Appendix O

Technical Memo – Site Characterization and Evaluation for Aquaculture/ Shellfish Propagation (evaluation criteria and ranking)

(March 13, 2016)

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Memorandum

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Subject	**Town of Orleans, MA** **Water Quality and Wastewater Planning** **Task Number 3.b – NT Demonstration Projects** **Technical Memorandum on Final Site Characterization and Evaluation for Aquaculture/Shellfish Propagation (evaluation criteria and ranking)**
Project Number	60476644
From	Thomas Parece, P.E., AECOM Project Manager
Date	03/13/16

1. Background

a. Purpose

The Final Site Characterization and Evaluation Technical Memorandum presents the process used to identify, evaluate, rank and ultimately recommend specific shellfish demonstration sites. This Memorandum including the following:

- Description of the initial process that was employed to develop the Orleans Consensus Plan and associated potential demonstration sites;
- Next steps that have been taken in the process of evaluating demonstration sites;
- Data that is available to help evaluate potential demonstration sites;
- Evaluation and ranking of sites based on the site selection matrix and criteria; and
- Recommended demonstration sites paired with specific shellfish propagation approaches (such as bottom planting hard shell clam, oyster beds or oyster aquaculture), and rationale for selection.
- Comments received as part of review of the Draft Site Characterization and Evaluation Technical Memorandum, and AECOM Shellfish Team responses (Appendix A).

In addition, key terms are defined including the categories of data that were evaluated. The site selection criteria and ranking system used to assess potential demonstration sites are also explained.

The purpose of the Orleans shellfish demonstration is to both locally measure the nitrogen-removal benefits of shellfish cultivation, as well as demonstrate the practical applications of shellfish propagation and aquaculture expansion within the Town of Orleans. The AECOM Shellfish Team has taken a **two-step approach** to plan and design demonstration projects for Orleans. The first step is to review existing data and evaluate a number of potential sites for overall suitability using a variety of criteria. At this stage, the team is ranking sites where a demonstration could be practically implemented. This siting evaluation is documented in this first Technical Memorandum and provides a transparent and objective assessment of possible locations in Orleans for the installation of shellfish based non-traditional technology demonstration projects. Comments received on the Draft Site Characterization Technical Memorandum, and the team's responses are also part of the evaluation process used to identify locations for shellfish demonstration projects.

Once the specific locations for demonstrations are selected, the next step will be to define the specific design parameters for each demonstration project site, including numerical targets for shellfish and nitrogen-removal. This detailed design and engineering will be presented in the next Technical Memorandum, entitled "Preliminary Engineering Design and Work Plan" and will contain a detailed monitoring plan for water quality as well as shellfish biomass, predators and diseases.

b. Definition of Aquaculture and Coastal Habitat Restoration (CHR)

In order to establish a consistent meaning of aquaculture and CHR in the context of this Technical Memorandum, these terms are defined as follows:

Aquaculture: the farming of shellfish in controlled or selected marine environments as single, unattached units, for eventual harvest. Farming involves using gear such as cages, floating bags or trays. Direct planting of shellfish on the sea floor after a period of growing in gear is also considered aquaculture. Marine aquaculture is usually located in bodies of saltwater, with land-based, manmade systems such as upweller tanks used for certain initial phases of growth.

Shellfish farming typically includes activities that seek to enhance production, including:

- Moving or splitting populations of shellfish to control density within gear;
- Locating shellfish in specific regions of the water column with better growing conditions; and
- Protecting from predation.

In Orleans, the most suitable shellfish species for aquaculture include American (or Eastern) oyster (Crassostrea virginica), hard clam (or northern quahog) (Mercenaria mercenaria), and blue mussel (Mytilus edulis). Shellfish aquaculture for the purpose of this Technical Memorandum involves growing single oysters and/or quahogs in gear such as bags, trays or cages until these shellfish reach a suitable size for bottom planting or harvest. Aquaculture systems that require supplemental feeding to support growth are not under consideration. Blue mussels were evaluated and rejected for a demonstration project due to the difficulty of growing this species at this time. Nitrogen-removal calculations are based on average shellfish uptake as demonstrated in published literature as well as through personal experience by the assembled Team.

Coastal Habitat Restoration (CHR): creating or rehabilitating native shellfish habitats; creating an ecosystem that includes a combination of shellfish species and associated organisms and plants that remove nitrogen from the water column. Establishing new shellfish areas and bed systems where native shellfish species have not existed historically is also considered CHR. Dense populations of oysters are often referred to as oyster bottoms, oyster beds, oyster bars, oyster banks, or oyster reefs. These terms refer to large colonial aggregations of living oysters and oyster shells that provide habitat for other species. Quahog bottom planting is also CHR, as propagation restores native shellfish populations, habitats and improves bottom sediment. Nitrogen-removal calculations are based on average shellfish uptake as demonstrated in published literature as well as through personal experience by the assembled Team.

Growing options include (1) bottom planting of shellfish raised from seed through hatcheries and propagation programs, (2) growing spat-on-shell (remote set) in trays or bags, and (3) bed establishment programs by means of substrate enhancement (cultch placement). CHR may also involve establishing and/or enhancing estuary salt marshes and eelgrass beds as part of an effort to create suitable coastal habitats.

Oyster Beds can be established both for harvest as well as for “no take” sanctuaries. Both contribute important ecosystems services, including:

- Nitrogen uptake;
- Improved sediment quality;
- Increased biological diversity; and
- Shoreline protection from erosion and storms.

The distinction is that “no take” sanctuaries are beds where removal of oysters for harvest is prohibited for a period of 5 years or more, to enable the bed structure to be established without the inevitable disturbances from harvest activities. No take areas also enable oysters to continue to grow after they have reached harvest size. These more mature shellfish are expected to produce larger spawns. In addition, allowing oysters to grow and spawn for several generations is expected to promote a more disease resistant population. Spawning sanctuaries are believed to increase native populations and thus support commercial and recreational harvest more than beds that are continuously harvested (Frankic et al, 2015; Frankic and Cataldo, 2007; Jones, 2006).

2. Introduction

a. Consensus Plan Description

The Orleans Water Quality Advisory Panel (OWQAP) was convened to achieve consensus and build widespread community support for a customized, affordable water quality management plan for the Town of Orleans. The panel consisted of stakeholder representatives (Orleans Selectmen and representatives of engaged citizen constituencies), and liaisons from key town boards and commissions, organizations, neighboring towns, and regional, state, and federal partners. The OWQAP met for twelve half-day meetings starting in July 2014, all of which were open to public attendance and comment.

Potential alternative planning scenarios to meet water quality standards were developed for the OWQAP and presented at meetings and workshops. Initially, a Hybrid Plan was designed that included specific sites for aquaculture and coastal habitat restoration (CHR), as well as permeable reactive barriers (PRB) and floating constructed wetlands (FCW). The number of acres of shellfish growing area (as well as linear feet of PRBs and square footage for FCW) were quantified to achieve specific nitrogen-removal targets. This exercise was undertaken to ensure that the quantities of shellfish (and all other non-traditional technologies) proposed in the Consensus Plan were feasible to install. These specific locations became the basis for potential demonstration site locations for aquaculture and CHR, as well as FCWs and PRBs.

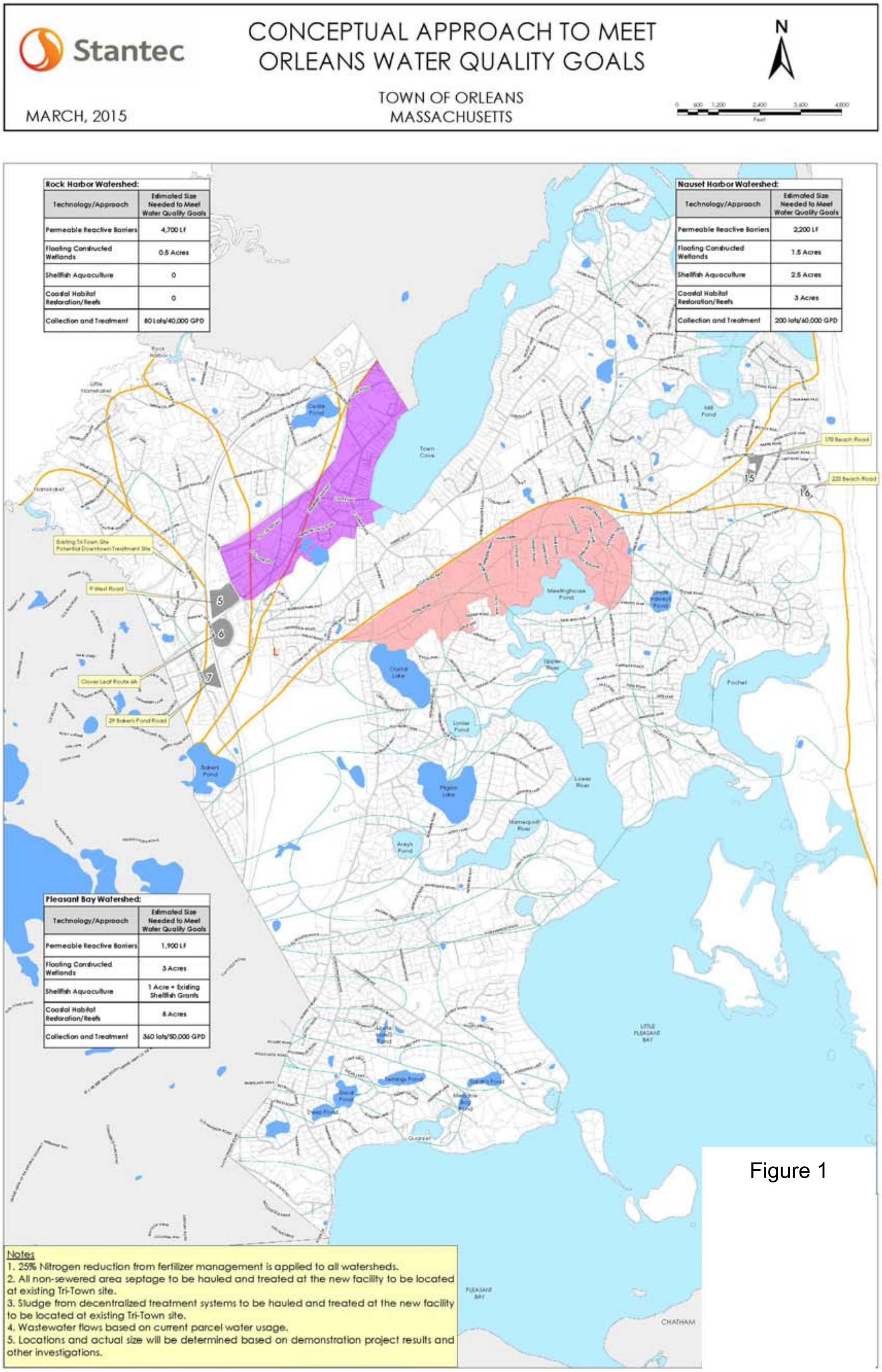
The Hybrid Plan was vetted through the OWQAP during three meetings, including a day-long workshop. This iterative process resulted in a draft Consensus Plan that included a combination of non-traditional and traditional technologies. Once the feasibility of using shellfish and other non-traditional technologies as part of the Town's nutrient management strategy was established, the OWQAP decided that the final Consensus Plan would not specify exact growing locations, but instead focus on overall area of shellfish and other alternative technologies needed to remove the appropriate mass of nitrogen at the watershed level.

The resulting map (Figure. 1), entitled Conceptual Approach to Meet Orleans Water Quality Goals (March 2015) shows the agreed upon water quality management plan and includes 5.5 acres of shellfish in the Nauset Harbor watershed and 9 acres of shellfish in Pleasant Bay. Neither coastal habitat restoration nor aquaculture is part of the plan for the Rock Harbor watershed. This map also specifies acreages for FCW and linear feet of PRBs.

b. Initial Process of Site Identification

As part of updating the 208 Plan, The Cape Cod Commission (CCC) created Traditional and Non-Traditional Scenarios that would meet the regulatory requirements for nitrogen formalized as Total Maximum Daily Loads (TMDLs) for Orleans' impaired water bodies. The Traditional Scenario for Orleans used centralized sewers exclusively. The Non-Traditional Scenario met nitrogen-removal goals through a subset of the many alternatives that are described in the 208 Plan's Technology Matrix. The subset of technologies in the Commission's Non-Traditional Scenario included PRBs, FCWs, CHR, shellfish aquaculture, fertigation, composting and urine-diverting toilets and innovative/alternative septic systems. In order to ensure consistency with this established regulatory framework, the Non-Traditional Scenario developed by the Commission became the starting point for customizing a non-traditional bookend for the OWQAP and consensus-building process.

This planning and design process for tailoring a non-traditional bookend for Orleans included studying the information prepared by the CCC, and collecting and analyzing a significant amount of additional local data that was not reviewed as part of the regional planning process undertaken by the Commission. Local data from satellite images, GIS maps, groundwater maps, and coastal pond bathymetry data was reviewed. Paper records on the history of local aquaculture, and Town shellfish propagation were aggregated into a database for trending and other analyses. Site visits both by land and by water were conducted to validate locations for shellfish aquaculture and CHR. Interviews with the Orleans Shellfish Constable, the former Shellfish Constable, and local shellfishers were also conducted to verify initial findings.



Rock Harbor Watershed:

Technology/Approach	Estimated Size Needed to Meet Water Quality Goals
Permeable Reactive Barriers	4,700 LF
Floating Constructed Wetlands	0.5 Acres
Shellfish Aquaculture	0
Coastal Habitat Restoration/Reefs	0
Collection and Treatment	80 Lots/40,000 GPD

Nauset Harbor Watershed:

Technology/Approach	Estimated Size Needed to Meet Water Quality Goals
Permeable Reactive Barriers	2,200 LF
Floating Constructed Wetlands	1.5 Acres
Shellfish Aquaculture	2.5 Acres
Coastal Habitat Restoration/Reefs	3 Acres
Collection and Treatment	200 lots/60,000 GPD

Pleasant Bay Watershed:

Technology/Approach	Estimated Size Needed to Meet Water Quality Goals
Permeable Reactive Barriers	1,900 LF
Floating Constructed Wetlands	3 Acres
Shellfish Aquaculture	1 Acre + Existing Shellfish Grants
Coastal Habitat Restoration/Reefs	8 Acres
Collection and Treatment	360 lots/50,000 GPD

Figure 1

This local data was used to:

- Evaluate depth to groundwater and aquifer thickness for PRB installations;
- Assess roads and neighborhoods for PRB installations;
- Classify water bodies in terms of suitability for aquaculture and/or CHR based on water quality data contained in Massachusetts Estuaries Project (MEP) Reports and data synthesis from the Pleasant Bay Alliance;
- Inventory potential and existing use conflicts (boating, moorings, aesthetic preferences);
- Identify specific areas for shellfish growing within waterbody; and
- Recommend different species for specific areas, including quahogs, oysters, and mussels.

This local data collection and evaluation allowed the Non-Traditional Bookend for Orleans to be based on key validated site parameters, ensuring that the non-traditional technologies were feasible in their planned locations. In addition, a Technical Memorandum on Non-Traditional Technologies (Appendix B) was prepared and submitted to the OWQAP. This Technical Memorandum detailed initial performance expectations, as well as key site and permitting considerations that should be used to verify the usefulness of these technologies for specific subwatersheds in Orleans.

The results of this detailed analysis and resulting initial locations for non-traditional technologies were presented and thoroughly discussed during the October 8, 2014 OWQAP Stakeholder meeting. Based on this technical review, as well as direction from the OWQAP, specific non-traditional technologies were then selected to be used to create a “Hybrid Plan” that included both non-traditional as well as traditional technologies for Orleans. The Hybrid Plan showed both technologies in specific locations in order to verify that appropriate nutrient loads could be removed.

c. Hybrid Plan Site Identification Criteria used during OWQAP Process

During a day-long OWQAP public workshop on December 17, 2014, the Hybrid Plan was presented, screened, and evaluated. This plan described a combination of traditional and non-traditional technologies that meet the MEP load-reduction targets for nitrogen in each impaired waterbody. The OWQAP then formed three subgroups to discuss, evaluate and revise the Hybrid Plan. To assist in this process, the OWQAP received a Technology Evaluation Decision Support Tool that allowed risks and benefits of each technology to be evaluated by subwatershed. Preliminary comparative costs were also presented on a relative dollars/kilogram of nitrogen removed basis. The Site Evaluation Matrix is included in Appendix C.

Ranked categories include:

- Nutrient removal certainty: nitrogen (saltwater), phosphorus (freshwater);
- Implementation certainty;
- Other benefits: ecosystems, economic, social;
- Adaptability to uncertainty in nutrient-reduction goals and build-out; and
- Contaminants of emerging concern (CEC) removal.

- Overall cost

Based on these criteria, all sites shown on the Hybrid Plan for both shellfish aquaculture and CHR were retained. These locations became the initial list of possible locations for demonstration projects, needed to validate the feasibility and nutrient-removal capacity of shellfish in Orleans. The following sites and activities (aquaculture and/or CHR) were identified as part of the process of defining the Consensus Plan and are being reviewed in greater detail as part of this next phase of work, currently underway:

- Town Cove (both aquaculture and CHR);
- Mill Pond (both aquaculture and CHR);
- Little Pleasant Bay (both aquaculture and CHR);
- Arey's Pond (aquaculture);
- Pochet (CHR);
- Lower River (CHR); and
- Quanset Pond (CHR).

d. Current Process of Site Review and Validation

The initial shellfish sites, taken from the Hybrid Plan developed during the OWQAP process were further evaluated by the Shellfish Technical Team that was subcontracted by AECOM to evaluate demonstration sites and prepare this Technical Memorandum. The specific methodology used for in-depth site evaluations included the following steps:

- Review Nauset Harbor and Pleasant Bay watersheds to identify potential demonstration locations that may not have been identified during the first phase of planning;
- Study available data (water quality and other data);
- Conduct land-based and water-based field investigations of potential sites;
- Discuss potential demonstration sites with Orleans Shellfish Constable/Harbormaster and Assistant Harbormaster;
- Refine criteria to be used in the Site Selection Matrix;
- Rank sites based on criteria using Site Selection Matrix;
- Assess the relative importance of each criteria to establish a weighting of criteria if appropriate;
- Perform QA/QC of initial ranking and criteria weighting;
- Review preferred demonstration sites that resulted from the Site Selection Matrix process;
- Submit Site Selection Matrix to Town of Orleans for review; and
- Recommend demonstration site locations.

This Technical Memorandum reports on the findings of these tasks.

3. Description of Proposed Sites

a. Definitions: Data Parameters

There are two categories of data used to assess potential demonstration locations: (1) information on site ecology, which includes the environmental conditions in the water bodies where shellfish will be raised, and (2) information on the surrounding environment, which addresses land use characteristics, as well as public and private uses associated with the demonstration sites. The specific data parameters associated with each data category are:

Site Ecology

- Water quality data which includes salinity, dissolved oxygen (DO), chlorophyll a, total nitrogen (TN), dissolved organic nitrogen (DON), particulate organic matter (POM), pH, and temperature;
- Tide and water flow (circulation);
- Bathymetry;
- Benthic Conditions;
- Eelgrass bed locations; and
- Local knowledge of shellfish species, predation and shellfishing activities at these sites.

Surrounding Environment

- Type and location of current uses;
- Abutter interests/potential conflicts;
- Acreage available within water bodies;
- Access points/easement requirements;
- Land ownership; and
- Viability of using existing shellfish grants as a demonstration.

Each of these data parameters is defined or explained for use in site selection as follows:

Site Ecology Terms

- **Bathymetry:** a measure of water depth.
- **Benthic Conditions:** the type of sediment present at a given site, expressed as grain size.
- **Chlorophyll *a*:** a green pigment responsible for the absorption of light to provide energy for photosynthesis. Phaeophytin *a* is also a photosynthetic pigment, often produced by the degradation of chlorophyll *a*. Chlorophyll *a*, as well as total pigment concentration can be used as a proxy for food concentration.

- **Dissolved Oxygen:** The amount of elemental oxygen, O_2, in solution under existing atmospheric pressure and temperature. Low levels of dissolved oxygen (DO) can slow the growth rate and reduce the survival of shellfish (Gosling 2003; Whetstone et al 2005).

- **Eelgrass bed locations:** mapped areas where eelgrass is currently growing.

- **Total Nitrogen:** the combined sum of all organic and inorganic forms of nitrogen in a water sample. These forms of nitrogen can include nitrate, nitrite, ammonia, particulate organic nitrogen and dissolved organic nitrogen.

- **Dissolved Organic Nitrogen**: the soluble form of nitrogen contained in organic (carbon-based) compounds such as amino acids, peptides, humic substances and protein.

- **Local knowledge of shellfish species, predation and shellfishing:** information gathered from Orleans Shellfish Constable/Harbormaster (past and present), Assistant Harbormaster, and local shellfishers.

- **Particulate Organic Matter:** the non-soluble components that can be filtered out of a water sample.

- **pH:** an expression of the acid-base relationship designated as the logarithm of the reciprocal of the hydrogen-ion concentration. The value of 7.0 expresses neutral solutions; values decreasing below 7.0 represent increasingly acidic solutions; values increasing above 7.0 represent increasingly basic solutions.

- **Salinity:** concentration of sodium, potassium, magnesium, calcium, bicarbonate, carbonate, sulfate, and halides (chloride, fluoride, bromide) in water.

- **Turbidity:** the relative clarity of a liquid, determined by measuring the amount of light that is scattered by suspended particles in the water column. The presence of suspended or colloidal matter or planktonic organisms reduces light penetration and increases turbidity.

- **Tide and Water Flow:** refers to the circulation of water within a site; currents and tidal exchange can affect both food and oxygen availability, as well as larval dispersion, transport and fate (Brumbaugh et al 2005).

Surrounding Environment Terms

- **Type and location of current uses:** there are other activities that occur on or near the site, such as boating swimming, and wild shellfish harvesting, which could limit the ability to install a demonstration project.

- **Abutter interests/potential conflicts:** neighbors are less likely to object to a well-designed demonstration location near them.

- **Acreage available within water bodies:** acreage must be sufficient for a demonstration at the site.

- **Access points/easement requirements**: a convenient, public location is available from which to access the site for installation, operation, and maintenance of the demonstration.

- **Land ownership:** there are parcels owned privately that limit or preclude access to the site.

- **Viability of using existing shellfish grants as a demonstration**: there may be an advantage to working with current holders of shellfish grants in Little Pleasant Bay to implement a demonstration project.

b. Introduction to Site Descriptions

Review of Town Cove and Mill Pond for demonstration locations considered the entire waterbody. The Shellfish Technical team conducted a desktop analysis, land-based field assessment and water-based survey of Pleasant Bay and determined that no additional demonstrations sites needed to be evaluated. Seven (7) potential demonstration sites were evaluated based on site ecology and surrounding environment parameters. These sites, shown in Figure 2, include:

- Town Cove
- Mill Pond
- Little Pleasant Bay
- Arey's Pond
- Pochet
- Lower River
- Quanset Pond

Key site ecological factors assessed include food availability, salinity and temperature because they are the primary water quality determinants of quahog and oyster distribution and abundance (Menzel 1989; Gosling 2003). Dissolved oxygen (DO) is also a significant parameter, as low levels of DO can limit growth and survival. These constituents are considered threshold factors in assessing site suitability.

The major natural source of food in marine environments for filter feeding organisms such as shellfish is phytoplankton, or algae. Phytoplankton contain chlorophyll a, therefore concentrations of chlorophyll a reflect food availability. Phaeophytin a is also a pigment found in algae. Chlorophyll a data, and in some cases total pigment data (chlorophyll a + pheophytin a) is available for each site. Quahogs and oysters are tolerant of wide temperature ranges; because they enter a dormant phase when water temperatures are below 4°C/40°F, both can survive temperatures below 0°C. Both species also tolerate a wide range of salinity. However, predation has been observed to decrease at salinities that are lower than ocean water (approximately 35 ppt). The temperature is consistent for all sites. Salinity varies among sites with data presented within each site description. Field evidence demonstrates that both oysters and quahogs are viable at current temperatures and salinities. All of the potential demonstration sites experience low DO concentrations at the bottom of the water column. These data are presented for each site within the site descriptions in Section 3.c.

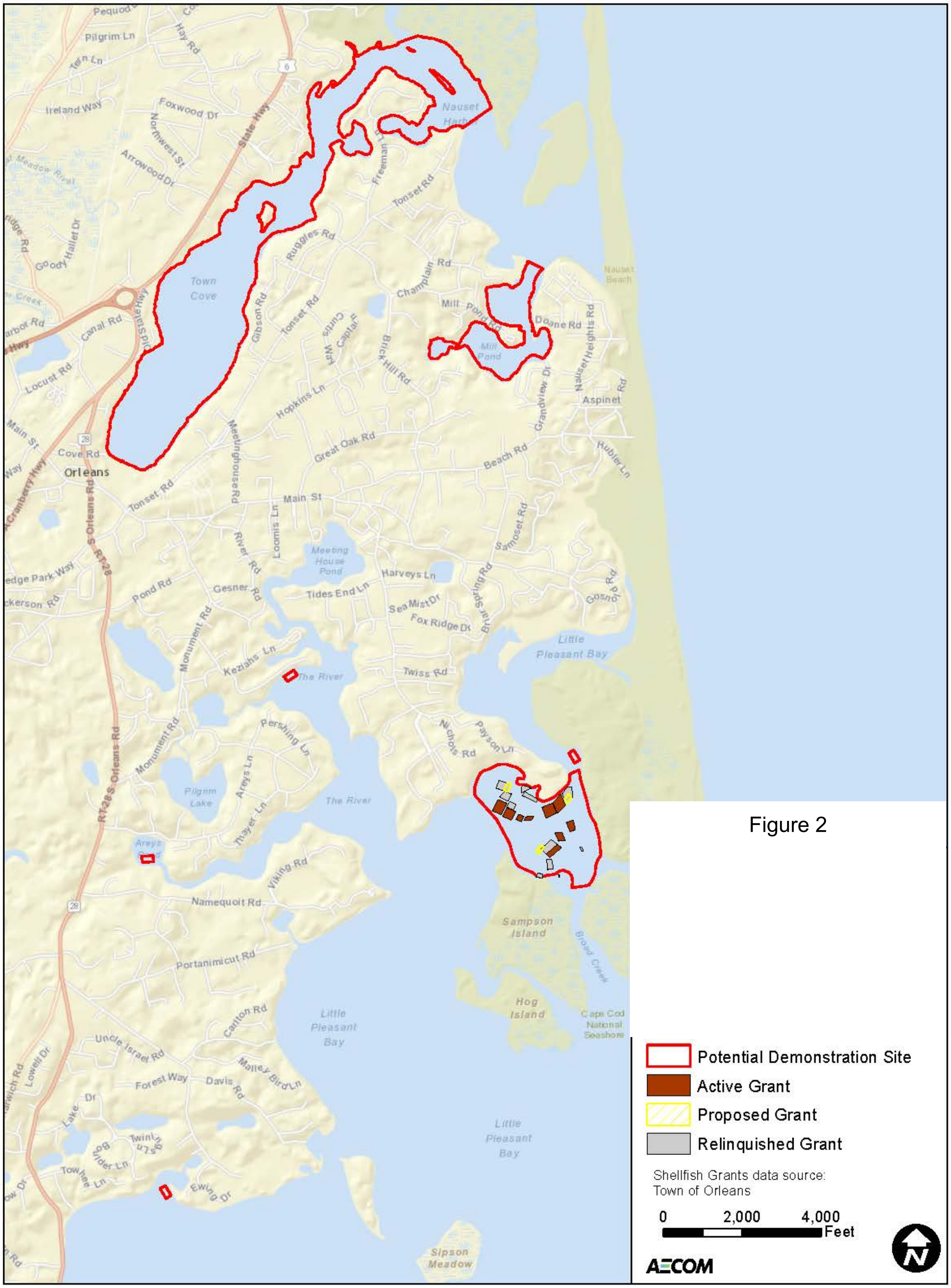


Figure 2
Potential Demonstration Site
Active Grant
Proposed Grant
Relinquished Grant
Shellfish Grants data source:
Town of Orleans
0
2,000
4,000
Feet
AECOM
Town Cove
Nauset Harbor
Mill Pond
Meeting House Pond
Little Pleasant Bay
The River
Pilgrim Lake
Sampson Island
Hog Island
Sipson Meadow
Orleans
C:\work\Orleans\Maps\PotentialDemonstrationSites.mxd

Site ecological information related to predation, bottom conditions and bathymetry is also presented, including absence of eelgrass beds, and sediment type, as these factors apply to the type of demonstration viable at the site. Each site description details the particular issues that favor a certain type of demonstration project. For example, the presence of significant populations of predators limits oyster growing locations. The sediment conditions at each site dictate whether bottom planting is feasible and whether oysters or quahogs are more appropriate. Oysters require a hard substrate on which to set during their late larval stage, or sandy bottom if they are planted as juvenile single, while quahogs can tolerate a sand/mud mix but can also grow in coarse substrates such as sand and gravel (Gosling 2003).

Based on a literature review, threshold site ecology parameters should have the following range of values:

Target Values for Site Ecology Parameters: Oysters

- Optimal salinity: 14 to 28 parts per thousand
- Optimal dissolved oxygen: >4 mg/L
- Food availability (Chlorophyll a): >2 µg/L
- Absence of major populations of predators such as oyster drill
- Absence of eelgrass
- Benthic conditions: hard bottom sediment
- pH range suitable for larvae (most sensitive stage of life cycle): 6.75 to 8.75
- Suitable annual temperature range: > -2 to ≤ 35 °C
- Optimal bathymetry (intertidal): 1 to 30 meters

Based on Whetstone, 2005; Gosling, 2003; Dame, 1996; Menzel. 1989; Stanley 1983.

Target Values for Site Ecology Parameters: Quahogs

- Optimal salinity: 20 to 25 parts per thousand
- Optimal dissolved oxygen: >4 mg/L
- Food availability (Chlorophyll a): >2 µg/L
- Absence of eelgrass
- Benthic conditions: bottom sediment a mix of sand and mud
- Suitable annual temperature range: > -6 to ≤ 35 °C
- Optimal bathymetry (intertidal): 1 to15 meters

Based on Gosling 2003; Dame 1996; Lorio 1994; Sellers 1984.

Surrounding Environment Data

Land use, access to the water, current uses, and neighborhood support for a demonstration are important considerations that are unique to each site. Specific access points are identified, and the character of the neighborhoods surrounding each potential demonstration site is discussed. Public uses such as boating, swimming and shell fishing are also critical. All sites have some form of public access available. The most convenient access is land-based, where a boat is not required to install, operate and maintain the demonstration project. Some of the proposed demonstration sites have fewer conflicting uses and more surface water on which to locate and operate. A preliminary assessment regarding the likelihood of neighbor support for a demonstration is also presented. These aspects of the surrounding environment are detailed in the site descriptions.

c. Potential Demonstration Site Descriptions

Nauset Harbor Watershed

(1) Town Cove

General - Town Cove was evaluated for both oyster aquaculture and CHR. An oyster aquaculture demonstration would include growing seed in an upweller, with transfer to floating bags once the seed reaches approximately 8 mm. At the end of the first growing season, oysters would be bottom planted and allowed to grow through a second season for recreational and commercial harvest once the oysters reached market size (3-inch). Some of the first year oysters could be overwintered in the floating bags. CHR would involve expanding the Town's current propagation program by purchasing seed at 25mm and bottom planting these quahogs in suitable locations in Town Cove for recreational and commercial harvest.

Site Ecology - The MEP Final Report for Nauset Harbor (2012) documents the necessary water quality parameters for Town Cove. Salinity ranges from approximately 32 ppt at the inlet to a minimum of 29 ppt near the head of the cove. Monitoring equipment that collects DO and chlorophyll *a* data in fifteen minute intervals was deployed in Town Cove as part of the MEP field investigations in 2003. This instrument was centrally located in the southern end of the estuary, approximately 1 mile from Hopkins Island and 4 miles from Nauset Inlet. DO levels at the bottom were frequently less than 2 mg/L and periodically approached 0 mg/L. DO levels < 3 mg/L were measured for 38 percent of the 29 day monitoring period. Food availability is indicated by chlorophyll *a* concentrations, which averaged 8.5 µg/L, exceeding the minimum site suitability threshold of 2 µg/L. Both by numerical thresholds as well as field confirmation that both quahogs and oysters are growing in Town Cove, it seems that there is adequate food supply to support shellfish growth in this estuary. Given the low DO concentrations in bottom waters, an oyster aquaculture demonstration would likely need to employ growing systems that suspend shellfish in the upper sections of the water column. Areas within this waterbody with higher DO levels would be better suited to quahog planting, to optimize growth rates. High salinity promotes predation, which is a significant issue in this waterbody.

The suitability of Town Cove for an oyster aquaculture or CHR demonstration is severely limited by the large population of oyster drills (*Urosalpinx cinerea)*. Other predators include moon snails (*Neverita duplicatus*) and starfish (*Asterios forbesis and A. vulgarism*). The Massachusetts Shellfish Officers Association and the Barnstable County Cooperative Extension urge against oyster propagation in areas that experience high predation by oyster drills. For this reason, the use of oyster aquaculture or oyster beds as part of CHR are not proposed for this site. Macroalgae accumulations also create significant fouling problems for gear-based systems. Because of oyster predation and fouling issues, Town Cove is mainly suitable for bottom propagation of quahogs. A population study to determine baseline quahog numbers and sizes is recommended as a first step, prior to the initiation of a demonstration project. Assessing current quantities of quahogs will provide the basis for evaluating the increase in quahogs from additional propagation efforts undertaken as part of a demonstration. For the past four years, there have been red tide blooms in Town Cove during in the spring and summer. According to the Division of Marine Fisheries, red tide is a toxic dinoflagellate (*Alexandrium fundyense*), and blooms are most likely when water temperatures are between 52 – 54 degrees F. Red tide can produce neurotoxins that accumulate in shellfish, which if eaten in large quantities, can cause serious illness or even death. Sampling for red tide cysts in Town Cove occurred in 2015. A report on this data collection is pending.

Town Cove has a waterbody surface area of 390 acres, providing ample area for a shellfish demonstration for quahog propagation. The MEP model estimates a target nitrogen removal load for this sub-watershed of almost 6700 kg N/year. Shellfish suitability areas and eelgrass beds (*Zostera marina*) are shown in Figure 3, derived from MassGIS databases. At present, eelgrass has nearly disappeared from Town Cove: therefore siting conflicts associated with this resource are not expected. According to Division of Marine Fisheries (DMF) mapping, Town Cove has suitable habitat for quahogs and oysters. Historically, the Town has operated a successful quahog propagation program in Town Cove. The Orleans Natural Resources Department currently plants approximately 600,000, one inch (25mm) quahogs annually near Hopkins Island. The existing quahog population has not been quantified. In Orleans, a private aquaculture grant is currently growing oysters in Town Cove. There are also seventeen aquaculture lease sites in the Eastham section of Town Cove, although only fourteen are useable according to the Eastham Harbormater. An area around the shoreline, extending to the boat ramp at the Orleans Yacht Club and seaward to a depth of three feet (measured at low tide) is closed for shellfishing by the Shellfish Constable to promote a sustainable year round recreational fishery. These data confirm that portions of Town Cove could support the growth of both oysters and quahogs.

The tide range in Town Cove is approximately 5 to 6 feet. Bathymetry data contained in the MEP Report and field verification with the Orleans Assistant Harbormaster document that at mean high tide, Town Cove north of Rocky Point has a maximum depth of 6.5 feet. At low tide, water is less than 2 feet deep. Over half of Town Cove is less than 8 feet deep at mean low tide. There is a basin (near 13 feet at low tide) located midway between Rocky Point and the Orleans Yacht Club, on the east side of Town Cove. Water depths are adequate to support both oyster and quahog growth. Sediment grain size varies throughout Town Cove, with some areas of coarse sand and other areas of fine-grained, organic rich materials.

Surrounding Environment - The land surrounding Town Cove is fully developed, with residential land use on the east side, and commercial uses along route 6A on the western shore. This estuary is a popular recreation destination, enjoyed by boaters of all types, swimmers, and shell fishers. There are several public boat landings, as well as private docks and a marina. Access to any demonstration project would be possible, but would require a boat. Overall, there are no parameters that preclude a demonstration at Town Cove.

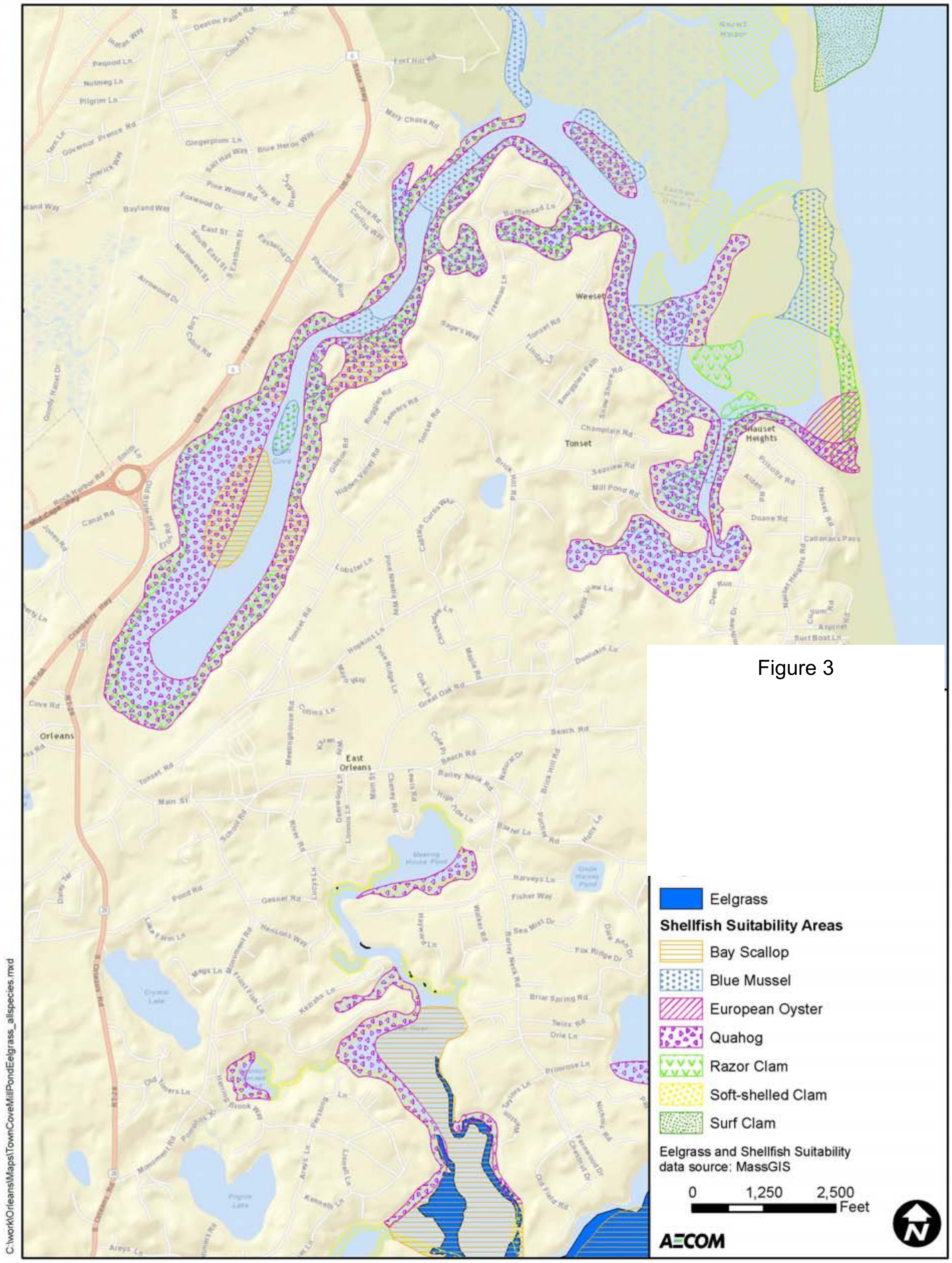

Eelgrass
Shellfish Suitability Areas
Bay Scallop
Blue Mussel
European Oyster
Quahog
Razor Clam
Soft-shelled Clam
Surf Clam
Eelgrass and Shellfish Suitability data source: MassGIS
0 1,250 2,500 Feet
AECOM
C:\work\Orleans\Maps\TownCoveMillPondEelgrass_allspecies.mxd
Weeset
Tonset
Nauset Heights
East Orleans
Orleans

Figure 3

(2) Mill Pond

General - Mill Pond was evaluated for both oyster aquaculture and CHR. An oyster aquaculture demonstration would include growing seed in an upweller, with transfer to floating bags once the seed reaches approximately 8mm. At the end of the first growing season, oysters would be bottom planted and allowed to grow through a second season for recreational and commercial harvest once the oysters reached market size (3”). Some of the first year oysters could be overwintered in the floating bags. When overwintering in bags, locations must be deep enough to avoid potential ice damage. CHR involves expanding the Town’s current propagation program by purchasing seed at 25mm and bottom planting these quahogs in suitable locations in Mill Pond for recreational and commercial harvest.

Site Ecology - The MEP Final Report for Nauset Harbor (2012) documents water quality parameters for Mill Pond. Salinity is approximately 30 ppt. Monitoring equipment that collected DO and chlorophyll *a* data in fifteen minute intervals was deployed in Mill Pond as part of the MEP field investigations in 2003. This instrument was located at a depth of 12 feet, off the Mill Pond boat launch, to avoid this estuary’s deep basin, yielding a more representative water sample. This station is approximately 3 miles from Nauset Inlet, in the main basin of Mill Pond. DO levels measured using this continuous sensor were typically between 6 mg/L and 8 mg/L. Since 2003, DO levels periodically drop to zero mg/L in water quality monitoring data that is collected at a single point in time during the July and August sampling period. Food availability, indicated by chlorophyll *a* concentrations, averaged 10.8 µg/L, exceeding the minimum site suitability threshold of 2 µg/L. By numerical thresholds as well as field confirmation that both quahogs and oysters are growing in Mill Pond, it seems that there is adequate food supply and DO to support shellfish growth in this estuary. High salinity promotes predation, which is a significant issue in this waterbody.

There are two volunteer-led oyster aquaculture projects in Mill Pond. A group of residents have worked with the Shellfish Constable and Barnstable County Cooperative Extension to plant oyster spat-on-shell, and the Orleans Pond Coalition grows approximately 50,000 oyster singles from seed in an upweller located at the Arey’s Pond Boat Yard and relays them to Mill Pond where these oysters are grown-out in cages. The suitability of Mill Pond for an oyster aquaculture or CHR demonstration is severely limited by the large population of oyster drills (*Urosalpinx cinerea)*. The Massachusetts Shellfish Officers Association and Barnstable County Cooperative Extensionand urge against oyster propagation in areas that experience high predation by oyster drills. For this reason, the use of oyster aquaculture or oyster beds as part of CHR are not proposed for this site. Mill Pond is mainly suitable for bottom propagation of quahogs, outside the deep basin. A population study to determine the baseline quahog numbers and sizes is recommended.

Mill Pond has a waterbody surface area of 81 acres, providing ample area for a quahog shellfish demonstration. The MEP model does not estimate a specific target nitrogen removal load for this sub-watershed but the load reduction target for the entire Nauset System, not including Town Cove, is approximately 1900 kg N/year. Shellfish suitability areas and eelgrass beds (*Zostera marina*) are shown in Figure 4, derived from MassGIS databases. Mill Pond does not have a history of eelgrass beds; therefore, siting conflicts with this resource are not anticipated. Although local observations report eelgrass in the in Mill Pond late 1970’s. According to Division of Marine Fisheries (DMF) mapping, Mill Pond has suitable habitat for quahogs and oysters. Historically, the Town has propagated quahogs in Mill Pond, but current populations have not been quantified. These data confirm that both oysters and quahogs could be grown as part of a demonstration.

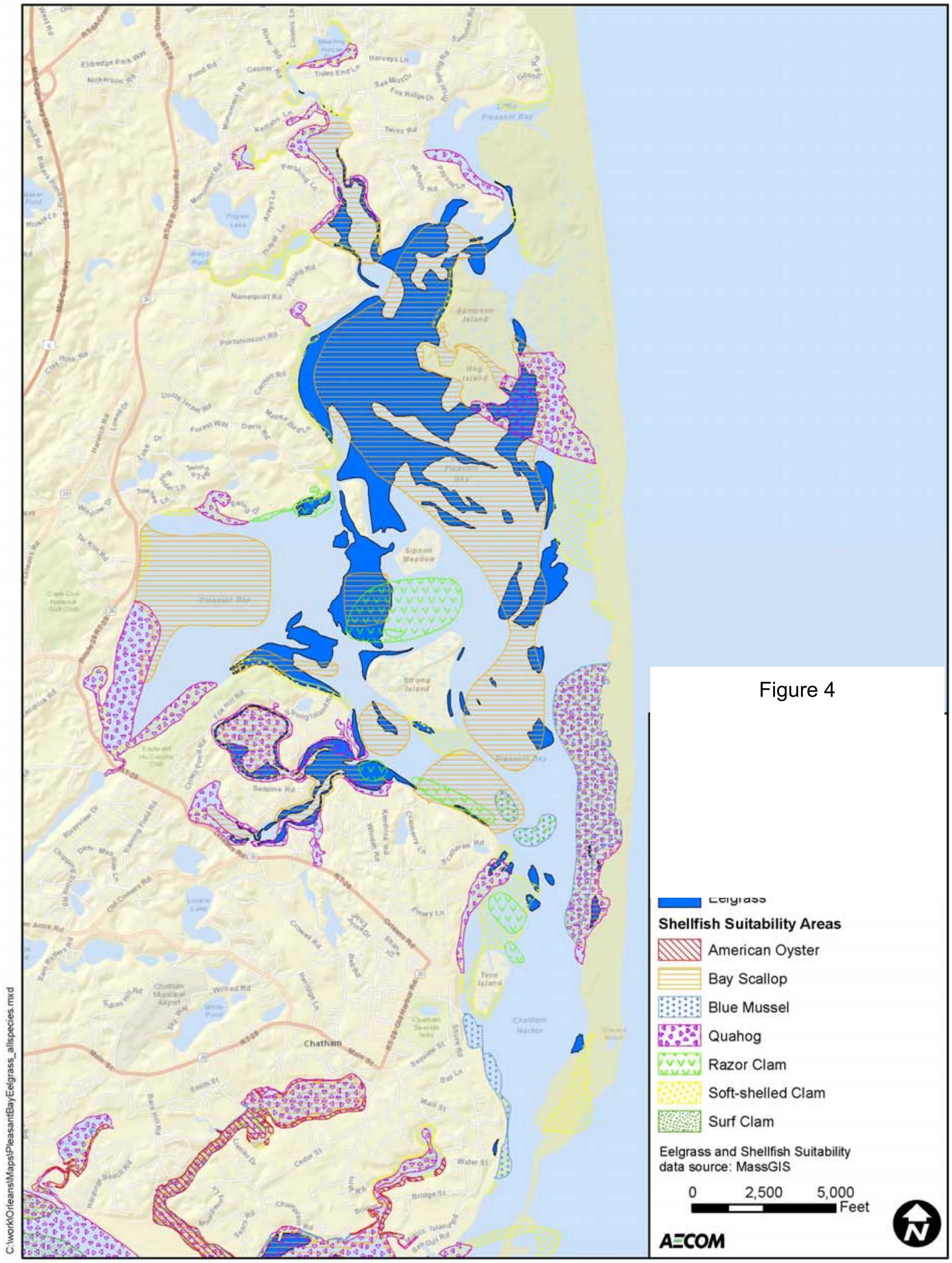

Eelgrass
Shellfish Suitability Areas
American Oyster
Bay Scallop
Blue Mussel
Quahog
Razor Clam
Soft-shelled Clam
Surf Clam
Eelgrass and Shellfish Suitability data source: MassGIS
0
2,500
5,000
Feet
AECOM
C:\work\Orleans\Maps\PleasantBayEelgrass_allspecies.mxd

Figure 4

The tidal range in Mill Pond is approximately 5 to 6 feet. Bathymetry data document that at mean low tide, water depth is an average of 15 to 18 feet. Mill Pond has a deep basin greater than 26 feet. Water depths are adequate to support both oyster and quahog demonstrations. Sediment grain size varies throughout Mill Pond, with some areas of coarse sand and other areas of fine-grained silt, particularly in the deep basin. Quahog propagation should be possible given this sediment regime.

Surrounding Environment - The land surrounding Mill Pond is a developed, residential area. Mill Pond has a family shell fishing area as well as a mooring field. There is also a small public boat launch area off Mill Pond Road. Access to any demonstration project would be possible, but would require a boat. Overall, there are no parameters that preclude a demonstration at this site.

Pleasant Bay Watershed

(1) Little Pleasant Bay

General - Little Pleasant Bay was evaluated for aquaculture and CHR. An oyster aquaculture demonstration would potentially involve working with some of the current operators of the Town's shellfish grants to evaluate and potentially enhance production. CHR would involve purchasing remote set (shells on which oyster seed has been set in controlled environment), growing in floating bags and trays for 8 to 12 weeks, and bottom planting to establish an oyster bed.

Site Ecology - Data for Little Pleasant Bay was found in reports by the MEP (2006) and the Pleasant Bay Alliance Water Quality Monitoring Program (Cadmus Group 2015). MEP did not deploy a monitoring instrument in Little Pleasant Bay as part of their field investigations. However, for the past fifteen years, a program of the Pleasant Bay Alliance's monitoring program collected water quality data during July and August. A monitoring station in Little Pleasant Bay, located between Old Field Point and Sampson Island, is approximately 1800 feet from the current shellfish grants. Based on this data, salinity is approximately 30 ppt and dissolved oxygen levels are over 5 mg/L. Food availability, as indicated by total pigment concentrations (chlorophyll *a* + phaeophytin *a*), declined significantly from 2002 to 2014, dropping from 4.5 µg/L to 2 µg/L. Therefore, food concentrations are approaching the minimum site suitability threshold of 2 µg/L. It will be important to collect data within the existing shellfish grants to determine whether this low concentration of total pigment is also occurring within the grant areas. This information will help develop rational expectations for shellfish harvest yields.

Little Pleasant Bay has a waterbody surface area of 270 acres, with approximately 120 acres identified as acceptable for demonstration sites(the area containing the current shellfish grants). The MEP model estimates a target nitrogen removal load for this sub-watershed of almost 824 kg N/year. The120 acres provide ample area for a shellfish demonstration and expansion. Shellfish suitability areas and eelgrass beds (*Zostera marina*) are shown in Figure 4, derived from MassGIS databases. At present, there are some eelgrass beds in Little Pleasant Bay, but not within the demonstration site area. According to DMF mapping, Little Pleasant Bay does not have suitable habitat for quahogs and oysters. However, both quahog and oyster aquaculture has been productive in this location. A demonstration project in Little Pleasant Bay would build on this success.

The tidal range in Little Pleasant Bay is approximately 5 to 6 feet. Bathymetry data from National Oceanic and Atmospheric Administration (NOAA) show that the depth of Little Pleasant Bay at mean low tide is 2 to 3 feet in many areas. Sediment grain size at the demonstration site in Little Pleasant Bay is dominated by coarse sand, with some areas of fine sand. These features make it possible to operate and maintain a demonstration by standing in the water during low tide, and potentially identifying areas for bottom planting oysters.

Surrounding Environment - The land surrounding the Little Pleasant Bay site is a developed residential area. This estuary is a popular recreation destination, enjoyed by boaters of all types, swimmers, and shellfishers. There are several public boat landings, private docks and a marina at Meetinghouse Pond. Access to any demonstration project would be possible, but would require a boat. Overall, there are no parameters that preclude a demonstration at this site.

This site provides a unique opportunity to engage the local shellfish grant holders in a demonstration project. These growers are using floating bags, racks and cages for oyster and some quahog aquaculture. There are currently 12 grants in operation, with several new areas proposed by the Shellfish Constable, producing a total combined harvest of approximately 1 million oysters annually. Figure 2 shows the location of these grants. The Orleans Assistant Harbormaster and Shellfish Constable/Harbormaster both suggested working with these growers to develop a demonstration project because grant holders already have the expertise, infrastructure and interest in aquaculture.

(2) Arey's Pond

General - Arey's Pond was evaluated for oyster aquaculture. An oyster aquaculture demonstration would include growing seed in an upweller, with transfer to floating bags once the seed reaches approximately 8 mm. At the end of the first growing season, oysters would be relayed to other locations for second-year growth because there is no suitable bottom in Arey's Pond. These oysters would then be available for recreational and commercial harvest once the oysters reach market size (3-inch). Some of the first year oysters could be overwintered in the gear and grown out in Arey's Pond, but the gear densities for second year growth are much lower than for first year. Because of space constraints, some of the first year oysters would need to be relayed to other locations.

Site Ecology - The MEP (2006) and the Pleasant Bay Alliance Water Quality Monitoring Program (Cadmus Group 2015) document water quality parameters that are fundamental to shellfish propagation. Salinity in Arey's Pond is approximately 26 ppt. Monitoring equipment that collects DO and chlorophyll *a* data in fifteen minute intervals was deployed in Arey's Pond as part of the MEP field investigations in 2003. The continuous monitoring station was centrally located in the pond. DO concentrations less than 2 mg/L were measured for 63 percent of the 36 day monitoring period. Recent data compiled by the Cadmus Group (2015) confirms that this anoxic condition persists. Food availability, measured by chlorophyll *a* concentrations, averaged 12.5 µg/L in 2003, exceeding minimum site suitability threshold of 2 µg/L. As part of the Pleasant Bay Alliance monitoring program, total pigment concentration (chlorophyll a + phaeophytin) data has been collected since 2008. The total pigment data, therefore food availability, is approximately 7 µg/L. Food supply is adequate to support shellfish growth in this estuary. Given the low DO of bottom waters, oyster aquaculture should employ growing systems that suspend shellfish in the upper sections of the water column.

Arey's Pond has a waterbody surface area of 13 acres, with a limited area for a shellfish demonstration because a mooring field occupies most of the pond. The MEP model estimates a target nitrogen removal load for this sub-watershed of almost 142 kg N/year. Shellfish suitability areas and eelgrass beds (*Zostera marina*) are shown in Figure 4, derived from MassGIS databases. At present there are no eelgrass beds in Arey's Pond, therefore siting conflicts associated with this resource are not anticipated. According to DMF mapping, Arey's Pond has suitable environmental conditions for quahogs and oysters.

The tidal range in Arey's Pond is approximately 5 feet. Bathymetry data from NOAA indicate that at mean low tide the water depth at the center of the pond is 14 feet, and areas along the perimeter and at the entrance from Namequoit River are 6 feet. Sediment grain size in Arey's Pond is dominated by very fine silt, rich in organic matter, precluding bottom planting of shellfish. Water depth dictates that a demonstration project would be worked by boat.

Surrounding Environment - The land surrounding Arey's Pond is a densely developed residential area. This estuary contains a dense mooring field covering most of the water area. Arey's Pond has a public access footpath, private docks and a commercial marina. The Orleans Pond Coalition uses an upweller located at this marina to grow approximately 50,000 oyster singles that are ultimately relayed to Mill Pond. Access to a demonstration project would be possible, but would require a boat for operation and maintenance and a confirmation of support from the neighbors that has been initially expressed. Overall, there are no parameters that preclude a demonstration at this site.

(3) Pochet

General - Pochet was evaluated for CHR, which would involve purchasing remote set (shells on which oyster seed has been set in controlled environment), growing in floating bags and trays for 8 to 12 weeks, and bottom planting to establish a bed environment.

Site Ecology - The MEP (2006) and the Pleasant Bay Alliance Water Quality Monitoring Program (Cadmus Group 2015) document water quality parameters for Pochet. Salinity in Pochet is approximately 30 ppt. Monitoring equipment that collects DO and chlorophyll *a* data in fifteen minute intervals was deployed in Pochet as part of the MEP field investigations in 2003. However, the station is approximately 2000 feet from the proposed demonstration sites. DO levels less than 5 mg/L but greater than 4 mg/L were measured for 50 percent of the 52 day monitoring period. Recent data compiled by the Cadmus Group (2015) shows that since 2008, DO levels have been approximately 3 mg/L at a monitoring station that is closer to the head of Pochet, approximately 3000 feet (linear distance) from the demonstration site. Figure 5 shows the Pleasant Bay Alliance monitoring station locations. Food availability, measured by chlorophyll *a* concentrations, averaged 5 µg/L during the 2003 MEP field investigation (exceeding minimum site suitability threshold of 2 µg/L). In 2004, the chlorophyll *a* concentration was 3 µg/L at a monitoring station in the same location as the MEP continuous monitoring equipment. There has not been additional data collected near this demonstration site for chlorophyll *a* or total pigment concentrations since 2004. Based on these data, Pochet has adequate food supply and DO levels to support shellfish bottom growth in this estuary.

Pochet has a waterbody surface area of 140 acres, ample area for a shellfish demonstration and expansion. The MEP model estimates a target nitrogen removal load for this sub-watershed of almost 413 kg N/year.

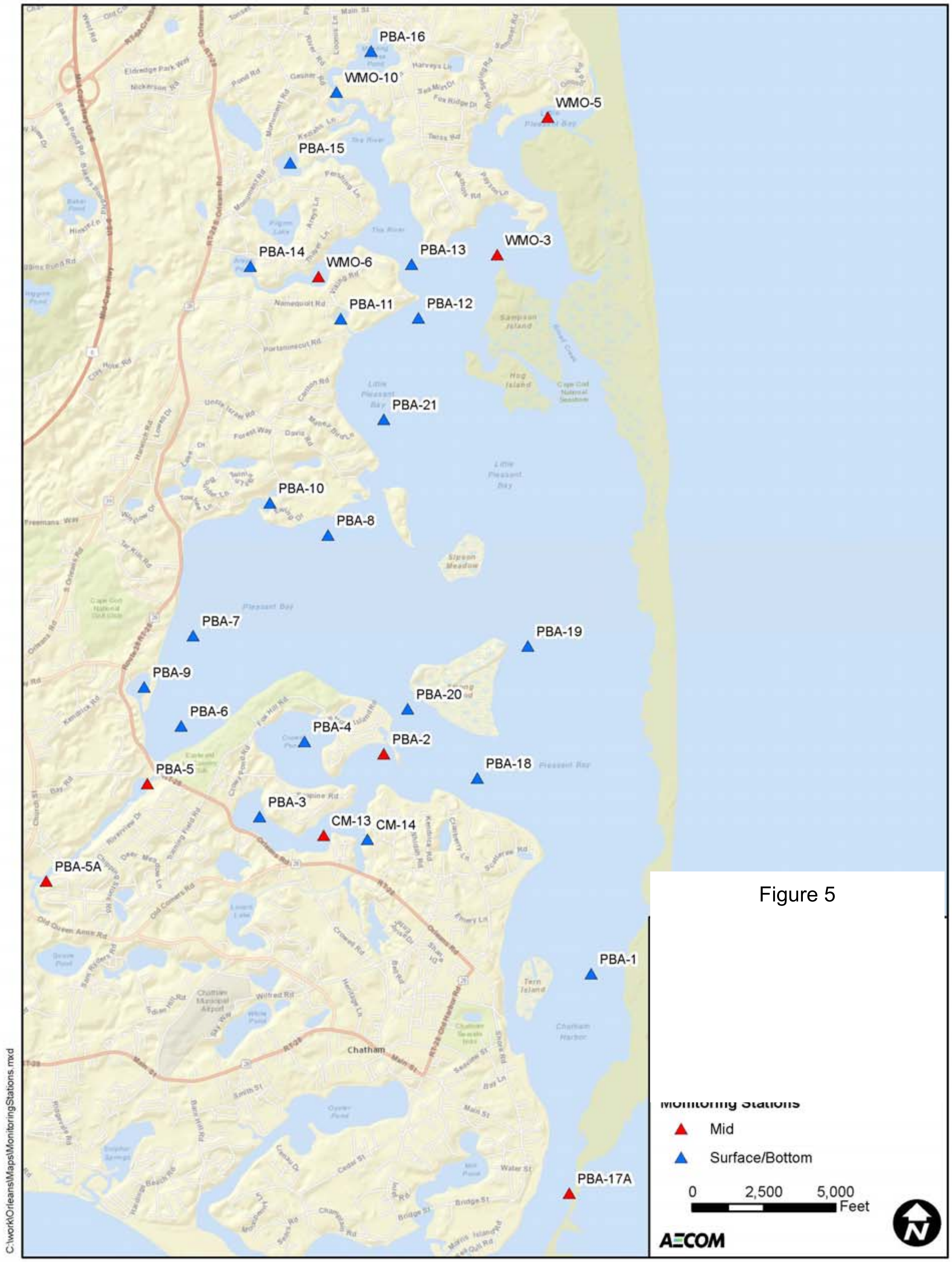

PBA-16
WMO-10
WMO-5
PBA-15
PBA-14
WMO-6
PBA-13
WMO-3
PBA-11
PBA-12
PBA-21
PBA-10
PBA-8
PBA-7
PBA-19
PBA-9
PBA-20
PBA-6
PBA-4
PBA-2
PBA-5
PBA-18
PBA-3
CM-13
CM-14
PBA-5A
PBA-1
PBA-17A
Monitoring Stations
Mid
Surface/Bottom
0
2,500
5,000
Feet
AECOM
C:\work\Orleans\Maps\MonitoringStations.mxd

Figure 5

Shellfish suitability areas and eelgrass beds (*Zostera marina*) are shown in Figure 4, derived from MassGIS databases. At present there are two small patches of eelgrass in Pochet, but during the team's field investigation, it was verified that eelgrass is not present at the demonstration site. According to DMF mapping, Pochet has suitable habitat for quahogs and other species not currently being considered for a demonstration. Given the success of oyster aquaculture in the nearby aquaculture grants, it is likely that oysters will grow at this site as well as quahogs.

The tidal range in Pochet is approximately 5 to 6 feet, with the range reported in the MEP Report of up to 9 feet along some areas of Pochet Island. Bathymetry data from NOAA show that this estuary is generally shallow. At mean low tide, the water depth at the Pochet inlet is 2 feet, with depths varying widely near the vicinity of the demonstration site. Only a shallow draft or pontoon-style boat would be suitable for working a project at this location. . Field investigation confirmed that the proposed demonstration area is shallow, approximately 3 feet. Sediment grain size at the demonstration site, and in this general area is coarse sand. Shifting substrate may cause siltation issues for any bottom-planted oysters.

Surrounding Environment - he land surrounding Pochet is residential, with a private island bordering the demonstration location. This site is also contained within the boundary of the Cape Cod National Seashore (CCNS). Access to a demonstration project would be possible, but would require a boat for operation and maintenance. Support of the neighbors and permission from the National Park Service is required. These two factors must be addressed before a demonstration project proceeds at this site.

(4) Lower River

General - Lower River was evaluated for aquaculture and CHR along the shore of Kent's Point. CHR involves purchasing remote set (shells on which oyster seed has been set in controlled environment), growing in floating bags and trays for 8 to 12 weeks, and bottom planting to establish a bed environment.

Site Ecology - The MEP (2006) and the Pleasant Bay Alliance Water Quality Monitoring Program (Cadmus Group 2015) document water quality parameters in Lower River. Salinity in Lower River is approximately 30 ppt. Monitoring equipment that collects DO and chlorophyll *a* data in fifteen minute intervals was deployed near Kent's Point as part of the MEP field investigations in 2003. The equipment recorded DO levels between 4 mg/L and 5 mg/L for 78 percent of the 36 day monitoring period. Recent data compiled by the Cadmus Group (2015) in the Upper River indicates that since 2008, DO levels have risen from 4 mg/L to over 5 mg/L. Food availability, measured as chlorophyll *a* concentrations averaged 8.5 µg/L at the Namequoit River monitoring location during the 2003 MEP field investigations, exceeding the minimum site suitability threshold of 2 µg/L. This monitoring location is very near the demonstration site. As part of the Pleasant Bay Alliance monitoring program, total pigment concentrations (chlorophyll *a* + phaeophytin *a*) have been collected at two stations. Total pigment concentration has been declining since 2000 at both stations, with current concentrations at 3 µg/L. Based on these data, there seems to be adequate food supply and DO levels to support shellfish bottom growth in this estuary.

Lower River near Kent's Point has a waterbody surface area of 20 acres, adequate for a shellfish demonstration. The MEP model estimates a target nitrogen removal load for this sub-watershed of almost 524 kg N/year. Shellfish suitability areas and eelgrass beds (*Zostera marina*) are shown in Figure 3, derived from MassGIS databases. At present there is only a small patch of eelgrass near the eastern edge of the shore, and during the team's field investigation, it was verified that eelgrass is not present at the potential demonstration site. According to DMF mapping, Lower River in the vicinity of Kent's Point has suitable habitat for quahogs, although it is likely that oysters will grow as well.

The tidal range in the Lower River is approximately 5 to 6 feet. Bathymetry data from NOAA indicate that this estuary is generally shallow. At mean low tide, the water depth at the demonstration site is 2 to 4 feet, enabling a demonstration to be worked without a boat. Sediment grain size is dominated by very fine silt throughout this area, which precludes bottom planting of oyster remote set as part of a bed installation as gear, such as trays, would be required.

Surrounding Environment - The land surrounding Lower River is the Kent's Point conservation area. This area has good visibility, visitation and access, which facilitate education and outreach activities. This location can be accessed from the shore, and does not require a boat for installation, operation or maintenance of a demonstration project. This estuary is a popular recreation destination, enjoyed by boaters of all types, swimmers, and walkers. Water skiers and dinghy sailors frequent this area. Floating gear may create user conflicts relating to aesthetics as well as navigation. Overall, there are no parameters that preclude a demonstration at this site, but use conflicts may be an issue.

(5) Quanset Pond

General - Quanset Pond was evaluated for aquaculture and CHR. CHR involves purchasing remote set (shells on which oyster seed has been set in controlled environment), growing in floating bags and trays for 8 to 12 weeks, and bottom planting to establish a bed environment.

Site Ecology - The MEP Final Report for Pleasant Bay (2006) and the Pleasant Bay Alliance Water Quality Monitoring Program Report (Cadmus Group 2015) document water quality parameters for Quanset Pond. Salinity is approximately 30 ppt. A monitoring instrument that collected DO and chlorophyll *a* data in fifteen minute intervals was deployed in Quanset Pond as part of the MEP field investigations in 2003. This station recorded DO levels less than 5 mg/L but greater than 4 mg/L for 48 percent of the 36 day monitoring period. Recent data compiled by the Cadmus Group (2015) indicates that since 2008, DO levels have risen from 4 mg/L to 5 mg/L. Food availability, measured by chlorophyll *a* concentrations averaged 8.9 µg/L at the Quanset Pond monitoring location during the 2003 MEP field investigations, exceeding the minimum site suitability threshold of 2 µg/L. The MEP monitoring location is very near the demonstration site. As part of the Pleasant Bay Alliance monitoring program since 2008, data for total pigment concentrations (chlorophyll a + phaeophytin) has been collected and is approximately 5µg/L. Based on these data, there seems to be adequate food supply, and DO levels to support shellfish bottom growth in this estuary.

Quanset Pond has a waterbody surface area of 13 acres, adequate for a shellfish demonstration and providing some expansion potential. The MEP model estimates a target nitrogen removal load for this sub-watershed of approximately 256 kg N/year. Shellfish suitability areas and eelgrass beds (*Zostera marina*) are shown in Figure 4, derived from MassGIS databases. At present there is no eelgrass near the demonstration site. According to DMF mapping, Quanset Pond has suitable habitat for quahogs, but it is likely that oysters will grow here as well.

The tidal range in Quanset is approximately 5 to 6 feet. Bathymetry data from NOAA indicate that this area is generally shallow. At mean low tide, the depth at the center of Quanset is 7 feet, with a depth of 0.5 feet at the demonstration site. Sediment grain size is dominated by coarse sand at the demonstration location, which is suitable for bottom planting of remote set. There is also a hydroconnection from Meadow Bog Pond and Sarah's Pond to Little Quanset Pond. Meadow Bog Pond is extremely shallow, and Sarah's Pond experiences an annual cyanobacteria bloom during the summer.

Surrounding Environment - The land surrounding Quanset Pond is moderate-density residential. This area has good visibility, visitation and access, which facilitate education and outreach activities. This location can be accessed from the shore, and does not require a boat for installation, operation or maintenance of a demonstration project. This estuary is a popular recreation destination, with a small mooring field in the deeper part of the basin. The demonstration site would not interfere with navigation or public enjoyment. Aesthetic impacts are mitigated by the fact that the use of surface gear is temporary and that it would be located outside the main beach area. Once the bed is established, any use of floating bags will be discontinued. Overall, there are no parameters that preclude a demonstration at this site.

4. Site Evaluation and Screening Criteria

To facilitate a systematic and objective evaluation of each of the potential demonstration sites, a decision support tool, called a Site Selection Matrix was developed. This Site Selection Matrix includes a number of criteria for Site Suitability, Permitting, and Project Evaluation. Site Suitability criteria address the environmental, land use and implementation characteristics of each proposed demonstration location. Permitting criteria assess the regulatory issues related to each proposed demonstration location. Project evaluation criteria estimate the likelihood of obtaining meaningful results from a proposed demonstration site. Other/Overriding Considerations refer to any threshold issue that precludes a demonstration at a given site.

These criteria were first presented as part of the process of developing the Orleans Consensus Plan. The Shellfish Technical Team refined the criteria after reviewing the Site Ecology and Surrounding Environment data as described above. The Site Selection Matrix now includes the following criteria:

a. Site Suitability

- Available Growing Area/Adequacy of Acreage
- Water Quality Indicators
- Disease/Predation
- Ease of Access
- Aesthetic Impacts
- Representativeness of the Site (Transferability)
- Use Conflicts
- Ability to Co-Locate with other Non-Traditional Technologies

b. Permitting

- Abutter Compatibility
- Wild Harvest Conflicts (DMF)
- Grow-Out to Harvest Size Allowed (DMF)
- Permittability

c. Project Evaluation

- Expected Survival
- Overall Likelihood of Monitoring Plan to Yield Quantified Results

The specific criteria within each evaluation category are defined as follows:

a. Site Suitability

- Available Growing Area/Adequacy of Acreage: an assessment of whether the amount of waterbody surface area is sufficient to implement the demonstration, and whether expansion potential exists.
- Water Quality Indicators: the environmental conditions needed to support shellfish growth. Key parameters include chlorophyll *a*, dissolved oxygen (DO), and salinity.
- Disease/Predation: presence of a population of predators that are likely to have a significant negative impact on survival of shellfish cultivated as part of a demonstration project.
- Ease of Access: locations are available from which demonstration sites can be installed, operated and maintained.
- Aesthetic Impacts: the visual impression that the project will have on vistas around the site.
- Representativeness of the Site (Transferability): a demonstration at this location would inform potential for shellfish to grow in other areas
- Use Conflicts: the likelihood that the proposed shellfish demonstration can occur without impeding the other activities currently taking place at proposed demonstration sites. This criteria evaluates whether there will be objections from the community of people who use the waters near the proposed demonstration sites both recreationally (boating, swimming, passive enjoyment) and for wild harvest of shellfish.
- Ability to Co-Locate with other Non-Traditional Technologies: As part of a post-demonstration, full-scale implementation strategy it is feasible to add floating constructed wetlands at this site in order to take advantage of any enhanced nitrogen uptake that may result.

b. Permitting

- Abutter Compatibility: the likelihood that the proposed shellfish demonstration can occur without significant objections from adjacent landowners and residents.

- Wild Harvest Conflicts: there are no populations (standing stock) of organisms that are currently harvested, which could trigger a denial of permission from DMF for a demonstration.

- Grow-Out to 3-inch Allowed: the sites are not closed to shellfishing, which would preclude grow out to harvest size.

- Permittability: there are no activities associated with the demonstration project that are prohibited activities under the Wetlands Protection Act, the Pleasant Bay Area of Critical Environmental Concern, Army Corps of Engineers regulations or Division of Marine Fisheries guidelines.

c. Project Evaluation

- Expected Survival: based on field evaluations, there is overall likelihood that shellfish grown at the demonstration site will live to harvest size

- Overall Likelihood of Monitoring Plan to Yield Quantified Results: based on review of map locations, watershed loading and water quality data, it is reasonable to expect that monitoring at a particular demonstration site will show statistically significant changes in water quality parameters, specifically chlorophyll a, total nitrogen and water clarity.

- Based on the MEP model, both the Nauset Harbor and Pleasant Bay System watersheds have recommended total nitrogen (TN) removal rates that are significantly higher than the expected TN removal of a shellfish demonstration project. The target nitrogen load reduction for the entire Pleasant Bay System is almost 17 million kg N/year, with each sub-watershed in the Pleasant Bay system having a lower target nitrogen removal rate than the system as a whole. Since the system circulates, it is not likely that a small uptake of nitrogen in just one sub-embayment will register a reduced TN concentration at the sentinel station in that sub-embayment, even if it is a significant percent of the nitrogen load reduction for that sub-watershed. The target nitrogen load reduction for the Nauset Harbor system is approximately 8600 kg N/year, while the Town Cove sub-embayment target load reduction is approximately 6700 kg N/year. Therefore, to quantify the nitrogen-removal of a demonstration project, monitoring plans will need to be designed to capture localized water quality improvements near the demonstration sites. This is accomplished by positioning monitoring stations upstream, instream and downstream of the demonstration site, with high spatial resolution. Sites with clearly defined upstream and downstream locations ranked highest for the criterion that monitoring plans will yield quantitative results.

5. Analysis: Evaluate and Rate Each Site Based on Criteria

To rank each criterion in the Site Selection Matrix, the Shellfish Technical Team assembled available data, and conducted a site visit. A ranking system was then developed to quantify how well each site met a specific criterion. The point-based system is as follows:

- Good = 1 point: A good ranking (1) was assigned if the criterion could be met fully.

- Neutral = 0 points: A neutral ranking (0) was assigned if the criterion could be met in part, but there were some potential issues and/or difficulties

- Poor = -1 point: A poor ranking (-1) was assigned if the criterion could not be met.

For the Site Suitability criteria, if a site was fully suitable based on the criterion being ranked it was assigned a numerical value of 1, if the site was mostly suitable based on the criterion being ranked it was assigned a ranking of 0, and if the site was unsuitable it was assigned a ranking of -1.

For the Permitting criteria, if a site was likely to be permitted based on the criterion being ranked it was assigned a numerical value of 1; if the site was likely to be permitted, but there were potential issues based on the criterion being ranked, it was assigned a ranking of 0; and if the site was unable to be permitted within a particular criteria, it was assigned a ranking of -1.

For the Project Evaluation criteria, if a site was likely to produce a successful demonstration based on the criterion being ranked it was assigned a numerical value of 1, if the site was probably able to produce a successful demonstration based on the criterion being ranked it was assigned a ranking of 0, and if a demonstration was unlikely to succeed at a site, based on a particular criterion, it was assigned a ranking of -1.

To apply this tool to each potential shellfish demonstration site, the Shellfish Technical Team held a day-long working session. At this session, the Team first reviewed and discussed all of the available information for each site: water quality data from the MEP Reports, Pleasant Bay Alliance data and reports, shellfish suitability and other GIS maps from the DMF, preliminary grain size maps from Center for Coastal Studies and notes from site visits with the Assistant Harbormaster and Shellfish Constable/Harbormaster. The Team then evaluated each demonstration site and ranked the criteria for each site based on this available information.

Once each site was ranked, the Team reviewed the numerical values assigned to each criterion across sites to ensure consistency. The Team also discussed whether any criterion was more important than another and determined that each criterion should be weighted equally.

The final step in site evaluations is to assign an overall rating to each site based on evaluation findings and criteria rankings. Before total criteria points were calculated and site rating assigned, the team deliberated over which sites seemed preferred for demonstrations from a qualitative and common sense perspective. Then, quantitative rankings were tabulated in the Site Selection Matrix. Results are discussed in Section 6.

6. Findings/Recommendations: Summarize Site Selection Matrix/Site Screening Results

The results of the Site Suitability ratings are as follows:

- Little Pleasant Bay Existing Grants (12 points);
- Quanset Oyster Bed (12 points);
- Pochet Oyster Bed (10 points);
- Arey's Pond Oyster Singles in Floating Bags (9 points);
- Town Cove quahog propagation (9 points);
- Mill Pond quahog propagation (9 points); and
- Lower River Oyster Singles in Floating Bags (7 points).

A maximum of fourteen (14) points is possible. Because the Team determined that all of the criteria were equally important to site selection, no one criterion impacted the overall ratings more than any other. Furthermore, this overall rating was consistent with the assessments made after deliberations but before numerical tabulations were completed.

The top two sites derived from both the Site Selection Matrix as well as Team deliberations are Little Pleasant Bay for shellfish aquaculture and Quanset Pond for an oyster bed (CHR). These two sites were also recommended by the Shellfish Constable/Harbormaster and Assistant Harbormaster during the site visits. To demonstrate the water quality benefits as well as implementation logistics and practical densities of oyster aquaculture, working with current shellfish grant-holders seems ideal. The expertise, gear and interest already exist. The Engineering Work Plan for this option will be detailed in the subsequent TM, but generally includes working with growers to optimize shellfish harvest numbers, identify the needs of this group, and design a monitoring plan that can capture water quality impacts. A preliminary monitoring plan has already been developed for this site (Science Wares, 2015). To demonstrate an oyster bed, Quanset Pond has several advantages, including ease of access and patrol, suitable bottom and nutrients, and a reasonable expectation of monitoring yielding quantifiable results. Pochet is also a favorable location for an oyster bed demonstration but access and patrol is more difficult, and therefore this site did not rank as highly as Little Pleasant Bay and Quanset.

Arey's Pond is space-constrained, and the sediment is unsuitable to bottom planting for second year grow-out. Thus, this site does not have good replicability to other areas. Pursuing a shellfish demonstration in Town Cove or Mill Pond is not recommended because (1) oyster propagation is precluded due to excessive oyster drill population (Massachusetts Shellfish Officers Association advises against oyster propagation where drills are prevalent as a Best Management Practice) and; (2) a population study for quahogs is necessary to establish a baseline before any new propagation can be quantified. Finally, given the potential use conflicts and difficulty of monitoring yielding quantifiable results, the Lower River is the least attractive site for a demonstration.

7. References

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Appendix A

General Comments or Notes from Chatham Shellfish Propagation

Comments from Ed Daly

Comments from Sandy MacFarlane

Comments from Dave Slack

General Comments or Notes from Chatham Shellfish Propagation and AECOM Shellfish Team Responses (in red) provided below.

Thank you for providing your comments and suggestions to the Technical Memorandum, we appreciate your input to this process.

GENERAL RESPONSE: Please also read our response to the comments from Cape Cod Cooperative Extension. Here, we explain in greater detail why the specifics of a demonstration project design are going to be the subject of the next Technical Memorandum, entitled “Preliminary Engineering and Design Work Plan”. We will also note in the Purpose section of the Final Site Characterization and Evaluation Technical Memorandum that preliminary engineering and design are addressed in a subsequent Technical Memorandum.

1. After reading the general AECOM memo for the Orleans Water Project here are a few comments or notes that came to light from the standpoint of Shellfish Propagation in a neighboring town. At no point in the memo was quantity or numbers discussed which makes use of gear and feasibility hard to judge as a realistic project. Growing 30,000 shellfish is very different and often requires different methods than growing 3,000,000.

   RESPONSE: The purpose of this Tech Memo is to characterize the sites for demonstration projects. This is not the design and monitoring plan for a demonstration, which is the subject of the next Tech Memo.

2. Setting that aside one of the major discussions missing from the memo was any discussion of predators or disease with the exception of a mention of oyster drills in Town Cove. Other predators and disease exist in these systems and water bodies and their absence or presence often dictates the methods used for growth. Predators such as, green crabs, blue crabs, starfish, moon snails to name a few are all present in these bodies of water and protection methods are needed in order to produce viable shellfish. Disease has also been known to be present and Best Management Practices are needed in order to minimize the chance of disease or spread.

   RESPONSE: We agree with your comment and the site engineering and the monitoring plans will include in detail the need for baseline studies and monitoring of disease and predation

3. The use of floating gear for oyster aquaculture has been a game changer for many growers and resource mangers. However, there are often draw backs with floating gear. The use of floating gear increases the size of the area (footprint) that it takes to grow your animals and also increases conflicts with boaters and moorings. Utilizing floating gear in a small pond with many moorings like Arey’s Pond is not always a good options as the hazards to navigation caused to boaters can be detrimental to the project. Utilizing floating gear can be labor intensive for large scale operations. In Massachusetts and most northern areas floating gear can not remain floating in the winter time due to the hazards from ice and winter storms. The gear must be sheltered enough that I doesn’t get affected by large wind events in the summer. A large pond area with no boating activity is ideal. Although there are not any specific discussions about methods to be utilized, the memo mentions putting Remote Set in floating bags multiple times. Floating remote set, although possible would not be a feasible option for most operations.

   RESPONSE: We agree with your comment that gear is both a game-changer and a challenge to site. The site engineering and the monitoring plans will include an assessment of the feasibility of gear-based systems in the specific locations where gear is recommended.

4. One of the targets listed for growing oysters was the necessity for having a hard bottom. If growing these animals on the bottom sediment this is needed, however this report mainly discusses growing seed oysters in floating gear and then transferring to a secondary broadcast area. The initial area can be located regardless of bottom conditions, and then the broadcast area can be anywhere. From an enforcement standpoint, broadcasting sub-legal oysters makes for additional labor enforcing these newly planted oyster beds. From recreational harvesters taking seed to grant holders transferring seed to their grants for final grow out, often restoration oyster beds are too good to resist for poaching.

   RESPONSE: We agree with your comment, and are focusing on areas that are visible and easily patrolled. And, additional staffing hours will be required to maintain adequate patrol.

5. This memo is a general site characterization, but more detail on the methods and quantity of shellfish are needed to truly evaluate the project from a propagation standpoint. Some of the water quality data is over 13 years old and some of the sites were almost ½ mile from the proposed sites. Water data and conditions change year to year and more fine scale information should be collected and reviewed.

   RESPONSE: Because the purpose of this Tech Memo is to characterize the sites for demonstration projects with the specifics of the design as well as monitoring plan as subject of the next Tech Memo, many details are not included. Baseline monitoring at the demonstration sites are an important first step in implementation.

We very much appreciate your comments and questions!

Comments from Ed Daly (in black) and AECOM Shellfish Team Responses (in red) provided below.

Comments on:

- Letter Report 12-1-15 Memorandum from AECOM
- Phase 1 Shellfish Tech Memorandum dated June 2015

GENERAL RESPONSE: Thank you for taking the time to review and comment on the Site Characteristics and Evaluation for Aquaculture/Shellfish Propagation Technical Memorandum (Tech Memo). Below are specific responses to your comments.

Summary

1. The reports are focused mostly on Pleasant Bay. Town Cove seems to be dismissed by comparison. Town Cove is far more in need of remediation than Pleasant Bay based on the nitrogen levels shown in Cadmus Report of June 2015 and current nitrogen monitoring data in Town Cove. So the plan is unbalanced. How will it become balanced?

2. Mussels are a historical feature of our Orleans shellfish culture. Again mussels in Town Cove dismissed in the report. Decision was not made with local input .

   RESPONSE: We believe that a key purpose of a shellfish demonstration project is to evaluate the impacts of shellfish propagation or/and aquaculture system on the water quality. For this reason, we are focusing on the areas that are likely to result in high shellfish survival, in order to maximize the potential for quantifying impacts. While we do not want to preclude opportunities to further scientific understandings related to various species propagation, we feel that it is important to focus on already proven approaches for growing shellfish species. We want this first demonstration to work well, so that the ongoing shellfish efforts can build on this success.

   We reviewed the idea of growing blue mussels (Mytillus edulis) in response to your comments and have the following observations:

   - We agree that mussels are an important species to include as part of the mix of shellfish used for nitrogen-removal.
   - We believe that shallow-water propagation of mussels reliably is still at the research stage, making it a higher risk for this project than demonstrating oysters or quahogs.
   - It is our understanding that the mussel bed propagation is difficult in shallow water due to severe predation from sea/bay ducks.
   - Siting can also be an issue, but this is the case with all gear-based aquaculture.
   - Deep-water mussel projects are not applicable to Nauset Harbor because these estuaries are too shallow to prevent ducks from diving to feed on them.
   - Presently, there are no seed mussels available from hatcheries for a demonstration project.
   - Relocating mussels from natural set may not be a reliable/sustainable, long term source for ongoing growth of mussel beds as part of a demonstration.
   - There is limited data on nutrient-removal from mussels, and no data for Cape Cod.

- There is one small mussel grant in Orleans, which we see as an opportunity for future efforts.
- As part of working with growers, mussel aquaculture in Town Cove and Mill Pond should be explored.
- We are not aware of any shallow-water mussel propagation or restoration efforts in New England (which is different from aquaculture efforts), nor published literature that describes a successful methodology for artificially propagating blue mussels on Cape Cod or similar areas. We have spoken to MBL about their efforts near Martha's Vineyard (both blue and ribbed mussels) but we think the blue mussel deep-water aquaculture project is not comparable to the sites in Orleans.

The EXCEL spread sheet with binary scores for all parameters for site selection does not show a thoughtful or correct analysis.

Engineering trade -off decision making relies on expert input to weigh the **importance** of each parameter. The Excel Spreadsheet analysis incorrectly treats every parameter with equal weight. The Excel spreadsheet must be redone correctly by weight assignment to each parameter. Outcomes may change for site selection.

RESPONSE: The shellfish team specifically discussed whether we felt that one factor was more important than another and we all agreed that the factors had equal weight. We believe that our analysis, based on available data for all parameters evaluated was thoughtful and correct. However, we recognized during our analysis that the Town may choose to assigned additional weight to one or more factors.

3. Reference is made to an "Shellfishermen Association directive" that eliminates oysters from consideration in Town Cove. Where is the reference documentation and analysis supporting this decision? Who made it? There are successful oyster grants in Nauset Harbor / Town Cove.

   RESPONSE: This information was presented by Cape Cod Cooperative Extension to the Massachusetts Shellfish Officers Association. The shellfish team confirmed this recommendation with Diane Murphy and Josh Reitsma, and included it in our report.

4. The planned demo by AECOM for Pleasant Bay is poorly explained in the reports. We need more technical detail to assess its efficacy. The Google earth site photo in Pochet is barely legible. What is the purpose, goal and cost of the demo? Please correctly explain what is planned in much greater detail including water flow paths , sampling station locations , monitoring plan and rationale for using commercial shellfish grants as a resource.

   RESPONSE: The purpose of this Tech Memo is to characterize demonstration sites. This is not the engineering plan for a demonstration, which will be the subject of the next Technical Memorandum entitled "Preliminary Engineering Design and Work Plan". Please read our response to the comments received by the Cape Cod Cooperative Extension. In our response, we explained in greater detail why the specifics of a demonstration design will be the subject of this next Tech Memo.

5. How will measured changes in nitrogen be made? Pochet shows a bioactive nitrogen level at one station to be very low and within DEP spec. If nitrogen levels are so low how will it be possible to measure small changes meaningfully? Please consult the 2015 Cadmus Report when considering your answer. Please show similar levels measurements in Wellfleet, Boston or Falmouth or anywhere else in the United States.

RESPONSE: Shellfish uptake phytoplankton, which can be estimated using empirically-derived chlorophyll-a concentrations. Phytoplankton-derived nitrogen is also contained in the particulate organic nitrogen (PON) fraction of the total nitrogen (TN) measured as part of water quality evaluations. In the datasets for Pleasant Bay, the PON fraction is approximately 25% of the TN. Moreover, a monitoring program for the demonstration locations will be designed to specifically measure localized (in situ) changes in water clarity, pigments (chlorophyll a), and particulate organic nitrogen (PON) as well as total nitrogen. This involves sampling with high temporal and spatial resolution. For example, the Little Pond Demonstration Project in Falmouth measured changes in PON effectively using this approach; as well as in the Wellfleet oyster restoration project. Measuring nitrogen changes where absolute concentrations are below 1 mg/L is not a problem because laboratory equipment is sensitive enough to measure to the μg/L level.

6. What is the estimated cost of removing a kilogram of nitrogen using oysters and quahogs ? We need capital and O&M costs for a full scale deployment ---exclude R&D demo costs. We have seen no backup to support any estimate. We need to compare these cost numbers to Sewering. Are there are nationwide sources and estimates from other Cape towns that provide cost numbers that can be used to help compare estimates of a cost for Orleans. What is the Orleans cost for the demos? **Cost will decide how the citizens support acquaculture remediation.**

Response: This is an important question but is outside the scope of this Tech Memo. These types of questions will be addressed in the next Tech Memo.

7. The recommended Hybrid Plan is based on obsolete requirements for nitrogen removal that are over a decade old. Nitrogen Levels in Town Cove are 50% higher now than then. **The current Hybrid system design will not restore water quality in Town Cove.** When will the correct design requirements be used so that a correct acquaculture deployment can be designed?

Response: This is an important question but is outside the scope of this Tech Memo. As part of Adaptive Management, A Technical Memorandum evaluating baseline conditions has been prepared and is currently under review by SMAST.

8. I am disappointed with the lack of accomplishment on the aquaculture project. Tasks scheduled for late 2016 and 2017 should have been already been completed. The Pleasant Bay plan using existing grants and shellfishermen is not scientifically supported in the report. The plan is not quantitative. I am not sure the community will support such a long non specific , fuzzy and expensive plan. Two years pass and not one oyster planted!

RESPONSE: The purpose of this Tech Memo is only about characterizing the sites. This is not the engineering plan for a demonstration, which will be the subject of the next Tech Memo, once the demonstration locations are selected. Please read our response to the comments from Cape Cod Cooperative Extension. In this response, we explain in greater detail why the specifics of a demonstration design are the subject of the next Tech Memo.

9. Has the Hybrid Plan been revised to reflect the decisions you made for elimination of oysters in Town Cove? What are the new remediation techniques now in the Plan? Do the recent WQAP costs presented reflect the revised techniques?

Response: Oysters have not been eliminated from Town Cove. Town Cove is simply not the preferred location for the first (of likely several) demonstration projects in Orleans. Quahogs are also an important species for Town Cove in the Hybrid Plan.

One excellent suggestion that has come from this review is to evaluate the potential for additional shellfish leases in Town Cove. In this way, oysters could be grown in Town Cove in gear-based systems, thus avoiding the bottom-planting that leads to increased drill populations.

10. Does the DEP agree with the proposed Orleans plan?

    Response: This is an important question but this Tech Memo is not the Orleans plan.

11. We know that oysters grow in Town Cove and Pleasant Bay. We know approximately how much nitrogen each oyster removes. Is there a more efficient and cost effective way to calibrate and assess how much nitrogen will be removed by a calculated quantity of oysters at a particular location? For example : 1)by extracting a known small quantity of oysters and water from a location then moving both to a laboratory location and 2) accurately measuring the nitrogen reduction over a predetermined length of time use the data to estimate from that location to estimate nitrogen from that location. I would be happy to discuss this approach further.

    Response: Field studies and comprehensive monitoring are critical to evaluating shellfish impacts to water quality because ecosystems are comprised of dynamic and interdependent variables. It is important to remember that shellfish filter water and in the process feed on the organic particles therein. These filtered particles include phytoplankton, suspended silt and clay, and detritus. Most of the particles that oysters ingest are microalgae (phytoplankton), but other particles are also metabolized. The nitrogen bound in organic particles may also be removed by this filtering process. Oysters do not directly remove inorganic nitrogen (nitrate and nitrite).

    In addition to removing the fraction of the total nitrogen in the water column that is in organic particles, water clarity and phytoplankton filtration are top-down controls on eutrophication. Therefore, monitoring these parameters in-situ is the best way to understand the value of shellfish for nitrogen-removal uptake, as well as water clarity improvement.

We very much appreciate your comments and questions!

Comments from Dave Slack (in black) and AECOM Shellfish Team Responses (in red) provided below

Thank you for taking the time to review the Site Characterization Technical Memorandum. We appreciate your comments.

1. I'm pessimistic about oyster reef viabiliy in either Nauset or P. Bay. Oysters in our waters love to die under the best of husbandry but particularly when left untended on the bottom. Natural set or recruitment would likely be negligible. To achieve significant N reduction with aquaculture would require thousands of pieces of equipment and hundreds of hours of maintenance. Quahogs doing poorly in much of P. Bay. Few growers currently are even buying Mm seed.

   RESPONSE: We agree that aquaculture is equipment and labor-intensive. Any solution to nitrogen-remediation is going to require a significant effort. We believe that the ecosystems services and economic as well as local food production benefits of shellfish warrant further analysis. In particular, we may find that the filtering of phytoplankton as a top-down control of eutrophication starts to improve water quality immediately. This ecosystems service may reduce the total nitrogen-removal required to achieve water quality.

2. Diane Murphy has studied disease and predation in P. Bay for years. It's brutal.

   RESPONSE: We agree that predation is going to be a major factor in determining how we grow shellfish in Pleasant Bay, and bottom-planting feasibility.

3. Diminished tide flow is disrupting oyster aquaculture in Town Cove. Unlikely that an oyster Demo Project would succeed there.

   RESPONSE: We have not recommended an oyster demonstration in Town Cove. We have heard from growers in Eastham that they have good success with oyster aquaculture, although fouling requires constant cleaning of gear.

4. What is the proposed interaction between existing growers and the Demonstration Project in P. Bay. Successful growers are already maxed out in terms of bottom and time.

   RESPONSE: The proposed interaction is to begin a dialogue to help build an understanding of the practical extent to which shellfish aquaculture can contribute to the town's water quality goals. Working with growers will also help define the needs of this group relative to the town's goals for shellfish.

5. What impact will Demonstration Project have on our already stressed public landings particularly Paw Wah where summer parking and access are already problematic.

   RESPONSE: We agree that access is a key factor in selecting a demonstration location. Your concern about public landings, and not increasing pressure on the limited parking is very important. We will make sure to keep this in mind as we plan the day-to-day logistics of installing and operating a demonstration project. Paw Wah is not being considered because it is currently an area closed to shellfishing.

We appreciate these thoughtful insights.

Comments from Sandy MacFarlane (in black) and AECOM Shellfish Team Responses (in red) provided below:

To: Sia Karplus
From: Sandy Macfarlane, Coastal Resource Specialists
Re: Review of the Technical Memorandum on Draft for Site Characteristics and Evaluation for Aquaculture/Shellfish Propagation
Date: March 4, 2016

You asked me to review and comment on the Technical Memorandum on Draft for Site Characteristics and Evaluation for Aquaculture/Shellfish Propagation.

In order to review this document, I also included earlier communiques including materials sent prior to the Shellfish Forum held in June, Orleans Shellfish Operations and Program Expansion Plan, the Orleans Water Quality Advisory Panel Consensus document and the spreadsheet matrix used to evaluate potential sites.

My comments include ones of both general and specific nature.

Thank you for providing your comments and suggestions to the Technical Memorandum, we appreciate your input to this process.

GENERAL RESPONSE: Please also read our response to the comments from Cape Cod Cooperative Extension. Here, we explain in greater detail why the specifics of a demonstration project design are going to be the subject of the next Technical Memorandum, entitled "Preliminary Engineering and Design Work Plan". We will also note in the Purpose section of the Site Characterization and Evaluation Technical Memorandum that preliminary engineering and design are addressed in a subsequent Technical Memorandum.

General:

1. I was surprised to see that Lonnie's Pond was not considered. At the shellfish forum, terminal ponds were identified as areas in greatest need of nitrogen remediation to meet TMDL's. A plan to address the needs of Meeting House Pond (the most severely degraded waterbody) exists but I have not seen a similar plan for Lonnie's Pond. Lonnie's was mentioned several times as potentially appropriate for certain types of shellfish propagation.

   RESPONSE: Lonnie's is under review for a PRB by the EPA. In addition, Lonnie's was identified in both the Hybrid Plan as well as by the Floating Constructed Wetlands (FCW) team as a preferred location for a FCW. Planning for a FCW demonstration project is proceeding at this site. Therefore, it was not included in the shellfish demonstration site selection. Shellfish could be part of full scale CWMP implementation at Lonnies, even though a first-round demonstration is not planned for this site.

2. The closest site to Lonnie's is the Lower River site at Kent's Point that was rejected (more on that later). With that rejection, Lonnie's is not covered at all from a remediation standpoint. While these are demonstration projects and a full-scale program may emanate from them, choosing sites that may have the most remediative qualities would seem to be appropriate.

   RESPONSE: Please see the Purpose section of this Technical Memorandum (Tech Memo) as well as comments to Cape Cod Cooperative Extension regarding the purpose of this Tech Memo. This is not the overall plan for remediation project. The reasons why Kent's Pond was not selected are based on important considerations.

3. In the pre-forum materials, approximately 17 acres were suggested for shellfish/restoration; in the current document, 13 acres are suggested (5.5 acres in Nauset and 9 in Pleasant Bay). The discrepancy is not explained anywhere that I can find. The memorandum does not contain the final tally of acres or amount of shellfish needed to achieve the stated goal at each site. It is not known if the estimate presented to forum panelists is the same as the amount presented to the advisory panel. Therefore, I cannot comment on the feasibility of the amount of shellfish to be raised. The amount and size of shellfish to be cultured will dictate the type and amount of gear to be used, especially if oysters are considered.

   RESPONSE: Please see the Purpose section of this Technical Memorandum (Tech Memo) as well as comments to Cape Cod Cooperative Extension regarding the specific purpose of this Tech Memo. This is not the overall plan for full-scale nitrogen removal in either Pleasant Bay or Nauset Harbor. The purpose of the current effort is to implement a demonstration project to test different aspects of shellfish propagation or aquaculture at a given location. Quantitative recommendations will be developed through an Adaptive Management process based on the findings of the demonstration projects.

4. Whereas identifying specific sites was rejected in favor of generalized areas, evaluation of specific grow-out methods is not feasible since actual site conditions can vary considerably. (See Macfarlane). Macfarlane, Sandra L., 1998. The evolution of a municipal quahaug (Hard Clam) Mercenaria mercenaria management program: a twenty year history - 1975-1995. Journal of Shellfish Research, Vol. 17(4):1015-1036.

   RESPONSE: The purpose of this Tech Memo is to characterize the sites for demonstration projects. This is not the design and monitoring plan for a demonstration, which is the subject of the next Tech Memo. Please see our comments to Cooperative Extension that explains in detail the process we have been using.

5. The amount of area to be used for each separate demonstration project was listed in the original materials but is not listed in the memorandum. I do not know if they remain the same.

   RESPONSE: The purpose of this Tech Memo is to characterize the sites for demonstration projects. This is not the design and monitoring plan for a demonstration, which is the subject of the next Tech Memo. Please see our comments to Cooperative Extension that explains in detail the process we have been using.

6. The only predator noted in the memorandum is the oyster drill. Both Nauset and Pleasant Bay have far more predators than just one.

   RESPONSE: We agree with your comment, the site characterizations were based on the available data; however, the site engineering and the monitoring plans will include in detail the need for baseline studies and monitoring of disease and predation.

7. Fouling was only mentioned for Nauset. Pleasant Bay would not be immune to fouling at the demonstration sites. The issue of fouling, especially as it relates to gear handling, length of time the gear is deployed, labor needed to address fouling, and eventual cost as a result is not examined to any degree in any of the documentation I have seen.

   RESPONSE: We agree with your comment, but the purpose of this Tech Memo is to characterize the sites. This is not the operation and maintenance plan for a demonstration project, which will be the subject of the next Tech Memo.

8. I cannot find any evaluation of removal of contaminants of emerging concern. They are mentioned once as a potential issue/threat but addressing them is not discussed.

   RESPONSE: Thank you for your comment. This Tech Memo did not address this issue. CECs will be considered for inclusion in the demonstration monitoring plan.

9. I am unsure of how the inventory of potential and existing conflicting uses was executed and the time of year the inventory was conducted.

   RESPONSE: This was accomplished by interviewing the Harbormaster and Shellfish Constable

10. I assume low DO measurements were usually bottom water (although not always specified in words) but the time of year the sampling was conducted is not mentioned. I also assume it was summer measurements when DO should be at their lowest level. If that is the case, shellfish would probably not be grown in the deepest part of the water body where low DO would be most problematic. If that is not the case, DO needs further exploration as a parameter.

    RESPONSE: Your assumptions are correct, DO was bottom water sampled during the summer. Quanset does not have low bottom-water DO. DO assessments will be part of the monitoring plan for each demonstration project.

11. It is unclear on whether eelgrass cover was based on existing maps or was ground-truthed to current conditions. If it was ground-truthed, there is no mention of when that was accomplished.

    RESPONSE: The published eelgrass maps have a degree of ground-truthing already. When we visited the sites by boat and on foot when near the shoreline, we performed visual verification of general presence/absence of eelgrass.

12. How the type and location of current uses of the waterways were determined is not fully explained.

    RESPONSE: This was accomplished by interviewing the Harbormaster and Shellfish Constable

13. How the relative importance of other uses in the numerical scale was determined is not explained. No factor has greater weight and I understand that, but if there were thresholds to get to a positive, neutral or negative scoring, those thresholds were not defined. (See Pleasant Bay Resource Management Plan and Macfarlane et al.).

    Macfarlane, S.L., J. Early, T. Henson, T. Balog, and A. McClennen, 2000. A resource-based methodology to assess dock and pier impacts on Pleasant Bay, Ma. Journal of Shellfish Research, Vol.19, No. 1, 455-464.

    "To apply this tool to each potential shellfish demonstration site, the Shellfish Technical Team held a day-long working session. At this session, the Team first reviewed and discussed all of the available information for each site: water quality data from the MEP Reports, Pleasant Bay Alliance data and reports, shellfish suitability and other GIS maps from the DMF, preliminary grain size maps from Center for Coastal Studies and notes from site visits with the harbormaster and shellfish constable. The Team then evaluated each demonstration site and ranked the criteria for each site based on this available information."

    Based on the above paragraph, there is no indication of how the separate pieces of the shellfish suitability index, for example, were fitted together to determine the eventual score at each site. The same is true for the other uses of the area that could be conflicting, especially boating.

    RESPONSE: For the purpose of this project, this was accomplished by using the developed Site Evaluation Matrix tool that is attached to this email response.

14. The memorandum states directly that "neighbors are not likely to object to a well-designed demonstration location near them." The origin and veracity of that statement is not explained; who was contacted, what were those people asked, how was the project described, etc.

RESPONSE: We did not directly contact neighbors. This statement is based on the team's experience implementing other demonstrations and the scale and location being proposed for this demonstration project. As potential demonstration sites move forward, neighbors will be contacted. Part of what a demonstration shows is how people feel about the project. A demo is ideal because it allows for reactions to be based on a real project, and allows for the demo to be discontinued if not acceptable. It is probably more accurate to say that "Neighbors are less likely to object to a well-designed demonstration". We will edit the Tech Memo accordingly.

15. Only two areas are noted for education and outreach and I find that curious, since many of the locations have some attributes for those activities.

RESPONSE: During our site visits, the areas mentioned seemed to have exceptional attributes for education and outreach and that is why they were called out. We agree that all the sites could have educational and outreach activities.

16. There is no mention of the size of the upweller system that would be needed nor is there any discussion of seed acquisition.

RESPONSE: This Tech Memo is only about characterizing sites. This is not the operation and maintenance plan for a demonstration. This is the subject of the next Tech Memo

17. Of great important is the follow-up after the demonstration project runs its course. If shellfish are to be utilized as part of a wastewater management plan, it would be an annual expenditure to grow the amount of shellfish needed to offset the nutrient loading, especially if the source of the nutrients is not addressed. Establishing natural shellfish productivity through propagation is possible but it is definitely not a guaranteed success. The numbers needed, despite the prolific nature of shellfish to reproduce, is high; a very small number survive to reproduce in natural conditions (for coastal habitat restoration as envisioned in the memorandum). For planning purposes, shellfish cultivation would have to be a long-term annual commitment. Seed availability and upweller operation annually would be crucial elements as well. Additionally, these are live animals that live in a complex environment where small perturbations, that can easily go unnoticed, can have severe deleterious effects.

RESPONSE: We completely agree with this statement and budgeting and planning will take these factors into account.

Specific areas:

1. Town Cove is a big body of water shared with Eastham. The map provided with the pre-forum materials showed three demonstration locations near the middle of the Cove. It is unclear where those sites actually are relative to the channel and therefore water depths and sediment types, at those sites are unknown. It is unclear why quahaugs are not considered for an upweller nursery. If I am not mistaken, an area near the Yacht Club is closed to shellfishing during part of the year but is open for family permit holders during the remainder of the year. The matrix spreadsheet does not downgrade the Town Cove because of it being a popular recreational destination. It is a busy place yet without knowing the area under consideration, it is impossible to say whether other uses would conflict (see #13 above).

   RESPONSE: All of Town Cove was considered in the selection process. Because of severe predation for oyster bottom-planting (per Shellfish Constable) and without a population study of existing quahogs, a demonstration here was not recommended as the first step for Orleans. The next Tech Memo will provide recommendations on design and engineering for demonstration projects and will include recommendations for both a quahog population study, and a study of the potential for expanding aquaculture in Town Cove.

2. The reason for rejecting mussels "due to the difficulty of growing this species at this time." The prolific nature of mussels, feeding habits and nature of gregarious setting would seem to be worth some sort of demonstration project.

   RESPONSE: We believe that a key purpose of a shellfish demonstration project is to evaluate the impacts of shellfish propagation or/and aquaculture system on the water quality. For this reason, we are focusing on the areas that are likely to result in high shellfish survival, in order to maximize the potential for quantifying impacts. While we do not want to preclude opportunities to further scientific understandings related to various species propagation, we feel that it is important to focus on already proven approaches for growing shellfish species. We want this first demonstration to work well, so that the ongoing shellfish efforts can build on this success.

   We reviewed the idea of growing blue mussels (Mytillus edulis) in response to your comments and have the following observations:

   - We agree that mussels are an important species to include as part of the mix of shellfish used for nitrogen-removal
   - We believe that shallow-water propagation of mussels reliably is still at the research stage, making it a higher risk for this project than demonstrating oysters or quahogs
   - It is our understanding that the mussel bed propagation is difficult in shallow water due to severe predation from sea/bay ducks
   - Siting can also be an issue, but this is the case with all gear-based aquaculture
   - Deep-water mussel projects are not applicable to Nauset Harbor because these estuaries are too shallow to prevent ducks from diving to feed on them
   - Presently, there are no seed mussels available from hatcheries for a demonstration project
   - Relocating mussels from natural set may not be a reliable/sustainable, long term source for ongoing growth of mussel beds as part of a demonstration
   - There is limited data on nutrient-removal from mussels, and no data for Cape Cod
   - There is one small mussel grant in Orleans, which we see as an opportunity for future efforts

- As part of working with growers, mussel aquaculture in Town Cove and Mill Pond should be explored

- We are not aware of any shallow-water mussel propagation or restoration efforts in New England (which is different from aquaculture efforts), nor published literature that describes a successful methodology for artificially propagating blue mussels on Cape Cod or similar areas. We have spoken to MBL about their efforts near Martha's Vineyard (both blue and ribbed mussels) but we think the blue mussel deep-water aquaculture project is not comparable to the sites in Orleans.

If you are aware of successful efforts, please let us know.

3. Mill Pond is a propagation site. Oysters in bags in oyster condos for the last three years have not been bothered by oyster drills but once they are bottom planted, they are heavily preyed upon. While it may take extra diligence, rejecting Mill Pond because of the drills may not be advisable. Mill Pond and Robert's Cove have, in the past, been high mussel producing areas, a species also preyed upon by drills. A combination of all three species in that area could be beneficial. Moreover, the semi-enclosed nature of the Mill Pond makes it a reasonable candidate to measure the nitrogen reduction capability of the shellfish.

   RESPONSE: We agree that oysters that are bottom planted will be heavily preyed-upon. We also support the polyculture paradigm. For the reasons stated above, we do not believe there is a reliable source of mussels for a demonstration, and are concerned that the sea and harbor ducks would eradicate any mussels before the drills got to them. We do support the implementation of remediation efforts in Mill Pond using gear-based systems. The use of gear-based aquaculture is a well-established practice, and we feel that a demonstration of this technique is not necessary. Instead, we recommend a program that explores working with growers already using gear-based systems. Based on comments, growers in Town Cove will be included in this exploration.

   In terms of finding locations with good potential for monitoring success, shellfish uptake phytoplankton, which can be estimated using empirically-derived chlorophyll-a concentrations. Phytoplankton-derived nitrogen is also contained in the particulate organic nitrogen (PON) fraction of the total nitrogen (TN) measured as part of water quality evaluations. In the datasets for Pleasant Bay, the PON fraction is approximately 40% of the TN, and is about 25% in Mill Pond. A monitoring program for the demonstration locations will be designed to specifically measure localized (in situ) changes in water clarity, pigments (chlorophyll a), and particulate organic nitrogen (PON) as well as total nitrogen. This involves sampling with high temporal and spatial resolution. For example, the Little Pond Demonstration Project in Falmouth measured changes in PON effectively using this approach; as well as in the Wellfleet oyster restoration project.

4. Little Pleasant Bay was set aside as a grant site because of its lack of natural productivity and because it is not in an area of as high in boating activity as other areas. Working with grant-holders for a demonstration project is laudable. However, reliance on private aquaculture to provide a public service of nutrient remediation should be fully examined.

   RESPONSE: We agree that a full examination is necessary, and in the next Tech Memo will detail a program for a full evaluation of this option.

5. Arey's Pond is another terminal pond where remediation is most needed. The accumulation of fine silt and heavy organic mud precludes the pond of being bottom planted as stated. Moreover, the number of boats in the pond limits the amount of floating gear that could be deployed. The area may require further scrutiny. It is not clear why aesthetic considerations are -1 but conflicting use is 0 at this site. The land around the pond is developed but there is a section of undeveloped land and the boating use is very high (again, see #13 above).

   RESPONSE: Ongoing use of floating bags are not considered as a vista-neutral approach, thus the -1 rating. The demo envisioned would be small and outside the boating area, with no real conflict with boating. The replicability is low and the operation and maintenance much more difficult.

6. Pochet is an interesting area to consider. According to the map, the site chosen is in the river heading to the broader area north of Pochet Island. Any part of the broader area has limited use as a demonstration site due to sediment conditions. If the demonstration project is where it is suggested, on the Pochet Island side of the river at the south eastern part of Barley Neck, it would be more or less out of the way but as stated, it would not be easily accessible.

   RESPONSE: Access is tough and requires permission from a private landowener and the National Seashore. With private aquaculture nearby, the team thought that this would make monitoring even more complex.

7. The analysis of Little River is difficult to understand. There is nothing stated to preclude its use for a demonstration project except that it is a popular recreational destination and for that, it has been excluded. It is not clear why aesthetics or user conflicts are determined to be higher at this site than elsewhere. There are more similarities between this site and others than differences.

   RESPONSE: Our understanding from field visits is that this area is very popular for water skiing and outside a ribbon of sand, most of the bottom is muck, which precludes bottom planting. It is these two factors together that ranked it lower than Quanset.

8. Quanset is also difficult to evaluate. All the information provided deals with the pond but the actual site for the work is not clear. If a reef is established in a shallow area of the pond that expands to the very narrow shallow channel, the reef will decrease the depth even more with sharp-shelled oysters. The pond is also a highly-used mooring area. If the reef is on the outside of the pond, as the original map indicates, that is a different situation entirely and it is not clear if a reef does eventually get established, whether it will expand to the shallower parts of this area.

   RESPONSE: This Tech Memo is only about characterizing sites. This is not the operation and maintenance plan for a demonstration. This is the subject of the next Tech Memo.

I hope these comments are useful as Orleans continues to evaluate the possibility of shellfish as part of a wastewater management program. However, shellfish at the end of the effluent trail does nothing to correct the root of the problem—the one that starts with the backyard septic system. Shellfish added to the ecosystem will help but they can't do it all and they are not a panacea.

We very much appreciate your comments and questions!

Sandy requested that these three comments came in via email on March 6, 2016:

First, as a person who no longer lives in the area, I am honored to have been asked to comment.

Second, while not the primary objective, the number of demonstration projects and the diversity of sites will present a positive impression to put shellfish front and center as a resource that provides many benefits. Residents and tourists alike will understand what it takes to get shellfish from the water to the table as well as the ecosystem services they provide. They will also hopefully understand the challenges involved in a long-term project designed to maintain shellfish populations and to establish new populations of certain species. My earlier review points to some of those challenges.

Third, I appreciate the introduction of the matrix approach as a tool to sort through a range of criteria. A little tweaking to define those might be helpful.

We appreciate these thoughtful insights.

Appendix B

Non-Traditional Technology Descriptions – Siting Criteria Limitations and Constraints

NON-TRADITIONAL TECHNOLOGY DESCRIPTIONS, SITING CRITERIA, AND LIMITATIONS AND CONSTRAINTS

BASELINE MEASURES

The DRAFT Cape Cod Area Wide Water Quality Management Plan Update (208 Plan) lists two main baseline measures that could be implemented in all watersheds, including:

- Non-structural source control measures such as fertilizer controls.
- Structural measures related to stormwater management best management practices (BMPs) promulgated through local regulations.
- Both stormwater and fertilizer remove sources of nitrogen from entering waterbodies.
- Timeframe for water quality improvements once implemented depend on distance to impaired waterbodies.

FERTILIZER MANAGEMENT

Technology Description, including information from the DRAFT Cape Cod Area Wide Water Quality Management Plan Update (208 Plan):

- Fertilizer load contributes 6% (1180 kg/year) of controllable nitrogen in Nauset Harbor watershed and 23% (8,135 kg/year) of the controllable load in Pleasant Bay watershed.
- Fertilizer controls are a source reduction strategy for this nitrogen source.
- 208 Plan recommends enforceable regulations and best management practices to reduce this load by 25%
- The cost of implementation is low.

The MEP model and a subsequent review of existing scientific literature and available data for the Massachusetts Department of Environmental Protection concluded that 20% leaching of applied fertilizer (used in the MEP models) was a reasonable rate for Cape Cod soil conditions (Horsley Witten Group Inc. 2009). A recent report prepared for the Cape Cod Commission, entitled "Cape Cod Pesticide and Fertilizer-Use Inventory" found that residential fertilizer use contributes the most to the fertilizer loading to groundwater on Cape Cod (Horsley Witten Group Inc. 2013). According to studies conducted by the golf course industry, leaching rates can be reduced to 10% or less using well-planned fertilization programs.

Best Management Practices (BMPs), education, and local fertilizer regulations will achieve nitrogen reduction. Effective enforcement is important. Unnecessary fertilizer applications are the component that leaches into groundwater. Prohibitions that remove these sources include:

- No fertilizer when grass is dormant
- No fertilizer on imperious surfaces (such as inadvertent application on driveways)
- No fertilizer before heavy rain events
- No over-fertilizing

Using slow-release instead of fast-release fertilizers, and appropriate watering and aerating can increase the health of turf and reduce the need for fertilizer. Transitioning to turf or other ground-cover that is less water and nitrogen-intensive is also useful. The concept of a "Cape-friendly Lawn" branding, and transitioning to other ground cover are seen as important goals for restoring impaired estuaries.

Performance

25% reduction in the nitrogen load (kilograms) attributable to the application of nitrogen from fertilizer.

Local Implementation

Orleans has an approved fertilizer control bylaw with enforceable regulations for the above BMPs. Moreover, this Bylaw prohibits any application of fertilizer within 100' of resource areas as defined by the Orleans Wetlands Regulations. Orleans has also drafted a phosphorus bylaw to accompany its grandfathered nitrogen bylaw, planned for fall 2014 Town Meeting approval. Enforcement through the Town Zoning Enforcement Officer (or designee) is likely to be complaints-driven, as is the case in many communities. This significant regulatory step would be enhanced by educational initiatives. There are a number of local organizations that may take the lead on public outreach and education. County-wide approaches may also be forthcoming.

Limitations and Constraints

- Awareness of and compliance with Bylaw

Next Steps

- Update Orleans Fertilizer Study to more accurately quantify the fertilizer nitrogen load.
- Identify groups that will lead or partner on educational initiatives.
- Notify property owners that are within 100' of resource areas about the bylaw. Town of Falmouth has sent a letter from the Enforcement Officer that can be used as a template.
- Notify lawn service companies about the bylaw. Scott's Lawn has already contacted Falmouth stating that they are identifying all customers with lawns within the areas where nitrogen-application is prohibited to develop lawn management programs that do not use nitrogen fertilizer.
- From the mailing list, and Fertilizer Study Update, quantify the nitrogen-removal benefit of the prohibition against applying nitrogen fertilizer within 100' of resource areas.

STORMWATER MANAGEMENT

Technology Description, including information from the 208 Plan:

- Stormwater load contributes 9% (1770 kg/year) of controllable nitrogen in Nauset Harbor watershed and 13% (4,576 kg/year) in Pleasant Bay watershed.
- 208 Plan recommends Best Management Practices to reduce this load by 25%.
- Stormwater BMPs are a source reduction strategy for both nitrogen, and phosphorous.
- The cost of implementation is moderate when included as part of a larger public works project, and the nitrogen-removal benefits are rapid once the BMP is installed.

There are several stormwater treatment systems that can provide significant nutrient removal capabilities. Vegetated systems such as phytobuffers, constructed wetlands/gravel wetlands, vegetated swales, and bioretention systems are usually engineered to enhance the retention time of storm events. Physical filtration, uptake within plant tissue, nitrification-denitrification, and other microbial biochemical processes are engineered either alone or in series to optimize nutrient uptake and removal. Phytobuffers, also known as vegetated filter strips are uniformly graded vegetated surfaces that receive runoff from adjacent impervious areas, and treat sheet flow or small concentrated flows that can be distributed along the width of the strip. These vegetated filter strips are designed to slow runoff velocities, trap sediment, promote infiltration, and biochemically metabolize pollutants. Water quality swales are vegetated open channels designed to treat water and convey runoff from a 10-year storm without causing erosion. They can be substituted for subsurface piping or open (unvegetated) channels to provide enhanced water quality treatment when constructed in association with other stormwater BMPs. Gravel or other constructed wetlands systems treat different categories of storm events, and are very effective at nutrient remediation because they include separate zones for aerobic (nitrification) and anoxic (denitrification) microbial activity. Depending on the system installed, it is estimated that stormwater BMPs remove 25% - 40% of nitrogen from impervious surfaces.

Performance
25% reduction in the nitrogen load (kilograms) attributable to the application of nitrogen from fertilizer.

Siting Criteria
- Space requirements vary by BMP.
- Orleans has conducted three major planning initiatives for stormwater management (an outfall inventory, an inlets and outfalls loading study, and a mapping initiative). These reports should be used to identify locations for installation of stormwater BMPs that have nitrogen-removal capacity.

Limitations and Constraints
- Life cycle costs
- Practical implementation (where to locate, size of catchment area, overall number of BMPs required to capture stormwater nitrogen and phosphorous loads)
- Actual nitrogen-removal rates given low starting concentrations in stormwater
- Maintenance and management

Pilot Projects on Cape Cod
The Environmental Protection Agency (EPA) has solicited proposals for stormwater BMPs on Cape Cod. Final project selection is expected before the end of 2014. Results of this EPA pilot and other studies should inform future implementation efforts.

INTENSIVE OYSTER AQUACULTURE, OYSTER REEFS, AND QUAHOG PROPAGATION

- Timeframe for water quality improvements (water clarity, nitrogen removal from water column) are within the first year of growth, once shellfish have been installed.
- This is a remediation technology.

Technology Description, including information from the DRAFT Cape Cod Area Wide Water Quality Management Plan Update (208 Plan):
Shellfish are biological filters, consuming the plankton that thrives on dissolved nitrogen and other nutrients in the water. By feeding, shellfish manage the concentration of plankton that continues to regenerate and grow as long as the water is warm. Plankton-removal improves water quality by both removing nitrogen and increasing water clarity. It has also been shown that the waste products of oysters in particular may augment denitrification of bottom sediments, thereby releasing nitrogen in the form of nitrogen gas to the atmosphere. Quahogs (Mercenaria mercenaria) benefit the benthos by hardening soft bottom sediments. According to the 208 Plan, co-benefits of oyster reefs may include habitat provision for juveniles and adults of commercially important fisheries as well as crustaceans (Coen et al. 2007), shoreline stabilization through reduced wave energy (Newell 2004), and increased removal of particulate matter, light penetration, and submerged aquatic vegetation growth, such as eelgrass, due to improvements in water clarity (Golden 2011). It is the synergistic ecologic benefits of nitrogen (and phosphorus) removal, water clarity improvements and improvement of bottom sediments that make shellfish cultivation an intriguing tool for estuaries restoration.

Shellfish aquaculture and reef restoration may also achieve economic and social benefits, in addition to meeting nutrient remediation and ecosystems restoration goals. Shellfish aquaculture and wild harvesting are established industries on Cape Cod, employing many growers and harvesters, and yielding a valuable end product. There are positive economic multipliers from local food production and jobs creation. Oysters are often the shellfish of choice because they are fast growing, and thus incorporate more nitrogen per growing season than other endemic shellfish. Moreover, growing techniques are well-understood and oysters have a relatively high market value. In Orleans, quahogs (Mercenaria mercenaria) are another important shellfish to consider because historically, quahogs have thrived here.

Performance

Cape Cod Cooperative Extension together with Woods Hole Sea Grant found that local Cape Cod oysters contain an average 0.28 grams of nitrogen per harvest size oyster (3 – 3.2", two years of growth). The nitrogen content of cultured off-bottom oysters was found to be slightly lower (0.26 grams/oyster). Mashpee reports 0.50 grams N per 3.5" oyster. Quahogs have slightly lower nitrogen content (0.22 grams of nitrogen per harvest size littleneck at 1" – 1.5", estimated four years of growth). Larger quahogs contain more nitrogen. Growing time for quahogs is twice that of oysters, and the market value is lower.

Oyster density is reported at 2,000,000 oysters per acre of reef in the Wellfleet restoration project. Falmouth's Little Pond Demonstration Project reports 1,250,000 oysters per acre for the first year of growth, with relay and bottom planting for the second year of growth at a density of approximately 1,000,000 oysters per acre. Commercial growers optimizing for a 2" oyster in one growing season have reported that they stock floating bags at lower densities (as low as 200 oysters per bag). Other growers stock at higher densities. The difference in nitrogen-removal is significant if oysters can be grown effectively at higher stocking densities. The range of densities presented in Table 1 is a function of the area being cultivated, the goals of the grower, and the growing method employed. Quahog densities presented in Table 2 are estimated by area and stocking density assumptions, and should be field-verified.

Table 1 and 2 incorporate research findings to date, for planning purposes. Denitrification rates are an important factor in calculating nitrogen-removal by oysters, and must be determined on a site-specific basis.

Table 1: Planning Estimates for Oyster Nitrogen Removal - Shell and Soft Tissue Only

Size Class	# oysters per bag MAX	Nitrogen removal (g/oyster)	# bags per acre	# oysters per acre at max oysters per bag	N Removal per Acre @ max oysters per bag (kg)
1"	1500	0.008	1200	1,800,000	15
1.5"	1000	0.019	1200	1,200,000	22
2"	500	0.067	1200	600,000	40
3"	200	0.260	1200	240,000	62
3" (at avg N)	200	0.280	1200	240,000	67
3" (at avg N)	400	0.280	1200	480,000	134
3" (bottom/reef)	NA	0.500	NA	1,000,000	500
Denitrification					

Table 2: Planning Estimates for Quahog (Mercenaria mercenaria) Nitrogen Removal - Shell and Soft Tissue Only

Size Class	# quahogs Planted	# quahogs harvested	Nitrogen removal (g/quahog)	N Removal per Acre (kg)
1" thick (Littlenecks)	1,000,000	800,000	0.08	64
2" thick (Quahogs)	1,000,000	800,000	0.24	192
4 years to grow				

Screening Criteria for Shellfish Propagation

- Biologically suitable areas for a range of growing methods:
    - Quahog growth in upwellers for eventual bottom propagation
    - Oyster off-bottom culture (individuals and spat-on-shell)
    - Oyster bottom culture (individuals and spat-on-shell)
    - Oyster Reefs
    - Coastal Habitat Restoration
- Suitable areas that do not conflict with current uses (boating) in terminal ponds and estuaries
- Suitable areas from a regulatory perspective
- Costs associated with management and logistics
    - Private versus public
    - Predation control
- Public acceptance (aesthetics of floating aquaculture equipment)
- Impact of climate change, rising water temperatures and ocean acidification on growth of shellfish, and future changes in predation and disease patterns

Key Permitting Authorities

- MassDEP – for TMDL-compliance credit
- USEPA – for TMDL-compliance credit
- Division of Marine and Fisheries (DMF)
- US Army Corps of Engineers through permit issued to the Commonwealth of Massachusetts (DMF)
- Board of Selectmen
- Harbormaster/ Shellfish Constable
- Department of Public Works (possible)
- Conservation Commission (possible)
- Pleasant Bay Area of Critical Environmental Concern may create other permitting requirements.

Next Steps - Quahogs:

To determine the feasibility of different shellfish scenarios in Orleans, the following are currently being reviewed:

- Current locations of quahogs (present/future)
- Current harvest of quahogs
- Carrying capacity (density) of quahogs per acre in Orleans
- Review results of propagation program in the 1990's (different terminal ponds were studied)
- Review operational needs

Next Steps - Oysters:

- Current nitrogen-removal benefits of Pleasant Bay Shellfish Grants
- Density (optimized) of oysters per acre growing in cages to harvest size in Orleans currently
- Denitrification rates under Grants
- Feasibility/acceptability/water quality benefits of "No Take" zones for spawn and nitrogen removal
- Feasibility/acceptability of harvested reefs for spawn and nitrogen removal
- Additional locations for oyster reefs, oyster aquaculture and quahog propagation
- Discuss Virginia Oyster Gardeners model for possible implementation in Orleans (terminal ponds/docks). 300 oysters/bag x 3300 bags = ~1M oysters)

Limitations and Constraints

- Life cycle and monitoring costs
- Practical implementation (where to locate, size of growing area, risk management)
- Conflicting uses of water (boating, aesthetics) for gear-based operations
- Actual nitrogen-removal rates for different growing systems
- Maintenance and management – significant effort

Pilot Projects on Cape Cod

Wellfleet, Mashpee, and Falmouth are conducting pilot projects. The results of these projects have been incorporated into the planning estimates provided. Orleans has a number of active private growers with Shellfish Grants. The current and potential future production of these operations and their water quality benefits is under review.

PERMEABLE REACTIVE BARRIERS – TRENCH METHOD, INJECTION WELL METHOD

- Timeframe for water quality improvements (reduced nitrogen concentration of groundwater) could be within one year, but depends on the groundwater flow rate, residence time in the barrier, mobility of the treatment, distance of PRB from impaired waterbody, and other factors.
- PRBs are a source-reduction technology (nitrogen does not enter the waterbody).

Technology Description, including information from the DRAFT Cape Cod Area Wide Water Quality Management Plan Update (208 Plan):

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). Two types of PRB installations are discussed: trench and injection wells.

Trench PRBs

Trench PRBs designed for removal of nitrogen may be comprised of a media (such as wood chips or sawdust) that provides a readily biodegradable carbon source for use by denitryfing bacteria. Generally, trenches are constructed vertically, perpendicular to groundwater flow, in order to intersect and treat horizontally flowing groundwater. A funnel-and-gate configuration may also be used in conjunction with low-permeability materials to direct (funnel) groundwater towards a permeable treatment zone (gate). A trench-style PRB is typically excavated to a certain thickness and depth, determined by the desired treatment zone and the retention time. Then the trench is filled with a media (carbon source) that facilitates denitrification. The practical maximum depth that can be achieved with typical trenching equipment is 40 – 45 feet.

Injection Well PRBs

An injection well PRB is a network of wells by which a carbon source is injected in to the subsurface where it reacts with contaminated groundwater. There are a wide variety of carbon sources that have been used successfully in the field, such as emulsified vegetable oil (EVO), guar gum, fructose, corn syrup, molasses, methanol and ethanol. The injection wells are spaced to provide overlapping radii of influence (ROI) to create a continuous reactive zone. Spacing is determined on a site-specific basis and depends on site hydrogeology and design objectives. Radius of influence is usually a function of soil permeability. Glacial outwash and moraine areas often have variable permeability, depending on the amount of fine fraction in the soil. First order estimates for spacing of borings prepared for the Town of Falmouth suggest a distance of 20-25 feet apart, having a radius of influence of 12-15 feet from each injection point (PRB Technical Memorandum 5b). Injection wells installation methods are able to achieve maximum depths much greater than 40 – 45 feet.

Injection well technology is well-understood, having been used extensively to remove a wide range of contaminants from soils. At a recent workshop on PRBs sponsored by the Environmental Protection Agency, details regarding injection well technology were presented. Of note is that nitrogen species are routinely reduced, as this must occur before microbial activity acts on perchlorate.

Performance

Based on research conducted as part of the 208 Plan Update, the Cape Cod Commission's Technology Matrix provides removal rates for PRBs ranging from 70% to 99% of the nitrate in the groundwater that is intercepted. An extensive literature and regulatory technical review was recently conducted for the Town of Falmouth as part of its PRB Demonstration Project. Based on this work, the recommendation was made to assume 80% nitrogen-removal for planning purposes (PRB Technical Memorandum 5b, CDMSmith). Actual removal depends on the reducing conditions, and how much ammonia is generated and not adsorbed.

Downgradient impacts of PRBs (anaerobic byproducts such as methane, manganese, sulfide, and ferrous iron) may be generated by both trench and injection well PRBs. Understanding these interactions is a critical part of the evaluation process. Potential effects of the PRB to water quality such as increasing concentrations of iron and other constituents are reviewed as part of laboratory (bench) and field analysis prior to installing a PRB. When flow conditions and dosing requirements are well-understood, carbon sources have be injected for groundwater remediation in a way that does not result in surfacing or other downgradient impacts.

In terms of longevity, Trench PRBs have operated for over 10 years. A widely-recognized study conducted in Ontario, Canada showed that only 3% of the wood chip-based carbon source had been metabolized over a seven-year test period, suggesting that the longevity of this system could extend for decades (Robertson 2000). Injection well PRBs require rejuvenation, the frequency of which is best determined by a bench scale test, as well as a field scale pilot study.

To determine the mass or load of nitrogen that will be treated by a PRB installation, the groundwater capture zone must be determined. There are multiple methods to estimate and model the capture zone using water table/groundwater flow direction maps, groundwater flow and contaminant transport models, aquifer properties and analytical solutions. One method, the WatershedMVP planning tool, enables septic capture areas to be defined and nitrogen load reductions to be calculated. Evaluation tools will require field confirmation using site-specific data. Of note is that the WatershedMVP only includes septic load in its calculations, but a PRB also captures any upstream fertilizer and stormwater load that enters the groundwater.

Screening Criteria for PRB Installations

- Publicly-owned locations (roadways or public rights of way). The Selection Criteria mapping tool developed as part of the 208 planning process shows a number of locations where depth to groundwater is less than 20', including areas around terminal ponds, and along The River. However, these areas have private property down to the water's edge. For planning purposes, it has been assumed that siting a PRB demonstration project in public locations is preferred.
- PRB location intersects a groundwater plume with high nitrogen concentrations (downstream of high density development, perpendicular to groundwater flow)
- Access for construction/ sites available up gradient and down gradient for monitoring
- As a secondary screen, review depth to groundwater to determine whether costs are impacted significantly by greater depths

General Installation Considerations

- Vertical thickness of the groundwater lens (thickness of the aquifer to reach saltwater interface). Penetrating at least 20 feet of saturated aquifer thickness is desired, depending on groundwater flow rate
- Matching or exceeding the hydraulic conductivity and permeability of the surrounding groundwater matrix
- Extent of utility conflicts during installation (trench PRB)
- In general, the injection well PRB can be installed in areas with steeper topography than a trench PRB.

- In general, the injection well PRB can be installed in areas where utilities limit the installation of trench PRBs.

Key Permitting Authorities

- U.S. Army Corps of Engineers (USACE)
- USEPA
- MassEPA Unit
- MassDEP
- Massachusetts Division of Fisheries and Wildlife (DFW)
- Massachusetts Historic Commission (MHC)
- Cape Cod Commission
- Conservation Commission
- Planning and Zoning (earthmoving)
- Landowner permission if not a town road

Limitations and Constraints

- Life cycle and monitoring costs
- Practical implementation (where to locate, risk management)
- Actual nitrogen-removal rates
- Maintenance and management

Next steps for implementation of Modified 208 Plan Recommendation:

- Compile additional irrigation well data, if available
- Begin with bench scale tests and field investigations, to determine whether pursuing a Demonstration Project (less than 1000 linear feet) is worthwhile

Planning a Demonstration Project involves two main analytical steps, including (1) bench scale tests and (2) field (pilot) investigations. Bench scale tests are used to evaluate soil demand for a reducing agent, and groundwater chemistry such as dissolved oxygen, sulphate, pH, and other constituents, in addition to nitrate. Field investigations enable collection of data on soil types, stratigraphy, groundwater flow, hydraulic conductivity and other parameters. Fluorescent tracer tests can be conducted as part of initial field investigations to evaluate the radius of injections, and rate of carbon solution consumption (reinjection rates). The type of carbon source can also be optimized during both the bench scale and field investigations. The decision to employ injection wells versus trench PRBs will also be made after field investigations because this choice depends on depths, flow rates and potential for plugging. Based on these two analytical steps, the nitrogen-removal rates, as well as cost of installation, monitoring, operation and maintenance can be accurately estimated. Moreover, potential issues can be identified.

NOTE: 208 Plan recommendations for PRBs in Eastham (Salt Pond, Minister's Pond) have not been evaluated as part of the Orleans CWMP update.

Pilot Projects on Cape Cod

The Town of Falmouth completed a feasibility analysis for PRBs, with an extensive literature review and siting criteria. The screening criteria proposed above are based on the work in Falmouth, as well as additional research by the Cape Cod Commission. EPA Region 1 recommends piloting injection well and trench PRBs to determine their potential effectiveness for removing nitrogen loadings on Cape Cod.

FERTIGATION WELLS

- Timeframe for water quality improvements once implemented depend on travel time to impacted waterbody.
- Fertigation is a source reduction technology (reduces fertilizer use, plant uptake of nitrogen), with co-benefit of drinking water conservation

Technology Description, including information from the DRAFT Cape Cod Area Wide Water Quality Management Plan Update (208 Plan):
Fertigation refers to a system that uses irrigation wells to capture nitrogen-enriched groundwater and deliver it to plants for both watering and fertilization. By using reclaimed wastewater, a fertigation system captures the fertilizer benefit of nutrient-containing effluent in addition to conserving drinking water. Because turf takes up nitrogen, fertigation can significantly reduce nutrient loads to downgradient surface waters as well as reduce fertilizer costs and potable water use. High concentration groundwater is often found at the discharge sites of wastewater treatment facilities, sewage disposal areas, golf courses, areas of dense development with septic systems, and other facilities with large septic systems. Irrigated turf areas include golf courses, athletic fields and lawns.

Performance
The DRAFT Cape Cod Area Wide Water Quality Management Plan Update (p. 3-18) estimates that the nitrogen load reductions for turfgrass areas (such as golf courses, athletic fields or lawns) is 3.8 kg/acre-year. This planning estimate is based on a groundwater nitrogen concentration of 5 mg/L and water use records for managed golf course operations on Cape Cod. The mass of nutrients removed by fertigation is the product of the concentration of nitrogen in the groundwater, and the volume of water used. The reduction in nitrogen load of a fertigation system in Orleans would be calculated using actual water use data and fertilizer application records for the end user, as well as measured groundwater nitrogen concentrations.

Screening Criteria for Fertigation Wells
- Groundwater sources near areas where irrigation and fertilization occur
- Confirmed nitrogen concentration in groundwater at 5 mg/L minimum
- Fertilizer application rates that would be replaced by a fertigation system
- Monitoring of plant uptake of nitrogen, as opposed to reintroduction into groundwater

Key Stakeholders/Permitting Authorities for Fertigation Wells
- MassDEP
- USEPA
- Board of Health
- Conservation Commission
- Land Owner(s)
- Department of Public Works

Pilot Projects on Cape Cod
Case study from the 208 Plan:
The Pinehills golf course community in Plymouth installed a series of fertigation wells downgradient of the discharge site of its wastewater treatment plant. The pumped water is distributed to the golf course, reducing the amount of other fertilizer that is applied. During a two-year monitoring period an average of 434 kg N/year was reused. EPA Region 1 recommends piloting fertigation wells to determine this technology’s potential effectiveness for removing nitrogen loadings on Cape Cod.

INNOVATIVE/ALTERNATIVE SEPTIC SYSTEMS

- Timeframe for water quality improvements once implemented depend on travel time to impacted waterbody.
- I/A Septic Systems are a source reduction technology

Technology Description, including information from the DRAFT Cape Cod Area Wide Water Quality Management Plan Update (208 Plan):

Single Unit Systems

Innovative and Alternative (I/A) septic systems collect and treat wastewater from individual dwellings, or commercial buildings and discharge it on the same lot. I/A systems are designed to remove more nitrogen than Title 5 septic systems and often include pumps, aerators, fans and other mechanical parts. Some I/A systems have provisions for chemical addition (pH adjustment and carbon source) increasing microbial denitrification in the unsaturated soils. There are numerous I/A system designs. However, there are only a few approved by MassDEP for the removal of nitrogen. When estimating nitrogen concentrations being discharged to groundwater, Title 5 systems are assumed to have a discharge concentration of 26.25 mg/L. This concentration includes all denitrification that occurs in the wastewater within the septic system and in the unsaturated soils as it reaches the water table. I/A systems achieve lower discharge nitrogen concentrations, but require a higher level of maintenance and are often more expensive to construct, operate and maintain than Title 5 septic systems. In terms of nitrogen-removal performance, I/A systems exhibit a range:

- Title 5 System – assumed discharge concentration of 26.25 mg/L
- Standard I/A System – Mass DEP approval to meet 19 mg/l effluent total nitrogen
- Enhanced I/A System – Mass DEP approval to meet 13 mg/l effluent total nitrogen
- Advanced I/A System – anticipated to routinely meet 5 - 12 mg/l effluent total nitrogen

Cluster I/A Systems

A single-stage cluster I/A system treats wastewater flows greater than 2,000 gallons per day. Subdivisions, apartments, condominiums, or businesses commonly employ cluster I/A systems. Nitrogen levels are typically treated to less than 15 mg/L. Two-stage cluster I/A systems also treat flows greater than 2,000 gallons per day, but include a separate denitrification stage. These systems may require chemical inputs, and an operator to monitor and run the system. Nitrogen levels are typically reduced to between 5 - 8 mg/L. Disinfection may be required as part of cluster I/A systems if the discharge is located within a Zone II of a public water supply well.

Screening Criteria for I/A Systems

- Lower density development
- Suitable hydrogeology
- Land area available
- Other permitting criteria can be met

Key Permitting Authorities for I/A Systems

- MA DEP – TMDL-credit
- Board of Health
- Pleasant Bay Area of Critical Environmental Concern may create other permitting requirements.
- For cluster I/A systems: other permitting authorities if system is part of a new construction project

Limitations and Constraints

- Reliable nitrogen-removal rates (tradeoff between cost and performance)
- Life cycle and monitoring costs
- Practical implementation (where to locate)

Pilot Projects on Cape Cod

The Alternative Septic System Test Center located at Joint Base Cape Cod is currently testing a number of I/A systems, including a non-proprietary “passive” design. In addition, the Test Center has an online database that lists the performance of every I/A system installed on Cape Cod. To use an I/A system not yet approved by MassDEP for nitrogen reduction, the system must go through an approval process. Proven, reliable nitrogen removal is a critical factor in the rating and approval process. Details of the I/A approval process, I/A system designs, and approved I/A systems are provided at the following MassDEP website: http://www.mass.gov/eea/agencies/massdep/water/wastewater/septic-systems-title-5.html#1 . In addition, the Town of Falmouth in collaboration with the Buzzards Bay Coalition has applied for a grant from to install at least 10 I/A Systems on shorefront homes in West Falmouth Harbor. Grant awards are expected in October.

ECO-TOILETS

- Timeframe for water quality improvements once implemented depend on the travel time to the impacted waterbody.
- Eco-Toilets are a source reduction technology

Technology Description, including information from the DRAFT Cape Cod Area Wide Water Quality Management Plan Update (208 Plan):

Eco-toilets separate human feces and urine from the wastewater system of a house or business. Once this source separation occurs, it is able to be composted on-site, or treated in a centralized facility. These human-derived components are then useable as a soil amendment that is rich in nutrients. There are significant environmental advantages to such a system including:

- Eco-toilets divert the nitrogen that is in the feces and urine, so it does not enter groundwater. This decentralized approach replaces traditional wastewater management methods that are capital and resource intensive.
- Eco-toilets use minimal amounts of energy to operate, in most cases a 5-watt exhaust fan for venting is the only energy requirement.
- Water supply infrastructure and current plumbing paradigms first treat water to drinking water standards, then pipe it to homes where thousands of gallons per person per year are flushed down the toilet. This use of drinking water is wasteful of significant amounts of financial and energy resources. Eco-toilets replace this costly approach with technologies that do not use large amounts of drinking water to flush human excrement.
- Human feces and urine can be composted, or treated in other ways, and then used as fertilizers and soil conditioners that are rich in a wide variety of micro and macro nutrients. This conserves valuable natural resources, particularly phosphorus.

Eco-Toilet Technology Descriptions, including information from the 208 Plan

Eco-toilets include composting, urine diverting, incinerating, and packaging toilets and are typically coupled with a conventional system for gray water disposal systems (sinks, showers, baths, dishwashers, and washing machines). Composting toilets can either be self-contained, or have remote bins that hold the compost. Installation, operation, and maintenance manuals for each of the eco-toilets described below are available on the manufacturer’s website

The energy use of the fans and heaters associated with each individual composting eco-toilet ranges from 120 to 540 watt-hours per day, or between 44 and 197 kilowatt-hours per year. Urine-diverting fixtures that discharge into a holding tank do not have any fans/heaters associated with them at present. However, the energy used to transport the stored urine should be considered. This will vary by distance.

Self-Contained Toilets

Self-contained toilets are not connected to household plumbing. These fixtures are easy to install, and are particularly useful in places where it is not feasible to connect the existing toilet to a central composting system. Such toilets are often found in basements, or where there is no space available for a central composting unit.

The following units have obtained Product Acceptance from the Massachusetts State Board of Plumbers and Gas Fitters and are approved alternative systems under 248 CMR 10.10:

- Envirolet/Santerra Green: A stand-alone composting toilet in which urine and feces are composted in the same built-in rotary composting unit. Compost is emptied by hand, typically at intervals of four to six months, depending on use. Various models are available. All Envirolet 120VAC electric models use a maximum of 540 watt-hours per day. 120VAC models have two 20W fans and one 500W heater. For more information, see www.envirolet.com .
- Sun Mar self-contained unit: A stand-alone composting toilet in which urine and feces are composted in the same built-in rotary composting unit (biochamber). Compost is emptied by hand, typically at intervals of four to six months, depending on use. Various models are available. Electricity use is 125 watts/day. (includes fan and heater, and assumes 50-percent operation) For more information, see www.sun-mar.com.
- BioLet: A stand-alone composting toilet in which urine and feces are composted in the same built-in rotary composting unit. Compost is emptied by hand at intervals. Various models are available. For more information, see www.biolet.com.

The following units require special permitting from the Massachusetts State Board of Plumbers and Gas Fitters.

- Separett: A stand-alone urine diverting toilet normally set up for hand disposal of both urine and feces that must/will be composted outside the home. The urine chamber of the Separett may also be connected to a large urine tank. For more information, see www.separett.com.
- EcoJohn incinerating toilets: These sewage waste combustion systems process both black and gray water. They are completely self-contained and operate without being connected to any septic or sewage systems. Energy requirements are significant. A small amount of sterile ash is produced. For more information, see http://ecojohn.com/index.html

The following unit can be used in conjunction with a composting system that has Product Acceptance.

Pacto Toilet: Urine and feces collected together in a sealed plastic sack that can be taken out of the toilet periodically and taken to a composting facility. Requires no electricity or bulking agent. For more information, see www.pacto.se, and Appendix 3-5.

Composting Toilet Systems with Remote Composting Bin(s)

Composting Toilet Systems with Remote Composting Bin(s) may consist of a central composting unit with either a single chamber, or a series of chambers filled consecutively. Multiple interchangeable composting units are also available. Composting systems can typically accommodate one or more toilet fixtures. Several different types of toilet fixture may be used. Waterless (dry) composting toilet fixtures as well as waterless (dry) urine-diverting fixtures are typically used when a bathroom toilet can be located directly above, or nearly above the composting unit.

Human waste is moved by gravity through a 10- to 14-inch diameter pipe, from the toilet fixture into the composting unit. Foam flush, micro flush, and vacuum flush toilet fixtures can be used in locations that are not directly above the central composting unit. Some composting toilet systems require connection to a water supply.

The following units have obtained Product Acceptance from the Massachusetts State Board of Plumbers and Gas Fitters and are approved alternative systems under 248 CMR 10.10:

- Advanced Composting Systems (ACS)/Phoenix: Up to four toilets may be connected to a single composting container. Several types of toilet may be connected to the central composting container. Normally the toilet fixture will be a single chamber type with a wide opening through which both urine and feces are transferred to the composting container and processed into compost. A urine diverting dry toilet may also be used with a separate connection to a large urine storage tank. In difficult situations where a toilet is too far away from the composting container, a foam flush toilet may be used. A dedicated vent stack must be installed. The system requires a 5-watt fan that runs 24 hours/day = 120 watt-hours per day. For more information see www.compostingtoilet.com.
- Clivus Multrim: The manufacturer recommends that only single chamber toilets that transfer both urine and feces to the central processing unit be used. Clivus Multrim markets its own foam-flush toilet (Neptune) for situations where the toilet is too far away from the composting chamber for gravity discharge to the compost bin. A dedicated vent stack must be installed. The system requires a 5-watt fan that runs 24 hours/day = 120 watt-hours per day. For more information see www.clivusmultrum.com.
- Envirolet/Santerra Green Central Units: Both direct-discharge dry toilets, as well as vacuum flush units are available. Several toilets may be connected to a single composting container. A high capacity double tank is also available. FlushSmart™ VF™ is a vacuum flush and composting toilet system combination that is recommended for installations on rock or with little or no room below, basements, garages, workshops, pool cabanas, yurts, and applications where a smaller toilet is needed or desired. A dedicated vent stack must be installed. Central models use a maximum of 540W per day. A detailed description is provided in the technical description of the self-contained unit. For more information, see www.envirolet.com.
- Sun Mar Central Units: Several dry toilets may be connected to a single composting container. For locations where a direct gravity feed is not feasible, the manufacturer recommends use of a Sealand 510 or 511 marine toilets. This is an ultra-low flush toilet that may be installed either directly above or up to 15-feet away from the central composting unit. A dedicated vent stack must be installed. Electricity use is 125 watts/day (includes fan and heater, and assumes 50-percent operation).For more information, see www.sun-mar.com .
- Eco-Tech Carousel: Several types of composting toilets, including urine diverting dry toilets and foam flush toilets, may be connected to this set of bins in a rotating chamber. The urine diverting toilet will require connection to a large urine tank and the foam flush toilet must be connected to the household water line. There are two sizes of rotating chamber and each rotating chamber has four separate bins, only one of which is in use at a time. This system requires a 5-watt fan that runs 24 hours/day = 120 watt-hours per day. For more information, see www.ecological-engineering.com/carousel.html.

The following unit requires special permitting from the Massachusetts State Board of Plumbers and Gas Fitters.

- Full Circle: A 55 gallon wheelie bin is connected to a single dry composting fixture with urine-diversion. The bin collects feces for composting, with a separate storage container for urine. Each bin serves only one toilet. A dedicated vent stack must be installed for each bin. For more information, see www.fullcirclecompost.org.
- EcoJohn incinerating toilets: These sewage waste combustion systems process both black and gray water. They operate without being connected to any septic or sewage systems, and the incinerating unit can be located remotely (away from the toilet). Energy requirements are significant. A small amount of sterile ash is produced. For more information, see http://ecojohn.com/index.html

Summary of the Toilet Fixtures used with Composting Systems

Worldwide, many toilet fixtures are being produced for use with composting systems. Manufacturers specify which toilet fixtures are compatible with their composting systems.

- Dry composting toilets (with and without urine-diversion) are installed as part of a composting system. See manufacturer's recommendations for dry composting fixtures that are compatible.
- Ultra-low Flush Composting Toilets: The Sealand 510 and 511 models are the only examples mentioned, and they are recommended for use on Sun Mar central units where toilets must be offset from the central unit.
- Foam Flush Toilets: These function and look much like conventional toilets. Using a mix of biocompostable soap and water, the foam-flush moves waste through a 4-inch pipe to a composting tank below. The foam mixture cleans the toilet bowl with every flush but uses only about three ounces of water, making it fully compatible with the composting process. Since the foam flush is using water to carry the waste, toilets can be offset by up to 45-degrees from the composting bin. This facilitates installations where there is not space for a composting bin directly under a current fixture. These toilets are connected to a home's water supply.
- Vacuum Flush Toilets: The flushing action on these fixtures opens a valve in the toilet, enabling the contents of the toilet to be sucked with pressure, instead of gravity alone. There are a number of different types of vacuum toilets, ranging from toilets connected to vacuum sewer systems to toilets with a vacuum assist, which creates pressure to help flush the contents of a toilet with minimal water usage. Vacuum toilets are common on airplanes and are also used on boats and in personal homes. Because the vacuum involved can exert a substantial force, a vacuum toilet requires little to no water. Some use sanitizing liquids instead of water to keep the toilet relatively clean. Vacuum toilets are often very low-odor.

Urine-Diverting Flush Toilet Systems

Urine-diverting (UD) flush toilet systems connect to the household water and wastewater systems. Each toilet bowl has two chambers, one for feces and toilet paper and the other for urine. The urine chamber is connected to a large urine tank, the larger chamber to the household wastewater line. The following units have Test Site Status from the Massachusetts State Board of Plumbers and Gas Fitters for the demonstration. Up to 40 test sites have been authorized. The urine-diverting tanks are typically installed outside the home, and must be DEP-approved septic tanks with provision for pump-out and sealed against air intrusion. The entire UD system must be installed by a licensed plumber to ensure there is proper venting and traps. A key concern is to avoid blockages and odors from the urine line.

- Dubbletten "double flush" toilet: The urine and feces/toilet paper chambers flush separately, the urine chamber with very little water. The user need not flush the urine chamber after every use. To save water, it is recommended that paper used after urinating is disposed of in a separate receptacle near the toilet, and not flushed. For more information, see www.dubbletten.nu.
- Wostman Eco-Flush toilet: The urine and feces/toilet paper chambers flush separately, the urine chamber with very little water. The user need not flush the urine chamber after every use. To save water, it is recommended that paper used after urinating is disposed of in a separate receptacle near the toilet, and not flushed. For more information, see http://wostman.se/en/.
- Aquatron Centrifuge composting system: Wastewater from the feces/toilet paper chamber of one or more urine diverting toilets passes through a gravity-driven centrifuge that separates solid matter from wastewater going to the septic system. Solid matter drops out into a composting container. The Aquatron centrifuge may be used with any flush toilet, but for our demonstration it will be used with urine diverting flush toilets such as the Dubbletten or Wostmann toilets. For more information, see www.aquatron.se/index-2.php.
- Waterless (or very low flush urinals): There are many models that may be used in conjunction with UD toilets in any UD system. Any fixture that has Product Acceptance may be installed.

Urine Tanks Used with Urine-Diverting Toilets and Waterless or Ultra-Low Water Urinals

Any MassDEP-approved septic tank may be installed as part of the demonstration to hold urine. Tanks with a 500-gallon capacity are being used in the demonstration.

Installation of Eco-Toilets

In most cases, installing composting and urine diverting toilets in existing homes requires modifications to existing plumbing and venting. Space constraints are an important consideration, and sometimes bathroom remodeling is required. Building permits must be granted for these changes, and plumbing work must be code-compliant and be done by a licensed plumber. Any plumbing fixture installed in Massachusetts must have a Product Acceptance number. Several composting toilets have this approval. However, urine-diverting fixtures, source separators (such as Aquatron), and other pilot-stage urine-diverting and composting toilet technologies do not currently have a Product Acceptance number from the Massachusetts State Board of Plumbers and Gas Fitters (MSBPF), and are therefore illegal to install in the state. In order to install equipment that is not already approved, special permitting from the MSBPGF is required.

Selecting the best eco-toilet system is an iterative process involving the physical constraints of the built environment as well as cost and ongoing maintenance considerations. A site visit from someone capable of making these kinds of assessments is a critical component for many people, providing unbiased information on the full-range of eco-toilet configurations and the maintenance requirements that should be expected once an eco-toilet is installed. In addition, plumbers do not have a lot of experience installing these technologies. A Technical Coordinator to work with property owners, plumbers and regulators during the selection and installation process is necessary.

All eco- toilets require some form of residuals management. This is generally performed by a licensed septic hauler. Urine diverting toilets require the removal of urine from a holding tank. The compost and leachate from composting toilets requires periodic removal. Leachate is the excess liquid that is not taken up during process of composting. Leachate is very high in nitrogen and phosphorus; volumes produced range from <1 – 4 gallons/month/person. Incinerating toilets have a small ash residual requiring removal. Packaging toilets will also require frequent residuals removal.

The Town of Falmouth is conducting two demonstration projects related to eco-toilets to determine the nitrogen removal capabilities, cost, installation logistics, operations, and public acceptance of a broad range of composting and urine-diverting systems. Test Site status from the MBPGF for equipment that did not have Product Acceptance was obtained. Data from these Demonstration projects is still being collected. For planning purposes, a residential household which converts all toilets to approved eco-toilets will be removing nitrogen equivalent to an Enhanced or Advanced Innovative/Alternative septic system.

Limitations and Constraints

- Life cycle and monitoring costs
- Public acceptance
- Practical implementation (how to retrofit in homes with more than one bathroom)
- Handling of residuals (compost, leachate and urine)

Screening Criteria for Eco-Toilets

- User acceptance
- Title 5 septic system for grey water (sinks, dishwashers, showers, baths, laundry)
- Feasibility of retrofitting plumbing and making floor area modifications for eco-toilet based on site-specific conditions
- Plumbing board approval for desired technology
- Areas near freshwater ponds due to enhanced ability for phosphorus removal

Key Permitting Authorities for Eco-Toilets

- Board of Health
- Building Department
- State Board of Plumbers and Gas Fitters for Product Acceptance

- Pleasant Bay Area of Critical Environmental Concern may create other permitting requirements.
- MA DEP – TMDL-credit

Pilot Projects on Cape Cod
The Town of Falmouth has initiated two significant demonstration programs for eco-toilets. Results from the installation of the first 6 - 10 systems are expected by the end of 2014.

INLET WIDENING

- **Inlet widening is not being proposed as part of the Orleans Non-Traditional Bookend.**

The following technology description is included for completeness:

Technology Description, including information from the DRAFT Cape Cod Area Wide Water Quality Management Plan Update (208 Plan):
Inlet widening involves the re-engineering and reconstruction of a bridge or culvert opening to increase tidal flow. Maintenance dredging may also provide a similar function. According to several MEP Reports in which inlet widening is identified as a potentially beneficial measure, increasing tidal flux is expected to decrease the nitrogen residence time within the embayment or salt marsh, thereby lowering the nutrient concentrations. With the return of natural salinities, nutrient balance, and improved tidal exchange, and with opportunities for sediment to move more naturally through a coastal system, native plant and animal species may return and thrive.

Key benefits of inlet widening include:
- Provides passive treatment with minimal O&M
- Has numerous ecosystem benefits
- Nitrogen removal rate is dependent on many factors, including scope of restoration up to full tidal exchange

Screening Criteria for Inlet Widening
Preliminary feedback from Water Quality Advisory Panel, as well as the depth differential between the ponds and Pleasant Bay indicates that inlet dredging would not increase tidal prism. **<u>Inlet widening is prohibited in the terminal ponds because they are part of the Pleasant Bay Area of Critical Environmental Concern (ACEC).</u>**

- Waterbodies identified in MEP Reports as potentially beneficial (**<u>none in Orleans watersheds under consideration</u>**)
- Waterbodies identified by local stakeholders as constricted, and where the increased tidal volume would lead to an enhanced tidal prism and thus nitrogen removal.

Key Permitting Authorities for Inlet Widening
- Conservation Commission
- MassDEP – TMDL-credit
- MassDOT
- Division of Marine and Fisheries (DMF)
- Coastal Zone Management
- Natural Heritage
- US EPA – TMDL-credit
- US Army Corp of Engineers

Pilot Projects on Cape Cod

The Town of Falmouth is currently in the design and permitting phase of an inlet widening demonstration project for Bournes Pond. This project involves widening the current inlet from 50' to 90', with a new road and bridge, and is expected to remove over 50% of the nitrogen load entering this coastal pond. The permitting and monitoring framework is currently being established, and could serve as a valuable blueprint for other inlet widening initiatives on Cape Cod.

COASTAL HABITAT RESTORATION

- Timeframe for water quality improvements (water clarity, nitrogen removal from water column) once implemented are within the first year of full growth.
- Coastal Habitat Restoration is a remediation technology.

Restoration of coastal habitats includes establishing and/or enhancing estuary salt marshes, eel grass beds, and enhancing historic shellfish beds or reefs together as an ecosystem. The installation of riparian buffer zones and floating islands are also tools for restoring coastal habitats. The focus of restoration in the context of the Technology Matrix is on creating or rehabilitating native shellfish habitats. The 208 Plan includes reef restoration as a key component of Coastal Habitat Restoration. Nitrogen-removal is based on shellfish uptake.

Under the Department of Fish and Game, the Division of Ecological Restoration (DER) has developed inventories of some potential wetland restoration sites throughout Massachusetts. The purpose of these inventories is to identify, evaluate, and prioritize restoration opportunities that can be advanced by DER and others. The Cape Cod Atlas of Tidally Restricted Salt Marshes describes 7 sites in Orleans, 2 of which are shared.

However, the use of Coastal Habitat Restoration as a tool for nitrogen-removal is a somewhat different paradigm that the DER program, as currently articulated.

Siting Criteria for Coastal Habitat Restoration

- Navigable waters (shoreline reef systems do not interfere in the same way as aquaculture)
- Freshwater stream inflow
- Adequate flushing
- River systems with shoreline available
- Areas where shoreline erosion is occurring
- Aquaculture not allowed by regulation, or acceptable due to aesthetics

Key Permitting Authorities for Coastal Habitat Restoration

- Conservation Commission
- MassDEP/US EPA – TMDL-compliance credit
- Division of Ecological Restoration (DER)
- Division of Marine and Fisheries
- MassDOT
- Natural Heritage
- US Army Corps of Engineers
- US Fish and Wildlife Service
- Coastal Zone Management
- Landowners
- Pleasant Bay Area of Critical Environmental Concern may create other permitting requirements.

Local departments that may also be involved:

- Department of Public Works

Limitations and Constraints

- Life cycle and monitoring costs
- Practical implementation (specific locations that lend themselves to habitat restoration, risk management)
- Actual nitrogen-removal rates for different growing systems
- Maintenance and management

Pilot Projects on Cape Cod

- None for nutrient remediation: any demonstration site should be a self-contained small estuary where benthic as well as water quality conditions can be easily characterized and monitored

Next Step:

- Review terminal ponds and estuaries where coastal habitat restoration might be feasible and desirable.
- Planning for this approach should include consideration of the spectrum of shellfish growing options including propagation, aquaculture and reef programs to determine the best approach for different waterbodies.

FLOATING CONSTRUCTED WETLANDS

- Timeframe for water quality improvements (water clarity, nitrogen removal from water column) once implemented are within the first year of full growth.
- Floating Constructed Wetlands are a remediation technology.

Manmade floating "islands" 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. The floating islands can also be designed to allow shellfish and seaweed to grow which can be harvested, offsetting some of the systems costs. Some systems circulate surface water through the island, exposing the water to the root zones of the plants. The islands can be installed with shellfish beds and/or salt marsh grasses potentially assisting with their establishment. The islands are generally stationary and can be installed with walkways to access and maintain the plants growing on the islands. The islands require little O&M and do not need to be removed during the winter months, even if freezing water is a concern.

Siting Criteria for Floating Constructed Wetlands

- Navigable waters (reef systems do not interfere in the same way as aquaculture)
- Freshwater stream inflow
- Adequate flushing
- River systems with shoreline available
- Areas where shoreline erosion is occurring
- Aquaculture not allowed by regulation, or acceptable due to aesthetics

Key Permitting Authorities for Floating Constructed Wetlands

- Conservation Commission
- MassDEP/US EPA – TMDL-compliance credit
- US Army Corps of Engineers
- Division of Marine and Fisheries

- Pleasant Bay Area of Critical Environmental Concern may create other permitting requirements.

Local departments that may also be involved:
- Department of Public Works
- Harbormaster/Shellfish Dept.

Limitations and Constraints
- Life cycle and monitoring costs
- Practical implementation (specific locations, risk management)
- Conflicting uses of water (boating, navigation)
- Actual nitrogen-removal rates for different growing configurations
- Maintenance and management

Pilot Projects on Cape Cod
- Martha's Vineyard demonstration project, collaboration between Floating Islands International and Martha's Vineyard Shellfish Group, was installed mid- summer of 2014. Monitoring began, and will continue through (at minimum) summer, 2015. Four sites, with 2 – 4 wetlands systems per site are being evaluated.

  The following research questions are being assessed:
  - Will the BioHaven® matrix bio□foul from natural marine aquatic organisms or suspended detritus to a point where the matrix will not provide positive benefits in these marine environments at this scale?
  - Does the matrix have any application for Geukensia demissa spat collection and/or culture?
  - Does the periphyton that becomes attached to the matrix exhibit nitrification and/or denitrification potential? If so, to what extent?

LAND USE CONTROLS

- Timeframe for water quality improvements (water clarity, nitrogen removal from water column) once implemented depend on growth timeframes and groundwater travel times.
- Land Use Controls are a source reduction technology.

Land use planning is often implemented through zoning changes. Compact and open space development, transfer of development rights and overlay districts are three of several possible land use planning tools that are highlighted in the Technology Matrix. Purchase of land for open space and conservation restrictions also reduce future growth. Currently, Orleans has an average of ¾ acre zoning throughout town, with 6 units/acre maximum for apartments in certain areas.

Orleans Buildout Analysis - Summary of Findings
Existing level of development

Single family homes	3617
Condominium units	642
2-family home units	88
3-family home units	18
Other multi unit dwellings	104
Housing Authority	115
Apts. in Industrial District	22
Apts. in Business dists.	
Permitted accessory apartments	3
Total existing dwelling units	4,609

Potential Future Development

Vacant developable (undividable) building lots	528
Potential new lots in Res. Districts	274
Potential new apts in business districts	412
Potential new apts. in Industrial District	98
Potential new apts. in the Village Center	290
Total Potential Development	1,768

Current Density: 2.05 residents per dwelling unit (US Census)

Siting Criteria for Land Use Changes

- Detailed build-out analysis based on "net useable land" has been completed by the Orleans Planning Department.
- Town Planner has confirmed that the findings are still valid.
- Findings incorporated into Comprehensive Wastewater Management Plan as "Practical Buildout"
- Land Use Controls should be pursued in the context of the Town's Local Comprehensive Plan

Key Approvals for Land Use Controls

- Planning Board
- Board of Selectmen
- Town Meeting

Local departments that will likely be involved:

- Planning Department

Limitations and constraints:

- Does not address current load
- Cannot stop all future load
- Public acceptance

SUMMARY OF 208 PLAN SCREENING LAYERS
Constructed Wetlands for Phyto-Technology
See 208 Screening Layers Map for exact locations

Locations include: Hopkins Island, parcel off White Pines Drive (wetlands), parcel off Route 6A at Boland Pond, and parcel off Indian Fort Hill Rd.

SUMMARY OF 208 PLAN SCREENING LAYERS
Constructed Wetlands for Groundwater Treatment
See 208 Screening Layers Map for exact locations

Rock Harbor:

- Constructed Wetlands for groundwater treatment - enhancement of existing wetlands system in two areas along creek
- Two parcels (wetlands) near Cedar Pond

Nauset Marsh – Town Cove:

- Constructed Wetlands for groundwater treatment – enhancement of existing wetlands at island E of Nauset Beach

Little Pleasant Bay:

- Constructed Wetlands for groundwater treatment – enhancement of existing wetlands east of Archer Lane, west of Sparrowhawk Rd along Bay, at Barley Neck (point) , Tar Kiln Road, Simpson Meadow island

Namskaket

- Constructed Wetlands for groundwater treatment - enhancement of existing wetlands system on several parcels

SUMMARY OF 208 PLAN SCREENING LAYERS
Constructed Wetlands for Wastewater Treatment
See 208 Screening Layers Map for exact locations

Rock Harbor:

- Constructed Wetlands for wastewater at Defiance Lane

Nauset Marsh – Town Cove:

- Constructed Wetlands for wastewater - several sites, to be reviewed as part of wastewater discharge planning

Little Pleasant Bay:

- Constructed Wetlands - several sites, to be reviewed as part of wastewater discharge planning

Namskaket

- Constructed Wetlands for wastewater at Boas Drive, off Salty Ridge Rod

Appendix C

Siting Evaluation Matrix

Town of Orleans, Massachusetts
Water Quality and Wastewater Planning
Aquaculture Demonstration Siting Evaluation

Criteria	Site A: Town Cove: Quahog Propagation		Site B: Mill Pond: Quahog Propagation		Site C: Little Pleasant Bay: Existing Grants		Site D: Pochet: Oyster Reef		Site E: Arey's Pond: Oyster Singles in Floating		Site F: Lower River: Oyster Singles in Floating		Site G: Quanset: Oyster Reef	
	Rating	Score	Rating	Score	Rating	Score	Rating	Score	Rating	Score	Rating	Score	Rating	Score
Site Suitability														
Available Growing Area/Adequacy of Acreage	1	1	1	1	1	1	1	1	0	0	1	1	1	1
Water Quality Indicators	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Disease/Predation	-1	-1	-1	-1	0	0	0	0	0	0	0	0	1	1
Ease of Access:	0	0	0	0	0	0	0	0	1	1	1	1	1	1
Aesthetic Impacts	1	1	1	1	1	1	1	1	-1	-1	-1	-1	1	1
Representativeness of the Site (Transferability)	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Use Conflicts	1	1	1	1	1	1	1	1	0	0	-1	-1	1	1
Ability to Co-Locate with other Non-Traditional Technologies	1	1	1	1	1	1	1	1	1	1	1	1	1	1
												-		-
Permitting														
Abutter Comaptability	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Wild Harvest Conflicts (DMF)	1	1	1	1	1	1	0	0	1	1	0	0	0	0
Grow-Out to harvest size Allowed (DMF)	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Permittability	1	1	1	1	1	1	0	0	1	1	1	1	1	1
												-		-
Project Evaluation														
Expected Survival	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Overall Likelihood of Monitoring Plan to Yield Quantified Results	-1	-1	-1	-1	1	1	1	1	1	1	0	0	0	0
												-		-
Other/Overriding Considerations														
Town Cove/Mill Pond: drills preclude oysters (per Mass Shellfish Growers Assn (communication with Shellfish Constable)		-	-	-	-	-	-	-	-	-	-	-	-	-
Town Cove: population study of quahogs needed prior to additional shellfish propagation/demo (communication with Shellfish Constable)		-		-	-	-	-	-	-	-	-	-	-	-
Pochet: monitoring difficult if LPB is also a demo	-	-	-	-	-	-	-	-	-	-	-	-	-	-
LPB: Shellfish Constable and Harbormaster recommended working with existing growers for demonstration														
Total Criteria Points	**9**		**9**		**12**		**10**		**9**		**7**		**12**	
Rank	**4**		**4**		**1**		**3**		**4**		**7**		**1**	

Notes:
- High Criteria Weight = Greater Importance
- Higher Rating = Better Conditions
- A good ranking (1) was assigned if the criterion could be fully met.
- A neutral ranking (0) was assigned if the criterion could be met in part, but not fully.
- A poor ranking (-1) was assigned if the criterion could not

Remarks

Arey's, Lower River and parts of Town Cove, much of the bottom is anoxic, fine-grained sediment (muck). This precludes bottom planting of oysters
Arey's has narrow Namequoit neck allowing better quantification of input water nitrogen concetrations, which increases likelihood that monitoring plan will quantify N
Pochet permitting may involve National Seashore, and access involves permission from private landowner
Pochet only measurable from a monitoring perspective if LPB aquaculture is not a demonstration
Pochet: Shellfish Contable thought this location was suitable for a "no take" zone/oyster reef
LPB has number of oysters being grown and harvested from required annual Shellfish Grant reporting
Town Cove/Mill Pond should have a quahog population study completed to establish baseline numbers before further quahog propagation/demonstration
Town Cove/Mill Pond have significant drill population; planting of oysters is not recommended per Massachusetts Shellfish Officers Association Best Management Practice
The Lower River is an open cove, causal water quality improvements are hard to quantify by monitoring
The Lower River has visibilty, good for public education