August 21, 2019
PEP TAC and Monitoring Leads Working Session
Summary

On August 21, 2019 the Peconic Estuary Program Technical Advisory Committee (PEP TAC) and water quality monitoring leads met in a joint working session to review and provide recommendations on two elements of the ongoing assessment of the Program's water quality monitoring strategy:

- Communicating water quality monitoring results to decision-makers and the public, and
- Linking monitoring activities to water quality-related objectives identified in the Program's updated (2019) CCMP.

Click here for CoastWise's presentation

- ➢ Draft Report from CoastWise Partners (attached) addressing:

1. Tracking progress towards CCMP water quality objectives
2. A summary of monitoring-related recommendations

Working session participants are identified in the sign-in sheet (attached). CoastWise Partners (CWP) provided background information for discussion prior to recommendations from the working session participants. The following is a summary of the recommendations provided for each element.

Session 1: Communicating water quality monitoring results
Objectives of this session were to

- Assess how to integrate monitoring information to help 'tell the story' of the Peconic Estuary status, trends and progress toward water quality-related goals;
- Identify elements of effective communication for target audiences (technical, interested public, and decision-makers); and
- Review examples from other coastal management programs and solicit input and recommendations from session participants.

Following presentation of an example of 'telling the story' from Tampa Bay, key elements of effective communication of the Peconic Estuary Story were assessed:

- Have target resources been identified? Yes. The PEP online survey that is currently underway is identifying clear water to support eelgrass, and open shellfish beds and swimming beaches, as important resources;
- Is there community buy-in? Yes. The public and local decision-makers recognize the importance of good water quality, and PEP partners are willing to work together on collaborative actions;
- Have science-based goals and targets been identified? Yes, partially. A TMDL addressing DO impairments is in effect, and some eelgrass-related water quality targets have been proposed;
- Is there an adequate long-term monitoring program in place? Yes, in large part. Some information gaps exist, however, which are discussed in Session 2 below;
- Is there a recognized 'convener'? Yes, PEP fills that role. Regular analysis of monitoring data and communication of results to decision-makers and the public need to be strengthened, however; and
- Have the economic values of a healthy bay been communicated to the local community? Not recently, but there is interest in doing so.

Following a presentation summarizing the ways monitoring results are used to help guide water quality management activities in Tampa Bay, Chesapeake Bay and the Gulf of Mexico, CWP provided several suggestions for the TAC and monitoring program leads to consider in 'telling the Peconic story':

- Focus on a limited number of target resources for annual reporting and for 'telling the story'. From the PEP online survey that is currently underway, 'clear water', 'supporting eelgrass recovery' and 'reducing HABs' are strong frontrunners. Open/closed shellfish beds and swimming beaches are important issues for users of those resources;
- Existing monitoring and reporting activities for shellfish beds and swimming beaches are adequate. Measurable, numeric water quality targets have been defined;
- To define 'clear water adequate to reduce HABs', use information included in the Suffolk County (2017) HAB Action Plan, the (2019) draft Subwatersheds Wastewater Plan and other resources to develop interim nutrient loading and/or water quality targets appropriate for reducing the frequency/severity/duration of HABs. Continue research on factors that stimulate or inhibit HABs in the Peconic Estuary and refine the water quality targets as additional information becomes available. Report annually the extent (acreage) and location (spatial distribution) of areas that do and do not meet target values;
- To develop measurable targets for 'clear water to support eelgrass habitat', use information from the PEP eelgrass bio-optical model that is currently being developed, the Suffolk County Subwatersheds Wastewater Plan (once finalized) and other relevant sources to define water quality targets adequate to support recovery and protection of eelgrass and other resources. Some potential examples include:
    - % light penetration (to bay bottom or to eelgrass leaf surface)
    - Chl *a* concentration (ug/l)
    - TSS concentration (mg/l)
    - Annual TN load (kg or metric tons/year)
    - TN concentration (mg/L)
    - Water temperature (^{o}C)
    - Sediment organic matter (%)
    - Sediment porewater sulfide concentration (mM)
- Once the numeric habitat suitability targets are developed, report the annual extent (acreage) and spatial distribution of target attainment and non-attainment in each waterbody segment identified by the bio-optical model. Track annual results over time, compared to adopted acreage targets for each segment.

Working session participants provided ideas and input on elements for a 'Peconic Estuary Story', including:

- Consider updating an economic valuation, to demonstrate the economic value of the Peconic Estuary. Include factors such as shoreline stabilization benefits, real estate values, job creation.
- Public interests are important factors to consider when identifying priority resources and setting targets; consider the 'what's in it for me' aspects
- Water temperature also appears to be a big factor in eelgrass management. Not just a water clarity issue.
- Public communication – talk about nutrient load reduction efforts and the potential for water quality improvement, don't promise specific outcomes (e.g., eelgrass recovery)
- Importance of social marketing in residential fertilizer management
- LISS incorporates macroalgal monitoring in citizen monitoring programs

- Show how WQ conditions change over time (public outreach)
- Importance of N loads entering bay via groundwater (an information gap at present)
- Clear water, reduced HABs, reduced macroalgae as potential WQ-related targets;
- Finfish (recreational) are also of interest to residents – but many of those species are migratory. Focus on resident species that may be more responsive to local water quality improvements?
- No monitoring of macroalgal biomass at present; how to include in monitoring and target setting? And how to engage public on the issue (as a water quality indicator). Reducing harmful and nuisance algae.
- Macroalgae more of an issue in better-flushed areas
- How to set water quality targets for shellfish production? They may prefer higher chl-a values than seagrass does. (But shellfish harvesting area closures due to FIBs and HABs are also an issue)
- Higher trophic levels (species that feed on phytoplankton, zooplankton, baitfish, etc.) should also be considered when setting chl-a targets.
- Social marketing and rainy-season fertilizer bans as potential management tools
- Bio-optical model has identified eastern and western eelgrass management areas. Water temperature an issue in western portion of system. Set different water clarity targets for the two areas?
- Use the zones identified in SWP, rather than or in addition to the bio-optical model segments, when setting targets for eelgrass habitat suitability?

RECOMMENDATIONS from TAC/Monitoring Leads for Management and Policy Committee consideration on communicating water quality monitoring results:

- Provide input on conceptual 'Peconic Estuary timeline story' based on priority resources identified by the Online Survey: clear water adequate to support eelgrass recovery and reduce HABs
- Focus on clear water, reducing HABs and macroalgae in public outreach
- Form TAC workgroup(s) to develop numeric targets for:
    - eelgrass habitat suitability (acres);
    - water quality metrics adequate to support eelgrass recovery and other resources;
    - water quality metrics adequate to reduce HABs and macroalgae
- Continue to evaluate other factors affecting eelgrass recovery (research element)

Additional recommended actions for Policy and Management Committee consideration:

- Charge TAC, CAC and staff to develop a draft Peconic Estuary Storyline presentation by [date], for review by the Management Committee and approval by the Policy Committee.
- Charge CAC and staff to assess the efficacy of a citizen monitoring program for shoreline macroalgae by [date], for review by the Management Committee and approval by the Policy Committee.
- Request TAC, CAC and staff keep the Policy and Management Committees informed of progress on the Storyline, citizen monitoring and TAC workgroups on a [quarterly?] basis.

Session 2: Using water quality monitoring data to track progress towards the management objectives of the updated (2019 draft) CCMP

Objectives of this session were to

- Review how data from the existing monitoring programs can be used to track progress on management objectives;

- Identify data gaps that will need to be filled to allow tracking;
- Outline options and steps that may be needed to fill these gaps.

Following a presentation outlining how monitoring data can be used to support management decisions, and a review of water quality-related objectives that are included in the draft CCMP, CWP suggested priorities for additional monitoring that will be needed to track progress toward those objectives:

- Annual nutrient loads delivered to the estuary via surface and groundwater;
- Transport of legacy nutrients in groundwater;
- Integration of water quality and eelgrass monitoring; and
- Water quality conditions in diadromous fish habitat.

Monitoring needs for key water quality-related draft CCMP objectives were reviewed and discussed as follows.

CCMP Objective WQ-1: Substantially reduce present-day and future sources of nutrient pollution in the watershed.

Information needed to track progress includes annual nutrient loads to the estuary from major source categories (e.g., atmospheric deposition, groundwater inflows, surface water inflows) and sub-categories (e.g., domestic wastewater; stormwater discharges from different land use categories).

Information not provided by existing monitoring programs include annual nutrient loads delivered via the Peconic River, and annual nutrient loads delivered via other surface and groundwater flows.

In order to fill gaps in the existing monitoring strategy, recommend consideration to:

- Initiate monitoring of nutrient concentrations at the USGS streamflow gage on the Peconic River. Sampling design should support high-confidence estimation of annual nutrient loads (e.g., of TN and any other nutrient forms of concern) at that location.
- Initiate a watershed-scale groundwater monitoring program adequate to support high-confidence estimation of annual nutrient loads delivered to the estuary via other groundwater inflows. The groundwater monitoring program could also be designed to help with calibration and verification of the groundwater solute transport model that is currently under development by USGS, and to provide cross-checks for groundwater loading estimates produced for the County's Subwatersheds Wastewater Plan.

TAC discussion:

- Including nutrient concentration data collection at new or existing groundwater wells would be priority.
- Adding water quality measurements at the Peconic River USGS streamflow gage, where continuous flow measurements are already being collected, would be a relatively inexpensive way to quantify nutrient loads from surface and groundwater at that location. An example of "low-hanging fruit."
- There is a need to have information on groundwater discharge, and estimates of delivery at the shoreline and offshore. As a first step, identify specific areas where higher groundwater discharge is occurring. Better quantification of N attenuation rates is also needed.
- Now is a good time to initiate a groundwater monitoring program and complete the picture of groundwater nutrient contributions. Monitoring data can be used to complement and serve as a cross-check for the new County and USGS groundwater models.

CCMP Objective WQ-2: Manage existing, historic nutrient loads in the groundwater that could enter the estuary.

Information needed to track progress include that needed for WQ-1, plus existing nutrient concentrations in groundwater plumes impacted by legacy sources and future changes in those plumes. Existing monitoring programs do not provide the information needed to track progress toward this objective. The USGS solute transport model that is currently under development is expected to be an important tool for managing the existing plumes. Monitoring data would be helpful for model calibration and verification.

In order to fill gaps in the existing monitoring strategy, CWP recommend consideration of the following:

- Initiate a groundwater monitoring program sufficient to map the size and location existing plumes from legacy sources, calculate the masses of nitrate-N and ammonium-N in the plumes, and create a gridded database suitable for use in the nitrogen-transport simulations.
- As for WQ-1, design the monitoring program so that it provides data that can be used to assist in the calibration and verification of the groundwater solute transport model that is currently under development.

CCMP Objective HE-3: Improve water quality to increase habitat suitability for eelgrass

CWP recommendations:

- Integrate surface water quality and eelgrass monitoring programs, to ensure that areas within the estuary that are suitable and unsuitable for eelgrass colonization and growth can be identified and mapped
- Once completed, the Peconic bio-optical model should be a helpful tool for designing updated monitoring and mapping efforts.
- Monitoring and mapping data can also be used to cross-check and update the model.
- Consider adding all the parameters identified in the bio-optical model, including CDOM, to the existing water quality monitoring program.

TAC discussion:

- If frequent collection of PAR data is too time-consuming for field crews, consider developing a relationship between PAR and Secchi disk depth, and then use Secchi if the relationship is strong enough.

CCMP Objective HE-6: Maintain, restore and enhance viable diadromous fish spawning and maturation habitat.

CWP recommendations:

- Initiate monitoring of water quality conditions relevant to diadromous fish habitat, such as DO, pH and water temperature in freshwater tributaries during periods when sensitive life stages are present.
- The SCDHS Point Source and Stream monitoring program currently includes each of these water quality parameters, but its sampling network was not designed to provide information on diadromous fish habitat. The timing and locations of its sampling sites may need to be modified to make them more applicable to this CCMP objective.

TAC discussion:

- Form a separate TAC workgroup with freshwater focus to develop recommendations
- Consider including sensors for temperature, DO and pH at all continuous monitoring sites? How important is this for continuous monitoring, or would seasonal or quarterly be adequate?
- May be helpful to identify the benefits for the public, to build support for additional monitoring.
- It is anticipated that one or more ecosystem simulation models will be developed by Stony Brook University. May be possible to develop elements addressing diadromous fish species, using the state's Fisheries Independent Monitoring trawl data.

NEXT STEPS for these objectives:

- Establish work group(s) within the TAC to develop specific recommendations on design and implementation of additional monitoring efforts
- Develop numeric, living resource-based water quality targets for these objectives.
- Consider focusing on meaningful targets for management and the public as priorities. Nutrient and temperature thresholds for HABs, for example. For HAB monitoring: PAR, temperature and continuous monitoring to identify algal types. USGS, DEC and other partners. Encourage the Governor's HAB Initiative to provide a monitoring platform in the Peconic.
- Develop recommendations for how to synthesize and integrate data to address CCMP Objectives.
- A QAPP will be needed for DEC monitoring and analysis.

Water Quality Monitoring
in the Peconic Estuary Program Area:
Linking Monitoring Activities to CCMP Objectives

August 21, 2019 Workshop Background Material & Worksheets

DRAFT – August 12, 2019

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BACKGROUND

The Peconic Estuary Program (PEP) and its partners are currently updating their Comprehensive Conservation and Management Plan (CCMP) for the estuary and its watershed. As part of the CCMP update the participants also wish to evaluate and update their water quality monitoring strategy. PEP and its host agency, the New England Interstate Water Pollution Control Commission (NEIWPCC), selected CoastWise Partners (CWP) to assist in that process.

The primary purposes of the PEP monitoring strategy are to ensure that water quality monitoring efforts are aligned with the resource management objectives identified in the draft 2019 CCMP and provide the information needed to track progress towards those objectives. As noted by the National Research Council (NRC 1990, 2000), the monitoring done to support coastal management programs should also make efficient use of available financial and human resources by streamlining monitoring efforts, encouraging cooperation and collaboration between monitoring programs, and eliminating unnecessary duplication of effort wherever possible.

As two initial steps in evaluating the existing monitoring strategy, PEP and CWP developed a summary of the water quality monitoring programs that are currently active in the estuary and its watershed and organized two workshops, including the PEP Technical Advisory Committee (TAC) and representatives of the existing monitoring programs, to solicit those groups' recommendations on two issues:

- the types of monitoring data and other information that will be needed to track progress toward CCMP objectives; and
- any modifications to the existing monitoring programs that may be needed to provide the needed data.

Those steps were summarized in two previous reports (CWP 2019a and 2019b), which are available upon request from the PEP program office.

The next step in the monitoring strategy development is to evaluate whether existing monitored water quality parameters are adequate to assess water quality objectives identified in the draft 2019 CCMP. The monitoring partners will be holding a workshop (scheduled for August 21, 2019) to:

- identify information gaps and redundancies (if any) in the existing monitoring strategy;
- prioritize the information gaps/redundancies that have the greatest potential impact on the partners' ability to track progress toward CCMP goals;
- identify potential alternative indicators; and
- begin the process of identifying which local and regional partners need what types of data, analyses and information from the monitoring program, and the frequencies, scales, and levels of detail that are needed in the reporting process.

The background material below provides a synthesis of the information collated in the initial two steps of this project, addressing interconnections between existing CCMP objectives and priority management issues, the environmental indicators selected to assess progress toward the objectives, the water quality parameters currently being monitored, and potential information gaps in the existing monitoring strategy.

Monitoring partners and other TAC members are encouraged to review this material, particularly the summary information on pp. 16-20, prior to the August 21 workshop and be prepared to provide suggested edits and other input during the meeting.

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CCMP OBJECTIVES INVOLVING WATER QUALITY MONITORING:

The current (April 2019) draft of the updated Peconic Estuary CCMP includes six water quality objectives that address the priority management issue of Clean Waters and Watersheds:

- Objective WQ-1: Substantially reduce present-day and future sources of nutrient pollution into the Peconic estuary watershed.
- Objective WQ-2: Develop and implement strategies to manage existing, historical nutrient loads presently in groundwater that could enter the Peconic estuary.
- Objective WQ-3: Reduce harmful algal blooms (HABs) in the Peconic estuary.
- Objective WQ-4: Reduce pathogen loading to the Peconic estuary.
- Objective WQ-5: Maintain and protect existing high-quality waters.
- Objective WQ-6: Understand various types of toxic contaminants and their impacts, and work to address current and emerging concerns.

The draft CCMP notes that these objectives are guided by three principles:

- protect areas with good water quality from additional pollution loadings (even if incremental increases in loadings from new developments or other activities might not themselves immediately cause poor water quality);
- reduce pollution loadings in areas where water quality is declining; and
- remediate areas where water quality is already poor.

Other PEP management priorities, such as Healthy Ecosystems with Abundant, Diverse Wildlife (HE), and Resilient Estuary Communities Prepared for Climate Change (CC), also include objectives that involve water quality, either directly or indirectly. These include:

- Objective HE-3: Improve water quality to increase habitat suitability for eelgrass and establish new or restored eelgrass beds.
- HE-4: Maintain existing high-value wetland areas, restore degraded areas, and improve wetland habitat using best management practices and adaptive management.
- Objective HE-6: Maintain, restore and enhance viable diadromous fish spawning and maturation habitat.

- Objective CC-3: Develop strategies to understand and address ocean acidification.

As summarized in CWP (2019a), a very robust network of water quality monitoring programs is currently present in the Peconic estuary and watershed, carried out by a combination of local, state and federal government agencies, university researchers and NGOs. The following sections assess ways the data provided by those programs can be used by the PEP partnership to track the progress that is being made toward meeting the 10 objectives listed above, and any information gaps that may prevent the partners from tracking progress on those objectives.

Objective WQ-1: Substantially reduce *present-day and future* sources of nutrient pollution into the Peconic estuary watershed.

Tracking progress toward achieving this objective will require regular monitoring of groundwater quality, in addition to the monitoring of fresh, estuarine and marine surface water that is currently being done by the Suffolk County Department of Health Services (SCDHS), New York State Department of Environmental Conservation (NYSDEC), U.S. Geological Survey (USGS) and other organizations. Nitrogen has been identified as the major nutrient of concern for the area's estuarine and marine waters, and nitrogen-related eutrophication has been associated with harmful algal blooms (HABs), hypoxia-related water quality impairments, fish kills, and the loss of critical estuarine habitats such as eel grass beds (PEP 2019). Because the PEP partners wish to track nutrient contributions from individual source categories, such as atmospheric deposition, point source discharges, and non-point discharges from undeveloped, residential, commercial and agricultural land uses, measurements or estimates of annual nitrogen loads (based on discharge volumes and nitrogen concentrations) from each of those source categories will also be needed.

An example of the amounts and types of monitoring data and other information that are typically required for this type of tracking is provided by the nitrogen TMDL that was developed by PEP for the program's study area in 2007 (PEP 2007). It relied on the following:

- Water quality data from the SCDHS surface and groundwater monitoring programs;
- Estimates of average groundwater nitrogen concentrations associated with different land use categories (e.g., agricultural, recreational, residential [sewered and unsewered] and undeveloped land);
- Estimates of nitrogen loads delivered by eight tributaries (Meetinghouse, Terry's, Sawmill, Birch, Mill and Hubbard creeks, and the Little and Peconic rivers);
- Discharge monitoring data from three sewage treatment plants (Sag Harbor, Shelter Island Heights and Riverhead STPs) and the Riverhead Aquarium;
- Estimated loads from other facilities, including the Brookhaven National Laboratory, the former Naval Weapon Industrial Reserve Plant, and Plum Island STPs;
- Estimated loads via wet and dry atmospheric deposition, using data provided by the National Atmospheric Deposition Program (NADP);
- Estimates of nitrogen loads in stormwater runoff, both from regulated municipal (MS4) stormwater management systems and from unregulated stormwater conveyances;
- Estimated historical (pre-European settlement) and potential future land use scenarios, and estimated changes in point and non-point source loads associated with those scenarios;

In order to evaluate progress on Objective WQ-1 it will be necessary to update and track estimated annual nitrogen loads to the estuary on a regular basis, preferably every three to five years. The nitrogen-related parameters currently being monitored by the SCDHS surface water program, which include total and dissolved N, ammonia N, and nitrate + nitrite N, appear appropriate and sufficient for this purpose. The NADP program also includes all the necessary reactive N forms present in atmospheric deposition. In terms of gaps in the existing water quality monitoring strategy, during the May 29th workshops (summarized in CCWP 2019b) and in subsequent conversations participants noted the following concerns:

- Comprehensive and consistent monitoring of nitrogen concentrations in groundwater needs to be initiated as soon as possible, by establishing and funding a baseline groundwater monitoring network and sustaining it through time. Although a large number of groundwater monitoring wells are present in the watershed, funding has not been available for consistent and sustained collection and analysis of water samples from those wells;
- Nitrogen loads to the estuary from the Peconic River watershed, which discharges a combination of surface and groundwater, could be quantified more accurately by resuming regular water quality monitoring at the USGS stream gage, located just downstream from Peconic Bog County Park. Ideally, water quality at the gage site would be sampled in a way that accurately characterizes constituent concentrations throughout the water column, both vertically and horizontally, at the stream cross-section where flow is measured. For accurate estimation of annual loads, the timing and frequency of sampling would also need to be designed to capture the full range of flow conditions that occur at the gage site over an annual period;
- The overall PEP monitoring strategy also needs to support quantification and tracking of the large seasonal changes in human population size (and associated nutrient loads) that occur in the watershed each year; and
- Accurate and up-to-date land use/land cover data and maps are crucial for estimating nonpoint-source loads.

With respect to groundwater nitrogen loads, the future availability of a groundwater solute transport model that is currently being developed for the PEP study area by the USGS (2019) should improve the accuracy and reduce the uncertainties of subsequent loading estimates. Based on modeling work recently conducted by the USGS in the geologically similar area of Cape Cod, the objectives of the project include: 1) developing data sets representing current and historic land uses relevant to nitrogen loading in coastal watersheds, 2) incorporating these data as source terms in models capable of simulating transport processes to estimate current estuarine loading rates and nitrogen concentrations in the aquifer, and 3) using these current-condition models to simulate the response of estuarine loading rates to possible wastewater-management actions carried out at a regional scale (USGS 2019).

The USGS is also collaborating with the Central Pine Barrens Joint Planning and Policy Commission to implement a comprehensive water resources monitoring program for the Central Pine Barrens Region (CPB; https://www.sciencebase.gov/catalog/item/59e8d498e4b05fe04cd50cfe). The surface and groundwater monitoring components of that project could perhaps be used as a template for designing future monitoring programs in other parts of the Peconic Estuary watershed.

Barusich (2013) provides a relatively recent overview of the SCDHS and USGS groundwater monitoring wells that are available in the watershed, and a summary of reports that have been developed using hydrologic and water quality data from those wells.

While nitrogen is the major nutrient of concern for estuarine and marine waters, fresh waterbodies such as lakes, streams and freshwater wetlands tend to be equally or more sensitive to phosphorus (P) loadings. Cyanobacterial blooms for example, which occur frequently in Suffolk County's fresh waterbodies (Hattenrath-Lehmann and Gobler 2016), are known to occur more frequently in waters enriched with P and N (Paerl and Otten 2013). Thus, if the PEP partners wish to track status and trends in nutrient loads to fresh waterbodies as part of Objective WQ-1, phosphorus forms (e.g., total P, dissolved organic and inorganic P) will also need to be included in the monitoring effort. SCDHS and the NYSDEC RIBS program currently include some P forms in their surface water monitoring programs (see CWP 2019a). If P forms are not typically transported in groundwater in the study area, they would not need to be included in the groundwater monitoring effort. Ullman et al. (2010) describe methods for estimating atmospheric P deposition.

Objective WQ-2: Develop and implement strategies to manage existing, historical nutrient loads presently in groundwater that could enter the Peconic estuary.

Tracking progress on this objective will require the same information on groundwater nitrogen loading to the estuary that will be used for objective WQ-1 and can be done as part of the same estimation and tracking process. The monitoring needs and modeling opportunities identified for WQ-1 also apply here.

During the May 29th workshops, the participants also made the following points regarding monitoring needs for this objective:

- Previous studies of legacy sources have identified the locations of several groundwater flowpaths (e.g., for nitrogen and agricultural chemicals from the North Fork) that should be re-examined to detect changes in constituent concentrations in those flowpaths over time; and
- Much of the previous groundwater monitoring has focused on drinking water issues, and existing monitoring wells thus tend to be located in inland areas. To better address estuary management issues, it would be helpful if the monitoring network could be extended to provide data from additional locations, including the hyporheic zone in streams and the estuary.

Objective WQ-3: Reduce harmful algal blooms (HABs) in the Peconic estuary.

Hattenrath-Lehmann and Gobler (2016) provided the following summary of HABs in Suffolk County:

> "The spatial and temporal expansion and increased intensity of HABs is a globally recognized phenomenon and this expansion has already been observed in Suffolk County where HABs have become a human health, economic and environmental threat to local waters. While HABs were not reported in Suffolk County from 1954 – 1984, today, Suffolk experiences at least five types of HABs annually, a distinction potentially unmatched in the US. Brown tide (*Aureococcus*) have occurred across the east end and south shore and caused and/or contributed to the demise of these once thriving fisheries. Freshwater toxic cyanobacteria blooms have occurred in more than two dozen lakes across the County. Rust tides caused by the dinoflagellate *Cochlodinium polykrikoides* occur in late summer within Shinnecock and the Peconic Estuary. Paralytic shellfish poisoning (PSP) due to the dinoflagellate *Alexandrium* and the presence of saxitoxin contaminated shellfish over federal regulatory limits has occurred more than a dozen times across six locations and shellfish contaminated with okadaic acid (diarrhetic shellfish poisoning [DSP] toxins) due to *Dinophysis acuminata* blooms have been found in multiple locations. Concurrent with these repeated occurrences of HABs have been the decline in shellfisheries and an increase in fish and animal kills associated with these HABs. These events have stimulated a need for action to protect our local waters."

Tracking progress toward objective WQ-3 will require continued monitoring of HAB organisms in Peconic waters, which is currently being conducted by SCDHS, NYSDEC and the Gobler Lab at Stony Brook University, and monitoring of HAB-associated biotoxins in shellfish tissue which is currently being conducted by NYSDEC in cooperation with SCDHS and other partners. During the May 29th workshops, participants noted the following:

- HAB monitoring needs to have the flexibility to detect new HAB species that may move into the area, and not just focus on species that have been detected in the past;
- In addition to monitoring, collaborative interdisciplinary investigations involving a broad range of expertise (e.g., academic and agency researchers, water quality modelers, resource managers) will be needed to improve abilities to predict, track and manage HAB blooms; and
- Most HABs currently present in the Peconic system are mixotrophic organisms, capable of photosynthesis and also acting as heterotrophs by taking up dissolved organic nutrients and/or practicing phagotrophy.

The presence of mixotrophic HABs may expand the list of water quality constituents that will need to be monitored in the future in order to understand bloom development and dynamics. The brown tide organism (*Aureococcus anophagefferens*) is reportedly an osmotroph, taking up urea, amino acids, acetamide, peptides and DON (Burkholder et al. 2008). *Cochlodinium polykrikoides* is reportedly phagotrophic, feeding on bacteria, cyanobacteria, cryptophytes and other algae, while *Alexandrium* species are known to utilize a combination of osmotrophy and phagotrophy (Burkholder et al. 2008). *Dinophysis acuminata* is also phagotrophic, reportedly feeding on the ciliate *Myrionecta rubra* (Burkholder et al. 2008). The HAB-forming cyanobacteria *Microcystis aeruginosa* and *Synechococcus spp.* are osmotrophs, taking up amino acids and urea as nitrogen sources (Burkholder et al. 2008). Many water quality monitoring organizations, such as SCDHS, have addressed this issue by including dissolved organic nitrogen (DON) in their list of analytes. Further research is required to determine whether other parameters may also need to be added to address organisms such as these that occupy multiple trophic levels.

The Suffolk County Harmful Algal Bloom Action Plan (Wise 2017) also provides several recommendations on additional HAB-related monitoring activities that could be considered in the Peconics:

- Suffolk County and the NYSDEC could institute routine monitoring for the presence of diarrhetic shellfish poisoning (DSP) toxin. Advanced monitoring technologies such as Passive Solid-Phase Adsorption Toxin Tracking (SPATT, water column) and the Abraxis Protein Phosphate Inhibition Assay (PP2A, shellfish meats) may be used by collaborating laboratories as an early warning sign to State and County agencies;
- Evaluate use of cutting-edge remote monitoring, modeling, buoys, and other in situ monitoring tools and technologies to detect the presence/abundance of toxic algal species in local waters;
- Develop an integrated HAB monitoring program, potentially including state-of-the-art imaging recognition technologies at sentinel sites, as is being done in Texas, California and Massachusetts; and
- Explore the possibility of citizen science monitoring for HABs, which is done at the national (Phytoplankton Monitoring Network), state (Maine, California, Florida), and regional (Puget Sound) levels. It would be necessary to provide training and put a standard operating procedure in place. Citizen monitoring can be used to achieve greater spatial and temporal sampling coverage than monitoring agencies may be able to support.

Objective WQ-4: Reduce pathogen loading to the Peconic estuary

Monitoring progress on this objective could be done in several different ways, providing information at different levels of detail and with substantially different costs. The simplest and least-costly approach would be to continue relying on existing monitoring programs that assess microbiological conditions at swimming beaches and shellfish harvesting areas. The largest of these are conducted by SCDHS and NYSDEC (see CWP 2019a). A smaller citizen monitoring program is also carried out by the Surf Rider Foundation/Blue Water Task Force which conducts sampling on a seasonal basis (weekly in summer, bi-weekly in spring and fall, monthly in winter) in fresh, estuarine and marine waters and at stormwater pond discharges.

These programs monitor levels of fecal indicator bacteria (FIB) such as fecal coliforms, *E. coli* and *Enterococcus*, which live in the intestinal tracts of warm-blooded animals and are introduced into the environment through fecal matter. Most FIB organisms are not pathogenic to humans, but their presence in water is an indication that fecal-associated pathogens may be present.

Methods for monitoring FIB have been used for more than 100 years to detect potential sewage contamination of drinking water and protect public health from waterborne bacterial diseases such as cholera and typhoid fever (NRC 2004). FIB monitoring has also been used for many decades in efforts to reduce health risks associated with recreational waters and shellfish harvesting areas. Epidemiological studies funded by EPA in the early 1970s indicated that elevated counts of *E. coli* and enterococci in water samples were correlated with gastroenteritis among swimmers in freshwater environments, while enterococci counts showed the highest correlations for waterborne illnesses in swimmers in estuarine and marine waters. Based on that information USEPA (2012) developed national water quality criteria for recreational waters using *E. coli* and enterococci as the preferred indicators. For shellfish harvesting areas, which are regulated by the FDA National Shellfish Sanitation Program (NSSP), the current bacteriological criteria are based on monitoring of total and fecal coliforms (NSSP 2015).

While FIB monitoring has been highly beneficial in reducing human health risks from waterborne bacterial diseases, the approach has limitations for other types of pathogens such as viruses and protozoans. FIB tend to have shorter survival times than many viruses and protozoan cysts and are inactivated more rapidly by exposure to sunlight or water purification processes. As a result, FIB counts are often poorly correlated (or uncorrelated) with pathogen levels in recreational waters or in highly treated (e.g., reclaimed) wastewater (e.g., Toze 1999, Hörman et al. 2004, Harwood et al. 2005, McQuaig et al. 2012).

FIB counts in water samples also provide no information on the sources of fecal contamination, such as humans, pets, agricultural livestock, birds and other wildlife, which can pose different levels of health risk to boaters, swimmers or consumers of shellfish (Girones et al. 2010). To help address this limitation, the NSSP protocols followed by NYSDEC staff who perform monitoring in shellfish harvesting areas also include periodic shoreline sanitary surveys to document potential pathogen sources. This provides an assessment of potential human health risks that is independent of in-water FIB counts. Like shellfish monitoring programs in many states, however, the NYSDEC program receives limited funding and is able to monitor only a fraction of the state's potential shellfish harvesting areas. NYSDEC currently has sufficient resources to monitor approximately 20 areas in the Peconics. If funding remains too low to allow monitoring of additional areas, many may remain closed to harvesting on a precautionary basis due to insufficient data rather than documented evidence of health risks.

In terms of monitoring technologies, more advanced alternatives or adjuncts to FIB sampling – such as microbial source tracking (MST) and molecular methods for detecting specific pathogens using polymerase chain reaction (PCR) techniques – are currently in various stages of development and deployment. They tend to be less standardized and more complex and costly to perform than FIB monitoring, however, and have not yet been widely adopted by water quality monitoring programs. NYSDEC, SCDHS and USGS are currently collaborating on a trial MST project for Suffolk County waters (https://www.usgs.gov/centers/ny-water/science/using-microbial-source-tracking-identify-pollution-sources-pathogen?qt-science_center_objects=0#qt-science_center_objects) that includes monitoring of FIB, host-specific *Bacteroides*, male-specific (F+) coliphage viruses, and stable isotopes of oxygen and nitrogen in surface and shallow groundwater to indicate pathogen source categories (e.g., humans, other mammals, birds) and estimate loads from each category. Stony Brook University staff are also collecting MST data in the watershed, using a different combination of source markers, on a biweekly basis. As these newer methods become more standardized and affordable, it should eventually be cost-effective to include them in a larger number of monitoring programs. Until that time, continued tracking of the frequency and areal extent of swimming beach and shellfish harvesting area closures based on the FIB approach appears to offer the most affordable option for tracking progress on this objective.

In addition to these points, participants in the May 29th workshops (see CWP 2019b) also noted that:

- Any monitoring that PEP helps fund must be done in compliance with an approved quality assurance project plan (QAPP). Other funding sources may not have that requirement. Program partners will need to discuss how/when/whether to use data not collected under a QAPP, and possibly consider a tiered approach for QAPPs that involve citizen monitoring; and
- There may be opportunities to work collaboratively with the NYSDEC Division of Water to develop an updated monitoring strategy for pathogen-related impairments. Waterbody segmentation is an example, where the PEP partnership could potentially coordinate with the state's 303(d) effort. The Priority Waterbodies List (PWL) delineations, available from the state, might be used as a basis for segmentation and assigning station locations. PEP partners might also consider integrating groundwater sub-basins with surface water segments to decide where monitoring stations should be located.

Objective WQ-5: Maintain and protect existing high-quality waters.

In order to track progress on this objective, high-quality waters will need to be identified and water quality status and trends in those waters will need to be monitored and reported on a regular (preferably annual) basis. The information that is tracked for objectives WQ-1 through WQ-4 can be used to assess nutrient loads, and the frequencies and magnitudes of HABs and closures of swimming beaches and shellfish harvesting areas (objectives WQ-3 and WQ-4) can be used to track those water quality issues. Information used to track progress on objectives WQ-6 (toxic contaminants), HE-3 (healthy seagrass beds), HE-4 (wetland condition), HE-6 (diadromous fish habitat) and CC-3 (coastal acidification) can also be used.

Several sources of information are available to help identify high-quality waters, such as the State's Priority Waterbodies List (https://www.dec.ny.gov/chemical/36748.html) and its list of impaired and non-impaired waterbodies (https://www.dec.ny.gov/chemical/31290.html), both of which are maintained by NYSDEC. The Federal Clean Water Act requires states to periodically assess and report on the quality of waters within their jurisdiction, and Section 303(d) of the Act requires them to identify waters whose quality fully meets their designated uses (such as drinking water supply, swimming, boating, fishing and shellfish harvesting), and those whose quality is impaired to the point that designated uses are not being fully met. The NYSDEC lists represent New York State's efforts to comply with those federal requirements.

Participants in the May 29th monitoring workshops offered the following suggestions regarding this objective:

- Additional monitoring needs to be directed towards the embayments within the Peconic Estuary, whose water quality may differ from the main stem areas where much of the current monitoring occurs;
- Digital infrared aerial photography could be used in spring and fall to help track groundwater discharge points by detecting differences in water temperature;
- Stable isotope analyses of reactive nitrogen forms (e.g., ammonia-N, nitrate-N) could be used to help identify and quantify the sources of nitrogen loads such as fossil fuel combustion, fertilizer, wastewater, livestock and wildlife, and internal cycling from sediments; and
- Additional atmospheric deposition monitoring could be considered in the watershed, to help quantify atmospheric nitrogen loads that may be contributed by nearby urban areas such as New York City.

In order to achieve this objective it may also be desirable for the PEP partners to develop a specific set of actions that will be taken by different components of the Management Conference (particularly the Technical Advisory Committee, Management Committee and Policy Committee) when water quality degradation is detected in a high-quality waterbody. The Tampa Bay Estuary Program (TBEP) uses this approach to guide management responses to water quality problems that arise in different portions of its project area, and has found it quite helpful for ensuring that all members of the management conference are aware of their responsibilities when water quality challenges are encountered. The methods used by the TBEP are summarized in Appendix A.

An approach like this could potentially be used by the PEP partners to track progress toward protecting water quality in areas where it is currently high. Baseline water quality levels for key parameters such as nutrient and chlorophyll-a concentrations, turbidity, total suspended solids (TSS), water clarity and light attenuation could be set based on existing values, and deviations from the baseline levels could be tracked on an annual basis using ongoing monitoring data. A decision matrix could be used to identify actions that will be taken by the Management Conference in areas where varying degrees of water quality declines are detected.

Objective WQ-6: Understand various types of toxic contaminants and their impacts, and work to address current and emerging concerns.

This appears to be a research-oriented rather than a monitoring-oriented objective, although existing toxics monitoring programs may need to be adjusted to include the contaminants of greatest management concern. If so, the nutrient monitoring in surface and groundwater addressed for Objectives WQ-1 and WQ-2 could potentially be expanded to include toxic constituents of concern.

With respect to this issue, participants in the May 29th monitoring workshops noted that:

- SCDHS and USGS have done a great deal of monitoring in the past for contaminants such as pesticides and industrial chemicals, as well as emerging contaminants such as personal care products. There is thus a wealth of surface and groundwater monitoring data and expertise that can be tapped for work on this objective;
- Other potential partners, such as the Suffolk County Water Authority, could also be encouraged to participate;
- Numerous groundwater flowpaths have been identified and sampled in the past for toxic contaminants. These should be monitored going forward to track temporal changes in constituent concentration and spatial changes in individual groundwater plumes; and
- In addition to monitoring concentrations of contaminants in surface and groundwater, the program also needs to consider impacts on living resources, such as seagrasses, shellfish, finfish and other organisms.

Objective HE-3: Improve water quality to increase habitat suitability for eelgrass and establish new or restored eelgrass beds.

Eelgrass (*Zostera marina*) beds provide essential habitat for many ecologically and commercially important fish and shellfish species, and historically played key environmental and economic roles in the Peconic estuary system. Over the past 100 years, however, eelgrass acreage has declined precipitously in the Peconics, in New York State's other coastal waters and throughout the species' range along the U.S. east coast. In recent decades much of the decline has been attributed to a combination of anthropogenic factors including: excessive nitrogen loading and eutrophication, leading to increased turbidity and lower light availability to underwater grasses; warmer water temperature associated with global climate change; and physical disturbance from boating impacts and some shellfish harvesting practices (Pickerell and Schott 2015, Simpson and Dahl 2018). SAV are also sensitive to contaminants such as herbicides, with impacts for some species from some compounds reported at ppb concentrations (Kemp et al. 1985).

Eelgrass beds in the Peconic Estuary were heavily impacted by an incompletely understood "wasting disease" in the 1930s, and again by brown tide blooms in the 1980s and 1990s that greatly reduced water clarity and light availability (PEP 2015). Although turbidity and water clarity levels have improved since the 1990s, and efforts have been made to re-establish beds in a number of locations, areal eelgrass cover and shoot densities in the Peconics have continued to decline (PEP 2015). Research indicates that conserving existing eelgrass beds and establishing new ones will be most successful if there is adequate water quality and clarity, minimal physical disturbance and manageable levels of grazing by waterfowl such as mute swans and Canada geese (Pickerell and Schott 2015).

Gobler (2007) provides the following overview of water quality and potential eelgrass habitat:

> "The Peconic Estuary contains strong gradients in depth and water clarity, with the western extreme of the estuary being shallow (2 – 3 m) but turbid and the eastern portion of the estuary being clear but deep (15 – 20m). As a consequence, Flanders Bay to the west is the only sub-estuary which likely receives > 20% of surface irradiance throughout its benthos. Eastern basins of the Peconics (Great Peconic, Little Peconic, Gardiners Bay) have levels of irradiance high enough to support eelgrass growth in their shallow, nearshore regions only."

In order to track progress on Objective HE-3, water quality conditions necessary to maintain existing eelgrass beds and establish new beds will need to be quantified, and the key water quality parameters that determine habitat suitability will need to be monitored in areas where viable eelgrass beds could potentially be maintained or restored. Fortunately, the water quality requirements of eelgrass have been thoroughly studied in the northeastern U.S. (e.g., Dennison and Alberte 1985, Dennison et al. 1993, Batiuk et al. 2000, Kemp et al. 2004, Kenworthy et al. 2014) and water quality targets have been developed for Long Island Sound (LISS 2003), Chesapeake Bay (Kemp et al. 2004) and the Peconic Estuary (PEP 2015). A subset of those targets is summarized in Table 1.

It appears likely that maintaining water quality at levels that have been documented to support existing eelgrass beds will prove to be a necessary but not sufficient condition for restoring eelgrass cover in the Peconic Estuary. Numerous studies (reviewed by Kenworthy et al. 2014) have shown that seagrasses growing in more eutrophic conditions can have water clarity and light requirements that are substantially higher than those in less eutrophic sites, possibly due to a number of physiological mechanisms related to sediment quality such as:

- Reduced light utilization efficiency due to increased plant respiration, impacted carbon balance and increased compensation points in areas with higher organic loadings and sediment organic content;
- Increased sulfide and ammonium toxicity, and increased anaerobic fermentation in roots leading to increased production of toxic compounds in more eutrophic areas; and
- Greater light attenuation by resuspension of fine sediments in shallow-water areas, or by epiphytes/ macroalgae on seagrass leaves, than might be predicted based on ambient water quality monitoring data.

Kenworthy et al. (2014) note that, if such sediment-related issues are present at a site, recovery of eelgrass may be delayed for a decade or more following nutrient load reductions while the system "processes the accumulated stores of sediment organic carbon and becomes more suitable for eelgrass growth."

Given the documented complexities involved in protecting and restoring eelgrass cover in estuaries with nutrient-impacted water quality, long-term success will apparently require an adaptive management approach that integrates consistent and well-designed water quality and SAV monitoring programs with effective management of anthropogenic nutrient loads . Remediation efforts involving transplanting or seeding have had variable levels of success in most geographic areas, indicating that site selection must be done carefully to identify locations where those techniques have the highest probabilities of succeeding (REFS). PEP is currently working to develop a calibrated bio-optical model that should be helpful in that regard.

Table 1. Water quality targets suggested for eelgrass management in various geographic areas.

Water quality parameter	Long Island Sound[a]	Peconic Estuary[b]	Chesapeake Bay[c]
Light attenuation coefficient, K_d (m^{-1})	<0.7 (annual)	0.75 ± 0.05 (annual)	<2 (growing season)
Light transmission (% of subsurface irradiance)			>22 (growing season; % light through water column) >15 (growing season; % light through water + epiphytes)
Total suspended solids, TSS (mg/l)	<30.0 (annual)		<15 (growing season)
Chlorophyll-*a* (µg/l)	<5.5 (annual)		<15 (growing season)
Total nitrogen (mg N/l)		≤0.4 (annual)	
Dissolved inorganic nitrogen (mg N/l)	<0.03 (annual)		
Dissolved inorganic phosphorus (mg P/l)			<0.01 (growing season)
Sediment organic matter (%)	<3.0 (annual)		0.4 – 16 (mixed species)
Secchi depth (m)	>0.7 (annual)		
Water temperature, Max. (^{o}C)		<28.0 (annual)	
Porewater sulfide (mM)			<1 healthy plants >1 growth reduced >2 death

Sources: a) LISS 2003; b) PEP 2015; c) Kemp et al. 2004, growing season values for meso and polyhaline waters

Participants in the May 29th monitoring workshops provided the following additional suggestions regarding this objective:

- In addition to herbicides, there needs to be a better understanding of the potential impacts of other water and sediment contaminants on eelgrass in the Peconic Estuary;
- The existing monitoring strategy may need to be modified to ensure that it is able to detect and quantify all the spatial and temporal changes in seagrass health and cover that are occurring in the estuary;
- Groundwater discharge may be a cooling factor in some of the persisting seagrass beds, and maps of discharge areas may be helpful for identifying areas where transplanting might be effective. The groundwater transport model could potentially assist in identifying such areas; and
- It would be helpful to map areas where PAR, water temperature and other habitat factors are at appropriate levels to support eelgrass growth, and focus restoration efforts there.

A meeting of New York seagrass experts that was held in 2007 (proceedings available at https://seagrant.sunysb.edu/Images/Uploads/PDFs/SeagrassMeeting07-Proceedings.pdf) also provides a number of recommendations regarding seagrass research, management and monitoring priorities. With respect to monitoring, the group's primary recommendations, several of which have already been incorporated into the PEP monitoring program and/or overlap with suggestions outlined above, are to:

- Monitor the physical conditions of seagrass beds, using light and temperature loggers. Include frequent (or continuous) light monitoring, with highest resolution during the growing season;
- Perform regular mapping of seagrass, with standardized methods and metadata, and timely reporting. Include analysis of historical aerial photos where usable to where seagrass existed at different times in the past, because spatial patterns of loss can provide clues about causes of loss. In terms of cost it may be advantageous to map Long Island Sound, the Peconics and SSER in the same years. Develop a consistent metric for defining seagrass habitat;
- Monitor seagrass beds themselves (see SeagrassNet [http://www.seagrassnet.org/] or Seagrass-Watch [http://www.seagrasswatch.org/monitoring.html] for methods;
- Use regression analysis to identify and quantify local sources of light attenuation (e.g., TSS, chlorophyll-*a*, CDOM), using water quality and Secchi or PAR data;
- Determine bathymetry of the estuary using 10 cm resolution and focusing on shallow waters. If light attenuation is one of the principal causes of seagrass mortality, bathymetry can provide information on locations where recovery may be possible given incremental improvements in water clarity; and
- Characterize the biota of seagrass beds, in terms of functional groups, secondary production, how animals are using the beds, and what value they are providing to the larger biotic community.

Objective HE-4: Maintain existing high-value wetland areas, restore degraded areas, and improve wetland habitat using best management practices and adaptive management.

Although much of the wetland degradation and loss that has occurred in the PEP study area has been caused by physical impacts such as dredging, filling and shoreline hardening, excessive nutrient loading and eutrophication are also known to have major impacts on the condition and extent of coastal wetlands. Deegan et al. (2012) provide the following overview, based on the results of a nine-year ecosystem-scale salt marsh nutrient enrichment experiment conducted in Massachusetts:

> "Nutrient levels commonly associated with coastal eutrophication increased above-ground leaf biomass, decreased the dense, below-ground biomass of bank-stabilizing roots, and increased microbial decomposition of organic matter. Alterations in these key ecosystem properties reduced geomorphic stability, resulting in creek-bank collapse with significant areas of creek-bank marsh converted to unvegetated mud. This pattern of marsh loss parallels observations for anthropogenically nutrient-enriched marshes worldwide, with creek-edge and bay-edge marsh evolving into mudflats and wider creeks… Our work suggests that current nutrient loading rates to many coastal ecosystems have overwhelmed the capacity of marshes to remove nitrogen without deleterious effects. Projected increases in nitrogen flux to the coast, related to increased fertilizer use required to feed an expanding human population, may rapidly result in a coastal landscape with less marsh, which would reduce the capacity of coastal regions to provide important ecological and economic services."

With respect to water quality monitoring, tracking progress on Objective HE-4 will require periodic monitoring of nutrient loadings to and nutrient concentrations in coastal wetlands. The most straightforward way to address this need would be to incorporate such wetlands as a water body category in the monitoring that is done to track progress on Objective WQ-1 (Substantially reduce present-day and future sources of nutrient pollution into the Peconic estuary watershed)**.**

Objective HE-6: Continue to maintain, restore and enhance viable diadromous fish spawning and maturation habitat in the Peconic Estuary watershed.

As noted in the draft 2019 CCMP (PEP 2019), dams were built on most of Long Island's freshwater tributaries in the late 1800s and early 1900s for "grist mills, cranberry bogs, other industrial uses, and as property line demarcations." These historical structures, along with more recent features such as causeways and road culverts, impede upstream access to spawning or maturation habitats for diadromous fish, such as river herring and American eel, which spend a portion of their life cycle in freshwater habitats and the remainder in saltwater. Dams and other manmade obstructions have excluded these fish from hundreds of acres of potential freshwater habitat in the Peconic Estuary watershed. Their populations have been declining over the past century, in part due to this loss of freshwater habitat (PEP 2019).

While much of the work on this objective will focus on providing renewed access for diadromous fish to currently-blocked freshwater areas (e.g., by installing fish passages at dams), water quality in those freshwater habitats will also need to be maintained at levels that will allow the fish to survive once they reach them. Maintaining appropriate water quality in other areas will also be important. A large hypoxic zone in the highly eutrophic tidal freshwater segment of western Europe's River Scheldt has been shown to act as an obstruction that reduces migratory opportunities and habitat availability for a number of diadromous species there, inhibiting movement to and from the freshwater portion of the watershed (Maes et al. 2007). A minimum dissolved oxygen target of 5 mg/l was recommended for the tidal fresh segment of the river to address the issue (Maes et al. 2007).

For the eastern U.S., the Atlantic States Marine Fisheries Commission (Greene et al. 2009) has provided a summary of the water quality and habitat requirements of native diadromous fish species at various life stages. The following information was excerpted from that document. For the anadromous river herring species (alewife [*Alosa pseudoharengus*] and blueback herring [*Alosa aestivalis*]), which migrate from saltwater to freshwater habitats as adults in order to spawn, the water quality and habitat requirements of spawning adults and sensitive egg and larval life stages will be of primary concern in the

PEP study area. Alewife spawn in the mid-Atlantic and southern New England region in late March or early April, moving as far upstream as possible and selecting slow-moving sections of rivers or streams with substrates ranging from sand, gravel or coarse stones to submerged vegetation or organic detritus. Optimal habitat for alewife eggs and larvae are freshwater (for eggs) or freshwater to low-salinity (for larvae) areas with "substrates of 75% silt or other soft material containing detritus and vegetation", dissolved oxygen concentrations >5.0 mg/l, pH between 5 and 8.5 and nontoxic levels of inorganic monomeric aluminum (Greene et al. 2009). Blueback herring also generally spawn in freshwater habitats above the head of tide, although brackish and tidal areas can also be used. In areas where blueback herring and alewife co-occur, blueback herring generally spawn three to four weeks later than alewife and prefer to spawn over gravel and clean sand substrates in areas with relatively high current velocities. Spawning adults prefer water temperatures between 20 and 25^{o}C, and all life stages require a minimum of 5.0 mg/l of dissolved oxygen (Greene et al. 2009). Optimal reported salinities are 0 to 2 for eggs and 0 to 22 for larvae.

Unlike the anadromous river herring, the American eel is a catadromous species that spawns in the Atlantic Ocean and migrates into river systems during juvenile (glass eel and elver) life stages (Greene et al. 2009). The final inland resident stage, called the yellow eel, inhabits a variety of habitats including ponds, lakes, streams, rivers and estuaries and seems to prefer water with dissolved oxygen concentrations greater than 4 mg/L (Greene et al. 2009). At maturity, around 7 - 13 years, these eels stop feeding, take on a silvery cast and begin downstream migrations. Silver eels migrate to the Sargasso Sea region of the Atlantic Ocean during the fall where it is believed they die after spawning (Greene et al. 2009).

Tracking progress on this CCMP objective will require periodic monitoring of water quality in the freshwater and estuarine portions of the PEP study area that are inhabited by diadromous fish species, particularly during periods of migration, spawning and when sensitive life stages are present. During the May 29th monitoring workshops, participants noted that although the USGS has a continuous monitoring station on the Peconic River that records several relevant water quality parameters (such as DO, pH, water temperature and salinity), most other tributary streams are not currently being monitored in a way that provides information on habitat suitability for diadromous fish.

Objective CC-3: Develop strategies to understand and address ocean acidification in the Peconic Estuary region

EPA has recently developed guidelines for tracking coastal acidification in the eastern U.S. (Pimenta and Grear 2018). The following information has been excerpted primarily from that document.

In the past few decades only half of the CO_2 released by human activity, including fossil fuel emissions, land use change and cement production, has remained in the atmosphere. Of the remainder about 30% has been taken up by the oceans, leading to changes in seawater carbonate chemistry and reductions in pH (acidification) in the open ocean. Coastal acidification is a more localized, additional reduction in pH in coastal waters that is primarily caused by increased biological respiration rates (typically by bacteria involved in decomposition of organic matter) that release additional CO_2 into the water. This is often fueled by nutrient loads entering the water from terrestrial watersheds and airsheds, which stimulate increased primary production by algae and other aquatic plants that eventually die and decompose. It occurs in coastal areas because of the elevated nutrient loads that often occur there (Pimenta and Grear 2018). Some important living resources are known to be highly sensitive to acidification, particularly calcifying organisms such as mollusks, corals, echinoderms and calcifying algae, while others such as finfish, crustaceans, seagrasses and fleshy algae may respond positively to changes in carbonate chemistry (Kroeker et al. 2010).

In order to track progress on this objective, it would be necessary to monitor status and trends in coastal acidification in the Peconic region. Current EPA guidelines recommend monitoring of pCO2, pH, dissolved inorganic carbon (DIC) and total alkalinity (TA) to track water column acidification processes and changes in the carbonate system. Pimenta and Grear (2018) note that "EPA's Atlantic Ecology Division (AED) in Narragansett conducts coastal acidification research focusing primarily on land-based drivers. In order to separate these from oceanic drivers and to determine when and where costly methods are necessary, high quality measurements are necessary. This work is closely coordinated with nutrient sampling and analysis." For organizations that are considering becoming involved in acidification monitoring they also present four equipment scenarios, covering a range of technological sophistication and costs, from a "water quality research laboratory" to "shellfish growers and hatcheries".

Participants in the May 29th monitoring workshop provided the following suggestions on this objective:

- New York State has an Ocean Acidification Task Force that has examined ways to enhance existing monitoring networks to include parameters relevant to the acidification issue. For information on the task force, see https://www.dec.ny.gov/lands/114877.html; and
- It may be possible to include climate change impacts such as this in water quality models to identify potential areas of impact. The local USGS office has expertise in this topic.

SUMMARY

A conceptual summary of the monitoring needed to track progress on these water-quality-related CCMP objectives is provided in Table 2. Rather than listing individual monitoring parameters, which may change over time with modifications in laboratory analytical techniques or managers' evolving understanding of the factors involved in particular resource management issues, it seeks to give a broad overview of data and information needs. Results of the August 21 Workshop will form the basis for more detailed recommendations for the PEP Monitoring Strategy.

Although the monitoring programs that are currently active in the PEP program area are quite robust and provide high-quality data, they were not designed to provide the data necessary to track progress on the recently-drafted CCMP objectives. As a result, a number of gaps exist between the data that are provided and the data needed to track the progress of PEP management efforts. Based on our review of existing water quality monitoring programs (CWP 2019a) and feedback provided by local experts at the monitoring workshops held on May 29, 2019 (CWP 2019b), we recommend that the PEP partners consider modifying their existing monitoring strategy along the following lines as expeditiously as possible in order to fill major data gaps:

- Add a groundwater monitoring program that includes nutrients, pesticides and other toxic contaminants, pathogens, and contaminants of emerging concern such and pharmaceuticals and personal care products. Work with local, state and federal partners to ensure that the program receives consistent funding, allowing it to provide long-term tracking of status and trends in groundwater quality and pollutant loads delivered from groundwater to surface waterbodies and wetlands. Once the groundwater solute transport model is developed, ensure that each of the water quality and hydrologic parameters needed to run and test the model are being monitored at the appropriate temporal and spatial scales;

- Initiate regular water quality monitoring at the USGS stream gage on the Peconic River, using a sampling protocol that is adequate to support calculation of annual loadings of nitrogen and other constituents of concern from the upstream portion of the Peconic River watershed;
- Integrate the surface water quality and eelgrass monitoring programs, to ensure that areas within the estuary that are suitable and unsuitable for eelgrass growth (e.g., due to light availability and water temperature levels) can be demarcated and tracked over time. Organizations currently monitoring water quality parameters relevant to potential eelgrass habitat in the estuary include the PEP LTEMP program (water temperature, PAR), SCDHS Estuarine/Marine monitoring program (N and P forms, chlorophyll-*a*, Secchi depth, water temperature, DO, salinity, TSS), NYSDEC Fishery-Independent Trawl Survey (water depth and temperature, salinity, DO, Secchi depth), NYSDEC Shellfish Growing Area monitoring program (salinity, water temperature), and the Gobler Lab at SBU/SOMAS (water and Secchi depth, DO, chlorophyll-*a*). It may be helpful to initiate discussions with those organizations to see if greater coordination might be possible between their programs in order to provide improved spatial coverage of sampling, streamline and reduce the overall cost of the monitoring efforts, and free up resources that could be used for other monitoring activities. And once the bio-optical model light attenuation model is completed, steps will need to be taken to ensure that each of the key water quality parameters identified by the model are being monitored on a consistent basis and with adequate spatial and temporal resolution. Chromophoric dissolved organic matter (CDOM), for example, is an important source of light attenuation in many estuaries, but is apparently not being monitored at present in the Peconics; and
- Initiate monitoring of water quality conditions relevant to diadromous fish habitat, such as DO, pH and water temperature levels in freshwater tributaries during periods when river herring are migrating or spawning. The SCDHS Point Source and Stream monitoring program currently includes each of these water quality parameters, but its sampling network was not designed to provide information on diadromous fish habitat and the timing and locations of its sampling sites may need to be modified to make them more applicable to this management issue.

Several other helpful recommendations were provided by monitoring partners and other TAC members during the May 29th workshops (CWP 2019b) and should be considered for inclusion in the PEP monitoring strategy as funding and other resources can be made available to support them.

To help improve the design and implementation of coastal monitoring programs, the National Research Council (NRC 1990; Chap. 7 in NRC 2000) has provided a number of informative case studies and recommended strategies. Participants in the August 21 PEP workshop are encouraged to review relevant sections of those reports, which are available in pdf form from the National Academies Press website (https://www.nap.edu/), prior to the meeting.

In order to make effective use of the data provided by the monitoring programs, the PEP partners may also wish to develop a ‘decision matrix’ outlining the steps that will be taken by the Management Conference when certain water quality conditions occur. An example of this approach, which is used on an annual basis by the Tampa Bay Estuary Program to help it meet its seagrass-based water quality targets, is provided in Appendix A.

Table 2. Conceptual summary of monitoring needed to track progress on CCMP objectives.

CCMP Objective	Parameters to be monitored or estimated (modeled)	Existing data/information gaps and steps suggested to fill them
WQ-1: Substantially reduce present-day and future sources of nutrient pollution into the Peconic estuary watershed	Concentrations of all nutrient forms of concern for all major source categories (atmospheric deposition, surface point and nonpoint sources, groundwater) and land use categories (e.g., residential, commercial and agricultural land uses). Flow volumes will also be needed for each source category of interest to support annual loading calculations.	Current monitoring data are not sufficient to allow annual nutrient loadings to be calculated for many important source categories. Nutrient monitoring should be initiated at the USGS streamflow gage on the Peconic River to allow loads to be quantified at that cross-section. Nutrient concentrations and flows also need to be measured or estimated (modeled) for major permitted point sources, ungaged surface water flows and groundwater inputs to the estuary. Loads from atmospheric deposition appear adequately characterized at present, but could perhaps be improved by additional targeted monitoring in urban areas. The design of the groundwater monitoring program could perhaps be done in conjunction with and using information from the solute transport model that is currently under development.
WQ-2: Develop and implement strategies to manage existing, historical nutrient loads presently in groundwater that could enter the Peconic estuary	As for WQ-1, for all nutrients of concern from *legacy* sources (e.g., historical agricultural activities) that are currently present in groundwater.	As for WQ-1, nutrient concentrations in groundwater that were contributed by legacy sources need to be quantified, and loadings entering the estuary from those sources need to be quantified and tracked over time.
WQ-3: Reduce harmful algal blooms (HABs) in the Peconic estuary	Frequency, severity and spatial extent of HABs. Monitoring of nutrient forms and other factors that are found to encourage specific HABs may also prove helpful, as those are identified.	Current monitoring programs appear sufficient to track progress on this objective. Going forward, the Suffolk County HAB Action Plan (Wise 2017) provides a number of monitoring-related recommendations that should be evaluated for possible

		implementation.
WQ-4: Reduce pathogen loading to the Peconic estuary	Fecal indicator bacteria (FIBs) and sanitary survey information. More advanced microbial techniques (e.g., microbial source tracking parameters, specific pathogens) can be added as standardized and affordable methods become available.	Current monitoring programs appear sufficient to track progress on this objective. More advanced microbial techniques (e.g., microbial source tracking, monitoring for specific pathogens) can potentially be added as standardized and affordable methods become available.
WQ-5: Maintain and protect existing high-quality waters	"High-quality" waters within the PEP project area need to be objectively defined, and their locations mapped. Status and trends in the water quality parameters tracked for Objectives WQ-1 through WQ-4, WQ-6, HE-3, HE-4, HE-6 and CC-3 can be used to track conditions in those waters.	Define and map "high quality" waters within the project area. For tracking of water quality conditions in those waters, see recommendations for Objectives WQ-1 through WQ-4, WQ-6, HE-3, HE-4, HE-6 and CC-3. To identify actions that should be taken in response to water quality issues that arise in high quality waters, consider implementing a decision matrix approach such as the one outlined in Appendix A.
WQ-6: Understand various types of toxic contaminants and their impacts, and work to address current and emerging concerns.	Concentrations and loads of toxic contaminants of concern, and their impacts on human health and environmental quality.	This appears to be a research-oriented rather than a monitoring-oriented objective, although existing toxics monitoring programs may need to be adjusted to include the contaminants of greatest management concern. If so, the nutrient monitoring in surface and groundwater addressed for Objectives WQ-1 and WQ-2 could potentially be expanded to include toxic constituents of concern.
Objective HE-3: Improve water quality to increase habitat suitability for eelgrass and establish new or restored eelgrass beds	Water and sediment quality parameters that impact seagrass survival, growth, reproduction and restoration such as light attenuation and its sources (e.g., chlorophyll-a, TSS, CDOM), DO, water temperature, sediment organic matter and porewater sulfide. Include herbicides and other toxins if they are present at potentially harmful levels.	As noted above, the existing surface water quality and eelgrass monitoring programs need to be integrated to ensure that areas within the estuary that are suitable or unsuitable for eelgrass growth (e.g., due to factors such as light availability, sediment chemistry, water temperature, etc.) can be identified, demarcated and tracked over time. The integrated monitoring program could perhaps be designed using information from the bio-optical model that is currently under development.

HE-4: Maintain existing high-value wetland areas, restore degraded areas, and improve wetland habitat using best management practices and adaptive management	Include wetlands as a waterbody category that is monitored as part of WQ-1.	See entry for WQ-1, above.
HE-6: Maintain, restore and enhance viable diadromous fish spawning and maturation habitat	Parameters that affect spawning success and survival of sensitive life stages of river herring and American eel, such as DO, pH and water temperature. Include pesticides and other toxins if they are present at potentially harmful levels.	Current monitoring programs do not appear to address this CCMP objective. A new monitoring effort designed to track status and trends in the relevant water quality parameters and water bodies will therefore need to be designed and implemented.
CC-3: Develop strategies to understand and address ocean acidification	Follow current EPA guidelines, currently include pCO_2, pH, dissolved inorganic carbon (DIC) and total alkalinity (TA) to track water column acidification processes	Current monitoring programs do not appear to address this CCMP objective. A new monitoring effort designed to track status and trends in the relevant water quality parameters and water bodies will therefore need to be designed and implemented. Because this is a regional issue, it could perhaps be addressed most effectively in collaboration with other regional, state and federal monitoring programs.

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Appendix A:

Tampa Bay Water Quality
Decision Framework and Decision Matrix

The Tampa Bay Estuary Program (TBEP) has adopted water quality targets for chlorophyll-*a* concentrations and light attenuation levels, based on the light requirements of native seagrass species, for each of the major segments of the bay (TBEP 2000). The program applies a decision framework on an annual basis to determine if the water quality targets are being met, and uses a decision matrix to identify actions that will be taken by the Management Conference if they are not met. An example of the process used for chlorophyll-a is shown in Fig. 1.

As the initial step, annual mean chlorophyll-*a* concentrations measured in each bay segment during the previous year are compared to the segment's numerical target. When the annual mean concentration is less than the target, there is no cause for concern, as represented by Outcome 0 in Figure 1. When mean concentrations are greater than target values, however, both the size of the difference and the duration of the difference are considered. Small differences for short time periods result in Outcome 1, while large differences for short time periods and small differences for long time periods result in Outcome 2. In the most severe condition, when large differences exist for long periods, the framework results in Outcome 3 (TBEP 2000).

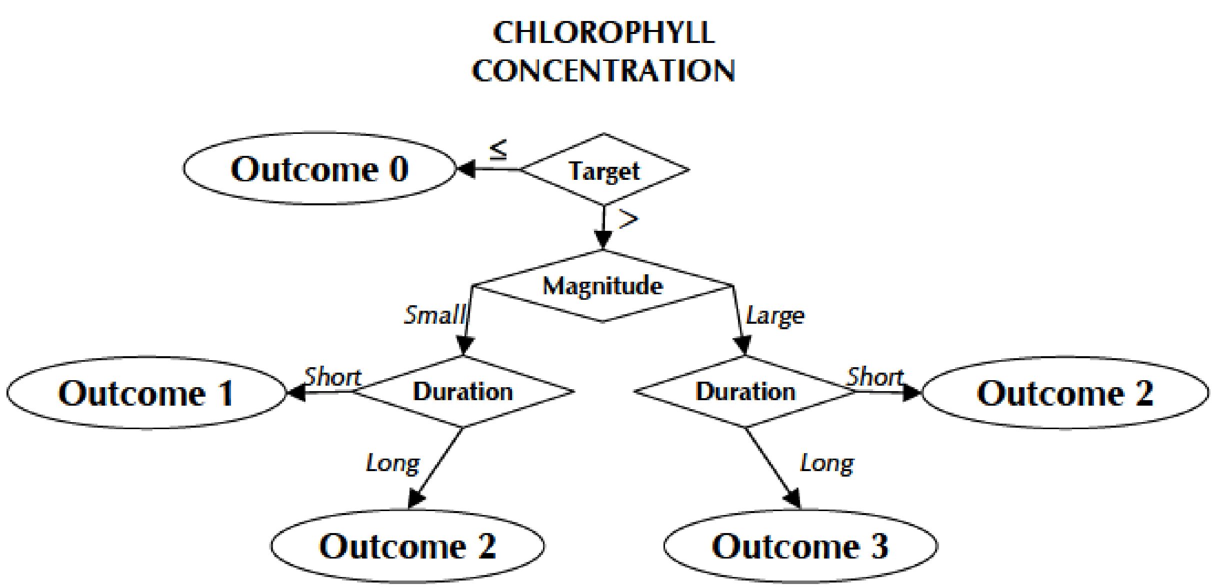

Figure 1. TBEP decision framework for chlorophyll-a. (Source: TBEP 2000).

The second step of the tracking process involves combining the outputs from the decision frameworks for chlorophyll-*a* concentration and light attenuation in a decision matrix to provide direction for management responses when targets are exceeded. The decision framework used for light attenuation is the same as that shown in Figure 1 for chlorophyll-a concentration.

The decision matrix incorporating the outcomes for chlorophyll-*a* concentration and light attenuation is shown in Table 1. When outcomes for both chlorophyll-*a* concentration and light attenuation are good, as represented by Outcome 0 for both, a condition exists in which targets are being met, and so no management response is required. This condition is signified by the green cell in Table 1.

Table 1. Decision matrix identifying appropriate categories of management actions in response to various outcomes of the monitoring and assessment of chlorophyll-a and light attenuation data. **(Source: TBEP 2000)**

CHLOROPHYLL	LIGHT ATTENUATION			
↓	Outcome 0	Outcome 1	Outcome 2	Outcome 3
Outcome 0	*GREEN*	*YELLOW*	*YELLOW*	*YELLOW*
Outcome 1	*YELLOW*	*YELLOW*	*YELLOW*	*RED*
Outcome 2	*YELLOW*	*YELLOW*	*RED*	*RED*
Outcome 3	*YELLOW*	*RED*	*RED*	*RED*

Outcome	Programmatic Response
0 (Green)	"Stay the course"; partners continue with planned projects to implement the CCMP. Data summary and reporting via the bay-wide Environmental Monitoring Report and annual assessment and progress reports.
1-2 (Yellow)	TAC and Management Board on caution alert; review monitoring data and loading estimates; attempt to identify causes of target exceedances; TAC report to Management Board on findings and recommended responses if needed.
3 (Red)	TAC, Management and Policy Boards on alert; review and report by TAC to Management Board on recommended types of responses. Management and Policy Boards take appropriate actions to get the program back on track.

When conditions are intermediate, as signified by the yellow cells in Table 1, differences from the targets exist for either or both chlorophyll-*a* concentration and light attenuation. These conditions may result in some type of management response.

When conditions are problematic, such that the outcomes for the parameters fall within the red cells of Table 1, stronger management responses may be warranted. The types of management actions resulting from the decision matrix are classified by color into three categories, shown following Table 1.

The results of the annual water quality assessment are circulated to all management conference members in the first quarter of each year, using a graphic-rich format that is readily interpretable by non-technical audiences. The initial page of the assessment for calendar year 2018 is shown in Fig. 2.

2018 Tampa Bay Water Quality Assessment

A Tampa Bay Estuary Program Initiative to Maintain and Restore the Bay's Seagrass Resources

TAMPA BAY ESTUARY PROGRAM
PARTNERSHIP FOR A HEALTHY BAY

For additional info visit:
www.tbeptech.org

Original Reference:
Janicki, A., D. Wade, & R.J. Pribble. 2000. TBEP Technical Report # 04-00.

Background

Light availability to seagrass is the guiding paradigm for TBEP's Nitrogen Management Strategy. Because excessive nitrogen loads to the bay generally lead to increased algae blooms (higher chlorophyll-a levels) (Figure 1) and reduce light penetration to seagrass, an evaluation method was developed to assess whether load reduction strategies are achieving desired water quality results (i.e. reduced chlorophyll-a concentrations and increased water clarity).

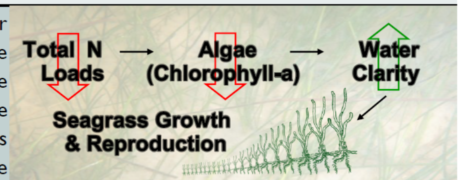

Figure 1: Guiding paradigm for Tampa Bay seagrass restoration through the management of nitrogen loads.

Decision Support Approach

Year to year algae abundance (measured as chlorophyll-a concentrations) and visible light penetration through the water column (depth of secchi disk visibility) have been identified as critical water quality indicators in Tampa Bay. Tracking the attainment of bay segment specific targets for these indicators provides the framework from which bay management actions are developed & initiated. TBEP management actions adopted in response to the annually-assessed decision support results are shown to the right.

Green	"Stay the Course." Continue planned projects. Report data via annual progress reports and Baywide Environmental Monitoring Report.
Yellow	"Caution Alert." Review monitoring data and nitrogen loading estimates. Begin/continue TAC and Management Board development of specific management recommendations.
Red	"On Alert." Finalize development and implement appropriate management actions to get back on track.

2018 Decision Matrix Results

Water quality (chlorophyll-a and light penetration) remained supportive of seagrass in Hillsborough Bay (HB), Middle Tampa Bay (MTB), and Lower Tampa Bay (LTB) (Table 1; Figure 2). The nuisance alga, *Pyrodinium bahamense,* was again reported in Old Tampa Bay (OTB) during the Summer and Fall 2018, contributing to a small magnitude chlorophyll-a exceedance. In all bay segments, separate algal bloom events contributed to individual stations exceeding the bay segment chlorophyll-a targets (Figure 3). However, effective light penetration was supportive of seagrass in all bay segments (Table 1).

Table 1: Observed water quality indicators & recommended management outcomes for 2018.

Bay Segment	Chlorophyll-a (ug/L)		Effective Light Penetration (m^{-1})		Management Response
	2018	Target	2018	Target	
OTB	9.2	8.5	0.68	0.83	Yellow
HB	13.9	13.2	1.09	1.58	Green
MTB	7.0	7.4	0.57	0.83	Green
LTB	4.7	4.6	0.59	0.63	Green

Historic Results:

Year	Old TB	Hills. Bay	Middle TB	Lower TB
1975	Red	Red	Red	Green
1976	Red	Red	Red	Yellow
1977	Red	Red	Red	Red
1978	Red	Red	Red	Yellow
1979	Red	Red	Red	Red
1980	Red	Red	Red	Red
1981	Red	Red	Red	Red
1982	Red	Red	Red	Red
1983	Red	Yellow	Red	Red
1984	Red	Green	Red	Yellow
1985	Red	Red	Red	Yellow
1986	Red	Yellow	Red	Green
1987	Red	Yellow	Red	Green
1988	Yellow	Green	Yellow	Green
1989	Red	Yellow	Red	Yellow
1990	Red	Green	Red	Yellow
1991	Green	Yellow	Yellow	Yellow
1992	Yellow	Green	Yellow	Yellow
1993	Yellow	Green	Yellow	Yellow
1994	Yellow	Yellow	Red	Red
1995	Red	Yellow	Red	Yellow
1996	Yellow	Green	Yellow	Green
1997	Yellow	Green	Red	Yellow
1998	Red	Red	Red	Red
1999	Yellow	Green	Yellow	Yellow
2000	Green	Green	Yellow	Yellow
2001	Yellow	Green	Yellow	Yellow
2002	Yellow	Green	Green	Green
2003	Red	Yellow	Green	Yellow
2004	Red	Green	Green	Yellow
2005	Green	Green	Yellow	Yellow
2006	Green	Green	Green	Green
2007	Green	Green	Green	Green
2008	Yellow	Green	Green	Yellow
2009	Yellow	Yellow	Green	Green
2010	Green	Green	Green	Green
2011	Red	Green	Yellow	Green
2012	Green	Green	Green	Green
2013	Green	Green	Green	Green
2014	Green	Green	Green	Green
2015	Yellow	Green	Yellow	Green
2016	Yellow	Green	Green	Green
2017	Yellow	Green	Green	Green
2018	Yellow	Green	Green	Green

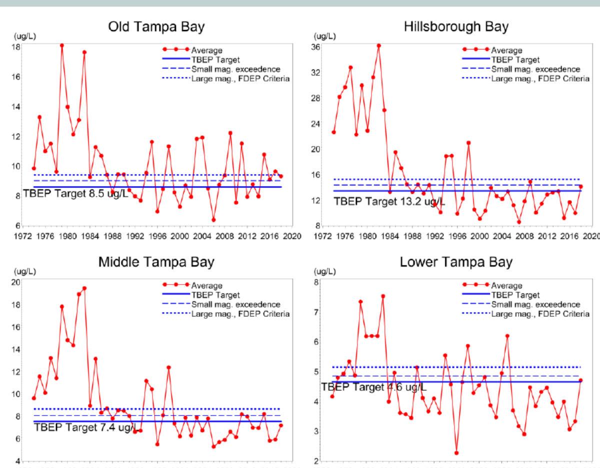

Figure 2: Historic chlorophyll-a annual averages for the four bay segments. Chl-a concentrations exceeded the management target for Old Tampa Bay in 2018.

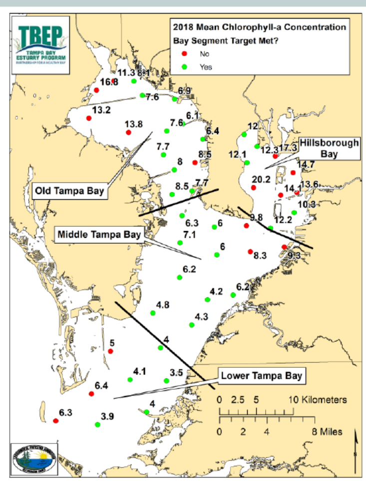

Figure 3: Map depicting 2018 individual station chlorophyll-a annual values in Tampa Bay.

Continuing water quality monitoring support provided by the EPCHC.

Consulting support provided by Janicki Environmental, Inc.

Burke, M. and G. Raulerson. 2019. 2018 Tampa Bay Water Quality Assessment. Tampa Bay Estuary Program Technical Report #01-19 TBEP, St. Petersburg, FL. 1

Figure 2. Example of Tampa Bay Estuary Program's water quality decision matrix. (Source: TBEP 2019).

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