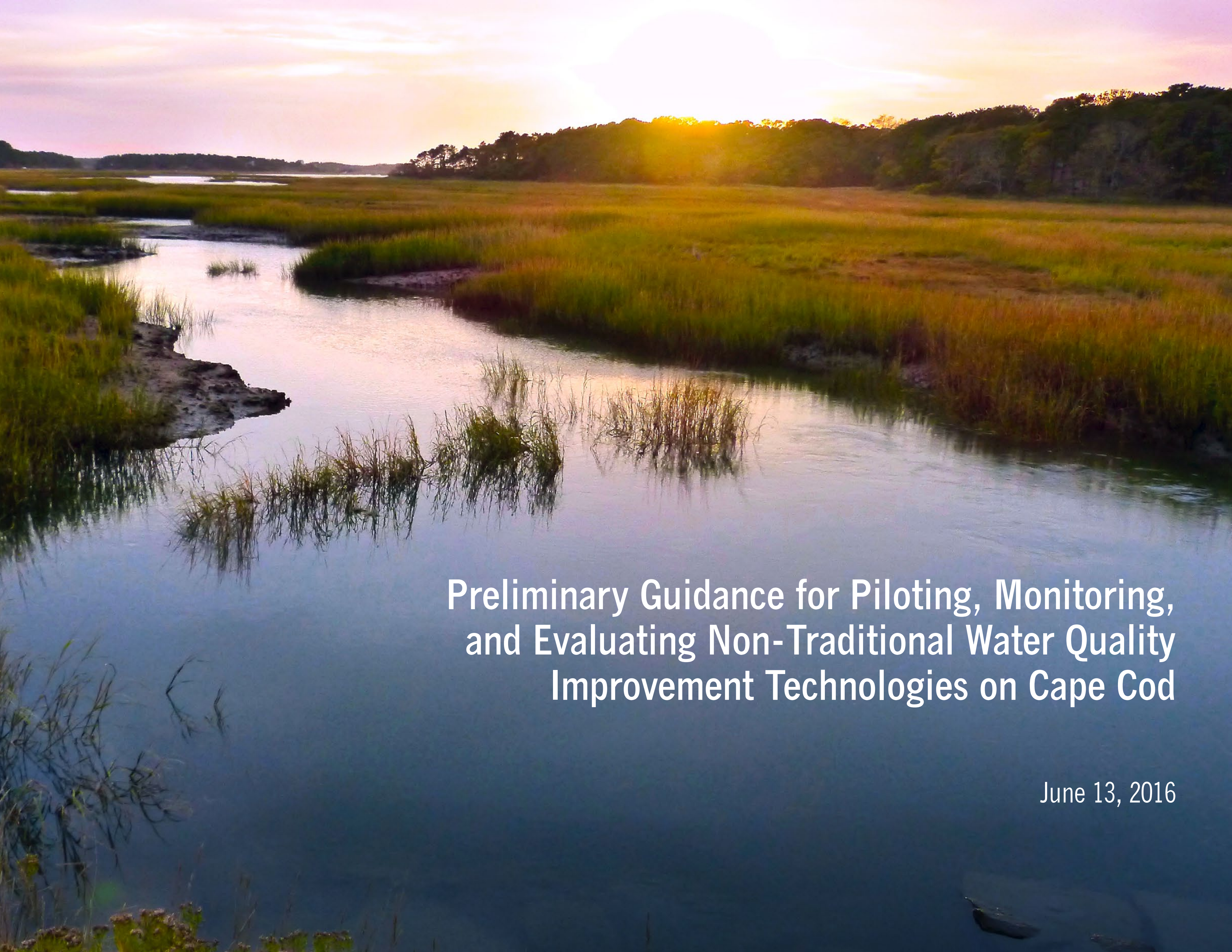

Preliminary Guidance for Piloting, Monitoring, and Evaluating Non-Traditional Water Quality Improvement Technologies on Cape Cod

June 13, 2016

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CHAPTER 1

INTRODUCTION

to Water Quality Improvement on Cape Cod

Water Quality on Cape Cod

Cape Cod is a peninsula in the eastern part of the state of Massachusetts known for its summer tourism, maritime history, and historic fisheries. Clean water, including both freshwater and saltwater, is a pillar of the local economy, supporting property values, recreational opportunities, tourism, fisheries, public health, and general quality of life.

As the population of Cape Cod increased over the last several decades, so has the volume of nutrient pollution entering its coastal waters and freshwater ponds. Excessive nitrogen and other nutrients such as phosphorus, are the documented cause of water quality degradation in a majority of Cape Cod estuaries and freshwater ponds. In estuarine systems, excessive nutrients lead to thick mats of algae that replace eelgrass, diminish shellfisheries, and decrease dissolved-oxygen concentrations (eutrophication)—occasionally leading to fish and shellfish kills and odor, and frequently resulting in violations of water quality standards.

The primary source of nitrogen pollution on Cape Cod is wastewater, with 80% of the controllable nitrogen pollution coming from this source. Wastewater from both older and newer housing stock is predominantly treated by on-site septic systems that do not adequately remove nitrogen. Nitrogen from septic systems is released to groundwater and ultimately discharged to its surrounding coastal waters. Since coastal waters are sensitive to relatively small increases in nitrogen, water quality degradation and eutrophication occur with these increases in nutrients.

The nitrogen impact of on-site septic systems on Cape Cod is significant and needs to be addressed. Cape Cod has less than 4% of the population yet has 20% of the systems in Massachusetts. Additionally, only 3% of the parcels and 15% of the wastewater flows on Cape Cod are centrally treated. The number of on-site septic systems creates a decentralized pollution problem that needs to be addressed on many scales to improve water quality.

The Cape Cod Area Wide Water Quality Management Plan Update.

In a January 30, 2013 letter, Massachusetts Department of Environmental Protection (MassDEP) Commissioner Kenneth Kimmell directed the Cape Cod Commission (CCC) to prepare an update to the 1978 Area Wide Water Quality Management Plan for Cape Cod (208 Plan Update), pursuant to Section 208 of the Clean Water Act, to address the degradation of Cape Cod's water resources from excessive nutrients, primarily nitrogen.

The 208 Plan Update was certified by the Commonwealth of Massachusetts on June 12, 2015 and approved by the United States Environmental Protection Agency (US EPA) on September 15, 2015. The overall goal of the 208 Plan Update is to improve water quality through regional, cost-effective, culturally appropriate, and sustainable strategies. It provides a framework for generating watershed-based solutions with a suite of technologies to meet water quality goals, and a process for adapting to changes in technology performance and/or changes in water quality over time. It encourages local communities to consider non-traditional technologies, coupled with traditional sewer collection and treatment, to reduce nitrogen at the source and nitrogen that is already impacting groundwater and coastal resources. It also provides a path forward for regulatory reform that will allow for more targeted plans and innovative solutions, as well as recommendations for minimizing the financial impact on year round residents.

Water Quality Improvement Technologies

The 208 Plan Update puts forth a set of optional technologies that communities can combine in various scenarios to create a watershed plan that addresses the nutrient problem in a particular watershed. Some technologies, such as sewer collection and treatment, are traditional technologies with a proven track record for nutrient management. However, these source reduction technologies are expensive and may not always be the best solution to account for the unique circumstances of the Cape's non-point source water quality issues. The plan highlights the need to expand the use of alternative and non-traditional technologies and management strategies necessary to meet the challanges faced on Cape Cod. For example, non-traditional nitrogen management strategies may intercept and treat nitrogen in the groundwater or assimilate and treat nutrients in the receiving waters. Watershed treatment practices include permeable reactive barriers (PRBs), constructed wetlands, phytoremediation, and fertigation wells, among others. Embayment treatment practices include, but are not limited to, shellfish bed restoration, aquaculture, floating wetlands, dredging and inlet modifications. A Water Quality Technologies Matrix detailing innovative alternative technology options is included in the 208 Plan Update. However, to validate the efficacy of non-traditional approaches, pilot projects must be designed, constructed, monitored and evaluated to analyze technology performance on the Cape before these technologies are widely implemented.

PILOTING INNOVATIVE TECHNOLOGIES

Many of the innovative alternative technologies presented in the 208 Plan Update have not been utilized on the Cape before and need to be vetted in the context of the Cape's unique environment to determine long term performance and cost effectiveness before they can be implemented on a wide scale.

MONITORING

A long-term monitoring program must then be established for each pilot project so that technology-specific performance data can be collected over time. Data must be collected in the same way and placed into a regional database that all Cape communities can reference. Monitoring protocols specific to each technology are needed to create data consistency critical in determining long term performance.

EVALUATION

Once the monitoring data has been collected, the performance, costs and other qualitative factors must be analyzed to determine long term applicability of a particular technology.

ADAPTIVE MANAGEMENT

The 208 Plan Update recommends an adaptive management approach to incorporate ongoing water quality monitoring data and evaluations from pilot projects into decision-making. Periodic evaluations (typically 5 year increments) provide for a discrete point in time at which to assess the performance of deployed technologies, recommend future actions, allocate resources and incorporate various forms of feedback into decision-making. The adaptive management process helps manage uncertainty of newer, non-traditional technologies with feedback loops that are evaluated on a set schedule.

Essential to the successful implementation of adaptive management plans is guidance for:

- Selecting and constructing successful pilot projects
- Collecting monitoring data consistently through the use of protocols
- Determining which are the best technologies to widely implement through the use of evaluation criteria and optimizing full scale design.

Purpose and Organization of this Document

This document contains guidance to move forward with the adaptive management framework. Specifically it includes:

- **Criteria for selecting Pilot Projects**
- **General Monitoring Guidance & Monitoring Protocols** for eight priority non-traditional technologies so that essential data is consistently collected.
- **Evaluation Considerations** to help determine which water quality improvement technologies are best to prioritize for implementation.

Before this guidance is presented, the roles and responsibilities of various agencies for implementing pilot projects, monitoring and evaluation as part of the adaptive management process are provided in the next section.

CHAPTER 2

ROLES AND RESPONSIBILITIES

for Pilot Project Monitoring and Evaluation

Monitoring Committee

To provide guidance on monitoring and adaptive management, an ad hoc Monitoring Committee was established in April 2014 to review monitoring needs for implementation and make recommendations regarding piloting and monitoring of non-traditional technologies.

Present Committee members include representatives from MassDEP, US EPA, the Provincetown Center for Coastal Studies (CCS), University of Massachusetts-Dartmouth School for Marine Science and Technology (SMAST), the Association to Preserve Cape Cod (APCC), Waquoit Bay National Estuarine Research Reserve (WBNERR), town representatives, and technical experts from other public institutions and private industry.

The mission of the Monitoring Committee is:

> To provide advice and guidance on appropriate monitoring protocols for technology efficiency and total maximum daily loads, while identifying a process for consolidating all available monitoring data in a central location and format.

In this DRAFT technical guidance document, the Committee has developed criteria for selecting and prioritizing pilot projects and a framework for monitoring and evaluating the projects. Recommendation I4.8 in the 208 Plan Update directs the Monitoring Committee to provide draft monitoring protocols for non-traditional technologies in a Technical Guidance document.The Committee has developed eight conceptual protocols for innovative/alternative (I/A) septic systems, eco-toilets, permeable reactive barriers (PRBs), shellfish bed restoration, aquaculture, inlet modification (IM), coastal restoration, and floating constructed wetlands (FCWs) that are included in Chapter 5 (see p. 5:1)

A proposed reporting template to ensure consistency in communicating project findings is also included in the Appendix.

STANDING MONITORING COMMITTEE

To build on the work already completed by the ad hoc Monitoring Committee, a standing monitoring committee of applied science experts will be established as a steering committee to provide policy related advice regarding information needs and monitoring protocols as projects are implemented over time. The Monitoring Committee will convene regularly. As set forth in the 208 Plan Update, the standing monitoring committee will:

- Recommend changes to compliance monitoring protocols for meeting total maximium daily loads (TMDLs) in the water body (embayment water quality monitoring locations and protocols)

At this time it is recommended that embayment water quality monitoring locations and protocols established by the Massachusettes Estuaries Project (MEP) be used unless and until locations and protocols are:

- updated via the Barnstable County Water Protection Collaborative's regionalized/standardized embayment monitoring program, or
- changed by mutual agreement by US EPA/MASS DEP/CCC, or
- changed by watershed permit, Capital Developmemt Regional Impact (CDRI) finding or condition, or 208 Consistency Review

The Monitoring Committee will establish performance monitoring protocols for technologies that may be part of watershed permits in the future.

- Continue to refine pilot project criteria
- Review pilot project proposals
- Review existing monitoring efforts
- Evaluate monitoring feedback/modifications
- Establish regionally consistant goals and approaches for monitoring (Quality Assurance Project Plans- QAPPs)

The Monitoring Committee will identify region-wide monitoring needs and develop proposals

- Review updates to the Water Quality Technologies Matrix
- Identify and track developing issues (contaminants of emerging concern, climate change)
- Participate in the annual Technologies Symposium

Technical Review Panel (for Adaptive Management Plans)

In recognition of the complexity associated with implementing a monitoring and adaptive management plan, the 208 Plan Update recommends that CCC and MASS DEP approvals and permits establish a Technical Review Panel for each Targeted Watershed Management Plan. The Technical Review Panel will meet regularly and is comprised of local, regional, and state representatives. The Technical Review Panel will: (1) evaluate pilot project design, development and monitoring; (2) advise on adaptive managment plans; and (3) advise on Targeted Watershed project funding, design, construction and permit compliance. The Technical Review Panel will also advise on compliance monitoring including baseline water quality and habit monitoring, for the subject embayment.

Technologies Panel (for the Water Quality Technologies Matrix)

The Technologies Panel was created during the Section 208 Update process. It is a panel of local, national, and international experts on the impact of nutrients in coastal waters, reduction, remediation and restoration approaches, and emerging technologies. The Technologies Panel provided review and input for the Water Quality Technologies Matrix. Members of this panel or other experts, as appropriate, will be invited to continue to review, confirm, and expand upon the matrix of technology options.

Pilot Project Implementation Team

The Pilot Project Implementation Team is the team of staff, consultants, community members, and individuals working on a pilot project to test one or a combination of non-traditional technologies. The Pilot Project Implementation Team will work closely with other organizations listed in this section to ensure that the pilot project meets the goals established in the 208 Plan Update and this guidance document. The Pilot Project Implementation Team will guide a project through all stages from its initial conception through site selection, design, funding, construction, operations and maintenance, monitoring and evaluation.

Waste Treatment Management Agencies (WMA)

Waste Treatment Management Agencies have several roles as defined in Chapter 8 of the 208 Plan Update. The primary goal of the WMA is to carry out the area-wide waste treatment management plan that may include one or several pilot projects an non-traditional technologies that require monitoring and evaluation as described in this document.

Cape Cod Commission (CCC)

The Cape Cod Commission will provide overall leadership and technical guidance through the implementation of pilot projects, monitoring and evaluation. The CCC will work closely with the Monitoring Committee and Technical Panels to provide assistance where knowledge and administrative gaps occur. The CCC may vary monitoring protocols for compliance and technologies monitoring through Massachusettes Environmental Policy Act Unit (MEPA) review comments, CDRI permitting, and/or 208 consistency review.

Massachusetts Department of Environmental Protection (MASS DEP)

MASS DEP will issue watershed permits for targeted watersheds on Cape Cod experiencing water quality degradation due to excess nutrients. They may vary monitoring protocols for compliance and technologies monitoring through MEPA review and/or in individual watershed permits.

CHAPTER 3

CRITERIA FOR PROPOSED PILOT PROJECTS

for Non-Traditional Technology Implementation

The goal of a pilot project is to demonstrate the degree to which a particular technology, either alone or in conjunction with other technologies, will provide a satisfactory level of nutrient reduction at a particular location(s). Pilot projects test how well a technology works and are typically limited in scope. An experimental approach may be proposed to evaluate the technology's efficacy under different conditions.

A pilot project is likely not proposed as the single intervention to achieve the total nutrient reduction required in a watershed. A successfully designed pilot project is one that may be scaled up or refined to achieve a greater portion of the percent of necessary nutrient removal in a larger area. Pilot project proposals are favored when they demonstrate promising chances of success, are well defined, and the variables are well understood.

The following checklist should be considered by the Pilot Project Implementation Team when developing pilot project proposals.

Pilot Project Context

- ☐ Describe the background information that indicates there is a water quality problem. How well is the water quality problem defined?
- ☐ Is a nitrogen threshold documented by a Massachusetts Estuaries Project (MEP) technical report, Total Maximum Daily Load (TMDL) or Cape Cod Commission scenario run?

Proposed Approach to Address Problem

- ☐ What are the goals and objectives of the proposed pilot project?
- ☐ What is the overall plan for addressing the watershed nutrient problem?
- ☐ How does the proposed pilot project fit into the overall watershed management plan?
- ☐ Does the Cape Cod Commission find that the pilot project approach is consistent with the 208 Plan Update?

Project Evaluation

SITE SELECTION

- ☐ How much nutrient reduction is needed at the site?
- ☐ Is the location appropriate to the objective?
- ☐ To what extent can the site variables be tested and controlled? Sites where the technology impact can be most clearly demonstrated and monitored will be preferred.

SITE CHARACTERIZATION

- ☐ Has the site been adequately characterized for the proposed technology? Are the soils, hydrology and climate appropriate for the technology being piloted?
- ☐ Are there habitat or other ecological considerations?
- ☐ Describe the existing information available. Is baseline nutrient, species (or other) data available for the area? Define suitable references/controls for comparison to pilot data.
- ☐ If additional characterization is required, describe the extent of work and relative proportion of the budget to be used in site characterization.

SUITABILITY

- ☐ Will the proposed construction methods and implementation schedule be suitable for the site?
- ☐ Will the project be socially acceptable to the surrounding community?
- ☐ What are the variables associated with the site and the proposed technology?

PILOT PROJECT SCALE

- ☐ What proportion of the watershed nutrient reduction goal is expected to be met by the pilot project?
- ☐ Does the proposal include an assessment of the feasibility of scaling up the pilot project to serve the intended neighborhood, watershed or other service area?
- ☐ What is the lifespan of the project? What are the variables that may limit the lifespan?
- ☐ What ongoing maintenance does the project require?

PERFORMANCE MEASURES

- ☐ Does the proposal include suitable performance measures, appropriate spatial monitoring points, and frequency of monitoring to judge the success of the project? Performance measures may be quantitative, semi-quantitative, or qualitative, in descending order of preference. Examples of performance measures:
  - For efficacy of method: Net reduction of nitrogen loading and/or nitrogen concentration in water column (or groundwater) decreases by X % (numerical performance measure), water clarity increases over baseline (qualitative performance measure), abundance and density of eelgrass beds increase over baseline (qualitative ecological performance measure).
  - Length of time to see results in the embayment?
  - Influent and effluent measurements.
  - Perturbations in the natural environment caused by the pilot.
  - Duration of testing, frequency of reports.
  - For feasibility: pilot test can be scaled up to meet needs of service area, operations and maintenance (O&M) plan is feasible, costs for operations and maintenance have been quantified and planned for.
  - For project management: project milestones identified, deliverables are provided on time and are complete and satisfactory; budget is met, roles and responsibilities are met.
  - Cost analysis- Include analysis of cost of this pilot (if it were to be scaled up) compared to other technologies
  - List of benefits returned, including ancillary benefits such as habitat improvement, recreation opportunities and public acceptance.

PILOT RESULTS

- ☐ Can the pilot results be extrapolated to similar projects in different locations?
- ☐ What are the lessons learned from the pilot?

EVALUATION OF RISK

- ☐ What are the risks associated with conducting the pilot? The proposal should identify potential adverse impacts. (see below "Adverse Impacts")

CONTINGENCY PLANNING

- ☐ What happens if the project fails to provide adequate nitrogen reduction? How will the project be decommissioned? Is there sufficient funding identified/allocated to decommission the project and return the site to an appropriate condition?

- ☐ How will the proponents cope with adverse impacts? (see below "Adverse Impacts")

Adverse Impacts

- ☐ Will the proposed pilot project cause temporary or permanent impacts on coastal or inland resource areas, rare species habitat, benthic habitat, essential fish habitat, or other natural resources?

- ☐ Will there be temporary or permanent impacts on public or private properties and infrastructure?

- ☐ Will public uses and activities be disrupted?

- ☐ Will the project inordinately impact environmental justice communities?

- ☐ Has the applicant proposed measures to minimize, avoid or mitigate temporary or permanent impacts?

- ☐ Do the environmental benefits due to nutrient removal from the project outweigh natural resources or other impacts?

Permitting

- ☐ What existing permits and approvals will be required?

- ☐ Is the permitting path clearly and completely defined?

- ☐ If approvals from some agencies (e.g., MEPA, MassDEP, Division of Marine Fisheries, Natural Heritage Endangered Species Program, etc) are required before applying for other permits, has the applicant contacted or consulted with relevant permitting agencies and obtained the necessary approvals?

- ☐ Are permits required for decommissioning the project?

Qualifications to Ensure Project Success

- ☐ Are roles and responsibilities defined?

- ☐ Do project team members have relevant knowledge, experience, demonstrated success, and references? For example, technologies that rely upon vegetative or microbial process shall include biologists or other specialty scientists as part of the design team.

Project Scope

- ☐ Are tasks and deliverables well-defined and will they meet the goals of the project?

- ☐ Has a schedule of deliverables and milestones been provided?

- ☐ Has funding been identified for the project and is the budget related to specific deliverables?

CHAPTER 4

MONITORING GUIDELINES

for Non-Traditional Technologies

Monitoring can be thought of as the systematic and continual documentation of key aspects of program performance that assesses whether a program is operating as intended. The following universal objectives of monitoring for water quality on Cape Cod are as follows:

- Ensure that routine monitoring data collection, flow, processing and utilization guidelines (defined below) support goals of the 208 Plan Update
- Monitoring serves as an early warning system that indicates when planned implementation activities are either a) not occurring or b) are not achieving planned outcomes
- Monitoring data provides an information basis to inform subsequent evaluations

Monitoring Needs

Developing and implementing watershed solutions will require a full command of data and information for design purposes and monitoring resources for adaptive management. To date, significant resources have been dedicated to monitoring Cape Cod waters, but more is needed to provide regionally consistent data to inform watershed management initiatives.

Monitoring data needs to be collected at two scales:

- At the scale of the watershed, overall water quality improvements will need to be evaluated at established sentinel stations.
- Performance data from pilot projects and their employed technologies must be collected

All monitoring data shall be defined and tracked in a centralized online database. It is anticipated that the Commission, in cooperation with the Cape Cod Water Protection Collaborative, will assume responsibility for developing and maintaining this database and making all data easily accessible.

MONITORING AT THE WATERSHED SCALE: WATERSHED PERMIT COMPLIANCE MONITORING

The 208 Plan Update recommends that MassDEP issue permits that will allow communities more flexibility in deciding which technologies to use to meet water quality goals. Monitoring therefore must occur at the scale of the watershed to ensure compliance with nutrient load limitations defined in the permit. To determine permit compliance, monitoring of the following will be necessary:

- Water quality, including watershed nitrogen reduction progress of general water quality
- Ecosystems
  - Benthic
  - Aquatic-eelgrass

PILOT PROJECT MONITORING FOR NON-TRADITIONAL TECHNOLOGIES

The expanded use of non-traditional approaches will require that specific monitoring take place to determine how well a technology is performing. Pilot projects will need to follow specific and consistent monitoring protocols and must demonstrate success to be fully incorporated as part of a multi-pronged watershed management scenario. To facilitate the standardized, coordinated monitoring of non-traditional technologies, protocols for eight technologies are provided in Chapter 5 of this document. These protocols will ensure performance is tracked over time in a consistent manner that can inform adaptive management plans.

General Monitoring Data Guidelines for Non-Traditional Technologies

The following generic guidelines apply for monitoring non-traditional technologies. These guidelines should be followed in addition to the specific monitoring protocols for each of the eight non-traditional technologies provided in Chapter 5.

DATA COLLECTION CATEGORIES

Define generic and unique standards for the collection of routine monitoring data. For each technology, monitoring data will be collected for the following categories: *Performance, Cost*, and *Operations & Maintenance.* Information about *Co-benefits* will be collected as appropriate.

COST

Cost categories should be disaggregated to allow for subsequent cost-effectiveness analyses. Early determination of data needs for cost effectiveness analyses are critical in terms of making the analysis possible or streamlining data collection efforts.

Cost categories could include the following: materials, operation & maintenance, capital, personnel, staff time (sub-categories can be created, i.e administration vs. planning). Funding sources should also be disaggregated.

At the regional level, determinations should be made and listed for the following:

- Analytical perspective of cost-effectiveness analysis (suggest societal perspective)
- Discount rate
- Costs should be measured in constant dollars of one fixed year
- Capital depreciation rate
- Allocating shared material costs
- Boundaries of staff time spent (avoid double-counting costs by specifying which staff track time, i.e contractors vs. volunteer monitoring committee members)
- Value of standard volunteer hour for matching funds

In areas where considerable uncertainty exists (denitrification in the sediments beneath restored oyster beds, for example) sensitivity analyses using different assumptions/datasets should be used to increase confidence in the range of results. A discussion of data discrepancies or controversies should accompany all cost-effectiveness analyses.

PERFORMANCE

Performance categories should measure technology impact on water quality parameters. Depending on the technology deployed, water quality parameters should include, as applicable: nitrogen uptake into harvested biomass (ie: shellfish, vegetation), sediment oxygen demand (SOD), rapid surveys of benthic animal communities, vegetation type and density, and nekton and avifauna communities. Other specific parameters for performance collection are listed within the eight technology monitoring protocols provided in Chapter 5.

OPERATION AND MAINTENANCE (O & M)

Nitrogen removal performance is in part dependent on following proper O&M guidelines for each technology. O&M responsibilities should be clearly defined and tracked in an online database with the collection of all other data. O & M involves both maintaining the physical technology and maintaining performance monitoring records (as defined by the eight technology monitoring protocols provided in Chapter 5) to ensure the technology is operating under acceptable parameters.

DATA COLLECTION & WAREHOUSE TRACKING SYSTEM

The discussion of data processing is constrained to data from performance monitoring for pilot projects. Data should be presented in a consistent manner such that all data related to a particular technology, and, to the extent feasible, data examined across technologies, can be easily compared without need to translate between units, metrics, etc. Automated quality checks for timeliness, completeness, accuracy and usefulness are recommended to be programmed into tracking programs and periodic reviews should take place according to a defined schedule.

Features of a data warehouse tracking system for the eight pilot technologies could include the following:

- Publically accessible via an internet connection
- Updated in real time when new information is added via remote technology or manually
- Pre-defined performance and maintenance ranges for all parameters. If data points fall outside individual ranges, the system should automatically flag these data points for review by system administrators
- Ability to sort by technology, watershed, town, performance or maintenance parameter, time period
- Ability to create charts, graphs or other graphics from data
- Each pilot project should be identified by a unique ID code and contain a file with all associated background information regarding site selection, design, permitting, and implementation. Events that fall outside the scope of routine data collection should be logged in each pilot project file by system administrators
- Contact information (phone, email) for system administrators

DATA FLOW

The data warehouse should include an appropriate and effective system for information sharing and feedback. A diagram shall be created showing the flow of data from providers to users and of feedback from users to providers.

All monitoring data generated by the eight pilot technologies shall be consolidated and made accessible to implementation partners, funding agencies, regulatory agencies and the general public.

DATA COLLECTION AND UTILIZATION

The procedures that ensure effective utilization of monitoring data should be divided into three categories: *Roles and Responsibilities*, *Reporting Format* and *Frequency*, and *Feedback Mechanisms*.

ROLES AND RESPONSIBILITIES

Roles and Responsibilities for data collection and utilization shall be defined and illustrated in a feedback flow diagram.

REPORTING FORMAT AND FREQUENCY

Standardized reporting format and frequency shall be established to ensure consistency and managerial efficiency. Formatting of information shall include:

- **Water quality compliance reporting:** including successes and failures to be used as case studies. The reporting shall occur both before and after project implementation at regular intervals, including annual or monthly averages for water quality parameters; upgradient and downgradient data collection; reference vs. study site.
- **Pilot Project Implementation:** Decisions on logistics and resource requirements, time allocation and areas that need more attention
- **Operations and Maintenance:** Supply and maintenance of shared materials, equipment and best practices. Monitoring of the quantity and quality of service delivery (materials, technical assistance)

FEEDBACK MECHANISMS

The concept of management by exception shall use monitoring data to trigger feedback mechanisms and/or other corrective action if data falls outside a pre-defined range.

- **Triggers:** Thresholds for corrective action should be constructed based on the monitoring data collected. In this sense, monitoring data can serve as an early warning system, indicating when implementation, performance or maintenance is not going according to design. If tasks have been executed according to design, the design itself may need to be re-visited. Adjustments to the management of the pilot project should be made concurrently with the collection of the monitoring data when thresholds are triggered.

CHAPTER 5

TECHNOLOGY MONITORING PROTOCOLS

for Non-Traditional Technologies

Reduction

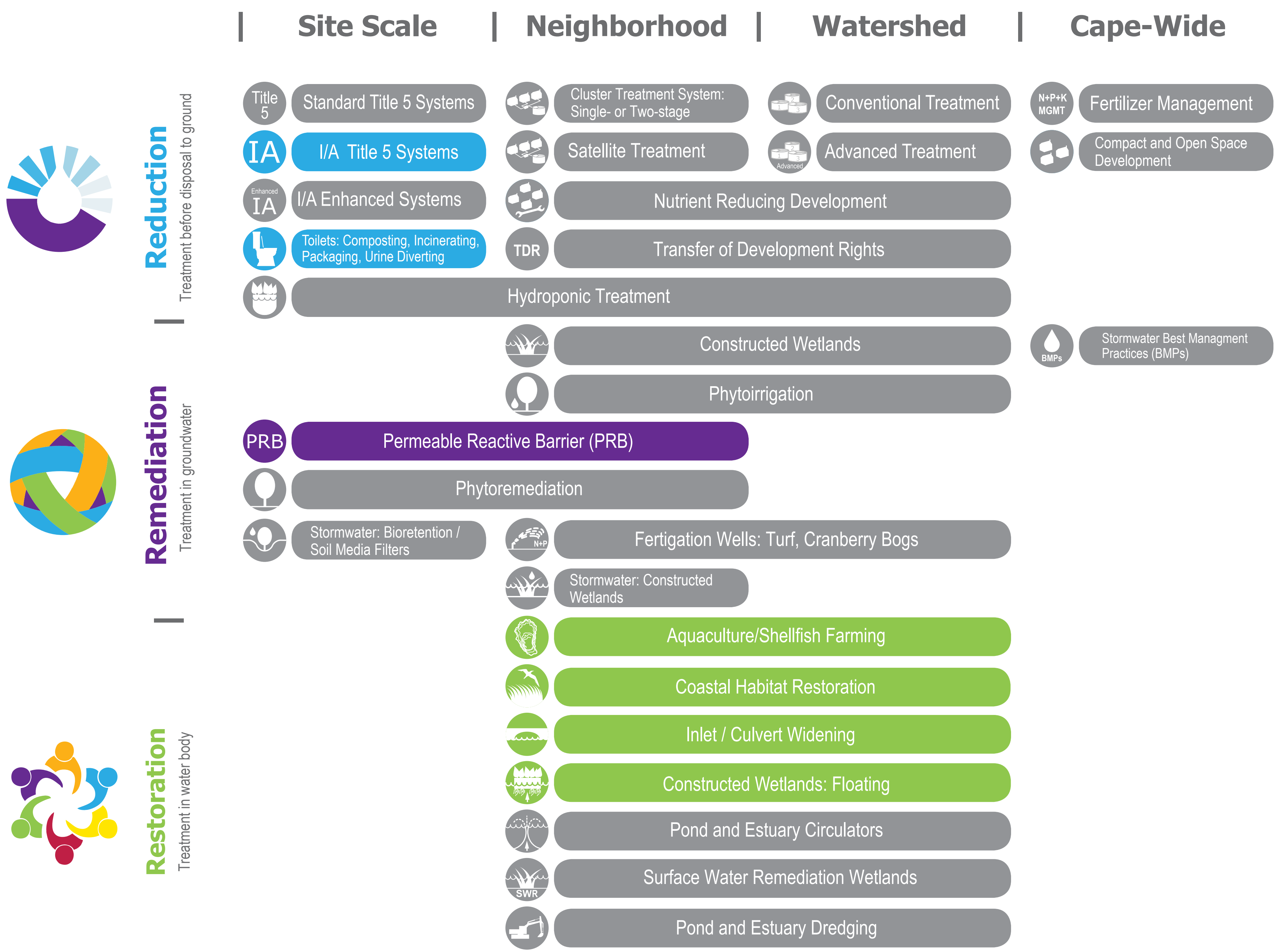
- INNOVATIVE/ALTERNATIVE SYSTEMS
- WASTE REDUCTION TOILETS

Remediation

- PERMEABLE REACTIVE BARRIERS

Restoration

- SHELLFISH BED RESTORATION
- SHELLFISH AQUACULTURE
- COASTAL RESTORATION
- INLET MODIFICATION
- CONSTRUCTED FLOATING WETLANDS



Site Scale
Neighborhood
Watershed
Cape-Wide
Reduction
Treatment before disposal to ground
Title 5
Standard Title 5 Systems
Cluster Treatment System: Single- or Two-stage
Conventional Treatment
N+P+K MGMT
Fertilizer Management
IA
I/A Title 5 Systems
Satellite Treatment
Advanced
Advanced Treatment
Compact and Open Space Development
Enhanced IA
I/A Enhanced Systems
Nutrient Reducing Development
Toilets: Composting, Incinerating, Packaging, Urine Diverting
TDR
Transfer of Development Rights
Hydroponic Treatment
Remediation
Treatment in groundwater
Constructed Wetlands
BMPs
Stormwater Best Managment Practices (BMPs)
Phytoirrigation
PRB
Permeable Reactive Barrier (PRB)
Phytoremediation
Stormwater: Bioretention / Soil Media Filters
N+P
Fertigation Wells: Turf, Cranberry Bogs
Stormwater: Constructed Wetlands
Restoration
Treatment in water body
Aquaculture/Shellfish Farming
Coastal Habitat Restoration
Inlet / Culvert Widening
Constructed Wetlands: Floating
Pond and Estuary Circulators
SWR
Surface Water Remediation Wetlands
Pond and Estuary Dredging

Non-Traditional Technology Monitoring Protocols

Introduction

Monitoring for water quality improvements and performance of non-traditional approaches outlined in the Technologies Matrix will be necessary in implementing the 208 Plan Update. Monitoring is important to measure progress toward meeting water quality goals; it will provide baselines and metrics for adjusting a watershed approach through an adaptive management plan. This section details the necessary components for monitoring water quality improvement on Cape Cod for eight non-traditional technologies.

Water Quality Technologies Matrix

Figure 5.1

The 208 Plan Update includes a menu of technologies that can be utilized as part of a comprehensive watershed plan to improve water quality. Monitoring protocols for eight of the priority non-traditional technologies (highlighted in color) are provided in this chapter.

The Committee has identified criteria for selecting and prioritizing pilot projects of nutrient remediation technologies (in the previous Chapter 4), as well as a strategy and framework for evaluating the performance of these technologies (in the following Chapter 6). Eight monitoring protocols included in this chapter are provided for innovative/alternative (I/A) septic systems, eco-toilets, permeable reactive barriers (PRBs), shellfish bed restoration, aquaculture, inlet modification (IM), coastal restoration, and floating constructed wetlands (FCWs). Each tool or practice has been categorized according to the scale and the situation in which it best performs. Technologies sorted as restoration are those that address nutrient rich water within an affected water body. Technologies categorized as remediation are those that treat nutrient rich water as it travels through the groundwater, before it reaches a water body. Technologies identified as reduction are those that reduce nitrogen before it enters the groundwater. It is anticipated that monitoring data collected from the pilot projects will support updates to the Technologies Matrix.

The need to better understand the effectiveness of non-traditional technologies will require rigorous technology-specific performance monitoring. At a minimum, a monitoring protocol should include an assessment of downgradient resources or sensitive receptors, placement of monitoring stations, parameters of evaluation, methods for collecting and analyzing data, and frequency of data collection. At a minimum, the monitoring protocols set forth in this document should be followed in addition to the General Monitoring Guidelines outlined in the previous Chapter 4.

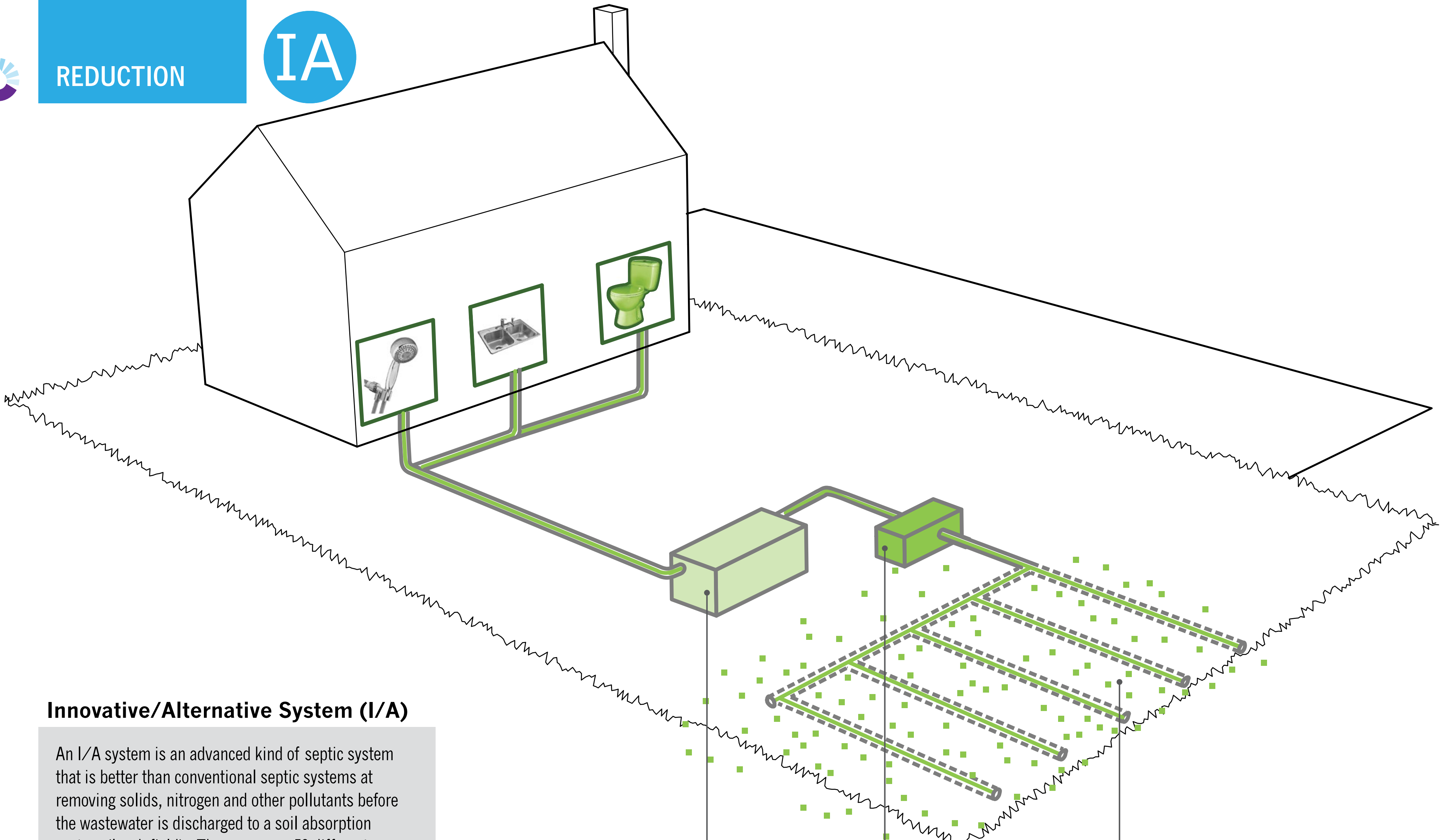
Pilot Project Reporting Template

Included the Appendix is a template to be used to create monitoring reports for pilot projects. This template shall be utilized to keep data collected in a consistent format. The Pilot Project Implementation Team shall collect and hold reports for submission to the Monitoring Committee at regular determined intervals. The reports shall also be used during evaluations of project performance. (see p. A:3)

Protocol Review and Updates

As new information emerges, an adaptive approach to monitoring should be utilized. Therefore, these recommendations for monitoring should be periodically reviewed and updated as new information becomes available.

IA



Innovative/Alternative System (I/A)

An I/A system is an advanced kind of septic system that is better than conventional septic systems at removing solids, nitrogen and other pollutants before the wastewater is discharged to a soil absorption system (leach field). There are over 50 different I/A technologies approved by MassDEP for use in Massachusetts. Owers of I/A systems have maintenance contracts with licensed individuals or companies to ensure they are functioning to meet water quality standards.

Innovative/Alternative Onsite Septic Systems

Technology Monitoring Protocol

Background

I/A septic systems are a possible water quality improvement option for watersheds where the nitrogen removal requirements from the wastewater component does not exceed approximately 50%. To date however, wastewater managers have not proposed I/A systems as a TMDL compliance strategy and there is no commonly accepted monitoring strategy. The following is a draft monitoring strategy for monitoring frequency and duration in watersheds where I/A technologies are applied to meet TMDLs.

Data Collection

MONITORING OF SERVICE CONTRACTS AND MAINTENANCE REQUIREMENTS

Since the performance of systems and the assurance that I/A systems are being properly operated is an essential part of an overall program, the first element of a monitoring program involves the oversight of maintenance contracts and inspections. It is recommended that all I/A systems serving as part of a TMDL compliance strategy be monitored continuously for service contracts and inspection schedules. The BCDHE Tracking Program or equivalent should be used to continuously monitor this aspect.

Note:

Barnstable County Department of Health and Environment (BCDHE) is presently in discussions with EPA Region 1 staff to develop a statistical tool for determining the sampling frequency for I/A systems based on the large dataset already collected under the BCDHE I/A Tracking Program. This proposed monitoring plan serves as an interim recommendation.

PERFORMANCE MONITORING

I/A systems in Barnstable County are subject to various monitoring requirements depending on the requirements of a board of health. Pursuant to the I/A program under Title 5, requirements range from no discharge monitoring to two year's duration of monitoring on a quarterly basis, to monitoring for an indefinite period. However, I/A installations proposed as part of a comprehensive wastewater management strategy will require more rigorous monitoring protocols.

The following are recommendations for monitoring:

	PERFORMANCE MONITORING
IA-1	**Frequency**: Systems installed in watersheds using I/A systems for TMDL compliance should be sampled according to a schedule approved by MassDEP. **Note: Efforts to determine a sampling plan that has statistical validity is currently underway and will determine the number of systems that have to be sampled.** For seasonal facilities, pre-season start-up procedures should be implemented in accordance with a MassDEP approved plan.
IA-2	**Monitoring Location(s):** All systems installed in watersheds using I/A systems for TMDL compliance should have an inspection/monitoring port that will provide a clean unbiased sample. This monitoring port should be approved with the plan submitted under the appropriate permitting protocol for review and approval by MassDEP.
IA-3	**Water Quality Parameters:** ■ All systems scheduled to be sampled shall be monitored for flow, pH, and Total Nitrogen (TN). ■ Monitoring for Biochemical Oxygen Demand (BOD 5-day) and Total Suspended Solids (TSS) should only be required where the system design includes a reduction in soil absorption system size or reduced depth to groundwater.

It is recommended that staff from the BCDHE conduct all monitoring that is part of TMDL compliance. Since BCDHE tracks all service contracts, the monitoring data collected will be immediately transmitted to the operator on record. This will save on costs for monitoring since the information base at BCDHE will enable the efficient scheduling of sampling regardless of the operator.

OTHER CONSIDERATIONS

Any variables that may influence performance monitoring results shall be described and documented.

O & M

Because nitrogen removal performance can be dependent on following proper O&M, responsibilities should be clearly defined and tracked.

CO-BENEFITS

Co-benefits (if any) shall be identified and monitored.

COST

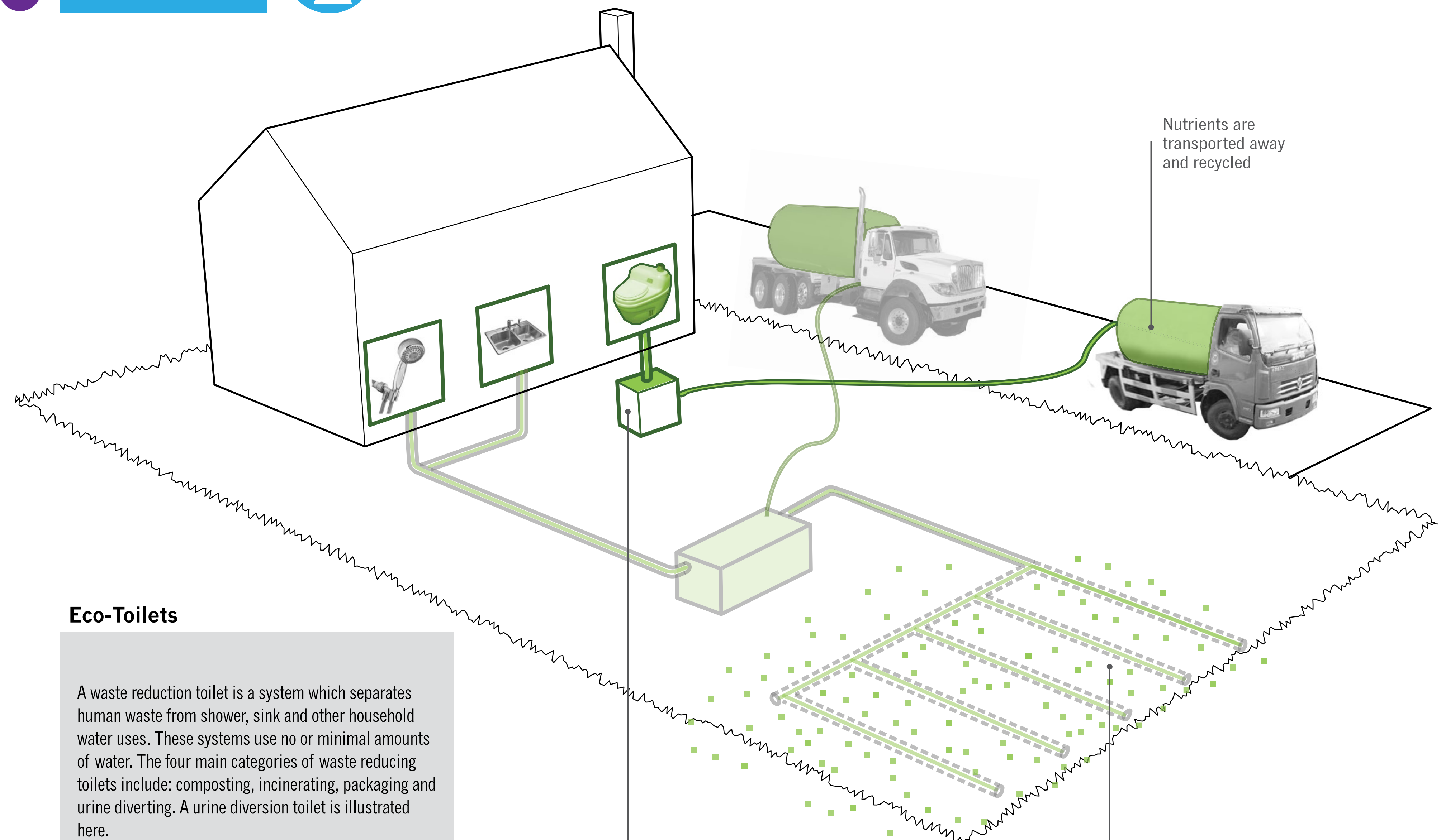
Including the requirements for service contracts that include regular inspection and maintenance, the following is an estimated annual cost for I/A system monitoring. The estimate does not assume any economy of scale and assumes that monitoring would be completed by a third party (not the operator of the system). It is likely that systems in a watershed will be geographically close and this would offer savings on the labor and mileage, particularly if many can be sampled on the same day.

Service Contract Estimate	$400.00
Tracking Fee as part of Management District	$50.00
Total nitrogen sampling at effluent	$720.00
Labor involved in sampling collection	$720.00
Travel (mileage) @ $.55/mile	$330.00
Total	$2,220.00
Monthly	$185.00

Cost categories should be disaggregated and should include the following: materials, O&M, capital, personnel, staff time (sub-categories can be created, i.e administration, planning, monitoring, reporting). Funding source should also be disaggregated. See "General Monitoring Data Guidelines" (Chapter 4, p. 4:2) for more details.

Data Analysis and Reporting

Raw data and the Project Report Template should be submitted to the Monitoring Committee for technical review. Consult "General Monitoring Data Guidelines" (see Chapter 4, p. 4:3) for further information on data processing, flow, and utilization.



Eco-Toilets

A waste reduction toilet is a system which separates human waste from shower, sink and other household water uses. These systems use no or minimal amounts of water. The four main categories of waste reducing toilets include: composting, incinerating, packaging and urine diverting. A urine diversion toilet is illustrated here.

Eco-Toilets
Technology Monitoring Protocol

Background

Eco-toilets include a range of strategies that divert various subsets of the residential wastewater stream to alternative methods of storage and handling. They include composting toilets (various designs) and urine diverting toilets. For residential composting toilets used in association with a graywater disposal system, a nitrogen credit eqivalent to a discharge of 19 mg/L TN is allowed per Title 5. There are no commonly accepted nutrient reduction credits for use of composting toilets for commercial or institutional facilities or for urine diverting toilets, so accordingly the monitoring and sampling strategy presented focuses on the pilot application of these technologies and the determination of appropriate reduction credits.

Data Collection

PERFORMANCE MONITORING

	PERFORMANCE MONITORING
ET-1	**Monitoring of Service Contracts & Maintenance:** Biannual inspections should be completed. Since the residual byproducts of all diversion technologies contain nutrients, the volume and disposition of all residuals (urine, compost and compost "tea") must be closely monitored. It is recommended that a contract be in place with all owners of homes and facilities having an eco-toilet and that these contracts be tracked and required to be continuously in force in order to obtain nitrogen credits. Prepayment for disposal is considered essential for ensuring proper residual disposal. Contracts should include a biannual inspection.
ET-2	**Monitoring Locations:** Monitoring of the discharge from the graywater disposal system (for composting toilets) and blackwater/graywater system (for urine diverting toilets) must be completed. Discharge samples should be taken in the distribution box situated distal to the septic tank and proximal to the soil absorption system.
ET-3	**Frequency:** The pilot application of eco-toilets should include a requirement for monthly sampling for TN to determine the nitrogen removal credit and the variability associated with performance of these systems.
ET-4	**Water Quality Parameters to Measure:** - Nutrients

OTHER CONSIDERATIONS

Any variables that may influence performance monitoring results shall be described and documented. The existing septic tank must be pumped and cleaned following the installation of the eco-toilet. If existing cesspool remains, it should be pumped and cleaned and access to the inlet pipe must be provided.

O & M

Because nitrogen removal performance can be dependent on following proper operation & maintenance guidelines, O&M responsibilities should be clearly defined and tracked.

CO-BENEFITS

Co-benefits (if any) shall be identified and monitored. Co-benefits identified in the Technologies Matrix include the energy savings, nutrient recovery and recycling benefits of eco-toilets.

COST

Including the requirements for service contracts that include regular inspection and maintenance, the following is an estimated annual cost for eco-toilet monitoring. The estimate does not assume any economy of scale and assumes that monitoring would be completed by a third party (not the operator of the system). It is likely that systems in a watershed will be geographically close and this would offer savings on the labor and mileage, particularly if many can be sampled on the same day.

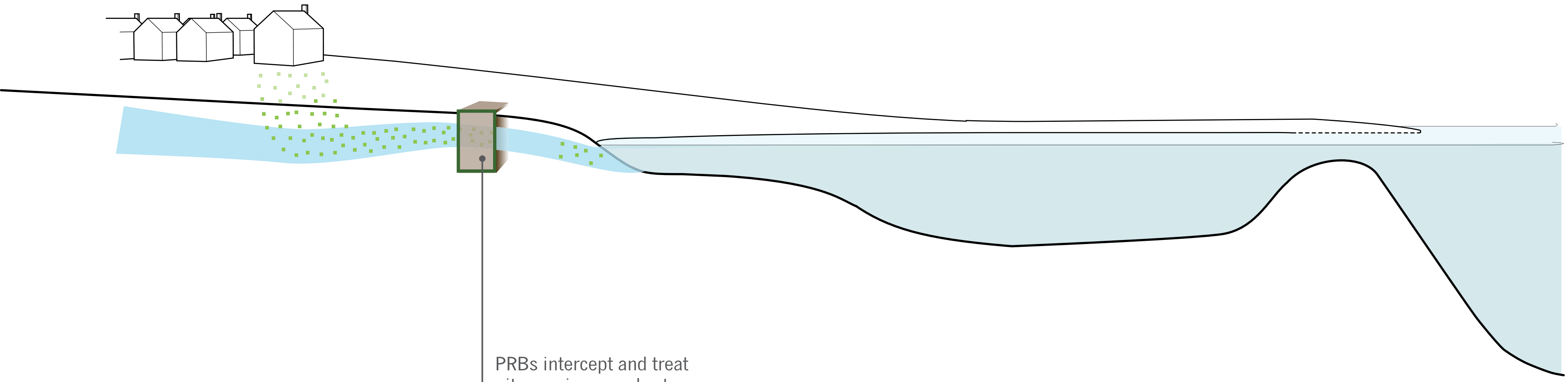
These costs do NOT include the cost of transporting and disposing of residual by products (compost, compost “tea” and urine).

Cost categories should be disaggregated and should include the following: materials, O&M, capital, personnel, staff time (sub-categories can be created, i.e administration, planning, monitoring, reporting). Funding source should also be disaggregated. See "General Monitoring Data Guidelines" (Chapter 4, p. 4:2) for more details.

Service Contract Estimate	$200.00
Tracking Fee as part of Management District	$30.00
Total nitrogen sampling at effluent	$720.00
Labor involved in sampling collection	$720.00
Travel (mileage) @ $.55/mile	$330.00
Total	$2,000.00
Monthly	$166.67

Data Analysis and Reporting

Raw data and the Project Report Template should be submitted to the Monitoring Committee for technical review. Consult "General Monitoring Data Guidelines" (see Chapter 4, p. 4:3) for further information on data processing, flow, and utilization.



Permeable Reactive Barrier

A permeable reactive barrier (PRB) is an in-situ (installed within the aquifer) treatment zone designed to intercept nitrogen enriched groundwater. Through use of a carbon source, microbes in the groundwater uptake the nitrogen, denitrifying the groundwater. There are two methods of installing PRBs: trenching and injection wells.

Permeable Reactive Barrier
Technology Monitoring Protocol

Background

A permeable reactive barrier (PRB) is a subsurface zone of reactive material designed to intercept and remediate contaminated groundwater. Utilizing different reactive media, PRBs have historically been used to treat groundwater contaminated by a broad range of contaminants including chlorinated solvents, arsenic, chromium, nitrate and other organic and inorganic compounds (US EPA 2012). PRBs may be installed using several different methods including trenches and injection wells.

PRBs provide a carbon source to microbes that exist in groundwater. The carbon source provides energy to allow the microbes to breakdown nitrogen to nitrogen gas. There are two means of providing the carbon source to the microbes in the groundwater: the trench and the injection well methods. The two methods are installed differently and provide a different carbon source; however the nitrogen reduction process works similarly.

Trench PRBs are comprised of a coarse grained soil mixed with a reactive media (such as wood chips or sawdust) that provides a carbon source for microorganisms that remove contaminants from groundwater. Generally, trenches are constructed vertically, perpendicular to groundwater flow, in order to capture and treat horizontally flowing groundwater. A trench-style PRB is typically excavated to a certain thickness and depth, then filled with some type of reactive media.

An injection well PRB is a network of wells where a reactive media is injected in to the subsurface where it reacts with contaminated groundwater. The wells are constructed by first drilling a series of boreholes and then injecting the reactive media under pressure in to the subsurface, often using a carrier fluid (e.g., high-pressure gas, water, or other solution). The injection wells are spaced to provide overlapping radii of influence (ROI) to create a continuous reactive zone. Borings are typically installed 20-25 feet apart, having a radius of influence of 12-15 feet from each injection point.

PRBs require detailed monitoring and site characterization during site selection, perhaps even more so than other non-traditional tools for nutrient management. In addition, all phases of implementation (pilots, initial startup, and compliance) require relatively regular, and sometimes intensive monitoring to assess PRB performance.

The following is a recommended strategy for monitoring of PRBs in watersheds where this technology is applied to meet TMDLs reduction targets. These broad monitoring recommendations are intended to help inform project-specific monitoring plans and/or Quality Assurance Project Plans which should be created specific to each PRB site selection, design, and installation effort. Detailed guidance on PRBs, including monitoring, can be found in the Interstate Technology & Regulatory Council (ITRC) guidance document, ITRC. 2011, Permeable Reactive Barrier: Technology Update. PRB-5. Washington, D.C.: ITRC, PRB: Technology Update Team.

Data Collection

SITE SELECTION PROCESS/ MONITORING

Appropriate site selection and site characterization are critical to the success of a PRB. Past experience

MONITORING AND DATA REQUIRED FOR SITE SELECTION	
PRB-1	**Level 1: GIS/Desk Level Screening** The first step in assessing appropriate PRB locations is done using existing datasets that includes review of the following: ■ Review of the previous site-specific hydrogeology and nitrogen fate and transport investigations ■ Identify previously installed monitoring points and data collection efforts ■ GIS data including water table contours, depth to groundwater, roads, sub-watershed nitrate removal targets, land use, protected natural areas, public property access, etc. ■ Particle tracking to determine groundwater flow direction
PRB-2	**Level 2: Site Reconnaissance Screening** Site reconnaissance screening occurs once potential sites have been identified at the GIS/desk level. At this site stage, monitoring wells are required for determining whether site-specific conditions are appropriate for PRB installation. It should be noted that since this level of characterization is needed to determine whether or not a given site is appropriate, it is expected that some sites that advance to this stage will ultimately be deemed inappropriate, and the installed monitoring wells will be abandoned. Therefore, the cost of evaluating multiple sites must be considered whenever PRBs are intended for use by a municipality to reduce nutrient loads. Site Reconnaissance Screening includes: ■ Logging of new borings to test geologic sediment samples, preferably taken at proposed PRB site cross-sections ■ Install exploratory monitoring wells to achieve at least 3 water table elevations at each site in order to determine the hydraulic gradient at the site; installed wells should be tested to determine the general hydraulic conductivity

has shown that inadequate performance of a PRB typically stems from incomplete site characterization and inadequate hydraulic design (ITRC 2011). For use in watersheds where PRBs are being used to meet TMDL reduction targets, the monitoring recommendations below have been broken down into ordered tasks in the process of site selection and characterization, including, 1) GIS/desk Level Screening; 2) Site Reconnaissance Screening; and 3) Site Characterization for PRB Design.

PILOT PROJECT PERFORMANCE MONITORING

Pilots of non-traditional tools for nutrient management are intended to determine their effectiveness and identify with more certainty potential construction and operation and maintenance costs. The 208 Plan Update has identified PRBs as a technology that requires piloting in order to minimize risk and avoid having many communities expend funds and time to design and install PRBs that may not perform as hoped. It is expected that a small number of pilot projects will be implemented in settings that allow for fair evaluation of performance. The specific goals of PRB pilots include determining the effectiveness of a particular PRB material or construction technique, optimizing installation and monitoring methods, developing load reduction calculation methods, etc.

MONITORING POINTS

Monitoring wells should be located upgradient and downgradient of the PRB, parallel to the direction of groundwater flow. At pilot sites, it is recommended that there is at least 1 upgradient and 1 downgradient well for each 100 linear feet of PRB, although additional wells may be needed especially if hydraulic conductivity and/or nutrient concentrations vary significantly across the PRB area. Additional monitoring wells located within the reaction zone, to the side of the reaction zone, and at deeper depths below the reaction zone, should be installed to fully characterize groundwater flow, assess bypass, and assess PRB performance. Additional wells downgradient may be used to further assess PRB performance by testing for redox indicators within the redox recovery zone, and may be used to detect secondary water quality issues associated with redox changes such as Fe, Mn, and other metals.

- Upgradient of PRB
  - Type: Single screen wells
  - Measure: Water levels, hydraulics, groundwater quality parameters

PRB-2

Level 2: Site Reconnaissance Screening

- Conduct the following sampling efforts to characterize area:
  - Water level recorders (need to determine 3 water table elevations for determining hydraulic gradient)
  - Nitrogen sampling: TN, N02/N03, TKN, NH3
  - Water quality sampling: DO, conductivity, alkalinity, DOC, pH, salinity
  - Multi-level sampling to characterize vertical profile; vertical profile may be done using direct-push methods done to the maximum depth achievable at the site.
  - Install ports that surpass/straddle depth of saltwater interface
- Conduct tracer testing to provide direct measurement of time-of-travel and groundwater velocity. This involves injecting bromide or fluorescent dye in wells situated immediately upgradient of the PRB, monitoring the downgradient wells for the tracer.
- Conduct single-well hydraulic tests such as slug-tests, specific capacity testing, and step-drawdown testing in each monitoring well and piezometer (if possible). Multi-well aquifer pumping tests can also be conducted (assumed duration of 8 hrs. will suffice). Performance of these hydraulic stress tests will provide response data to estimate hydraulic properties of the geologic sediments in the PRB area.

PRB-3

Level 3: Site Characterization for PRB Design

PRB design is focused on ensuring that groundwater flow is captured by the PRB, and that the dimensions of the PRB and materials used are appropriate for remediating intercepted nutrients in groundwater. To achieve this, a comprehensive site characterization is required at the PRB design level. Monitoring at this level should be consistent with an evaluation needed to develop a detailed, three-dimensional, understanding of site conditions including flow and nutrient concentrations and the spatial variability of each. Monitoring at this level should include:

- Vertical profiling of hydraulic conductivity, in addition to the analytes and WQ parameters listed above
- If injection is to be used for PRB emplacement, an injection test should be conducted with monitoring wells surrounding the injection point to confirm design parameters.
- Cores should be collected of subsurface materials (e.g. using direct-push methods) in order to characterize materials and variability in hydraulic properties.
- A site-specific groundwater model may be developed to better understand how variations in hydraulic conductivity effect groundwater flow and expected interaction with the PRB.

- Purpose: Characterize upgradient conditions such as hydraulic gradient and nitrate concentrations
- Directly Adjacent to PRB (upgradient and downgradient)
  - Type: Multi-level Sampling (MLS) Wells
  - Measure: Tracer/Breakthrough testing, saltwater interface, groundwater quality parameters
  - Purpose: Determine hydraulic impacts, nitrate attenuation performance, saltwater interface characterization
- Downgradient of PRB
  - Type: Single screen wells
  - Measure: Water levels, hydraulics, groundwater quality parameters, tracers
  - Purpose: Characterize downgradient conditions such as hydraulic gradient, iron mobilization/demobilization, breakthrough potential, and nitrate concentrations
- Ends of PRB
  - Type: Piezometers
  - Measure: Water levels
  - Purpose: Determine hydraulic impact of PRB
- Tidal
  - Type: Stilling well
  - Measure: Tidal water level data for saline water body nearest PRB location
  - Purpose: To estimate the "hydraulic diffusivity" of the geologic sediments between the shoreline and the PRB location, cross-check hydraulic properties of aquifer, determine hydraulic impact of PRB construction/installation by measuring changes in groundwater level responses due to tidal water level variations.

The following table, taken directly from CDM Smith's Technical Memorandum on PRB Monitoring, details the aforementioned monitoring points:

Set	Primary Purposes	Type	Time of Installation	Location along PRB Length	Pattern	Approx. Distances from PRB (ft)	Vertical Placement
A	upgradient hydraulic & water quality conditions	Monitoring wells	Before PRB	Mid-point	Transect	25 & 50	Middle of fresh groundwater collumn
B	Nitrate attenuation & hydraulic impacts immediately adjacent to PRB upgradient downgradient	Multi-port monitoring wells	At time of PRB installations	Mid, 25%, & 75% points	Pairs straddeling PRB	10	4 ports spaced equally accross fresh groundwater collumn & 1 port immediately below saltwater interface
C	Downgradient iron mobilization-demobilization & hydraulic conditions	Monitoring wells	Before PRB	Mid-point	Transect	25, 50, & 100	Middle of fresh groundwater collumn
D	Hydraulic impact on ambient groundwater flow	Piezometers	Before PRB	Beyond PRB ends	N/A	10 to 25	Immediately below water table
E	Tidal signal and its propogation for hydraulic characterization	Stilling well	Before PRB	Mid-points	Triangular	near shoreline	Shallow, in layer hydraulically connected to saline water body

PARAMETERS/CHARACTERIZATION				SAMPLING STAGES/FREQUENCIES/LOCATIONS			
				PRE-AMBIENT CONDITIONS CHARACTERIZATION	IMMEDIATELY BEFORE & AFTER INSTALLATION	POST INSTALLATION- FIRST 2 MONTHS	POST INSTALLATION- AFTER 2 MONTHS
	Nitrate Attenuation	Iron Mobilization & Demobilization	Septic Systems Indicators	1 to 3 rounds	2 rounds	3 rounds	6 rounds
Temperature	X	X	X	A, C	A, B, C	B, C	B, C
Dissolved Oxygen (DO)	X	X	X	A, C	A, B, C	B, C	B, C
pH	X	X	X	A, C	A, B, C	B, C	B, C
Salinity	X			A, C	A, B, C	B	B
Reduction/Oxidation (Redox Potential)	X	X	X	A, C	A, B, C	B, C	B, C
Conductivity	X	X	X	A, C	A, B, C	B, C	B, C
Nitrate	X		X	A, C	A, B, C	B	B
Nitrate	X		X	A, C	A, B, C	B	B
Ammonia	X		X	A, C	A, B, C	B	B
Total Kjeldahl Nitogen (TKN)	X		X	A, C	A, B, C	B	B
Sulfate	X		X	A, C	A, B, C	B	B
Sulfide	X		X	A, C	A, B, C	B	B
Dissolved Organic Carbon (DOC) /(TOC)	X		X	A, C	A, B, C	B	B
Methane	X		X	A, C	A, B, C	B	B
Ferric Iron		X		A, C	A, B, C	C	C
Ferrous Iron		X		A, C	A, B, C	C	C
Manganese		X		A, C	A, B, C	C	C
Sodium		X		A, C	A, B, C	C	C
Chloride		X		A, C	A, B, C	C	C
Alkalinity		X		A, C	A, B, C	C	C
Boron			X	A, C			
Methyl blue active substances (MBAS)			X	A, C			
Water level recording				A, C, D, E	A- E	A- E	A- E
Manual water levels				A, C, D, E	A- E	A- E	A- E
Salinity/ temperature probe recording					B	B	B

SAMPLING FREQUENCIES

1) Pre-PRB Ambient Conditions Characterization: 1-3 rounds

2) Immediately Before & After Installation: 2 rounds, one within a week of the start of construction and one within a week of the end of construction. Because of it's close proximity to the PRB, set B will be installed during PRB installation rather than before PRB construction like sets A, C, D & E. Thus set B wells will only provide after installation data.

3) Post- Installation- First 2 months: 3 rounds at 2 weeks, 4 weeks, and 8 weeks after the last set of sampling round immediately after installation.

4) Post Installation- After 2 months: 6 rounds, mountly for 4 months, then quarterly, unless issues or concerns arise due to monitored conditions.

5) Water level recording: Semi-permenant deployment in sets C & E, and in 2 set B ports opposite each other, plus up to 5 very short-term deployments for hydraulic property testing (slug tests, specific capacity tests, aquafer performance tests.

6) Manual water levels: measure each time an MW is sampled for other water quality parameters.

7) Salinity/temperature probe recording: Deploy in set B mid-point ports straddeling the PRB laterally, and screened above and below the saltwater interface, for a total of 4 ports.

MONITORING PARAMETERS

Determining nitrate attenuation requires the following water quality parameters to be monitored:

- temperature
- dissolved oxygen
- pH, salinity
- redox potential
- conductivity
- nitrate
- ammonia
- TKN
- sulfate
- sulfide
- dissolved organic carbon or total organic carbon
- methane
- temperature

Determining whether septic system effluent is specifically present requires the additional monitoring of boron and MBAS (both components of detergents).

Determining whether iron mobilization is occurring and is likely to be demobilized sufficiently requires the following water quality parameters to be monitored:

- temperature
- dissolved oxygen
- pH
- redox potential
- conductivity
- ferric iron
- ferrous iron
- manganese
- sodium
- chloride
- alkalinity

Upgradient and downgradient wells can be used to assess nutrient attenuation, which can be converted to a load reduction using site-specific hydrogeology and the properties of the reactive media. A simple approach to calculating load reductions is to first calculate specific discharge using Darcy's Law. However, a site-specific groundwater flow model may offer a better method for determining flux through the PRB and calculating the nutrient load reduction.

SAMPLING FREQUENCY AND DURATION

The frequency and duration of pilot monitoring should be determined in an adaptive monitoring plan that responds to changing site conditions and monitoring results. In general, the frequency of monitoring should begin as monthly, but could be reduced to quarterly depending on the variability of monthly results:

- First two months - Sampling rounds should be conducted at week 2, week 4, and week 8.
- Month 2 – Month 6 – Sampling rounds should be monthly
- Month 6 – End – Sampling rounds should occur quarterly

PRB effectiveness can be demonstrated within 1 year, depending on spacing between upgradient-downgradient MLS monitoring wells. However, the duration of pilot monitoring is expected to extend for several years (e.g. approximately 5 years), amicrobial growth develops over time and eventually the PRB reaches optimal performance. It is important to note that this monitoring period includes not only repeated rounds of nutrient and water quality sampling, but also repeated assessments of the groundwater flow regime and how it may change over time (e.g. seasonal variation, variation with changes in PRB hydraulic properties, etc).

The previous table, taken directly from CDM Smith's Technical Memorandum on PRB details recommended sampling parameters and frequencies:

COMPLIANCE MONITORING

Compliance monitoring is intended to establish nutrient load reduction credits for the PRB, and to ensure the PRB continues to achieve expected results over its life. In general, monitoring during the initial, start-up phase of a PRB will be more intensive than over the long-term phase, once the PRB reaches optimal performance.

INITIAL MONITORING

Initial monitoring will assess the effectiveness of the PRB, and provide the data needed to calculate a nutrient load reduction. As described in Section 2.0 for Pilot Monitoring, a monitoring well network with wells upgradient and downgradient of the PRB should be used to evaluate nutrient attenuation and the associated load reduction. The monitoring well network should be sufficient to characterize the groundwater flow regime around and through the PRB, in addition to measuring nutrient concentrations upgradient and downgradient of the PRB. Initial monitoring (i.e. sampling and groundwater flow assessment) is expected to extend for up to 2 years following PRB construction as the PRB establishes itself, during which time monitoring should be conducted at least quarterly.

LONG-TERM PERFORMANCE MONITORING

Once the PRB reaches optimal performance and monitoring results from the initial period demonstrate that the PRB is effective over time, sampling extent and frequency can be reduced during long-term performance monitoring. Performance monitoring is expected to continue for the life of the PRB. Sampling and assessment of changes in the groundwater flow regime during this period may be reduced to semi-annual.

One additional component of long-term monitoring is process monitoring, which is intended to evaluate the need for system adjustments. Process monitoring generally occurs within the PRB itself and/or within the reaction zone immediately downgradient. Process monitoring should inform the need to replenish PRB material, consistent with the life-expectancy of the material chosen. Replenishment of PRB materials should trigger a period of more frequent monitoring, similar to the initial monitoring period in order to re-establish performance criteria for the PRB.

CONFOUNDING FACTORS

The optimal design of a PRB that intercepts the groundwater plume must consider the local hydrology and surrounding aquifer properties. In order to ensure groundwater interception, the vertical thickness of the groundwater lens relative to the depth of the PRB must be considered. The practical maximum depth that can be achieved with trench designs is 40 – 45 feet. Injection wells installation methods have the potential for a much deeper design. PRBs should also be designed to match the hydraulic conductivity and permeability of the surrounding groundwater matrix.

With regard to downgradient impacts of PRBs, anaerobic byproducts such as methane, manganese, sulfide, and ferrous iron may be generated, but are anticipated to return to background levels at short distances downgradient (less than 100 feet) of the PRB Monitoring points downgradient of the PRB will elucidate whether unwanted geochemical changes are occurring.

O & M

Because nitrogen removal performance can be dependent on following proper operation & maintenance guidelines, O&M responsibilities should be clearly defined and tracked.

CO-BENEFITS

PRBs may have the capacity to filter out additional contaminants in groundwater other than nitrates including chemicals of emerging concern (CECs), heavy metals, and other organic and inorganic compounds.

COSTS

Cost categories should be disaggregated and could include the following: materials, operation & maintenance, capital, personnel, staff time (sub-categories can be created, i.e administration, planning, monitoring, reporting). Funding source should also be disaggregated. See "Monitoring Data Guidelines" for more details.

The costs for PRBs include design, permitting, construction, and operation and maintenance. Design includes site characterization (including hydrogeologic study), identification of existing subsurface infrastructure and engineering plans. Permitting is variable depending upon site locations and scale. Construction costs vary depending upon installation method (trench versus injection wells). Operation and maintenance includes monitoring and potentially rejuvenation of reactive media. CDM Smith recently completed a cost analysis for a proposed pilot project to test PRB technology in the Town of Falmouth. The following table summarizes the estimated costs of this pilot project using two alternative installation methods. It is anticipated that additional costs analyses and feasibility studies are forthcoming, as EPA and the Southeast New England Coastal Watershed Restoration Program have funded initial studies in five Cape Cod towns regarding PRB pilot projects.

ESTIMATED COST OF GREAT HARBORS PILOT PROJECT IN FALMOUTH, MA	One-Pass Trench
Design/Permitting	$100.00
Construction – One Pass Trench	$1,386,000
Construction – Injection Wells	$673,120
Monitoring Well Installation	$75,000
Sampling & Analysis	$80,000/yr.
Interpretation of Results	$25,000
Rejuvenation (Injection Wells)	$234,000

Estimated cost of Great Harbors Pilot Project in Falmouth, MA (Source: CDM Smith)

Data Analysis and Reporting

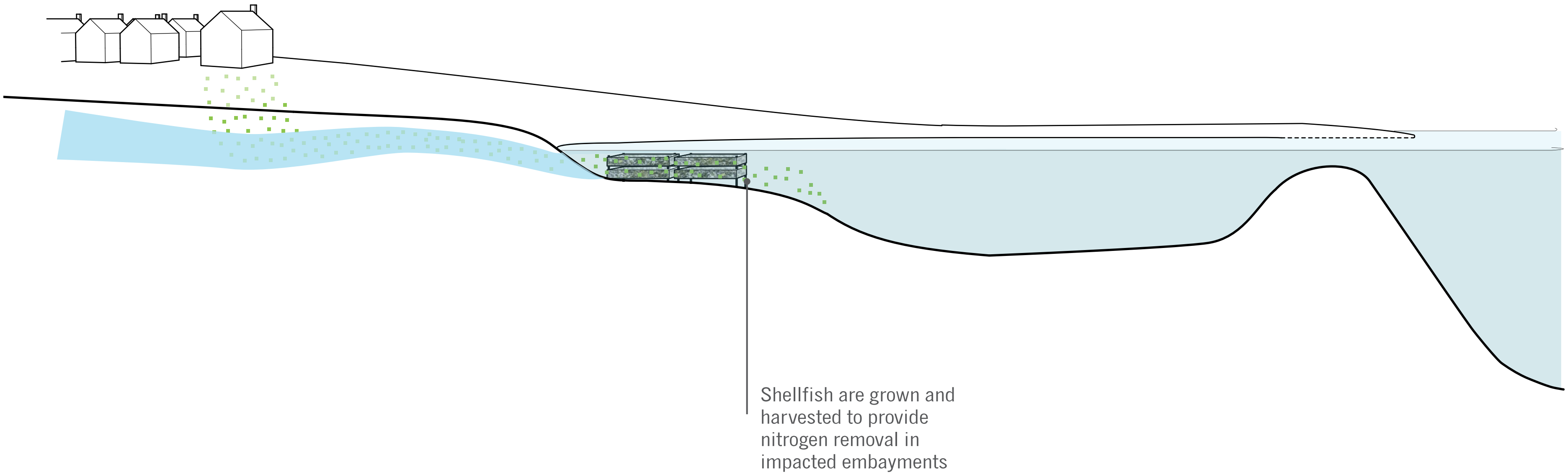
Raw data and the Project Report Template should be submitted to the Monitoring Committee for technical review. Consult “Monitoring Data Guidelines” for further information on data processing, flow, and utilization.

RESEARCH NEEDS

The extent to which different chemical and biological pathways remove nitrogen from groundwater within a PRB, as well as determining the useful lifetime of PRBS for nitrate removal, could be better defined through further research and more widespread deployment for nitrate removal purposes.including chemicals of emerging concern (CECs), heavy metals, and other organic and inorganic compounds.

References

CDM Smith. (2012). *Technical Memorandum No. 4: Monitoring During the Permeable Reactive Barrier (PRB) Pilot Project* - DRAFT.



Shellfish Aquaculture

Shellfish, specifically oysters, remove nitrogen from their environment. The growing and removal of the mature oysters can remove nitrogen from an estuary, reducing the estuary's nitrogen load. Aquaculture can become a dual purpose project where shellfish are harvested for market with the added benefit of nitrogen reduction in the surrounding waters.

Background

This section describes recommended monitoring procedures for shellfish aquaculture and projects that involve using remote set (spat-on-shell) to establish reef-like growing areas. Shellfish aquaculture for nitrogen management involves setting up and maintaining shellfish aquaculture and harvesting operations for the purpose of reducing nitrogen concentrations in estuarine waters.

Monitoring of shellfish aquaculture will differ depending on the mechanism of nitrogen removal that needs to be documented for credit. There are two different mechanisms involved when shellfish are used to reduce nitrogen concentrations: direct uptake of nitrogen and denitrification. Both can be important and so a third mechanism would be to account for both. The three mechanisms are described below:

- **Direct uptake of nitrogen into shellfish tissue and shells followed by harvesting:** When shellfish filter-feed, they ingest organic particles containing nitrogen (e.g., algae, plankton, organic detritus) and this nitrogen is converted into shellfish tissue and shells. The nitrogen in shellfish tissue and shells is removed from the estuary when shellfish are harvested. The key removal mechanism is uptake of particulate nitrogen from the water column by shellfish. Research and pilot tests show that the nitrogen content of shellfish varies with species, size, salinity, and aquaculture configuration (i.e., on-bottom culture vs. floating culture). (For more information on studies of nitrogen content in shellfish, see References at the end of this section on p. 5:29)
- **Microbial processes additionally occur that favor denitrification:** Living shellfish excrete nitrogen-containing wastes into the surrounding water and sediments. Microbial nitrogen-cycling processes (e.g., ammonification, nitrification, denitrification) convert the nitrogen into dissolved inorganic forms (ammonia, nitrate) and gaseous forms (primarily N2) . Dissolved inorganic nitrogen re-enters the water column and can be used by algae. However, denitrification converts dissolved nitrate into gaseous nitrogen (N2) which is not available to most algae and hence this nitrogen gas may be considered as nitrogen removed from the estuary. More research is needed to characterize denitrification rates in Cape Cod environments (Reitsma et al., 2014). The key removal mechanism here is denitrification, since only a small amount of nitrogen is permanently buried in sediments. It should be noted that shellfish may also decrease ambient denitrification rates if the loading of organic matter to the sediments is very high and especially if the shellfish aquaculture causes local oxygen depletion in bottom waters.
- **A combination of shellfish harvesting and microbial denitrification:** Combining both of the above mechanisms should result in a larger net reduction in nitrogen in the estuary. Monitoring methods will therefore differ depending on which nitrogen-removal mechanism must be documented in order to get credit. If the goal is to demonstrate direct uptake and removal of nitrogen by shellfish harvesting, monitoring will be relatively straightforward and based on routine

observations; this type of monitoring is likely to be feasible for municipalities. However, if the goal is to demonstrate that denitrification or burial in sediment is removing nitrogen from the water column, more complex scientific monitoring is needed to analyze and quantify microbial nitrogen cycling and nitrogen removal processes. This requires scientific knowledge of microbial nitrogen cycling and scientific expertise to design and implement field and perhaps lab studies to address specific questions; this is likely to be best conducted by scientists or scientific consulting firms working with scientists. Finally, if the goal is to demonstrate that both mechanisms of nitrogen removal are operating, then both monitoring approaches would be used.

Note: *Local research indicates that the percentage of total nitrogen in shellfish (including both tissue and shell) averaged 0.67% for quahogs from Cape Cod, 0.69% for oysters from Cape Cod, compared to 0.34% and 0.45% for wild Chesapeake oysters and cultured Chesapeake oysters, and that shellfish size is the most important parameter that determines the amount of nitrogen taken up by shellfish; that is, as shellfish get larger, they take up more nitrogen (Reitsma et al., 2014). A local pilot study in Falmouth confirmed the size-uptake relationship and measured nitrogen removal (e.g., 1,190,000 2-inch oysters per acre removed 58,482 kilograms of nitrogen when oyster bags were maximized (A. Karplus, 7/17/14).*

Data Collection

PERFORMANCE MONITORING

SHELLFISH UPTAKE OF NITROGEN

Recommendations for monitoring of shellfish uptake of nitrogen fall into two categories: pilot testing for proof-of-concept and long-term implementation projects. Both types of projects will require monitoring before and after shellfish aquaculture is installed. Monitoring of environmental conditions before shellfish aquaculture is installed is necessary in order to establish baseline environmental

	MONITORING FOR PILOT PROJECTS For each location and aquaculture configuration being tested, monitoring parameters that are needed to estimate the amount of nitrogen removed by shellfish include:
SA-1	**Shellfish parameters:** ■ Number of shellfish in a standard harvested volume (e.g., bushel, peck, barrel, etc.), size classes present in the standard harvested volume, and numbers of shellfish in each size class (or weight of shellfish in each size class). ■ Number of standard volumes or weights of shellfish that are harvested at a given location in a given unit of time (e.g., year). ■ For each size class, measure dry weights of shellfish tissue and shell separately, using a pooled sample of 10-20 animals. ■ For each size class, measure the percentage of nitrogen in tissue and shell separately, using a pooled sample of 10-20 animals (note that the shell has a low percentage of nitrogen but due to its weight can account for 25% or more of nitrogen removal) ■ Geographic differences in nitrogen uptake related to the particular estuary ■ Species-specific differences in nitrogen uptake related to the shellfish species being tested. ■ Survival and mortality rates (useful for determining if the site is suitable for growing shellfish) ■ Frequency of monitoring nitrogen removal in harvested shellfish: annual.

SA-2

Calculations to perform:

- Total number of shellfish grown and harvested (calculated by multiplying the total number of shellfish in a standard harvested volume by the number of volumes harvested).
- Total number of shellfish in each size class harvested (calculated by multiplying the number of shellfish in each size class by the number of standard harvested volumes).
- Calculate the total amount of nitrogen taken up by harvested shellfish as follows: for each size class, calculate the amount of nitrogen taken up by shellfish tissue by multiplying the number of shellfish harvested by the average nitrogen concentration of shellfish tissue for that size class. Do this for all size classes. Repeat this for shell for all size classes. Sum the amounts of nitrogen in shellfish tissue and in shell for all size classes.
- If calculating nitrogen removal by weight of shellfish, tabulate wet weight to dry weight correlations using regression analysis
  - Determine nitrogen uptake by total weight of shellfish in each size class
    - Use correlation between the total weight of shellfish (shell and tissue) in each size class and dry weight.
    - Multiply by % nitrogen for size class

SA-3

Water quality parameters: .

- Water clarity (Secchi disc, TSS, turbidity)
- Total nitrogen
- Particulate nitrogen
- Dissolved oxygen, at several depths in the water column (at a minimum, in the surface layer, mid-water-column, and near-bottom)
- Chlorophyll a
- If more than one shellfish species are being tested, monitor for species-specific differences in the above parameters
- Frequency of monitoring water quality; Initially, water quality should be monitored every two weeks for all parameters except dissolved oxygen. For dissolved oxygen, continuous monitoring of near-bottom water would be best as dissolved oxygen can vary a great deal on a daily basis.
- Sediment quality parameters, as necessary (seeSA-4, p. 5:26 for parameters)

conditions. Monitoring of environmental conditions after aquaculture is installed is used to determine whether aquaculture results in improved environmental conditions compared to baseline or pre-restoration conditions.

DURATION OF PILOT TESTING

- For each location where shellfish aquaculture is being considered, pilot testing should be conducted for at least two years in order to generate enough useable data to evaluate feasibility.
- For multiple locations that are being tested, geographic differences in the above parameters should be evaluated.

MONITORING LONG-TERM IMPLEMENTATION

Once pilot testing demonstrates that sufficient shellfish uptake of nitrogen occurs consistently and is otherwise feasible, then long-term monitoring parameters for each location and aquaculture configuration where shellfish aquaculture is being used, should include:

ANNUAL SHELLFISH HARVEST DATA

- Number of standard volumes or total weight of shellfish harvested
- Average number of shellfish per standard volume, based on samples, or total weight
- The total number of shellfish harvested, based on multiplying the two numbers above; or total weight
- Size classes present in standard volumes or weights, based on samples
- Number or weight of shellfish in each size class, based on samples
- Estimated amount of nitrogen removed by each size class, summed over all size classes (calculated as described on p. 5:24 under Pilot Testing)

WATER QUALITY

As water quality changes, monitor nitrogen concentrations in shellfish tissue and shell, by size class, every few years; occasional water quality monitoring for dissolved oxygen, total nitrogen, and chlorophyll a (e.g., four times a year) if credit for denitrification is being taken:

PERFORMANCE MONITORING – Shellfish Denitrification and Burial of Nitrogen

Recommendations for monitoring of shellfish denitrification and burial of nitrogen fall into two categories: pilot testing and long-term implementation. Monitoring for denitrification is only necessary if credit for this nitrogen removal pathway is being taken as part of the project.

SA-4 **Monitoring for Pilot Projects**

Monitoring for the pilot test should include monitoring at both the reference station(s) and sites where shellfish aquaculture is being tested. Baseline monitoring to establish pre-treatment conditions should be conducted for at least one year prior to the installation of the test shellfish aquaculture plots. For each location, monitoring parameters include:

- Changes in sediment nitrogen removal via denitrification and other possible sediment impacts due to increased organic matter deposition to the sediments.
- To document benthic communities, their biomass and nitrogen content, conduct rapid surveys of benthic animal community (grabs) within proposed aquaculture operation and then at some suitable reference sites, upstream and downstream of farm. Frequency: annually.
- Sediment water oxygen demand (SOD) and benthic nutrient fluxes should be monitored within five to eight cores within proposed shellfish aquaculture or shellfish bed area. At the reference site, five to 10 cores should be monitored. Frequency: three to four times a year initially (May, July, Aug, Oct) and in the first few years.
- Measurements of sediment denitrification via a whole core method (i.e., not potentials) using either isotope pairing or N2/Ar). Three to five cores within beds and at a nearby reference site. Frequency: two to three times during spring-fall, with at least one mid summer.
- Sediment percentage of nitrogen (% N) and organic carbon (% C): measured at five sites within and outside of the beds, once a year.
- Bottom water oxygen, before and after the shellfish farm is installed, within the shellfish bed area and at least one other location outside the shellfish bed area (ie. in the reference area). Ideally this would be continuously logged from May-October.
- If more than one shellfish species are being tested, monitor for species-specific differences in the above parameters.

Note: Rapid surveys of benthic communities and measurements of sediment denitrification via a whole core method are expensive and may not need to be done every year. After the initial assessment, SOD could be an indicator of sediment changes and the first and third bullet above may not need to be repeated unless SOD or water column O2 changes.

For multiple locations that are being tested, geographic differences in the above parameters should be evaluated.

SA-5	**Monitoring Long-term Implementation** Once pilot testing demonstrates that sufficient shellfish denitrification and/or burial of nitrogen occurs and is otherwise feasible, then long-term monitoring is conducted using many of the same monitoring parameters used for pilot tests, but monitored at a reduced frequency: For each location where shellfish aquaculture is being used: ■ Occasional monitoring of sediment quality data and water quality monitoring (e.g., dissolved oxygen, total nitrogen, chlorophyll a). ■ Frequency of sediment quality monitoring: sediments could be monitored every two to three years for some parameters. Monitoring of denitrification may be repeated every five to six years or if water quality starts to deteriorate. ■ Frequency of water quality monitoring: At least four times per year if the goal is to determine if shellfish aquaculture is successful.
	PERFORMANCE MONITORING – Combined Shellfish Harvesting and Microbial Denitrification
SA-6	Monitoring parameters for pilot testing and long-term implementation of combined shellfish harvesting and denitrification/burial will include combinations of the parameters described in the tables above.

SEDIMENT

Occasional sediment quality data (e.g., every two to three years – see SA-4, p. 5:26 for parameters)

In order to ensure that shellfish harvesting meets nitrogen removal targets, institutional processes should be in place to track and record shellfish harvests as described above. If shellfish harvesting cannot be completed for some reason (e.g., closure due to red tide, oil spills, or other reasons) then the amount of nitrogen that is not removed needs to be accounted for.

OTHER CONSIDERATIONS

SHELLFISH DISEASES AND SEAFOOD SAFETY

For both pilot tests and long-term implementation, shellfish aquaculture will also require routine monitoring for shellfish diseases (e.g., Dermo, MSX) and shellfish safety (e.g., fecal coliform bacteria, Enterococcus bacteria, *Vibrio parahaemolyticus*, paralytic shellfish poison due to harmful algal blooms) as required by state and federal regulations. Research on new and emerging shellfish diseases and pathogens and methods to control or minimize their impact are critically important, as is providing outreach.

HARMFUL INVASIVE SPECIES

In order to maintain the health and sustainability of the shellfish bed, routine monitoring for harmful invasive species or predators such as green crabs should be conducted. If found, they should be removed if feasible to do so without harming other aquatic life, water quality, or the environment.

OCEAN ACIDIFICATION

Ocean acidification due to increasing levels of carbon dioxide in the atmosphere and oceans could be a concern for shellfish aquaculture, wild shellfish populations and shellfish hatcheries alike. Excess carbon dioxide in the ocean causes carbonate concentrations in seawater to decrease, which impacts shell formation and larval survival (Washington State Fact Sheet, May 2014). In 2008 in the Pacific Northwest, increased upwelling of carbon dioxide-rich water contributed to ocean acidification which caused production at some oyster hatcheries to decline by as much as 80%. Adaptive measures included monitoring ocean acidity and shutting off seawater intake valves when acidity increased (NOAA, January 2012). However, ocean acidity varies regionally due to river inputs, upwelling, and other factors. This may be less of an issue in the Northeast, but scientific monitoring programs should continue and the results should be relayed to shellfish managers and regulators. Such monitoring is difficult and expensive and is beyond the scope of town monitoring programs.

CONTINGENCY PLANS

A contingency plan should describe steps to take if shellfish aquaculture were to be impacted by a natural disaster or if harvesting were to be stopped or curtailed for some reason. The contingency plan should specify how backup removal of nitrogen will be provided if shellfish aquaculture or harvesting is partially or completely halted. In the event that shellfish are unsafe to consume (e.g., due to red tide, paralytic shellfish poisoning, or other causes) but are otherwise functioning to remove nitrogen, backup plans may include harvesting and proper disposal of inedible shellfish to prevent dead shellfish from re-entering the nitrogen cycle, switching to another method of nitrogen removal, or other measure.

O & M

Because nitrogen removal performance can be dependent on following proper operation & maintenance guidelines, O&M responsibilities should be clearly defined and tracked.

COSTS

Cost categories should be disaggregated and should include the following: materials, O&M, capital, personnel, staff time (sub-categories can be created, i.e administration, planning, monitoring, reporting). Funding source should also be disaggregated. See "General Monitoring Data Guidelines" (Chapter 4, p. 4:2) for more details .

- Fixed costs, variable costs, and start-up costs should be tracked separately

CO-BENEFITS

Co-benefits (if any) shall be identified and monitored. Co-benefits identified in the Technologies Matrix include improved habitat and biodiversity, improved green space, buffering the impacts of extreme weather, and energy savings, nutrient recovery and recycling benefits

Data Analysis and Reporting

Raw data and the Project Report Template should be submitted to the Monitoring Committee for technical review. Consult "General Monitoring Data Guidelines" (see Chapter 4, p. 4:2) for further information on data processing, flow, and utilization.

RESEARCH NEEDS

The use of shellfish aquaculture to reduce or manage nitrogen in estuaries is a new approach to nutrient management. Scientific research to examine the effectiveness of shellfish in taking up and cycling nitrogen is also relatively new, and there are still many research needs. Some examples of research needs are:

- Determining the degree of variability in shellfish uptake of nitrogen and nitrogen cycling processes in different Cape Cod embayments and for different shellfish species (Reitsma et al., 2014)
- Methods of controlling shellfish diseases
- Methods of controlling invasive species that prey on shellfish
- Monitoring the effects of ocean acidification on shellfish aquaculture and wild shellfish in Cape Cod waters.

REFERENCES

Falmouth Water Quality Management Committee. Quality Assurance Project Plan for Little Pond Shellfish Demonstration Monitoring. Posted at: http://www.falmouthmass.us/depart.php?depkey=waterq , or http://www.falmouthmass.us/waterq/qappyr1final.pdf . This QAPP incorporates the QAPP for the Massachusetts Estuaries Project (Howes, B. and R. Samimy. June 2003. Massachusetts Estuaries Project Quality Assurance Project Plan (QAPP), The DEP/SMAST Massachusetts Estuaries Project, Year One Final. 400 pp.).

Note: The QAPP for the Massachusetts Estuaries Project is also known as "2003 Massachusetts Estuaries Project for Management and Restoration of 89 southeastern Massachusetts Embayments. Quality Assurance Project Plan. Final Report to MA Department of Environmental Protection and USEPA, 650 pp. Published by MADEP".

Karplus, A., personal communication. Nitrogen removal per acre of shellfish aquaculture, by size class and age.

Massachusetts Water Resources Authority: Examples of some QAPPs for monitoring the Boston Harbor Sewage Outfall:

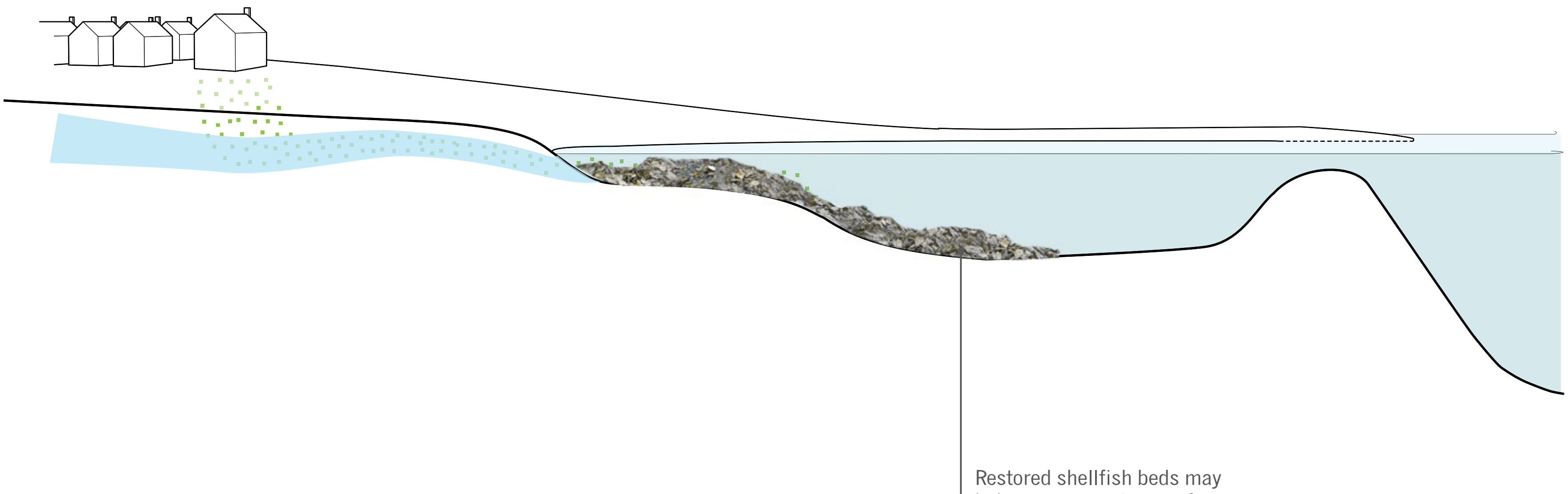
> Nestler, E.C., A.E. Pembroke and R.C. Hasevlat. 2011. Quality Assurance Project Plan for Benthic Monitoring 2011–2014. Boston: Massachusetts Water Resources Authority. Report 2011-07, 90 pp. plus Appendices. Posted at: http://www.mwra.state.ma.us/harbor/enquad/trlist.html .
>
> Costa A., E. Larson, and K. Stamieszkin. 2014. Quality Assurance Project Plan (QAPP) for Water Quality Monitoring in Cape Cod Bay 2014-2016. Boston: Massachusetts Water Resources Authority. Report 2014-07. 94 p. Posted at: http://www.mwra.state.ma.us/harbor/enquad/trlist.html .
>
> Constantino, J., W. Leo, M.F. Delaney, P. Epelman, and S. Rhode. 2014. Quality Assurance Project Plan (QAPP) for sediment chemistry analyses for harbor and outfall monitoring, Revision 4 (February 2014). Boston: Massachusetts Water Resources Authority. Report 2014-02. 53 p. Posted at: http://www.mwra.state.ma.us/harbor/enquad/trlist.html .

NOAA National Marine Fisheries Service webpage. January 2012. *NOAA's Science Supports Shellfish Aquaculture*. Posted at: http://www.nmfs.noaa.gov/aquaculture/docs/shellfish/noaa_science_spprts_shellfsh_aq.pdf .

NOAA Fact Sheet. January 2013. *State of the Science Fact Sheet on Ocean Acidification.*

Reitsma, J., D. Murphy and A.F. Archer. January 2014. *Shellfish, Nitrogen, and the Health of our Coastal Waters*. Woods Hole Sea Grant Program and Cape Cod Cooperative Extension. 4 pp.

University of Washington and Washington Sea Grant. May 2014. *Fact Sheet on Ocean Acidification in the Pacific Northwest.* May 2014. Posted at: http://www.wsg.washington.edu/admin/pdfs/ocean-acidification/ocean-acidification-brochure.pdf .



Restored shellfish beds may help to remove nitrogen from embayments, even when shellfish are not harvested.

Shellfish Bed Restoration

Restored shellfish beds, specifically oysters, can help to remove nitrogen in degraded water bodies. New reefs can be created by depositing old oyster shells and oyster spat into embayments where nitrogen removal is desired.

Background

Shellfish bed restoration involves setting aside and protecting and/or restoring natural shellfish habitat to promote growth and restoration of shellfish beds. Shellfish bed restoration provides several valuable ecosystem services which are monitored using the following measures of success (Bruchsbaum et al., 2006):

- Recruitment and growth of the shellfish population undergoing restoration;
- Providing habitat for other associated species
- Direct and indirect improvement in local water quality; and
- Shoreline protection

Shellfish bed restoration may be designed and undertaken with the intent that shellfish are not harvested, in order to provide a natural habitat and ecological functions that would otherwise be disrupted by harvesting. For example, in an un-harvested shellfish bed where older individuals are left in place, natural selection may foster survival of disease-resistant shellfish, growth of shellfish beds may promote enhanced nitrogen cycling, and so on.

Communities may wish to undertake shellfish bed restoration for some or all of the above ecosystem services, not just water quality improvement alone. For communities that are considering shellfish bed restoration for nitrogen management, the third measure of success is the most interesting; that is, improving water quality through enhanced uptake or removal of nitrogen by restored shellfish beds.

On Cape Cod, the Town of Wellfleet in collaboration with UMass Boston and the Center for Coastal Studies spearheaded an oyster reef restoration project in Wellfleet Harbor beginning in 2012. Two of the primary goals of this project were to improve water quality and habitat quality and increase the commercial and recreational oyster industry and naturally disease resistant oyster spawning stock. In two years, the project has established approximately 4.5 million oysters in a two-acre zone (Frankic Report, 2012, 2013). Throughout this project, oyster growth and abundance, spat settlement, reef biodiversity, and water quality were monitored.

The Wellfleet project is monitoring Total Nitrogen (TN), chlorophyll, and turbidity and other water quality parameters in the source waters upstream of the reef and waters downstream of the reef. These differences are substantial enough to show a reduction in nitrogen, chlorophyll, and turbidity (due to a combination of all the above parameters) as a result of the establishment of the oyster reef. Other improvements observed in this project (but unfortunately not quantified) are a decrease in coverage by sea lettuce (*Ulva lactuca*) and a decrease in silt.

When it comes to removal of nitrogen from the ocean, there is a key difference between shellfish aquaculture and shellfish bed restoration. Shellfish aquaculture involves harvesting of shellfish which directly removes some nitrogen from the ocean. In contrast, shellfish bed restoration often involves leaving shellfish in place to provide habitat, increase biodiversity, serve as a spawning sanctuary, protect against erosion, etc. If harvesting of restored shellfish is not done, then direct removal of nitrogen via removal of shellfish does not occur. Furthermore, if shellfish are left in place, when they die their tissues rapidly decompose and return nitrogen back to the marine environment. Even if shellfish temporarily clear the water column due to their feeding activities, when they die their nitrogen will re-enter the environment. Thus shellfish bed restoration without harvesting cannot be credited for the direct uptake and removal of nitrogen that can be credited to shellfish aquaculture nitrogen.

However, shellfish beds may enhance denitrification, as described in the previous section on Shellfish Aquaculture. Credit for nitrogen removed via denitrification would be established using the methods described in the Shellfish Aquaculture section. More research is needed to understand how shellfish beds promote nitrogen cycling and the significance of denitrification in natural and restored shellfish beds. There is some experimental evidence that if shell is used as a substrate for shellfish bed restoration, new growth of shellfish on shell material increases nitrogen removal, but shells release nitrogen as well (Bricker et al., 2014).

Data Collection

PERFORMANCE MONITORING

Monitoring long-term water quality improvements in and above restored shellfish beds may be the most direct way to demonstrate their role in reducing nitrogen concentration. This section describes monitoring to measure effects of shellfish bed restoration on water quality, based on Bruchsbaum et al (2006), as well

	PERFORMANCE MONITORING
SBR-1	**Water Quality Parameters:** Recommended water quality parameters for monitoring before and after shellfish bed restoration is established include: ▪ Water clarity (secchi disc, total suspended solids (TSS), turbidity) ▪ Total nitrogen ▪ Particulate nitrogen ▪ Dissolved oxygen, at several depths in the water column (at a minimum, in the surface layer, mid-water-column, and near-bottom) ▪ Chlorophyll a ▪ If more than one shellfish species are being tested, monitor for species-specific differences in the above parameters.
SBR-2	**Frequency of monitoring water quality:** Initially water quality should be monitored every two weeks for all parameters except dissolved oxygen. For dissolved oxygen, continuous monitoring of near-bottom water would be best as dissolved oxygen can vary a great deal on a daily basis.
SBR-3	**Additional monitoring parameters:** are the same as for shellfish aquaculture (see p. 5:17): water quality monitoring to demonstrate improvement in water quality, whether it is due to shellfish uptake and/or denitrification or other processes.

as monitoring recommendations for shellfish aquaculture. For monitoring other ecosystem services, see Bruchsbaum et al. (2006). In addition, the Massachusetts Audubon Society, Wellfleet Bay Sanctuary has established and monitored an experimental oyster reef for the purpose of enhancing biodiversity (Faherty, 2011). Their monitoring protocols and Quality Assurance Project Plan are available at the Massachusetts Bays National Estuary Program website. (http://www.mass.gov/eea/agencies/mass-bays-program/grants/oyster-reef-wellfleet-2011.html).

Both pre-restoration and post-restoration monitoring is necessary. Monitoring of environmental conditions before the shellfish bed is restored (ie. pre-restoration monitoring) is necessary in order to establish baseline environmental conditions. In order to establish baseline conditions, monitoring should be performed for at least a year prior to commencement of shellfish bed restoration operations. Monitoring of environmental conditions after shellfish beds are restored (ie. post-restoration monitoring) is used to determine whether shellfish bed restoration results in improved environmental conditions compared to baseline or pre-restoration conditions.

OTHER CONSIDERATIONS

SHELLFISH DISEASES AND SEAFOOD SAFETY

Shellfish aquaculture will also require routine monitoring for shellfish diseases (See Shellfish Aquaculture protocol p. 5:17)

HARMFUL INVASIVE SPECIES

Monitoring for harmful invasive species or predators such as green crabs should be conducted, followed by removal if feasible.

OCEAN ACIDIFICATION

Ocean acidification due to increasing levels of carbon dioxide in the atmosphere and oceans could be a concern. (See Shellfish Aquaculture protocol p. 5:17)

CONTINGENCY PLANS

A contingency plan should address steps to take if the shellfish bed restoration project were to be impacted by a natural disaster or if harvesting were to be stopped or curtailed for some reason. The contingency plan should specify how backup removal of nitrogen will be provided if shellfish aquaculture or harvesting is partially or completely halted. In the event that shellfish are unsafe to consume (e.g., due to red tide, paralytic shellfish poisioning, or other causes) but are otherwise functioning to remove nitrogen, backup plans may include harvesting and proper disposal of inedible shellfish to prevent dead shellfish from re-entering the nitrogen cycle, switching to another method of nitrogen removal, or other measure.

O & M

Because nitrogen removal performance can be dependent on following proper operation & maintenance guidelines, O&M responsibilities should be clearly defined and tracked.

COSTS

Cost categories should be disaggregated and should include the following: materials, O&M, capital, personnel, staff time (sub-categories can be created, i.e administration, planning, monitoring, reporting). Funding source should also be disaggregated. See "General Monitoring Data Guidelines" (Chapter 4, p. 4:2) for more details.

- Fixed costs, variable costs, and start-up costs should be tracked separately.

CO-BENEFITS

Co-benefits (if any) shall be identified and monitored. Co-benefits identified in the Technologies Matrix include improved habitat and biodiversity, buffering the impacts of extreme weather, and energy savings, nutrient recovery and recycling benefits.

Data Analysis and Reporting

Raw data and the Project Report Template should be submitted to the Monitoring Committee for technical review. Consult "General Monitoring Data Guidelines" (see Chapter 4, p. 4:30) for further information on data processing, flow, and utilization.

RESEARCH NEEDS

More research is needed to measure the effects of shellfish bed restoration projects on nitrogen cycling and nitrogen removal or reduction at scales and timeframes that are useful for environmental remediation (Brumbaugh et al., 2006).

REFERENCES

Bricker, S.B., K.C. Rice and O.P. Bricker, III. 2014. From headwaters to coast: influence of human activities on water quality of the Potomac River estuary. Aquatic Geochemistry 20: 291-323.

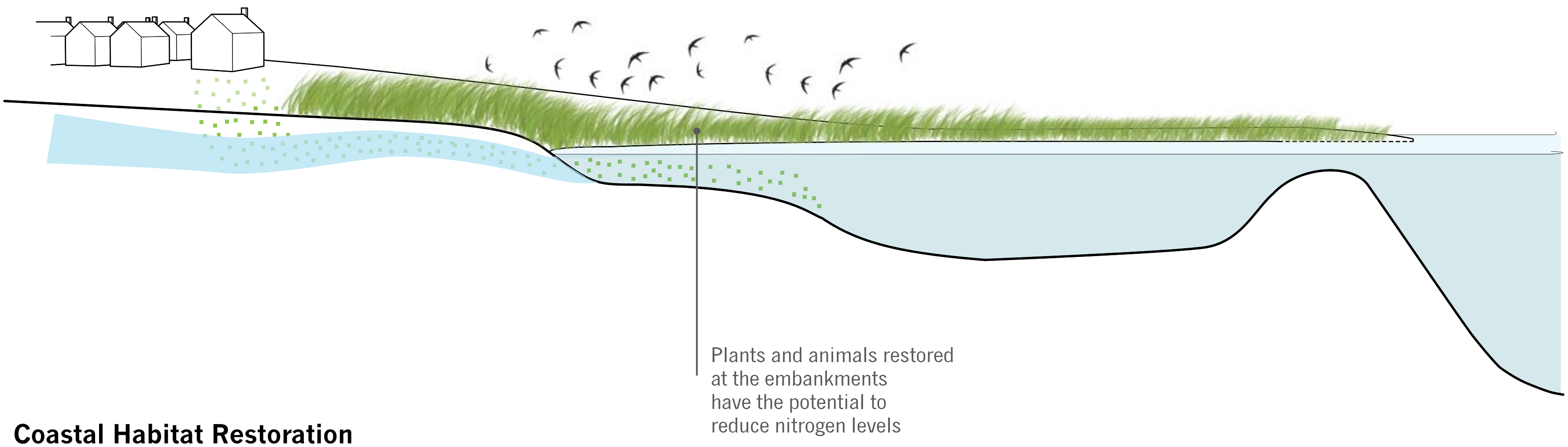
Brumbaugh, R.D., M.W. Beck, L.D. Coen, L. Craig and P. Hicks. 2006. A Practitioners Guide to the Design and Monitoring of Shellfish Restoration Projects: An Ecosystem Services Approach. The Nature Conservancy, Arlington, VA.

Faherty, M. January 30, 2011. Oyster reef restoration and monitoring, Wellfleet, MA. Final Report. Prepared for Massachusetts Bays National Estuary Program (MassBays) Research and Planning Grant, FY2011. Posted at: http://www.mass.gov/eea/agencies/mass-bays-program/grants/oyster-reef-wellfleet-2011.html .

Massachusetts Audubon Society, Wellfleet Bay Sanctuary, MA. May 27, 2011. Oyster reef restoration and monitoring, Wellfleet, MA: Quality Assurance Project Plan.

Prepared for Massachusetts Bays Program (MBP) Research and Planning Grant, 2011.

Posted at: http://www.mass.gov/eea/agencies/mass-bays-program/grants/oyster-reef-wellfleet-2011.html.



Coastal Habitat Restoration

Restoration of coastal habitats includes establishing and/or enhancing estuary salt marshes, eel grass beds, as well as shellfish and oyster beds together as an ecosystem.When considering restoration of coastal habitats, implementing these ecosystems jointly should be considered. Habitat restoration should focus on creating or rehabilitating habitats, including creating communities that are natural to the area.

Inlet Modification for Coastal Habitat Restoration

Technology Monitoring Protocol

RESTORATION

Background

This monitoring protocol is based on the Association to Preserve Cape Cod (APCC's) Salt Marsh Monitoring Program which monitors tidally restricted and restored salt marshes. It is intended for monitoring a salt marsh restoration project as a component of inlet widening. It does not address coastal restoration that does not include a salt marsh component.

The study design is two-fold and based, in part, on Coastal Zone Management's (CZM) W.H.A.T. (Wetland Health Assessment Tool) and CZM's monitoring manual, *A Volunteer's Handbook for Monitoring New England Salt Marshes* (Carlisle, B. et al. 2002). From these documents, APCC developed a state-approved Quality Assurance Project Plan (QAPP) for monitoring salt marshes that involves monitoring the following:

- Biological and physical conditions at a reference site and the study site: a side by side comparison of an unrestricted referene salt marsh (usually located downstream of the tidal restriction) with the restricted marsh or study site.
- Comparison of the study site and the reference site before and after restoration – documents the health of the marsh and tracks response to tidal inundation over time, before tidal restoration and after restoration.

Data Collection

OTHER CONSIDERATIONS

Every site responds to tidal restoration or inlet opening differently, depending on the change in opening size, tidal inundation, freshwater influence,

	PERFORMANCE MONITORING
CHR-1	**Frequency:** Ideally monitoring will be conducted three years prior to construction (tidal restoration) and then yearly for three consecutive years following tidal restoration and then again five years and 10 years after restoration.
CHR-2	**Monitoring Location(s):** Establish randomly selected transects that run roughly perpendicular from the creek bank to the upland boundary of the marsh. Stations shall be located along each transect at 60 foot intervals, unless a transect is shorter than 120 feet, then the stations shall be located closer together (30 or 15 foot intervals).
CHR-3	**Water Quality Parameters to Measure:** ▪ **Salinity:** Pore and surface water salinity. Pore water is taken from a depth of 10 centimeters (cm) to measure the salinity of the water that is within the plant root zone. A minimum of 12 stations should be established per site/side. At the salinity stations located along the creek bank, surface water is taken from the creek. Often pore water is not extractable at this location due to the drainage. Samples should be taken twice a month, +/- 2 hours from low tide. ▪ **Vegetation:** Monitor percent abundance and coverage of living plant species growing during the current field season (growing season). Vegetation monitoring should be done once a year at each station. A minimum of 24 stations should be established per site/side. All plants are identified within a one meter square quadrat and percent cover is estimated using EPA standard cover classes. Surveying should be done at peak plant growth (August through September) around low tide. The relative abundance and height of *Phragmites australis* should be measured within a quadrat as well as the height of the 10 tallest plants. Depending on the site and the objectives, state listed, threatened species or species of concern (*Spartina cynosuroides, Carex mitchelliana*), should also be monitored.

PERFORMANCE MONITORING

CHR-4

Water Quality Parameters to Measure (continued):

- **Nektons:** Measure all organisms that are in the water column that can be caught by a net. Generally these consist of fish, crabs and shrimp. Ideally, at least two nekton stations on the reference side of the marsh and two on the study side of the marsh should be established. Nektons are collected using a block seine net method. Monitoring should include one bag seine and one block seine, 10 meters apart. All nekton should be identified, measured for standard length and weighed before being returned to the creek. Fishing should be done on either a 1/3 flood tide or a 2/3 ebb tide, once a month from June through August. During each seining event water quality parameters should be measured with a YSI probe (water temp, dissolved oxygen, pH, specific conductivity, salinity).
- **Avifauna (Birds):** Counts should be conducted for 20 minutes per site using visual and auditory information. Record all species and individuals seen or heard within wetland plus a 50 foot buffer outside the marsh. Bird monitoring is conducted between sunrise and 8 am, once every three to five weeks (once a month) during various tides.
- **Water quality monitoring:** Nutrients, turbidity, dissolved oxygen, pH, salinity, and specific conductivity should be monitored once a month, at a minimum. Temperature, specific conductivity, and dissolved oxygen can be monitored on site using a water quality probe (e.g. YSI). Water samples need to be collected for nutrient analyses including dissolved and particulate nitrogen, phosphate, carbon/nitrogen ratios, and dissolved organic carbon. Samples should be taken during the last three hours of an outgoing tide and must be kept cold.
- **Water elevation:** Water elevation should be monitored throughout a full lunar cycle (ie. Lunar month). Water elevation can be easily measured using water level dataloggers (e.g. HOBO water level dataloggers) that measure water pressure using pressure transducers. Dataloggers can be attached to stakes driving into the stream channel on the marsh plain. Water depths are translated into water elevations based on surveyed spot elevations taken at the water level datalogger stations. The distance from the datalogger to the ground surface needs to be taken into account.
- **Water velocity:** Water velocity should be monitored once a month for three months prior to and after restoration, ideally including a spring tide event.

and marsh surface elevation. Some marshes show an immediate response while others take years to respond. It also depends on what is used as the indicator of success or response (e.g. surface water salinity increase, nekton community change, halophyte abundance increase). Adequate sediment supply is necessary to help ensure that the salt marsh plain accretes in response to rising sea level.

O & M

Because nitrogen removal performance can be dependent on following proper operation & maintenance guidelines, O&M responsibilities should be clearly defined and tracked. For a restored salt marsh, this involves monitoring salt marsh biological and physical conditions (as described above) as well as monitoring of the physical infrastructure such as culverts, tidegates, bridges or other infrastructure that maintains tidal flow that nourishes salt marshes. If infrastructure needs to be manually or automatically operated in order to maintain tidal flow, O & M is especially critical.

CO-BENEFITS

Co-benefits (if any) shall be identified and monitored.

COSTS

Cost categories should be disaggregated and should include the following: materials, O&M, capital, personnel, staff time (sub-categories can be created, i.e administration, planning, monitoring, reporting). Funding source should also be disaggregated. See "General Monitoring Data Guidelines" (Chapter 4, p. 4:2) for more details.

Data Analysis and Reporting

Typical measurements for reporting coastal restoration data include:

- Before and after restoration or inlet modification
- Annual average salinity at reference and study sites before and after restoration or inlet modification
- Monthly average salinity, as above
- Transect and station average salinity, as above
- Pore water vs surface water quality (primarily salinity), as above
- Compare stations to assess spatial extent of saltwater inundation
- Compare reference and study sites to assess efficacy of tidal restoration/inlet modification
- Relative abundance (vegetation, halophytes, nekton), at reference and study sites, before and after restoration or inlet modification
- Species richness (vegetation, nekton, birds), as above (i.e. at reference and study sites, before or after restoration or inlet modification
- Transient vs resident (nekton, birds), as above
- Marine or estuarine vs freshwater (nekton, vegetation), as above
- Biomass (vegetation, nekton), as above
- Percent wetland dependent species (nekton, birds), as above
- Water elevations, as above
- Water velocity seaward and landward of inlet/culvert, as above
- Water temperature, as above
- pH, as above
- Dissolved oxygen, as above
- Nitrogen concentrations, as above
- Phosphorus concentrations, as above

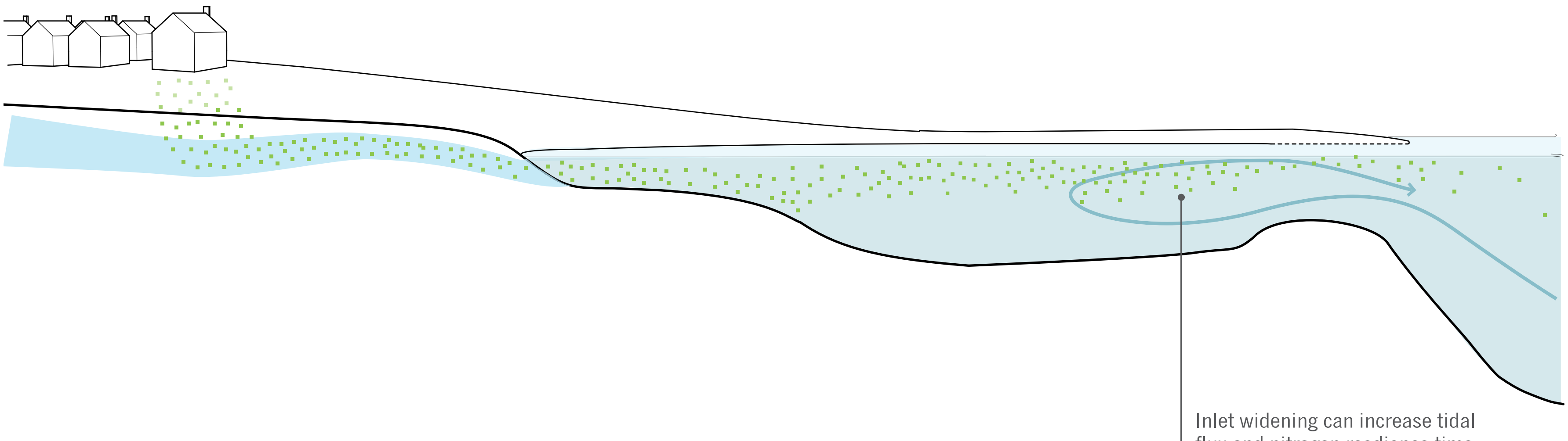
Photographic documentation is a great way to visually assess changes. It is critical that the photo be taken from the exact same location, at the same level and angle in order to reflect changes. Additionally, it is useful to include a marker, if possible, such as a telephone pole, the edge of a bridge or fencing post.

Raw data and the Project Report Template should be submitted to the Monitoring Committee for technical review. Consult "General Monitoring Data Guidelines" (see Chapter 4, p. 4:2) for further information on data processing, flow, and utilization.

REFERENCES

Association to Preserve Cape Cod. 2006. Quality Assurance Project Plan (QAPP) for *"Volunteer Salt Marsh Monitoring of Massachusetts Wetlands Restoration Program Priority Sites"*.

Carlisle, B.K., A.M. Donovan, A.L. Hicks, V.S. Kooken, J.P. Smith, and A.R. Wilbur. 2002. *A Volunteer's Handbook for Monitoring New England Salt Marshes*. Massachusetts Office of Coastal Zone Management, Boston, MA.



Inlet/Culvert Widening

This approach considers re-engineering and reconstruction of bridge or culvert openings to increase the tidal flux through the culvert or inlet. In the right settings, increasing the tidal flux can decrease the nitrogen residence time, lowering the nutrient concentration in the estuary and/or tidal marsh upstream of the widened inlet or culvert.

Inlet Modification

Technology Monitoring Protocol

Background

Inlet-widening/modification has been proposed as a non-traditional strategy to improve estuarine water quality and ecological function by removing nitrogen loads more quickly from the estuarine water column through increased tidal flushing. The general concept is based on the assumption that inlets, to one degree or another, act to limit tidal exchange between the enclosed estuary and its oceanic source. Within the estuary, this restriction should result in a smaller tidal range and attenuated tidal phase relative to its oceanic source. Less tidal exchange will also be characterized, within the estuary, by longer water mass residence times, greater watershed-derived nutrient concentrations and lower salinities. It is therefore proposed that increasing the width and/or depth of an inlet will lessen the restriction on tidal exchange, increase tidal flushing and allow more effective removal of estuarine nitrogen loads.

Inlet modification (IM) is attractive as a nitrogen mitigation approach because of its simplicity of concept and its potential cost-effectiveness. In light of the complexity of the coastal hydrodynamic and sedimentological environment, there has been concern about the method's practical effectiveness, long-term maintenance costs and potential for unintended environmental consequences. These questions related to the efficacy of IM as viable mitigation strategy will not be discussed here in detail, but to enumerate a few:

- Does IM actually result in a significant and long-term increase in tidal exchange in a given system?
- Will the modified inlet maintain its enlarged dimensions without the need for frequent and costly maintenance dredging?
- Would IM increase local storm flooding risks? Adequate modeling and project design may help answer and/or alleviate some of these concerns for individual projects.

On Cape Cod, several IM projects have been discussed and two have been formally proposed, Bournes Pond in Falmouth and Muddy Creek in Chatham, though only the former is motivated primarily for the purpose of nitrogen mitigation. At present, IM as an effective strategy for nitrogen removal is still largely theoretical and the need exists for well-controlled and monitored pilot projects to assess the methodology and varying degrees of effectiveness based on site specificity.

Planning and Design Considerations

CRITERIA FOR IM PILOT PROJECT LOCATIONS

Optimal locations for IM should have minimal risk of inland flooding and marsh erosion, as well as be located in an embayment that is highly impacted by nutrients with few other effective options for nutrient removal. There are a number of locations that are being discussed for inlet modification for coastal restoration. These range from rather large to small projects. Each will need to be reviewed, if nitrogen credit is used to leverage resources to implement the project.

Because there are many potential "spider effects" of IM, choosing a location where outlying areas can be measured for potential impacts needs to be considered.

Data Collection

PRE-OPERATION MONITORING REQUIREMENTS

To assess the specific effectiveness of an approved and deployed IM pilot project, additional monitoring protocols should be in place to monitor the hydrodynamic conditions that underlie the IM approach. Approved IM projects should include vetted hydrodynamic modeling that predicts specific tidal characteristics that are indicators of enhanced tidal exchange. These would include forecast changes in tidal range, (e.g. Mean high water, mean sea level, mean low water), as well as storm surge flooding. For example, in Falmouth's Bourne's Pond IM proposal modeler John Ramsey indicates that there should be a detectable drop in mean low water post inlet modification, which in turn implies achieving greater tidal flushing (and more nitrogen removal). Modeling efforts should also predict erosion scenarios that could result after IM. It would be best if there were at least one year of hydrodynamic monitoring or equivalent documentation prior to inlet modification for both modeling and post-alteration comparison purposes.

PERFORMANCE MONITORING

IM project plans specify precise inlet channel dimensions as these are fundamental to the IM approach. These dimensions, before and after modification, are used as the basic modeling variables for quantifying the degree of enhanced tidal exchange and estimation of nitrogen removal. They are also used to predict inlet current velocities critical to the ability of the channel to maintain itself.

	PERFORMANCE MONITORING
IM-1	**Duration:** After inlet modification, another one year of sampling should occur.
IM-2	**Frequency & Measurement Parameters:** Both pre- and post-modification, should have automated continuous monitoring of 1) water levels inside and outside the estuary (for a total of two tidal stations), and 2) inlet current velocities. Tidal stations ought to have precise vertical control for relative reference. Inexpensive equipment (~$1000/unit) is available to continuously monitor each of these parameters, although there would be personnel costs associated with maintenance and data analysis.
IM-3	**Water Quality Parameters:** If hydrodynamic modeling predicts a measurable decrease in TN, water quality parameters should be sufficient to demonstrate and characterize changes to the system. Parameters such as dissolved oxygen, suspended sediments, nutrients, and larval retention, if appropriate, should also be measured to understand the effects of IM on water quality and nitrogen removal.

OTHER CONSIDERATIONS

Unintended environmental impacts of IM include increased flooding, enhanced erosion of salt marshes near the inlet mouth, and excessive shoaling. There have been instances where IM has not improved water quality and has even caused it to become worse. For example, existing salt marsh restoration projects have resulted in nutrients being exported further down-gradient into another system.

Changes made to an inlet may not remain and the inlet could begin to close. This could result in abandoning the project altogether or performing frequent inlet maintenance/dredging. Because of the dynamics of the system and the uncertain relationship between IM and water quality, it is critical that pilot projects be implemented to test the applicability of this technology on Cape Cod.

O & M

A primary concern about the viability of IM mitigation is the very real potential for frequent infilling of the inlet. Should the inlet dimensions vary from design criteria, as a result of shoaling for example, then the desired tidal flushing would also be at variance from design. If IM nitrogen mitigation is to function as planned, then inlet morphometry must be maintained as close to design as possible. So, the need for frequent monitoring of inlet morphometrics is a critical oversight component for IM mitigation projects. Concurrent inlet morphometry, current velocity and inlet water level can be used to directly calculate tidal exchange and can be checked against model prediction.

How often should inlet bathymetry be surveyed? This is a difficult but critical question and is dependent on understanding the complex interaction of the local sedimentological and hydrodynamical environment, a situation extremely hard to model or forecast with accuracy. However some reasonable estimate of infilling must be applied in order to calculate the frequency of inlet maintenance and its associated costs. Historical inlet maintenance records might provide a minimum frequency estimate. However, infilling might be expected to increase after alteration as inlet velocities would likely lower as a consequence of cross-sectional enlargement. It would be prudent to survey more frequently (quarterly) in the early post-modification period and develop a survey schedule based on observed infilling over time.

In addition, when additional dredging and maintenance does occur, water quality during those procedures should be monitored.

COSTS

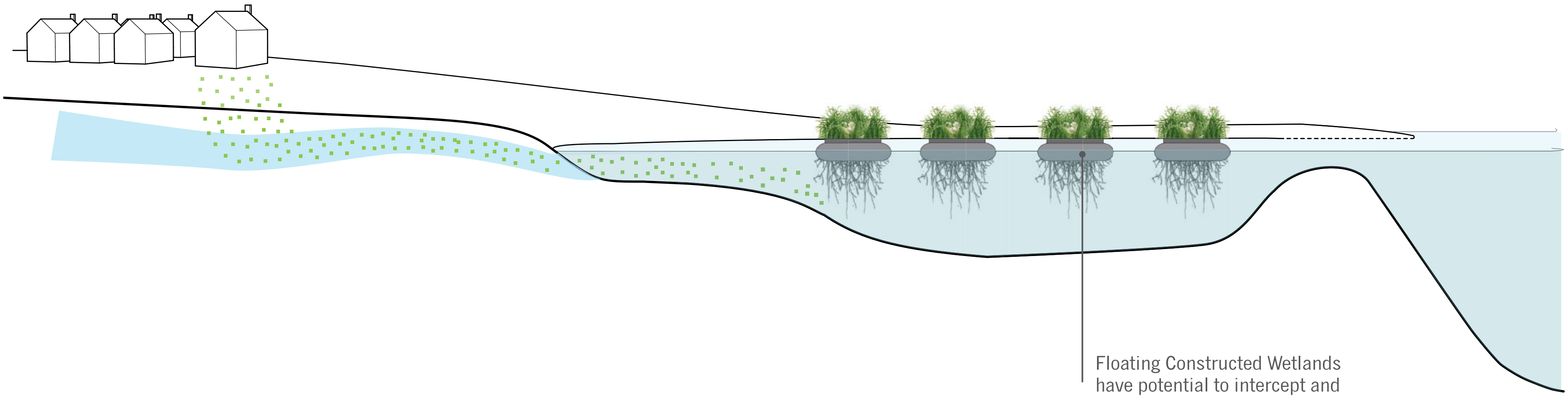
Cost categories should be disaggregated and should include the following: materials, O&M, capital, personnel, staff time (sub-categories can be created, i.e administration, planning, monitoring, reporting). Funding source should also be disaggregated. See "General Monitoring Data Guidelines" (Chapter 4, p. 4:2) for more details.

CO-BENEFITS

Co-benefits (if any) shall be identified and monitored. Co-benefits identified in the Technologies Matrix include improved habitat and biodiversity, improved green space, buffering the impacts of extreme weather, and energy savings, nutrient recovery and recycling benefits.

Data Analysis and Reporting

Raw data and the Project Report Template should be submitted to the Monitoring Committee for technical review. Consult "General Monitoring Data Guidelines" (see Chapter 4, p. 4:2) for further information on data processing, flow, and utilization.



Floating Constructed Wetlands

FCWs are manmade floating "islands" that act as floating wetlands that treat waters within ponds and estuaries. The islands are made of recycled materials that float on ponds or estuaries, exposing the plant's roots to the pond and estuarine waters. The root zones provide habitat for fish and microorganisms while reducing nitrogen and phosphorus levels.

Background

Floating Constructed Wetlands (FCW) can be used for nitrogen management in either inland water bodies or coastal embayments. Benefits of FCW include:

- Nutrient removal from water column via assimilation in plant, animal, algal and biofilm biomass; subsequent processing and metabolism
- Provision of habitat for birds, insects, fin fish, shellfish
- Production of food for various trophic levels
- Carbon sequestration
- Removal of sediments
- Heavy metal and other contaminant sequestration

The primary pathways for nitrogen removal are uptake into the tissue of FCW organisms and denitrification in the root zone and underlying sediments.

Direct uptake into plant or 'volunteer' community tissue:

- In plants, percentage of nitrogen per unit of tissue varies by species but has been reliably characterized in previous applications (National Aquarium 2013)
- 'Volunteer' communities are organisms that were not originally placed on the FCW and include organisms such as mussels, polychaetes (segmented worms), associated microbial communities, and others that have a beneficial effect on nitrogen concentration

Denitrification:

- Hanging root zone through microbial processes
- Deposition to underlying sediments

FCWs have been implemented for atleast two decades, though to date more applications have been conducted in freshwater systems than in saltwater systems. One of the only applications of FCWs in estuarine waters in the northeast was conducted in Baltimore Inner Harbor by the National Aquarium and the Waterfront Partnership of Baltimore. These organizations launched a FCW pilot project in 2010, with full-scale implementation in 2012. The FCWs have been monitored for plant species, animal colonization, and nutrient uptake. This monitoring protocol draws on some of these data findings.

Note: FCWs can be capable of 5 to 10 grams of ammonium/day/ft^3 of FCW , however, this is based on small scale systems with an uncertain potential to scale up and does not consider the ultimate fate of nutrients assimilated into FCW. (National Aquarium 2013) Project specific monitoring and evaluation on Cape Cod needs to be completed.

Planning and Design Considerations

PILOT PROJECT PLANNING CONSIDERATIONS

- Potentially conflicting uses may be: beaches, boating, navigation, shellfish grants
- Potential for neighborhood objections to the visual or aesthetic impacts
- Access for implementation and ongoing activities: right-of-way, roads or waterways
- Site selection: substrate analysis, tidal mixing rate, salinity, presence or absence of other complementary technologies, needs, other suitability criteria

PERFORMANCE MONITORING

FCW-1 **Plants- Monitoring Nitrogen & Phosphorus Uptake:**

- Recommend carbon, hydrogen, nitogen (CHN) instrumental analysis for nitrogen
- Recommend Aplisa method for phosphorous
- Recommend sampling each species three times, then averages for each species
- Alternatives: Dumas combustion for nitrogen and Inductively Coupled Plasma Optical Emission Spectrometry for phosphorus (Hunt et al. 2012); TKN digestion (National Aquarium 2013)

FCW-2 **Volunteer Communities**

- Macroscopic animals can be estimated by counting the animals present (and identifying to the lowest practicable taxonomic level) in a subsample of known size and then multiplying the count of animals present in the subsample by the appropriate multiplier to scale up to the entire project area
- Measure densities of dark false mussels, whip mud worm, clam worm, bryozoans, hydras and various protists to determine denitrifying volunteer communities created via bacterial activity on shell surface or in digestion systems. The community in Baltimore Harbor is capable of 5 to 10 grams of ammonium/day/ft^3.

FCW-3 **Sediments**

- Monitor with similar core sampling techniques as bio-deposition of oyster aquaculture and reef restoration (see SA:4, p.5:26)

FCW-4 **Water Quality Parameters**

Sample the following at FCW and a control site 15 meters away to compare the following measurements to determine effectiveness of the FCW:

- pH, alkalinity, ammonium, nitrite, nitrate, phosphate, bromide
- Temperature, salinity and Dissolved Oxygen (DO)
- In highly open estuarine systems, residence time of water beneath FCWs is likely very short due to tidal and wind mixing. General similarity of water quality parameters under FCW and at control sites is to be expected in these conditions. Statistically significant differences may arise in water bodies that are less well mixed, i.e ponds or flow-restricted inlets (National Aquarium 2011).

DESIGN CONSIDERATIONS

- Sampling considerations should be incorporated into design process. For example, the need to take root samples should inform the design in terms of ease of accessibility
- Modular design with attachments for easier implementation, sampling, maintenance, end-of-lifecycle harvest
- Plastic mesh, buoyant marine foam, pier pilings or other substrate for plant growth
- Navigational buoys
- Anchors (cinder block anchors in ponds, low flow areas or more traditional harbor style anchors in high flow areas)
- Goose fencing if necessary, to avoid trampling damage
- Plants: Selection Goals and Considerations
  - Maximize nitrogen assimilation into tissue
  - Provide native habitat for wildlife
  - Temporal and spatial variation
    - Overplant in anticipation of a certain survival rate, then thin to ensure optimal growth
    - Create a root structure of varying lengths
    - Complementary growth habits (vertical, spreading, climbing)

Data Collection

OTHER CONSIDERATIONS

- Depending on month of installation, a FCW can take several weeks to establish, and uptake rates vary by maturity of island
- Seasonal variation – rates of uptake vary depending on growth seasons of the organisms that inhabit the FCW
- Nitrogen is only removed via uptake into tissue if the tissue is removed from the system, i.e if maintenance and regular harvesting of the biomass is occurring.

Because sources of nitrogen are both anthropogenic and natural, certain environmental parameters must be collected in order to effectively analyze patterns and suggest management options. Environmental sources of nitrogen variation include season, atmospheric deposition, tidal flushing rates, rate of uptake from plants, and others. Furthermore, there are many forms of nitrogen (nitrate, nitrite, ammonium, atmospheric nitrogen) and various forms can be stored and released in the sediments, introducing a time lag element between nitrogen concentrations and overall water quality. Because of environmental and temporal variation, multiple years of monitoring data should be required before valid conclusions can be drawn (Ohrel 2007).

The long-term fate of nutrients assimilated into algal, bacterial, plant and animal biomass is unclear. However, collectively, plants, volunteer communities and other FCW processes "are likely to take nutrients from a form that is readily available to harmful algal bloom species and direct it into a much slower and more natural nitrogen pathway typical of functioning, intact tidal wetlands" (National Aquarium 2011).

O & M

Because nitrogen removal performance can be dependent on following proper operation & maintenance guidelines, O&M responsibilities should be clearly defined and tracked, including the following:

- Removal of undesirable invasive species

- Visual inspection of component integrity (attachments, buoys, substrate)
- Removal of obvious debris – trash, sediments
- Re-planting of areas that do not take
- Thinning dense areas
- Repair storm damage, wildlife trampling, other forms of damage
- Repair goose fencing
- Anchors have the potential to sink into the substrate of the benthic area, causing islands to sink. High densities of plant, volunteer and other invasive organisms can also weigh down the island. Document if these issues occur.

HARVEST

- Track when FCWs are harvested. Typically this is completed annually in early October, before plant material and other organisms seasonally decay and return nutrients to the water.
- In situ harvest of emergent and submerged biomass to the extent practicable
    - Samples for analysis: emergent and submerged biomass differentiated by modular unique identifier, bagged separately for lab analysis
    - Protocol and schedule for desiccation and lab analysis to be determined
    - Remaining material can be delivered to a composting facility
- Depending on substrate starting material and end of season condition, can be either discarded, recycled, or reused. Anchors, attachments and frames may be salvaged. This should be tracked and documented.

Cost categories should be disaggregated and should include the following: materials, O&M, capital, personnel, staff time (sub-categories can be created, i.e administration, planning, monitoring, reporting). Funding source should also be disaggregated. See "General Monitoring Data Guidelines" (Chapter 4, p. 4:2) for more details.

CO-BENEFITS

Co-benefits (if any) shall be identified and monitored. Co-benefits identified in the Technologies Matrix include improved habitat and biodiversity, improved green space, buffering the impacts of extreme weather, and energy savings, nutrient recovery and recycling benefits.

Data Analysis and Reporting

Raw data and the Project Report Template should be submitted to the Monitoring Committee for technical review. Consult "General Monitoring Data Guidelines" (see Chapter 4, p. 4:3) for further information on data processing, flow, and utilization.

REFERENCES

Hunt et al. 2012. *Evaluation of Floating Wetland Islands (FWIs) as a retrofit to Existing Stormwater Detention Basins*. North Carolina Department of Environment and Natural Resources – Division of Water Quality

National Aquarium 2011. *Initial Assessment of the Habitat Value, Local Water Quality Impacts and Nutrient Uptake Potential of Floating Island Wetlands in the Inner Harbor, Baltimore MD*. Maryland Department of the Environment

National Aquarium 2013. 2012 National Aquarium's *Final Report on Habitat Value and Nutrient Uptake of the Floating Island Wetland Project – Inner Harbor, Baltimore MD.* Maryland Department of the Environment

Meng, P. et al. 2014. *Effect of Different Plant Species on Nutrient Removal and Rhizospheric Microorganisms Distribution in Horizontal-Flow Constructed Wetlands.* Environmental Technology 35.7: 808–816

Mitsch, W. et al. 2014. V*alidation of the Ecosystem Services of Created Wetlands: Two Decades of Plant Succession, Nutrient Retention, and Carbon Sequestration in Experimental Riverine Marshes*. Ecological Engineering 72: 11–24

Ohrel, R. and Register, K. 2007. *Volunteer Estuary Monitoring: A Methods Manual 2nd ed*. EPA and The Ocean Conservancy

Wang, C., Sample D., and Bell, C. 2014. *Vegetation Effects on Floating Treatment Wetland Nutrient Removal and Harvesting Strategies in Urban Stormwater Ponds*. Science of the Total Environment 499: 384–393

CHAPTER 6

EVALUATION GUIDELINES

for Pilot Projects

Once monitoring data is collected, the following evaluation guidelines shall be used to evaluate the non-traditional technology pilot projects in the context of the larger watershed plans and regional goals for water quality improvement on Cape Cod.

A program evaluation is an individual study conducted periodically or on an as-needed basis that assesses how well a pilot project is working in the context of the entire watershed plan. The express goal of a program evaluation is to use the information collected to improve program management and/or learn which benefits can be directly traced to individual pilot projects and/or the overall watershed plan approach. A program evaluation typically uses monitoring data, existing reports and several forms of primary data collection in order to assemble the necessary information. Both monitoring and evaluation are used to improve management of both the individual pilot projects and overall watershed plan, but evaluations generally make use of more in-depth and wide-ranging information sources that are not feasible to collect on an ongoing basis during routine monitoring.

The following evaluation guidelines provide guidance on the evaluation process for pilot projects, and consider the scope of the evaluation, the team composition, the expected deliverables, the methodology, the evaluation duration, supervisory responsibilities and, most importantly, the evaluation issues/questions to be addressed. Often – although not always – funding organizations that provide grants will require that evaluations be conducted as part of the granting process.

SCOPE

The scope of an evaluation may be applied at the scale of several pilot projects or the scale of an individual project implementing non-traditional technologies in the Technologies Matrix. The 208 Plan Update specifies periodic technology evaluations for **performance**, **cost-effectiveness** and **co-benefits** on five year intervals as part of an adaptive management plan. This is in addition to spot adjustments and improvements based on routine monitoring information that is collected on more frequent intervals.

TECHNICAL REVIEW PANEL

A Technical Review Panel, as described earlier in this document on page 2:2, will meet regularly and is comprised of local, regional, and state representatives. The Technical Review Panel will: (1) evaluate pilot project design, development and monitoring; (2) advise on adaptive managment plans; and (3) advise on Targeted Watershed project funding, design, construction and permit compliance. The Technical Review Panel will also advise on compliance monitoring including baseline water quality and habit monitoring, for the subject embayment.

CONCLUSIONS OF THE EVALUATION

Based on the analysis, the evaluation will draw specific conclusions and make proposals and/or recommendations for any necessary further action by the pilot project implementation team to ensure that the overall goals of the regional watershed plan are met. Any proposal for revisions should include precise specification of objectives and the major suggested inputs and desired outputs.

- **Triggers:** Thresholds for corrective action should be constructed based on the conclusions of the evaluation. If tasks have been executed according to pilot project design, as part of adaptive management, adjustments to the pilot projects or overall regional watershed plan approach may need to take place to correct contribution to the overall watershed plan.

EVALUATION OBJECTIVES AND COMPONENTS

The **specific objectives** of an evaluation are:

- Improved understanding of nitrogen removal/remediation performance and cost-effectiveness of pilot non-traditional technologies on Cape Cod
- To understand factors in the watershed program environment that may impede or contribute to its success and use of this understanding to improve resource allocation, service delivery and program effectiveness
- To understand associated co-benefits of the non-traditional pilot technologies and link co-benefits to other regional priorities and needs

Based on these specific objectives the evaluation addresses the following interrelated major components:

- Water quality
- Ecosystem health
- Existing and future economic activity, including tourism, coastal property values and other water-quality dependent industries

EVALUATION ISSUES/QUESTIONS

Evaluation criteria are sorted into four categories: **relevance, efficiency, sustainability and impact.** In addition to the basic criteria, a process evaluation will assess the extent to which an individual pilot project in the context of the overall watershed program operated according to both design and expectations. The process evaluation seeks to answer the question of whether or not the program was carried out as intended.

The evaluation will ultimately provide the Pilot Project Implementation Team, WMA, Cape Cod Commission, MassDEP, EPA, and current and prospective funders with comprehensive information regarding outputs, outcomes, and impacts of technologies, with recommendations on the feasibility of a scaled approach to the problem.

The primary evaluation criteria include:

RELEVANCE

- ☐ Relevance to major components: What is the relevance of the pilot project(s) to ongoing Barnstable County priorities, needs, strategies and policies in each of the major component areas: water quality, ecosystem health and economic activity?
- ☐ Relevance to pilot project criteria: What is the relevance of the implemented pilot project(s) as compared with criteria for pilot projects, including but not limited to the following questions:
  - Are pilots implemented in areas where the tested technology impact can be most clearly demonstrated? (Is good baseline information available? Are variables controlled?)
  - Can performance measures be monitored on a spatial and frequency scale to judge success of project?
- ☐ Relevance of the design: Is there consistency between the baseline data and the objectives, between the inputs and the outcomes within each piloted technology and across the different piloted technologies within an overall watershed plan?

- Are towns working across jurisdictions to site pilot projects such that a) the impact of adjacent pilots can be isolated and/or b) the impact of adjacent pilots is maximized across jurisdictions?
- Are maintenance plans being followed according to design?

☐ Relevance of the evaluations: Is there consistency between previous evaluations? Create consistency to the extent practicable.

☐ Relevance to other long term monitoring efforts: What is the relevance to the eel grass surveys by MassDEP (for example,) or other ongoing regional monitoring efforts?

EFFICIENCY

☐ Cost-effectiveness: What are the least cost methods for removing or remediating nitrogen?

☐ Technical efficiency: What was the quality and quantity of technical support provided by the Commission, Monitoring Committee and other Technical Review Panels to Pilot Project Implementation Team and WMA?

☐ Organizational efficiency: What is the extent of town administrative support and commitment? How effectively has the Project Implementation Team been working? Were there enough case studies collected pre-implementation to guide the project? Review the logical and regulatory framework, indicators and other monitoring data collected for supportive supervision, internal and external communication procedures.

☐ Procedural efficiency: Were the project management tasks related to reporting, feedback, follow up, supplies and funding requests, meetings/minutes useful and did they add value to the attainment of the overall project results?

☐ Timing: How quickly did the technology produce measurable results in receiving waters?

SUSTAINABILITY

☐ Provide an overview of the costs for the different components of the project as compared to the estimated benefits.

☐ Provide an assessment of the sustainability of the achievements: maintenance, overheads, management, ownership, etc

☐ What was the quality of community participation in problem identification, planning, implementation and monitoring, reporting and feedback/problem solving?

☐ Was their empowerment and ownership by stakeholders?

☐ Provide a critical analysis of the possibility, capacity and mechanisms to continue the activities without external financing or technical support.

☐ Provide an assessment of the durability of pilot technologies to environmental perturbations, both routine and extraordinary (i.e flooding)

IMPACT

The evaluation will systematically assess the progress towards the overall watershed plan results and outcomes on the following items: water quality, ecosystem health, and economic activity.

Evaluation for Nitrogen Removal

☐ Provide an impact evaluation for nitrogen remediation or reduction, including estimations of the following individual parameters and aggregates:

- In the absence of the program, what amount of nitrogen could reasonably be expected to exist?
- What is the Nitrogen uptake into biomass? (if applicable)
- What is the averted nitrogen through designed reduction? (for source-reduction technologies such as eco-toilets and I/A systems)
- Were pilot project expectations regarding nitrogen remediation or reduction met?

☐ Provide an impact pathways analysis for nitrogen removal via denitrification processes

- Were denitrifying and filter feeding organisms observed at expected densities? (f applicable)
- Were downstream concentrations of nitrogen as expected?

☐ What corrective efforts were taken after identifying constraints through monitoring?

Evaluation of other themes

- ☐ Provide an impact evaluation for co-benefits, including but not limited to: ecosystem function, habitat creation, carbon sequestration, shoreline protection, job creation, economic activity, and aquaculture products.
- ☐ How does the pilot project water quality improvement compare with other sources of nitrogen reduction or remediation as outlined in the 208 Plan Update? Include nitrogen reduction comparison to:
    - Smart growth planning (Creation of designated growth areas)
    - Fertilizer management
    - Stormwater Best Management Practices (BMPs)
- ☐ If pilot projects do not perform as expected in terms of impact, have alternative, more certain contingencies for water quality improvement been implemented according to the adaptive management plan?
- ☐ What unintended effects were observed (if any)?
- ☐ How were risks assessed and managed? (for example, predation or disease to oyster populations.)

METHODOLOGY

An appropriate methodology to carry out the evaluation should include, but is not limited to the following:

DESK REVIEW OF EXISTING DOCUMENTS

The evaluation shall consider all relevant and available reports and monitoring data related to the project, including agreements with local partners and authorities; baseline reports; periodic technical and financial plans; a literature review and relevant data and analyses.

FOCUS GROUP DISCUSSIONS

Field missions should be scheduled for five of the Barnstable county towns, which should provide the Technical Review Panel with a comprehensive overview of the program outputs. A focus group discussion should be held at each of the field mission sites, with effort to include relevant stakeholders based on the technologies piloted in that town. Examples of participants could include town officials, community group leaders, researchers, contractors, maintenance personnel, and others. These discussions will help to answer the questions in the criteria about ongoing issues or relevance that may not be initially obvious to the Pilot Project Implementation Team or WMA.

KEY INTERVIEWS

In-depth semi-structured interviews shall be conducted with Commission staff, state and federal authorities involved in the project, beneficiaries, and partners to assess the program's effectiveness in comparison with regional goals. All information will be triangulated and validated to the greatest possible extent. The analysis will adhere to Commission and partner agencies' reporting and ethical guidelines.

EVALUATION DELIVERABLES AND DURATION

The primary output of the evaluation by the Technical Review Panel is a written report in accordance with the Evaluation Guidelines in this document. The report should contain findings and recommendations based on discussions with all concerned parties. An evaluation report, written by the Technical Review Panel, may include the following chapters, with graphics and maps as needed.

I. EXECUTIVE SUMMARY
II. EVALUATION APPROACH
III. METHODS INCLUDING QA/QC
IV. IMPLEMENTATION SCHEDULE
V. ANALYSIS
VI. FINDINGS/RESULTS (as per the evaluation issues/questions section above)
VII. LESSONS LEARNED
VIII. CONCLUSION AND RECOMMENDATIONS
IX. REFERENCES

Appendices will contain all relevant background information for the evaluation that is not necessary in the body of the report.

The final products of the evaluation should also include:

- Cleaned and fully referenced electronic data sets based on the established data warehouse format with copies of the original data collection forms
- Full transcripts of all in-depth interviews and focus group discussions in an electronic format, including a list of places visited and people met
- A hard copy of the evaluation report in five copies with detailed findings and recommendations
- An 8-10 page illustrated summary document suitable for general consumption and an electronic version of the summary document suitable for posting on websites
- A public presentation of results

The duration of the evaluation should be approximately 45 days, if possible.

SUPERVISION/REPORTING

The Technical Review Panel will report directly to the. Pilot Project Implementation Team or WMA. Designated staff from the Monitoring Committee will have technical oversight.

APPENDIX

Pilot Project Fact Sheet Template {Example}

GENERAL INFORMATION:

Technology: Permeable Reactive Barrier (Trench)

Project Location (town): Harwich

Project Location Description: North of Flax Pond

Project Implementation Organization(s)/Town(s): Town of Harwich

Funding Source(s) and Amount(s): EPA Region 1 - $250K; Town of Harwich – $20K

TECHNOLOGY PERFORMANCE:

Technology Dimensions and Specifications: 1200 linear feet, constructed to a depth of 30 feet below land surface. Reactive media = woodchips.

Nitrogen (Nitrate) Removal Ranges:

% removal of influent nitrate concentration: 82% - 91%

N removal Kg/yr: 300

TIMEFRAME AND COSTS

Project Phase	Date Range	Cost
Planning/Design	January 2015- December 2015	$50K
Permitting	January 2016-May 2016	$25K
Construction	May 2016-June 2016	$150K
O & M	June 2016- present	$500- avg per month
Monitoring Pre-construction:	July 2015- May 2015	$20K
Post-construction:	June 2016- present	$40K