitigation and/or other restoration sites.

1.6 Quality Objectives and Criteria for Measurement Data

The project quality objective is to collect accurate and precise data in order to determine the conditions of wetlands throughout the Delaware and Barnegat Bay Estuaries. A goal of this project is to take field data and accurately transfer it to a computer database without error. This will be accomplished by following through with established quality assurance checks throughout the project. These checks will include checking of data sheets in the field before leaving a site, this will include the Field team leader and one other team member independently looking to make sure all fields are filled in the field data sheet. Each of these team members will sign the bottom of each field sheet to signify that they have verified that all data has been recorded for that site. Quality checks by a non-interested party of 10% of the data will be preformed once in a digital format. This will be documented by the non-interested party by signing with their name, initials, date and documenting which data they have specifically QCed on the last page of the field data sheet in which they have QCed.

The field team will consist of trained individuals and will always include either a PDE or BBP staff scientist or a suitable partnering Ph.D. scientist (e.g. from Academy of Natural Sciences or Rutgers University) to ensure consistency across all estuary sites. For at least the first few years, PDE will lead field efforts on biological assessments and a subawardee partner, the Academy of Natural Sciences (ANS), will lead field efforts for physical/chemical assessments. Therefore, the routine responsibility for quality assurance compliance will depend on the lead scientists involved for PDE and ANS, and PDE and BBP will jointly oversee auditing for QA purposes. Any and all deviations from said protocol will be duly documented and reported to the QA officer as soon as possible.

Only by being precise in our acquisition of data from the field, will the data be able to be compared throughout this study. This study acknowledges that wetlands are a dynamic, living environment and that the strength and rigor of resulting data will depend on numerous repeated measures in time and space across the larger system. The four fixed stations represent different subpopulations and this bias needs to be understood when looking at any data from this study. With additional findings, we intend to strengthen the representation of different subpopulations by increasing the number of monitoring stations beyond the nucleus of pilot stations established here.

We hope to use methods set out in this QAPP and transfer them to other partners in the area in order to have as much comparability as possible, and therefore make the data stronger. We also aim to link this monitoring program together with other tidal marsh monitoring efforts in the Mid-Atlantic and nation and so we will stay abreast of the emerging data quality dialogue.

Precision

Precision is the measure of the degree to which two or more measurements are in agreement. Precision is assessed through the collection and measurement of field replicates. Relative Percent Difference (RPD) shall be calculated for each of the replicates collected for all the parameters analyzed. Precision in the laboratory is assessed through the calculation of RPD for matrix spikes and matrix spike duplicates and of the field split samples.

RPD is calculated using the equation $RPD = \frac{S - D}{0.5(S + D)} \times 100$

Where:

S = Amount in Spike 1 **or** concentration of parameter in original

D = Amount in Spike 2 **or** concentration of parameter in replicate

Accuracy

Accuracy is the degree of agreement between an observed value and an accepted reference value. However, for some of the planned monitoring and assessment measured envisioned within MACWA, there may be no established reference methods. For new condition or functional measures for which there are no established benchmarks (i.e. for high versus low condition), we will assess the relative differences among the sample population and thereby begin to establish ranges for estimation of base accuracy for true condition. As data are collected for various watersheds, the highest scoring values will be considered as high references and the lowest scoring values will be considered as low references. The range between the two should be broad enough to define the full gradient, per metric. Accuracy in the field will be assured by the ability of the measures to yield values that best represent the true values, as determined by a weight of evidence approach using any literature information and our own measures. For some condition metrics, the context should also be partially understood from the complimentary rapid assessment methods (RAM) being employed for Tier 2 of MACWA. For example, high RAM condition scores should generally be obtained in the vicinity of fixed stations that represent high condition and functionality (i.e. references), and vice versa. Whereas, RAM that are performed in the vicinity of indicator stations situated in heavily impacted areas should yield lowest RAM scores, and vice versa. Accuracy assurance will therefore be determined and strengthened over time as more SSIM and RAM sampling is completed.

Bias

Systematic or persistent distortion of a measurement process causing errors in one direction (bias) is not anticipated in either RAM or SSIM analyses. Data collectors will be trained to be objective and only record true observations. All personnel who will participate in collecting data must pass an annual field team audit.

Repeated measures by different teams (e.g., for 10% precision tests) will ensure that the results are not biased by any individual or team. Some of the new field metrics being developed will require this repeated measures approach (using different field teams to reassess the same metric) to examine the level of bias, which will evaluated to the best of our ability. Any adjustments that are deemed necessary to reduce bias will be refined during the first fall/winter season by the MACWA workgroup, and any appropriate changes will be incorporated to reduce bias in the following field season. If and when acceptance criteria are revised or established, the QAPP will be revised to include those criteria. In additon, the final report will describe the manner in which bias was evaluated for the project.

Representativeness

Representativeness expresses the degree to which data accurately and precisely represent a characteristic of a population, parameter variations at a sampling point, a process condition, or an environmental condition. Representativeness is dependent upon the proper design of the sampling program and will be satisfied by ensuring that the sampling and analysis plan is followed and that proper sampling techniques are used.

Completeness

Completeness is a measure of the amount of valid data obtained from a measurement system compared to the amount of data that was expected to be obtained under normal conditions. Field completeness is a measure of the amount of valid measurements obtained from all the measurements taken in the field. The completeness goal for this project would be to install 3 SETs at each of the 4 watersheds; take SET readings, perform RTK GPS contour analyses, survey vegetation with line transects, measure aboveground/belowground biomass, sediment chlorophyll, and survey fauna integrity at least twice at each station over the course of this grant.

Completeness will be calculated as the ratio of the number of sample results to the total number of samples analyzed with a specific matrix and/or analysis. Following completion of all data collections for a given station sampling or project, the percent completeness will be calculated by the following equation:

$$Completeness = \frac{V}{P} \times 100$$

Where:

V = Number of valid measurements.

P = Number of planned measurements.

Comparability

Comparability is an expression of the confidence with which one data set can be compared with another. Comparability is dependent upon the proper design of the sampling program and will be satisfied by ensuring that the field sampling plan is followed by all personnel and that proper training and measuring techniques are used consistently. Resulting data will be determined to be comparable when similar sampling and analytical methods are used, documented in the QAPP, and when fixed station data outcomes for similar types of monitoring stations within the sample frame yield similar condition or functionality results. Comparability is also dependent on similar QA objectives.

Sensitivity

The sensitivity for each analytical metric can be found in the appropriate SOP (see appendix to this QAPP). If the minimum concentration cannot be measured that specific sample will not be used in analysis. If it is determined that a sampling protocol is not capturing a majority of samples then the metric will be reevaluated by the MACWA group.

1.7 Special Training Needs/Certification

See Intensive Monitoring and Assessment Program for Tidal Wetlands of Delaware, New Jersey & Pennsylvania, Version 1.0 Section 1.7

1.8 Reporting, Documents and Records

See Intensive Monitoring and Assessment Program for Tidal Wetlands of Delaware, New Jersey & Pennsylvania, Version 1.0 Section 1.8

The final report for this project is due before March 31, 2014, reports will be provided to the funder, EPA Region2, on an annual basis before then.

2 Data Generation and Acquisition

2.1 Sampling Process Design (Experimental Design)

This study aims to elaborate and expand wetlands work that is currently being done in the Delaware Estuary and Barnegat Bay by such partners as the States of Delaware and New Jersey, and other academic institutions. The area of interest includes The Barnegat Bay, a shallow lagoonal estuarine system, as well as the Delaware Estuary, with more classical estuary geography. It is hoped that this program will continue beyond the initial projects into a annual monitoring occurring in the states of Delaware, Pennsylvania and New Jersey.

The Tier 4 design establishes a network of stations in representative subpopulations of the estuary. These stations are intended to represent the diversity of prevailing conditions, representing various types of tidal wetlands and stressor conditions. Some stations will be located in relatively undisturbed areas and these will serve as reference stations; whereas, others will be situated in sub-watersheds that may be affected by local stressors. Unfortunately in both the Barnegat and Delaware Bays there are few "reference" marshes to retrieve data from. All 4 stations this project addresses are not a reference but a representation of the typical marsh of the area. There is little historical data to compare our metrics to, though the team plans on doing an extensive literature review once this project commences to find any and all available data. The goal of this study is to better understand the current predominant condition of tidal wetlands across both the Delaware Estuary and Barnegat Bay Estuary and to create a linked framework for future monitoring and assessment.

This program is working with the latest national guidance from USEPA (http://www.epa.gov/owow/wetlands/monitor/) and in concert with other documents such as; Application of Elements of a State Water Monitoring and Assessment Program for Wetlands (April 2006) by the Wetlands Division Office of Wetlands, Oceans and Watersheds, U.S. Environmental Protection Agency.

Many of these measurements and metrics to be used are considered standard while others are more experimental in nature. Use of standard metrics will ensure that useful data will be collected for comparative purposes to other historical and current data sources. Some experimental metrics will be included if they might potentially yield more helpful, additional, or locally relevant information about the condition of tidal wetlands in the study population.

The subpopulations of this study will be wetland type (oligohaline, mesohaline, polyhaline), state (DE, NJ, PA), and estuary watershed (Delaware Bay, Barnegat Bay). By including these subpopulations it is hoped that these data can be extrapolated to give a baseline of the overall condition of tidal wetlands in the Mid-Atlantic sub-region between coastal New Jersey and coastal Delaware. Four watersheds were chosen for this project (Table 3). Each of the watersheds was chosen in order to compliment other data taken by partners in the same watershed as well as to geographically distribute the study sites. Geographic locations of each of the watershed can be found in Figures 4-7. While the exact latitude and longitude of the SETs, and therefore the transects, will be chosen once the project starts, Figure 4-7 give the best scientific guess of locations based off of some reconnaissance and some aerial photography. Once each site is properly located, a GPS unit that has been properly calibrated according to its manufacturer will be used to fix the position and record information in a field notebook including which GPS unit was used.

Table 3. Sub- watersheds being considered for station locations for the project.

Watershed	State	Estuary
Crosswicks	NJ	Delaware Bay
Dennis	NJ	Delaware Bay
Barrier Island	NJ	Barnegat Bay
Mantoloking	NJ	Barnegat Bay

The intent is to establish MACWA fixed stations that can be sustained and for long-term study and which will yield vital information for coastal managers for sea level rise planning and natural resource management. Resulting data will aid decision making and priority setting regarding land use planning, climate adaptation planning, and fisheries management.

Each of the stations will be intensively monitored at least once per year during peak growing season (late July to late September), and additional seasonal measurements may be collected for some metrics. In the first year for each new station, it will be visited at least two times for reconnaissance purposes and baseline site characterization. If resources permit, each station will thereafter be visited annually for intensive measurements and potentially also seasonally (spring, summer and fall) for general descriptive purposes (photo and rapid assessment monitoring; sediment elevation measurements). The intensive monitoring as per this QAPP will be performed generally once per year in summer.

The National Estuary Programs (PDE and BBP) will coordinate overall efforts among subawardees of grants to the NEP's, most likely the Academy of Natural Sciences and Rutgers University which are partners in MACWA. Similarly, any MACWA-associated projects awarded to non-NEP partners will be coordinated by the awardee institutions with participation and data sharing with the appropriate NEPs. Contingent on resources and subawardee selection, the Academy of Natural Science is expected to take a leadership role in coordinating all fixed station data for MACWA at least for the first few years of the SSIM effort. During this time, the Academy will lead the collection of physical and chemical data, with assistance by the NEPs, other academic partners (e.g. Rutgers), and state/federal partners. The NEPs will lead the collection of biological data at fixed stations, in partnership with the Academy of Natural Sciences and others.

Within one week after each sampling or post-collection analysis of samples, any discrete water quality and sediment data (or samples for analysis) will be delivered to the Academy of Natural Sciences as per standard operating procedures (SOPs). Biological samples or data will similarly be delivered to NEP staff within one week of collection (or sooner if specified in SOPs) for NEP processing (or subawardees if appropriate.)

Laboratory analyses of biological samples will be performed at either the Academy of Natural Sciences, Drexel University, Rutgers University or Cheyney University, depending on the specific metrics and subawardee workplans. Although neither PDE nor BBP maintain laboratory facilities, the science director at PDE (Dr. Kreeger) maintains affiliated appointments at Drexel and Cheyney Universities where she maintains laboratories capable of analyzing samples for biomass and biochemical samples, whereas the Academy maintains labs for physical and chemical sample analyses.

We expect to see considerable variability among reference stations due to their subpopulation characteristics, but this is intentional. The marshes in Barnegat Bay and Delaware Estuary are vastly different in their freshwater and sediment budgets, and it will be difficult to compare the two estuaries. There will also be some seasonal differences in the data, the field teams will not be able to install all SETs within a short period, though we hope to take readings at least during the second year within two weeks of each other. Other natural causes of variation not within the teams control include; tidal, weather, and various stressors to the marshes.

2.2 Sampling Methods

Methods for collecting biological, chemical and physical metrics data at fixed stations are summarized above and are further described below. Table 4 summarizes the biological measures and associated standard operating procedures and other reference material, and Table 5 similarly summarizes the chemical and physical measures.

See Section 1.5 for a description and diagram (Figures 8 and 9) of the general station sampling approach and definitions of terms used here.

1. **Biological**. Biological measures will be collected with both non-destructive and destructive methods, which will generally be collected in systematic and random quadrats, respectively, as well as biomass plots and soil cores (See Section 1.5 and Fig. 9). Non-destructive methods include characterizing and quantifying plant community assemblage (a) and conducting fauna surveys (b). Destructive methods include collecting fauna biomass (c) and soils (d). Some of the non-destructive measures might be collected in both systematic and random quadrats to facilitate comparability and correlations between more rapid, qualitative measures and intensive, quantitative measures.

Table 4. Summary of biological measurements to be collected at fixed stations and references to associated methodologies.

Biological Component	Metrics	Sampling Approach	Method(s)
Biomass	Aboveground	Destructive sampling in random quadrats in low vs. high marsh	SOP #019
	Belowground	Destructive sampling in random quadrats in low vs. high marsh	SOP #020
Sediments	Sediment Quality*	Non-destructive sampling in random quadrats in low vs. high marsh	SOP #005,007,023
Plants	Floristic Quality Index[2]	Non-destructive sampling in random quadrats in low and high marsh; also in systematic quadrats along transects	
	Species Richness[2]		
	Percent Cover by Species[2]		
	Blade Height by Species		
	Light Intensity at Surface		
Animals[1]	Ribbed Mussel Density (visible shell lip counts)	Non-destructive sampling in random quadrats in low and high marsh; also in systematic quadrats along transects	Visual count
	Ribbed Mussel Density (quantitative excavation)	Destructive sampling in random quadrats in low vs. high marsh	SOP #017
	Ribbed Mussel Size Classes and Biomass	Destructive sampling in random quadrats in low vs. high marsh	SOP #017
	Ribbed Mussel Condition*	Destructive sampling in random quadrats in low vs. high marsh	SOP #014-017

1 *where present*
2 *post-processing in lab or office*
* *secondary metric to be assessed if resources permit*

Bioassessment of the fixed stations will include measurement of biomass, sediment conditions, plant community integrity, and fauna community integrity (Table 4.)

a. Plants. The plant community assemblage will be characterized along line transects established for SETs as well as within both systematic and random quadrats. Once per year at peak biomass (July – August), main transects (3 per station) will be surveyed to document the species present along transects. Emergent macrophyte species that are in direct contact with the line (defined as within the 1 m wide belt to the right of a transect line heading away from the transect origin point) will be identified. RTK GPS will be used to mark the location and elevation of plant community changes along transects.

A series of 1.0 m^2 permanent systematic quadrats will also be established along main transects at specific intervals (10 – 25 m) (Figure 9.) To ensure some quadrats are situated in both the low marsh and high marsh, the distance between quadrats may be shorter near the marsh edge and then longer along the (typically) more expansive high marsh transects. Systematic quadrats will be marked by stakes and GPS.

Systematic quadrats will be surveyed every year for species richness (the # of species present), pecies cover (%, Brower et al. 1998), average canopy height for each plant species (see SOPs in SSIM Umbrella QAPP,) and light intensity at the surface and above the canopy (FieldScout Quantum Light Meter, PAR 400-700 nm, range 0-1,999 µmol m^{-2} s^{-1}, accuracy ±5%.) The light intensity at the surface will assess the availability of photosynthetically active radiation available for benthic algal production and the difference between above-canopy and surface light intensity (attenuation) will be serve as a secondary indicator of canopy density. Where possible, light intensity will be measured during midday and under sunny conditions; however, notes on time of day and cloud cover will be collected and considered when interpreting data.

In addition, each year, randomly placed 1.0 m^2 plots will be surveyed within the AA of each station (Figure 9.) A minimum of six random plots (1.0 m^2) will be established, three in the low marsh and three in the high marsh zones (divided among the three study plots per station.) Random quadrat locations will be determined by throwing a quadrat frame over the rear shoulder into the assessment area (>3 m and <50 m from SETs and transects. Quadrats will then be shimmied over any standing vegetation to be as near to the ground as possible and flat. Plants will be assessed within random quadrats using the same non-destructive measures as used in systematic quadrats (see above) to expand the replication of the vegetation community and ensure that vegetation data along the transect (systematic) are representative of the rest of the AA.

If funding permits, additional replicates will be divided among the three study plots per station, ideally increasing replication to 9 in the low and 9 in the high marsh (up to 6 per study plot as in Fig. 9 and up to 18 per station.) Random quadrats will be no closer than 15 m and no further than 50 m from any transect or SET. These quadrats will be surveyed for plant species richness (# of species present), species cover (%), average canopy height of each species, and light intensity at the surface.

As data from both RAM and SSIM activities are accumulated for the various tidal wetland types within the MACWA sample frame, presence/absence species data might be used to calculate a mean Coefficient of Conservatism (C) per species (Lopez and Fennessey 2002.) Taken together and spanning many tidal wetland types and estuary areas, these C values will eventually represent a Floristic Quality Assessment (Lopez and Fennessey 2002; Mushet et al. 2002) for MACWA, providing the framework for calculate an individual Floristic Quality Index (FQI) for each systematic or random quadrat (SSIM) or an assessment area of a RAM sampling point. FQI values tend to be greater in undisturbed areas than in disturbed areas and have been used to gauge the success of restoration and management practices. To our knowledge, no group has determined C values for tidal marshes of the mid-Atlantic region and so these will need to be developed after at least one year of data accumulation. Since this floristic quality assessment does not need to be calculated during sampling, we will examine the utility of FQI as MACWA data accumulate, and prepare an SOP for future QAPP amendments if warranted. It remains unclear whether sufficient data will be collected during the timeline of this project to enable FQA, but data from this study will lead to a FQA eventually.

Plant species assemblages and ecological community types will also be interpreted according to the National Vegetation Classification System described for the Delaware Estuary by Westervelt et al (2006).

.b. Animals. Non-destructive surveys of fauna will be conducted in systematic quadrats along each fixed transect as described in Section 1.5 (Figure 9.) Destructive sampling for fauna will also be undertaken within random quadrats (see Table 4 and Figure 9.) The subset of random quadrats will also be sampled using non-destructive measures to facilitate cross-comparison and correlations between destructive and non-destructive metrics. For example, visual counts of live mussels within quadrats (non-destructive) will under-represent true abundances because many individuals are sediment-coated, buried, too small to be seen, or are hidden within blades of vegetation. Therefore, a regression relationship will be developed between actual and visual-based mussel densities (within quadrats). Replication of systematic and random quadrats will be as described for plants, adjusted based on field conditions and cost as determined after initial field tests.

Where present, ribbed mussel (*Geukensia demissa*) densities will be assessed within quadrats since this species is considered the functional dominant animal in typical salt marshes of the mid-Atlantic (Jordan and Valiela 1982, Kreeger and Newell 2000) where they can outweigh all other metazoans combined and filter more water than all other bivalves combined. Where dense along marsh edges, they might also help to stabilize against erosion.

Mussel densities will be determined non-destructively by counting the number of exposed shells of live individuals >1 cm shell length that can be seen within the frame of the sampling quadrat. Mussel shells are easily seen by the trained eye. In random quadrats, destructive sampling for ribbed mussels will entail excavation or uprooting and washing of vascular plants and sediments in 5 gallon buckets of water. All individuals greater than 1 cm shell length will be counted, sized with a digital micrometer and the entire wet biomass of the mussel sample will be weighed on a balance in the field (to the nearest gram). At least 4 and up to 12 adults (<4 cm shell height) will be added to a sample bag and placed on ice for transport to the laboratory and then immediately frozen.

Depending on costs for other elements, subsequent laboratory analyses of mussels might include assessment of theirl condition index and proximate biochemical composition of tissues (see SSIM Umbrella QAPP for SOP.) Physiological status of bivalves is represented by the condition index (Crosby and Gale 1990) and tissue biochemical composition (Kreeger 1993), in comparison to expected norms for the season sampled.

Three species of fiddler crabs are native to tidal wetlands in the MACWA region and they are ecologically important for bioturbation and food web support. As a proxy for fiddler crab density, the number of crab burrows within systematic and random quadrats will be counted.

In addition to these density estimates of ecologically significant species, additional metazoan epifauna will be qualitatively assessed within quadrats. Populations of amphipods and gastropods are ecologically important grazers and decomposers. Therefore, the marsh sediment surface, wrack, and vegetation will be examined within each quadrat and the presence of any snails, crustaceans or other invertebrates besides ribbed mussels and fiddler crabs will be recorded. If necessary, samples will be collected for positive taxonomic identification later in the laboratory. Calculations will include species richness and macrofaunal integrity. If any invertebrate species is found that is either numerically prominent or large in size, the size class distribution or abundance will also be recorded.

Finally, the presence of any vertebrates (fish, birds, turtles, muskrats) or large-sized invertebrates (blue crabs, horseshoe crabs) observed during field sampling will be recorded on data sheets only if they occur within the assessment area and can be positively identified by sight by scientific experts during routine monitoring by the bioassessment team.

Faunal sampling will follow SOP #028 in the SSIM Umbrella QAPP. Our approach is informed by published sampling and analysis approaches (e.g., Colby and Fonseca 1984, Grace 1984, Bertness 1985) as well as by previous transect and quadrat sampling for mussels by one of the lead scientists (Kreeger and Newell 2001.)

c. Biomass. Once per year, three 0.25 – 0.5 m^2 biomass plots (similar to random quadrats but smaller) will be established in both low marsh (e.g., nearest distance to the main water body) and high marsh (farthest distance from the main water body) within the assessment area (>15 m and <50m from each SET or transect) of each station, adjacent to SETs and fixed transects (see Figure 9 which shows all replicates in one study plot but they might be dispersed across study plots). Depending on site-specific geomorphology, the two biomass collection areas (high and low marsh) may differ in elevation and plant community as well as distance from the water body and sediment source, as shown in Figure 9. The three plots will be no less than 15 m from any SET-MH or MH to avoid disturbing those fixed monitoring sites.

At maximum annual productivity (late July to mid-August), aboveground, wrack, and belowground biomass will be collected. The biomass will be washed and separated into live and dead material. All material will be dried, ground, and measured for loss on ignition. Samples will be stored for biochemical analysis if needed. This is a time intensive element for both collection and sample processing. This element will be done once per year at each fixed station, funding permitting. See SOPs in SSIM Umbrella QAPP for details.

- Peak biomass, one time per year
- 3 areas in low marsh, 3 areas in high marsh (mean ± s.d.)
- Clip standing biomass and collect all litter on the marsh surface
- Collect core (15-cm diameter x 30-cm depth) for belowground biomass
- Sort by species, live and dead
- Dry, grind, LOI

d. Sediments. Soil cores (5-cm diameter x 30-cm depth) will be taken from each study plot as shown in Figure 9 and sectioned into 3 depths (surface, mid and below the root zone) and analyzed for CNP and LOI. Three cores will be collected adjacent to the biomass plots (see above.) Sediment organic content and quality (% carbon, nitrogen, and phosphorus) will be determined for 3 depth intervals of 0 – 10, 10- 20, and 20 – 30 cm.

- Cores will be collected for LOI and sediment quality (see SOPs in SSIM Umbrella QAPP,) 3 depths, each core

2. **Chemical.** Potential water quality metrics are summarized in Table 5.

   a. *Water Quality*. Refer to Section 1.5, Table 3, and SOPs in SSIM Umbrella QAPP.

Table 5. Summary of chemical measures to be collected at fixed stations and references to their methodologies.

Component	Indicator	Core or Secondary	Main Metrics	Method (SOPs in SSIM Umbrella QAPP)
Chemical	Water Quality	Secondary*	Chla	SOP #002
			NH3-N	SOP #001
			Cl	SOP #003
			N	SOP #004
			DNitrite & Nitrate	SOP #005
			%OM	SOP #006
			Particulate P	SOP #007
			O-P & TP	SOP #009
			TSS	SOP #010
			D Sulfate	SOP #011
Physical	SET Light	Core	Accretion	SOP #018
	SET Benchmark		Accretion	SOP #013
	Study Area Polygon			Figure 4a

* *degree of replication, sampling frequency, and effort will be scaled to available funding and on site conditions*

3. **Physical.** Physical metrics will be sampled along transects established at each MACWA fixed station as shown in Figure 8.) Each station's assessment area will contain up to 3 study plots, each having surface elevation tables paired with marker horizons (SET-MHs) and MHs alone (Figures 8 and 9.) Three distances from a major water body have been established along a set of transects where SET-MH and MHs have been established. The distances and locations selected for SET-MH and MH placement are dependent on the size and configuration of the wetland site as well as the logistics of field work. SET-MH and MH locations in an individual wetland vary in hydrology and sediment availability (distance to water body) and may vary in elevation and plant community. MHs alone are established as replicates to SET-MHs with the assumption that sub-surficial processes such as compaction vary similarly at that particular distance from the water body.

    a. *SET Light.* Marker horizons of multi-colored glitter and sand will be established in pairs of 1.0 m^2 square areas to sample sediment accretion. Sand is used to hold down the glitter during tidal flooding. It can also be used as a marker. A Russian peat corer, which makes a horizontal cut to minimize sampling compaction, will be used to collect shallow cores. Sediment accretion will be measured as depth from the sediment surface to the top of the glitter/sand horizon in sampled cores.

Stainless steel rods will be pushed down into the marsh to refusal. Depth to refusal in restoration sites can be generally from 3.0 to 6.0 m, but exceeded 11m at some locations in the *Phragmites* restoration sites. These rods are used as permanent bench marks for elevation. Glitter/sand and rod sample locations will be surveyed to a horizontal and vertical accuracy of 0.25 cm using GPS equipment. A compensating level with micrometer will be used to obtain marsh surface elevations in the glitter/sand and plate sample locations each sampling time, using the rod benchmark elevations. Level measurements will be read to the nearest 0.1 mm. Repetitive measures taken to the benchmark rod at the time of each sampling had a standard deviation of 0.3 mm. Shallow subsidence is determined as the change in marsh elevation minus vertical accretion. These methods are very similar to those described in Cahoon *et al.* (1995).

b. *SET benchmarks.* Where SET benchmarks are established, the USGS method will be used, as adapted by the University of Maryland and DNREC. Description of the USGS method can be found at: http://www.pwrc.usgs.gov/set/. SET installation as well as measurements will follow SOP #013.

2.3 Sample Handling and Custody Requirements

See Intensive Monitoring and Assessment Program for Tidal Wetlands of Delaware, New Jersey & Pennsylvania, Version 1.0 Section 2.3

2.4 Analytical Methods

1. *Biological*

For more information, please see SOPs in SSIM Unbrella QAPP.

A. Biomass

Plant biomass will be taken back to the lab, washed and sorted into species-specific categories of live and dead. Belowground biomass will be washed through a mesh sieve to capture all biomass that will not wash through a 1mm screen. Biomass samples will be dried at 60°C until a constant weight. A subsample of each category of biomass will be ground and placed into a muffle furnace at 450°C four 8 hours. The percent of weight loss on ignition (LOI) will allow us to calculate the ashfree dry weight of the biomass, with inorganic sediments factored out.

B. Soils

Soil cores will be sectioned into three depth sections of 0 – 10, 10 – 15, and 15 – 20 cm. Each section will be dried at 60°C until a constant weight. The percent LOI (SOP #021), C, N, and P will be determined.

C. Faunal Integrity

In random quadrats, destructive sampling for ribbed mussels will entail excavation or uprooting and washing of vascular plants and sediments in 5 gallon buckets of water. All individuals greater than 1 cm shell length will be counted, sized with a digital micrometer and the entire wet biomass of the mussel sample will be weighed on a balance in the field (to the nearest gram). At least 4 and up to 12 adults (<4 cm shell height) will be added to a sample bag and placed on ice for transport to the laboratory and then immediately frozen.

If undertaken, subsequent laboratory analyses might include assessment of mussel condition index and proximate biochemical composition of tissues. Physiological status of bivalves is represented by the condition index (Crosby and Gale 1990) and tissue biochemical composition (Kreeger 1993), in comparison to expected norms for the season sampled. By integrating these data with abundance and population biomass measurements, population-level clearance rates might be able to be calculated for the low and high marsh zone per station using established literature based clearance rates (Kreeger and Newell 2001). These rates, scaled for allometric relationships with body size, could be contrasted with size class distributions and associated biomass to tally the total clearance rate within a study plot, yielding a total "biofiltration potential" per hectare by the bivalve community residing in the different tidal marshes where the animals are found.

D. Water Quality

Tidal creek samples will be collected and taken back to the lab on ice. Samples will then be analyzed for chlorophyll a, percent organic matter, dissolved organic and inorganic forms of nitrogen and phosphorus.

2.5 Testing, Inspection, Maintenance and Calibration Requirements

See Intensive Monitoring and Assessment Program for Tidal Wetlands of Delaware, New Jersey & Pennsylvania, Version 1.0 Section 2.5

2.6 Data Management

See Intensive Monitoring and Assessment Program for Tidal Wetlands of Delaware, New Jersey & Pennsylvania, Version 1.0 Section 2.6

Assessment and Oversight

3.1 Assessments and Response Actions

See Intensive Monitoring and Assessment Program for Tidal Wetlands of Delaware, New Jersey & Pennsylvania, Version 1.0 Section 3.1

3.2 Reports to Management

The QA officer will be responsible for compiling all assessments. The QA officer will write these reports and provide it to the Project Manager or PDE science staff for review. In annual progress reports for the project prepared for EPA, will be provided along with a final report due no later than March 30th, 2014.

Data Validation and Usability

4.1 Data Review, Verification, Validation and Usability

See Intensive Monitoring and Assessment Program for Tidal Wetlands of Delaware, New Jersey & Pennsylvania, Version 1.0 Section 4.1

4.2 Verification and Validation Methods

See Intensive Monitoring and Assessment Program for Tidal Wetlands of Delaware, New Jersey & Pennsylvania, Version 1.0 Section 4.2

4.3 Reconciliation with user Requirements

See Intensive Monitoring and Assessment Program for Tidal Wetlands of Delaware, New Jersey & Pennsylvania, Version 1.0 Section 4.3

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Appendix A: Example Chain of Custody

Project Name	Project leader:
Samplers:	

Partnership for the Delaware Estuary
One Riverwalk Plaza
110 South Poplar Street, Suite 202
Wilmington, DE 19801
(800) 445-4935 or (302) 655-4990

Sta. No.	Date	Time	Station location		TOC	Metals	PCB	Bivalve	Benthic # samples	Pic #	Notes

Relinquished by:	Date/Time	Received by:	Remarks:
Relinquished by:	Date/Time	Received by:	
Relinquished by:	Date/Time	Received by:	

Appendix B: Acronym Definitions

AA- Assessment Area

ANSP-Academy Natural Sciences Philadelphia

DEWMAP-Delaware Estuary Wetland Monitoring and Assessment Project

DEWWG-Delaware Estuary Wetland Workgroup

DNREC-Department of Natural Recourses and Environmental Control, Delaware

MACWA – Mid-Atlantic Coastal Wetland Assessment

MAWWG-Mid-Atlantic Monitoring and Assessment Wetland Workgroup

MidTRAM- Mid-Atlantic Rapid Assessment Method

NJDEP-New Jersey Department of Environmental Protection

NWMAWG-National Wetlands Monitoring and Assessment Workgroup

PADEP- Pennsylania Department of Environmental Protection

PDE: Partnership for the Delaware Estuary

QA- Quality Assurance

QAPP- Quality Assurance Project Plan

RAM-Rapid Assessment Method (Tier 2 studies)

RQ – Random Quadrat

SOP-Standard Operating Procedure

SQ – Systematic Quadrat

SSIM – Site-Specific Intensive Monitoring (Tier 4 studies)

STAC-Science and Technical Advisory Committee, part of PDE

Appendix C: SET Data Form

Wetland Surface Elevation Technology Data Entry Form

Location Contact Info.

Site Plot Vegetation Community

Other Site Descriptors 1) 2) 3)

Northing (DDMMSS.SS) Easting (DDMMSS.SS) Elevation (m)

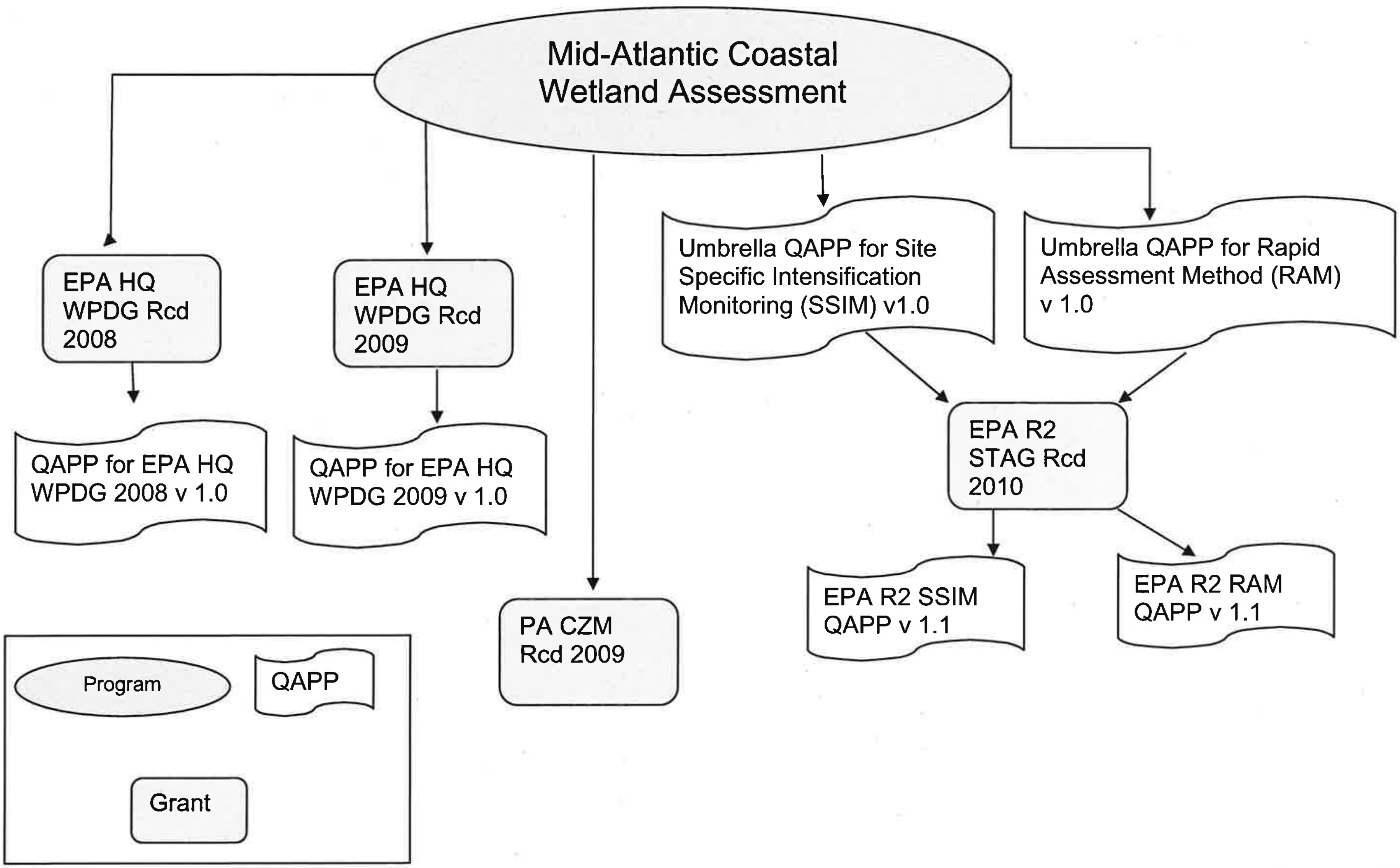
SET Instrument Vertical Offset (m) Tilt Angle (deg.)

Operator Date (mm/dd/yy)

Position Pin Pin Height (XX.X cm)

Comment Please indicate if SET reading is suspect for any reason (explain in notes, below)
Notes

Appendix D: Project List and Flow Chart



Project Management and Objectives Elements

1.1 Quality Assurance Project Plan Approval Sheet

Program Title: Intensive Monitoring and Assessment Program for Tidal Wetlands of Delaware, New Jersey and Pennsylvania, Version 1.0 (MACWA SSIM Umbrella QAPP V1.0)

Project Title: Development and Implementation of an Integrated Tidal Wetlands Monitoring and Assessment Program in the Barnegat Bay and Delaware Estuaries (New Jersey – Coastal Plan Region.) (MACWA SSIM R2 QAPP 1.1)

Note: QAPP Nomenclature. Any future modifications to the Version 1.0 Umbrella QAPP for MACWA SSIM (site specific intensified monitoring) efforts will require approval and necessitate renaming as new versions (e.g. 2.0, etc.) Addendum QAPP's for projects will be sequentially referenced as Version 1.1, 1.2, etc. in line with the most current version of the umbrella QAPP. The QAPPs for MACWA SSIM efforts (Tier 4 studies) are not to be confused with separate QAPPs for MACWA Rapid Assessment Methods (Tier 2 studies.)

Organization names: Partnership for the Delaware Estuary & Barnegat Bay Partnership

Effective date: September 1, 2010[1]

Approval:

Project Start Date: September, 1, 2010

Project End Date: December 31, 2013

Project Manager &: QA Officer
______________________________ Date: ________
Danielle Kreeger, PhD, Science Director
Partnership for the Delaware Estuary

______________________________ Date: ________
Martha Maxwell-Doyle, Project Coordinator
Barnegat Bay Partnership

EPA Project Officers:
______________________________ Date: ________
Kathleen Drake
EPA Wetland Protection Team, USEPA Region 2

EPA QA Officers:
______________________________ Date: ________
Donna Ringel
EPA Region 2

NJ DEP
______________________________ Date: ________
Mark Ferko
NJ DEP Office of Quality Assurance

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[1] Effective date may be changed to reflect the date of signature of agreement between EPA HQ, EPA Region 2, and the Partnership