Joint Adaptive Management Plan (AMP)

Submitted by the following members of the Municipal Alliance for Adaptive Management (MAAM)

Dover, Milton, Newington, Portsmouth, Rochester and Rollinsford

(Exeter, a member of MAAM, will report separately)

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EPA NPDES Permit Number **NHG58A000**

Prepared by the municipal members of the Municipal Alliance for Adaptive Management (MAAM), with assistance from NH Department of Environmental Services (NHDES), the consulting firm Brown & Caldwell, the University of New Hampshire Stormwater Center (UNHSC) and the Piscataqua Region Estuaries Partnership (PREP).

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Background

Great Bay Total Nitrogen General Permit

The Great Bay Estuary (Estuary) is a network of tidal rivers, inland bays, and coastal harbors that extends inland from the mouth of the Piscataqua River between Kittery, Maine and New Castle, New Hampshire to Great Bay proper and the Upper Piscataqua River. Over 52 New Hampshire and Maine communities are entirely or partially located within the watershed.

The Estuary is protected in part by the operation of 17 publicly-owned wastewater treatment facilities (WWTFs), including 13 in New Hampshire and 4 in Maine. The various municipal owners operate these WWTFs to clean wastewater generated by and collected from residential households; businesses; educational institutions; federal, state and local government facilities; and other persons and entities in the watershed. For many years, various municipalities have invested funds collected through user fees on these sources of wastewater to increase the ability of their WWTFs to remove a particular pollutant, total nitrogen (TN).

The U.S Environmental Protection Agency (EPA), in coordination with the State of New Hampshire Department of Environmental Services (NHDES), issued the National Pollutant Discharge Elimination System (NPDES) Great Bay Total Nitrogen General Permit for Wastewater Treatment Facilities in New Hampshire (No. NHG50A000) (General Permit) on November 24, 2020. The General Permit became effective beginning on February 1, 2021. It establishes TN effluent limitations, monitoring requirements, reporting requirements and standard conditions for the 13 eligible WWTFs in New Hampshire. The discharge of all pollutants other than TN from these WWTFs will continue to be authorized by each WWTF's respective individual NPDES permit.

The General Permit consists of two main operative parts. Part 2 establishes "Effluent Limitations and Monitoring Requirements" representing a control regime for TN discharges from the covered WWTFs in accordance with specified rolling seasonal averages. Compliance must be confirmed through a rigorous program of weekly monitoring in accordance with EPA methods and certified reports to EPA on a monthly basis.

Part 3 establishes an opportunity for the municipalities to advance the development of broader "Adaptive Management Framework" for the Estuary, which includes ambient water quality monitoring, pollution tracking, reduction planning, and review, as well as collaboration between EPA, the State of New Hampshire, and public, private, and commercial stakeholders. Part 3 of the General Permit is discussed further in the next section of this plan.

By opting to be covered by the General Permit, the municipalities are supporting implementation of the General Permit as part of the next phase of appropriate water quality management approach for the Estuary.

Joint Adaptive Management Plan (AMP)

As noted above in the Introduction, Part 3 of the General Permit provides an adaptive management framework to include ambient monitoring, pollution tracking, reduction planning, review, and timeline for a TN management threshold target. Implementation of adaptive management includes collaboration between EPA, the State of New Hampshire, and public, private, and commercial stakeholders.

An adaptive management process is a valuable approach to refining and advancing watershed-level water quality protection programs, while continuing to develop a better understanding of the watershed to support appropriate investments. An effective adaptive management process is needed in the case of the Estuary to more precisely determine the desired ambient water quality conditions to support desired habitat and aquatic life. Notably, eelgrass is of significant interest due to its decline over the past few decades. The adaptive management process is a means to further TN control measures to improve scientific knowledge specific to the Great Bay Estuary and better understand the substantial scientific causes of the eelgrass decline (i.e., whether the eelgrass decline is caused primarily by TN levels or by a complex combination of factors in the Estuary). Through an iterative process that ensures progress on nitrogen reductions supported by an ever increasingly robust data set to minimize uncertainty of the contributing environmental factors, the adaptive management process is intended to lead to the identification of an appropriate TN management threshold target.

The General Permit and the decision of the municipalities to opt into coverage under it, represent an opportunity to advance water quality planning and implementation of management measures in the face of these uncertainties. This process enables work to proceed on important, inter-related fronts simultaneously. To realize these important benefits for the Great Bay Estuary, the municipalities have elected to work in collaboration with other units of government including EPA and NHDES to enhance their mutual efforts. Examples of the benefits of aligning the General Permit with a broader adaptive management effort include:

- Continue improving and protecting water quality based on sound science and public policy;
- Increasing collaboration and avoiding disputes and delays over uncertain and unanswered underlying scientific and issues related to management of the Estuary;
- Aligning federal, state and local governments on near-term actions and investments;
- Continuing WWTF TN removal, increasing stormwater TN controls, and enhancing ambient monitoring efforts and scientific understanding; and
- Laying a better-informed foundation for any needed additional investments and improvements.

The combination of the General Permit and the adaptive management framework promote effectiveness and cost-effectiveness of TN controls through a balance of wastewater and stormwater controls, while accommodating and strengthening the needed scientific effort to better understand what actions will best protect the Estuary in the long-term. In other words, by carrying out Part 2 (effluent limitations) and Part 3 (Adaptive Management Framework) of the General Permit in parallel, the General Permit advances reasonable further progress in the near-term and appropriately considers the complex technical issues that must be better understood before appropriate TN management thresholds can be determined.

This joint AMP describes and details the activities and measures that are currently being implemented and are planned for the future to achieve the terms and conditions of the General Permit. Consistent with the concept of adaptive management and the annual budgeting process of municipalities, to advance TN controls this is a living document that is being updated at least annually during the permit term.

Municipal Alliance for Adaptive Management (MAAM)

In an effort to better understand and accomplish water quality monitoring and improvement in the Great Bay watershed, MAAM was formed in the winter and spring of 2021 in order to facilitate and enhance community collaboration, stakeholder input, resource sharing, expertise, and efficient use of investment. Currently, Rochester, Dover, Portsmouth, Exeter, Newington, Rollinsford, and Milton have joined as members of MAAM, representing seven communities and eight WWTFs (representing 827 lb/day of the 1,024 lb/day total permitted effluent limitations in the General Permit, i.e., over 80% of the total permitted load). MAAM is overseen by an Executive Board, composed of Rochester, Dover, Portsmouth, Exeter and Newington. In addition, a Stakeholder Committee has been formed for MAAM, led by Conservation Law Foundation (CLF). As background information, a copy of the MAAM agreement is included within Appendix F.

Settlement Agreement By and Between Conservation Law Foundation and Cities of Dover, Rochester, and Portsmouth

In March 2021, a Settlement Agreement was reached between Conservation Law Foundation and the Cities of Dover, Rochester, and Portsmouth. The Settlement Agreement averted an appeal of the General Permit and aimed to enhance collaborative efforts in the watershed. Pursuant to the Settlement Agreement, Dover, Rochester, and Portsmouth recognized and affirmed their commitment to undertaking the activities envisioned in Part 3 of the General Permit, all as an effort to make reasonable further progress on TN source reductions. Like the MAAM agreement, the Settlement Agreement is included here for information because it, along with the General Permit, reflect a new era of collaborative efforts. The Settlement Agreement specifically includes commitments of those three communities, reporting mechanisms, accountability mechanisms, and a shared vision of improved water quality through collaborative efforts. A copy of the Settlement Agreement is included within Appendix H.

Town and City Specific Backgrounds

Dover

The City of Dover is approximately 29 square miles, with a population of 32,000 and is considered one of the fastest growing communities in New Hampshire. The city is bordered by tidal rivers and the New Hampshire Great Bay. The City's Wastewater Treatment Facility (WWTF), located on Middle Road, treats on average 2.5 MGD from approximately 2/3 of the community, while the remaining population continues to use private septic systems. The city also owns and operates a complex citywide network of stormwater infrastructure. The stormwater management is regulated by the NPDES MS4 program, however, the City of Dover has a long history of exceeding the minimum requirements and has invested heavily in Low Impact Development infrastructure and retrofits throughout the city. Additionally, the city recently invested in a multi-million dollar investment at the WWTF to improve nitrogen removal discharging to the Great Bay.

Dover is in the process of developing a Stormwater and Flood Resilience Utility, which is anticipated to be implemented in July 2024. This will incentivize public and private landowners to implement nutrient reducing best management practices in order to receive credit from the fee. As part of the implementation of the utility, staff will receive requests for credits from private property owners outlining the BMP's that have been installed on their property. When staff receives these, the BMP's will be entered into PTAP, which will better account for the non-point source load reductions. Currently PTAP only includes public practices and practices that have been installed in the last few years.

Milton

The Town of Milton is a small community with a population of approximately 4,600 people within the Town's total area of approximately 34.34 square miles. Milton is a manufacturing, resort and residential town, and includes the village of Milton Mills which is the most densely populated area with a total of 575 people. The community is located along the Salmon Falls River, just north of Route 75. The Milton Wastewater Facility services approximately 300 units in the town of Milton and treats annually approximately 22,593,000 gallons of sewerage at an average daily flow of 62,000 gallons. The facility operates at around 62% of plant design capacity allowing future growth within the community.

Newington

The Town of Newington is a small community with a population of approximately 800 people within the Town's total area of approximately 12.5 square miles (8.2 square miles of land, 4.2 square miles of water). The Town includes a large commercial/industrial area, a large area encompassing the Pease International Trade port and NH Air National Guard (NHANG), and Great Bay National Wildlife Refuge. The remaining areas of the Town are mainly slowly developing rural residential areas. Future development and population growth shall be governed by the Town as identified in the Newington Master Plan (May, 2020). The Town's urbanized area (+/- 3.5 square miles) includes very few homes and is almost entirely commercial, industrial, NHANG and Trade port properties. The Town was granted an MS4 waiver in 2013 based on the Town's minimal urbanized area and potential impacts associated within this area. Additionally, Newington site plan regulations include the standards outlined in the Southeast Watershed Alliance Model Ordinance. As such, all redevelopment projects are required to significantly improve stormwater runoff and nitrogen loading. Newington's commercial area is poised for major redevelopment and thus is anticipated to have meaningful nitrogen reductions.

The Newington Sewer Commission, on behalf of the Town of Newington, owns and operates a wastewater collection, treatment and disposal system which serves the entire industrial, office and commercial zoned areas of Town, as well as a small number of residential users. The 0.29-MGD wastewater treatment facility (WWTF) processes sewage as well as septage from residential users which are not connected to the collection system. The collection system includes two pumping stations and approximately 11 miles of sanitary sewers. In anticipation of the Great Bay Total Nitrogen Permit, the Town proactively proceeded with an $8.2M WWTF & Pump Station upgrade project in 2016 to improve performance and provide nitrogen removal capabilities. The WWTF upgrades have allowed the facility to consistently reduce nitrogen to < 3 mg/L (< 2.5 lbs TN/day) during the growing season. This improvement in effluent total nitrogen represents a significant reduction in total nitrogen loading to the Great Bay.

Portsmouth

The City of Portsmouth (City) is a historic community located in southeastern New Hampshire at the mouth of the Piscataqua River. The City has a population of approximately 22,000 people and is a frequently visited tourist destination due to its restaurants, historic past, geographic location, and other amenities. The overall land area of the City is approximately 16.8 square miles (15.6 square miles of land and 1.2 square miles of water). Downtown Portsmouth is densely developed with mixed commercial and residential properties with intermixed industrial development. Outside the downtown, land use is still urban in nature and primarily residential and multi-unit residential with mixed commercial zones. The City has within its boundaries the Pease International Tradeport and NH Air National Guard. The primary land area of the City is private property (~71%) with the remaining land area comprised of Department of Transportation roadway right-of-way (~6%), City roadway right-of-way (7%) and City owned properties (16%). Growth in the City is controlled through land use and zoning ordinances and approval of proposed development through the Planning Board, Zoning Board of Adjustment, Historic District Commission and Conservation Commission as applicable. The City is compliant with its MS4 permit effective July 1, 2018 and NPDES permits for its two wastewater treatment facilities, Pease Tradeport WWTF and Peirce Island WWTF.

The City's Department of Public Works is organized into multiple utility groups overseeing the stormwater collection system, sewer collection system, combined sewer overflows, and water distribution system. The sewer group oversees the treatment of sewerage at the Pease Tradeport WWTF and Peirce Island WWTF. The water group oversees treatment at the Madbury Water Treatment Plant and the Pease Water Treatment Plant. This water group is primarily responsible for the day-to-day operations and long term projects associated with stormwater best management practices, points source discharge points of nitrogen (e.g. WWTFs), and water source protection and water conservation.

The City has long been a regional leader in environmental stewardship and innovation. In 2007 the City Council voted on a resolution to become an Eco-Municipality and use the four principles of The Natural Step (https://thenaturalstep.org/approach/) to guide sustainable decision-making. The City's commitment to sustainability and environmental stewardship shows up in its many proactive efforts to curb pollution, supports science, and minimize impacts on the Estuary. These items cannot always be quantified as a specific nitrogen reduction but are important to support the nitrogen control and reduction efforts and include the following:

- Professional Staffing and Organizational Structure: The City has developed a Stormwater Specialist Position and reorganized personnel to establish a Stormwater Division within the Public Works Department. The City has also hired seasonal interns for the past ten years who's primary work is associated with stormwater field data collection, sampling, and GIS updates. In 2020, we sponsored a University of New Hampshire Capstone project where four engineering students assisted in field work and data input to evaluate stormwater Best Management Practices (BMPs) throughout the city. They utilized the UNH Stormwater Center's Pollution Tracking and Accounting (PTAP (Pollutant Tracking and Accounting Program)) methodology in this project. At the Planning Department there are staff dedicated to site plan regulation compliance for private property and developments. Wastewater operations staff are trained licensed professionals who participate in professional organizations including New Hampshire Water Pollution Control Association, New England Water Environment Association/WEF, and others. Staff participate in these associations to maintain training and stay in front of the most recent industry trends and to optimize treatment operations. NH Department of Environmental Services joined the New Hampshire Water Pollution Control Association to present the 2023 NDES Wastewater Plant of the Year Award to the City's Peirce Island WWTF at the August 21, 2023 City Council meeting.
- Incorporation of Stormwater BMPs: The City incorporates stormwater controls and other BMPs into City projects. Staff continue to work on developing new BMPs by working with consultants and the UNH Stormwater Center. Some examples include Community Campus Athletic Fields

gravel wetland and bio retention stormwater treatment, State Street sand filtration and tree box filters, use of compost tea and incorporation of pervious pavement and other LID (Low Impact Development) type projects within the City. The City has and will continue to work with private and public entities in the installation of rain gardens, tree box filters and other stormwater controls.

- Consulting Services: The City is continuing to work with its stormwater consultant and rate modelling team to identify projects and to initiate a stormwater utility depending on the regulatory landscape.
- Regulations and Ordinance Adjustments: The City Site Plan Review Regulations promote the use of Low Impact Development to the maximum extent practical and set limits more restrictive than the MS4 permit for redevelopment projects. Ordinance changes have increased wetland buffers with credit for going green projects that show added nitrogen removal. Recent efforts include further strengthening controls in the wetland buffers to protect water quality.
- Outreach and Education: City staff work with the Seacoast Stormwater Coalition to develop BMP implementation and regular operation and maintenance requirements for private properties.
- Address the Future: Working with stakeholders, the City seeks to address stormwater, sea level rise, and coastal resiliency issues that impact Portsmouth. This includes addressing the overlap in project needs to address coastal resiliency and impact of tidal changes on stormwater controls in areas like Prescott Park. The City also held a City Council work session to discuss future stormwater management options, including the potential to develop a stormwater utility.

These are some of the efforts put forth by Portsmouth toward supporting improvement of water quality for the Great Bay Estuary. The greatest and most impactful, however, is the recently completed upgrade of the Peirce Island WWTF. Over the last 5 years the Peirce Island WWTF underwent a significant upgrade converting the once primary level treatment facility to a tertiary level nitrogen removal facility with biological treatment. This $92 Million project has decreased the amount of nitrogen discharged to the estuary by over 84%, total suspended solids by over 86%, and biochemical oxygen demand by over 90%.

Rochester

The City of Rochester, located in southeastern New Hampshire, is the one of the five largest municipalities in the state. The City has a land area of 44.8 square miles, water area of approximately .6 square miles and a population of 32,000. The majority of land abutting the .6 square miles of water in the City is owned by private property owners. The City owns 213 parcels containing approximately 1,668.5 acres, but also controls approximately 1,050 acres of right-of-ways. The State of NH Department of Transportation also owns and controls approximately 42% of the right-of-ways (775 acres) located within the City. The City owns and operates a wastewater treatment facility (WWTF) which discharges treated effluent to the Cocheco River. The Cocheco River is within the Great Bay watershed and forms the Piscataqua River at the confluence of the Cocheco and Salmon Falls Rivers. The City has listed planned projects along with associated, estimated capital budget costs in Appendix D.

Rollinsford

The Town of Rollinsford is a small community with a population of approximately 2600 people within the Town's total area of approximately 7.6 square miles along the Salmon Falls River bordering Maine. The Town is densely populated in about 20% of the area. The rest of the Town is mainly slowly developing rural residential areas and conservation land. The Town is an MS-4 community and sweeps 20 lane miles of roadway and cleans 115 catch basins annually, in addition to several outreach measures as a provision of the MS-4 permit. Rollinsford is currently working on a stormwater asset management loan program through NH DES to catalog and map stormwater assets in the Town.

The Rollinsford Water Sewer District is governed by a Commission separate from the Town and provides water and wastewater services to the more densely populated area of Rollinsford.

a) Monitor Ambient Water Quality in Great Bay

In accordance with Part 3-1.a. of the General Permit, this section of the joint AMP outlines the approach to monitor the ambient water quality and eelgrass in the Great Bay Estuary as part of the evaluation of factors affecting eelgrass health.

a.1 Statement of Responsibilities

The Piscataqua Regional Estuaries Partnership (PREP), part of the School of Marine Science and Ocean Engineering at the University of New Hampshire, is currently the organization relied upon by MAAM (and presumably other agencies and stakeholders given PREP's existing responsibilities and capabilities) for ambient water quality monitoring. Through the MAAM, the members are addressing Part 3-1.a. of the General Permit by funding an equitable and proportional amount of the PREP ambient monitoring in the estuary. To date, MAAM has approved funding of $751,100 towards this work and has committed to continue funding monitoring efforts.

To fully implement the research initiatives, it is the hope that all regulated communities participate in proportional and equitable funding. MAAM understands that other communities are participating at some level, however, it is not at an equitable amount based on contributed flow. The following tables show a comparison between an equitable distribution of funding and the actual distribution of funding borne by MAAM communities:

THEORETICAL COST ALLOCATION
for work completed by PREP

FACILITY			
NAME	**Total Permitted Flow**	**SHARE**	**$ 751,100.00**
Rochester	5.03	18.65%	$ 140,082.80
Portsmouth	6.13	22.73%	$ 170,717.20
Dover	4.70	17.43%	$ 130,892.47
Exeter	3.00	11.12%	$ 83,548.39
Durham	2.50	9.27%	$ 69,623.66
Somersworth	2.40	8.90%	$ 66,838.71
Pease ITP	1.20	4.45%	$ 33,419.35
Newmarket	0.85	3.15%	$ 23,672.04
Epping	0.50	1.85%	$ 13,924.73
Newington	0.29	1.08%	$ 8,076.34
Rollinsford*	0.15	0.56%	$ 4,177.42
Newfields	0.12	0.44%	$ 3,341.94
Milton*	0.10	0.37%	$ 2,784.95

ACTUAL COST ALLOCATION
for work completed by PREP

FACILITY			
NAME	Total Permitted Flow	SHARE	$ 751,100.00
Rochester	5.03	24.42%	$ 183,399.66
Portsmouth	6.13	29.76%	$ 223,506.94
Dover	4.70	22.82%	$ 171,367.48
Exeter	3.00	14.56%	$ 109,383.50
Pease ITP	1.20	5.83%	$ 43,753.40
Newington	0.29	1.41%	$ 10,573.74
Rollinsford*	0.15	0.73%	$ 5,469.17
Milton*	0.10	0.49%	$ 3,646.12

MAAM is also funding the work of its consultants, Brown & Caldwell, who have been working with the PREP team on the continued development of the monitoring program. See Appendix F and Appendix G of this AMP for MAAM agreement and authorization to fund work.

a.2 Summary of Plan

This plan covers "ambient water quality" monitoring including potential physical and biological stressors that may be affecting eelgrass health in the estuary, including but not limited to nitrogen. The starting point for this plan was PREP's RAMP (Appendix A) and the Research/Monitoring Prospectus (Appendix B). Since 2020, PREP, PRMC, and MAAM have conducted an annual planning exercise that involves various discussions over the year and leads to MAAM's annual prioritization of funding opportunities. All monitoring data described in this section, including the underlying information used to calculate nutrient loads, will be made publicly available.

Data Collection

- Nutrient load estimating
  - Calculated for point and non-point sources on an annual basis.
- Water quality monitoring (e.g., dissolved oxygen, nutrient concentrations, total suspended solids (TSS), chromophoric dissolved organic carbon, etc. [1]) in seven tributaries to Great Bay Estuary
  - Samples are taken between March and December for each year of the permit period. Results are generally available by summer of the following year.

[1] The complete list of water quality analytes will be specified in related monitoring documents and will include factors that potentially cause or contribute to conditions that many affect eelgrass health as well as other general water quality parameters.

- Water quality monitoring at approximately 12 stations in the Great Bay Estuary, including the same parameters monitored in the rivers, as well as light penetration, plankton and chl-a.
  - Samples taken between April and December for each year of the permit period. In addition datasondes will automatically collect certain data every 15 minutes.) Results are generally available by summer of the following year.
- Beginning in 2023, for both tributary and estuarine monitoring, sampling has been extended into the winter months for all stations that are accessible during these months.
- Eelgrass
  - Distribution
    - Tier 1 aerial monitoring was originally planned to be assessed every two years, however, the MAAM communities have seen value in having more frequent data and are now funding an annual assessment.
  - Measures of eelgrass abundance and health (e.g., percent cover, canopy height, biomass, density, epiphyte load)
    - Tier 2 assessments at 25 sites in June/July with 8 sites being sub-sampled in April and October.

  - Water quality and sediment monitoring associated with Tier 2 are described in Appendix C.

  - Green crabs
    - Additional measures of green crab abundance have been implemented in recent years to assess potential eelgrass damage caused by this stressor. Information is available from the State of Our Estuaries: Extended Version, located at: https://scholars.unh.edu/prep/466/

- River discharge measurements

  MAAM has funded a PREP study with the goal of extending existing tributary discharge monitoring at three locations. The project has two major steps: (1) a review of appropriate methods; and (2) working with USGS to deploy stage height sensor and build a rating curve. The first step was funded in 2023 and will serve to establish methods and initiate measurements. Full rating curves will be not be available in 2023, but would presumably be developed as soon as sufficient discharge measurements are available.
- Seaweed
  - Measures of abundance (e.g., percent cover, biomass, ID of species) are incorporated into the Tier 2 program mentioned above at all 25 sites.
- Sediment
  - Percent organic matter and grain size are part of Tier 2 at 25 sites.

Data Analysis and Accessibility

- Data Analysis
  - The monitoring data described in the prior section is being evaluated to assess relationships between potential eelgrass stressors and the metrics of eelgrass health. The data will also be appended to prior monitoring data collected by PREP to

contribute to the long-term data collection effort already underway. Temporal trends in the data will be assessed as new data become available.

- Data Accessibility
    - PREP provides broad access (see below) to all data collected, so that the data will be available to the municipalities, EPA, NHDES, and stakeholders for their own analyses.

      PREP intends that all data will be accessible to the public through PREP's new data management system. This system can be accessed through the Piscataqua Watershed Data Explorer (http://data.prepestuaries.org/data-explorer/).

Stakeholder Engagement

- The Piscataqua Region Monitoring Collaborative (PRMC), meets at least once a year to coordinate monitoring and science for the Great Bay Estuary. Participation in the PRMC is open to all municipalities in the Piscataqua Watershed.
- Technical recommendations on science activities come from the PREP Technical Advisory Committee (TAC) process, which is open and transparent and consensus based.
- MAAM has hired Brown & Caldwell to consult and advise MAAM on current and future PREP ambient water quality monitoring and to make recommendations for both short-term and long-term efforts suited to informing the AMP and future efforts by the communities. In particular, Brown & Caldwell will be advising on the studies necessary to broaden our review of the stressors on eelgrass beyond simply measuring nitrogen levels in the estuary.
- A Stakeholder Committee has been convened by CLF to provide insight and recommendations on activities and efforts of MAAM, and to track progress on commitments made in the Settlement Agreement. The Stakeholder Committee includes technical experts as well as representatives from Dover, Portsmouth and Rochester.
- MAAM representatives participate in the Project Advisory Committee (PAC) of the Great Bay Eelgrass Resilience Project, a NOAA-funded research project led by the University of New Hampshire, the Great Bay National Estuary Reserve System, and PREP.
- MAAM and the respective municipalities invite and encourage broad participation by interested parties in the stakeholder engagement process to provide insight and recommendations on activities and efforts of MAAM. MAAM meetings are publicly noticed and generally open to the public. Public MAAM meetings provide an opportunity for public input by those in attendance.

See Appendix B of this AMP for full PRMC prospectus

b) Methods to track reductions and additions of total nitrogen

In accordance with Part 3-1.b. of the General Permit, this section of the joint AMP outlines the method(s) to track reductions and additions of TN loads over the course of the permit.

b.1 Statement of Responsibilities

The municipalities are coordinating with NHDES, UNHSC, EPA Region 1, other permitted communities and other stakeholders to participate in the Pollution Tracking and Accounting Program (PTAP). The PTAP program has been developed by NHDES in response to the request for assistance by the regulated communities and is intended to provide a cost-effective means by which communities can effectively address the tracking and accounting requirements of this General Permit while also providing the flexibility and ability to track other potential water quality stressors. To date, NHDES has been the lead on implementing PTAP using resources developed by EPA Region 1 for this purpose. The MAAM members are addressing Part 3-1.b. of the General Permit through continued participation and equitable funding of PTAP efforts through MAAM as well as implementing the tracking and accounting program within the municipality. As with other aspects of this AMP, the proposed tracking and accounting program, PTAP, is reviewed annually and, if appropriate, updated to take into account the latest information. The PTAP program also has the ability to track other pollutants such as Total Phosphorus, Total Suspended Solids, metals and runoff volume within the same program.

PTAP has been funded primarily by NHDES, with $50,000 annually approved from the MAAM communities intended to provide additional technical assistance and assist in one-on-one community support for any municipality that needs it in the watershed regardless of their affiliation with MAAM. In future years, additional appropriations would be needed to fund and operate this program. The following tables show a comparison between an equitable distribution of funding and the actual distribution of funding borne by MAAM communities:

THEORETICAL COST ALLOCATION
For PTAP work

FACILITY			
NAME	**Total Permitted Flow**	**SHARE**	**$ 100,000.00**
Rochester	5.03	18.65%	$18,650.00
Portsmouth	6.13	22.73%	$22,730.00
Dover	4.70	17.43%	$17,430.00
Exeter	3.00	11.12%	$11,120.00
Durham	2.50	9.27%	$9,270.00
Somersworth	2.40	8.90%	$8,900.00
Pease ITP	1.20	4.45%	$4,450.00
Newmarket	0.85	3.15%	$3,150.00
Epping	0.50	1.85%	$1,850.00
Newington	0.29	1.08%	$1,080.00
Rollinsford*	0.15	0.56%	$560.00
Newfields	0.12	0.44%	$440.00
Milton*	0.10	0.37%	$370.00

ACTUAL COST ALLOCATION
for PTAP work

FACILITY			
NAME	**Total Permitted Flow**	**SHARE**	**$ 100,000.00**
Rochester	5.03	24.42%	$24,420.00
Portsmouth	6.13	29.76%	$29,760.00
Dover	4.70	22.82%	$22,820.00
Exeter	3.00	14.56%	$14,560.00
Pease ITP	1.20	5.83%	$5,830.00
Newington	0.29	1.41%	$1,410.00
Rollinsford*	0.15	0.73%	$730.00
Milton*	0.10	0.49%	$490.00

b.2 Summary of Plan

PTAP is a comprehensive sub-watershed based tracking system for quantifying the nitrogen load reductions and additions through implementation activities that include, but are not limited to:

a. Land use conversions
b. New or modified structural stormwater control measures
c. New or modified non-structural activities
d. New, modified or removed septic systems

Tracking elements include parcel/treatment area identification information that document the municipality, land use, hydrologic unit code (HUC-10), hydrologic soil group or estimated infiltration rate, drainage area, and impervious cover area.

Additional information regarding structural stormwater control measures collected from each community include structural control measure type, runoff volume storage at design capacity (also known as design storage volume), and runoff depth from impervious cover.

Additional information regarding non-structural implementation measures for each community is also collected, including catchbasin cleaning, street sweeping, leaf litter collection and fertilizer control programs. Units and metrics to track these efforts more effectively are still being developed. In keeping with the EPA Region 1 letter of endorsement dated August 15, 2022 and signed by Melville Cote, Chief Surface Water Protection Branch Water Division, the current accounting for sweeping includes use of the credits developed under the Clean Sweep Panel Process Additional technical assistance may be required to update the EPA BMP Accounting and Tracking Tool (BATT) with these methods once a final determination on future accounting metrics is made.

Additional nonstructural practices for tracking include outreach and education, wetland buffer protection/conservation land, pet waste collection and oyster bed restoration along with other efforts, with the intent of identifying promising future water quality improvement activities. It should be noted that there are no existing approved nitrogen load reduction credits that exist for these important efforts and future collaborations to create them are anticipated.

Finally, wastewater management approaches planned for tracking include installation of innovative septic systems and enhanced treatment technologies and connection of septic systems to public sewer. Another area for technical assistance from the region is the determination of appropriate credits for these methods, particularly elimination of NPS loads through sanitary sewering. Many methods to credit this exist, we anticipate a collaborative effort will be necessary to standardize attendant load reduction credits.

Accounting

Preliminary accounting metrics that include changes in nitrogen, phosphorus and TSS loads attributable to changes in effective impervious area are currently included in the PTAP database. NHDES along with UNHSC use the input information to import into the EPA Region 1 BMP Accounting and Tracking Tool (BATT). The BATT provides automated reporting features to credit tracked structural and nonstructural implementation measures and provide reduction estimates consistent with the methodologies used to develop the reduction estimates presented in Appendix F of the MA and NH MS4 permits.

https://www3.epa.gov/region1/npdes/stormwater/nh/2017-appendix-f-attach-3-sms4-nh-mod.pdf

Results from permit year 2 are included for all participating communities in Appendix E.

Long-term tracking of nitrogen loads from land use conversions

In combination with local tracking and accounting, MAAM expects to track changes to TN loadings as well as other nutrient and pollutant changes due to land use, through Geographic Information Systems (GIS) analysis. Thematic mapping of land is planned to be undertaken every 5 years in coordination with UNH GRANIT, New Hampshire's Statewide GIS Clearinghouse. GRANIT collects the necessary GIS feature classes such as land use, hydrologic soil group (HSG), and impervious cover. Changes in one of ten categories of consolidated land uses will be tracked in addition to impervious cover. Changes to nitrogen loads associated with land use changes over the permit term will use EPA provided NLERs. A summary of land use changes has been developed through the efforts currently being led by EPA Region 1 on the hydrologic response unit and opti-tool project. MAAM communities anticipate a collaborative effort to distill and standardize these changes will occur over the next permit year. Determination of positive or negative pollutant loading due to land use change requires collaboration and agreement between all parties involved in the GBTNGP.

Municipal Participation: Program Development and Technical Assistance for Tracking Activities

Community participation in PTAP is supported through regular workgroup meetings to provide opportunities for end users to offer input on PTAP tracking database functionality, reporting units for tracking, accounting methods, and more. To date, the PTAP workgroup has met 23 times over the course of several years and has a strong record of collaborative PTAP tool development. MAAM member communities will continue to participate in these work groups. Work group meetings are typically facilitated by UNHSC and NHDES staff and have clear outcomes that are intended to further PTAP tracking tool development. Additionally, UNHSC and NHDES staff offer technical assistance for PTAP database use, as needed. Assistance includes one-on-one trainings, focused workshops, expert panel reviews, and resources made available on the internet on UNHSC, GRANIT, and NHDES platforms.

Tracking of activities is accomplished through the addition of PTAP filing as part of a land development permitting requirement. Much of these tracking elements are already part of both state and local permitting requirements for many land development projects, such as changes in impervious cover, land use conversion, area and volume treated, treatment measures, etc. PTAP is a central repository where this information can be uploaded by project permittees and stored for later use by the municipality for annual reporting requirements.

c) Overall Source Reduction

In accordance with Part 3-1.c. of the General Permit, this section of the joint AMP provides an outline for overall source reductions of TN over the course of the permit.

c.1 Statement of Responsibilities

The MAAM members intend to address Part 3-1.c. of the General Permit by creating and maintaining an updated list of current and anticipated capital improvement projects, non-structural best management practices, stand-alone projects with structural best management practices, and municipally owned properties with high nitrogen removal potential, as well as diverse initiatives intended to address water quality improvement in the Great Bay Estuary.

c.2 Summary of Plan

The lists of projects, practices, properties and initiatives is intended as a non-binding statement of present intent by the MAAM members. Completion of these projects is dependent on the continued validity of the General Permit, technical study and feasibility, purchasing approvals from governing bodies of the respective municipalities and/or other public officials, funding appropriations of the respective Municipalities (which funding appropriations are at the sole discretion of the governing body of the respective municipalities), any other requirements of law, potentially including federal/state/local permitting, and general public support. The MAAM members may select projects that are likely to improve water quality, including those for which nitrogen removal is one of multiple benefits.

See Appendix D of this AMP for Current Source Reduction Plans for each MAAM member community.

d) Process for Comprehensively Evaluating Significant Scientific and Methodological Issues

In accordance with Part 3-1.d. of the General Permit, this section of the joint AMP outlines an inclusive and transparent process for comprehensively evaluating any significant scientific and methodological issues relating to the permit, including the choice of a load-based threshold of 100 kg/ha/yr versus any other proposed threshold, including a concentration-based threshold of 0.32 mg/L.[2] This submission shall include detailed milestones culminating in submission of a report to EPA for inclusion in the administrative record for permit renewal. That report shall be completed prior to expiration of the permit term and shall indicate whether NHDES concurs with the findings.

d.1 Statement of Responsibilities

The municipalities participate in a collaborative process building upon the research efforts of PREP described above. Both non-regulatory and regulatory monitoring components of this plan are being implemented. The regulatory component encompasses the monitoring activities that are required by the General Permit, whereas the non-regulatory component encompasses all other monitoring described in this plan. The non-regulatory components are facilitated by PREP through its Technical Advisory Committee and PRMC processes, both of which are open to the public, are transparent, and use consensus-based decision making. The municipalities expect that the threshold target will be developed cooperatively with NHDES, using data collected through this plan and will be accessible to all parties. An expert review panel is an element of this plan, most likely involving several meetings with stakeholders to understand the issues, review the data, and share preliminary and final recommendations. Currently, an expert review panel comprised of four external ecologists is advising PREP and partners with regard to the Research and Monitoring Plan (RAMP) as well as the State of Our Estuaries Report and the NOAA-funded "Eelgrass Resilience Project". These four experts have been agreed on between PREP, DES and the MAAM and consist of Jud Kenworthy, Simon Courtenay, Michael van den Heuvel, and Lora Harris. It is important to acknowledge that this group may need to change when the focus shifts to the development of an appropriate TMDL or TMDL alternative, since these particular experts were not chosen with that particular objective in mind."

The MAAM members are addressing Part 3-1.d. of the General Permit by funding an equitable and proportional amount of the PREP work and other research initiatives through MAAM and by participating in both components individually or through MAAM representatives. To date MAAM has funded $751,100 toward monitoring activities which will feed data into the modeling and analysis components of Section d. See Appendix F and Appendix G of this AMP for the MAAM agreement and invoices.

[2] Reference to these load based and concentration based threshold numbers are for example only and are not an endorsement or prediction of the final TN management target thresholds.

d.2 Summary of Plan

This plan evaluates potential eelgrass stressors in the Estuary to identify levels of potential stressors that are protective of water quality and eelgrass health. To identify an appropriate TN target, this plan includes an evaluation of latest scientific data and information described above in this AMP it is necessary to understand how various levels potential stressors affect eelgrass health and improve water quality.

Once the transport and concentrations of relevant constituents throughout the estuary are better understood and the tools and information are developed to reliably translate loads to concentrations at numerous locations in the estuary, the work can begin to understand the potential impacts of nitrogen and other stressors on eelgrass health and water quality impairments in the Great Bay estuary. MAAM anticipates that this work will contribute to developing a scientific consensus on the factors affecting eelgrass health in the estuary in order to establish appropriate water quality and target thresholds that promote eelgrass restoration and improved water quality.

Water Quality Model Translation between Concentrations and Loads

Managing anthropogenic contaminants in an estuary requires an understanding of how changes in loading will affect concentrations in the waterbody. To address this issue, PREP plans to use a recently developed 3D hydrodynamic model to understand how loads relate to concentrations. The transport component of the model includes exchange of materials between the sediment bed and water column to account for the potential of sediment to be a local source or sink of modeled constituents.

A three-year proposal (See Appendix C) to apply and modify the model described above has been successfully funded by the National Oceanic and Atmospheric Administration (NOAA) program. It is anticipated that the milestone of developing an initial version load-concentration translator will be met by November 2024. Additional work will be necessary to take the project results and develop the translator model. For example, this version of the model will simulate ambient water quality processes in a simplistic fashion, and will not (yet) support a full eutrophication simulation. Also, while this model covers the entire estuary, much of the recent empirical validation work was conducted in Great Bay Great Bay Proper. Further work may be required to extend this work to other portions of the Estuary.

Although the load-concentration translator is not expected to be ready for full application this general permit term, it will serve as the foundation for related efforts in the following permit term.

Determining appropriate TN management thresholds

As noted in the 2014 peer review, setting guidance for nutrient levels will require several components. First, we will need to use the data referred to in previous sections to conduct stressor response analyses and to move toward a process-based ecosystem model. This will enable our communities to understand how different parts of the Estuary are responding to the complex dynamics at work, and the role that nitrogen and other stressors play in eelgrass health. The tools and information will be available to all parties to evaluate on their own and/or as a collaborative group. In addition, an expert review panel will review available information and provide recommendations regarding the studied stressors, eelgrass health in the estuary, and potential management actions or target thresholds.

Originally, the tool for relating loads to concentrations in the estuary was expected to be complete no later than September 30, 2024. As the project has moved forward, it is clear that additional work will be necessary after this date, working with the Expert Review Panel, to relate loads to concentrations in Great Bay Proper. More work needs to happen to consider extending this approach to other parts of the Estuary. The work of moving from project results to translation of loads to concentrations will be led by NHDES.

Using the information gathered in that project, MAAM plans to complete a report prior to the permit term as required by Part 3 of the General Permit. This report will include status of technical activities and interpretations of stressor-response, including the current understanding of the role of nitrogen and associated loading or concentration thresholds. It will also outline a path forward for refinement of technical tools and completing a TMDL or TMDL alternative. At this time, the MAAM members anticipate submitting a report to EPA for inclusion in the administrative.

Inclusivity and Transparency

The processes outlined above includes periodic discussion and review by MAAM members and/or its Executive Board. MAAM continues to consult its members, non-MAAM members, state and federal regulators, and other stakeholders throughout the process for their input. Additionally, the MAAM's Stakeholder Committee, led by Conservation Law Foundation, attends MAAM meetings to provide input, perspective, and any data or other information to be considered. Finally, as outlined above, the technical work will be completed by PREP and will consider input from any interested party. MAAM members also coordinate the work with NHDES periodically and at critical decision-making intervals, such that the NHDES will either concur with the submission entirely or to the maximum extent of possible consensus, with any areas lacking consensus called out and the parties' respective views explained.

e) Timeline for Completion of TMDL or TMDL Alternative

In accordance with Part 3-1.e. of the General Permit, this section of the joint AMP outlines a proposed timeline for completing a Total Maximum Daily Load (TMDL) or TMDL Alternative for TN in Great Bay and for submitting it to EPA for review and approval.

e.1 Statement of Responsibilities

The MAAM members are strongly committed to supporting appropriate efforts to establish a scientifically-sound, cost-effective approach to determining appropriate TN threshold targets for the Great Bay Estuary and recognize that establishing a TMDL or a potentially more appropriate but effective alternative to a TMDL may be beneficial. The currently proposed timeline for completion of a TMDL (or appropriate alternative plan) is set forth in section e.2. below. As with other aspects of this AMP, the proposed timeline will be reviewed annually and, if appropriate, updated to take into account the latest information. Ultimately, NHDES will take the lead on the establishment of a TMDL (or appropriate alternative plan), and will dictate the final timeline.

e.2 Summary of Plan

As described in previous sections, this AMP includes new monitoring, pollution tracking, reduction planning, scientific investigation and analysis, and related decision-making elements for the Great Bay Estuary. These elements will improve our scientific understanding of the Great Bay estuary, the role of nitrogen, and the role of other stressors. Toward the end of the first permit term, it is anticipated that sufficient new information will become available to support thoughtful consideration of potential regulatory and non-regulatory applications, including potentially a TMDL or TMDL Alternative for TN to be completed over the subsequent permit term(s).

Similarly, new information may support an alternative approach to addressing TN loading necessary for eelgrass protection taking into account the state of the science and various practical considerations that may favor other water quality management planning approaches supported by EPA and state agencies. An example would be a 5R plan that addresses multiple stressors and relies on iterative implementation/monitoring. In certain circumstances, these alternative approaches to planning for water quality protection may be preferable to a TMDL to leverage on-going restoration activities and adapt implementation to new information.

With this background, and with the support of NHDES, the MAAM communities propose a TMDL or TMDL Alternative completion timeline of Year 5 of the Second Permit Term (or at the end of 10 years in the event that the EPA is delayed in issuing a second permit term). This is an expeditious timeline that supports municipal investment in data monitoring, data analysis, related studies, computer modeling, and long-term management plans. Pursuant to the General Permit and this AMP, TN reductions will occur in parallel with these important activities. Further background on the basis for the proposed timeline, and how the proposed timeline enables integration of the various major tasks under Part 3 of the General Permit and this AMP, is as follows.

Consistent with the adaptive management outline elements specified by the General Permit, the proposed timeline assumes an initial focus on improved scientific understanding, followed by a decision point on the restoration planning approach.

We are currently at the end of the second year of the first permit term, by the end of the fourth year we anticipate making a recommendation to either pursue a TMDL or TMDL Alternative, such as a 5R restoration plan. Our proposal would include a rationale and recommendations for technical approaches for developing the TMDL or TMDL Alternative plan. The proposed timeline for completion accommodates elements for reaching consensus on the path forward in time to incorporate elements of the restoration planning process into the second General Permit.

Regardless of which restoration planning approach is chosen, we anticipate that its development will be a major activity of the second permit term. The proposed timeline accommodates adaptation of data and tools for regulatory purposes, additional modeling, drafting of the TMDL or TMDL Alternative plan, and extensive stakeholder review/communications to achieve consensus. Because the proposed completion timeline aligns with the end of the second General Permit term, the results would be available in time to inform the permit renewal for the third term. This proposed completion timeline is subject to revision as appropriate based on future developments.

Illustration of MAAM Anticipation Milestones Associated with Proposed Completion Timeline for Final Plan – Final timeline to be dictated by NHDES

Activity	First Permit Term					Second Permit Term				
	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
Monitoring & scientific studies										
Synthesis and interpretation of first term monitoring										
Proposal: Restoration planning approach (TMDL vs. alternative)										
Reach consensus on restoration planning approach										
Modeling/technical analysis to support restoration plan										
Draft plan										
Final plan										

Appendix A

Integrated Research and Monitoring Plan for Piscataqua Region Estuaries Partnership (RAMP)

Integrated Research and Monitoring Plan

FOR

Piscataqua Region Estuaries Partnership

OVERVIEW OF APPROACH: GOALS, CONCEPTUAL MODELS, QUESTIONS

DRAFT: MAY 2020

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Piscataqua Region Estuaries Partnership (PREP)

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ACKNOWLEDGEMENTS

The development of this update to the Piscataqua Region Estuaries Partnership was funded wholly or in part by the United States Environmental Protection Agency. The contents of this document do not necessarily reflect the views and policies of the Environmental Protection Agency, nor does the EPA endorse trade names or recommend the use of commercial products mentioned in the document.

Input was provided by technical experts from the Piscataqua Region, including researchers from the University of New Hampshire, the NH Chapter of The Nature Conservancy, NH Fish & Game, NH Department of Environmental Services, and the Great Bay National Estuarine Research Reserve. In addition, this outline has been influenced by two external advisors: Brad Peterson from Stony Brook University and Jud Kenworthy, retired from NOAA. Finally, significant input has been provided by the PREP Technical Advisory Committee (TAC) co-chairs: Bonnie Brown and Wilfred Wollheim, both of UNH.

The Piscataqua Region Estuaries Partnership (PREP) is a nonprofit organization and a National Estuary Program, a joint local/state/federal program established under the Clean Water Act with the goal of protecting and enhancing nationally significant estuarine resources. PREP focuses on the Great Bay Estuary and the Hampton-Seabrook Estuary.

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INTRODUCTION

The purpose of the PREP Integrated Research and Monitoring Plan (hereafter, "the Plan") is to list and prioritize the most critical research and monitoring activities with the goal of tracking the status and trends of key biological resources as well as understanding the trends; "understanding" is critical for developing appropriate management actions. The plan is also intended to lead to increased integration of work and consolidation of resources. The scientific activities are driven by the goals of the PREP Comprehensive Conservation and Management Plan (CCMP). (The CCMP can be accessed at: https://scholars.unh.edu/prep/22/).

The first Monitoring Plan for PREP was published in 2004 and last updated in 2008. (Accessible at: https://scholars.unh.edu/prep/71/). Since then, new data programs have been initiated; others have been terminated, and our understanding and questions about our estuaries have evolved. PREP manages or supports some of these programs, but many are led and supported financially by state and federal partners or non-governmental organizations. It is PREP's role to facilitate these partnerships and regularly synthesize, analyze, and report on science activities relevant to the management of our estuaries. This new Plan provides an opportunity to re-engage scientists and stakeholders around its cooperative implementation.

Rather than revise or polish the previous plan, PREP has elected to take a step back and approach the ew RAMP from a fresh perspective. Following examples from other successful estuary programs, this process starts with Goals, proceeds to Questions (both monitoring and research questions) and then to Methods. Finally, we include a Priorities step at the end so that new resources can be more efficiently allocated, and so we can tackle problems in a logical chronological order.

This plan focuses on five foci that are strongly featured in the CCMP; however, not everything in the CCMP is represented in this Plan. Rather, we have chosen five subjects that have considerable "leverage,": that is, to address these subjects necessitates addressing other issues of significant import. The five foci are: fish; shellfish; salt marsh; eelgrass; and humans. Issues and scientific activities not addressed by focusing on these five subjects are likely to be addressed in Plan addenda in the future.

See the following page for an illustration of the phased approach with an approximate timeline and salient process notes.

Process Notes for the May 2020 Draft

The first four sections (Shellfish, Eelgrass, Salt Marsh and Fish) were all reviewed, voted on and approved by the PREP Technical Advisory Committee (TAC) at a virtual meeting held April 20. The "Humans" section is expected to be approved by the TAC by early July, either electronically via an additional virtual meeting.

Integrated Research & Monitoring Plan Phases & Timeline

Purpose: Create an integrated plan focused on fish, shellfish, salt marsh, eelgrass and humans; these focus areas are based on PREP's Comprehensive Conservation Management Plan (CCMP). The plan will proceed from resources goals (e.g., 10 million oysters) to science questions to metrics and relationships to specific methods. Finally, methods will be prioritized so that new resources will be applied to those activities that need to be tackled first.

Goals (by February 2020)

For key resources, review existing goals and add more detail (e.g., around health as well as abundance) where required. (Not re-assessing currently established goals.)

Models/Questions (by April 2020)

Using conceptual models, formulate questions needed to assess whether goals are reached and, if not, what management actions are most likely to help.

Methods (by September 2020)

Decide on the most appropriate scientific activities (monitoring and research) to answer the questions; this includes the means, place and frequency of data collection, as well as how data will be analyzed.

Priorities (by December 2020)

For each key resource, prioritize all activities so that new resources can be applied to the most critical next step.

Salient Process Notes

- Small groups of subject-matter experts used to work out details and drafts for each of the above elements.
- PREP Tech Advisory Committee (TAC) comes to consensus on the above elements.
- External (that is, non-local) expertise used for Questions, Methods and Priorities.
- Three TAC meetings expected in 2020 (~April, ~September, ~December); electronic sharing of ideas happens between TAC meetings.
- When Priorities have been established, additional time will be necessary to complete and format report. Expected completion is May 2021.

RAMP APPROACH TO GOALS

The CCMP (https://scholars.unh.edu/prep/22/) was published in 2010 after considerable stakeholder input. For the development of the RAMP, PREP has decided not to re-negotiate established goals, such as the goal to increase oyster abundance in the Great Bay Estuary to 10 million oysters; we do not feel that we have the data to justify increasing or decreasing established numerical goals. However, we do feel it's appropriate to recommend additional goals needed to better restore and protect estuarine resources. Using oysters as an example, we recommend that some measure of oyster "productivity" be added as a goal so that we can then develop scientific questions and methods to address these goals. The theme of adding "productivity" as a central concern pervades many of the recommendations in this document.

Overarching Goals

The TAC co-chairs recommend that PREP articulate an "overarching goal" that is short, ambitious and easily understood. More detailed and nuanced goals can be added, both for the whole ecosystem as well as for each individual focus area (e.g., fish, salt marsh, etc.). After several meetings with technical experts with different specializations, several themes emerged around the overarching goal:

- Although it seems arbitrary, the overarching goals and sub-goals need to reference a point in time in recent history; starting this period in the early 1970s made the most sense since many data collection programs began in the 70s and 80s.
- Consider using multiple goal statements at various levels of scale, so the statements are more digestible.
- The sub-goals need to recognize that some changes are inevitable; therefore, goals should be ambitious but recognize that some species shifts will occur no matter what management steps are taken.

Draft Overarching Goal Statements

Highest Level Goal

We strive for a balanced, productive ecosystem of indigenous aquatic species and habitats.

Sub-Goal 1

We focus in particular on the following non-human resources: shellfish, eelgrass, salt marsh and fish. We strive for these resources to be as abundant and productive as they were at their respective peaks during the period beginning in the early 1970s and extending to the present day.

Sub-Goal 2

We also focus on humans. In that regard, we strive to have fish and shellfish that are safe for human consumption as well as clean water that is safe for swimming.

More specific goals for the five "resources"—shellfish, eelgrass, salt marsh, fish and humans—can be found in the specific resource sections that follow.

THE PLAN'S USAGE OF CONCEPTUAL AND ECOSYSTEM MODELS

This plan will use general conceptual models and more detailed ecosystem models. These models serve several purposes, including:

- Communicating to stakeholders which ecosystem components are under consideration and how they relate to each other;
- Organizing and prioritizing data needs and gaps;
- Providing a quantitative method for understanding potential impacts of certain management actions. In other words, when we have enough data, we can use quantitative models to better understand how different components could impact each other.

*Note that using conceptual models doesn't preclude other analytical tools (e.g., statistical modeling).

Each of the five resources will have its own general and detailed models. The model below is the most general model, illustrating the five focus areas and major stresses upon those components.

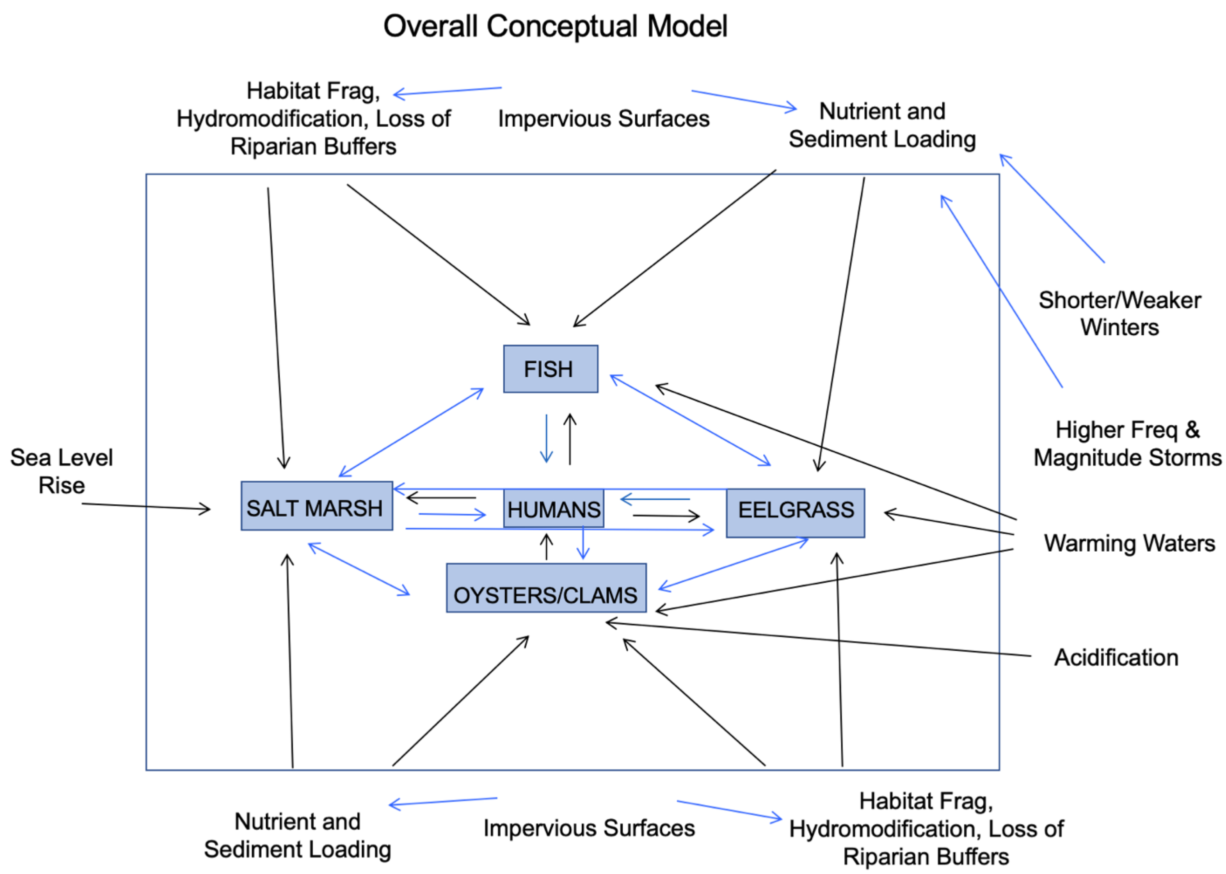


Figure 1. Conceptual model showing five focus areas of the RAMP. Blue arrows indicate an "increasing effect" while black arrows indicate a "decreasing effect." (E.g., Humans can have a negative impact on eelgrass through pollution, while eelgrass has a positive effect on humans through storm buffering.) Not all relationships are indicated by arrows in order to minimize visual complexity. Note that stressors on the left and right of the model are less amenable to management. The stressors on the top and bottom of the model are the same and are considered more amenable to management. More detailed conceptual models will accompany each focus in this Plan—shellfish, eelgrass, salt marsh, fish and humans.

SHELLFISH

This section focuses on the "Eastern Oyster" (*Crassostrea virginica*) in Great Bay Estuary and soft-shelled clam (*Mya arenaria*) in Hampton-Seabrook Estuary. Other species of shellfish, including mussels, different species of oyster and clam as well as lobsters and horseshoe crabs will be addressed in future addenda to the RAMP.

<u>Goals Specific to Oysters and Soft-Shell Clams</u>

- From CCMP
    1. Increase the number of adult clams in the Hampton-Seabrook estuary to 5.5 million clams by 2020. *(In 2018, there were less than 2 million clams.)*
    2. Increase the abundance of adult oysters at the six documented beds in the Great Bay Estuary to 10 million oysters and restore 20 acres of oyster reef habitat by 2020. *(In 2016, it was estimated that we had 2.8 million oysters. With regard to restoration, more than 20 acres of restoration "footprint" has occurred, but restoration activities have not all been successful. More monitoring is required to determine the amount of oyster reef currently present.)*
- Additional Goal Recommendations
    a) Add a productivity metric for both oysters and clams. The metric should encompass different aspects of productivity such as: larval production, settlement, survival to adult stage, with the goal that the resource is more self-sustaining.

    Reminder: Goals/metrics around safety for human consumption—which could include legacy and emerging toxic contaminants, biotoxins and bacteria—will be addressed in the "Humans" section.

OYSTER MONITORING AND RESEARCH QUESTIONS

<u>Approach to Reaching Above Goals</u>

Management actions (e.g., modification of harvest regulations; restoration; aquaculture, etc.) are currently underway or under consideration. The key question is: <u>Should current management actions be continued, discontinued, modified or added to?</u>

Monitoring Questions are presented below on a spectrum from Level 1 to Level 3.

Level 1 = Monitoring questions catalyzed by simplest conceptual model (see Figure 2).

Level 2 = Monitoring questions catalyzed by detailed conceptual model (see Figure 3).

Level 3 = Questions based on detailed model that require preliminary investigation before becoming monitoring or research questions; or, questions that call for time-limited, discrete research projects.

***Note** The levels are not prioritization tiers; they simply provide an organizational scheme for making sure all factors are addressed. When we prioritize, we may find that the highest priority activities are a mix of Level 1, 2 and 3 activities.*

Current and potential management actions and their impacts must be considered in relation to factors amenable to management (e.g., harvest regulations, restoration, sediment management) versus factors that are less amenable to management (e.g., warming waters, acidification, etc.). Therefore, science activities need to consider both kinds of factors and how they relate to each other.

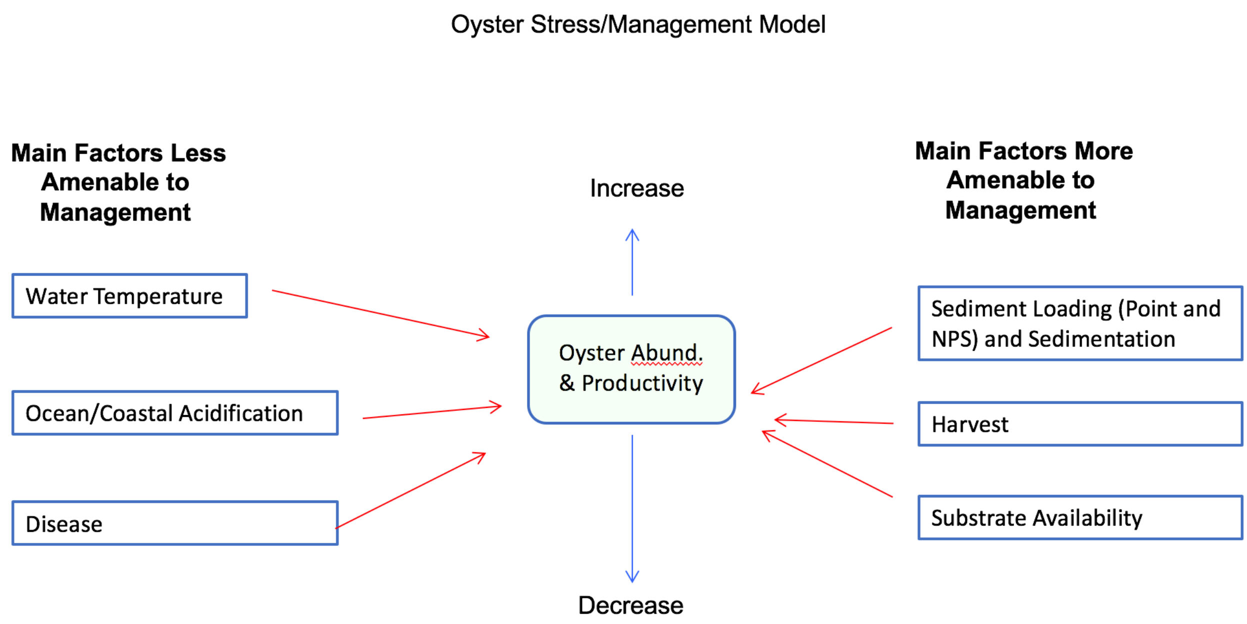
Some current management actions include:

- Oyster Restoration
- Aquaculture (producing additional larvae)
- Substrate Addition
- Nutrient and Sediment Reduction (Non-Point and Point)

Some potential management actions include:

- Increased nutrient and sediment reduction efforts.
- Increased restoration experimentation and monitoring.
- More coordination with seagrass restoration efforts.
- Improved shoreline management.

Figure 2. Simplest conceptual model of oyster abundance/health and stressors, catalyzing "Level 1" questions.



<u>"Level 1" Monitoring Questions for Oysters</u>

1. What is the maximum area that is habitable by oysters?

2. Are oyster abundances at natural and restored sites increasing, declining, or remaining stable?

3. Is oyster productivity increasing….?

4. Is water temperature increasing…?

5. Is acidification increasing….?

6. Is the prevalence of relevant diseases (including aquacultured organisms) increasing….?

7. Is sediment loading increasing…? (CROSS CUT WITH EELGRASS)

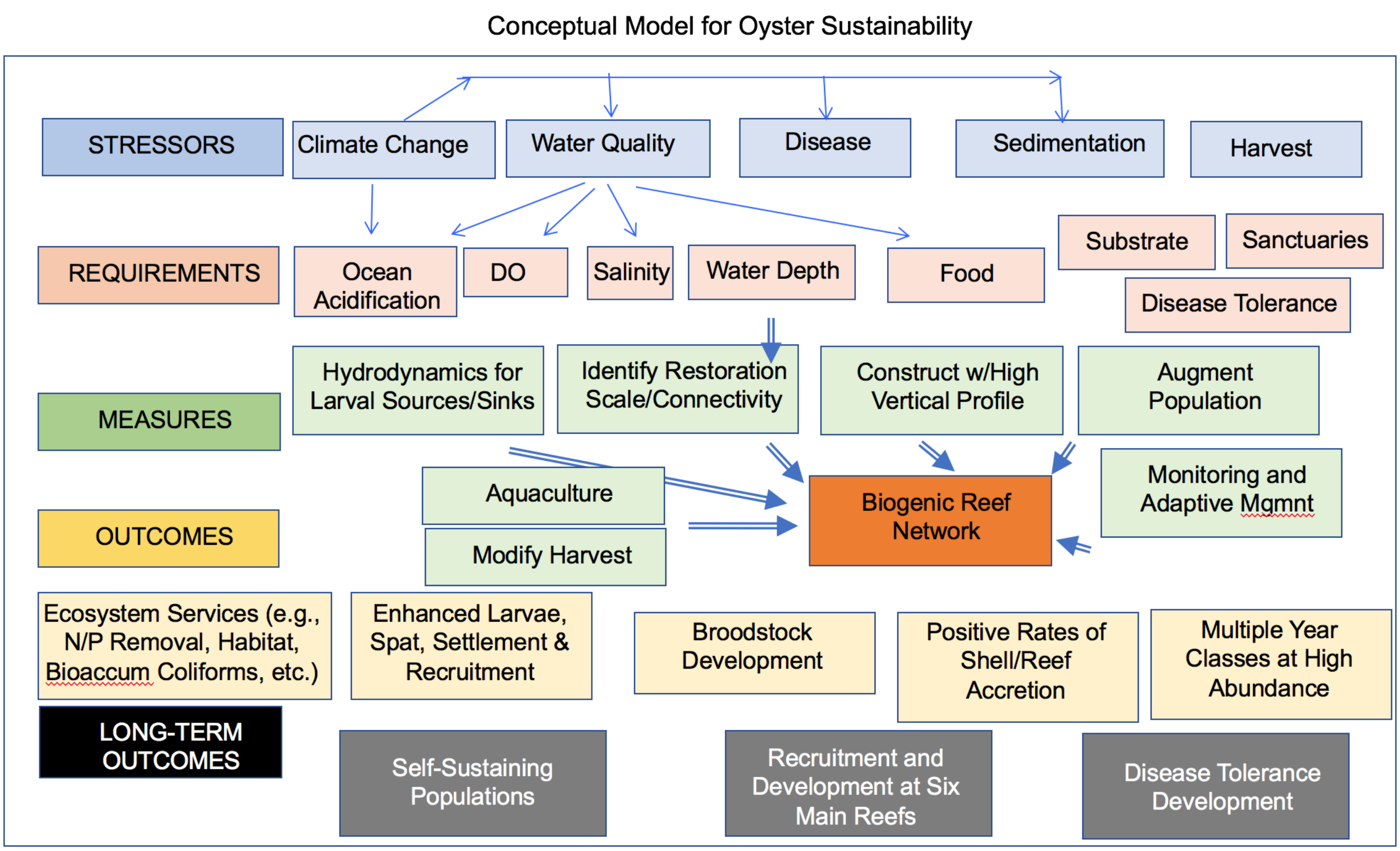
8. Is sedimentation increasing…? (CROSS CUT WITH EELGRASS)

9. Are harvest rates increasing….?

10. Is substrate availability increasing…?

*"Cross Cutting" questions apply to more than just one of the five resources.

Figure 3. Ecosystem/conceptual model for oyster sustainability, catalyzing "Level 2" and "Level 3" questions.



Conceptual diagram for sustainable oyster reefs in Great Bay Estuary, adapted from US Army Corp of Engineers. 2012. Chesapeake Bay Oyster Recovery Plan. "Retentiveness" refers to places where larvae remain due to hydrodynamics. "Scale/Connectivity" refers to planning how much restoration is required and where sites should be placed based on issues related to connectivity and hydrodynamics. "Augment Population" refers to practices such as "spat on shell." "Biogenic Reef Network" refers to a reef that demonstrates continued oyster growth on top of existing oysters. "Broodstock" refers to an adult population that helps to maintain the overall community.

“Level 2” Monitoring Questions for Oysters

*** For all questions below, will need to discuss spatial and temporal aspects during the “Methods” phase.*

1) Are dissolved oxygen, salinity and bathymetry increasing, decreasing or remaining the same?

2) Is phytoplankton (chl-a) increasing, decreasing or remaining stable?

3) Are the types and sizes of phytoplankton changing or remaining stable? For example, could use “size fraction” as a metric here. *(note the importance of the temporal/spatial component here)*

[These first three questions are all CROSS CUTTING.]

4) Are areas of larval retention changing or remaining stable?

5) Are TSS increasing, decreasing or remaining stable? (CROSS CUT WITH EELGRASS)

6) Are the number and productivity of commercial aquaculture operations increasing, decreasing or remaining stable?

7) Are bottlenecks at various stages of recruitment (larval production, settlement, survival, etc.) changing or remaining stable?

8) Is disease tolerance increasing, decreasing or remaining stable?

** Methods Note: During the “methods” phase of the Plan development, we should discuss in detail issues related to how often certain variables need to be monitored. Several scenarios may apply, such as:*

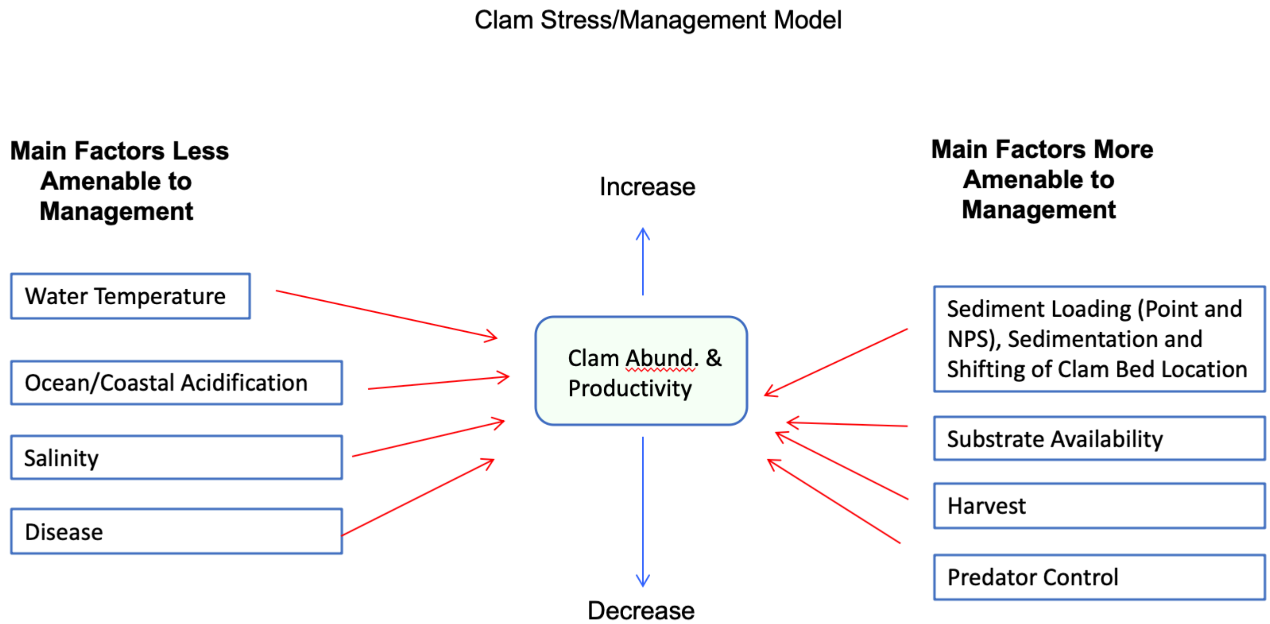
- *Lots of data exist; need only to check-in every few years to see if patterns have changed.*
- *Less data exists; need to monitor annually at high temporal resolutions before backing off to the above level.*

“Level 3” Questions/Activities for Oysters

** Note: We expect more questions to be added to this list during the “Methods” discussions, since exploratory research is often necessary to determine most appropriate methods for some questions. Also, spatial and temporal aspects for questions below need to be worked out. For each question, it will be important to suss out spatial and temporal variability and proceed accordingly to reduce uncertainty.*

- Understanding difference in productivity of sanctuaries versus “open for harvest” areas.
- Consider experimenting with additional harvesting regulations.
- Continue to develop and improve restoration plan for oyster habitat in Great Bay Estuary, building on Nature Conservancy work.
- Continue to test and monitor best methods for restoration of oyster reefs (e.g., vertical profile, spat on shell, etc.).
- Based on recruitment studies, investigate mechanisms that have the greatest impacts on key recruitment bottlenecks.
- How do we include feedbacks from other bio resources (e.g., more oysters lead to less chl-a and less TSS; more fish leads to more grazing of epiphytes; more carbon from eelgrass feeds fish drivers, etc.) CROSS CUTTING!
- Can we use hatchery-raised oysters to address disease-related bottlenecks?
- How much of TSS involves resuspended sediments versus new sediments from riverine or ocean or wastewater sources? CROSS CUTTING!
- Develop a nutrient budget specific to subtidal habitats (e.g., oysters and eelgrass). CROSS CUT WITH EELGRASS
- Develop a sediment budget specific to subtidal habitats (e.g., oysters and eelgrass). CROSS CUT WITH EELGRASS
- What do we know about the impact of green crabs and other predators on oyster reefs? CROSS CUT!
- How can seagrass and oyster folks work better together to find common ground? (Use Kenworthy’s NC case study; Brad may also have some good ideas)
- Lit review and follow up: what is the impact of toxic contaminants (including microplastics) on oysters? (Use GulfWatch to understand what concentrations might be.)
- Is there an amount of recovery that creates a tipping point so that the recovery becomes self-reinforcing? CROSS CUT!
- Should we have a monitoring program for kelp due to its role as habitat for shellfish? CROSS CUT WITH FISH

Figure 4. Simplest conceptual model of clam abundance/health and stressors, catalyzing "Level 1" questions.



<u>"Level 1" Monitoring Questions for Clams</u>

*** For all questions below, will need to discuss spatial and temporal aspects during the "Methods" phase.*

1) What is the maximum area that is habitable by clams?

2) Is substrate availability increasing…?

3) Is the location and size of clam flats changing and, if so, how?

4) Are clam abundances at natural sites increasing, declining, or remaining stable?

5) Is clam productivity (quality/sustainability) increasing….?

6) Is water temperature increasing…? CROSS CUTTING

7) Is acidification increasing….? CROSS CUTTING

8) Is the prevalence of relevant diseases (including aquacultured organisms) increasing….?

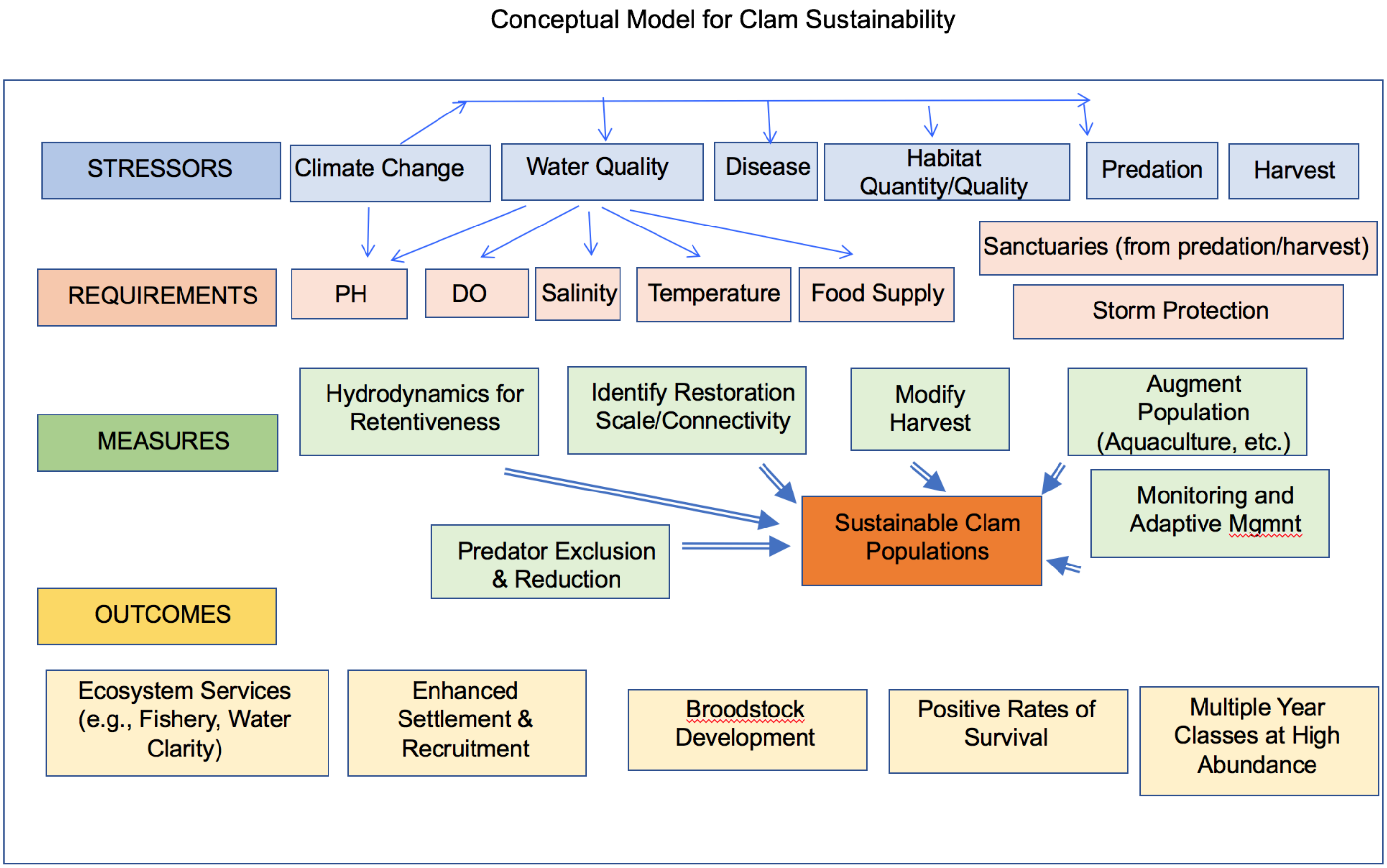
9) Is sediment loading increasing…? CROSS-CUTTING

10) Is sedimentation increasing…? CROSS-CUTTING

11) Are harvest rates increasing (counts of clammers on flats, etc.)?

12) Is clam predation (by green crabs and other animals) increasing…?

Figure 5. Detailed ecosystem/conceptual model of clam abundance/health and stressors, catalyzing "Level 2" and "Level 3" questions.



Conceptual diagram for sustainable soft-shell clam populations in Hampton-Seabrook Estuary, adapted from US Army Corp of Engineers. 2012. Chesapeake Bay Oyster Recovery Plan. "Retentiveness" refers to places where larvae remain due to hydrodynamics. "Scale/Connectivity" refers to planning how much restoration is required and where sites should be placed based on issues related to connectivity and hydrodynamics. "Broodstock" refers to an adult population that helps to maintain the overall community.

"Level 2" Monitoring Questions for Clams

*** For all questions below, will need to discuss spatial and temporal aspects during the "Methods" phase.*

1) Are dissolved oxygen, salinity and bathymetry increasing, decreasing or remaining the same?

2) Is phytoplankton (chl-a) increasing, decreasing or remaining stable?

3) Are the types and sizes of phytoplankton changing or remaining stable? (note the importance of the temporal/spatial component here)

4) Are areas of larval retention changing or remaining stable?

5) Are TSS increasing, decreasing or remaining stable? (CROSS CUT WITH EELGRASS)

6) Are bottlenecks at various stages of recruitment (settlement, survival, etc.) changing or remaining stable?

7) Include impacts of human harvesting of clams on the population (re-word later)

** Methods Note: During the "methods" phase of the Plan development, we should discuss in detail issues related to how often certain variables need to be monitored. Several scenarios may apply, such as:*

- *Lots of data exist; need only to check-in every few years to see if patterns have changed.*
- *Less data exist; need to monitor annually at high temporal resolutions before backing off to the above level.*

<u>"Level 3" Questions/Activities for Clams</u>

* Note: We expect more questions to be added to this list during the "Methods" discussions, since exploratory research is often necessary to determine most appropriate methods for some questions.

- Beginning with modeling perhaps, consider experimenting with additional harvesting regulations and/or predator-exclusion/aquaculture a la Brian Beal.
- Review Brian Beal recruitment studies. Do we need to investigate mechanisms that have the greatest impacts on key recruitment bottlenecks, for our estuary compared with his work in Southern Maine?
- Sediment map/budget for H-S estuary
- What is the age structure of the clams at H-S estuary?

- Experiment with different incentives/methods for removing green crabs. (talk to Gabby Bradt & Manomet Center in Massachusetts)
- Lit review and follow up: what is the impact of toxic contaminants on clams? (use GulfWatch to understand what concentrations might be)

EELGRASS

Goals Specific to Eelgrass

- From CCMP
    1. 2900 acres of eelgrass (greater than 10% cover.)

       The 2019 assessment indicated under 1700 acres of eelgrass.
- Recommendation for New Goal Statements Related to Abundance/Health
    1. Establish goals for separate zones of the Great Bay Estuary:
        - Great Bay
        - Little Bay
        - Lower Piscataqua River
        - Upper Piscataqua River
        - Coastal Areas (inc. Portsmouth Harbor)*
    2. Establish an abundance (e.g., percent cover, density, biomass) benchmark and goal for these same areas**

* These sections are based on hydrodynamic designations from Bilgili et al. 2005. Note that the zones penetrate up the tributaries roughly between 1 and 3 miles, depending on dams and head of tide locations.

**Note: Use SeagrassNet sites at Portsmouth Harbor and Great Bay for more detailed causal investigations of patterns seen at the more spatially expansive scales. This approach reflects "Tiered Monitoring" approach from Neckles et al. 2012.

EELGRASS MONITORING AND RESEARCH QUESTIONS

Approach to Reaching Eelgrass Goals

Management actions (e.g., nutrient and sediment reductions; restoration) are currently underway or under consideration. Understanding that we will need to make decisions without certainty*, the key question is: Should current management actions be continued, discontinued, modified or added to?

** The complex and dynamic nature of ecosystems stymie cause and effect certainty. The TAC recommends using multiple lines of evidence to create a suite of options indexed to how protective the Piscataqua Region wants to be with regard to estuarine ecosystems.*

Monitoring Questions are presented below on a spectrum from Level 1 to Level 3.

Level 1 = Monitoring questions catalyzed by simplest conceptual model (see Figure 6).

Level 2 = Monitoring questions catalyzed by detailed conceptual model (see Figure 7).

Level 3 = Questions based on detailed model that require preliminary investigation before becoming monitoring or research questions: or, questions that call for time-limited, discrete research projects.

***Note** The levels are not prioritization tiers; they simply provide an organizational scheme for making sure all factors are addressed. When we prioritize, we may find that the highest priority activities are a mix of Level 1, 2 and 3 activities.*

Current and potential management actions and their impacts must be considered in relation to factors amenable to management (e.g., nutrient reduction, shoreline protection) versus factors that are less amenable to management (e.g., warming waters, more frequent extreme storms, etc.). Therefore, science activities need to consider both kinds of factors and how they relate to each other.

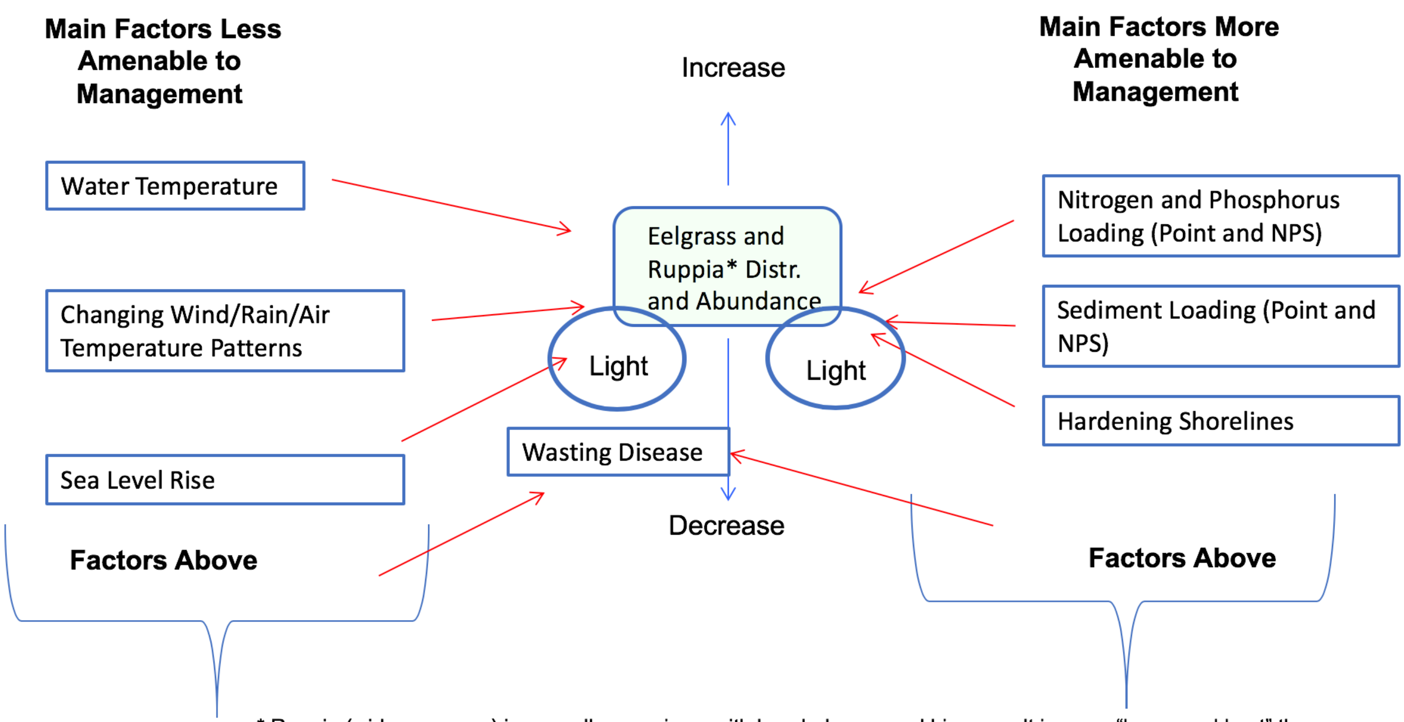
Some current management actions include:

- Nutrient and sediment reduction efforts from point (improvements and upgrades) and non-point sources (new stormwater practices, etc.)
- Buffer protection.
- Land conservation.

Some potential management actions include:

- Increased nutrient and sediment reduction efforts.
- Pilot-scale eelgrass restoration efforts.
- Improved shoreline management.
- Improved invasive species (e.g., green crab, etc.) management.

Figure 6. Simple model of eelgrass abundance/health and stressors, catalyzing "Level 1" questions.



* Ruppia (widgeon grass) is a smaller species—with less belowground biomass. It is more "boom and bust" than eelgrass. and is known to be more tolerant of freshwater and warmer temperatures.

<u>"Level 1" Monitoring Questions for Eelgrass</u>

1. What is the maximum area that is habitable by eelgrass, based on bathymetry, light, etc.?

2. Is eelgrass (and Ruppia) acreage overall and in each of the five areas of the estuary increasing, declining, or remaining stable?

3. Is abundance (e.g., cover, biomass, density, deep edge) in each of the five areas of the estuary increasing, declining or remaining stable?

4. Is water temperature in eelgrass beds in each of the five areas…? CROSS CUTTING

5. Are wind (speed and direction), rain, air temperature patterns….? CROSS CUTTING

6. Is Sea Level Rise….? CROSS CUTTING

7. Is nitrogen and phosphorus loading (total and for each sub-watershed) increasing, decreasing or remaining stable? CROSS CUTTING

8. Is sediment loading increasing…? CROSS CUTTING

   - Make sure to account for/assess resuspension of estuarine sediments

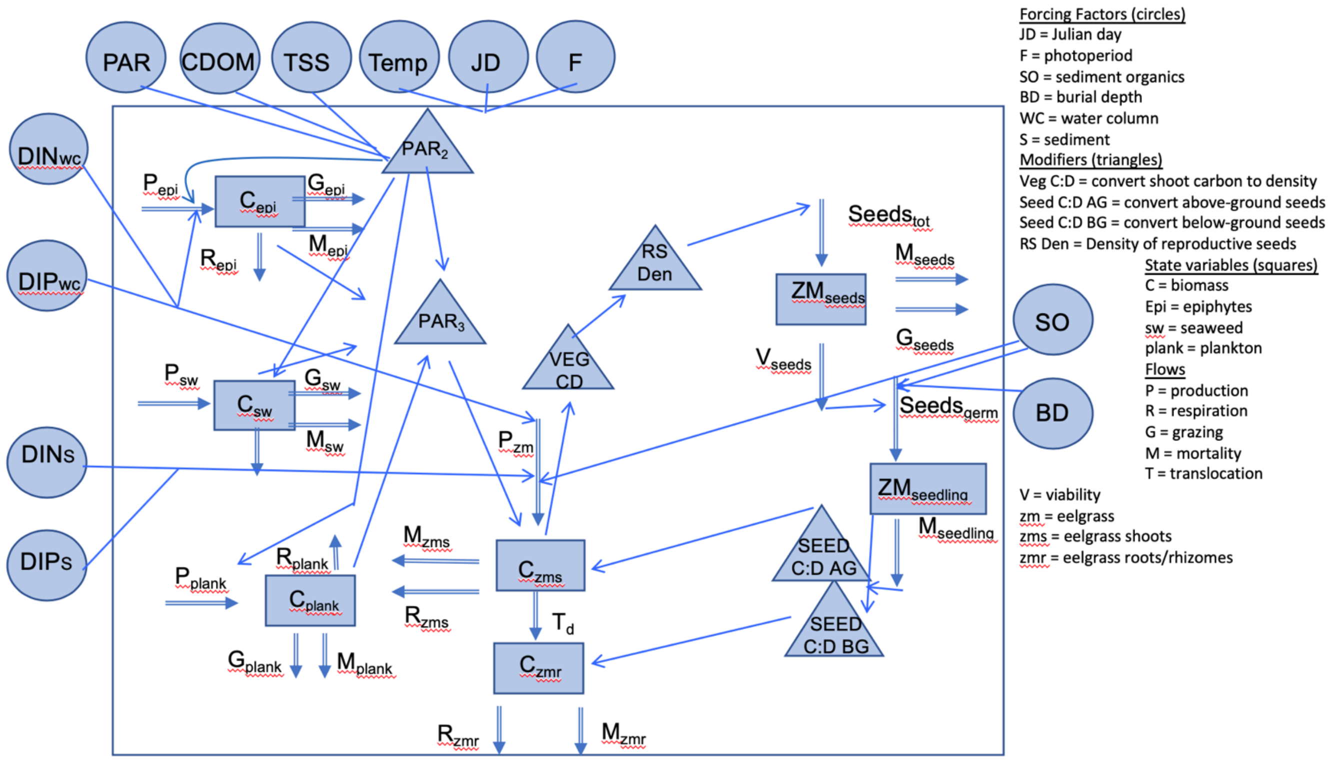
9. How is shoreline hardening changing in each of the zones? CROSS CUTTING

10. Is wasting disease increasing…?

11. Is Ruppia distribution increasing…?

12. Is light penetration increasing…? (see next model) CROSS CUTTING

Figure 7. Detailed conceptual model of eelgrass ecosystem (adapted from Jarvis et al. 2014), catalyzing "Level 2" and "Level 3" questions.



Conceptual diagram for eelgrass production and sexual reproduction. Circles = forcing functions, triangles = modifiers, squares = state variables, thick arrows = flows, and thin arrows = connections. Temp, JD, and F affect multiple processes so are not connected to minimize diagram complexity.

<u>"Level 2" Monitoring Questions (starting with forcing functions and then proceeding from the upper left corner of Figure 7 and moving right and downwards)</u>

** For all questions below, will need to discuss spatial and temporal aspects during the "Methods" phase. Some of these questions will only be answered for specific sites where more intense monitoring happens.

1. Is incident light and light attenuation (PAR_2 and PAR_3) increasing, decreasing or remaining the same? CROSS CUTTING
    a. Need to get assessments of these parameters at different times of the year and in at least 3 zones (great bay, little bay, Portsmouth harbor)

2. Is phytoplankton (chl-a) increasing, decreasing or remaining stable? CROSS CUTTING
    a. Need to get assessments of this parameter at different times of the year and in at least 3 zones (great bay, little bay, Portsmouth harbor)

3. Are dissolved inorganic nitrogen and phosphorus (both in water column and sediments) increasing, decreasing or remaining stable? CROSS CUTTING
    a. Need to get assessments of these parameters at different times of the year and in at least 3 zones (great bay, little bay, Portsmouth harbor)

4. Are TSS increasing, decreasing or remaining stable? CROSS CUTTING
    a. Need to get assessments of these parameters at different times of the year and in at least 3 zones (great bay, little bay, Portsmouth harbor)

5. Is epiphyte production and biomass increasing….?
    a. Need assessments….

6. Is seaweed production and biomass increasing…? CROSS CUTTING
    a. Need assessments…

7. Is production and biomass (above and belowground) of eelgrass increasing…?
    a. Need assessments…*(for repro factors, prob need to look each assessment zone…may need to specify for other questions, too, re: the zones)*

8. Are the number of reproductive shoots increasing…?
    a. Need assessments…

9. Are the number and viability of seeds and seedlings increasing…?
    a. Need assessments…

10. What is the burial depth of seeds? Increasing…?
    a. Need assessments…

11. Is sediment organic matter increasing…? CROSS CUTTING
    a. Need assessments...

** Methods Note: During the "methods" phase of the Plan development, we should discuss in detail issues related to how often certain variables need to be monitored. Several scenarios may apply, such as:*

- Lots of data exist; need only to check-in every few years to see if patterns have changed.
- Less data exist; need to monitor annually at high temporal resolutions before backing off to the above level.

<u>"Level 3" Questions/Activities for Eelgrass</u>

** Note: We expect more questions to be added to this list during the "Methods" discussions, since exploratory research is often necessary to determine most appropriate methods for some questions. Also, spatial and temporal aspects for questions below need to be worked out. For each question, it will be important to suss out spatial and temporal variability and proceed accordingly to reduce uncertainty.*

Synthesize existing data (water quality—both grabs and sondes—and SeagrassNet) in reference to the model to discern what info we have and what gaps remain. CROSS CUT WITH OTHER FOCI

- Look at the data we have on CDOM (or FDOM) and chl-a to determine how these components should be included in the model: as forcing functions or as a state variable.
- How can we include feedback mechanisms (e.g., loss of eelgrass increases sediment resuspension; biogeochemical) in our model and assessments?
- How do we include feedbacks from other bio resources (e.g., more oysters leads to less chl-a and less TSS; more fish leads to more grazing of epiphytes; more carbon from eelgrass feeds fish drivers, etc.) CROSS CUTTING
- Should we consider developing an optical model to provide higher resolution to the model?
- Do we have the data we need to understand whether sediment and water column nutrient levels are impacted by regeneration of nutrients from previous years? If so, what is our assessment of the contribution from regeneration? (This will be different for each of the five zones.)
- Develop a nutrient budget specific to subtidal habitats (e.g., oysters and eelgrass). CROSS CUT WITH OYSTERS
- Develop a sediment budget specific to subtidal habitats (e.g., oysters and eelgrass). CROSS CUT WITH OYSTERS
- What is the relationship between tributary inputs of nutrients, organic matter and TSS and estuarine biological response (phytoplankton, seaweed and eelgrass)?
- Do eelgrass shoots (in 5 different zones) show signs of sulphur intrusion? (Note Fraser and Kendrick 2017, showing relationship between cadmium and Sulphur metabolism.)
- How does eelgrass leaf tissue nitrogen and CNP ratios relate to nutrient loadings and concentrations? (benefits of using seaweed tissue over eelgrass?)

- Consider using the Short et al. Nutrient Pollution Index

- How do carbon reserves in belowground biomass relate to other variables (carbon reserves being an indicator of stress)?
- Can we use genetic markers for resilience—and perhaps link this to the hydrodynamic model—to better understand distribution patterns and add insight into restoration priorities? (see April TAC transcript.)
- Based on existing and emerging data, should we prioritize particular zones as places to prioritize management action?
- How can restoration pilot-projects help us answer these questions and others?
- How much of TSS involves resuspended sediments versus new sediments from riverine or ocean or wastewater sources? CROSS CUT!
- What do we know about green crabs, invertebrate grazers and fish for these different zones… CROSS CUT since we know that this can have a significant impact on eelgrass? Especially with regard to predation on seeds.
- How do wind and precipitation relate to TSS and other light attenuators?
- How does hardened shoreline patterns and wind combine to impact waves and resuspension?
- How important is it to keep track of silica, because it drives diatoms and also because it can be taken up as a defense mechanism to heavy metal toxicity?
- How does the location and magnitude of fresh and cold groundwater intrusion into the estuarine zone relate to other variables, such as: eelgrass distribution, health, nutrients, eelgrass health?
- Should groundwater levels be tracked as research or more regularly? (In particular, look at updating the Ballestero 2004 study?) CROSS CUT WITH SALT MARSH
- How do changing patterns in Ruppia distribution relate to changes in temperature, wind, etc.?
    - What are the feedback consequences (e.g., sediments, sediment resuspension, etc.) of greater amounts of Ruppia?
- Consider how model inputs can help feed a restoration/habitat suitability model
- How can seagrass and oyster folks work better together to find common ground? (Use Kenworthy's NC case study; Brad may also have some good ideas) CROSS CUTTING

SALT MARSH

Goals Specific to Salt Marsh

- From CCMP
    1. Develop and implement a restoration program to restore Saltmarsh Sparrows to five currently unoccupied sites by 2020.

       (Awaiting updates on these sites.)

       Consensus recommendation to change the goal to: "Increase overall percentage of sparrow breeding success," because some sites may no longer be viable.
    2. Restore or enhance an additional 300 acres of salt marsh by 2020 through removal of tidal restrictions or invasive species management.

       (It's estimated less than 50 acres of this goal has been achieved.)
- Options for Additional Goal Statements
    1. Maintain current acreage of salt marsh, (with the understanding that some marshes will drown but others might be able to migrate).
    2. Use some goal around health (e.g., high marsh to low marsh, unvegetated to vegetated, etc.) for both Great Bay and Hampton-Seabrook Estuaries. *(Actual goal can be decided in "Methods" phase.)*
    3. Include a goal around usage by wildlife (e.g., birds, fish, etc.)? (not decided)

SALT MARSH MONITORING AND RESEARCH QUESTIONS

Approach to Reaching Above Goals

Management actions (e.g., protecting migration pathways, etc.) are currently underway or under consideration. The key question is: Should current management actions be continued, discontinued, modified or added to?

Monitoring Questions are presented below on a spectrum from Level 1 to Level 3.

Level 1 = Monitoring questions catalyzed by simplest conceptual model (see Figure 8).

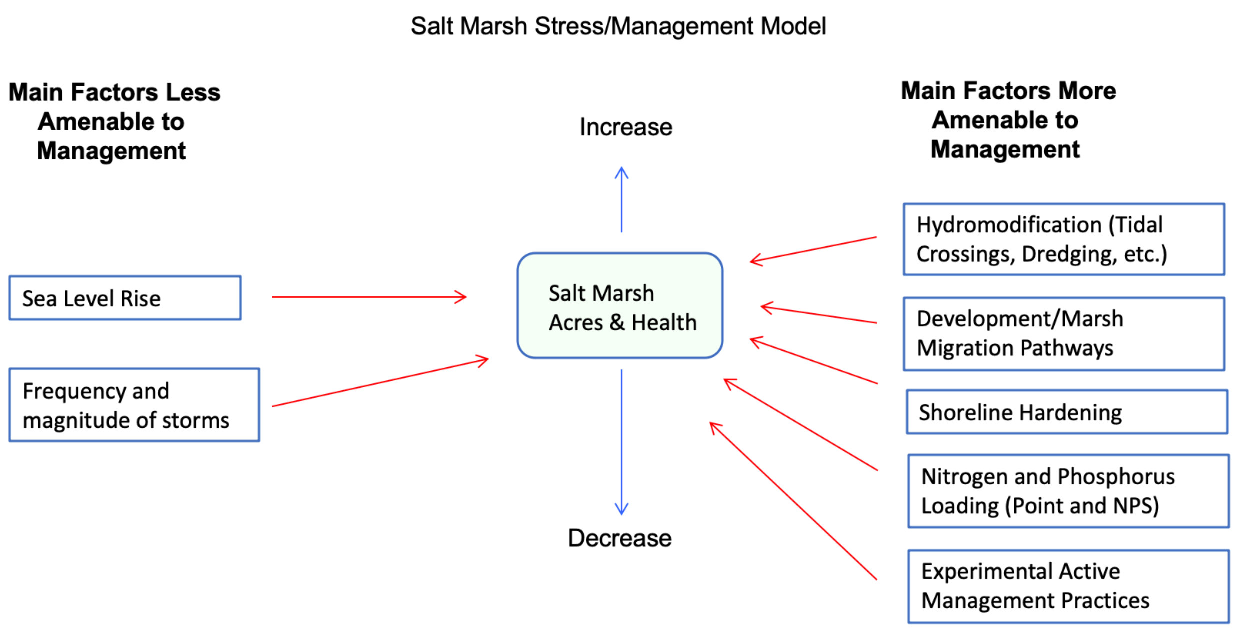
Level 2 = Monitoring questions catalyzed by detailed conceptual model (see Figure 9).

Level 3 = Questions based on detailed model that require preliminary investigation before becoming monitoring or research questions; or, questions that call for time-limited, discrete research projects.

***Note** The levels are not prioritization tiers; they simply provide an organizational scheme for making sure all factors are addressed. When we prioritize, we may find that the highest priority activities are a mix of Level 1, 2 and 3 activities.*

Current and potential management actions and their impacts must be considered in relation to factors amenable to management (e.g., restoration, sediment management) versus factors that are less amenable to management (e.g., Sea Level Rise, storm surge, etc.). Therefore, science activities need to consider both kinds of factors and how they relate to each other.

Figure 8. Simplest conceptual model of salt marsh abundance/health and stressors, catalyzing "Level 1" questions.



<u>"Level 1" Monitoring Questions for Salt Marsh</u>

***A high priority activity is extending intense monitoring from Great Bay Estuary to Hampton-Seabrook Estuary.*

1. Is salt marsh acreage increasing, decreasing, or remaining the same? *(Note: We will need to keep track of where acres gained/lost are coming from: not just sum total of acreage.)*

2. Is salt marsh acreage increasing, decreasing, or remaining the same? *(Note: We will need to keep track of where acres gained/lost are coming from: not just sum total of acreage.)*

3. For both estuaries, is salt marsh health (metrics to be decided on later; could include veg vs unveg; high marsh vs low marsh; ecotone shifting, etc.) increasing, decreasing, or remaining the same?

4. Is the rate of Sea Level Rise (for each estuary) increasing…? CROSS CUTTING

5. Are storm and storm surge events increasing, decreasing or remaining stable? CROSS CUTTING

6. Is development in areas that could become migration pathways (encompassing) tidal wetlands/brackish marsh) increasing, decreasing or remaining the same?

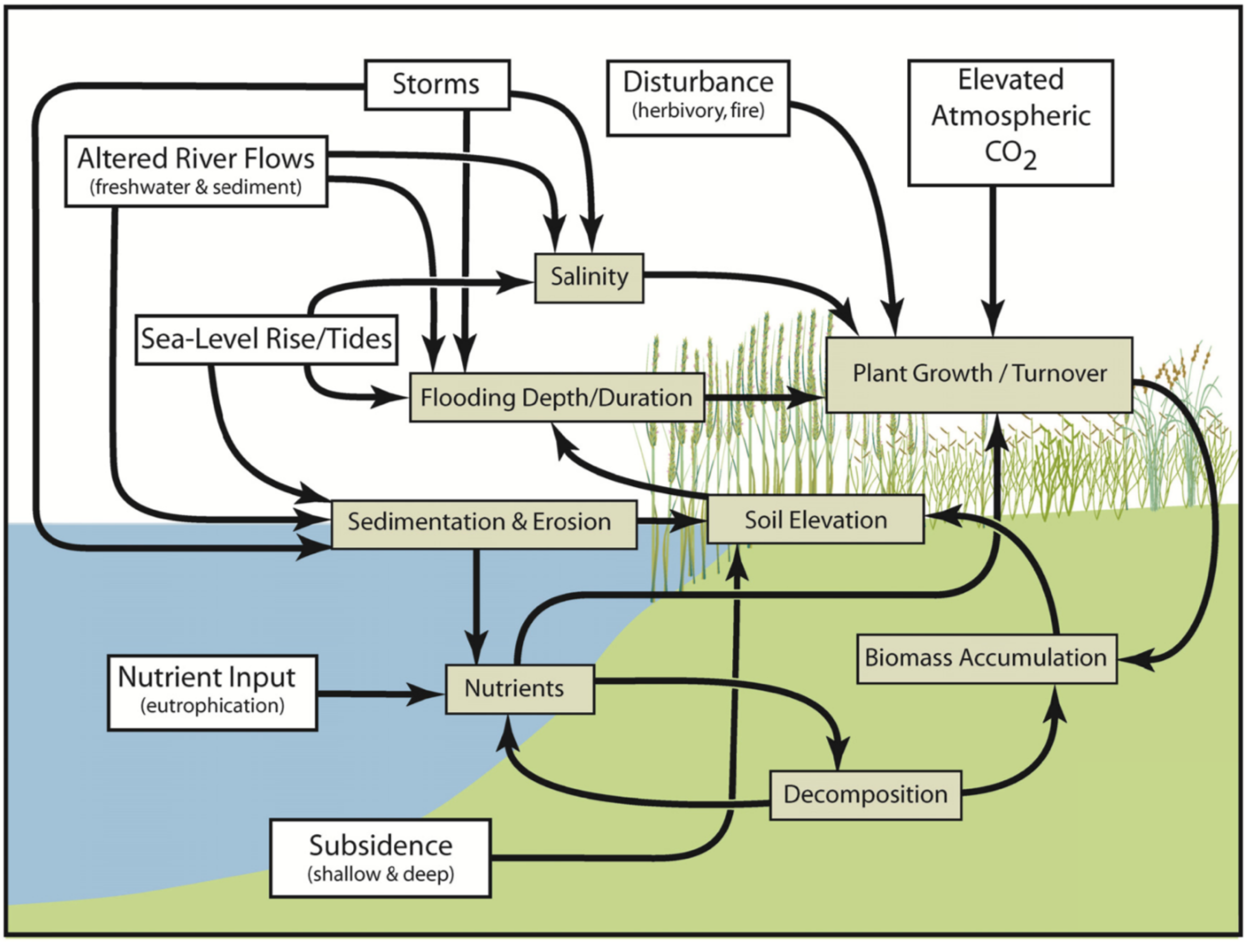
7. Are migration pathways and migration barriers (encompassing tidal wetlands/brackish marsh) overall increasing, decreasing or remaining the same? *(Note: this monitoring will need to be spatially explicit: not just sum total.)*

8. Is nutrient loading increasing, decreasing or remaining stable? CROSS CUTTING

9. Is shoreline hardening increasing, decreasing or remaining the same? (CROSS CUT WITH EELGRASS, FISH, SHELLFISH)

10. Are past experiments in active marsh restoration mapped, tracked, and being assessed?

Figure 9. Conceptual model of salt marsh ecosystem, from Cahoon et al. 2009, catalyzing "Level 2" and "Level 3" questions.



<u>"Level 2" Monitoring Questions (based on Figure 9 above)</u>

** For all questions below, will need to discuss spatial and temporal aspects during the "Methods" phase. Some of these questions will only be answered for specific sites where more intense monitoring happens.

1) Are storm and storm surge events increasing, decreasing or remaining stable?

2) Are freshwater and sediment delivery increasing, decreasing or remaining stable? CROSS CUT WITH EELGRASS

3) Are high tide extents increasing, decreasing or remaining stable?

4) Are salt marsh sparrow populations increasing, decreasing, changing locations…or remaining stable?

5) Is disturbance (from herbivory, etc.) increasing, decreasing or remaining stable?

6) Is atmospheric CO_2 increasing, decreasing or remaining stable? CROSS CUTTING

7) Is flooding depth/duration increasing, decreasing or remaining stable?

8) Is plant growth/turnover increasing, decreasing or remaining stable?

9) Is sedimentation and erosion increasing, decreasing or remaining stable? CROSS CUTTING

10) Is soil elevation increasing, decreasing or remaining stable?

11) Is nutrient loading increasing, decreasing or remaining stable? CROSS CUTTING

12) Are nutrient concentrations increasing, decreasing or remaining stable? CROSS CUTTING

13) Is biomass accumulation increasing, decreasing or remaining stable?

14) Is decomposition increasing, decreasing or remaining stable?

15) Is subsidence increasing, decreasing or remaining stable?

** Methods Note: During the "methods" phase of the Plan development, we should discuss in detail issues related to how often certain variables need to be monitored. Several scenarios may apply, such as:*

- Lots of data exist; need only to check-in every few years to see if patterns have changed.

- Less data exist; need to monitor annually at high temporal resolutions before backing off to the above level.

“Level 3” Questions/Activities for Salt Marsh

** Note: We expect more questions to be added to this list during the “Methods” discussions, since exploratory research is often necessary to determine most appropriate methods for some questions. Also, spatial and temporal aspects for questions below need to be worked out. For each question, it will be important to suss out spatial and temporal variability and proceed accordingly to reduce uncertainty.*

- Continue to develop and improve salt marsh restoration plans for Great Bay Estuary and Hampton-Seabrook Estuary building on Nature Conservancy work.
- What areas are most appropriate for site-specific and experimental management practices, such as:
    - thin-layer sediment addition (what are other ways to get sediment on marsh?)
    - tax easements for allowing overwash
    - lowering terrestrial border to create migration pathways
        - …and what are the impacts of these different techniques?
- How do we include feedbacks from other bio resources (e.g., connections between salt marsh, eelgrass, fish, shellfish, etc.) CROSS CUTTING
- What do we know about the impact of green crabs and other predators (some moving northward, such as: fiddler and purple marsh crabs) on salt marshes? CROSS CUTTING
- Is it possible to get salt marsh sparrows to use a new site that’s perfect for them?
- Should groundwater levels be tracked as research or more regularly? (In particular, look at updating the Ballestero 2004 study?) CROSS CUT WITH EELGRASS
- Develop a nutrient budget specific to salt marshes.
- Develop a sediment budget specific to salt marshes.
- Implement a sediment-oxygen-nutrient-exchange (SONE) study.
- Can/should various measures be collected merged into a “resilience” index?
- What is the ongoing/future impact and/or effectiveness of past management techniques, e.g., ditching, etc.?
- Should we have a monitoring program for invasives (more broadly than just green crabs), perhaps partnering with the BioBlitz program.)

FISH

Goals Specific to Fish

- From CCMP
    1. Restore native diadromous fish access to 50% of their historical mainstem river distribution range by 2020, and improve habitat conditions encountered throughout their life cycle.

       (This is in the process of being determined.)
    2. Document existing populations of native Eastern brook trout and protect or restore the integrity of the sub-watersheds that support them.

       (A good amount of documenting has occurred but less has happened in terms of protection, with some exceptions.)

- Recommendation for Additional Goal Statements
    1. Develop productivity (in addition to abundance) goals for key migratory indicator species (e.g., herring, trout).
    2. Develop abundance and productivity goals around sensitive estuarine species (e.g., smooth flounder) that use our estuaries as nursery habitat. (One option is to fashion a goal statement that is general and decide on particular species at a later time.) For example…"Restore/maintain the abundance and productivity of key indicator species that use estuaries at key stages during their life cycle."

FISH MONITORING AND RESEARCH QUESTIONS

Approach to Reaching Fish Goals

Management actions (e.g., conservation, water quality improvements, fishway improvements, etc.) are currently underway or under consideration. The key question is: Should current management actions be continued, discontinued, modified or added to?

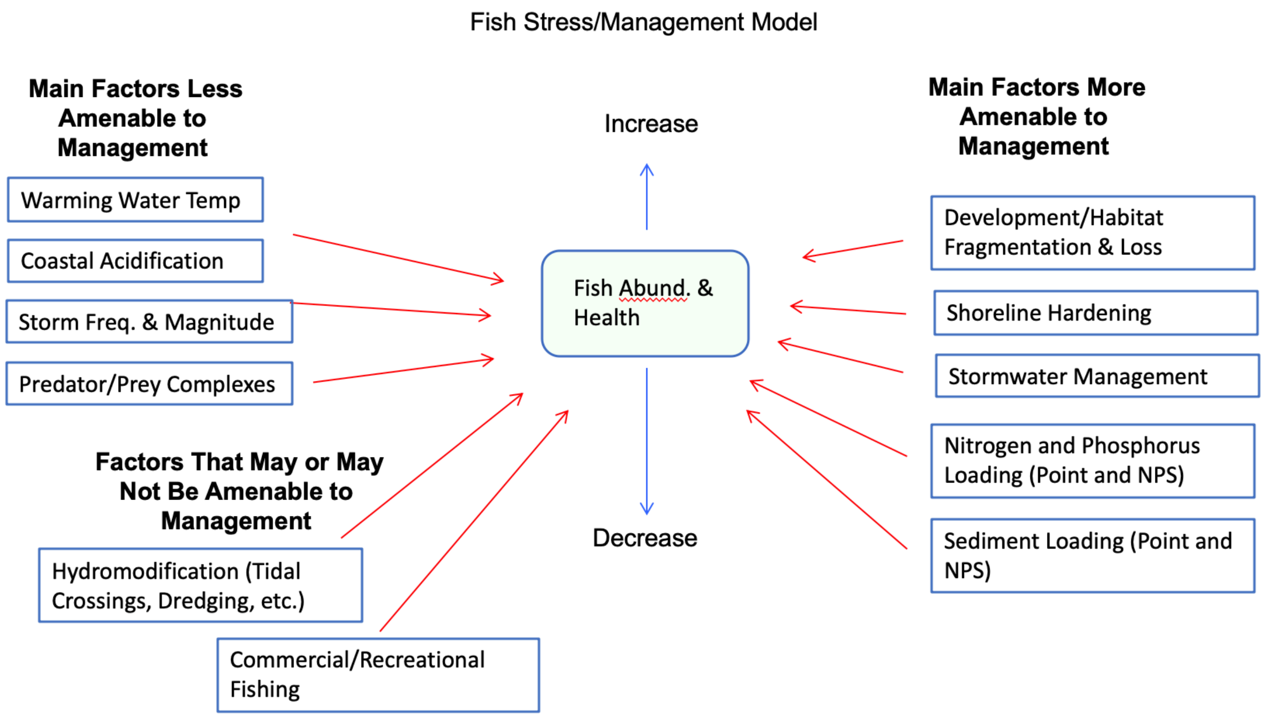
Monitoring Questions are presented below on a spectrum from Level 1 to Level 3.

Level 1	Monitoring questions catalyzed by simplest conceptual model (see Figure 10).
Level 2	Monitoring questions catalyzed by detailed conceptual model (see Figure 11).
Level 3	Questions based on detailed model that require preliminary investigation before becoming monitoring or research questions; or, questions that call for time-limited, discrete research projects.

***Note** The levels are not prioritization tiers; they simply provide an organizational scheme for making sure all factors are addressed. When we prioritize, we may find that the highest priority activities are a mix of Level 1, 2 and 3 activities.*

Current and potential management actions and their impacts must be considered in relation to factors amenable to management (e.g., restoration, conservation) versus factors that are less amenable to management (e.g., warming waters, etc.). Therefore, science activities need to consider both kinds of factors and how they relate to each other.

Figure 10. Simplest conceptual model of fish abundance/health and stressors, catalyzing "Level 1" questions.



<u>"Level 1" Monitoring Questions for Fish</u>

**Questions below apply to both Great Bay and Hampton-Seabrook Estuaries.

1. Are migratory (diadromous) fish counts increasing, decreasing, or remaining stable?
2. For some species, this question should be repeated for multiple stages in life cycle: spawning adults, post-spawn adults, fry, juveniles
3. *For diadromous fish…we're focused currently on herring but we also have American eel, smelt and sturgeon and sea lamprey. Data exist for many of these species. Need to decide which species will be followed.*

4. Is the health/productivity of diadromous fish (species TBD) increasing, decreasing, or remaining stable?

5. Are smooth flounder counts increasing, decreasing, or remaining stable?

6. Consider repeating for multiple stages in life cycle: spawning adults, post-spawn adults, fry, juveniles

7. Is the health/productivity of smooth flounder increasing, decreasing, or remaining stable?

8. Are estuarine indicator species (e.g., smooth flounder) increasing, decreasing, or remaining stable?

9. Are water temperatures and measures of coastal acidification increasing, decreasing, or remaining stable? CROSS CUTTING

10. Is the rate of Sea Level Rise (for each estuary) increasing….? CROSS CUTTING

11. Are storm frequency and magnitude increasing…? CROSS CUTTING

12. Are tidal crossings, dams and other migration barriers increasing, decreasing, or remaining stable?

13. Is habitat fragmentation increasing, decreasing, or remaining stable? CROSS CUTTING

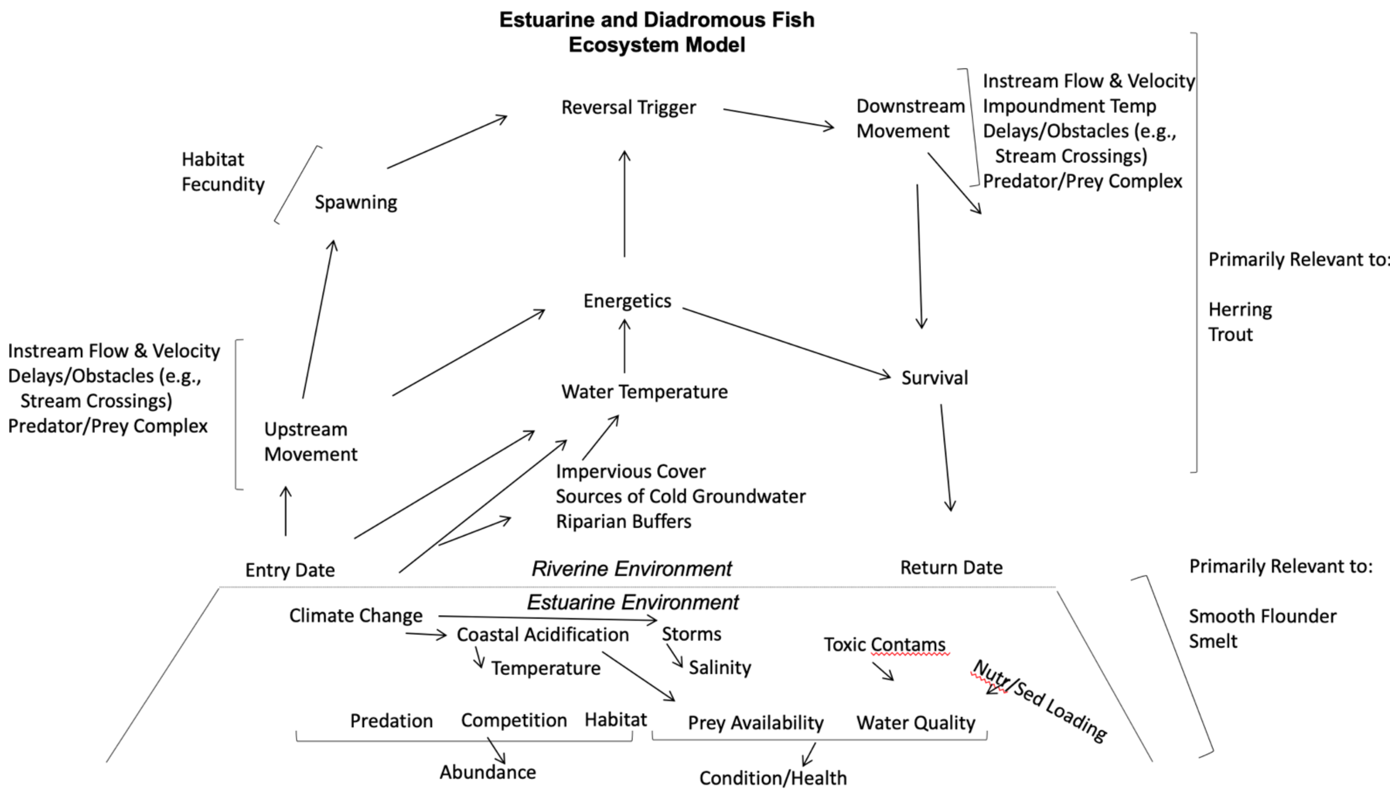
14. Is shoreline hardening increasing, decreasing or remaining the same? (CROSS CUT WITH EELGRASS, FISH, SHELLFISH)

15. Is stormwater volume increasing, decreasing, or remaining stable?

16. Are nutrient (nitrogen and phosphorus) and sediment loading increasing, decreasing, or remaining stable? CROSSCUT WITH OTHER FOCUS AREAS

17. Is TSS increasing, decreasing, or remaining stable? CROSS CUTTING

Figure 11. Ecosystem/conceptual model for diadromous fish and smooth flounder, adapted from Castro-Santos and Letcher (2010), catalyzing "Level 2" and "Level 3" questions.



<u>"Level 2" Monitoring Questions for Fish</u>

** For all questions below, will need to discuss spatial and temporal aspects during the "Methods" phase. Some of these questions will only be answered for specific sites where more intense monitoring happens.

1) Are estuarine habitats (e.g., mudflats, oyster reefs, salt marsh, eelgrass) critical for diadromous fish and smooth flounder increasing, decreasing, or remaining stable?

2) Are toxic contaminant concentrations in the sediment and water column increasing, decreasing, or remaining stable? CROSS CUTTING

3) Are estuarine predators (e.g., green crabs, great blue herons, cormorants) increasing, decreasing, or remaining stable?

4) Are salinity patterns changing or remaining stable? CROSS CUTTING

5) Are impervious surfaces, sources of cold groundwater and riparian buffers increasing, decreasing, or remaining stable?

6) Are in-stream flows increasing, decreasing, or remaining stable?

7) Are stream temperatures increasing, decreasing, or remaining stable?

8) Are estuarine water temperatures increasing, decreasing, or remaining stable? CROSS CUTTING

9) Is the fecundity of adults increasing, decreasing, or remaining stable?

10) Are metrics for bioenergetics (size and condition of fish) increasing, decreasing, or remaining stable?

    - This should apply to fish in estuarine and freshwater portion of the cycle.

11) Are returning diadromous fish (adults and juveniles) increasing, decreasing, or remaining stable?

** Methods Note: During the "methods" phase of the Plan development, we should discuss in detail issues related to how often certain variables need to be monitored. Several scenarios may apply, such as:*

- Lots of data exist; need only to check-in every few years to see if patterns have changed.
- Less data exist; need to monitor annually at high temporal resolutions before backing off to the above level.

<u>"Level 3" Questions/Activities for Fish</u>

** Note: We expect more questions to be added to this list during the "Methods" discussions, since exploratory research is often necessary to determine most appropriate methods for some questions.*

Spatial and temporal aspects for questions below need to be worked out. For each question, it will be important to suss out spatial and temporal variability and proceed accordingly to reduce uncertainty.

- Continue to develop and improve fish habitat restoration plans for Great Bay Estuary and Hampton-Seabrook Estuary.
- Important to track whether regional and marine dynamics are accounting for some of the year to year variability in fish abundance and condition. CROSS CUTTING
- What areas are most appropriate for site-specific and experimental management practices, such as:
    - Bog and other wetland restoration to provide colder water habitat
    - Woody debris additions
    - Stream crossing reductions
    - Dam removal
    - Stock enhancement
    - Maintenance of minimum in-stream flows through management of withdrawal, etc.
        - …and what are the impacts of these different techniques on fish abundance and health?
- Based on recruitment studies, investigate mechanisms that have the greatest impacts on key recruitment bottlenecks for key species: herring, smelt, sturgeon, American eel, sturgeon, trout, sea lamprey.
- Depending on resources, could include: eggs created; survival to juvie; survive downstream; survive to sexual maturity; etc.
- How do we include feedbacks from other bio resources (e.g., connections between salt marsh, eelgrass, fish, shellfish, etc.) CROSS CUTTING WITH OTHER RESOURCES!
- Should groundwater temperatures be tracked as research or more regularly?
- Should we develop an index of biotic integrity specific to our estuaries?
- Should we have a monitoring program for invasives (including but more broadly than just green crabs), perhaps partnering with the BioBlitz program.) CROSS CUT WITH SALT MARSH
- We know green crabs are having an impact. What can we do to decrease their abundance? CROSS CUT WITH EELGRASS, SALT MARSH AND SHELLFISH
- Should we have a monitoring program for kelp due to its role as habitat for fish and shellfish? CROSSCUT WITH SHELLFISH

HUMANS

This section will focus on the following health issues:

- Health concerns related to the consumption of shellfish, especially with regard to bacteria, biotoxins (from algae) but also including other toxic contaminants.
- Health concerns related to the consumption of fish, especially with regard to toxic contaminants, such as mercury as well as contaminants of emerging concern.
- Health concerns related to recreational water contact in the estuaries.

Once these issues are addressed, it is possible that other human health issues will be tackled.

Goals Specific to Humans

- From CCMP

    1. Water quality in the Piscataqua region watersheds supports shellfish harvesting, recreation, wildlife, aquatic life, and drinking water consistent with the clean Water Act, and existing high-quality waters are maintained at 2010 conditions.

        (This is a general statement from the CCMP. It was not written to be specific to human health topics. For purposes of this discussion, it implies that metrics related to the three bullets at top of page should be no worse now than in 2010.)

    2. Improve water quality and identify and mitigate pollution sources so that additional estuarine areas meet water quality standards for bacteria for shellfish harvesting.

        (The "Shellfish Harvest Opportunity" metric encompasses this goal. Note, however, that the metric is also impacted by non-bacteria such as biotoxins. Overall, this metric has shown gradual improvement since 2010, with some short-term exceptions due to sewer infrastructure issues and/or harmful algal blooms.)

    3. Monitor and reduce loading of toxic contaminants and emerging contaminants to the estuaries and the ocean.

        (The above statement focuses on loading but most of PREP's activities up to this point have focused on concentrations. The revised (as of 2020) CCMP notes that monitoring should include loading and concentration. Therefore, this plan should include plans to increase understanding of loadings. The CCMP also stipulates that monitoring will include better understanding sources of contaminants and will also include monitoring of shellfish tissue.)

- Recommendation for Additional Goal Statements

    No recommendations for particular goal statements. However, the sub-group suggested that this section broaden its approach to the various organisms or pollutants that could impact human health.

For example, microplastics may or may not be a direct threat to humans, however, it is known that other contaminants adhere to the surface of microplastics. Therefore, microplastics should be included in this part of the Plan.

Similarly, up to this point, biotoxins have been focused on only in terms of their concentration in shellfish tissue. However, some biotoxins such as cyanotoxins can harm human health simply through contact with water and, some studies indicate, through the air we breathe.

HUMAN HEALTH MONITORING AND RESEARCH QUESTIONS

Approach to Reaching Humans Goals

Management actions (e.g., stormwater and wastewater treatment improvements, etc.) are currently underway or under consideration. The key question is: Should current management actions be continued, discontinued, modified or added to?

Monitoring Questions are presented below on a spectrum from Level 1 to Level 3.

Level 1 Monitoring questions catalyzed by simplest conceptual model (see Figure 12).

Level 2 Monitoring questions catalyzed by detailed conceptual model

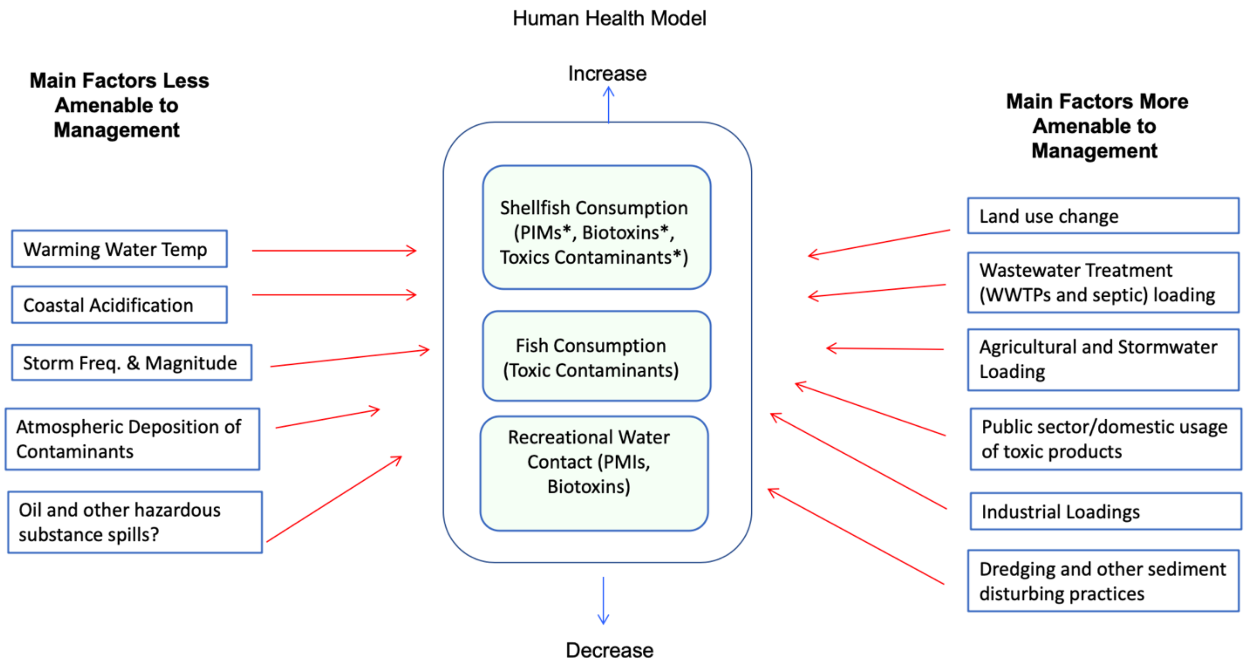
**Note: Due to the breadth of this focus area, the human health section does not have a more detailed conceptual model. Models for specific aspects of this focus area may be developed later.*

Level 3 Questions that require preliminary investigation before becoming monitoring or research questions; or, questions that call for time-limited, discrete research projects.

***Note** The levels are not prioritization tiers; they simply provide an organizational scheme for making sure all factors are addressed. When we prioritize, we may find that the highest priority activities are a mix of Level 1, 2 and 3 activities.*

Current and potential management actions and their impacts must be considered in relation to factors amenable to management (e.g., stormwater management) versus factors that are less amenable to management (e.g., atmospheric deposition of toxics, etc.). Therefore, science activities need to consider both kinds of factors and how they relate to each other.

Figure 12. Simplest conceptual model of the human health stressors focused on in this phase. This model will link to conceptual models for the other four focus areas.



PIMs stand for Pathogenic and Indicator Microorganisms. Vibrio vulnificus is an example of a pathogenic bacteria, while Enterococcus bacteria exemplify indicator organisms. They are not harmful per se but are used as an indicator of human sewage. Biotoxins include those that cause shellfish related poisoning (e.g., amnesiac, paralytic, etc.) as well as cyanotoxins. Toxic contaminants include legacy pollutants (e.g., mercury, PAHs, pesticides) as well as emerging contaminants (e.g., PFAS, pharmaceutical and personal care products, and microplastics).

"Level 1" Monitoring Questions for Human Health

**Questions below apply to both Great Bay and Hampton-Seabrook Estuaries.

**Note that many of the questions below assume that we can quantify amounts so that we can assess if concentrations or loading are increasing. However, in some cases, we may only be able to measure presence/absence. In those cases, the question will need to be reworded appropriately, perhaps to say "increasing in distribution" or some other alternative.

1. Are pathogenic and indicator microorganisms, biotoxins and toxic contaminants in shellfish increasing, decreasing, or remaining stable?

2. Are pathogenic and indicator microorganisms, biotoxins and toxic contaminants in water or air increasing, decreasing, or remaining stable?
    - (For Questions 1 and 2) Monitoring approaches will change depending on the biotoxin. For some, monitoring the plankton will be more practical; for other biotoxins, monitoring the actual toxin itself may be more practical.

3. Are toxic contaminants concentrations in fish tissue (increasing….? CROSS CUTTING

4. Are water temperatures increasing…? CROSS CUTTING

5. Is coastal acidification in increasing…? CROSS CUTTING

6. Are storm frequency and magnitude increasing, decreasing, or remaining stable? CROSS CUTTING

7. Is the atmospheric deposition of toxic contaminants increasing…?

8. Are oil and other hazardous spills—or, the amount of substance from these spills—increasing…?

9. Are land uses trends changing in ways that would increase, decrease or stabilize toxic contaminants as well as pathogenic and indicator microorganisms? CROSS CUT WITH THE OTHER FOUR FOCUS AREAS

10. Are loadings of pathogenic and indicator microorganisms, biotoxins and toxic contaminants from WWTPs and septic tanks increasing…?

11. Are loadings of pathogenic and indicator microorganisms, biotoxins and toxic contaminants from agriculture and stormwater increasing…?

12. Is domestic and public/sector application of toxic substances (e.g., PFAS; PAHs, microplastics, etc.) increasing…?

13. Are industrial discharges of contaminants increasing…?

14. Are loadings from sediment disturbance events (e.g., dredging, etc.) increasing…?

15. Are sediment quality indices (Sediment Triad Approach) increasing…?

    - Triad approach involves sediment chemistry, benthic community analysis, and toxicity tests (using organisms such as *Ampelisca abdita,* or *Leptocheirus plumulosus)*
    - *Note that the Triad Approach is also relevant to fish and less directly to shellfish and eelgrass (through impacting grazers) as well. CROSS CUT WITH FISH, SHELLFISH, AND EELGRASS*

** Methods Note: During the "methods" phase of the Plan development, we should discuss in detail issues related to how often certain variables need to be monitored. Several scenarios may apply, such as:*

- Lots of data exist; need only to check-in every few years to see if patterns have changed.
- Less data exist; need to monitor annually at high temporal resolutions before backing off to the above level.

<u>"Level 3" Questions/Activities for Human Health</u>

** Note: We expect more questions to be added to this list during the "Methods" discussions, since exploratory research is often necessary to determine most appropriate methods for some questions. Spatial and temporal aspects for questions below need to be worked out. For each question, it will be important to suss out spatial and temporal variability and proceed accordingly to reduce uncertainty.*

- Synthesize existing data in reference to the model to discern what info we have and what gaps remain. CROSS CUT WITH OTHERS
- Monitoring and research around land use, and land use conversion should include population changes. CROSS CUT WITH OTHERS
- What concentrations of microplastics are necessary to pose a threat to human health?
- Which biotoxins (e.g., DSP, PSP, ASP, cyanotoxins) are posing the greatest threat to human health? Which should be monitored most closely? How can we better manage and contain risks associated with these biotoxins?
- What's the evidence for BMAA being aerosolized around the Great Bay Estuary? How about Hampton-Seabrook Estuary?
- What do we know and need to know about synergistic effects between BMAA and mercury, and how should that influence management actions? Are there synergistic effects between other biotoxins and other toxic contaminants, either legacy or emerging?
- Do we understand the relationship between ph and toxicity of heavy metals, such as cadmium? How will coastal acidification impact heavy metal toxicity? *(note that cadmium may also interfere with Sulphur processing by eelgrass, leading to sulfide toxicity)*
- Build off of DES and Paula Mouser work to develop a source and loading report similar to the "Great Bay Nitrogen Non-Point Source Study," focused on key and representative toxic contaminants.
- What is the impact of changing storm frequency/magnitude on bacterial concentrations in the water column and in shellfish? (Note: Currently, we have random sampling for shellfish—

go out in any weather—as well as some "dry-weather" sampling. During the "Methods" phase, this should be discussed.)

- How does microbial source tracking fit into this monitoring and research approach?

LIST OF CROSS CUTTING QUESTIONS

Applicable to All Five Focus Areas

1. Synthesize important existing data relevant to the focus area to discern what info we have and what gaps remain.
2. Confirm that we're adequately monitoring water temperatures at the right temporal and spatial scales.
3. Are sediment loading and sedimentation increasing, decreasing or remaining stable?
4. Is nutrient loading (both N and P) increasing, decreasing or remaining stable?
5. Is TSS increasing, decreasing or remaining stable?
6. How much TSS involves resuspended sediments versus new sediments from riverine or ocean or salt marsh erosion or wastewater sources?
7. How do we include feedbacks for each resource (e.g., more oysters leads to more oysters) as well as feedbacks from other resources (e.g., more oysters leads to less chl-a and less TSS, which can benefit eelgrass, which can benefit fish, etc.)?
8. How can the UNH CCOM Hydrodynamics Model be used add insight to questions for each of the five focus areas?
9. Are demographics, land use patterns and impervious cover changing or remaining stable?
10. How are regional and marine dynamics accounting for some of the year to year variability in key metrics for each of the five focus areas?
11. Are storm and storm surge events increasing, decreasing or remaining stable?

Applicable to Four of the Five Focus Areas in this Draft Plan

12. What do we know about the impact of green crabs (and other predators) on the four resources?
13. We know that green crabs are having mostly a negative impact on all four resources. What can we do to decrease their abundance?
14. Is there an amount of recovery that creates a tipping point (for each of the four non-human focus areas) so that the recovery becomes self-reinforcing?
15. Are dissolved oxygen, salinity and bathymetry increasing, decreasing or remaining the same?
16. Is phytoplankton (chl-a) increasing, decreasing or remaining stable?
17. Are the types and sizes of phytoplankton changing or remaining stable? For example, could use "size fraction" as a metric here. *(note the importance of the temporal/spatial component here)*
18. How is shoreline hardening changing in the different zones of each estuary?
19. Is light penetration increasing, decreasing or remaining stable?
20. Should we have a monitoring program for invasives (including but more broad than just green crabs), perhaps partnering with the BioBlitz program?

LIST OF CROSS CUTTING QUESTIONS (cont'd)

Applicable to Three of the Five Focus Areas

21. What is the relationship between tributary inputs of nutrients, organic matter and TSS and estuarine biological response (phytoplankton, seaweed and eelgrass)?
22. Do we have the data we need to understand whether sediment and water column nutrient levels are impacted by regeneration of nutrients from previous years? If so, what is our assessment of the contribution from regeneration? (This will be different for each of the five zones.)
23. Is seaweed production and biomass increasing, decreasing or remaining stable?
24. Is acidification increasing, decreasing or remaining stable?

Applicable to Shellfish and Fish

25. Should we have a monitoring program for kelp due to its potential role as habitat for fish and shellfish?
26. Is acidification increasing, decreasing or remaining stable?
27. Is sediment organic matter increasing, decreasing or remaining stable?

Applicable to Salt Marsh and Eelgrass

28. Are freshwater and sediment delivery increasing, decreasing or remaining stable?
29. Is sea level rise increasing, decreasing, or remaining stable?
30. Should groundwater levels be tracked as research or more regularly? (In particular, look at updating the Ballestero 2004 study?)
31. Develop a nutrient and sediment budget relevant to salt marshes and eelgrass.

Applicable to Eelgrass and Shellfish

32. Develop a nutrient and sediment budget relevant to salt marshes and eelgrass.

Applicable to Fish and Salt Marsh

33. Develop nutrient and sediment budgets for both salt marshes and eelgrass.

Applicable to Fish and Humans

34. Are toxic contaminant concentrations in the sediment and water column increasing, decreasing, or remaining stable?
35. Are toxic contaminants concentrations in fish tissue (increasing, decreasing or remaining stable?
36. Are the Sediment Triad indicators increasing, decreasing or remaining stable?

NEXT STEPS

- Vote to appove Humans section.
- Begin the "Methods" phase, involving small-group meetings and then a large group meeting to review.
- Then, move on to "Priorities" phase, involving small-group meetings and then a large group meeting to review.
- Produce draft of final document and review.
- Begin working on addenda, including issues around lobsters, horseshoe crabs and other components not covered by this version of the RAMP.

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Appendix B

Piscataqua Region Monitoring Collaborative

Piscataqua Region Monitoring Collaborative (PRMC)

Research/Monitoring Prospectus

Overview of Science Activities in Support of Estuarine Health

DRAFT: November 2020

(This draft focuses on issues related to general water quality and other factors related to eelgrass. Later drafts will broaden focus to include shellfish, salt marshes, fish, and humans.)

Compiled by:

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ACKNOWLEDGEMENTS

The development of this prospectus relies on the parallel development of the new Research and Monitoring Plan (RAMP), due to be completed in spring of 2021. The RAMP has been developed with input provided by technical experts from the Piscataqua Region, including researchers from the University of New Hampshire, the NH Chapter of The Nature Conservancy, NH Fish & Game, NH Department of Environmental Services, and the Great Bay National Estuarine Research Reserve. In addition, this outline has been influenced by two external advisors: Brad Peterson from Stony Brook University and Jud Kenworthy, retired from NOAA. Significant input has been provided by the PREP Technical Advisory Committee (TAC) co-chairs: Bonnie Brown and Wilfred Wollheim, both of UNH.

An early draft of the RAMP was reviewed by the full TAC in April 2020 and is available on PREP's website at: https://unh.app.box.com/s/cg7l31xw1l637k3qilglsaeh6b52dp80

We also acknowledge the contributions of everyone who has attended PRMC meetings over the last couple of years, and we are thankful to the PRMC Chairs, Ted Diers and Jennifer Perry, for their time and leadership.

The Piscataqua Region Estuaries Partnership (PREP) is an EPA-funded nonprofit organization and a National Estuary Program, a joint local/state/federal program established under the Clean Water Act with the goal of protecting and enhancing nationally significant estuarine resources. PREP is housed at UNH and focuses on the watersheds of the Great Bay Estuary and the Hampton-Seabrook Estuary.

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EXECUTIVE SUMMARY

The purpose of the Piscataqua Region Monitoring Collaborative (PRMC) is to coordinate amongst diverse partners in order to implement the monitoring and research activities necessary to understand and protect the health of our estuaries.

This Prospectus articulates the most critical activities (and the costs of those activities), necessary to understand the dynamics of the eelgrass ecosystem in the Great Bay Estuary as well as the most relevant water quality parameters that impact eelgrass. The Prospectus is based on the Research and Monitoring Plan (RAMP), which is being developed in parallel with the Prospectus. By spring of 2021, we anticipate that the Prospectus will also include activities and costs for other critical components of estuarine health, such as salt marshes, shellfish, fish and humans.

Focusing on only the most critical activities, the Prospectus notes a cost (for the 2021 field season) of $397,000, as compared with anticipated funds of $171,000. This leaves a gap of $226,000. Without the generous contributions—both discrete and in-kind—of our many PRMC partners, this funding gap would be much greater.

On the other hand, until we find a way to consistently bridge this gap, we will continue to struggle to understand and manage the changing health of our estuaries, and to understand what we should do in response to changes.

While the pandemic adds a further challenge to budgets—for example, NH DES has been asked to reduce its budget requests by 20%—it's clear that the funding gap is a long-term and systemic challenge that the PRMC partners need to address.

This would be true even if all we cared about was eelgrass, which is obviously not the case. Eelgrass receives a great deal of attention because of its role as an indicator of overall estuarine health, in addition to the critical functions eelgrass habitats provide. But equally important are efforts to better understand the changing nature of salt marshes, shellfish habitats, fish and, finally, issues related to humans, such as being able to recreate in and on the water safely as well as consume shellfish and fish without fear for personal health. Expanding to other components of the ecosystem will also mean a geographic expansion so that subsequent drafts of the Prospectus will have a greater focus on the Hampton-Seabrook Estuary as well.

At this time, we estimate that a Prospectus that includes these other components—which we hope to do by spring of 2021—would show a funding gap much higher than $226,000: possibly as high as $800,000.

Again, that gap would be even higher without the great work of our partners. For example, GBNERR and NH DES have made significant strides in salt marsh monitoring in recent years. The Nature Conservancy, working with UNH partners, has done the same with regard to oyster habitat in the Great Bay Estuary; NH Fish and Game collects and publishes extensive data on migratory fish, while the NH DES Shellfish Program works very hard to monitor the factors that impact shellfish in our waters; NextEra contributes over $80,000 annually to monitoring of clam flats in the Hampton-Seabrook Estuary. In fact, this Prospectus indicates that the PRMC receives the benefits of over $1 million in built-in annual funding and over 5 years of cumulative personnel time over one field season year. And this doesn't even include municipal efforts such as receiving water monitoring or land conservation efforts…and many others.

These success stories would indicate that we are capable of erasing this funding gap. It is our hope that continued PRMC collaboration will increase the chances of that happening. Thank you for your partnership.

Kalle Matso (PREP)

Ted Diers (NH DES) and Jennifer Perry (Town of Exeter), PRMC Co-Chairs

INTRODUCTION

The Purpose of the PRMC

The purpose of the PRMC is to coordinate amongst diverse partners in order to implement the monitoring and research activities necessary to understand and protect the health of our estuaries (Great Bay and Hampton-Seabrook). The underlying reasoning is that enhanced coordination will lead to: 1) shared decision making, 2) more resources from more partners in the Piscataqua Watershed, 3) more effective use of those resources for the benefit of our estuaries, and 4) better data sharing and dissemination.

The Purpose of this Prospectus

To communicate a high-level summary of goals, science questions, monitoring and research activities, and the budgets associated with those activities. For more detailed discussions of the goals and science questions, please see the RAMP.

Process Notes for this Prospectus

This Prospectus is based on the RAMP, which is currently in draft form. Since the release of the last version of the RAMP, technical experts have met to advance the specific methods related to eelgrass and general water quality activities. Similar work for salt marsh, shellfish, fish and humans is currently being planned.

The plan is for the Prospectus to be developed and released in tandem with the RAMP, which is slated for completion in the spring of 2021. We are hoping that a much more advanced version of the Prospectus will be ready for the next meeting of the PRMC, currently planned for June 2021. We anticipate that meeting in June will better enable all partners to plan for contributions for the 2022 field season.

GOALS FOR ESTUARINE HEALTH (from the RAMP)

- We strive for a balanced, productive ecosystem of indigenous aquatic species and habitats.
- We focus in particular on the following non-human resources: shellfish, eelgrass, salt marsh, and fish. We strive for these resources to be as abundant and productive as they were at their respective peaks during the period beginning in the early 1970s and extending to the present day.
- We also focus on humans. In that regard, we strive to have fish and shellfish that are safe for human consumption as well as clean water that is safe for swimming.

The above goals were developed through the TAC and are based on PREP's Comprehensive Conservation and Management Plan (CCMP). The CCMP (https://scholars.unh.edu/prep/22/) was last published in 2010 after considerable stakeholder input; the 2020 – 2030 CCMP is currently in the process of being revised.

The RAMP uses the conceptual model below (Figure 1) to guide development of research questions and data collection priorities.

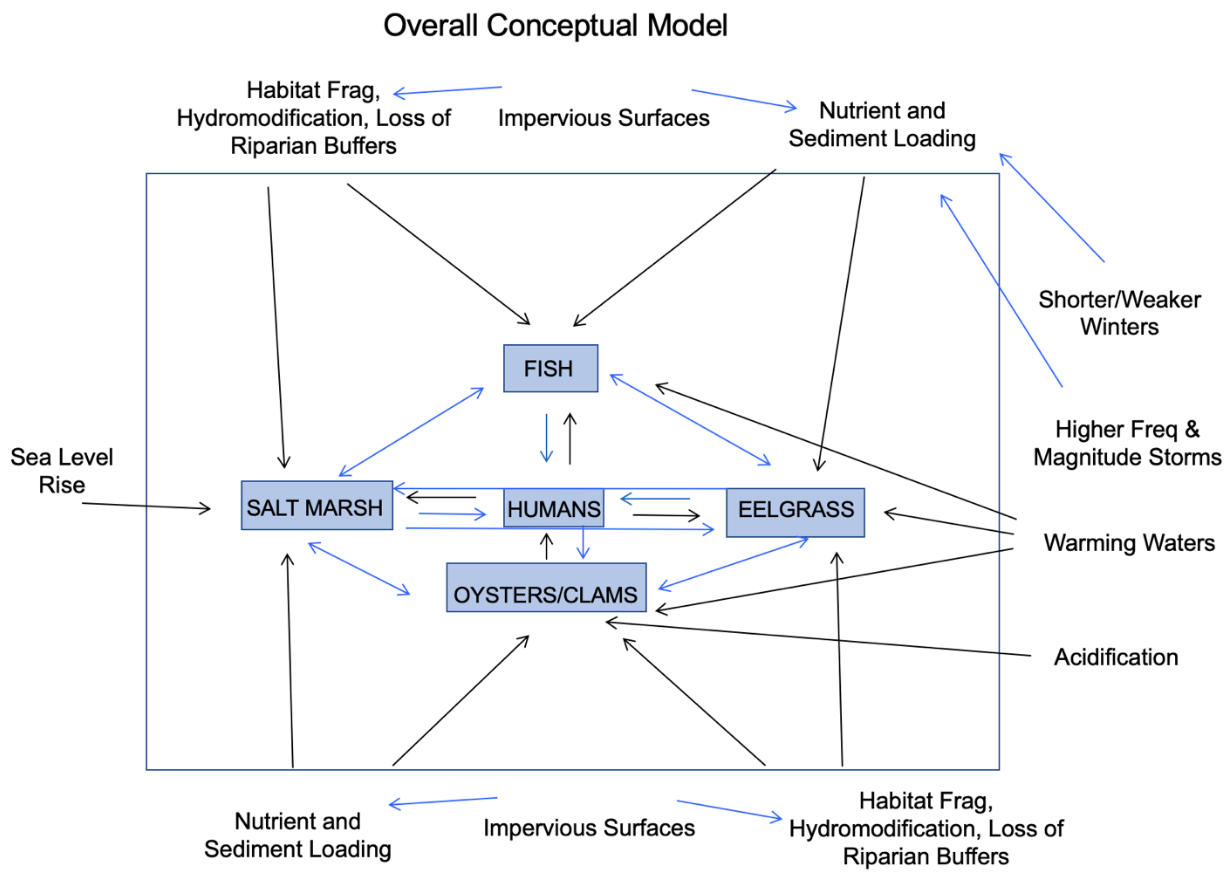


Figure 1. Conceptual model showing five focus areas of the RAMP. Blue arrows indicate an "increasing effect" while black arrows indicate a "decreasing effect." (E.g., Humans can have a negative impact on eelgrass through pollution, while eelgrass has a positive effect on humans through storm buffering.) Not all relationships are indicated by arrows in order to minimize visual complexity. Note that stressors on the left and right of the model are less amenable to management. The stressors on the top and bottom of the model are the same and are considered more amenable to management. More detailed conceptual models will accompany each focus in this Plan—shellfish, eelgrass, salt marsh, fish and humans.

GOALS, QUESTIONS, MODELS FOR EELGRASS (AND WATER QUALITY)

- Current goal from CCMP
    1. 2900 acres of eelgrass (greater than 10% cover.)

       The 2019 assessment indicated under 1700 acres of eelgrass.
- Recommendation for New Goal Statements Related to Abundance/Health
    1. Establish goals for separate zones of the Great Bay Estuary*:
        - Great Bay
        - Little Bay
        - Lower Piscataqua River
        - Upper Piscataqua River

- Coastal Areas (inc. Portsmouth Harbor)

2. Establish an abundance (e.g., percent cover, density, biomass) benchmark and goal for these same areas**

* These sections are based on hydrodynamic designations from Bilgili et al. 2005. Note that the zones penetrate up the tributaries roughly between 1 and 3 miles, depending on dams and head of tide locations.

**Note: Use SeagrassNet sites at Portsmouth Harbor and Great Bay for more detailed causal investigations of patterns seen at the more spatially expansive scales. This approach reflects "Tiered Monitoring" approach from Neckles et al. 2012.

EELGRASS MONITORING AND RESEARCH QUESTIONS (from the RAMP)

Approach to Reaching Eelgrass Goals

Management actions (e.g., nutrient and sediment reductions; restoration) are currently underway or under consideration. Understanding that we will need to make decisions without certainty*, the key question is: Should current management actions be continued, discontinued, modified or added to?

** The complex and dynamic nature of ecosystems stymie cause and effect certainty. The TAC recommends using multiple lines of evidence to create a suite of options indexed to how protective the Piscataqua Region wants to be with regard to estuarine ecosystems.*

Current and potential management actions and their impacts must be considered in relation to factors amenable to management (e.g., nutrient reduction, shoreline protection) versus factors that are less amenable to management (e.g., warming waters, more frequent extreme storms, etc.). Therefore, science activities need to consider both kinds of factors and how they relate to each other.

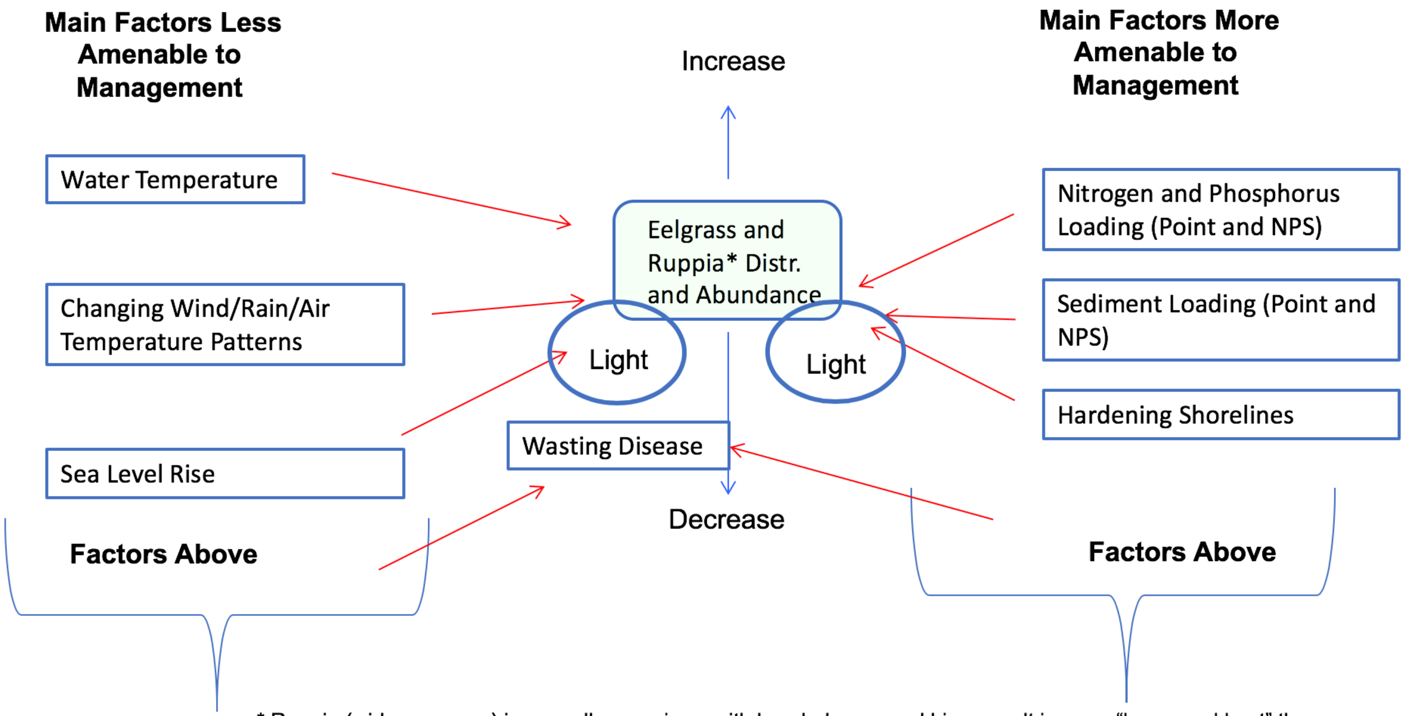
Some current management actions include:

- Nutrient and sediment reduction efforts from point (improvements and upgrades) and non-point sources (new stormwater practices, etc.)
- Buffer protection.
- Land conservation.

Some potential management actions include:

- Increased nutrient and sediment reduction efforts.
- Pilot-scale eelgrass restoration efforts.
- Improved shoreline management.
- Improved invasive species (e.g., green crab, etc.) management.

Figure 2. Simple model of eelgrass abundance/health and stressors.



* Ruppia (widgeon grass) is a smaller species—with less belowground biomass. It is more "boom and bust" than eelgrass. and is known to be more tolerant of freshwater and warmer temperatures.

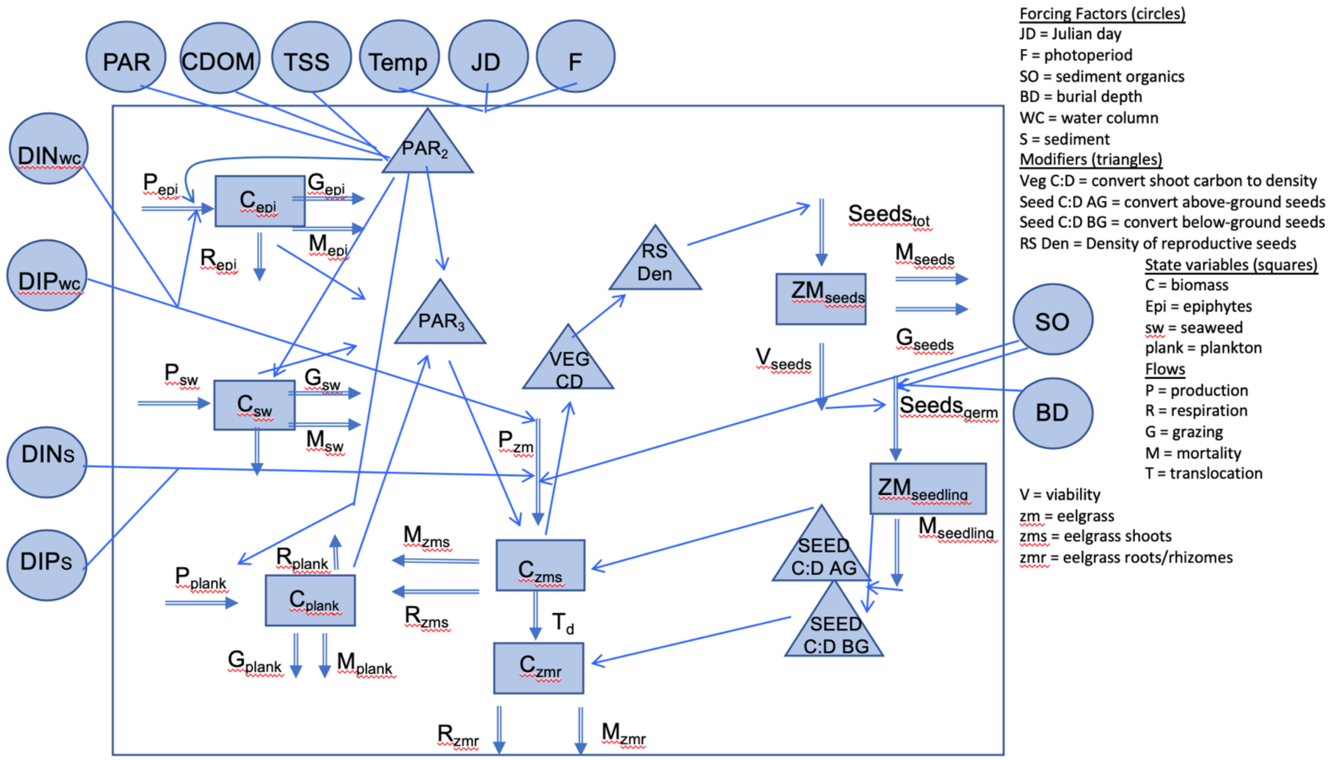
<u>Monitoring Questions Stemming from Figure 2</u>

1. What is the maximum area that is habitable by eelgrass, based on bathymetry, light, etc.?
2. Is eelgrass (and Ruppia) acreage overall and in each of the five areas of the estuary increasing, declining, or remaining stable?
3. Is abundance (e.g., cover, biomass, density, deep edge) in each of the five areas of the estuary increasing, declining or remaining stable?
4. Is water temperature in eelgrass beds in each of the five areas…?
5. Are wind (speed and direction), rain, air temperature patterns….?
6. Is Sea Level Rise….?
7. Is nitrogen and phosphorus loading (total and for each sub-watershed) increasing, decreasing or remaining stable?
8. Is sediment loading increasing…?
   - Make sure to account for/assess resuspension of estuarine sediments
9. How is shoreline hardening changing in each of the zones?
10. Is wasting disease increasing…?

11. Is Ruppia distribution increasing…?

12. Is light penetration increasing…? (see next figure)

Figure 3. Detailed conceptual model of eelgrass ecosystem (adapted from Jarvis et al. 2014).



Conceptual diagram for eelgrass production and sexual reproduction. Circles = forcing functions, triangles = modifiers, squares = state variables, thick arrows = flows, and thin arrows = connections. Temp, JD, and F affect multiple processes so are not connected to minimize diagram complexity.

Research and Monitoring Questions Based on Figure 3

1. Is incident light and light attenuation (PAR_2 and PAR_3) increasing, decreasing or remaining the same?
2. Is phytoplankton (chl-a) increasing, decreasing or remaining stable?
3. Are dissolved inorganic nitrogen and phosphorus (both in water column and sediments) increasing, decreasing or remaining stable?
4. Are TSS increasing, decreasing or remaining stable?
5. Is epiphyte production and biomass increasing….?
6. Is seaweed production and biomass increasing…?
7. Is production and biomass (above and belowground) of eelgrass increasing…?
8. Are the number of reproductive shoots increasing…?
9. Are the number and viability of seeds and seedlings increasing…?
10. What is the burial depth of seeds? Increasing…?
11. Is sediment organic matter increasing…?

Other Research Questions/Activities for Eelgrass

- Synthesize existing data (water quality—both grabs and sondes—and SeagrassNet) in reference to the model to discern what info we have and what gaps remain.
- Look at the data we have on CDOM (or FDOM) and chl-a to determine how these components should be included in the model: as forcing functions or as a state variable.
- How can we include feedback mechanisms (e.g., loss of eelgrass increases sediment resuspension; biogeochemical) in our model and assessments?
- How do we include feedbacks from other bio resources (e.g., more oysters leads to less chl-a and less TSS; more fish leads to more grazing of epiphytes; more carbon from eelgrass feeds fish drivers, etc.)
- Should we consider developing an optical model to provide higher resolution to the model?
- Do we have the data we need to understand whether sediment and water column nutrient levels are impacted by regeneration of nutrients from previous years? If so, what is our assessment of the contribution from regeneration? (This will be different for each of the five zones.)
- Develop a nutrient budget specific to subtidal habitats (e.g., oysters and eelgrass).
- Develop a sediment budget specific to subtidal habitats (e.g., oysters and eelgrass).
- What is the relationship between tributary inputs of nutrients, organic matter and TSS and estuarine biological response (phytoplankton, seaweed and eelgrass)?
- Do eelgrass shoots (in 5 different zones) show signs of sulphur intrusion?
- How does eelgrass leaf tissue nitrogen and CNP ratios relate to nutrient loadings and concentrations? (benefits of using seaweed tissue over eelgrass?)
- How do carbon reserves in belowground biomass relate to other variables (carbon reserves being an indicator of stress)?
- Can we use genetic markers for resilience—and perhaps link this to the hydrodynamic model—to better understand distribution patterns and add insight into restoration priorities?
- Based on existing and emerging data, should we prioritize particular zones as places to prioritize management action?
- How much of TSS involves resuspended sediments versus new sediments from riverine or ocean or wastewater sources?
- What do we know about green crabs, invertebrate grazers and fish for these different zones… since we know that this can have a significant impact on eelgrass?
- How do wind and precipitation relate to TSS and other light attenuators?
- How does hardened shoreline patterns and wind combine to impact waves and resuspension?
- How important is it to keep track of silica, because it drives diatoms and also because it can be taken up as a defense mechanism to heavy metal toxicity?

- How does the location and magnitude of fresh and cold groundwater intrusion into the estuarine zone relate to other variables, such as: eelgrass distribution, health, nutrients, eelgrass health?
- Should groundwater levels be tracked as research or more regularly?
- How do changing patterns in Ruppia distribution relate to changes in temperature, wind, etc.?
    - What are the feedback consequences (e.g., sediments, sediment resuspension, etc.) of greater amounts of Ruppia?

BUDGETS

In this section, we try to bound the costs of the most salient science activities related to estuarine/tidal tributary water quality and eelgrass. Eventually, we hope to produce budget assessments that capture full costs: that is, including ongoing/built-in salaries, overhead, etc. At this stage, however, we will focus on discretionary dollars (with some exceptions) connected to the annual budgets of the many partners that comprise the PRMC. While this Prospectus does not cover all estuarine monitoring and research, we estimate that it does over 90% of the monitoring activities that are used for PREP's State of Our Estuaries Reports as well as NH DES' 303(d)/305(b) Assessments.

How PRMC Monitoring Overlaps with Monitoring for EPA Great Bay Total Nitrogen Permit

The monitoring suggested by EPA for the Permit was developed by EPA Region 1. In contrast, the RAMP has been developed by PREP's TAC with the advice of External Advisors. When the Permit comes into effect, there will have to be a process of reconciling PREP's monitoring recommendations with those of EPA. For the moment, they are separate processes.

Main Contributors to the PRMC and Their Roles

Over the last decade, the main contributors to the PRMC have been PREP (funded primarily by EPA), GBNERR (funded primarily by NOAA), NH DES (with some funding from NOAA), Great Bay 2020 (a collaboration between PREP, NH DES, The Nature Conservancy NH, GBNERR, and Conservation Law Foundation), and municipalities (See Figures 5, below). Contributing municipalities have included: Portsmouth, Rochester, Dover, Newmarket, Stratham, Exeter, Durham, Newfields, and Hampton.

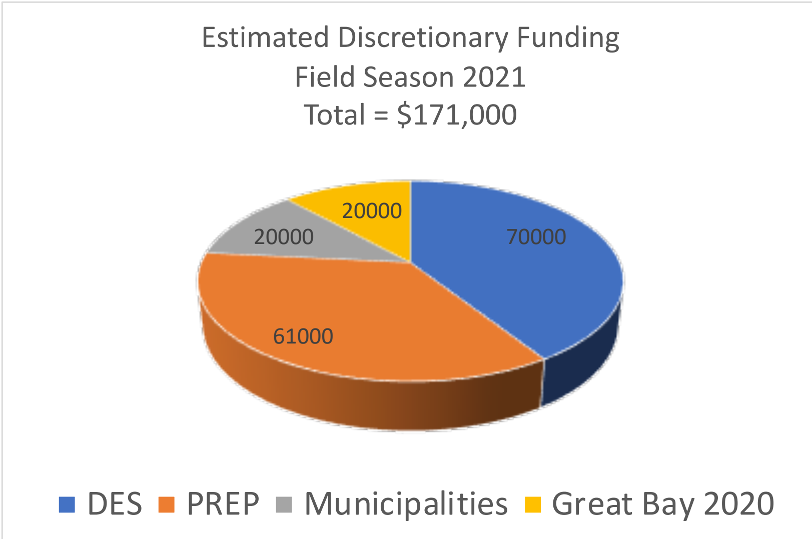


Figure 4: In past years, municipalities have contributed as much as $90,000;
However, Covid has caused decreased projections for 2021.

Discretionary Funds

PREP's EPA funds are somewhat flexible but have most often contributed to eelgrass presence/absence and estuarine/tidal tributary water quality (datasondes and grab sample stations). DES funds have mostly supported estuarine water quality monitoring as well as efforts around characterizing seagrass and seaweed in the estuary. In addition, a portion of the DES funds come from the Shellfish Program, which focuses on water quality sondes and stations. Great Bay 2020 funds have supported various efforts, such as the purchase of equipment and the establishment of the new SeagrassNet station in Portsmouth Harbor.

Pre-Allocated Funds and Resources

GBNERR's funds (~$121,000) are allocated to water quality sondes and grab sample stations (Lamprey River, Squamscott River, Great Bay and Oyster River). The Town of Newmarket contributes to additional water quality monitoring in the Lamprey as part of their agreement with EPA; NERACOOS funds support the "Great Bay Buoy" and instrumentation at the Coastal Marine Lab in Portsmouth Harbor, as well as web-based systems for making real-time data available to the public.

Contributions have also come from local NGOs, such as the Lamprey River Advisory Committee. Additionally, in 2019, PREP received a donation of $525,000 from the Town of Durham in association with a settlement agreement that was reached with Eversource Energy. Those funds are being applied to various efforts, including the development of the RAMP (helping to pay for External Advisors); processing and analysis of archived samples/data; the development of a new PREP Data Management System and an expert elicitation process around nonstructural BMPs.

The detailed budget in the Appendices indicates that the PRMC receives the benefits of over $1 million of built-in annual funding and investment from partners through their organizational efforts, and over 5 years of cumulative personnel time over one field season year.

Costs of Recommended Science Activities

Table 1 below lists the highest priority science activities and their costs; it does not include many of the questions at the bottom of page 9 and the top of page 10, but it does encompass the questions on pages 7 and 8.

Table 1: RAMP Science Questions, Methods and Costs. A more detailed version can be found in the Appendices.

#	RAMP Question/Issue	Method	Annual Cost ($)	Frequency	Cost Comments
1	Is Presence/Absence (distribution) of Eelgrass and Widgeon Grass Changing Over Time?	"Tier 1" Aerial or Drone Remote Sensing with Field Verification	50000	Every Two Years	PREP Staff Time Contributed
2	Is eelgrass condition (and seaweed species composition and biomass) in each of 4 estuarine zones changing over time?	"Tier 2" Sampling (~ 50 sites): Eelgrass and Seaweed Parameters; Sediment characteristics at a subset of sites	35000	Annual (Summer)	PREP Staff Time Contributed
3	Is the health of eelgrass and related factors at key index sites changing over time?	"Tier 3" using SeagrassNet protocol. Extensive eelgrass parameters at a site in Great Bay and a site in Portsmouth Harbor.	31000	Annual (Summer)	PREP Staff Time Contributed
4	Are light conditions at key sites changing over time?	3 Units; 2 PAR Sensors with wipers per unit; one in Portsmouth Harbor, Little Bay, Great Bay	23,000	Annual (Growing Period)	One-Time Purchase of 3 "light stations"; annual calibration costs (~2400) after that
5	Are important water column parameters changing over time?	Nutrients, Turbidity, TSS, ph, Temperature, Salinity, Dissolved Oxygen, etc., using grab samples and datasondes at 11 sites.	86,000	Annual (April through August)	Costs are for a low to medium temporal and spatial frequency. GBNERR, NERACOOS, Town of Newmarket contributing funds (see narrative).
6	Are phytoplankton size and species composition changing over time?	Assessed using FlowCam and Flow Cytometry	0	Annual (Weekly at Adams 2 sites)	Courtesy of Elizabeth Harvey Lab (UNH)
7	Tidal Tributary Water Quality/Nitrogen Loading	Nutrient Concentrations and TSS at 8 Tributaries	13,000	Annual (April through December)	n/a
8	How is Point Source and NPS Nitrogen Loading Changing over Time?	Communication with WWTPs for Point Sources; Modeling and Surface Water data	24000	Every Three Years	n/a
9	Nutrient Budget: How much of nutrient loading is absorbed in the estuary versus exported to the ocean and atmosphere?	Use Existing Data to assess Loads: (organics, sediments, nutrients) versus what leaves Great Bay	0	One-Time Project, most likely	Paid for via Anna Lowien Masters project from NOAA, GBNERR, McDowell Lab, PREP, LRAC
10	Nutrient Budget: Where are nutrients being stored within the estuarine system (e.g., plants, algae, microbes, sediments, etc.)?	New Field Surveys, Combined with Hydrodynamic Modeling, to understand and model loads, internal processes and impacts on primary producers and water quality	79,000	One-Time Project; may need to be repeated in 10 years	Total of 120K; Rest paid for Through NOAA grant to Anna Lowien
11	External Advisors	Contract with Jud Kenworthy (North Carolina) and Brad Peterson (NY)	14,000	Annual	n/a
12	Additional Data Analysis associated with above datasets	Contractor (TBD)	42,000	Annual	n/a
13	How is Point Source and NPS Phosphorus Loading Changing over Time?	Phosphorus Loading from Point and Non-Point Sources	25000	Annual	n/a
14	What is the source of Sediment Loading to the Great Bay Estuary?	Combination of sediment cores, bathymetry and hydrodynamic modeling	40000	One-Time Project; may repeat in future	n/a
15	How is Shoreline Hardening Changing over time?	Tracks the percentage of shoreline area that has been hardened against erosion.	12,000	Every 5 or 10 years	n/a
		Total Discrete Annual Costs for Highest Priority Items (#s 1 thru 12)	397,000		
		Total Discrete Annual Funds	171,000		
		Funding Gap	226,000		
		Funding Gap (Including Items 13 through 15)	303,000		

Costs of Recommended Science Activities (cont'd)

Table 1 includes some items that won't be required every year (e.g., Tier 1 eelgrass assessment) but it also omits some items that are needed periodically, such as revising the assessments of impervious cover. We assume that these inclusions and omissions will roughly balance out over time. *Finally, we note that the June 2021 version of the Prospectus will add an across-the-board 10% line item to account for unforeseen expenses.*

The Costs of Covid

This Prospectus focuses on discretionary funds. Our need for discretionary funds is obviously impacted by non-discretionary funds, such as the money that GBNERR spends on water quality monitoring every year or the money that the NH DES Shellfish Program spends on water quality monitoring to ensure that our shellfish are safe to eat. Unfortunately, the pandemic will no doubt impact these non-discretionary funds. For example, the Shellfish Program's FY 2021 budget was originally $515,334. However, due to Covid, it is likely that this amount will be reduced by $75,000.

No doubt many of our other partners, both governmental and non-governmental, will feel similar budget pressures over the coming years.

Expanding the Prospectus to Include Other Parts of the Estuarine Ecosystem

Please recall that this draft of the Prospectus is focused on eelgrass and those water quality factors that impact eelgrass. By spring of 2020, we hope to broaden the Prospectus to include salt marshes, shellfish habitats, fish and, finally, issues related to humans, such as being able to recreate in and on the water safely or consume shellfish and fish without fear for personal health.

Expanding to other components of the ecosystem will also mean a geographic expansion so that subsequent drafts of the Prospectus will have a greater focus on the Hampton-Seabrook Estuary as well. Because there is little eelgrass in Hampton-Seabrook, that estuary is largely absent from this draft of the Prospectus.

Meetings with experts and partners associated with these other ecosystem components are underway, and budgets are being built to mirror what has been presented here for eelgrass. At this time, we estimate that a Prospectus that includes these other components as well—which we hope to do by spring of 2021—would show a funding gap much higher than $303,000: possibly as high as $600,000.

This does not include what the RAMP refers to as "Crossover" science issues: issues not particular to just one component. For example, better monitoring the impacts of green crabs is critical information that will help us with regard to salt marshes, shellfish and fish—not just eelgrass. Including Crossover issues in our budget could increase the gap to $800,000.

Once again, this gap would be even higher without the great work of our partners. For example, GBNERR and NH DES have made significant strides in salt marsh monitoring in recent years. The Nature Conservancy, working with UNH partners, has done the same with regard to oyster habitat in the Great Bay Estuary. NH Fish and Game collects and publishes extensive data on migratory fish, while the NH DES Shellfish Program works very hard to monitor the factors that impact shellfish in our waters. And NextEra contributes over $80,000 annually to monitoring of clam flats in the Hampton-Seabrook Estuary.

Please see the Appendices for a more detailed budget, a list of datasonde/grab sample stations, as well as a map of the Great Bay Estuary showing the locations of various monitoring activities.

The collaborations noted in this Prospectus indicate that we are capable of erasing this funding gap. It is our hope that continued PRMC coordination will increase the chances of that happening. Thank you for your partnership.

NEXT STEPS FOR THE PROSPECTUS

- Hear feedback at Nov. 30th meeting and implement suggestions for improvement.
- Ask for suggestions electronically as well; implement those.
- Expand the Prospectus to include non-discrete (i.e., full costs that include overhead, personnel salaries, etc.)
- Expand the Prospectus to include costs for other components of the RAMP, including salt marshes, shellfish, fish and humans.

REFERENCES

Bilgili A, Proel JA, Lynch DR, Smith DW and Swift MR. 2005. Estuary/ocean exchange and tidal mixing in a Gulf of Maine Estuary: A Lagrangian modeling study. *Estuarine, Coastal and Shelf Science*, 65: 607-624.

Jarvis JA, Brush MJ and KA Moore. 2014. Modeling loss and recovery of *Zostera marina* beds in the Chesapeake Bay: The role of seedlings and seed-bank viability. *Aquatic Botany*. 113: 32-45

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APPENDICES

Appendix 1: Table, Detailed Budget

Appendix 2: Table, Station by Station Explanation of Datasondes and Grab Samples

Appendix 3: Map of Great Bay Estuary, Showing Eelgrass-Related and Water Quality Science Activities

Appendix 1:

#	RAMP Question/Issue	Reason Important	Method (Personnel)	Annual Discrete Cost ($)	Annual Built-in Funding ($)	Annual Built-in Personnel Time (Months)	Frequency	Cost Comments
1	Is Presence/Absence (distribution) of Eelgrass Changing Over Time?	To track changes in eelgrass distribution throughout estuary.	"Tier 1" Aerial or Drone Remote Sensing with Field Verification (PREP + Contractor)	50000	0	0.5	Every Two Years	Built in component comes from PREP salary
2	Is eelgrass condition in each of 4 estuarine zones changing over time?	To understand key aspects of eelgrass condition at a broad spatial scale.	"Tier 2" Sampling (~ 50 sites): Eelgrass and Seaweed Canopy height, percent cover, epiphytes, # reproductive shoots, seedlings, seeds, seed burial depth. Subset (20 sites): biomass, sediment org matter, porosity, grain size, eelgrass tissue stable isotope analysis. (JEL/PREP/)	35000	0	3	Annual (Summer)	Built in component comes from PREP salary
3	Is the health of eelgrass and related factors at key index sites changing over time?	High resolution data on condition and other factors helps to answer questions related to why trends are happening.	"Tier 3" using SeagrassNet protocol. Once per year in July/August at peak biomass. Includes: seaweed biomass, light, temp, salinity, sediments, wasting disease, evidence of grazing (JEL and PREP)	31000	0	2	Annual (Summer)	Built in component comes from PREP salary
4	Are light conditions at key sites changing over time?	Higher resolution light data is necessary to understand trends in eelgrass health and distribution.	3 Units; 2 PAR Sensors with wipers per unit; one in Portsmouth Harbor, Little Bay, Great Bay (JEL)	23,000	0	0.5	Annual (Growing Period)	One-Time Purchase of 3 "light stations"; annual calibration costs (~2500 dollars) after that. Built in component comes from PREP salary
5	Are important Water Column parameters changing over time?	Provides info on many water column factors affecting eelgrass, oysters, fish, salt marsh and humans.	Nutrients, Turbidity, TSS, ph, Temperature, Salinity, Dissolved Oxygen, etc., using grab samples and datasondes (JEL)	86,000	711,000	25	Annual (April through August)	Costs are for a low to medium temporal and spatial frequencyj. Built-in costs: Great Bay NERR (121K), NERACOOS (300K and 4 months) NH DES Shellfish Program (250K and 20 months), Town of Newmarket (40K and one month)
6	Are Phytoplankton Size and Species Composition changing over time?	An important metric for food webs and eutrophication.	Assessed using FlowCam and Flow Cytometry (Elizabeth Harvey Lab, UNH)	0	23,500	1	Annual (Weekly at Adams Point and North Beach, Hampton)	Courtesy of Harvey Lab
7	Tidal Tributary Water Quality/Nitrogen Loading	To understand tributary WQ and calculate nutrient loading	Nutrient Concentrations and TSS at 8 Tributaries (Michelle Daley Shattuck, Bill McDowell Lab, UNH)	13,000	0	0.25	Annual (April through December)	Built in comes from PREP salary

Appendix 1 (cont'd)

#	RAMP Question/Issue	Reason Important	Method (Personnel)	Annual Discrete Cost ($)	Annual Built-in Funding ($)	Annual Built-in Personnel Time (Months)	Frequency	Cost Comments
8	How is Point Source and NPS Nitrogen Loading Changing over Time?	Essential for assessing eutrophication.	Communication with WWTPs for Point Sources; Modeling and Surface Water data (Michelle Daley Shattuck, Bill McDowell Lab, UNH)	24000	0	0.25	Every Three Years	Built in comes from PREP salary
9	Nutrient Budget: How much of nutrient loading is absorbed in the estuary versus exported to the ocean and atmosphere?	Critical for any model where nutrients are important. (What comes in, what goes out.)	Use Existing Data to assess Loads: (organics, sediments, nutrients) versus what leaves Great Bay; start with Great Bay; expand later (Anna Lowien of McDowell Lab, UNH)	0	56,000	12	One-Time Project, most likely	Built in comes from Anna Lowien, Masters Student, and Mcdowell (UNH).
10	Nutrient Budget: Where are nutrients being stored within the estuarine system (e.g., plants, algae, microbes, sediments, etc.)?	Critical for any model where nutrients are important.	New Field Surveys, Combined with Hydrodynamic Modeling, to understand and model loads, internal processes and impacts on eelgrass, seaweed, phytoplankton, sediments, and CDOM (Anna Lowien, Lippmann Lab)	79,000	41,000	13	One-Time Project; may need to be repeated in future	Built-in funds and personnel time through NOAA and GBNERR grant to Anna Lowien. Built in costs comes from McDowell and Tom Lippmann (UNH)
11	External Advisors	Increase in scientific credibility to have external advisors, in addition to local experts.	Contract with Jud Kenworthy (North Carolina) and Brad Peterson (NY)	14,000	0	0	Annual	n/a
12	Additional Data Analysis associated with above datasets	PREP Staff insufficient to conduct all necessary analyses of above data	Contractor (TBD)	42,000	0	1	Annual	Built in comes from PREP salary
13	How is Point Source and NPS Phosphorus Loading Changing over Time?	As nitrogen loads (and other factors change) the impact of P can also change.	Phosphorus Loading from Point and Non-Point Sources (Michelle Daley Shattuck, Bill McDowell Lab, UNH)	25000	0	0.25	Annual	Built in comes from PREP salary
14	What is the source of Sediment Loading to the Great Bay Estuary?	Sediment source and transport important for light and productivity.	Combination of sediment cores, bathymetry and hydrodynamic modeling	40000	0	0	One-Time Project; may need to be repeated in 10 years	n/a
15	How is Shoreline Hardening Changing over time?	Shown to impact eelgrass health and water quality	Tracks the percentage of shoreline area that has been hardened against erosion. (DES Intern)	12,000	0	0	Every 5 or 10 years	n/a

Appendix 1 (cont'd)

#	RAMP Question/Issue	Reason Important	Method (Personnel)	Annual Discrete Cost ($)	Annual Built-in Funding ($)	Annual Built-in Personnel Time (Months)	Frequency	Cost Comments
16	Processing and Syntheses of Previous Monitoring Activity/Data	To assess past patterns and determine future mehtods.	Work to be completed by PREP, partners and contractors.	0	106,000	6	One-Time	Already paid for through Town of Durham/Eversource
17	Data Management System	Data security and access.	Creation of a new PREP Database (Miguel Leon, McDowell Lab, UNH)	0	67,000	1	One-Time	Already paid for through Town of Durham/Eversource
		Total Discrete Annual Costs for Highest Priority Items (#s 1 thru 12)		397,000				
		Total Discrete Annual Funds		171,000				
		Funding Gap		226,000				
		Funding Gap (Including Items 13 through 15)		303,000				
		Estimate of Built-in Funding Contributions		1,004,500				
		Estimate of Built-in Personnel Time Contributions (months)		65.75				

APPENDIX 2

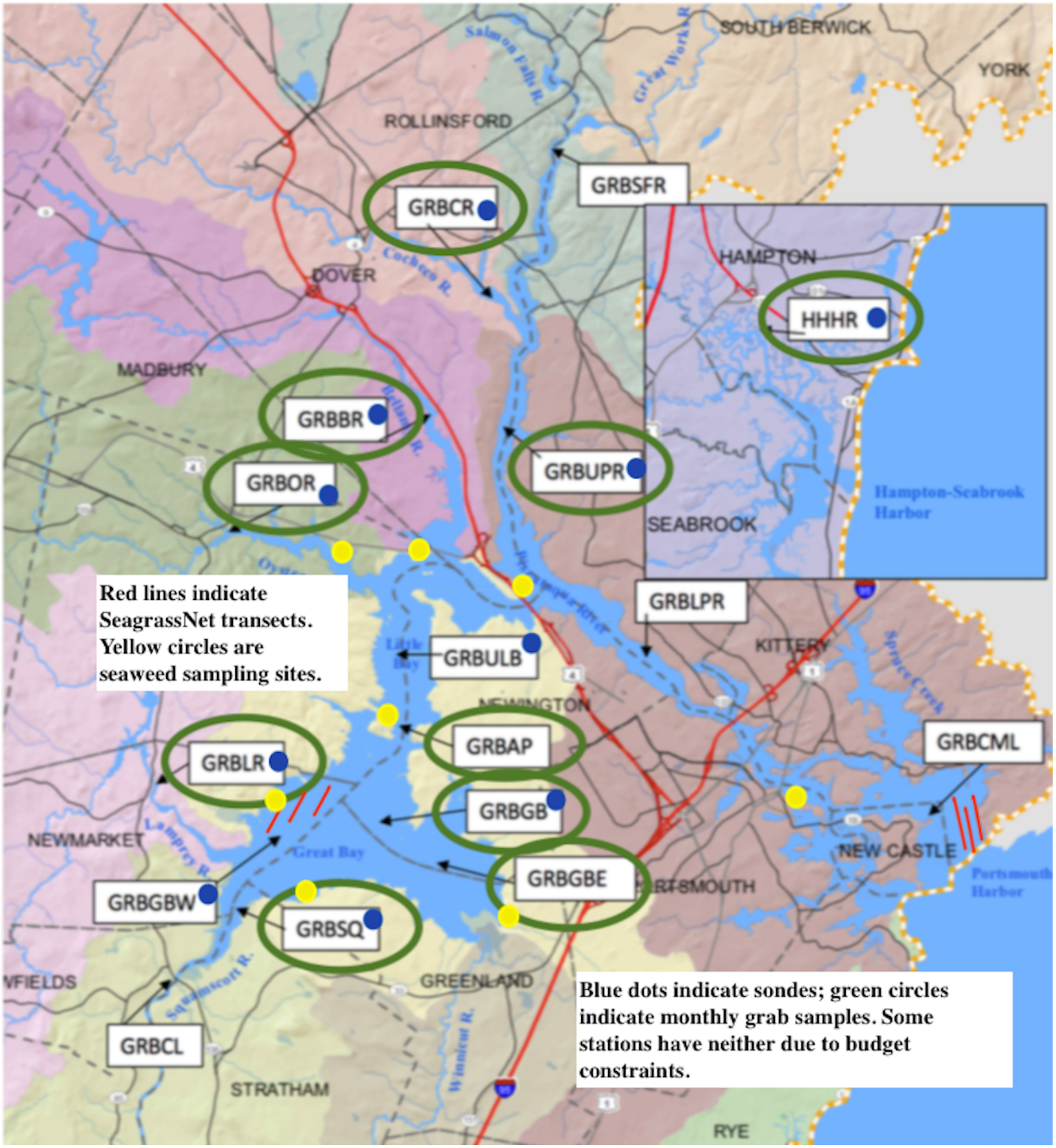
Estuarine Monitoring Activities 2021. Does not include work in the freshwater portion of the Tributaries.

This work is proposed only. Final decisions will be based on available dollars.

$ source	Staiton ID	Location	Sonde #	Additional Sonde Parameters[A]	Sonde Duration	Additional Analytical/Grab Parameters[B]	Grab Sample Tide Stage	Grab Sample Duration
Coalition	GRBBR	Bellamy River	1	fDOM total chl	April - Aug	Bacteria	Low & High	April - Dec
Coalition	GRBCR	Cocheco River	2	fDOM total chl	April - Aug	Bacteria	Low & High	April - Dec
Shellfish	GRBLB	Little Bay	3	fDOM total chl	April - Dec	n/a	n/a*	n/a
Shellfish	HHHR	Hampton River	4	fDOM total chl	April - Dec	n/a	Low	April - Dec
NERR	GRBOR	Oyster River	5		April - Dec	n/a	Low	April - Dec
NERR	GRBSQ	Squamscott	6		April - Dec	n/a	Low	April - Dec
NERR	GRBGB	Great Bay	7		April - Dec	n/a	Low	April - Dec
NERR	GRBLR	Lamprey River	8	fDOM total chl	April - Dec	Bacteria	Low	April - Dec
NERACOOS	GRBBUOY	Great Bay	9	fDOM total chl	April - Dec	n/a	n/a**	n/a
PREP/DES	GRBUPR	Upper Pisc River	10	fDOM total chl	April - Aug	Bacteria	Low	April - Dec
PREP/DES	GRBGBW	Great Bay West	11		April - Aug	n/a	Low	April - Dec
PREP/DES	GRBGBE	Great Bay East	n/a	n/a	n/a	n/a	Low	April - Dec
PREP/DES	GRBAP	Adams Pt	n/a	n/a	n/a	Bacteria	Low & High	April - Dec
Portsmouth	GRBCML	Coastal Lab	12	n/a	n/a	n/a	n/a	n/a
n/a	GRBSF	Salmon Falls		n/a	n/a	n/a	n/a	n/a
n/a	GRBLPR	Low Pisc River		n/a	n/a	n/a	n/a	n/a
n/a	GRBCL	Chap Landing		n/a	n/a	n/a	n/a	n/a

APPENDIX 3

Note that the current plan for 2021 is to integrate the seaweed sampling (see yellow dots below) into the "Tier 2" eelgrass sampling program. The Tier 2 program is currently designed to visit 50 sites throughout the Great Bay Estuary on an annual basis.



Appendix C

Resilience and positive feedbacks: Water quality management and eelgrass health in the Great Bay Estuary, NH/ME

1) **Project Title**: Resilience and positive feedbacks: Water quality management and eelgrass health in the Great Bay Estuary, NH/ME

2) **Project Lead/Fiscal Lead/Technical Lead (primary contact for project)**

a) William H. McDowell, Professor
b) University of New Hampshire (UNH)
c) 603-862-2249
d) Department of Natural Resources, James Hall, 56 College Rd., Durham, NH 03824
e) bill.mcdowell@unh.edu

3) **Additional Team Members**

Cory Riley, GBNERR; 603-868-1095; cory.riley@wildlife.nh.gov; Co-Collaborative Co-Lead
Kalle Matso, Piscataqua Region Estuaries Partnership (PREP); UNH; 603-781-6591; kmatso@unh.edu; Collaborative Co-Lead
Chris Peter, GBNERR; 603-294-0146; christopher.peter@wildlife.nh.gov; Team Member
Anna Lowien, UNH; 240-538-3029; al1290@wildcats.unh.edu; Team Member
David Burdick, UNH; 603-862-5129; david.burdick@unh.edu; Team Member
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Brian Howes, UMASS Dartmouth; 508-326-0912; bhowes@umassd.edu; External Advisor

4) **Fiduciary Information**
UNH; Contact = Dianne Hall, Senior Grant and Contract Administrator; dianne.hall@unh.edu

5) **Name of Reserve**: Great Bay National Estuarine Research Reserve

6) **Budget Request**: $549,923

7) **Project Duration**: October 1, 2021 - September 30, 2024

8) **Project Summary**: In the Great Bay Estuary, on the border of New Hampshire (NH) and Maine, loss of eelgrass habitat has resulted in EPA recently releasing a Total Nitrogen General Permit that addresses both point and non-point sources of nitrogen (N). The NH Department of Environmental Services and permitted municipalities are looking to their partners to provide the critical scientific insights needed to meet the new permit requirements. Gaps in understanding of how eelgrass responds to changes in water quality limit the management tools available for ensuring eelgrass health. This project combines hydrodynamic modeling and new field observations along a spatial gradient to delineate the relationships among N loading, *in-situ* N processing, sediment dynamics, light, and eelgrass resilience. Finally, well-resourced collaboration efforts will link the science to decision making and actions that are urgently needed to facilitate progress on the most contentious management issue for this estuary.

1) **Problem Statement and Response to End User Needs**

The Great Bay Estuary (Figure 1) is an important local and regional resource that supports fishing, recreation, wildlife, and an oyster aquaculture industry. However, the Estuary is currently listed as nitrogen impaired, largely based on decreases in eelgrass (*Zostera marina)* habitat. Despite 14 years of discussion, controversy continues over the factors that impact eelgrass health in the Estuary and the role of nitrogen (N) reduction, hampering efforts to address the problem. Multiple parties and divergent claims about the Estuary have created an atmosphere of confusion and distrust, only made worse by significant data gaps. In 2009, the Piscataqua Region Estuaries Partnership (PREP) and the New Hampshire Department of Environmental Services (DES) released the "Numeric Nutrient Criteria" report, describing a relationship between N, plankton, light attenuation and eelgrass loss (Trowbridge 2009).

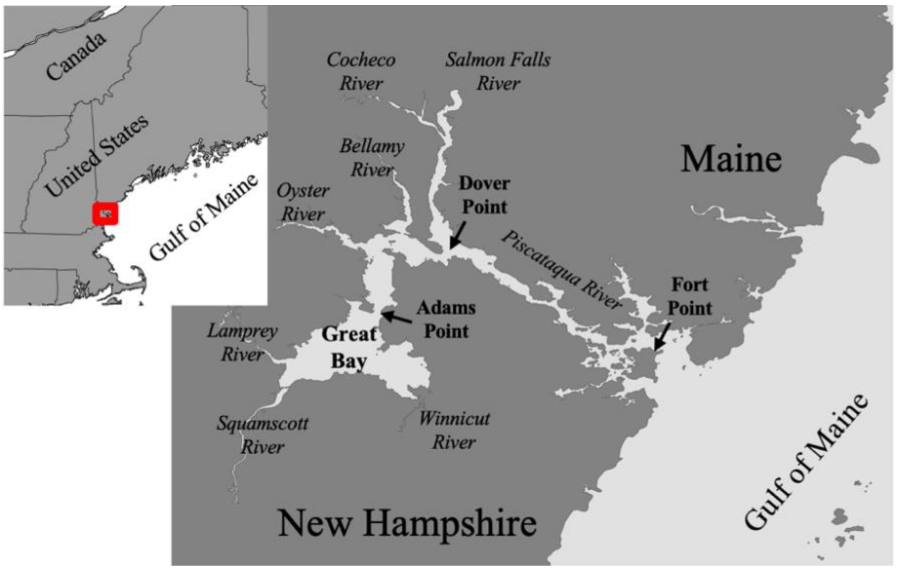

Figure 1. Map of the Great Bay Estuary and "Great Bay," the area south of Adams Point.

Five years later, an independent peer review (Bierman et al. 2014) reported that N could very well be a problem in the Estuary, but the statistical approach taken in the 2009 report was not sufficiently robust. In 2017, a new peer review commissioned by PREP (PREP 2017) encouraged further N reductions but noted, like the previous review, that future monitoring and discussions of the extent of N reductions required the coupling of a verified hydrodynamic model with either a stressor-response model, a mechanistic (process) model or a hybrid approach. This is exactly the work of this proposal. In addressing these critical gaps, this proposal will also investigate feedback cycles and the filtration capacity of eelgrass (Aoki et al. 2020). The feedback cycles are important to understand whether focusing on a subset of the active stressors can increase eelgrass health, which in turn can mitigate other stressors.

The primary management need at the core of this proposal is making our eelgrass habitats more resilient. Encompassed in that goal is the need to provide guidance associated with new regulatory requirements. In November 2020, US EPA released the "Great Bay Total Nitrogen General Permit," focused on reducing N loading from 13 communities with Wastewater Treatment Facilities (WWTF) but also offering options on how to control N inputs through non-point source (NPS) controls (EPA 2020). There is broad agreement that our system is impacted by both point sources (accounting for 33% of total N loading, largely as inorganic N) and NPS, which account for 67% of N loading, mostly as dissolved organic N (PREP 2017). However, since the most recent assessment in 2017, some cities have significantly reduced point-source N loading through WWTF upgrades. To incorporate progress made by the communities and changes observed in the Estuary, the Permit lays out an adaptive management plan that calls out the need for exactly the activities proposed in this project. In fact, as the communities are developing their adaptive management approaches, they are in close contact with the PIs on this proposal in hopes of referencing this project to help achieve their goals. Regular ambient monitoring is another element of the adaptive approach, so the communities will be supporting ongoing data collection to complement proposal activities. Finally, with the current Permit scheduled to expire in five years, EPA has clearly articulated that the Permit will be modified based on scientific analysis of changes to the Estuary over the coming years. Advanced understanding of the relationships between N, sediment dynamics, light, and eelgrass will directly inform the adaptive management requirements contained in the Permit.

Direct End User Engagement in Proposal Development: Three of our primary end users—the Great Bay National Estuarine Research Reserve (GBNERR), DES, and PREP—have been

Table 1: End user needs and involvement. ***Italics denote key feedback that shaped the proposal.***

End User	Connection to Topic	Info Needs	Involvement
PREP	Key issue for organizational goals.	Data to develop a long-term and adaptable process-based ecosystem model of the Estuary.	Collaboration Lead; Science and Data Provider. Proposal co-author. Provided support letter.
GBNERR	Addresses stated Reserve needs. Also addresses Reserve goal of advancing scientific literacy.	How anthropogenic stressors impact water quality and estuarine habitats.	Collaboration Lead; Science and Data Provider. Proposal co-author. Provided support letter.
DES	Requires data and analyses to work with EPA on regulations.	*Improved residence times and field observations to lay the foundation for a future TMDL allocation.*	Participated in meetings at pre and full proposal stage. Helped edit the proposal. Provided support letter.
Multiple municipalities: Dover, Exeter, Rochester, Portsmouth, Somersworth, Newfields, Newington	Regulated community under the Great Bay Total Nitrogen Permit.	How to monitor for adaptive management? Data to justify modifications to N loads. *Make clear how work connects to Permit monitoring. Do not let academic questions detract from pragmatic data gaps. Do not assume N is the only factor.*	All seven communities in Column 1 collaborated on support letter. Four communities participated in full proposal stage and helped edit the proposal.
Conservation Law Foundation (CLF)	Key issue for organizational goals.	How to best monitor for adaptive management? *Will the pollution reductions in the Great Bay Total Nitrogen Permit be sufficient to support eelgrass resiliency?*	Participated in full proposal stage. Provided support letter.

monitoring the Estuary collaboratively for over 15 years. In 2019, these end users led an effort to develop the Integrated Research and Monitoring Plan or RAMP (PREP 2020), with scientists, resource managers, regulators, and municipalities. The research described in this proposal is a high priority in the RAMP. Other primary end users include regulated municipalities—7 of which signed on to the submitted municipal support letter—and local non-profit organizations that are committed to estuarine health and resilience (Table 1). As part of proposal development, targeted meetings were held with these users to ensure that outputs would meet their needs. If funded, we will expand the end user group to other regulated communities including those from Maine as well as Maine's Department of Environmental Protection (DEP).

Building Relationships: PREP, DES, GBNERR, Conservation Law Foundation (CLF) and the City of Dover have been working in close concert over recent years, and especially the last year, around the development of the RAMP. However, this proposal has already led to deeper collaborations between PREP and other involved municipalities, due to the singular importance of coupling hydrodynamics to field observations. PREP is also now planning to work with consultants from Brown and Caldwell (Andover, MA)—under contract with Portsmouth, Dover, and Rochester—to better plan for the adaptive management challenges related to the new Permit.

Reserve Involvement: The Great Bay NERR has been an invaluable partner in the development of the RAMP and in the work presented here. The Reserve Manager, Cory Riley, and Reserve Research Coordinator, Chris Peter, are central and active participants in the RAMP process; both have worked closely with the team to develop this proposal, as has the Reserve Education Coordinator, Kelle Loughlin. This project directly addresses two focus areas highlighted by the NOAA Science Collaborative at the national level as well as locally at Great Bay Reserve: water quality and habitat resilience. Specifically, this project fits within the Great Bay NERR's stated need for understanding of "water quality," and "enhanced understanding of how anthropogenic stressors—especially excess nutrients, hydrological change, sedimentation—are impacting our water quality and critical habitats in Great Bay." The "Project Approach" below describes in detail how this effort addresses these Reserve needs.

2) **Project Approach**

In the "Project Approach" section, we start with core research questions and hypotheses and then describe our technical, educational, and collaboration methods. A series of integrated, collaborative events will be used to link science to end users throughout the project (Figure 2; Appendix I-2).

Core Research Questions: Our high-level research question asks: ***Have recent nitrogen loading reductions improved eelgrass health or resulted in positive feedbacks that enhance the resilience of eelgrass in Great Bay Estuary?*** Excessive N inputs can harm eelgrass through stimulation of algal and epiphytic growth, creating competition for light (Ralph et al. 2007; Short et al. 1995). We recognize that eelgrass health is influenced by a combination of hydrodynamic, biogeochemical, and ecological drivers that have already been documented in the scientific literature. Therefore, our Research Question 1 and accompanying hypotheses seek to illuminate

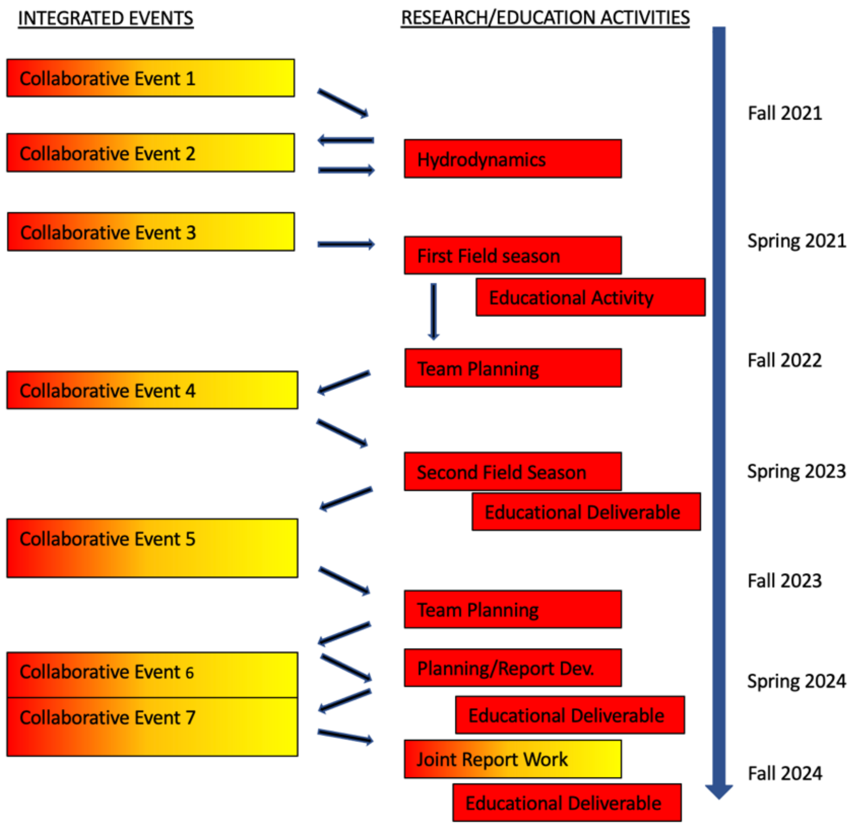

Figure 2. Depiction of how collaborative and other components work together throughout the project timeline. Boxes that are red and yellow indicate processes involving the project team and end users. Red boxes primarily involve the project team. For a more detailed version of this diagram, showing the specific nature of each activity, see Appendix I-2.

the strength of individual stressor-response relationships in Great Bay using a systematic approach in which we characterize conditions in the Bay and relate eelgrass health—assessed by measuring eelgrass biomass, density, percent cover, and canopy height—to conditions at a given site. Our approach is comprehensive and only feasible because we will combine funding for this proposal with funding for a new—starting in 2021—annual monitoring program in the Great Bay Estuary, funded by PREP and its partners: the "Tier 2 Eelgrass and Seaweed Monitoring Program," hereafter referred to as "Tier 2." Tier 2 includes 50 sites throughout the Estuary, 30 of the sites within Great Bay. At each site, Tier 2 monitoring focuses on eelgrass, seaweed, and sediment parameters. Funding for this proposal will enable us to couple these activities to hydrodynamic modeling outputs as well as light attenuation and water quality parameters at the same sites, in order to address Research Question 1, below:

1) Does eelgrass health vary spatially in response to variability in water residence time, bed shear stress, algae, epiphytes, and water quality?
   H_0: There is no relationship between eelgrass health and any measured driver.
   H_1: Eelgrass health will be better at sites with long water residence times.
   H_2: Eelgrass health will be negatively correlated with shear stress.
   H_3: Eelgrass health will be negatively correlated with abundance of algae and epiphytes.
   H_4: Eelgrass health will be related to N concentrations in the water column.
   H_5: Eelgrass health will be related to light attenuation.
   H_6: Eelgrass health will be related to relative proportions of light attenuating components (CDOM, plankton and TSS).

Communities have already made substantial investments in point-source N reduction. In addition, several low rainfall years have led to anecdotal reports of increased eelgrass in the Estuary. Therefore, our second project component is to understand the role that initial eelgrass recovery could play in reducing the further impacts of N and other stressors. As a coastal filter, eelgrass mediates its microenvironment through assimilation of N and by increasing the settling rate of sediments. Because these processes reduce turbidity and N availability for the competitors of eelgrass such as seaweed and planktonic algae (Aoki et al. 2020), a positive feedback loop may be created in response to reduced N inputs to an estuary. A further component of this amplification and positive feedback can occur due to the effects of eelgrass on light levels. Enhanced growth of eelgrass results in reduced shear stress (Zhang et al. 2020) and less sediment resuspension, further enhancing conditions for growth and persistence of eelgrass beds. The degree to which eelgrass can affect levels of N in estuarine waters and accelerate its own recovery from excessive N inputs is likely to vary as a function of other aspects of the system such as water residence time, rates of N removal processes (i.e., burial, assimilation, and denitrification), total suspended solid (TSS) levels, and biological responses of epiphytes, plankton, and seaweed (more formally referred to as "macroalgae") (Figure 3). Thus, we propose to balance our first question about how the environment impacts eelgrass with Research Question 2, which addresses how eelgrass impacts the environment.

2) Does N/sediment filtration vary along transects that span unvegetated areas to eelgrass?
   H_0: The N/sediment filter processes do not vary spatially across eelgrass transects.
   H_1: Water column N and TSS concentrations decrease along a transect from unvegetated to heavily vegetated eelgrass beds
   H_2: N filter processes (denitrification and assimilation) increase with increasing water residence time.
   H_3: N/sediment filter processes vary with water parcels of different origin.
   H_4: Eelgrass health and growth vary with N/sediment filter processes.

For this question, we will use sampling sites that overlap with a portion of the 30 "extensive" sites within Great Bay from Tier 2, creating 4 "intensive" transects that span unvegetated areas to the middle of eelgrass beds. Depending on the hydrodynamic outputs, transects could be made up entirely of Tier 2 sites; alternatively, we have budgeted for the contingency of adding up to 12 sites (3 per transect) if there is not sufficient overlap.

We recognize that storms and precipitation are not included in our sampling regime, and that major storms and changing precipitation patterns can affect eelgrass. Storms increase N, sediment and CDOM loading and modify the temperature and salinity of the Estuary. However, it is beyond the resource scope of this project to include additional sampling to characterize storm dynamics as well as the "base flow"condition. Nevertheless, if our proposal is funded, PREP and partners will work with communities to augment the sampling approach so that we can understand how storms could affect base flow conditions.

Technical Approach: The Great Bay Estuary has long-term records of riverine N and TSS inputs; TSS, N, and chlorophyll-a from grab samples taken at multiple stations in the Bay; salinity, temperature, and turbidity from multiple sondes during the growing season; and eelgrass coverage over several decades from aerial photography (Appendix I). Existing N loads to the Bay (PREP 2017) and an assessment of its ecological health were used to establish the current

EPA permit. Our project approach will utilize newly collected hydrodynamic, biogeochemical, and ecological data as well as these foundational data to build an empirically based stressor-response model. In this proposal we will focus on documenting any stressor-response relationships that can be used to develop a more detailed and sophisticated understanding of how eelgrass health in Great Bay responds to its potential drivers. We focus on N, algae, epiphytes, TSS and CDOM, as they can each affect multiple processes in the Great Bay ecosystem. We do not propose to build a numerical simulation model, but rather to document the importance of these potential water quality stressors and the positive feedbacks that may affect eelgrass resilience. By placing our site-scale work into the context of Great Bay, with its specific hydrodynamic regime, relatively large inputs of light-absorbing CDOM, and significant point sources of inorganic N, we hope to provide insights that will be valuable to resource managers concerned about the Great Bay and the entire Great Bay Estuary, as well as other high energy estuaries.

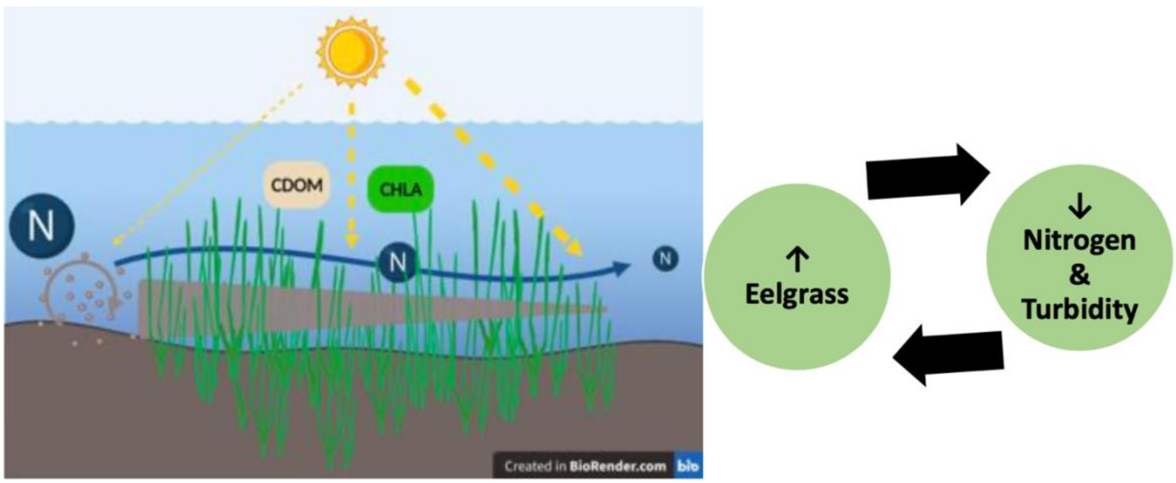

Figure 3. Schematic on eelgrass as coastal filter. As a parcel of water flows from unvegetated areas over an eelgrass bed, N concentrations, sediments, turbidity, and light attenuation decrease. This creates more favorable growing conditions for eelgrass, resulting in further eelgrass growth and further decreases in N, sediments, etc.

<u>Hydrodynamics</u>: Team Member Tom Lippmann and his research group have already implemented a widely used, open-source 3D hydrodynamic model (COAWST; Warner et al. 2008) in Great Bay Estuary, and have verified the model for currents, water levels, sediment bed shear stress (CSTM; Warner et al. 2010), and surface waves (SWAN; Cook et al. 2019; Cook et al. 2021). These models can be used to predict water flow velocities and bed shear stresses important to resuspension, transport, and settling of sediments (Warner et al. 2008), nutrient fluxes across the fluid-seafloor boundary (Wengrove et al. 2015; Cook et al. 2021), and aquatic plant structural integrity (Luhar and Nepf 2011). Models are implemented in estuarine systems with grids that typically range in resolution from 10-30 m, and can be forced with winds, waves, tides, and subtidal oscillations. Hydrodynamic numerical models can estimate and map flow fields through heterogeneous estuaries that include complex tidal channels (Cook et al. 2019), wetting and drying regions such as mudflats (over tidal cycles; Bilgili et al. 2005), and spatially variable aquatic vegetation (such as eelgrass beds; Cook et al. 2019). Modeled Eulerian velocities and water levels are compared with observations made at select locations where instruments can be deployed to determine the skill of the models. Numerical Lagrangian particle tracking experiments can be conducted using the estimated flow fields (after estimating eddy

diffusivity) to determine transport pathways, and also estimate residence times as a function of spatial location within the Estuary (e.g., Bilgili et al. 2005).

Although residence times have been estimated for the Estuary prior to this work (Bilgili et al. 2005), previous efforts were not based on 3D models nor did they include vegetation. To depict residence time as accurately as possible and to inform the biogeochemical/ecological field work, the team will use a verified 3D numerical model established in the Great Bay Estuary (Cook et al. 2019) to characterize Great Bay's hydrodynamic conditions, including wave properties (height, period, direction), flow velocities and water level fluctuations (tidal and subtidal), and bed shear stress (wave, current, and combined). This characterization will be a function of spatial location across the Estuary and will include areas with and without eelgrass. This characterization will result in maps of the probability density functions for shear stress magnitudes, which can be used to create "heatmaps" of shear stresses showing where sediment is more likely to be resuspended within Great Bay; these maps were specifically requested by team members and our end users in early scoping of this proposal.

The team will model the residence time of a water parcel as a function of elevation within the water column at different locations within the Estuary. Estimates will be made at small scales (0 to 100 m) and differences resolved across and between regions with and without eelgrass. Eulerian flow fields from the hydrodynamic model (Cook et al. 2019) will be coupled with an offline Lagrangian particle tracking model (Choi et al. 2018) to develop estimates of residence times. This is coupled with field work to estimate eddy diffusivities across the Estuary obtained from observations of GPS-based surface drifter trajectories and 1-particle statistics (Davis 1987).

Finally, the hydrodynamic team will define the spatial and temporal history of water parcels found within specific regions of the Estuary. Transport pathway trajectories of water particles found from our Lagrangian particle tracking experiments within any area of interest will be back traced to their origin as a function of time scales ranging from hours to several tidal cycles. Estimating the path that water parcels travelled prior to arriving at a destination will allow an assessment of connectivity within the Estuary. For example, we can scale N loading from each tidal tributary to the proportion of water in an eelgrass bed that originates from each river. By coupling the water parcel origin with biogeochemical processes, we will improve understanding of the effects of N loading and transport as a function of location in the Estuary.

The work described above will be front-loaded in our timeline, because better understanding of hydrodynamics informs all our subsequent work on the effects of water quality management on eelgrass health in Great Bay. It also informs our sampling array, ensuring we include a wide range of residence times across eelgrass beds. We will use the two other outputs from the hydrodynamics, shear stress and origin of water parcel delivered to our study plots, to further characterize how hydrodynamics and water quality interact to affect various measures of eelgrass health. We anticipate that the initial completion of the hydrodynamic work will be an important inflection point for the collaborative aspect of the project (see "Collaborative Approach" section), since there have been numerous misunderstandings about hydrodynamics in the Great Bay Estuary (Matso 2018), despite the centrality of the issue (Bierman et al. 2014).

<u>Primary Producer Health/Abundance/Growth</u>: While the hydrodynamic work includes the entire Estuary, our field observations will be focused on Great Bay (Figure 4). As part of Tier 2 monitoring (funded separately from this proposal), 30 sites will be established in the Great Bay before the 2021 field season. Sites are located randomly, with the "sample frame" defined as any area that had eelgrass in 2019. Tier 2 protocols include placing 4 quadrats at each site, and

assessing biomass and percent cover of both eelgrass and seaweed as well as eelgrass density, canopy height and epiphytic load. C:N analysis will also be conducted on eelgrass tissue. Since these sites will be sampled in 2021—one year before this project's first field season—the team will have a good idea if the sites sufficiently capture gradients in eelgrass health. We will also strive to capture a range of hydrodynamic conditions and may have to alter some sites after we review the hydrodynamic outputs early in the first year of this project. We have budgeted for the contingency of adding new sites to the 30 established in 2021. In 2022, we will augment sampling at these spatially extensive sites, adding water quality, light attenuation and phytoplankton assessments to the eelgrass, seaweed and sediment work that is already paid for (Appendix I-1) in order to address our Research Question 1.

Figure 4. Aerial image of the Great Bay taken in 2019. Thirty extensive sites (not shown) will capture variability throughout the Bay for Research Question 1. Four transects of intensive sites, prospective locations shown above, will provide detailed understanding of eelgrass and water quality interactions (Research Question 2).

To address Research Question 2, we will use our hydrodynamic modeling outputs to establish 4 intensive transects in Great Bay (Figure 4), which will be sampled three times in two separate years during the peak of primary productivity in June/July. Along these four transects (12 sites total), we will emulate the measurements occurring as part of Tier 2, and we will also measure *in-situ* growth rates of both eelgrass (Gaeckle and Short 2002) and macroalgae (Wallace and Gobler 2014) over 7-10 days. Ten replicate shoots will be pinned and collected for growth measurements as well as epiphytic biomass by gravimetric analysis. Growth measurement for algae will include the two most common seaweed competitors: *Ulva* (*U. lactuca, U. australis*, both blade-form) and *Agarophyton vermiculophyla* (an exotic red) set up in five separate cages per site. Pre-deployment trials will indicate the optimal amount of algae to add to the cages (e.g., 2 grams damp weight) to estimate growth rates. Algae will be collected and cleaned of sediments, damp-dried and weighed before being caged, transported in coolers to the study site and deployed 20 cm above the bottom for 7-10 days. Collected cages will be transported to the lab in coolers and washed, damp-dried and reweighed, then dried (for wet/dry ratio and dry weight biomass), weighed, and ground for C:N analysis. Tissue analysis of eelgrass and seaweeds (noted in Appendix I-1) will be combined with growth rates to determine N uptake rates.

<u>Light Attenuation and Light Attenuating Components</u>: It is well known that light penetration is one of the most important controls on seagrass health (Ralph et al. 2007) and very likely for eelgrass in the Great Bay Estuary (PREP 2017). We will assess variations in light penetration as well as the proportions of light attenuating components (LACs) at both the extensive and intensive sites, in order to address Research Question 1. For light attenuation, we follow the procedures of Gall et al. (2019) as their protocols effectively deal with issues related to the variability of incident light. Briefly, light attenuation (Kd) for photosynthetically available radiation (PAR) is assessed using paired PAR sensors at depth increments. Incident light is also measured before and after light penetration in order to correct for changes in cloud cover, etc.

Kd (PAR) does not capture the impacts of epiphytes and seaweed, despite the importance of those components in well-flushed estuaries (van den Heuvel et al. 2019) and the evidence of seaweed abundance in the Great Bay (Burdick et al. 2019). Therefore, we will combine epiphytes and seaweed into a separate index of light interception, which will be based on site-specific assessments of algal biomass and published attenuation values for relevant species.

<u>Water Quality and Bed Sediments</u>: Water quality will be measured at each of our extensive 30 sites and along our intensive four transects using discrete grab samples collected annually at extensive sites and 3 times per season at intensive sites. Water samples will be analyzed at the UNH Water Quality Analysis Laboratory (WQAL) for NO_3^-, NH_4^+, and PO_4^{3-} using a Smartchem robotic analyzer. CDOM will be measured spectrophotometrically. Total dissolved nitrogen (TDN) and dissolved organic matter, quantified as dissolved organic carbon, will be measured with a Shimadzu TOC-V CSH. TSS will be measured gravimetrically. Chlorophyll a will be assessed via standard filtration, extraction and analysis by AquaFluor fluorometry; the plankton community will be assessed via flow cytometer as well as a "FlowCam" in order to capture full size range of species. This work will occur through a collaboration with the Harvey Lab at UNH (see Appendix H). These data, when combined with eelgrass health and hydrodynamics, will be used to answer our first Research Question.

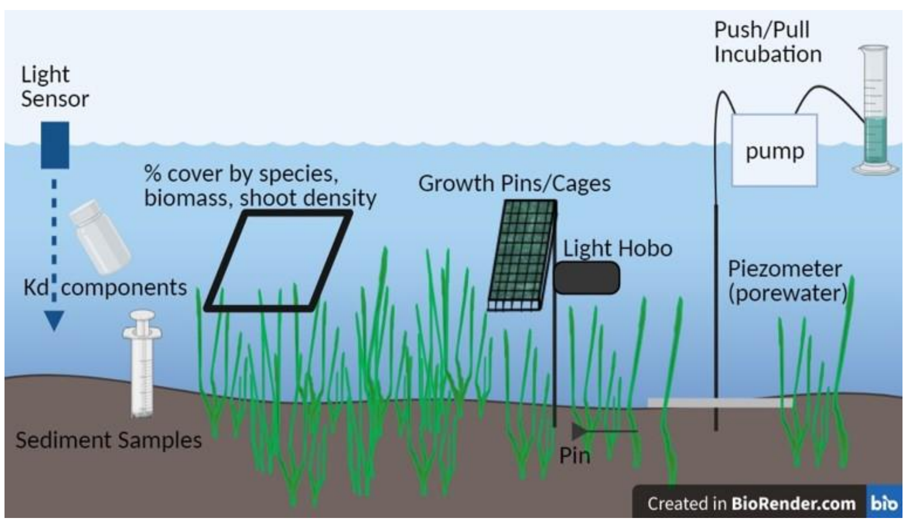

Figure 5. Schematic of measurements for intensive sites in Great Bay, including quadrats to characterize primary producers, *in-situ* growth for eelgrass (pin method) and seaweed (cages), water quality sampling, light measurements, sediment cores and push-pull samples for denitrification.

At all sites, the upper 7.5 cm of sediments will be collected in triplicate by core and measured for organic matter and grain size, which can influence eelgrass success (Mascaró et al. 2009). At the intensive sites only, we will also measure porosity and one core will be dried and analyzed for particulate N content on a CHN Elemental Analyzer to assess N accumulation in sediments. Additionally, water samples will be collected from the sediment porewater using piezometers. Porewater will be extracted from a depth of 5 cm to correspond with eelgrass rooting depths. Oxidation-reduction potential (Eh) of porewater will be measured with an ORP probe. To determine both rate of N removal and whether N is transformed within eelgrass beds, membrane inlet mass spectrometry (MIMS) will be used to measure ambient N_2 and N_2:Ar to detect denitrification (Bernot et al. 2003).

Also at the intensive sites only, rates of denitrification, a potential N filter mechanism, will be measured using *in situ* push-pull experiments and MIMS analysis along each eelgrass gradient as described by Aoki and McGlathery (2017). The push-pull method they describe is adapted from the traditional push-pull method used in subtidal sediments. This method is preferrable to cores or slurries, as it allows comparison of *in situ* rates that may be influenced by other variables such as water residence time, water source area, and eelgrass productivity, density, and canopy height. The push-pull method involves deployment of mini-piezometers into the sediment bed that enable extraction of porewater over several hours following low tide. Porewater will be extracted, amended with $^{15}NO_3^-$ and an argon gas tracer, and returned to the sediment using a peristaltic pump (Aoki and McGlathery 2017). The porewater will be allowed to incubate *in situ* for 30 minutes after being pushed back into the sediment bed. Duplicate water samples will then be extracted every 30 minutes over 2 hours. The push-pull method will be completed along with other field efforts at each station and gradient site. Samples will be analyzed for $^{28}N_2$, $^{29}N_2$, $^{30}N_2$, and Ar gas concentrations using MIMS at the UNH WQAL.

Data Analysis and Statistics: In a complex environment such as an estuary, isolating individual causes of a specific biotic response such as declining eelgrass coverage over time is a difficult task. We will address this challenge by using a suite of multivariate approaches to tease apart the likely drivers of spatial variability in eelgrass health, and to assess the likelihood that positive feedbacks occur within eelgrass beds that could lead to greater resilience of those beds. Simple depictions of trends in drivers over time, or correlation of those eelgrass declines with individual drivers such as nitrogen concentrations over time, has not provided much insight into the fundamental causes of eelgrass declines in Great Bay (Bierman et al. 2014).

Table 2. Data categories for multivariate approach to analyze drivers of eelgrass health. Italics denote data collected only at intensive sites for use in similar multivariate approaches.

Sample Units	Response Variables	Environmental Drivers
Extensive Sites	Eelgrass	Hydrologic: residence time, *point of origin*, bed shear stress
Intensive Sites	Health:	Light attenuation: Kd, CDOM, TSS, phytoplankton
Unvegetated	Biomass	Water quality (water column & *porewater)*
Eelgrass bed edge	Canopy ht	TDN, NO_3^-, NH_4^+, PO_4^-, & DOC concentrations
	Density	*Macroalgae/epiphyte biomass, growth, & C:N ratio*
Eelgrass bed center	% cover	*Denitrification*
	Growth	*N Assimilation (Eelgrass N content + growth)*
		Sediment: org. matter, grain size, p*orosity, N content, redox*

This is the case for most estuaries, where a more sophisticated multivariate approach such as Principal Components Analysis (PCA) is needed to asses relationships among variability within an estuary or among estuaries (Coffin et al. 2018). After assessing our individual hypotheses (typically with univariate statistics) we will then employ multivariate approaches to assess the relative importance and strength of relationships among our response variables, various measures of eelgrass health, and our predictors (water quality, light attenuation, water residence time and source, and algal/epiphytic abundance; Table 2). Our general approach will be to use PCA to assess the strength of associations between eelgrass health metrics (e.g., biomass per unit area) and potential drivers using data that are collected in common at both intensive and extensive sites. We will then explore the strength of individual drivers and eelgrass response variables at our intensive sites using multiple linear regression analysis and partial least squares analyses (e.g., Diemer et al. 2015). We recognize that our approach to light attenuation falls short of a fully calibrated bio-optical model, but using the multivariate model approach from Gall et al. (2019) will provide valuable insights into the individual importance of different light attenuating components as drivers of light attenuation over eelgrass beds.

Educational Curriculum Development/Application: The problem of eelgrass habitat degradation is complex and inherently difficult to explain to a lay audience of any age. However, we believe the patterns we see historically and within our results will support and improve our understanding of the ecosystem and how human activity influences the Estuary. Fundamental Next Generation Science Standards (NGSS) pedagogy embraces our educational approach that individuals need several touch points throughout their lives to engage with concepts that may be difficult to understand. Promotion of citizen stewardship of coastal resources is realized over time and by a variety of educational techniques designed to meet learners of all ages at their respective learning levels. We propose to translate project results to teachers and students in two ways: 1) Teachers on the Estuary (TOTE) workshop for middle and high school level; and 2) The "All about Eelgrass – Travelling Trunk" for grades 3-6.

<u>TOTE</u>: A Great Bay NERR 2-day (16-hour) TOTE course will be developed for the middle and high school level, addressing ecosystem stressors and relationships between N, sediment, light and eelgrass. TOTE is a multi-day research and field-based teacher training program held at each Reserve annually, with emphasis placed on exploring coastal habitats and conducting field investigations, and integrating local and national monitoring data into the classroom. The course will include field-based exploration and interactions with this project's estuarine scientists. Teachers will explore eelgrass beds, analyze samples at UNH's water quality lab, as well as learn how to use a data visualization of particle movements based on the hydrodynamic model outputs. Teachers will understand how N and sediments move through the system, and their relationship to eelgrass as well as other estuarine species. A curriculum will be developed and implemented with the following supporting concepts, activities, and products: sources of estuarine pollution, light attenuation, estuarine feedback loops, seasonal detrital food webs, eelgrass contribution to coastal resilience, and a "Follow the Flow!" board game. Post-course stewardship teacher stipends will be provided to be used in student-driven water quality community awareness campaigns. Project data scientist, Miguel Leon, will use the new platform "Frame VR" (framevr.io), which includes a spatial context often missing in video conferencing platforms, to create an engaging virtual science conference where students can reinforce their learning by seeking answers to questions posed by teachers.

<u>"All about Eelgrass - Travelling Trunk" for grades 3-6</u>: Following best practices for NGSS, the "All about Eelgrass – Travelling Trunk" will be developed for teachers to borrow from the Great Bay Discovery Center. Currently, thematic trunks with curriculum material, activities and specimens are regularly checked out and utilized by teachers to support their curricula. A travelling trunk will be developed with supporting concepts, activities, and products, such as: "Estuary Soup – What lives in an estuary and how does it get there?" and "All about plants – How can a plant flower underwater?"

The Collaborative Process: To ensure that end user needs are met, we will create a Project Advisory Committee (PAC) comprised of representatives from the end user organizations noted in Table 1. The team will also invite all other regulated municipalities to have a representative on the PAC and will include three external advisors as well. We anticipate the PAC will have approximately 20 members. As many of the PAC members also participate in other watershed collaborative efforts (PREP sub-committees, municipal coalitions related to water quality topics, etc.), the collaborative leads will use existing communication mechanisms and meetings whenever possible. Our "End User Advisor" is Ted Diers of DES; he is the perfect choice for this role because he is very familiar with both EPA and municipal perspectives, having participated in many meetings on regulation and estuarine health.

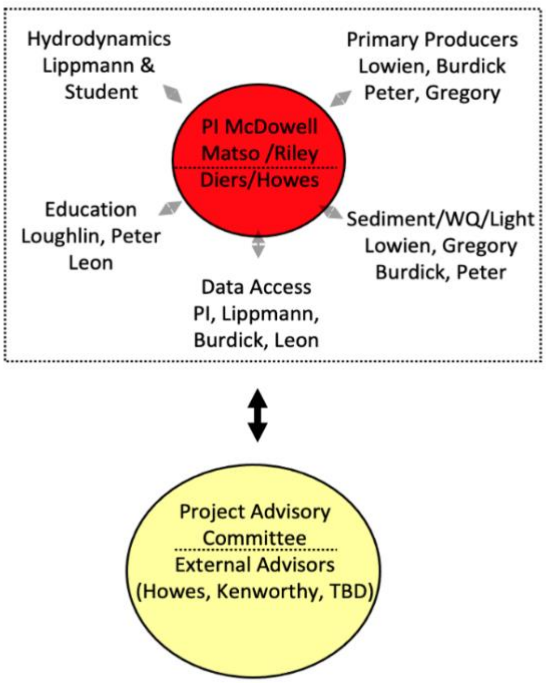

Figure 6. Project organization. Effective team management is as important as effective engagement of end users. At the beginning of the full proposal development process, we created a "Team Charter" noting participation norms, roles/responsibilities and how decisions would be made. If funded, this Charter will be updated to encompass the PAC. See Appendix I-2 for diagram connecting team organization to the integrated approach and timeline.

Working closely with the PAC (Figure 6), the team will hold a series of "Integration Meetings," preparing end users incrementally and leading up to two separate 2-day "Results Charettes," which will be held in the final year of the project. These charettes will be co-hosted by PREP and Great Bay NERR. To better understand both the team structure and our approach to integration over the timeline of the project, see Appendix I-2, which illustrates the multiple points we have created for the PAC to impact the research and vice versa.

Heuristic Approach: As noted earlier, it is anticipated that this project provides value in a number of ways, including providing the basis for a long-term process model for the Estuary and laying the foundation for future TMDL allocations. In addition, we hope this project can clarify much of the confusion around calls for N reduction, particularly given that the project will end just before EPA's new Permit will be re-visited. We are designing our collaborative approach to bring maximum value to that inflection point. We will not know the "magic number" for N loading or N concentrations in a numeric nutrient criterion context at the end of this project; however, we will create a hydrodynamic model and establish relationships between N-mediated processes (e.g., seaweed proliferation; epiphyte or plankton proliferation) and eelgrass health. Having trusted science on these topics will advance future modeling, monitoring plans, and ultimately regulatory decisions. In a review of coastal eutrophication case stuides, Boesch (2019) notes how management actions become anemic when stakeholders cannot agree on the basics of what is happening in the ecosystem.

To clarify the implications of our results, we envision building a stepwise heuristic for putting the different aspects of our project in an adaptive management context. The heuristic framework uses major components of the project (hydrodynamics; primary producers; sediments and water quality; and light) to answer two questions about each component: 1) based on X component, is the case for further N reduction a) strengthened, b) weakened, c) not affected; and 2) based on X component, what changes in the future would signal that N reduction is or is not having the expected impact? In this way, our project can address both the issues of the importance of N reduction and also how to structure an appropriate monitoring program for adaptive management. This approach draws on successful science communication and expert elicitation techniques from climate science decision making (CCSP 2009).

Collaborative Methods: A Project Kick-Off Meeting will occur in October 2021 and focus on the project plan and give end users a chance to discuss the research questions, the collaborative approach, and the outputs/outcomes. It will be important to discuss how the hydrodynamic work connects to our choices of sampling sites for the first season and ensure that all users have a shared understanding of that step. It will also be necessary to review our planned statistical analyses so that we can make sure that our sampling regime accommodates any modifications. The final goal of the kick-off meeting will be to get some focused feedback on the first Integration Meeting subject: hydrodynamics. This will make the first Integration Meeting more productive and offers more chances for user feedback to impact research activities, since the hydrodynamics team will begin their work shortly after project commencement. There will be three other Integration Meetings before the first charette (Appendix I-2).

Similar heuristic approaches as the one suggested above have been used by project partners in recent years, and we learned that these complex conversations are usually shortchanged in terms of time. For this reason, we plan to use the first charette to make progress and pose difficult questions. The second charette will allow experts and users time to develop answers to unresolved questions. The final component of the second charette will focus on jointly outlining a project "So What" Report, focusing on key management implications. The Report will continue to be developed after the charette, using electronic methods to get feedback from all participants and describe areas of overwhelming consensus as well as minority reports.

To increase credibility, three external experts will participate in the Integration Meetings, the charrettes, and will review project outputs, including the "So What" Report. One of the external experts will be Dr. Brian Howes, who is included on our project team. A second external expert will be Jud Kenworthy (retired, NOAA), who participated in both previous peer reviews on the Great Bay Estuary. The third expert will be chosen collaboratively by the PAC. Compensation for Kenworthy and the third expert will be funded by PREP.

Collaboration Leads Matso and Riley will work together to plan and conduct all meetings and charettes. Both leads are trained facilitators with decades of experience managing deliberative processes. This feedback will be used to design each meeting. At the actual events, flip charts and audio recordings will capture additional feedback, which will be used for post-event reports and communications. After each meeting, a concise recap of subjects covered, decisions made, and resulting action items/next steps will be sent out to the PAC. Given the importance of science translation (Cash et al. 2003), the team has budgeted for an expert, Miguel Leon (UNH Water Quality Analysis Laboratory), to produce data visualizations in addition to ensuring maximum data accessibility. These science translation products will be used at the Integration Meetings and, particularly, in the charettes and the So What Report. We will also use Frame VR—introduced in the Education section above—as a supplemental mechanism for extending the reach of our project collaborations to stakeholders beyond the PAC.

Outputs:	*End User Interest*	*Outcomes:*
• Maps of hydrodynamic bed shear stresses, residence times, and particle path trajectories that estimate connectivity across the estuary. • Statistical analysis relating eelgrass health to N, light, TSS, CDOM, seaweed and plankton. • Scenarios exploring how stressor-response relationships are most likely to change with increases/decreases in eelgrass filtration capacity.	Recommendations from the 2014 & 2017 Peer Reviews: required to better understand extent of N reduction needed. Also, cities have to monitor changes in Estuary, per new Permit. Also, project addresses Reserve and PREP's goals re: water quality/habitat.	• A shared understanding regarding Great Bay hydrodynamics and the factors that influence eelgrass health in the Great Bay. • Shared understanding on how to monitor the estuary going forward in order to evaluate potential changes to the Nitrogen Permit. • A jointly developed foundation for further discussions on N and sediment management, and for developing a TMDL in the future.
• A two-part "Results Charette," involving in-depth interactions between project & external experts and end users. Part 1 will focus on results implications; Part 2 will focus on Part 1 questions that require more investigation. • A "So What?" Report, relating science to management concerns, and based on the Results Charettes.	Effective two-way dialogue is needed to address confusion about science debates over past decade.	• Increased trust in what the best available science says about the major stressors on eelgrass, and what we can do about it.
• Curriculum tools about water quality management for teachers in our watershed.	Educators more able to teach students and parents about estuarine health.	• Increased interest and literacy about estuarine health amongst families in our watershed.
• Presentation at NERRS Annual Meeting	Plus, professional sharing between different Reserves.	• Other Reserves learn about innovative approaches to linking stressors to eelgrass health.

Figure 7. Major outputs, connections to end users and expected outcomes for the project.

3) **Outputs and Outcomes**

Listed outputs and outcomes are considered "short term" and will be assessed through post-event and post-project surveys (Figure 7). Data outputs will be maintained through a collaboration between DES and PREP. More complex outputs such as analyses and reports will be maintained by PREP and disseminated through State of Our Estuary Reports—updated every five years at: stateofourestuaries.org.

4) **Team**

Project Lead/Fiscal Lead/Technical Lead: **Dr. McDowell**, who has extensive experience managing large collaborations, will be the overall project lead, fiscal lead, and technical lead. *Co-Collaboration Leads*: Great Bay NERR Reserve Manager **Cory Riley** brings experience on many successful NERRS Science Collaborative Projects to her role. **Dr. Matso** directs the PREP Coastal Science Program and is an experienced facilitator and participatory process designer. Both the co-leads have significant experience coordinating large-team collaborations. *Team Members*: **Anna Lowien** is a graduate student and Margaret A. Davidson fellow with the Great Bay NERR. She will work on collecting and analyzing field data, coordinating closely with the Project Lead and the Collaboration Leads on overall project management. **Chris Peter** coordinates the Great Bay NERR Research Program and is well placed locally and within NERR system workgroups to apply project results broadly. **Dr. Burdick** has decades of experience working on seagrass and seaweed field studies and will direct those portions of the work. **Dr. Lippmann** of the UNH Department of Earth Sciences has many publications on hydrodynamic modeling and will oversee that project portion. **Tom Gregory** directs the water quality sampling efforts at the UNH Jackson Estuarine Laboratory as lead for NERR SWMP and also participates in eelgrass monitoring. **Kelle Loughlin** is the Education Coordinator at GBNERR and will supervise the educational component of the project. **Miguel Leon** is a data scientist at UNH and will focus on data management and data visualization for the project. *External Technical Advisor:* **Dr. Howes** of UMASS Dartmouth will draw on decades of experience working with estuarine TMDLs to advise the project team. *External End User Advisor:* **Ted Diers** of NH DES is the primary contact on regulation and science assessments for the Great Bay Estuary.

5) **Data Accessibility**:

This project is using a mixture of existing datasets, data being collected by regular monitoring programs occurring simultaneous to this project, and new data collected by this team (Table 3; Appendix I-1. Note that PREP has already engaged Team Member Miguel Leon (using separate funds) to work with DES in order to tie all the datasets below into one easily navigated user interface. This data management system is due to be completed by Fall 2022. Funds are included in the budget justification to incorporate all new data into this system.

Table 3. Datasets, ownership, and accessibility. Note that any data that is "owned" by PREP is owned by all the communities in the Piscataqua Region Watershed.

Dataset	Category	Ownership	Accessibility.
Eelgrass Distribution	Exist/To Collect	PREP/DES	scholars.unh.edu/prep/
Eelgrass Health	Exist/To Collect	PREP	
Seaweed Abundance	Exist/To Collect	PREP	and
Water Quality	Exist/To Collect	PREP	
Sediment Characteristics	To Collect	PREP	New data management
Light	Exist/To Collect	PREP	system (currently under
Hydrodynamics	Exist/To Collect	UNH/PREP	construction)

APPENDIX A -- TIMELINE

2021 Collaborative Research Grant Timeline

Project Lead: William McDowell

Project Title: Resilience and positive feedbacks: Water quality management and eelgrass health in the Great Bay Estuary, NH/ME

Project Start Date: October 1, 2021

Project End Date: September 30, 2024

Reserve(s): Great Bay NERR

Project Task/Activity	Associated Output(s)	Year 1				Year 2				Year 3			
		Fall	Wint	Spr	Sum	Fall	Wint	Spr	Sum	Fall	Wint	Spr	Sum
Project Kick-Off Meeting	In-Depth Two-Way Interactions	X											
Drifter Experiments and Hydrodynamic Modeling	Spatial Maps of Hydrodynamics, Flow Paths, etc.	X	X										
Integration Meeting #1: Sediments/Water Quality	In-Depth Two-Way Interactions		X										
Integration Meeting #2: Primary Producers/Light	In-Depth Two-Way Interactions			X									
First Field Season: Data Collection	Statistical Relationships re: Stressors and Eelgrass				X								
	Future Scenarios from Stressor-Response Results				X								
Development of Educational "Traveling Trunks"	Educational Curriculum Tools				X								
Integration Meeting #3: First Cycle Review	In-Depth Two-Way Interactions						X						
Second Field Season: Data Collection	Statistical Relationships re: Stressors and Eelgrass								X				
	Future Scenarios from Stressor-Response Results								X				
Integration Meeting #4: Second Cycle Review/Heuristic	In-Depth Two-Way Interactions									X			
Deliver "Traveling Trunks"	Educational Curriculum Tools								X				
Results Charette 1	In-Depth Two-Way Interactions										X		
Results Charette 2	In-Depth Two-Way Interactions											X	
"So What" Report Development	"So What" Report on Results Implications											X	
TOTE Workshop at GBNERR	Educational Curriculum Tools												X
"So What" Report Delivery	"So What" Report on Results Implications												X

APPENDIX B – LIST OF REFERENCES

Aoki & McGlathery. 2017. Push-pull incubation method reveals the importance of denitrification and dissimilatory nitrate reduction to ammonium in seagrass root zone. *Limnology and Oceanography: Methods.*

Aoki et al. 2020. Seagrass restoration reestablishes the coastal nitrogen filter through enhanced burial. *Limnology and Oceanography.*

Bernot et al. 2003. Comparing Denitrification Estimates for a Texas Estuary by Using Acetylene Inhibition and Membrane Inlet Mass Spectrometry. *Appl. and Environmental Microbiology*.

Bierman et al. 2014. Joint Report of Peer Review Panel for Numeric Nutrient Criteria for the Great Bay Estuary. NH DES.

Bilgili et al. 2005. Estuary/ocean exchange and tidal mixing in a Gulf of Maine Estuary: A Lagrangian modeling study. *Estuarine, Coastal and Shelf Science*.

Boesch. 2019. Barriers and Bridges in Abating Coastal Eutrophication. *Front. in Mar. Science*.

Burdick et al. 2020. Seaweed Monitoring in the Great Bay Estuary: 2019 Annual Report. *PREP Reports & Publications*.

Cash et al. 2003. Knowledge systems for sustainable development. *Proceedings of the National Academy of Sciences*.

CCSP. 2009. Best Practice Approaches for Characterizing, Communicating, and Incorporating Scientific Uncertainty in Climate Decision Making. NOAA.

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Coffin et al. 2018. An empirical model using dissolved oxygen as an indicator for eutrophication at a regional scale. *Marine Pollution Bulletin*.

Cook et al. 2019. Modeling nonlinear tidal evolution in an energetic estuary. *Ocean Modelling.*

Cook et al. 2021. The influence of submerged aquatic vegetation on modeled estimates of bed shear stress and nutrient resuspension in a tidally dominant estuary. *Estuarine, Coastal and Shelf Science, sub judice.*

Davis. 1987. Modeling eddy transport of passive tracers. *Journal of Marine Research*.

Diemer et al. 2015. Nutrient uptake along a fire gradient in boreal streams of Central Siberia. *Freshwater Science*.

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Gaeckle & Short. 2002. A plastochrone method for measuring leaf growth in eelgrass, Zostera marina L. *Bulletin of Marine Science*.

Gall et al. 2019. Predicting visual clarity and light penetration from water quality measures in New Zealand estuaries. *Estuarine, Coastal and Shelf Science*.

Luhar & Nepf. 2011. Flow-induced reconfiguration of buoyant and flexible aquatic vegetation. *Limnology and Oceanography*.

Mascaró et al. 2009. Experimental manipulation of sediment organic content and water column aeration reduces Zostera marina (eelgrass) growth and survival. *J. of Exper. Mar. Bio. & Eco*.

Matso. 2018. Flushing Time Versus Residence Time for the Great Bay Estuary. PREP Reports and Publications. 413.

PREP. 2017. Final Environmental Data Report December 2017: Technical Support Document for the 2018 State of Our Estuaries Report. PREP Publications. 383.

PREP. 2020. Draft Integrated Research and Monitoring Plan for Piscataqua Region.

Ralph et al. 2007. Impact of light limitation on seagrasses. *J. of Exper. Mar. Bio. and Ecology*.

Short et al. 1995. Mesocosm experiments quantify the effects of eutrophication on eelgrass, Zostera marina. *Limnology and Oceanography*.

Trowbridge. 2009. Numeric Nutrient Criteria for the Great Bay Estuary. NH DES.

van den Heuvel et al. 2019. Inorganic nitrogen has a dominant impact on estuarine eelgrass distribution in the Southern Gulf of St. Lawrence, Canada. *Limnology and Oceanography*.

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Warner et al. 2010. Development of a Coupled Ocean–Atmosphere–Wave–Sediment Transport (COAWST) Modeling System. *Ocean Modelling*.

Wengrove et al. 2015. Field and laboratory observations of bed stress and associated nutrient release in a tidal estuary. *Estuarine, Coastal and Shelf Science*.

Zhang et al. 2020. Turbulence and Particle Deposition Under Steady Flow Along a Submerged Seagrass Meadow. *Journal of Geophysical Research: Oceans*.

APPENDIX F – RESUMES

William H. McDowell
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Web of Science Researcher ID E-9767-2010
https://colsa.unh.edu/person/william-mcdowell
Professor of Environmental Science
University of New Hampshire
Durham, New Hampshire 03824

I. Professional Preparation

Amherst College	Amherst, MA	Biology	B.A., *magna cum laude,* 1975
Cornell University	Ithaca, NY	Aquatic Ecology	Ph.D., 1982

II. Appointments

University of New Hampshire	Interim Chair, Dept. Natural Resources and Environment, 2018
University of New Hampshire	Presidential Chair, 2008-present
University of New Hampshire	Chairperson, Department of Natural Resources, 2001-2006
University of New Hampshire	Director, NH Water Resources Res. Center 2000-present
Charles University, Prague	Fulbright Scholar, 1995-1996
University of New Hampshire	Professor, Assoc. Professor, Assistant Professor 1989-present
SUNY College at Oswego	Research Associate and Senior Staff Associate, 1985-1989
Univ. Puerto Rico, Rio Piedras	Senior Scientist I and Scientist II, Center for Energy and Environment Research, 1982-1985
Cornell University	Research Associate II, Ecosystems Research Ctr, 1981-1982

III. Representative Publications (from over 225 total)

McDowell, W.H. and G.E. Likens. 1988. Origin, composition, and flux of dissolved organic carbon in the Hubbard Brook valley. Ecological Monographs 58:177-195.

Aber, J., W. McDowell, K. Nadelhoffer, A. Magill, G. Bernston, M. Kamakea, S. McNulty, W. Currie, L. Rustad, and I. Fernandez. 1998. Nitrogen saturation in temperate forest ecosystems: Hypotheses revisited. BioScience 48:921-934.

Peterson, B.J., W. Wollheim, P.J. Mulholland, J.R. Webster, J.L. Meyer, J.L. Tank, N.B. Grimm, W.B. Bowden, H.M. Vallet, A.E. Hershey, W.H. McDowell, W.K. Dodds, S.K. Hamilton, S.V. Gregory, and D.J. D'Angelo. 2001. Stream processes alter the amount and form of nitrogen exported from small watersheds. Science 292:86-90.

McClain, M.E., E. W. Boyer, C. L. Dent, S. E. Gergel, N. B. Grimm, P. M. Groffman, S. C. Hart, J. W. Harvey, C. A. Johnston, E. Mayorga, W. H. McDowell, and G. Pinay. 2003. Biogeochemical hot spots and hot moments at the interface of terrestrial and aquatic ecosystems. Ecosystems 6:301-312.

Cole, J.J., Y.T. Prairie, N.F. Caraco, W.H. McDowell, L.J. Tranvik, R.G. Striegl, C.M. Duarte, P. Kortelainen, J.A. Downing, J.J. Middelburg and J. Melack**.** 2007. Plumbing the global carbon cycle: Integrating inland waters into the terrestrial carbon budget. Ecosystems 10:171-184.

Mulholland, P.J., A.M. Helton, G.C. Poole, R.O. Hall Jr, S.K. Hamilton, B.J. Peterson, J.L. Tank, L.R. Ashkenas, L.W. Cooper, C. N. Dahm, W.K. Dodds, S.E.G. Findlay, S.V. Gregory, N.B. Grimm, S.L. Johnson, W.H. McDowell, J.L. Meyer, H.M. Valett, J.R. Webster, C.P. Arango, J.J. Beaulieu, M.J. Bernot, A.J. Burgin, C.L. Crenshaw, L.T. Johnson, B. R. Niederlehner, J.M. O'Brien, J.D. Potter, R.W. Sheibley, D.J. Sobota, S.M. Thomas. 2008. Stream denitrification across biomes and its response to anthropogenic nitrate loading. Nature 452:202-206.

Koenig, L.E., M.D. Shattuck, L.E. Snyder, J.D. Potter, and W.H. McDowell. 2017. Deconstructing the effects of flow on stream solute interactions using a high-frequency aquatic sensor network. Water Resources Research 53:10655–10673.

Snyder, L., J.D. Potter, and W.H. McDowell. 2018. An evaluation of nitrate, fDOM, and turbidity sensors in New Hampshire streams. Water Resources Research 54: 2466–2479.

Wymore, A.S., J. Potter, B. Rodríguez-Cardona, and W.H. McDowell. 2018 Using in-situ optical sensors to understand the biogeochemistry of dissolved organic matter across a stream network. Water Resources Research 54: 2949-2958.

Gavin, A.L., S. J. Nelson, A. J. Klemmer, I.J. Fernandez, K.E. Strock, and W.H. McDowell. 2018. Acidification and climate linkages to increased dissolved organic carbon in high elevation lakes. Water Resources Research 54: 5376-5393.

Coble, A.A., L.E. Koenig, J.D. Potter, L.M. Parham, W.H. McDowell. 2019. Homogenization of dissolved organic matter within a river network occurs in the smallest headwaters. Biogeochemistry 143:85-104.

Fazekas, H., A.S. Wymore, and W.H. McDowell. 2020. Dissolved organic carbon and nitrate concentration-discharge behavior across scales: land use, excursions, and misclassification. Water Resources Research 10.1029/2019WR027028

IV. Synergistic Activities and Awards:

1) Fellow, American Geophysical Union; elected 2020
2) Fellow, American Association for the Advancement of Science; elected 2018
3) International LTER co-chair, representing US LTER network. 2011-2020
4) LTER Network Information Strategic Advisory Committee, member, 2009-2013
5) NEIWPCC (New England Interstate Water Pollution Control Commission) working group on emerging contaminants, 2006-2011

Cory Riley
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EDUCATION

University of Massachusetts Boston, Boston, MA *May 2002*
M. S. Environmental, Coastal, and Ocean Sciences and Policy

College of William and Mary, Williamsburg, VA *May 1997*
B.S. Biology

EXPERIENCE

New Hampshire Department of Fish and Game *April 2012- present*
Great Bay National Estuarine Research Reserve, Manager

- Plans, coordinates and administers all research, education, monitoring, technical assistance and land management operations related to the Great Bay National Research Reserve
- Hires, supervises and evaluates performance of research, education, land protection, coastal training, and monitoring staff
- Oversees reserve compliance with federal and state leadership and policy
- Manages grant amounts averaging in excess of 800,000 dollars a year
- Secures funding and administers grants for programs and facilities related to reserve activity
- Creates, maintains, and implements projects with partners in southeastern NH and southern Maine to protect water quality and habitat and prepare for climate change impacts in the Great Bay watershed

National Oceanic and Atmospheric Administration, Estuarine Reserve Division
August 2002- April 2012

- Interpret, communicate and implement state and federal coastal policy as the NOAA liaison to National Estuarine Research Reserves (NERR)s in New Hampshire, Maine, Massachusetts, Rhode Island, Virginia, Maryland, Delaware, New Jersey and North Carolina.
- Coordinate county government, state agencies, universities, nonprofit organizations and federal partners to implement research, education, land management, construction, and land acquisition activities.
- Review work plans and budgets, administer, and monitor performance for federal financial assistance awards to reserves totaling more than $5 million dollars annually.
- Create consensus on budget recommendations for the federal NERR allocation between $16,000,000 and $27,000,000.
- Represent the National Oceanic and Atmospheric Administration at meetings with state and federal partners, in national conferences, and in negotiations.
- Write and design communication materials for web, brochures, blogs, and newsletters on behalf of the National Oceanic and Atmospheric Administration.
- Work with state and local partners to create and implement a national performance measures system, a data collection system, and analysis plan.

- Assist in program development for national habitat mapping, restoration, estuarine research, and adult training programs.
- Supervise interns and contractors and lead teams to complete time sensitive products including budget projections, written communication materials, evaluation findings, synthesis of research findings, and guidance documents.
- Assist in the development and implementation of a competitive research program that administers 5 million dollars annually to connect scientists to local natural resource needs.
- Lead facilitator for meetings lasting up to five days and for meetings with up to 200 people.

Urban Harbors Institute *Sept 2000- June 2002*

- Conduct background research, perform data analysis, and contribute to written reports for local, state, and international organizations and private business in coastal planning, policy analysis, port and harbor management, and community involvement contracts.
- Wrote and edited a natural resource inventory and recommendations for an Area of Critical Environmental Concern for the Massachusetts Department of Environmental Management.
- Co-authored the Baseline Study on the Use of Performance Measures in the National Estuarine Research Reserves for the National Oceanic and Atmospheric Administration.
- Contributed writing and research to the Massachusetts Aquatic Invasive Species Plan for the Massachusetts Coastal Zone Management Office.

AWARDS AND PROFESSIONAL ASSOCIATIONS

- Piscataqua Regional Estuaries Partnership, Management Committee Chair
- National Estuarine Research Reserve System and Association Award 2016
- Past President, National Estuarine Research Reserve Association (2016-2018)
- Department of Commerce Bronze Medal Award : “Achievement Award for the development of the Program Design and Evaluation Course” December 2004
- Chesapeake Bay National Estuarine Research Reserve “Service Award” 2005
- Member of The Coastal Society, Coastal Estuarine Research Federation

PRESENTATIONS AND PUBLICATIONS

More than 75 oral presentations given over the last fifteen years.

Selected presentations:

- Riley, C and Patrick, D. April 2018 “Buffer Options for Great Bay” Saving Special Places, Alton, NH.
- Riley, C. August 2011 “A case study; how to direct funding to ensure that research is applied in decision making” National Coastal Zone Conference, Chicago, IL

Publications:

- Riley et.al. 2010. A case study: how research funders can increase the use of science. *The Journal of Coastal Management.* 39.3
- Bowen, R. and C. Riley. 2003. Socio-economic indicators and integrated coastal management. *Ocean and Coastal Management.* 46. 229-312.

Kalle Matso

Manager, Coastal Science Program
Piscataqua Region Estuaries Partnership (PREP)
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PROFESSIONAL EXPERIENCE

Manager, Coastal Science Program, Piscataqua Region Estuaries Partnership — Feb., 2015 – Present

Affiliate Assistant Professor, Dept. Natural Resources and the Environment, University of New Hampshire (UNH) — March, 2014 - Present

Consulting Participatory Process Designer/Facilitator — Jan. 2013 - Present

Project Investigator, NERRS Science Collaborative, UNH — Sept., 2009 – Feb., 2015

Project Investigator, Cooperative Institute for Coastal & Estuarine Technology (CICEET), UNH — June, 2000 – Sept., 2009

EDUCATION

Ph.D. 2012. University of New Hampshire; Natural Resources and Earth Systems Science.
Dissertation Title = "Producing Science that Gets Used by Coastal Communities: What Funders Should Do to Link More Science with Decisions"

M.S. 2000. University of New Hampshire; Department of Natural Resources.
Thesis Title = "Beach Seine, SCUBA and Remote Video: A Comparison of Three Methods for Assessing Faunal Species Richness and Abundance in Eelgrass Beds"

B.A. 1989. The Colorado College; Department of English

FUNDED RESEARCH

NERRS Science Collaborative — 2009 – 2014

Co-Investigator, National Coastal and Estuarine Research and Technology Program. Awarded $23 million from NOAA.

New England Sustainability Consortium (NEST) — 2013 – 2015

Co-Investigator. Awarded $6 million award from NSF.

ICNet: Generating and Translating New Knowledge for Sustainable Transportation in a Changing Climate. — 2014 – 2015

Steering Committee Member. $750,000 Research Coordination Network grant from NSF.

PROFESSIONAL ACTIVITIES

Journal/Proposal Reviewer

North Carolina Sea Grant

National Sea Grant

National Park Service, Hurricane Sandy Mitigation Award

Environmental Management

Society and Natural Resources

Estuaries and Coasts

Journal of Community Engagement and Scholarship

PUBLICATIONS

Refereed Journal Articles

Trueblood D, S Almazán-Casali, J Arnott, M Brass, MC Lemos, K Matso, J Read, L Vaccaro & J Wondolleck. 2019. Advancing Knowledge for Use in Coastal and Estuarine Management: Competitive Research in the National Estuarine Research Reserve System, *Coastal Management*, DOI: 10.1080/08920753.2019.1598221

Matso, KE and ML Becker. 2014. What Can Funders Do to Better Link Science with Decisions? Case Studies of Coastal Communities and Climate Change. *Environmental Management.* DOI 10.1007/s00267-014-0347-2

Matso, KE and M Becker. 2013. Funding Science that Links to Decisions: Case Studies Involving Coastal Land Use Planning Projects. Estuaries and Coasts. DOI: 10.1007/s12237-013-9649-5

Riley, C, KE Matso, D Leonard, J Stadler, D Trueblood and R Langan. 2011. How research funding organizations can increase application of science to decision making. Coastal Management. 39:336-350

Matso, K.E., M.O. Dix, B. Chicoski, D.L. Hernandez, J.R. Schubel. 2008. Establishing A Minimum Standard for Collaborative Research in Federal Environmental Agencies. *Journal of Integrated Environmental Assessment and Management.* 4:362-368.

Short, F.T., K.E. Matso, H.M. Hoven, J. Whitten, D.M. Burdick, and C.A. Short. 2001. Lobster use of eelgrass habitat in the Piscataqua River on the New Hampshire/Maine Border, USA. *Estuaries.* Vol. 24, No. 2, p. 277-284

Refereed Book Chapters

Matso KE. 2012. Challenge of Integrating Natural and Social Sciences to Better Inform Decisions: A Novel Proposal Review Process. In, “Restoring Lands: Coordinating Science, Politics, and Action,” Eds., H. Karl., M. Flaxman, JC Vargas-Moreno and PL Scarlett. Springer Publishing, Dordrecht, the Netherlands.

Christopher R. Peter

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Christopher.Peter@wildlife.nh.gov

GREAT BAY NATIONAL ESTUARINE RESEARCH RESERVE

Education

M. S. | UNIVERSITY OF NEW HAMPSHIRE 2004 - 2007

- Major: Natural Resources
- Thesis: Enhancing natural barriers to invasive species

B. S. | UNIVERSITY OF NEW HAMPSHIRE 1998 - 2002

- Major: Water Resource Management
- Minor: Geology

Experience

RESEARCH COORDINATOR 2018 - *present*
Great Bay National Estuarine Research Reserve

RESEARCH TECHNICIAN III 2007 - 2018
University Of New Hampshire

RESTORATION SCIENCE CONSULTANT 2007 - 2017
Wells National Estuarine Research Reserve

RESEARCH / TEACHING ASSISTANT 2004 - 2007
University Of New Hampshire

FIELD BIOLOGIST 2004 - 2007
University Of New Hampshire

Skills & Abilities

Field and lab analysis: water quality, meteorological, soils, vegetation, algae, invertebrates, fish
Research experience: fresh, brackish and marine aquatic systems
Languages: English, Chinese (fluent), Spanish (basic knowledge)

Presentations (selected)

Synthesizing NERR Sentinel Site Data to Improve Coastal Wetland Management across New England. Coastal Estuarine Research Federation, Mobile, AL 2019

Integrating Point Intercept and Ocular Cover Plant Datasets. New England Estuarine Research Society, York, ME 2019

New Technology for Old Problems – Using DNA Methods to Monitor Invasive Species and Biodiversity in Estuarine Systems. NERR Annual Meeting. Duluth, MN 2018

Electromagnetic Induction as a Tool to Map Porewater Salinity across Tidal Marshes. New England Estuarine Research Society, Bristol, RI 2015

Measuring Salt Marsh Plant, Soil, and Hydrologic Response to Restoration Using Performance Benchmarks from Local Reference Systems at NERRs. Restore America's Estuaries. Tampa Bay, FL 2012

Publications (selected)

Burdick, D.M., G. Moore, A.C. Mathieson, A. Payne, L. Martin and **C. Peter**. 2020. Seaweed Monitoring in the Great Bay Estuary: 2019 Annual Report. PREP Reports & Publications. 442. https://scholars.unh.edu/prep/442

Burdick, D.M, G.E. Moore, S.C. Adamowicz, G.M. Wilson, and **C.R. Peter**. 2019. Mitigating the Legacy Effects of Ditching in a New England Salt Marsh. https://doi.org/10.1007/s12237-019-00656-5

Wasson K., K. Raposa, M. Almeida, K. Beheshti, J.A. Crooks, A. Deck, N. Dix, C. Garvey, J. Goldstein, D.S. Johnson, S. Lerberg, P. Marcum, **C. Peter**, B. Puckett, J. Schmitt, E. Smith, K. St. Laurent, K. Swanson, M. Tyrrell, & R. Guy. 2019. Pattern and Scale: Evaluating Generalities in Crab Distributions and Marsh Dynamics from Small Plots to a National Scale. Ecology. 100 (10): https://doi.org/10.1002/ecy.2813

Raposa, K.B., S. Lerberg, C. Cornu, J. Fear, N. Garfield, **C.R. Peter**, R.L.J. Weber, G.E. Moore, D.B. Burdick and M. Dionne. 2018. Evaluating Tidal Wetland Restoration Performance Using National Estuarine Research Reserve System Reference Sites and the Restoration Performance Index (RPI). Estuaries and Coasts. 51: 36-51

Grizzle, R.E., K.M. Ward, **C.R. Peter**, M. Cantwell, D. Katz and J. Sullivan. 2016. Growth, Morphometrics and Nutrient Content of Farmed Eastern Oysters, *Crassostrea virginica* (Gmelin), in New Hampshire, USA. Aquaculture Research. 48: 1525-1537

Grizzle, R.E., L.G. Ward, D.W. Fredriksson, J.D. Irish, R. Langan, C.S. Heinig, J.K. Greene, H.A. Abeels, **C.R. Peter** and A.L. Eberhardt. 2014. Long-term Seafloor Monitoring at an Open Ocean Aquaculture Site in the Western Gulf of Maine, USA: Development of an Adaptive Protocol. Marine Pollution Bulletin. 88: 129-137

Nichols, W.F., G.E. Moore, N.P. Ritter and **C.R. Peter**. 2013. A Globally Rare Coastal Salt Pond Marsh System at Odiorne Point State Park, Rye, New Hampshire. *Rhodora* 115: 1-27

Moore, G. E., D. M. Burdick, **C. R. Peter,** and D. K. Keirstead. 2012. Belowground biomass of *Phragmites australis* in coastal marshes. Northeastern Naturalist 19: 611-626

Moore, G.E., D.M. Burdick**, C.R. Peter** and D.R. Keirstead. 2011. Mapping Soil Pore Water Salinity of Tidal Marsh Habitats Using Electromagnetic Induction in Great Bay Estuary, USA. Wetlands. 31: 309-318

Peter, C.R. and D.M. Burdick. 2010. Can Plant Competition and Diversity Reduce the Success of Exotic *Phragmites australis* Invading a Salt Marsh? Estuaries and Coast. 33: 1225-1236

Moore, G.E., **C.R. Peter**, D.M. Burdick, and D.R. Keirstead. 2009. Status of the Eastern Grasswort, *Lilaeopsis chinensis* (L.) Kuntze (Apiaceae) in the Great Bay Estuary, New Hampshire, USA. *Rhodora*. 111: 171-188

Anna E. Lowien

Water Quality Analysis Laboratory
University of New Hampshire
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(240) 538-3029

EDUCATION

M.S. Natural Resources, University of New Hampshire, expected 2021
B.S. Environmental Science and Policy, University of Maryland, 2019

PROFESSIONAL EXPERIENCE

Graduate Research Assistant, UNH Water Quality Analysis Laboratory, Durham, NH — Aug. 2019 – present

- Operated water quality analysis instruments, including SmartChem Chemistry Analyzer, Dionex Ion Chromatograph, Shimadzu TOC-V CSH, SEAL AQ2 Discrete Analyzer, and Shimadzu GC-2014
- Participated in Piscataqua Region Estuaries Partnership technical advisory board meetings

Soil Judge, UMD Soil Judging Team, College Park, MD — Aug. 2018 – April 2019

- Quantified characteristics of soils to determine feasibility for agriculture, development, or restoration
- Collaborated with four other soil judges to complete soil descriptions of various soil series at regional and national soil judging collegiate competitions

NOAA Hollings Scholar, Kachemak Bay National Estuarine Research Reserve, Homer, AK — May 2018 – Aug. 2018

- Conducted hydrologic field research to quantify temporal fluctuations in riverine discharge using an Acoustic Doppler Current Profiler and Marsh McBirney Flow-Mate™
- Executed and presented data analysis project to characterize hydrologic variability of salmon-bearing rivers for the Alaska Department of Fish and Game

Research Assistant, UMD Department of Geology, College Park, MD — March 2017 – May 2019

- Managed laboratory stable isotope data collection for paleoclimate reconstruction
- Coordinated the collection and preparation of cellulose data sets for analysis and electronic delivery
- Composed technical instrument protocols and conducted systematic troubleshooting of mass spectrometer malfunctions

LEAF Outreach Team Intern, UMD Office of Sustainability, College Park, MD — Oct. 2016 – May 2018

- Organized campus wide and semester long sustainability programs including the "Green Terp Program", which encouraged the development of sustainable living habits for on campus residents
- Supervised and trained fifteen outreach interns as team leader for 2017-2018 academic year

Stewardship Intern, Anacostia Watershed Society, Bladensburg, MD — June 2016 – Aug. 2016

- Engaged in environmental stewardship through programming of community education and outreach
- Quantified the impact of urbanization on the Anacostia River through trash-trap collection
- Restored wetlands through invasive species removal, monitoring data collection, and native plant reintroduction

Scholar, UMD College Park Scholars Program, College Park, MD — Aug. 2015 – May 2017

- Facilitated invasive aquatic species management at the Kenilworth Aquatic Gardens
- Developed and presented a practicum project on river restoration methods for Anacostia River

CONFERENCE ABSTRACTS

Lowien, A.E., C. Walker, J. Argueta, & R.S. King. 2018. Scales of Hydrologic Variability in the Kenai Lowlands, presented at 2018 Annual National Estuarine Research Reserve (NERR) Meeting, 6 Nov.

Lowien, A.E., M.D. Shattuck, & W.H. McDowell 2020. Assessing the Transporter/Transformer Hypothesis using a Nitrogen Budget for the Lamprey River, NH, presented at 2020 AGU Fall Meeting.

REPORTS AND PUBLICATIONS

Lowien, A., Shattuck, M. & McDowell, W. H. *Nitrogen Budgets for Mainstem Segments of the Lamprey River*. 48 https://www.lampreyriver.org/UploadedFiles/Files/Nutrient_Budgets_final_report.pdf (2020).

AWARDS & FELLOWSHIPS
2020 Inaugural Cohort of Margaret A. Davidson Fellows – Great Bay National Estuarine Research Reserve, NH
2019 First Place, University of Maryland Soil Judging Team, National Soil Judging Contest, San Luis Obispo, CA
2018 – 2019 Green Fellowship in Environmental Science and Restoration
2018 Fourth Place, Individual Competition, North East Regional Soil Judging Contest, Wilmington, Ohio
2018 Student Research Poster Contest Winner, 2018 NERR Annual Meeting
2017 – 2019 National Oceanic and Atmospheric Administration: Hollings Scholarship
2015 – 2017 UMD College Park Scholars Academic Citation and Achievement Awards

University of New Hampshire
School of Marine Science and Ocean Engineering

DAVID M. BURDICK, Ph.D.

Associate Research Professor
Director, Jackson Estuarine Laboratory
Department of Natural Resources and the Environment
University of New Hampshire, Durham, NH 03824
david.burdick@unh.edu 603-862-5129

RESEARCH AREAS

Ecology and restoration of coastal wetlands and their plants
Science and management of created and restored wetlands

EDUCATION

1973-1977 **B.S. Chemistry**, Hobart College, Geneva, NY
1982-1988 **Ph.D. Marine Sciences**, Louisiana State University, Baton Rouge, LA

TEACHING

Wetland Ecology & Management
Wetlands Restoration & Mitigation
Freshwater Resources
Science and Management of Coastal Wetlands
Salt Marsh Restoration & Monitoring at Eagle Hill

HONORS & AWARDS

LSU Alumni Fellowship
GERS Freeport Sulfur Award
LSU Lipsey Award
Mayors Award: Great Bog
Coastal America Partnership
Greater Piscataqua Education Partners Award
UNH Outreach Scholar
Gulf of Maine Council's Visionary Award
Gulf of Maine Council's Susan Snow Cotter Leadership Award
EPA Environmental Merit Award

PROFESSIONAL APPOINTMENTS

1979-1981 Research Assistant, Center for Coastal Studies, Provincetown, MA
1981-1982 Research Assistant, National Marine Fisheries Service, Sandy Hook, NJ
1982-1988 Graduate Student, Department of Marine Sciences, Baton Rouge LA
1988-1990 Postdoctoral Investigator, Biology Department, WHOI, Woods Hole, MA
1990-1993 Research Scientist, Jackson Estuarine Laboratory, UNH, Durham NH
1993-1999 Assistant Research Professor, Jackson Estuarine Laboratory, UNH, Durham NH
1999-Present Associate Research Professor, NREN & Jackson Estuarine Laboratory, UNH
2011-2013 Class of 1937 Professorship in Marine Science, Marine Program, UNH
2014-2019 Interim Director, Jackson Estuarine Laboratory
2020-Present Director, Jackson Estuarine Laboratory

SERVICE AND OUTREACH

Societies: Northeastern Estuarine Research Society, Coastal Estuarine Research Federation, Society of Wetland Scientists, Society for Ecological Restoration

Recent and Current Activities: National Academy of Sciences: Monitoring and Assessment of Gulf of Mexico Restoration Activities; NH Coastal Adaptation Workgroup; Advocates for North Mill Pond; Piscataqua Region Estuaries Partnership, Technical Advisory Committee; Great Bay NERR Research Advisory Board; NHDES Landowner Technical Assistance Program

SELECTED PUBLICATIONS - *Peer-Reviewed Journals*

Burdick, D.M. and I.A. Mendelssohn. 1990. Relationship between anatomic and metabolic responses to soil waterlogging in the coastal grass *Spartina patens*. Journal of Experimental Botany 41:223-228.

Short, F.T., D.M. Burdick, J. Kaldy. 1995. Mesocosm experiments quantify the effects of coastal eutrophication on eelgrass, *Zostera marina* L. Limnology and Oceanography 40:740-749.

Short, F.T., D.M. Burdick. 1996. Quantifying eelgrass habitat loss in relation to housing development and nitrogen loading in Waquoit Bay, Massachusetts. Estuaries 19:730-739.

Burdick, D.M., M. Dionne, R.M. Boumans, F.T. Short. 1997. Ecological responses to tidal restorations of New England salt marshes. Wetlands Ecology and Management 4:129-144.

Short, F.T., D.M. Burdick, C.A. Short, R.C. Davis, P. Morgan. 2000. Developing success criteria for eelgrass, salt marsh and mud flat habitats. Ecological Engineering 15:239-252.

Boumans, R.M.J., D.M. Burdick, M. Dionne. 2002. Modeling habitat change in salt marshes following tidal restoration. Restoration Ecology 10: 543-555.

Seliskar, D.M., J.L. Gallagher, D.M. Burdick, L.A. Mutz. 2002. The regulation of ecosystem functions by ecotypic variation in the dominant plant: *Spartina alterniflora*. Journal of Ecology 90:1-11.

Konisky, R.A., D.M. Burdick, M. Dionne, H.A. Neckles. 2006. A regional assessment of salt-marsh restoration and monitoring in the Gulf of Maine. Restoration Ecology 14:516-525.

Morgan, P.A., D.M. Burdick, F.T. Short. 2009. The functions and values of fringing salt marshes in northern New England, USA. Estuaries and Coasts 32:483-495.

Eberhardt, A.L, D.M. Burdick, M. Dionne. 2011. Effects of road culverts on nekton in New England salt marshes. Restoration Ecology 19: 776-785.

Chmura, G.L., D.M. Burdick, G.E. Moore. 2012. Recovering salt marsh ecosystem services through tidal restoration. pp. 233-251 *In:* Roman, C.T. and D.M. Burdick (eds.), Tidal Marsh Restoration: A Synthesis of Science and Practice. Island Press. Washington. 406 pp.

Vincent, R.E., D.M. Burdick M. Dionne. 2013. Ditching and ditch-plugging in New England salt marshes. Estuaries and Coasts DOI 10.1007/s12237-012-9583-y

Mora, J.W., D.M. Burdick. 2013. Effects of man-made berms upon plant communities in New England salt marshes. Wetlands Ecology & Management DOI 10.1007/s11273-013-9285-7

Eberhardt, A.L., D.M. Burdick, M. Dionne, R.E. Vincent. 2015. Rethinking the freshwater eel: salt marsh trophic support of the American eel. Estuaries and Coasts 38: 1251-1261.

Raposa, K.B., M.L. Cole Ekberg, D.M. Burdick, N.T. Ernst, S.C. Adamowicz. 2016. Elevation change and the vulnerability of Rhode Island (USA) salt marshes to sea-level rise. Regional Environmental Change. DOI 10.1007/s10113-016-1020-5

Raposa, K.B., S. Lerberg, C. Cornu, J. Fear, N. Garfield, C. Peter, R.L.J. Weber, G. Moore, D. Burdick, M. Dionne. 2018. Evaluating tidal wetland restoration performance using National Estuarine Research Reserve System reference sites and the Restoration Performance Index (RPI). Estuaries and Coasts 41:36-51. https://doi-org.libproxy.unh.edu/10.1007/s12237-017-0220-7

van Ardenne, L.B., S. Jolicouer, D. Berube, D. Burdick, G.L. Chmura. 2018. The importance of geomorphic context for estimating the carbon stock of salt marshes. Geoderma 330:264-275.

SELECTED PUBLICATIONS - *Outreach Products*

Dock Design with the Environment in Mind. D.M. Burdick and F. T. Short. UNH, Jackson Estuarine Laboratory. CD/Web distribution 2003/2005

Eelgrass Restoration Site Selection Model. F.T. Short and D. M. Burdick. UNH, Jackson Estuarine Laboratory. CD/Web distribution 2005/2006

Tidal Marsh Restoration: A Synthesis of Science and Practice. Roman, C.T., D.M. Burdick (eds.). 2012. Island Press. Washington. 406 pp.

Effective Monitoring to Evaluate Ecological Restoration in the Gulf of Mexico. 2016. The National Academies of Sciences Press, Washington, DC. 10.17226/23476

A Case for Restoration and Recovery of *Zostera marina* L. in the Great Bay Estuary. 2020. Burdick, D., K. Edwardson, T. Gregory, K. Matso, T. Mattera, M. Paly, C. Peter, F. Short, D. Torio. University of New Hampshire, Durham NH. 37 pp37. http://scholars.unh.edu/prep/441

BIOGRAPHICAL SKETCH

THOMAS C. LIPPMANN

Professional Preparation

Linfield College	McMinnville, OR	Mathematics and Biology	B.A.	1985
Oregon State University	Corvallis, OR	Geological Oceanography	M.S.	1989
Oregon State University	Corvallis, OR	Geological Oceanography	Ph.D.	1992

Appointments

University of New Hampshire	Associate Professor	2013-
University of New Hampshire	Research Associate Professor	2008-2013
Ohio State University	Research Scientist	1999-2008
Scripps Institution of Oceanography	Research Oceanographer	Assoc. 2002-06 Asst. 1999-02
Naval Postgraduate School	NRC Postdoctoral Fellow	1992-1995

Recent Products Most Closely Related to the Project

1. Cook, S. E., T. C. Lippmann, K. Koetje, M. Wengrove, and D. Foster, The influence of submerged aquatic vegetation on modeled estimates of bed shear stress and nutrient resuspension in a tidally dominant estuary, *Estuarine, Coastal, and Shelf Science*, *sub judice*, **2020**.
2. Wengrove, M. E., D. L. Foster, L. H. Kalnejais, V. Purcuoco, and T. C. Lippmann. Field and laboratory observations of bed stress and associated nutrient release in a tidal estuary, *Estuarine, Coastal, and Shelf Science*, 161, 11-24, **2015**. DOI:10.1016/j.ecss.2015.04.005.
3. Cook, S., and T. C. Lippmann, Verification of a three-dimensional hydrodynamic model in a tidally dominated estuary, *Ocean Modelling,* 36, 13-27, **2019**. DOI: 10.1016/j.ocemod.2019.02.009.
4. Lippmann, T. C., A. E. Simpson, S. E. Cook, and P. Kirshen, Effects of sea level rise on modeled storm surge and current speeds in New Hampshire Estuaries, *ASCE Journal of Waterw. Ports Coastal Engineering*, 147(2), **2021**. DOI: 10.1061/(ASCE)WW.1943-5460.0000613
5. Lucking, G., N. Stark, T. C. Lippmann, and S. Smythe, Variability of in situ sediment strength and pore pressure behavior of tidal estuary surface sediments, *Geo-Mar Lett,* 37(5), 441-456, **2017**. DOI: 10.1007/s00367-017-0494-6.
6. Pe'eri, S., J. R. Morrison, F. Short, A. Mathieson, and T. Lippmann, Eelgrass and macro-algea mapping for nutrient criteria for New Hampshire's estuaries using hyperspectral imagery, *J. Coastal Res.*, 76, 209-218, **2016**. DOI: 10.2112/SI76-018.
7. Choi, J.-G., Y.-H. Jo, I.-J. Moon, J. Park, D.-w. Kim, and T. C. Lippmann, Physical forces determine the annual bloom intensity of the giant jellyfish *Nemopilema nomurai* off the coast of Korea, *Reg. Studies in Mar. Sci.,* 24, 55-65, **2018**. DOI: 10.1016/j.rsma.2018.07.003.
8. Wengrove, M.E., D. L. Foster, T. C. Lippmann, M. A. de Schipper, and J. Calantoni, Observations of Bedform Migration and Bedload Sediment Transport in Combined Wave-Current Flows, *J. Geophys. Res.,* 124, 4572-4590, **2019**. DOI: 10.1029/2019JC014555.
9. Humberston, J.H., J. McNinch, and T. C. Lippmann, Observations of wave influence on alongshore ebb-tidal delta morphodynamics at Oregon Inlet, NC, *J. Mar. Geo.,* 418, **2019**. DOI: 10.1016/j.margeo.2019.106040
10. Lippmann, T. C., J. Irish, and J. Hunt, Observations of the vertical structure of tidal currents in two inlets, *J. Coastal Res*., 65, 2029-2034, **2013**. DOI:10.2112/SI65-343.1.

Other Recent Selected Publications

1. Lippmann, T. C., and A. J. Bowen, The vertical structure of low frequency motions in the nearshore, Part 2: Theory, *J. Phys. Oceanogra.*, 46(12), 3713-3727, **2016**. DOI: 10.1175/JPO-D-16-0015.1.
2. Lippmann, T. C., E. B. Thornton, and T. P. Stanton, The vertical structure of low frequency motions in the nearshore, Part 1: Observations, *J. Phys. Oceanogra.*, 46(12), 3695–3711, **2016**. DOI: 10.1175/JPO-D-16-0014.1.
3. Perkovic, D., T. C. Lippmann, and S. J. Frasier, Longshore surface currents measured by Doppler radar and video PIV techniques, *TGRS*, 47(8), 2787-2800, **2009**. DOI:10.1109/TGRS.2009. 2016556
4. Hansen, J., B. Raubenheimer, S. Elgar, J. List, and T. C. Lippmann, Physical linkages between

offshore bathymetry and surf zone morphologic change, *J. Geophys. Res.,* 122(4), 3451-3460, **2017**. DOI: 10.1002/2016JC012319.

5. Marin Jarrin, M.J., and T. C. Lippmann, Interannual variability of mixed layer dynamics in the Ecuadorian ocean, *J. Geophys. Res.,* 124, **2019**. DOI: 10.1029/2019JC015086.
6. Kirillin, G. B., M. S. Lorang, T. C. Lippmann, C. G. Gotschalk, and S. Schimmelpfennifg, Surface Seiches in Flathead Lake, *Hydrology and Earth Systems Sciences*, 19, 2605-2615, **2015**. DOI:10.5194/hess-19-2605-2015.
7. Fandel, C. L., T. C. Lippmann, D. L. Foster, and L. L. Brothers, Observations of pockmark flow structure in Belfast Bay, Maine. Part 3: Implications for sediment transport, *Geo-Mar Lett.,* 37(1), 23-34, **2017**. DOI: 10.1007/s00367-016-0474-2.
8. Fandel, C. L., T. C. Lippmann, D. L. Foster, and L. L. Brothers, Observations of pockmark flow structure in Belfast Bay, Maine. Part 2: Evidence for cavity flow, *Geo-Mar Lett.,* 37(1), 15-22, **2017**. DOI: 10.1007/s00367-016-0473-3.
9. Fandel, C. L., T. C. Lippmann, J. D. Irish, and L. L. Brothers, Observations of pockmark flow structure in Belfast Bay, Maine. Part 1: Current-induced mixing, *Geo-Mar Lett.,* 37(1), 1-14, **2017**. DOI: 10.1007/s00367-016-0472-4.
10. Monfort, C. L., and T. C. Lippmann, Assimilation of airborne imagery with a wave model for bathymetric estimation, *J. Coastal Res.*, 62, 40-49, **2011**. DOI:10.2112/SI_62_5

Synergistic Activities

1. *Principal Investigator* for projects conducted along New Hampshire coastlines and estuaries funded by ONR, NOAA, NERACOOS, TNC, and PNSY, including research directly related to modeling flooding and inundation from extreme storms and sea level rise scenarios.
2. *Member Center for Coastal and Ocean Mapping* (UNH). Efforts focused on modeling sediment transport in shallow water environments for assessment of bathymetric evolution and variability in navigable waterways, and development of measurement systems for shallow water mapping in hazardous environments.
3. *Observation and modeling of flows and sediment transport in Estuaries and Tidal Inlets.* Efforts include verifying a coupled numerical model for hydrodynamics in the Great Bay, NH, sediment transport of the Hampton/Seabrook, NH, inlet and harbor over a 5-year period, and working on developing a transport pathways model for sedimentation prediction in Oregon Inlet, NC.
4. *PI-Nearshore Processes Field Experiments*: Duck94 (1994), MBBE I & II (1996), SandyDuck (1997), AVS (1997-present), RIPEX (2001), NCEX (2003), Lake Erie (2002), Portsmouth Inlet (2008), Great Bay (2009), Ghana, Africa (2010), Belfast Bay (2011), Hampton Inlet (2011), RIVET (2012), Flathead Lake, MT (2012), Little Bay, NH (2013), Flathead Lake (2014), Portsmouth Naval Shipyard Surveys (2015), Great Bay, NH (2014, 2015, 2016, 2017, 2018, 2019), Hampton/Seabrook Harbor (2016, 2017), Oregon Inlet (2019)
5. *Member Coastal Flood Risk Science and Technical Advisory Panel (STAP)* Serving as a science and technical advisor on the STAP for the New Hampshire Coastal Risk and Hazards Commission.

Graduate Advisors and Postdoctoral Sponsors: Holman, Robert A. (Oregon St. Univ.); Thornton, Edward B. (Naval Postgraduate School)

Graduate students advised (17): Salme Cook (PhD. UNH, 2019); Josh Humberston (PhD. UNH, 2021); Katie Kirk (PhD. UNH, 2022); Jang-Geun Choi (PhD. UNH. 2021); Kate von Krusenstiern (M.S. UNH, 2020); Cameron Murphy (M.S., UNH, 2019); Cassie Bongiovanni (M.S., UNH, 2018); Maria Marin Jarrin (M.S., UNH, 2016); Josh Humberston (M.S., UNH, 2015); Christy Fandel (M.S., UNH, 2013); Lindsay McKenna (M.S., UNH, 2013); Anastasia Abramova (M.S., UNH, 2012); Gabe Smith (M.S., OSU, 2005); Senthilnathan Kannan (M.S., OSU, 2003); Srinivasa Chopakatla (M.S., OSU, 2003); Carther Jorgensen (M.S., NPS, 1996); Henry Brookins (M.S., NPS, 1993).

Ph.D. Thesis committees (23): Current: Choi (OCE), Kirk (OCE), Humberston (OCE), Gloeckler (ENE), Melendez-Oyola (OCE), Kates Varghese (OCE), Lush (OCE), Devoe (OE), Marry (OE)

THOMAS K. GREGORY
Ocean Process Analysis Laboratory
University of New Hampshire
Durham, NH 03824
(603) 862-5136
tom.gregory@unh.edu

PROFESSIONAL PREPARATION:

1995	B.S. Chemical Oceanography	Florida Institute of Technology
1999	M.S. Marine Science	University of San Diego

POSITIONS HELD:

Project Director III
University of New Hampshire, Ocean Process Analysis Laboratory, August 2016 – present.

- Principal Investigator for Great Bay SWMP program and several other estuary monitoring projects.
- Continue Research Scientist II work, with added responsibilities and leadership.

Research Scientist II
University of New Hampshire, Ocean Process Analysis Laboratory, April 2007 – August 2016.

- Direct biogeochemical and optical research programs in the Great Bay Estuary for national, regional and municipal water quality monitoring projects.
- Handle all aspects of deployments, instrument work and validation sampling for a NERACOOS-funded monitoring buoy in the Great Bay Estuary. Buoy sensor suite includes fluorometers, radiometers, CTD and a met package as well as novel nutrient sensors for measurement of nitrate, phosphate and ammonium.
- Organize and manage research cruises in the Gulf of Maine and near Martha's Vineyard aboard R/V Gulf Challenger and R/V Tioga.

Hawaii Ocean Time-series Project Director
University of Hawaii at Manoa, Department of Oceanography, May 2002 – April 2007.

- Plan, mobilize and lead monthly Hawaii Ocean Time-series cruises on UNOLS Global Class and Ocean/Intermediate Class ships.
- HOT cruise participation: 54 cruises including 19 as Chief Scientist.
- Serve as HOT Program Lab Manager and analytical chemist including assisting Principal Investigator with the management and recruitment of technical staff as well as the acquisition and implementation of analytical instrumentation.
- Re-develop dissolved organic carbon analysis program to meet the standards and approval of recognized world leaders in marine DOC determination.

Research Project Specialist, Oceanographic – Hawaii Ocean Time-series
University of Hawaii at Manoa, Department of Oceanography, August 2001 – May 2002.

- Lab Manager for biogeochemistry and microbiology components of the Hawaii Ocean Time-series program. Handle new hire orientation and training, inventory control and compliance with hazardous material and radioisotope regulations.
- Responsible for preparation, analysis and data reduction of many core measurements including chlorophyll, phycoerythrin, particulate phosphorus, particulate silica, dissolved oxygen and primary production using wet chemical and instrumental techniques.
- Participate in monthly Hawaiian Ocean Time-series research cruises.

- Renovate and maintain oceanographic field equipment including free-drifting primary production and sediment trap arrays.

Research Project Support Specialist
University of Hawaii at Manoa, Department of Oceanography, Nov. 1999 – August 2001.

- Lab Manager and Radiochemical Facility Manager. Use complex wet chemical protocols to prepare seawater, biological and sediment samples for radiochemical analyses, operation of radiochemical instrumentation, and administration of general lab tasks.
- Participate in monthly Hawaiian Ocean Time-series research cruises aboard the *R/V KOK* and in semi-annual research cruises aboard the *R/V Townsend Cromwell*, working independently of other scientists aboard.

Instructor of Chemistry
Hawai`i Pacific University, Kaneohe, Hawai`i, Fall 1999 and Spring 2001 Semesters.

Graduate Research Assistant
University of San Diego, San Diego, California; January 1996 – December 1998.

Work – Study Volunteer
Bermuda Biological Station for Research, Inc., St. George's, Bermuda; Summer 1995.

SELECTED PUBLICATIONS:

Barnard, A. H., Koch, C., Egli, P., Hanson, A., Gregory, T., Ragan, M. A., Jones, B., Campbell, R., Needoba, J. 2011. Performance validation of the cycle-PO4, an instrument for in-situ and long-term orthophosphate monitoring. 2011 ASLO Aquatic Sciences Meeting, February 13-28, 2011, San Juan, Puerto Rico.

Koch, C R; Wetzel, C; Zaneveld, J R; Gregory, T K; Pennock, J R; et al. 2010. CYCLE-PO4: an in-situ instrument for high temporal resolution phosphate measurements over long deployments. In Proceedings from the 2010 AGU Ocean Sciences Meeting, American Geophysical Union.

Gregory, T K; Morrison, J R; Novak, M G. 2008. Progress in observing estuarine and coastal ocean processes with the Great Bay Coastal Buoy. In Proceedings from the 2008 AGU Ocean Sciences Meeting, American Geophysical Union.

Morrison, J R; Trowbridge, P; Gregory, T K; Novak, M G. 2008. Hyperspectral Airborne Remote Sensing for Assessing Water Quality and Clarity in the Great Bay Estuary of New Hampshire. 2008 Ocean Sciences Meeting.

Gregory T.K., J.R. Morrison and M.G. Novak. 2007. Investigating high-frequency nutrient dynamics in an estuary using an autonomous sampling platform. 2007 ASLO Session CS06.

Gregory, T K; Santiago-Mandujano, F. 2006. Celebrating 17 Years of Observations at Station ALOHA. In EOS, Transactions, American Geophysical Union, American Geophysical Union.

Sturz, A., and Gregory, T. 1997. High nutrient waters, Powell Basin, Antarctica. NASA-JOVE Annual Conference. Pasadena, CA.

Gregory, T. and Charette, M. 1997. Heavy metal contamination of sediment from Crane Creek, FL. *Florida Scientist,* 60(2): 81-88.

Kelle Loughlin

59 NOTTINGHAM ROAD, DEERFIELD NH, 03037 – (603) 556-1049

QUALIFICATIONS SUMMARY

Director of established environmental/marine education center, with proven leadership skills, working in fast-paced, varied environments demanding strong science teaching background, interpersonal, motivation and analytical skills, and ability to make quick and difficult decisions. Detail oriented, creative and resourceful in developing and completing projects.

EMPLOYMENT EXPERIENCE

1998–PRESENT Great Bay National Estuarine Research Reserve/New Hampshire Fish and Game Department

Director, Great Bay Discovery Center/Education Coordinator GBNERR

- Oversees programs and operations of Great Bay Discovery Center, staff and volunteers - 15,000-20,000 visitors & 5,000+ students annually
- Secured over $1,000,000 in private donations, and $1,000,000 from and individual donor in support of Reserve education programs
- Develops curricula, trains teachers and students in estuarine literacy
- Liaison with Great Bay Stewards, friends group of Reserve
- Coordinate with local conservation education groups and programs to develop and implement programs and initiatives
- Editor, Great Bay Matters Magazine

1991-1998 New Hampshire Fish and Game Department

Aquatic Resources Education Coordinator

- Coordinated state-wide Aquatic Resources Education Program, recruiting, training and supervising 150+ volunteers annually. Developed curricula used locally and nationally. Developed State-wide Angler Education Programs.
- Conducted teacher trainings, school programs and general public workshops.
- Newsletter production, public relations, radio and television programs
- Instructor, Watershed Ecology Institute-Grad/Undergrad Course

-UNH

- Chair-National Aquatic Resources Education Conference, Northeast Fish and Wildlife Conference, Becoming An Outdoors Woman
- Member - Outdoor Writers Association, Member- National Task Force on Angling Ethics

1990–1991 Science Center of New Hampshire Holderness, NH
Educator, Wildlife Care and Rehabilitation

EDUCATION

M.Ed. Environmental Science 1994 Plymouth State University
B.A., Outdoor Education/Psychology 1988 University of New Hampshire

THEODORE E. DIERS

71 Broadway, Concord, NH 03301
theodore.e.diers@des.nh.gov

PROFESSIONAL EXPERIENCE

Watershed Management Bureau -- Dept. of Environmental Services, Concord, NH (2011 to Present)

Administrator – Responsible for the management of the bureau with 20 separate programs and total of 45 employees. $12 million annual budget. Duties include supervising staff and budgets, setting bureau policies, and signing permits and enforcement actions related to water quality violations on river, lakes, beach, pools/spas and aquatic invasive plants throughout the state. Responsible for biennial water quality assessment to Congress, control of invasive plants, public health issues related to water-borne diseases, setting water quality standards for the state, and coastal zone management.

New Hampshire Coastal Program – Dept. of Environmental Services, Portsmouth, NH (2004 to 2011)

Program Manager – Responsible for the management of the program with a $2.7 million annual budget. Duties include supervising staff of 8, creating budgets, setting policies, interacting with elected officials, coordinating programs with Federal agencies, facilitating communication amongst coastal stakeholders, reacting to state and Federal policy issues, testifying to NH legislature and US congress, closely coordinating with Congressional Delegation on behalf of the Department, and interacting with media on a regular basis. Conducted interagency assessment of wetlands regulatory program. Facilitated major water quality initiative in Great Bay. Gained thorough knowledge of both the Clean Water Act and Coastal Zone Management Act. Chaired national work group on development of performance measures. Supervised regulatory program (Federal Consistency Review). Past-Chair of Coastal States Organization. Past Chair of Gulf of Maine Council on the Maine Environment, working group. Chair of Northeast Regional Ocean Council

New Hampshire Coastal Program -- Office of Energy and Planning, Concord, NH (1996 - 2004)

Principal Planner -- Coordinated several large salt marsh restoration projects; raised over $800,000 in grants for coastal projects; supervised employees; mediated interagency conflicts; assisted in the creation of the NH Corporate Wetlands Restoration Partnership; and coordinated 3-year, $1.5 million multi-agency groundwater study. Assisted Department of Environmental Services in writing wetland policies and administrative rules; created new program to empower communities to make better land-use planning decisions (NROC); served as agency designee to the NH Wetlands Council; and assessed state policies in the areas of wetlands and cumulative and secondary impacts of development. Translated science for a lay public, presented at local, regional and national conferences, and created outreach materials for the public on a variety of issues.

Merrimack River Watershed Council, Concord, NH (1993 - 1996)

Program Coordinator -- Duties included: policy analysis, fundraising, media relations, project administration/creation, and personnel management. Controlled the budget and expenditures of $100,000+ program. Supervised three employees, responsible for hiring and firing. Raised over $120,000 in two years to fund nonpoint source pollution, environmental justice, and ecotourism projects.

EDUCATION

- New Hampshire Public Manager Training Program -- Certified Public Supervisor.
- Yale University School of Forestry and Environmental Studies -- Master's in Environmental Management.
- Ripon College -- B.A. in Economics and Political Science. Summa Cum Laude, Phi Beta Kappa.

VOLUNTEER EXPERIENCE

- Trustee – Five Rivers Conservation Trust
- St. Andrew's Episcopal Church Vestry and church school teacher
- Youth soccer, softball and taekwondo coach
- Cub Scout Pack 86 Den Leader and Scoutmaster

OTHER

- Leadership New Hampshire Associate -- Class of 2008.
- Manchester Union-Leader "40 under 40" -- 2008.

Curriculum Vitae

Brian L. Howes, Chancellor Professor bhowes@umassd.edu
School for Marine Science and Technology
University of Massachusetts Dartmouth

Education: Ph.D. Biology, Boston University Marine Program
M.S. Biology, Boston University Marine Program
B.A. Biology, Rutgers College of Arts and Sciences, Rutgers University

Positions and Honors

Positions and Employment

2019-present Chancellor Professor, School of Marine Science and Technology, UMassD
2002-2019 Technical Director, Massachusetts Estuaries Project
2001-2019 Professor, School of Marine Science and Technology, U.Mass. Dartmouth
2000-present Faculty, UMass Intercampus Graduate School of Marine Sciences
1997-present Director Coastal Systems Program (restoration of coastal bays & wetlands)
1997-2001 Senior Fellow, Center for Marine Science and Technology UMassD.
1995-2003 Adjunct Professor, Boston University Marine Program
1991-1997 Associate Scientist, Woods Hole Oceanographic Institution
1989-2003 Adjunct Professor, Boston University Department of Earth Sciences
1988-1997 Graduate Faculty Associate Member, Rutgers Univ. Ecology Prgm.
1987-1991 Assistant Scientist, Woods Hole Oceanographic Institution

Other Experience and Professional Memberships

2003-present USEPA/USCG-ETV Technical Participant for Development of Test Protocol to Verify Ballast Water Technologies
2002-present Ponds and Lakes Stewardship Technical Advisor (with Cape Cod Commission)
2002-2010 Alternative On-site Wastewater Technology Testing Center, Technical Advisory Committee
2000-2003 Department of Environmental Protection- Wetlands Restoration Committee & Science Committee
1997-present Technical Advisor Town of Mashpee Estuarine and Wastewater issues
1995-present Technical Advisor, Marthas Vineyard Commission
1987-present Falmouth Pondwatch Program, Director

Expert Witness:

U.S. Congress, Subcommittee on Science Hearings on Environmental Protocol for Antarctica;
Commonwealth of Massachusetts: Rivers Act Cases: Weymouth Back River, Westport River
Wetlands Cases, Commonwealth of Massachusetts, State of Connecticut
Coastal Issues before MassDEP and USEPA

Honors

2013 Department of the Interior FY 2013 Partners in Conservation Awards for NOPP collaborative project "Developing Environmental Protocols and Monitoring to Support Ocean Renewable Energy and Stewardship"
2011 UMASS Dartmouth Alumni Association University Service Award

Areas of Research: Dr. B.L Howes is the author or co-author of more than 70 refereed journal articles, over 120 published general articles and reports, 2 book chapters, 2 estuarine monographs and 42 presentations and national and international Conferences and Symposia. His work through the Coastal Systems Program currently focuses on the linkages between watersheds and down-gradient receiving waters, particularly how changes in nutrient and sediment loads result in ecological change and how to restore nutrient overloaded aquatic systems through non-traditional management solutions. At present Dr. Howes' group are quantifying the efficiency of nitrogen removal by a variety of these solutions (shellfish, freshponds, wetlands, PRBs) and tracking wetland and aquatic restorations in S.E. Massachusetts. Dr. Howes work on wetlands, ponds and estuaries, requires collaborative efforts of ecologists, physical oceanographers, chemical oceanographers and engineers and is funded through municipal, state and federal agencies dealing with coastal issues and environmental restoration.

Publications: Selected Peer-reviewed Publications and/or Books and Chapters

Hamersley, M.R. and B.L. Howes. Contribution of denitrification to nitrogen, carbon cycling in tidal creek sediments of a New England salt marsh. Mar. Ecol. Prog. Series 2003 **262**:55-69.

Hamersley, M.R. and B.L. Howes. Coupled nitrification-denitrification measured in situ in Spartina alterniflora marsh with a $^{15}NH_4$ tracer. Mar Ecol Prog Series 2005 **299**:123-135.

Howes, B.L., J.M. Teal and S. Peterson. Experimental Phragmites control through enhanced sediment sulfur cycling. Ecological Applications 2005 **25**:292-303.

Turner, R.E., B.L. Howes, J.M. Teal, C.S. Milan, E.M. Swenson and D. D. Toner. Salt marshes and eutrophication: An unsustainable outcome. Limnol. and Oceanogr. 2009 **54**:1634-1642.

DeMoranville, C., B. Howes, D. Schlezinger, and D. White. Cranberry phosphorus management: How changes in practice can reduce output in drainage water. Acta Hort. (ISHS) 2009 **810**:633-640.

Medeiros, D. L., D.S. White, B.L. Howes. Replacement of Phragmites australis by Spartina alterniflora: The Role of Competition and Salinity. *Wetlands, Journal of the Society of Wetland Scientists*, 2013 DOI **10.1007**/s13157-013-0400-6

Benson J.L., D.R. Schlezinger, B.L. Howes. Relationship between nitrogen, light, and Zoster marine habitat quality and survival in southeastern Massachusetts estuaries. *Journal of Environmental Management*. 2013 Dec 15; **131**-129-37. doi: 10.1016/jenvman.2013.09.033. Epub 2013 Oct 23.

Buzzelli, C., Z. Chen, T. Coley, P. Doering, R. Samimy, D. Schlezinger, B. Howes. Dry Season Sediment-Water Exhcanges of Nutrients and Oxygen in Two Florida Estuaries: Patterns, Comparisons, and Internal Loading. Florida Scientist, 2013 76(1):54-71.

Sawabini, A., M. Sundermeyer, B. Howes, D. Schlezinger. Regional Forcing by Light on Dissolved Oxygen in Shallow Temperate Estuaries. *Estuaries and Coasts*, 2014 doi.**10.1007**/s12237-014-9879-1.

Tucker, J. A.E. Giblin, C.S. Hopkinson, S.W. Kelsey, B.L. Howes. Response of Benthic Metabolism and Nutrient Cycling to Reduction in Wastewater Loading to Boston Harbor. *Estuarine, Coastal and Shelf Science*. 151: 54-68, 5 December 2014

Howes, B.L., Samimy, R.I. The Massachusetts Estuaries Project: University Engagement of Municipalities and Citizens, State and Federal Regulatory Agencies, and Non-Governmental Organizations to Rehabilitate and Sustain the Environmental Resources of Coastal Massachusetts. In: *UMASS Dartmouth, Engaged Scholarship Collection*, Vol. 1/2015 pp. 146, ISBN 978-1-329-18188-5.

Shaw, KC, B L Howes, DR Schlezinger b Macroalgal composition and accumulation in New England estuaries. Journal of Environmental Management 2017 206 (2018) 246-254.

Miguel C. Leon
5046 Ludlow St miguel.leon@unh.edu
Philadelphia, PA 19139 (267)-294-6866

SKILLS SUMMARY:

Data scientist with extensive experience developing scripts for data management using Python, R, and Django web applications for the Earth Sciences community. GIS professional with background in spatial statistics and web- based GIS systems. R developer, user with package development experience. Extensive experience delivering data, from samples and sensors to the web. Experienced with SQL, databases, drupal module creation with PHP, JavaScript, Python. Extensive project management experience developing detailed specifications, budgets, managing groups of software engineers, and delivering final products with quality assurance and software usability.

EDUCATION:

Masters of Urban Spatial Analytics **August 2009-May 2011**
University of Pennsylvania, School of Design, Philadelphia, PA
***Capstone Project:** *A real-time landslide warning system for Northeastern Puerto Rico*.
Bachelors of Science in Computer Science (BSc) **September 2000-May 2005**
University of Wisconsin, Schools of Arts & Sciences, Madison, WI
*** University of Wisconsin School of Engineering Co-Op;** Nestle, Jefferson, WI
June 2004-March 2005.
***McNair Scholar Research Program**; University of Minnesota-Twin Cities, June 2003-August 2003.

RESEARCH AND WORK EXPERIENCE:

Information Technologist IV June 2019 to Present
Department of Natural Resources and the Environment
University of New Hampshire
* NSF Award #1831952 Zimmerman J.K., #1831952, McDowell, W.H., NSF Award #1831952, Derry L. A., NSF Award #1903760

- Develop CZ Manager software for site level operations of environmental observations for sensors and samples. Maintain operational database.
- Information Manager Luquillo Long Term Ecological Research (LUQ-LTER)
- Data Manager Luquillo Critical Zone Observatory.
- Data Manager for Piscataqua Region Estuaries Partnership (PREP)
- Developed a synthesis dataset of ecosystem responses to hurricanes across North America, the Caribbean and Taiwan 1985 to 2018 and posted metadata to EDI.
- Developed an ODM2 database for PREP including additional tools for mapping and plotting data from more than 2,700 sampling locations with 450,000+ measurements and 11.5 million+ sensor based observations.
- Migrated PREP buoy sensor data to Dendra for QA/QC.
- Developed and implemented a data and metadata migration plan for the Critical Zone Observatory Network to a long term data repository, HydroShare.

Information Manager- Luquillo Critical Zone Observatory January 2010-June 2019
Department of Earth and Environmental Science
University of Pennsylvania, School of Arts and Sciences, Philadelphia, PA
*NSF Award #1331841, McDowell, W.H., NSF Award # 0722476, Scatena, F.N.

Miguel C. Leon
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Philadelphia, PA 19139 (267)-294-6866

*BiG-CZ Community Advisory Board Co-Chair
- Develop CZ Manager for site level data management of environmental observations. (http://odm2.github.io/CZ-Manager/).
- Programming on Loadflex: R library extending RLoadest for composite method. (https://github.com/USGS-R/loadflex).
- Generate datasets and web pages for use by K-12 students (LCZO /LTER Data Jam).

Software Project Manager **March 2007-April 2009**
Miles Technologies, Moorestown, NJ
- Managed teams to achieve project development, testing, user validation, and deployment enterprise wide systems into production.
- Fielded diverse range of clients: legal, construction, healthcare, pharma, retail, tourism.
- Managed CRM, ERP, Project management, accounting, e-commerce, and social media.
- Merged custom web apps with: SAP B1, Quickbooks, MS Dynamics.
- Completed integration of clinical trial tracking system, SAP B1, and Salesforce.com

Information Systems Management Trainee **June 2005-March 2007**
Nestlé, Allentown, PA
- Implemented Format formula optimization tool with factory HMI Software to improve efficiency in utilization of ingredients.
- Tabulated variance reports connecting IBM AS400 data and SQL formula optimizations.
- Improved usability of Maximo with ASP.NET reports for preventive maintenance.
- Provided general IT support, including role out of a new operating system platform.

SELECTED PUBLICATIONS AND PRESENTATIONS:

Leon, M.C.; Heartsill-Scalley, T.; Santiago, I.; McDowell, W.H. Hydrological Mapping in the Luquillo Experimental Forest: New Local Datum Improves Watershed Ecological Knowledge. Hydrology 2021, 8, 54. https://doi.org/10.3390/hydrology8010054

McDowell, W.H., Leon, M.C., Shattuck, M.D., Potter, J.D., Heartsill-Scalley, T., González, G., Shanley, J.B. and Wymore, A.S. (2021), Luquillo Experimental Forest: catchment science in the montane tropics. Hydrological Processes. Accepted Author Manuscript e14146. https://doi.org/10.1002/hyp.14146

Wymore A.S., Leon M.C., Shanley J.B., McDowell W.H., 2019. Hysteretic response of solutes and turbidity at the event scale across forested tropical montane watersheds. Frontiers in Earth Science Biogeoscience. DOI: https://doi.org/10.3389/feart.2019.00126

Appling A.P., Leon M.C., McDowell W.H. 2015. Reducing bias and quantifying uncertainty in watershed flux estimates: The R package loadflex . *Ecosphere.* https://doi.org/10.1890/ES14-00517.1

McGee S., Báez N., Leon M., and Scholl M. 2016. Luquillo LTER/CZO Schoolyard Data Jam dataset. https://www.hydroshare.org/resource/ab5d6ebea61c4d74b2cc582e774139f1/

APPENDIX I-1

Detailed descriptions of existing and complementary datasets versus newly collected data for this project.

Dataset/Ownership	**Connection to Project**	**Accessibility**
Eelgrass Distribution (Tier 1) Dataset begins in early 1980s. Currently, this data is collected every other year by PREP.	Data is used along with "eelgrass health" data to establish sampling locations, since most of the sampling will occur in eelgrass beds (either at the edge or the middle). Some sampling will occur in unvegetated areas; these will be added to existing sites.	scholars.unh.edu/prep/ Relevant Quality Assurance Project Plan (QAPP) can be found at the above site.
Eelgrass Health and Seaweed Abundance "Tier 2" Seagrass and Seaweed Data (occurring at 30 sites in Great Bay and 20 sites in rest of Estuary.) For each site, four quadrats will be sampled. This protocol will begin in 2021 and occur annually going forward. (paid for PREP and Partners). Tier 2 sites (already paid for) include: eelgrass and seaweed biomass and percent cover; eelgrass density and canopy height; sediment organic matter and grain size; C:N eelgrass tissue analysis. SeagrassNet (Tier 3) Data (Biomass, density, canopy height, percent cover, sediment characteristics etc.) exists from 2007 to present and is updated annually. There is one site (3 transects) in the western portion of Great Bay.	Tier 2 data will be incorporated into "extensive" and "intensive" sampling schemes when they fall within this project's sampling design (determined by eelgrass health and hydrodynamics.) We have built in flexibility to expand sites in places where there is not sufficient overlap. SeagrassNet (Tier 3) data will be incorporated if the locations correspond to hydrodynamic gradients. This project will add the following parameters to Tier 2 sites (and Tier 3 sites, when applicable): N concentration in water column; CDOM; plankton (analysis paid for by Elizabeth Harvey Lab, UNH); light attenuation and light attenuating components analysis.	scholars.unh.edu/prep/ & DES Relevant QAPPs can be found at the above site. (Note that the Tier 2 QAPP is currently in draft form and will be available my mid-May, after approved by EPA.)

<u>Plankton</u> The Elizabeth Harvey Lab (UNH) has been collecting information on plankton in the Great Bay since 2020. The Harvey Lab collects data on chlorophyll-a as well as species composition using flow cytometry and a FlowCam, both of which are needed to capture the full-size range of species. Data is owned by the Harvey Lab and shared with PREP .	For this project, containers of water will be brought back to the Harvey Lab for processing of plankton using the three different methods described. Equipment is already purchased. Additional undergraduate time and supplies (>$1000) will be paid for by PREP, not this proposal budget.	scholars.unh.edu/prep/ Data is not currently available but will be added to the Scholars Repository if the proposal is funded.

APPENDIX I-2
INTEGRATION AND TIMELINE

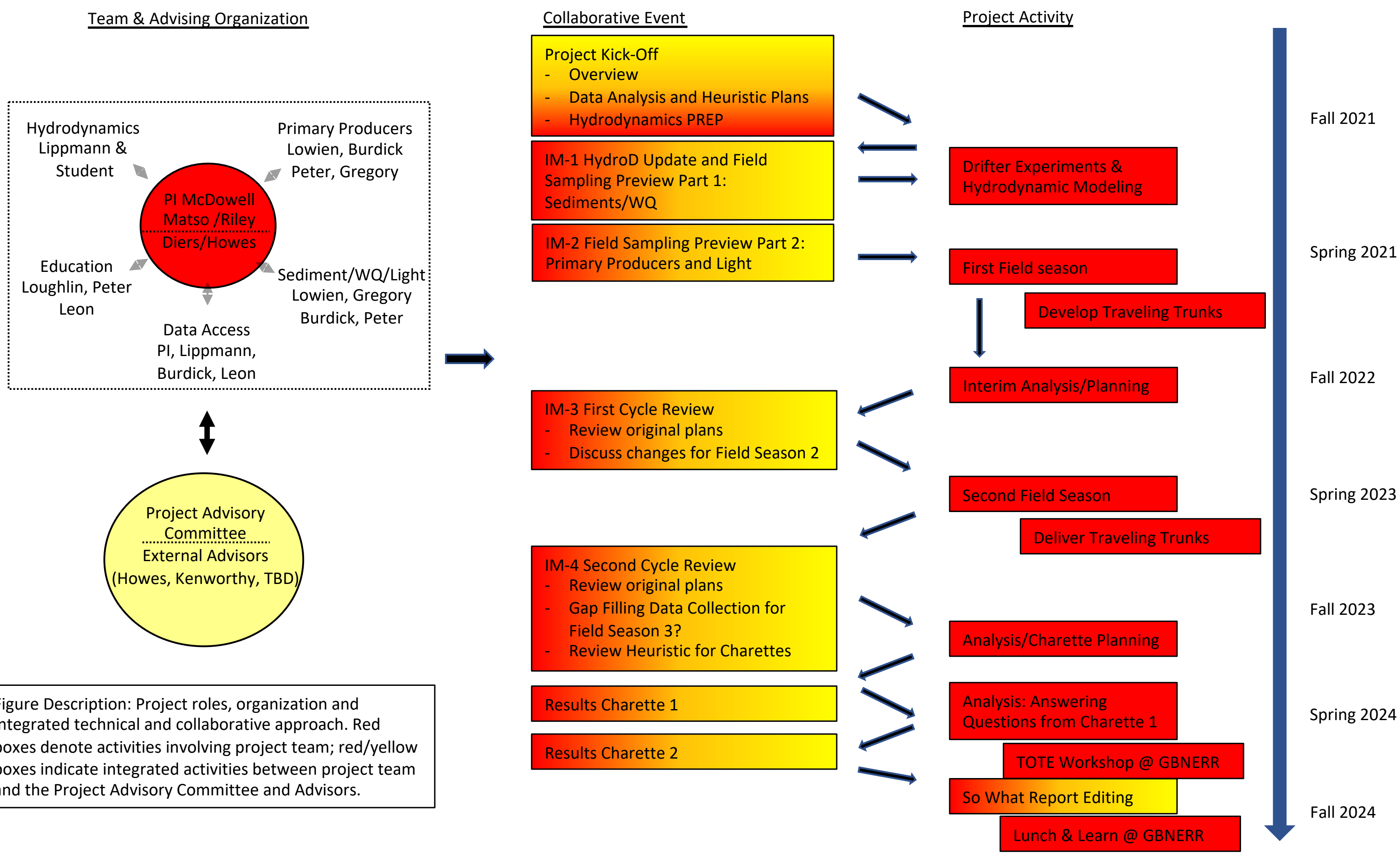

Figure Description: Project roles, organization and integrated technical and collaborative approach. Red boxes denote activities involving project team; red/yellow boxes indicate integrated activities between project team and the Project Advisory Committee and Advisors.

Appendix D

Overall Source Reduction Plan

Dover

Planned Structural BMPs – The following list includes projects that are already planned in CIP, design phase, etc.

Year	Project	Description	Estimated Load Reduction Potential (lbs TN/yr)	Costs
2023	Hough Street Culver Replacement	Emergency repair to old and undersized culvert network that conveyed Berry Brook.	?	$100,000
2024-2026	Court, Union, and Middle Streets	Capital Improvement work to improve drainage to include BMP's	43 lbs TN/yr	$1,125,000
2022-2024	Fifth and Grove Streets	Capital Improvement work to improve drainage to include BMP's	26 lbs TN/yr	$275,000
2022-2025	Oak, Broadway, Central neighborhood reconstruction	Capital Improvement work to improve drainage to include BMP's	412 lbs TN/yr	$27,000,000
2028	Atlantic Avenue	Capital Improvement work to improve drainage to include BMP's	17 lbs TN/yr	$375,000
2026	Horne St	Capital Improvement work to improve drainage to include BMP's	35 lbs TN/yr	$62,500
2027	Tanglewood	Capital Improvement work to improve drainage to include BMP's	47 lbs TN/yr	$900,000
2024	Retaining Wall Reconstruction	Capital Improvement work to reconstruct a wall along the Cochecho River that currently has erosion and collapsing closed drainage network	TBD	$1,800,000

2025	Henry Law and River Street Reconstruction	Capital Improvement work to improve roadway and drainage	TBD	$7,110,000
Planning	Henry Law Park	City has SRF funding to design an innovative, Nitrogen focused Water Quality BMP in the Henry Law Park area. This would be able to capture and provide treatment for approx. 120 acres of highly urbanized commercial and residential areas in the City's Downtown.	568 lbs TN/yr	$6,000,000
Planning	Chapel Street Ravine	Using NHDES SRF loan program to design a plan to incorporate water quality treatment and flood management downstream of substantial stormwater culvert	TBD	TBD
2024	Drainage System Improvement – Cochecho St Outfall	Reconstructing and improving existing failing outfall near Cochecho Street into the Cochecho River south of the dam.	TBD	$2,500,000
2025	Lower Central Ave Street Reconstruction	Capital Improvement work to improve entrance corridor into City from the south. To include a road diet and new BMP's	TBD	$7,890,000

2025	Reyners Brook Bridge Reconstruction	Capital Improvement work to improve and widen an existing culvert to remove flow restrictions.	TBD	$655,000
2026	Sixth Street Bridge Replacement	Replace an existing undersized bridge that is restricting flow under Sixth Street.	TBD	$1,100,000
Planning	Bellamy Culvert	The City of Dover was recently selected for FEMA grant funding to improve an existing culvert and dam abutment restriction in the Bellamy River which will enable approximately 11 miles of new fish passage.	TBD	$421,600 (planning phase)
Planning	Central Ave Drainage (Old Rollins to 6th street)	Capital Improvement Plan to improve drainage along Central Ave.	TBD	TBD
Planning	Jenness Street Reconstruction	Capital Improvement Plan to improve Jenness Street including drainage system.	TBD	TBD
Planning	Rutland Street Reconstruction	Capital Improvement Plan to improve Rutland Street including drainage system.	TBD	TBD

Non-structural BMPs – The following list includes existing ongoing and future planned efforts:

Anticipated Year of initial implementation (ongoing work)	Project	Description	Estimated Load Reduction Potential (lbs TN/yr)	Costs
2024	Stormwater and Flood Resilience Utility	City is looking to adopt a Stormwater and flood resilience utility which will incentivize implementation and maintenance of Best Management Practices including reduced nitrogen fertilizer.	TBD	$200,000/yr
Ongoing	Street Sweeping	Mechanically sweep downtown area (50 miles) once a week for 9 months of the year	**43 lb TN/yr**	-
Ongoing	Leaf Litter Management	Leaf pick up for 6 weeks in the fall	**400 lb TN/yr**	-
Ongoing	Leaf Litter Management	Provide location for residents to drop off leaf and yard waste year-round	**95 lb TN/yr**	-
Ongoing	Catch Basin Cleaning	CB's are cleaned in accordance with MS4 requirements	**17 lb TN/yr**	-
In Place	Wetland Buffer	Ordinance has increased wetland buffers (see credit for going green project)		-
In Place	Stormwater Regulations	Site Plan Regulations include SWA recommendations for development and redevelopment (reduction = 0.012 * baseline)	**1,011 lb TN/yr** 0.012 * 84,312 lbs TN	-
In Place	Slow Release nitrogen requirement for all new projects	As part of Site Plan approval, a maintenance plan shall be in place and *"Best practices to minimize environmental impacts, such as the use of low-phosphorus fertilizer and slow-release nitrogen, shall be included in the management plan."*	**350 lb TN/yr**	-

Ongoing	Atmospheric Deposition	Assumes a 14% reduction off the baseline for TN	**11,803 lbs TN/yr**	
Ongoing	Leaf Litter Management	Enhanced street leaf pick up in fall	**400 lbs TN/yr**	
Ongoing	City Organic Fertilizer Program	The city is committed to using only organic, slow-release fertilizers on city owned and maintained properties (1,000,000 sf and 80% reduction).	**800 lb TN/yr**	
Ongoing	Fertilizer Bans and Reductions	Including a credit in the Stormwater Utility		
Ongoing	Fertilizer Outreach and Education Program	Provide and promote landscaping for water quality initiatives and programs		
Ongoing	Pet Waste Outreach and Education Program	Provide pet waste management educational materials with every dog license.		
Ongoing	Leaf and Yard Waste Outreach and Education Program	Promote proper leaf and yard waste management.		
Ongoing	Septic System Outreach and Education Program	Participate and promote NHDES Septic Smart Week. Send septic smart information to private septic system owners.		
Ongoing	Outreach and Education	The City outreach and education exceeds what is required by the MS4. Staff regularly hold tours or presentations of the innovative BMP's being implemented. Additionally, completed and shared a video for the installation of a filtering catch basin BMP. Staff also regularly speak at conferences about technologies and		

		particularly focus on maintenance and long-term performance.		
Planning	Septic System Performance Requirements	Advocate for a state-wide requirement to remove nitrogen in septic systems.	381 lbs TN/yr	

Other Efforts – The following list includes innovative efforts

Anticipated Year	Project	Description	Estimated Load Reduction Potential (lbs TN/yr)	Costs
2021 and ongoing	Inflow/Infiltration	Inflow and infiltration into the sewer collection system resulting elevated peak flows through the WWTP biological system which can affect the nutrient reduction capacity during those events.	**1,750 lbs TN/yr** Assume a storm event causes an effluent peak of 14 mg/l, seven times a year for 24 hrs at a time. Assume the storm flow is 5 mgd.	$1,000,000 in 2024
2025	Citywide Drainage Model & Master Plan	Develop a strategic plan for stormwater improvements		$350,000
Planning	Extending Sewer to Septiced areas	Continually assessing opportunities		
Ongoing	Commitment to exploring new BMP's and participating in innovative initiatives	Berry Brook and the continuation of bringing new BMP's into urban redevelopment settings and working with UNHSWC to test the effect, Volunteering to work with the NHDES/Prep Fellowship team to investigate SAFE strategies for Stormwater Funding, Volunteer to work with SRPC to analyze urban		

		trees and innovative tree box filters, Volunteer to work with SRPC to look at BMP's v/s socioeconomic disparities, participating in the PTAP program, participating in multiple credit for going green projects lead by PREP		
Ongoing	Training and Commitment to Innovation	Leadership in NEWEA/ Biological Nutrient Removal Classes - Our WWTP staff are at the forefront of discussions for WWTP practices.		
Ongoing	Professional Staff	The City has created an Environmental Project Manager Position. This positions focus is dedicated entirely to environmental improvements, including a commitment to the protection and improvement of the Great Bay. This person is taking an active role in organizing regional commitment and implementation of the MS4 permit and the new NGP permit.		
Ongoing	Intern Work	Additional Staff to meet MS4 outfall testing requirements. Wet weather testing in particular is dangerous.	ZERO TN found or removed	$50,000 - $100,000 per year
Ongoing	Water Quality BMP's as standard practice for city reconstruction projects	This is the language from our standard RFQ for design of reconstruction projects: *"As part of the drainage improvements, the City*		

		wishes to enhance the drainage system and incorporate easily maintainable, low impact development strategies to provide conveyance, treatment, and infiltration where practical. The Consultant shall make recommendations for an improved drainage system." The commitment to implementing the water quality work is demonstrated in several recent redevelopment projects.		

Pilot Projects – The following list includes pilot projects:

Anticipated Year	Project	Description	Estimated Load Reduction Potential (lbs TN/yr)	Costs
2021	Stakeholder Committee Project	MAAM communities fund $45,000 towards Great Bay water quality-related project as selected by the Stakeholder Committee (CLF)	?	$15,000 (from Dover)
Permitting	Catch Basin Spoils Facility	Remove decant water from sump and treat at WWTF to 5-8 mg/l	**195+ lbs TN/yr**	$3,500,000

Initiatives at WWTFs – The following list includes efforts aimed at reducing TN output from WWTFs during the eelgrass growing season. Such efforts may include optimization of plants, projects aimed at reducing inflow/infiltration, facility upgrades, or similar measures.

Anticipated Year	Project	Description	Estimated Load Reduction Potential (lbs TN/yr)	Costs
Nutrient Load Reduction	New aeration and secondary settling tank.	The City has just bid out and funded a project to improve the aeration in the WWTF treatment stream. Additionally, the city is about to receive bids for the construction of a third secondary settling tank. These two improvements will result enhanced nutrient reduction, particularly improving treatment during rain events.	**27,524 lbs TN/yr**	$5,000,000
Nutrient Load Reduction	Reductions below 167 lb/day during non-growing season	The growing season improvements will also improvement conditions in off season.	**12,517 lbs TN/yr**	

Co-Benefits of Nonpoint Source Reductions – Though beyond the scope of the submission called for in Part 3-1.c. of the General Permit, the MAAM communities feel it is important to plan and account for the removal of other pollutants or stressors of eelgrass coincident to the TN source reductions listed above. This dovetails with the monitoring efforts undertaken by MAAM and its partners, which is expected to include study of confounding factors and stressors. PTAP tracking and accounting has been created to also calculate phosphorus and total suspended solid reductions.

Milton

Planned Structural BMPs – The following list includes projects that are already planned in CIP, design phase, etc.

Anticipated Year	Project	Description	Estimated Load Reduction Potential (lbs TN/yr)	Costs
-	TBD	-	-	-

Non-structural BMPs – The following list includes existing ongoing and future planned efforts:

Anticipated Year of initial implementation (ongoing work)	Project	Description	Estimated Load Reduction Potential (lbs TN/yr)	Costs
Current	**Ordinance/Regulations**	Site Plan Regulations include SWA recommendations for development and redevelopment (reduction = 0.012 * baseline)	**413 TN/yr**	-
Ongoing	**Street Sweeping**	Mechanically sweep as required in MS4	**TBD**	-
	Septic System Programs	Advocate for and work with State RE: advanced septic system treatment for nitrogen and enforcement of connection to public sewer law within 100'	TBD	-
Ongoing	Septic System Programs	Mandate enhanced regulations for treatment systems beyond State requirements	**TBD**	-

Municipal Lands with potential for pollutant load removal – The following list include municipally owned property derived by sorting hot spots data for parcels with high TN loads:

Year	Project	Description	Estimated Load Reduction Potential (lbs TN/yr)	Costs

N/A	**-**	**?**	**?**	**-**
N/A	**-**	**?**	**?**	**-**

Other Efforts – The following list includes innovative efforts

Anticipated Year	Project	Description	Estimated Load Reduction Potential (lbs TN/yr)	Costs
-	-	-	-	-

Pilot Projects – The following list includes pilot projects:

Anticipated Year	Project	Description	Estimated Load Reduction Potential (lbs TN/yr)	Costs
2021	Stakeholder Committee Project	MAAM communities fund $45,000 towards Great Bay water quality-related project as selected by the Stakeholder Committee (CLF)	?	

Initiatives at WWTFs – The following list includes efforts aimed at reducing TN output from WWTFs during the eelgrass growing season. Such efforts may include optimization of plants, projects aimed at reducing inflow/infiltration, facility upgrades, or similar measures.

Anticipated Year	Project	Description	Estimated Load Reduction Potential (lbs TN/yr)	Costs
-	**WWTF management**	**Continue to manage and test existing effluent**	**TBD**	**-**

Co-Benefits of Nonpoint Source Reductions – Though beyond the scope of the submission called for in Part 3-1.c. of the General Permit, the MAAM communities feel it is important to plan and account for the removal of other pollutants or stressors of eelgrass coincident to the TN source reductions listed above. This dovetails with the monitoring efforts undertaken by MAAM and its partners, which is expected to include study of confounding factors and stressors. PTAP tracking and accounting has been created to also calculate phosphorus and total suspended solid reductions.

Newington

Planned Structural BMPs – The following list includes projects that are already planned in CIP, design phase, etc.

Anticipated Year	Project	Description	Estimated Load Reduction Potential (lbs TN/yr)	Costs
TBD	Major redevelopment of commercial areas.	Redevelopment shall meet towns stormwater regulations	TBD	-

Non-structural BMPs – The following list includes existing ongoing and future planned efforts:

Anticipated Year of initial implementation (ongoing work)	Project	Description	Estimated Load Reduction Potential (lbs TN/yr)	Costs
Current	Ordinance/Regulations	The Town has a Stormwater Management section in their Site Plan Review regulations which references the NH Stormwater Management Manual and EPA Stormwater Regulations, including development and redevelopment regulations for stormwater, and mandated reductions in total nitrogen.	**383 TN/yr**	-

Municipal Lands with potential for pollutant load removal – The following list include municipally owned property derived by sorting hot spots data for parcels with high TN loads:

Year	Project	Description	Estimated Load Reduction Potential (lbs TN/yr)	Costs
N/A	Newington Municipal Complex	?	?	-
N/A	Newington Public School	?	?	-

Other Efforts – The following list includes innovative efforts

Anticipated Year	Project	Description	Estimated Load Reduction Potential (lbs TN/yr)	Costs
-	-	-	-	-

Pilot Projects – The following list includes pilot projects:

Anticipated Year	Project	Description	Estimated Load Reduction Potential (lbs TN/yr)	Costs
2021	Stakeholder Committee Project	MAAM communities fund $45,000 towards Great Bay water quality-related project as selected by the Stakeholder Committee (CLF)	?	$15,000 (from Dover)

Initiatives at WWTFs – The following list includes efforts aimed at reducing TN output from WWTFs during the eelgrass growing season. Such efforts may include optimization of plants, projects aimed at reducing inflow/infiltration, facility upgrades, or similar measures.

Anticipated Year	Project	Description	Estimated Load Reduction Potential (lbs TN/yr)	Costs
Completed - 2016	WWTF Upgrade	Nitrogen removal upgrades	**4,379 TN/yr**	$8.2M

Portsmouth

The following narratives and tables describe on-going and planned nitrogen reduction activities for the City of Portsmouth. This list is a snapshot of the ongoing and planned activities funded through the City's annual operating budget and Capital Improvement Plan (CIP). The City will update and adjust this list as needed based on changes in anticipated funding, adjustments to achieve the highest efficiencies for nitrogen reduction and other conditions or technical reasons that may not be known or anticipated at this time.

Innovative WWTF Operations: In 2020 the City completed a major facility upgrade at the Peirce Island Wastewater Treatment Facility, an investment of over $92 million, which has resulted in significant nitrogen load reductions based on the reported effluent data in 2020. The facility began startup in Jan 2020 and which has resulted in a treatments system that produces more stable and lower concentrations of total nitrogen. The load reduction calculations in the following paragraphs incorporate data from the Pease WWTF as well as the Peirce WWTF since the Great Bay Total Nitrogen General Permit limits nitrogen for the combined effluent.

In 2022, the Peirce Island WWTF had a 7-month rolling average (April 1 - Oct 31) TN load of 133.5 lbs./day and the Pease WWTF had 30.1 lbs./day. This equates to 163.6 lbs. TN/day and is 177.4 lbs. TN/d less than the permitted effluent limit of 341 lbs. TN/day. This equates to a TN load reduction of 37,778 lbs. for the 7-month growing season period.

During the non-growing season, a conventional WWTF configured and properly sized for nitrogen removal would achieve a total nitrogen effluent concentration in the range of 10 to 12 mg/L. The Peirce Island WWTF is configured and has been operated in a manner to achieve concentrations that are substantially lower than conventional treatment. See the summary table below of nitrogen load reductions. The City anticipates continuing to run the PI WWTF in this configuration for continued substantial nitrogen removal.

Significant nitrogen load reductions have been achieved when comparing the observed average daily loads of 708 lbs. and 204 lbs. TN /day for the 7-month growing seasons of 2019 (prior to biological treatment) and 2020 (startup/operation of biological treatment), respectively, based on effluent data. This data represents pre and post-conditions of the Peirce Island WWTF upgrade. The observed 504 lbs. TN/day difference in the average daily loads between these two years translates to an overall annual nitrogen load reduction of approximately 106,000 lbs. As anticipated the data for 2022 growing season was even lower as operations have been further stabilized.

Summary of WWTF Recent Nitrogen Load Reductions

WWTF Facility	Season	Description	Load Reduction (lbs. TN)
Peirce Island & Pease	7-month growing season	Total Lbs. TN = Permitted Daily (341 lbs./d) – Observed (163.6 lbs./d) = 177.4 lbs./d x 213 days (Apr 1 – Oct 31)	~37,778 lbs.
Peirce Island	5-month non-growing season	Total Lbs. TN = Ave Conc Decrease = 5 mg/L x avg. daily flow (3.81 MGD) x 8.345 x 150 days	~30,800 lbs.
		Annual Total	**~68,578 lbs.**

Stormwater and Other Nutrient Reduction BMPs

The following describes several major drainage capital improvement projects where potential structural stormwater BMPs will be evaluated. Two structural BMPs were recently completed behind the DPW facility. Various nonstructural measures are also highlighted including good housekeeping, regulation updates, organic fertilizer use, land protection efforts, and a proposed sewer extension, to name a few. The total annual nitrogen load reduction for these efforts is estimated at 5,700 lbs./year.

Structural BMPs: The following projects are included in the City's FY24-FY29 CIP

Original Anticipated Year	Project	Description	Approx. Load Reduction (lbs. TN/yr.)
2022	Islington Street Compete Streets – Phase II	This project will include full roadway reconstruction (sidewalk, curb, grass strip, roadway, and utilities) from the Dover Street intersection to the intersection with Congress/Maplewood Streets (5,000 linear feet). The work will include sewer separation with separated stormwater being redirected through water quality units upstream of the Brewster Street stormwater outfall to North Mill Pond. The project may cause a net increase in the volume of stormwater discharged to the North Mill Pond but will reduce volume and # of combined sewer overflow events during wet weather. Nitrogen levels and overall loads are generally higher in CSO discharges than in stormwater. Opportunities to treat roadway runoff will be evaluated. The overall stormwater catchment area served by this project is approximately 6.4 acres.	See Note 1
2024	Peverly Hill Road Reconstruction	This project will include full roadway reconstruction from the intersection with Middle Road to the intersection with West Road (5,000 linear feet). The work will include construction of a new sidewalk from Middle Road to Mirona Road on the north side of the roadway (3,600 linear feet) and construction of a new 8 to 10-ft wide shared use path from Middle Road to Banfield Road on the south side of the roadway (3,400 linear feet). Curbs will be added to the roadway and stormwater will be re-routed through a planned stormwater gravel wetland that will discharge to the headwaters of Sagamore Creek. The overall stormwater catchment area served by this project is approximately 17 acres.	See Note 1
2023	Willard Ave Sewer Separation	This project will include full roadway reconstruction (sidewalk, curb, grass strip, roadway, and utilities) along Willard Avenue from the intersection with Marston Street to the intersection with Lafayette Road, Ash Street from the intersection with Willard Avenue to Orchard Street and Orchard Street (2,000 linear feet). The work will include sewer separation with separated stormwater being redirected through water quality units near Parrott Avenue upstream of the stormwater outfall to South Mill Pond. The project may result in a net increase in overall stormwater discharge to the South Mill Pond but will reduce the volume and # of combined sewer overflow events during wet weather. Nitrogen levels and overall loads are generally higher in CSO discharges than in stormwater. The overall stormwater catchment area served by this project is approximately 3.4 acres.	See Note 1

Original Anticipated Year	Project	Description	Approx. Load Reduction (lbs. TN/yr.)
2023	Union Street Sewer Separation	This project will include full roadway reconstruction (sidewalk, curb, grass strip, roadway, and utilities) along Union Street from the Middle Street intersection to the State Street intersection (1,000 linear feet). The work will include sewer separation with separated stormwater being redirected to the stormwater system on Middle Street that discharges through water quality units near Parrott Avenue upstream of the stormwater outfall to South Mill Pond. The project may increase the overall stormwater discharge to the South Mill Pond but will remove stormwater from the combined sewer collection system thus reducing combined sewer overflow events during wet weather. Nitrogen levels and potential overall loads are generally higher in CSO discharges than in stormwater. The overall stormwater catchment area served by this project is approximately 1.9 acres.	See Note 1
2023	Fleet Street Sewer Separation	This project will include full roadway reconstruction (sidewalk, curb, roadway, and utilities) along Fleet Street from the Court Street intersection to the intersection with Hanover Street (1,000 linear feet). The work will include sewer separation with separated stormwater being redirected through a new outfall and water quality unit near Maplewood Avenue upstream of a new stormwater outfall to North Mill Pond. The project may result in a net increase in overall stormwater discharge to the North Mill Pond but will remove stormwater from the combined sewer collection system thus reducing combined sewer overflow events during wet weather. The overall stormwater catchment area served by this project is approximately 4 acres. The project limits may expand to include an area of Congress Street from Fleet Street to Maplewood Avenue (540 linear feet) and Vaughan Mall from Congress Street to Hanover Street (450 linear feet). The scope of work and ultimate discharge of separated stormwater would be the same as described above for the Fleet Street work. The stormwater catchment area served by this additional area is about 1.6 acres.	See Note 1
2022	Corporate Drive Road & Drainage Upgrade	The City is working on two phases of work to improve drainage on Corporate Drive in Portsmouth. The first phase seeks to improve the drainage flow through swales adjacent to Corporate Drive in Portsmouth through swale improvements, culvert modifications and stormwater water quality unit installation. The second phase includes roadway reconstruction and selective drainage improvements along Corporate Drive from Rye Street to Grafton Road (6,000 linear feet). The overall stormwater catchment area served by this project is approximately 5 acres.	See Note 1
Complete	Gravel wetland /Bioretention System at DPW/Recreation Fields	New gravel wetland treating ~ 25 acres of 2021 existing IC area with WQv = 0.18" N Rem Eff = 33%; Bioretention system w/ internal storage reservoir treating ~ 51.8 acres of existing IC	406

Original Anticipated Year	Project	Description	Approx. Load Reduction (lbs. TN/yr.)
		Estimated Annual N Load Reduction Total (lbs./yr.)	>406

Notes:

1. Engineering design for these planned road/drainage system improvements are in the early phase or have not yet begun. As a result, the potential stormwater nitrogen discharge cannot be determined. The feasibility for stormwater treatment will be evaluated as part of the design efforts.

Non-Structural BMPs: Annual nitrogen load reductions due to ongoing operation and maintenance activities and recent connected impervious (IC) area disconnection included in this plan. The effect of the program on homeowners or commercial applicators' behavior could be measured through pre and post random surveys.

Anticipated Year	Project	Description	Approx. Load Reduction (lbs. TN/yr.)[1]
Street Sweeping	Ongoing Maintenance	City sweeps all streets monthly, 8 months of the year with High Efficiency Regenerative Vacuum Sweeper on estimated 345 acres of area	70
Leaf Litter Management	Ongoing Maintenance	City provides curbside leaf litter pickup for Residential Areas (~80% of City)	250
Catch Basin Cleaning	Ongoing Maintenance	City cleans approx. 25% of the total CB's each year	80
Regulations	New Regulations adopted Jan. '21	City adopted new stormwater treatment requirements for new & redevelopment disturbing 15,000 sq ft or more area	215
Impervious Disconnection	Recent IC disconnection	City has installed at least 18 tree filters, 4 rain gardens, converted ~ 0.5 mile of road shoulder and 0.3-acres of parking lot at Four Tree Island to porous pavement; IC disconnect ~ 3 acres	45
Organic Fertilizer Program	Ongoing Maintenance	City switched to an organic compost tea to fertilize its recreational fields; Results in an application rate of 0.7 lbs. N /1000 sf or ~30% less than a more typical application rate of at least 1 lb. /1000 sf	570
		Estimated Annual N Load Reduction Total (lbs./yr.)	**1,440**

Notes:

1. The nitrogen load reduction values represent general estimates based on the methods and assumptions included in the generic load reduction template spreadsheet provided by the UNH Stormwater Center for municipal use in preparing Element C of the Adaptive Management Plan with some minor adjustments to reflect City specific conditions especially with respect to fertilizer use and IC disconnection.

Potential Future BMPs on Municipal Lands: The following is a list of potential BMP locations derived by analyzing hot spots data from the UNH Stormwater Center for parcels with high TN loads

Anticipated Year	Project	Description	Load Reduction (lbs. TN/yr.)
By 2025	To Be Determined	To Be Determined	To Be Determined

Notes:

The City has initiated a City-wide analysis to identify potential feasible stormwater BMP retrofit locations on City owned property for planning purposes. The results of this ongoing study will be used to assess the potential feasibility and cost-effectiveness of constructing stormwater BMP retrofits to achieve additional nitrogen load reductions as either standalone projects or as part future facility upgrades of municipal properties. This study may also review certain select private properties that have a high amount of impervious cover and available space. This information will be utilized for outreach as applicable to private property owners.

Other Efforts: Summary of Other Innovative Efforts/Pilot Programs

Anticipated Year	Project	Description	Approx. Load Reduction (lbs. TN/yr.)[1]
2022	Sewer Extension to Sagamore Creek Area (approx. 88 homes)	Assume 50% are connected in the planned extension	260[2]
Ongoing	Atmospheric Load Reduction based on more current air quality data	UNH SC/NHDES suggests atmospheric N load has decreased by ~14%; GBNNPS study estimated delivered atmospheric N Load for Portsmouth = 18,618 lbs./yr.	2,610
Complete	Land Protection in Bellamy Reservoir	City purchased conservation easement for ~180 acres of land adjacent to Bellamy Reservoir targeted for development – prevents additional stormwater and septic load from ~ 32 homes	1,010
	Estimated Annual N Load Reduction Total (lbs./yr.)		**3,880**

Notes:

1. The N load reduction values represent general estimates based on the methods and assumptions provided by the UNH Stormwater Center for municipal use in developing Element C of the Adaptive Management Plan.

2. The City currently has plans to extend sewer to approximately 88 homes in the Sagamore Creek watershed area, which represents one of the last major developed areas in the City that utilize septic systems. The table above presents anticipated N load reductions associated with this sewer extension based on an assumption that only half of the potential homes connect in the first 5 years.

Outreach and education: In addition to using an organic compost tea produced from yard waste compost to fertilize City fields as well as updating the Site Plan regulations to include language that encourages new development to minimize the creation of new managed turf, the City would support a statewide or regional effort to ban or limit the use of lawn fertilizer and/or a collaborative regional education and outreach effort that engages homeowners and commercial applicators to minimize its use and/or apply only when necessary.

The NHDES Great Bay Nitrogen Nonpoint Source Study (GBNNPSS) estimated an annual N load of just under 90,000 lbs/yr contributed from lawn fertilizer usage within the 12 communities subject to this GBTN GP, which represents approximately 25% of the total estimated N load from these communities. Published data from the Chesapeake Bay Network suggests that developing a comprehensive education and outreach campaign designed to change homeowner behavior and commercial applicator practices could reduce fertilizer usage by anywhere from 5% to 15% depending in the program elements. If such a program could reduce fertilizer use by event 5%, this could result in a significant benefit relative to the load reduction estimates for the other activities

Explore Long Term Sustainable Funding Mechanisms: The City previously conducted a stormwater utility feasibility study that was completed in 2011 but it did not gain approval by City Council to move forward at that time. The City plans to revisit the feasibility of stormwater utility. In 2022 the City contracted with two engineering firms to explore the feasible options for creating a stormwater utility. These options were presented to City Council in October 2022. Staff continued to work on this project through 2023 and will continue to do so in 2024.

Tracking Post-Development Stormwater Treatment BMP Inspection and Maintenance (I&M) Activity: The City is taking the lead in managing and administrating a project being funded by and in collaboration with various communities that are part of the Seacoast Stormwater Coalition to develop methods to assist communities in tracking post-development I&M activity for stormwater BMPs on private property that were approved through local site plan regulations and related ordinances. The goal is to ensure that the long-term stormwater treatment performance is maintained through I&M activity and the potential pollutant load reduction credits particularly for redevelopment projects can be tracked and accounted for through the NHDES/UNH SC PTAP system or an equivalent process. This project builds off an initial pilot study conducted by a student Capstone project done in conjunction with the UNH Engineering Department and UNH Stormwater Center.

Think Blue Outreach:

- Postcards and video campaigns have been developed by the stormwater division that focus on: Lawn care, Yard waste and Pet waste, with consistent "Think Blue" branding and web page links for more information.
- Household Hazardous Waste Collection Days are held each May and October. They are hosted by the City of Portsmouth at our DPW facilities and include Newington and Greenland.
- Safe Water Advisory Group (City Council Advisory Committee) meets quarterly in collaboration with the Water/Stormwater Division to raise public awareness of the Great Bay Watershed and residents' impact.

Following up on the collaboration with Strawbery Banke Museum, UNH and the City's Planning and Public Works Department (who created the exhibit: "Water Has a Memory: Preserving Strawbery Banke and Portsmouth from Sea Level Rise" the city was a co-host of the national Keeping History Above Water conference in 2023. Talks included efforts to manage stormwater and spread the city's "Think Blue" message. Site visits included a tour to the City's "Think Blue" exhibit at Strawbery Banke as part of their "Water Has a Memory" exhibit.

Rochester

The City of Rochester reserves the right to update the project year/start dates, estimated load reductions, estimated costs or items listed as "TBD" in the columns below either annually or as appropriate.

Planned Structural BMPs – The following list includes projects that are already planned in CIP, design phase, etc.

Year	Project	Description	Estimated Load Reduction Potential (lbs TN/yr)	Costs	2023 Progress Update	2024 Anticipated Progress
2021-23	Colonial Pines Sewer Extension - Phase 3	Phase 3 of a neighborhood sewer extension project with drainage infrastructure improvements	TBD	$5,500,000	Construction of drainage infrastructure improvements is 100 % complete.	Design for Phase 4.
2021-23	Strafford Square Roundabout	New roundabout installation project with drainage infrastructure improvements including new BMPs	3.59	$6,000,000	Construction of drainage and roadway in 2023.	Construction is anticipated to be complete December 2023.
2022-23	Woodman Area Infrastructure Improvements	Neighborhood Complete Streets project with drainage infrastructure improvements including improved outfalls and new BMPs	6.01	$7,000,000	Construction continues.	Construction is anticipated to be on-going into 2024.
By 2025	Union Street Municipal Parking Lot	Parking lot reconstruction with drainage infrastructure improvements including new BMPs	7.14	$1.5M+	Conceptual design is being reviewed. Final design began in fall 2022.	Final design is anticipated to be completed in 2023. Construction 2024-25.
TBD	Wakefield Street Reconstruction	Complete Streets project with drainage infrastructure improvements	16.54	TBD	Design consultant has been selected by the City.	Other infrastructure priorities have superseded this project.

		including new BMPs				

Planned Structural BMPs (continued from previous page) – The following list includes projects that are already planned in CIP, design phase, etc.

Year	Project	Description	Estimated Load Reduction Potential (lbs TN/yr)	Costs	2023 Progress Update	2024 Anticipated Progress
2023 – 25	Columbus Ave/Summer St. Intersection Improvements	Includes stormwater treatment prior to discharge to Cocheco River.	TBD	$2M+	In preliminary design	Final design.
2023-	Water St. Redevelopment Project	Borders Cocheco River. Design to include pollutant reductions.	TBD	TBD	Design 2023-24	Design complete.

Non-structural BMPs – The following list includes existing ongoing and future planned efforts:

Anticipated Year of initial implementation (ongoing work)	Project	Description	Estimated Load Reduction Potential (lbs TN/yr)	Costs	2023 Progress Update	2024 Anticipated Progress
Ongoing	Street Sweeping	Sweep curbed streets monthly (Apr-Nov); sweep Downtown weekly (Apr-Nov)	250	TBD	Swept approximately 440 lane miles and removed approx. 500 CY of sediment so far in 2022.	Continued high frequency of street sweeping.
Ongoing	Leaf Litter Management	Collect leaf litter monthly (Apr-May, Oct-Nov); collect bagged organic waste for 2 wks in spring and fall	690	TBD	Collected bagged leaf litter twice in May and plan for twice in November.	Continued frequency of leaf litter collection.
Ongoing	Leaf Litter Management	Provide location for residents to drop off leaf and yard waste	TBD	TBD	Residential disposal of yard waste provided	Continue to provide yard waste disposal

		year-round			at WM.	at WM.
Ongoing	Catch Basin Cleaning	Ensure CB sumps are no more than 50% full at any time	290	TBD	Cleaned approx. 900 CBs 8/1/22 – 6/26/23	Continue to target a goal of 25% of all CBs cleaned yearly.
Ongoing	Fertilizer Program	Exclusively use slow release fertilizer on municipal property; advocate for and work with State RE: nitrogen fertilizer restrictions	TBD	TBD	Continued stated fertilizer practices on municipal property.	Continue fertilizer practices and advocate with the State.

Other Efforts – The following list includes innovative efforts

Anticipated Year	Project	Description	Estimated Load Reduction Potential (lbs TN/yr)	Costs	2023 Progress Update	2024 Anticipated Progress
Ongoing	Existing Municipal Structural BMPs	77 existing municipal structural stormwater BMPs have been catalogued in the City's Asset Management Program.	1,080	TBD	BMPs inspected and begun to track for improved maintenance.	Entry of BMPs into PTAP complete. Start to scope maintenance and plan for work 2024.
2023-25	Colonial Pines Sewer Extension – Phase 3	Extension of public sewer collection system to connect homes on septic systems (Phase 3 – 71 properties)	364	$5,500,000	Construction of sewer infrastructure is 100% complete.	Design for Phase 4 started. Construction 2024-2025.
Ongoing	Nitrogen Source Identification Report	Identify catchment areas with potentially high nitrogen loading and BMP potential, including primarily municipal properties.	TBD	TBD	Draft report was finalized in June 2022. Report was updated in June 2023 to include planned retrofit date, estimated cost & feasibility.	Review potential catchments with high loading and BMP potential ongoing.
Ongoing	Public Education/ Outreach	Distribute targeted messaging regarding grass clippings/ fertilizer	TBD	TBD	Grass clippings/ fertilizer, pet	Continue messaging to target audiences

Anticipated Year	Project	Description	Estimated Load Reduction Potential (lbs TN/yr)	Costs	2023 Progress Update	2024 Anticipated Progress
		(Apr-May), pet waste (Jun-Jul), and leaf litter (Aug-Oct)			waste, and leaf litter messages delivered.	during seasonally appropriate time periods.
Ongoing	Public Education/ Outreach	Distribute targeted messaging regarding septic system maintenance and LID development	TBD	TBD	Septic system and LID messages delivered.	Continue messaging to target audiences.
New 2023	Existing Private BMPs: Quantify nutrient load reductions	City to catalog inventory of existing privately owned BMPs, quantify nutrient load reductions and enter into PTAP	TBD	$22,000	New	Complete
Ongoing	Private Development/ Redevelopment	Enforce City's updated Chapter 218 Stormwater Ordinance requiring treatment	100-300[3]	TBD	June 7, 2022 Stormwater Ordinance revision requires pollutant accounting information by developers.	Continued enforcement of Stormwater Ordinance/use of PTAP for pollutant tracking.
2021	Staffing/Resources	City funded a third Assistant City Engineer position to focus on stormwater related projects and Ordinance enforcement	TBD	TBD	Position populated.	Anticipated increase in capacity to focus on stormwater.
Ongoing	Septic System Programs	Advocate for and work with State RE: advanced septic system treatment for nitrogen and enforcement of connection to public sewer law within 100'	TBD	TBD	NHDES met with certain communities	Continue to advocate for amendments to the septic system requirements.

[3] The City's estimates for load reductions of 100 to 300 lbs. N/year were estimated to occur as a result of structural BMP retrofits through redevelopment on commercial properties as required by revised City stormwater ordinance. These estimates were based on an assumption that 10 to 50 acres of impervious area are redeveloped and retrofitted with BMPs, which depends upon actual development activity.

2022-2023	Water Pollution and Flooding Reduction Study	Through a public workgroup and broader public outreach the City will consider a dedicated stormwater funding source.	TBD	TBD	Workgroup held 3 meetings in 2022-2023. Process may be impacted Residual Designated Authority initiative.	Prepare final report with recommendations to City Council.

Pilot Projects – The following list includes pilot projects:

Anticipated Year	Project	Description	Estimated Load Reduction Potential (lbs TN/yr)	Costs	2023 Progress Update	2024 Anticipated Progress
2021	Pilot Septage Receiving Facility Upgrade	Receive septage at the Headworks Facility and observe process response	TBD	$15,000	Pilot evaluation concluded that receiving septage at the headworks facility did not significantly impact secondary or tertiary WWTF processes.	Anticipated construction of the Septage Receiving Facility Upgrade by 12/31/24.

Initiatives at WWTFs – The following list includes efforts aimed at reducing TN output from WWTFs during the eelgrass growing season. Such efforts may include optimization of plants, projects aimed at reducing inflow/infiltration, facility upgrades, or similar measures.

Anticipated Year	Project	Description	Estimated Load Reduction Potential (lbs TN/yr)	Costs	2023 Progress Update	2024 Anticipated Progress
2023 -	Septage Receiving Facility Upgrade	Construct new septage receiving facility at a location more favorable for nitrogen treatment at the WWTF	TBD	$600,000+	Completed pilot evaluation and received federal funding for construction of the Septage Receiving Facility Upgrade.	Anticipated design, bid and construction by December 31, 2024.

Anticipated Year	Project	Description	Estimated Load Reduction Potential (lbs TN/yr)	Costs	2023 Progress Update	2024 Anticipated Progress
2022	Aeration Automation Project	Complete construction of automation equipment for operation of aeration; optimize for nitrogen removal with Septage Receiving and Carbon Feed	TBD	$400,000	Installation of equipment and programming to optimize aeration automation is complete	Complete
2021-24	Sewer System Master Plan	Evaluate sewer collection system for sources of Inflow/ Infiltration	TBD	TBD	Scope of work submitted to EPA and NHDES in fall 2021. Ongoing efforts for data collection and monitoring including smoke testing during Summer 2023.	City anticipates continuing the master planning effort over the next several years, culminating in a final Master Plan.
2024	Nitrogen Reduction Report	Evaluate progress to date regarding nitrogen reduction and indicate any further action needed to ensure compliance with effluent limit	TBD	TBD	Report effort was commissioned in 2023. Project team will include the City's consultants for the Sewer System Master Plan, and for the WWTF optimization.	Completion of report by 10/31/24.
2022	Carbon Storage and Feed Building	Complete construction of new facility for storage and metered injection of a carbon source into the SND process	TBD	$3,300,000 +	Construction of the carbon storage and feed building project is 100% complete.	Operational indications are that nitrogen reductions are hovering between interim and final limits of the GBGP for nitrogen and trending towards final.

Co-Benefits of Nonpoint Source Reductions – Though beyond the scope of the submission called for in Part 3-1.c. of the General Permit, the MAAM communities feel it is important to plan and accountfor the removal of other pollutants or stressors of eelgrass coincident to the TN source reductions listed above. This dovetails with the monitoring efforts undertaken by MAAM and its partners, which is expected to include study of potential eelgrass stressors.

Anticipated Year	Project	Description	Estimated Reduction of TSS (lbs/yr)	Estimated Reduction of Phosphorus (lbs/yr)
2021-23	Colonial Pines Sewer Extension - Phase 3	Phase 3 of a neighborhood sewer extension project with drainage infrastructure improvements	TBD	TBD
2021-23	Strafford Square Roundabout	New roundabout installation project with drainage infrastructure improvements including new BMPs	TBD	TBD
2023-24	Woodman Area Infrastructure Improvements	Neighborhood Complete Streets project with drainage infrastructure improvements including improved outfalls and new BMPs	TBD	TBD
By 2025	Union Street Municipal Parking Lot	Parking lot reconstruction with drainage infrastructure improvements including new BMPs	TBD	TBD
By 2025	Wakefield Street Reconstruction	Complete Streets project with drainage infrastructure improvements including new BMPs	TBD	TBD
Ongoing	Street Sweeping	Sweep curbed streets monthly (Apr-Nov); sweep Downtown weekly (Apr-Nov)	TBD	TBD
Ongoing	Leaf Litter Management	Collect leaf litter monthly (Apr-May, Oct-Nov); collect bagged organic waste for 2 wks in spring and fall	TBD	TBD
Ongoing	Catch Basin Cleaning	Ensure CB sumps are no more than 50% full at any time	TBD	TBD
Ongoing, June 2021	Private Development/ Redevelopment	Enforce City's updated Chapter 218 Stormwater Ordinance requiring treatment	TBD	TBD

Rollinsford

Planned Structural BMPs – The following list includes projects that are already planned in CIP, design phase, etc.

Anticipated Year	Project	Description	Estimated Load Reduction Potential (lbs TN/yr)	Costs
-	TBD	-	-	-

Non-structural BMPs – The following list includes existing ongoing and future planned efforts:

Anticipated Year of initial implementation (ongoing work)	Project	Description	Estimated Load Reduction Potential (lbs TN/yr)	Costs
Current	Ordinance/Regulations	Site Plan Regulations include SWA recommendations for development and redevelopment (reduction = 0.012 * baseline)	**221 TN/yr**	-
Ongoing	Street Sweeping	Mechanically sweep as required in MS4	**TBD**	
Ongoing	Catch Basin Cleaning	Ensure CB sumps are no more than 50% full at any time	**TBD**	

Municipal Lands with potential for pollutant load removal – The following list include municipally owned property derived by sorting hot spots data for parcels with high TN loads:

Year	Project	Description	Estimated Load Reduction Potential (lbs TN/yr)	Costs
N/A	Morton Park	?	17.53	?
N/A	Fire Station	?	9.6	?
N/A	Police Department	?	4.7	?

Other Efforts – The following list includes innovative efforts

Anticipated Year	Project	Description	Estimated Load Reduction Potential (lbs TN/yr)	Costs
-	-	-	-	-

Pilot Projects – The following list includes pilot projects:

Anticipated Year	Project	Description	Estimated Load Reduction Potential (lbs TN/yr)	Costs
2021	Stakeholder Committee Project	MAAM communities fund $45,000 towards Great Bay water quality-related project as selected by the Stakeholder Committee (CLF)	?	

Initiatives at WWTFs – The following list includes efforts aimed at reducing TN output from WWTFs during the eelgrass growing season. Such efforts may include optimization of plants, projects aimed at reducing inflow/infiltration, facility upgrades, or similar measures.

Anticipated Year	Project	Description	Estimated Load Reduction Potential (lbs TN/yr)	Costs
-	WWTF management	Continue to manage and test existing effluent	TBD	-

Co-Benefits of Nonpoint Source Reductions – Though beyond the scope of the submission called for in Part 3-1.c. of the General Permit, the MAAM communities feel it is important to plan and account for the removal of other pollutants or stressors of eelgrass coincident to the TN source reductions listed above. This dovetails with the monitoring efforts undertaken by MAAM and its partners, which is expected to include study of confounding factors and stressors.

Anticipated Year	Project	Description	Estimated Reduction of TSS (lbs /yr)	Estimated Reduction of Phosphorus (lbs /yr)
-	-	-	-	-

Appendix E

Pollutant Load Reduction Reports

Appendix F

Municipal Alliance for Adaptive Management (MAAM) Intermunicipal Agreement

Great Bay TN Reduction Progress

	Non-Point Source TN reduction (lb/yr) *	WWTF TN reduction over permitted load (lb/yr) **	Non-Point Source TP reduction (lb/yr)	Non-Point Source TSS reduction (lb/yr)
Dover	918***	2,307	233	24,773
Durham	257	-	39	8,934
Epping	0	-	0	0
Exeter	25	-	3	784
Milton	0	-	0	0
Newfields	33	-	4	1,309
Newington	7	2,536	2	536
Newmarket	1	-	0	105
Portsmouth	562	68,578	62	32,381
Rochester	3,326	-	618	261,302
Rollinsford	0	-	0	0
Somersworth	0	-	0	0
TOTAL	**5,129**	-	**961**	**330,124**

* *Only BMP's that have been entered into PTAP and classified as "installed" receive credit. There are still many structural and non-structural initiatives that communities are taking that have meaningful reductions but are not yet accounted for in PTAP.*

*** Only some communities provided data for this MAAM report. All WWTF loads reported directly to EPA.*

**** Dover is in the process of inputting BMP's from private properties that were installed prior to requiring PTAP tracking.*

State	NEW HAMPSHIRE
Municipality	DOVER
Permit Type	MS4
Permit Number	
Major Watershed	N/A
TP Load Reduction Target	N/A
TN Load Reduction Target	N/A
TSS Load Reduction Target	N/A

Table 1. Project Summary Credit for DOVER, NEW HAMPSHIRE

Project Type	Removed Phosphorus Load (lb/yr)	Removed Nitrogen Load (lb/yr)	Removed Sediment Load (lb/yr)
Structural	73.50	508.72	24772.97
Non-Structural	*160.16	*408.85	0
Land Use Conversion	0	0	0
Total	233.66	917.57	24772.97

*Measured and Modeled Street Sweeping credit was calculated in the *UNHSC Street Sweeping Calculator v1.1* and added to the BATT Non-Structural output.

Table 2. Structural Project Summary for DOVER, NEW HAMPSHIRE

Project ID	BMP Type	BMP Storage Capacity (ft³)/ Filter Depth (in.)	Phosphorus BMP Efficiency (%)	Nitrogen BMP Efficiency (%)	Sediment BMP Efficiency (%)	Removed Phosphorus Load (lb/yr)	Removed Nitrogen Load (lb/yr)	Removed Sediment Load (lb/yr)	Impervious Area Treated (ac)	Runoff Depth (in.)
1. Circle K #7264	BIORETENTION	6209.45	63	40	100	0.94	5.07	317.01	0.84	2.04
2. American Durafilm Co. Inc.	BIORETENTION	8440.53	63	40	100	0.89	4.77	298.14	0.79	2.94
3. American Durafilm Co. Inc.	GRASS SWALE (CONVEYANCE)	345	6.94	4.26	52.25	0.04	0.21	63.09	0.32	0.3
4. Community Trail	INFILTRATION TRENCH	1230	89.88	97.97	98.98	0.71	4.7	147.73	0.34	1
5. Innovative Tree Box Filter - City Design	BIORETENTION	380	14.52	9.33	45.17	0.26	1.41	170.47	1	0.1
6. Chelsey Street	BIORETENTION	1146	42.73	27.09	95.91	0.47	2.14	235.76	0.56	0.56
7. Central Ave - Gravel Wetland	GRAVEL WETLAND	23707	48.67	54.91	88.91	10.22	97.7	3959.15	11.8	0.55

8. Upper Horne Street	INFILTRATION BASIN	3220	53.58	70.27	81.03	4.32	40.72	1461.83	4.11	0.22
9. Cemetery - F&G Facility	INFILTRATION TRENCH	546	28.85	64.23	48.01	0.77	10.42	242.33	1.15	0.13
10. Woodman Park School	INFILTRATION TRENCH	3415	52.4	81.6	76	4.08	38.66	1120.89	3.36	0.28
11. Richardson Drive	INFILTRATION TRENCH	14302	92	98	100	8.41	54.44	1729.46	3.94	1
12. Roosevelt Ave	BIORETENTION	1836	42.24	26.74	95.49	0.76	3.47	385.63	0.92	0.55
13. Lowell Ave	BIORETENTION	970	26.25	16.73	71.29	0.62	2.85	378.66	1.21	0.22
14. Building Addition Q LLc.	EXTENDED DRY DETENTION POND	9217	13.6	21.38	48.2	0.34	4.55	256.5	1.41	1.8
15. STONE1-035-RG	BIORETENTION	1682.4	63	40	100	0.01	0.06	3.77	0.01	46.35
16. Snow Ave	GRASS SWALE (CONVEYANCE)	495	1.59	1.11	22.99	0.05	0.27	173.58	1.72	0.08

17. Glencrest Ave	BIORETENTION	2262	28.02	17.76	74.53	1.37	6.24	814.58	2.49	0.25
18. ELM001-010-FCB	BIORETENTION	15.6	38.04	23.74	91.89	0.01	0.04	3.47	0.01	0.43
19. HELLM1-010-RG	BIORETENTION	1788.36	63	40	100	0.06	0.3	18.87	0.05	9.85
20. CENTR1-046-BRS	BIORETENTION	583.8	57.62	36.62	99.92	0.11	0.61	41.48	0.11	1.46
21. SILVE1-022-RG	BIORETENTION	60	18.15	11.64	53.44	0.04	0.21	24.2	0.12	0.14
22. GLENC1-010-BRS	BIORETENTION	743.4	25.29	16.17	69.53	0.45	2.44	262.39	1	0.2
23. LOWEL1-050-BRS	BIORETENTION	603	63	40	100	0.01	0.06	3.77	0.01	16.61
24. HAMIL1-010-FCB	BIORETENTION	27.6	14.95	9.6	46.15	0.02	0.1	12.19	0.07	0.11
25. BELLA1-010-RG	BIORETENTION	1049.4	63	40	100	0.01	0.06	3.77	0.01	28.91
26. Middleton Chiropractic	BIORETENTION	3390.78	63	40	100	0.26	1.39	86.8	0.23	4.06
27. CHESL1-010-RG	BIORETENTION	78.83	31.61	19.86	81.13	0.04	0.21	21.43	0.07	0.31
28. MOUNT2-020-FCB	BIORETENTION	42	8.53	5.48	26.79	0.03	0.16	19.21	0.19	0.06

29. MOUNT2-010-FCB	BIORETENT ION	36	21.18	13.57	60.32	0.02	0.12	13.66	0.06	0.17
30. ROBER1-010-FCB	BIORETENT ION	38.1	53.5	32.5	99.1	0.01	0.05	3.74	0.01	1.05
31. ROBER1-020-FCB	BIORETENT ION	28.8	47.87	30.9	97.97	0.01	0.05	3.7	0.01	0.79
32. ROBER1-030-FCB	BIORETENT ION	28.8	47.87	30.9	97.97	0.01	0.05	3.7	0.01	0.79
33. ROOSE1-010-FCB	BIORETENT ION	23.52	44.96	28.72	97.24	0.01	0.04	3.67	0.01	0.65
34. ROOSE1-015-FCB	BIORETENT ION	25.12	45.84	29.38	97.46	0.01	0.04	3.68	0.01	0.69
35. HORNE1-010-RG	BIORETENT ION	2076	63	40	100	0.01	0.06	3.77	0.01	57.1 9
36. Lundy Point LLC - Transfer of Development Rights Subdivision	BIORETENT ION	1509 1	63	40	100	0.99	4.51	351.1 6	0.8	5.2
37. Lundy Point LLC - Transfer of Development Rights Subdivision	BIORETENT ION	3068	58.09	37.06	100	0.64	2.93	245.8 1	0.56	1.51
38. Little Bay Marina	BIORETENT ION	1728	58.87	37.52	100	0.35	1.59	131.6 8	0.3	1.59
39. Little Bay Marina	POROUS PAVEMENT	3348 0	78	79	97	1.83	13.37	510.9 4	1.2	7.69
40. Little Bay Marina	EXTENDED DRY	1688	12.16	13.74	46.16	0.1	0.83	87.13	0.43	1.08

	DETENTIO N POND									
41. 1795 Gundalow Landing, residential apartments, portland avenue dover nh	EXTENDED DRY DETENTIO N POND	3273 6	14	23.13	49	0.25	2.97	195.7 3	0.91	9.91
42. Locust Street Inn & Locust Common	BIORETENT ION	8200	63	40	100	0.46	2.71	210.7	0.48	4.71
43. Locust Street Inn & Locust Common	BIORETENT ION	1896 0	63	40	100	0.79	4.62	359.9 4	0.82	6.37
44. Pointe Place - Mixed Use Development - Phase 4	INFILTRATI ON BASIN	1718 5	98.98	100	100	7.37	53.58	1668. 01	3.8	1.25
45. Pointe Place - Mixed Use Development - Phase 4	INFILTRATI ON BASIN	5750	98.8	100	100	0.97	7.05	219.4 8	0.5	3.17
46. Pointe Place - Mixed Use Development - Phase 4	BIORETENT ION	6472	58.5	37.3	100	1.32	6.05	504.7 9	1.15	1.55
47. Pointe Place - Mixed Use Development - Phase 4	BIORETENT ION	5375	60.84	38.7	100	0.99	4.53	364.3 3	0.83	1.78
48. Pointe Place - Mixed Use Development - Phase 4	BIORETENT ION	1308 0	61.11	38.86	100	2.38	10.9	873.5 1	1.99	1.81
49. Pointe Place - Mixed Use Development - Phase 4	BIORETENT ION	6746	56.66	35.66	99.73	1.51	6.84	595.3 8	1.36	1.37
50. Pointe Place - Mixed Use Development - Phase 4	BIORETENT ION	2089	53.46	32.46	99.09	0.58	2.52	239.2 3	0.55	1.05

51. Pointe Place - Mixed Use Development - Phase 4	BIORETENTION	588	47.43	30.57	97.86	0.2	0.91	90.2	0.21	0.77
52. Pointe Place - Mixed Use Development - Phase 4	BIORETENTION	13858	63	40	100	1.79	8.18	636.48	1.45	2.63
53. ROOSE1-010-RG	BIORETENTION	747.78	63	40	100	0.01	0.06	3.77	0.01	20.6
54. Dover III	INFILTRATION BASIN	2630	100	100	100	1.14	8.18	254.59	0.58	1.25
55. 19034 Crosby Road	GRASS SWALE (CONVEYANCE)	3833	36	23.13	90	0.22	1.19	115.48	0.34	3.11
56. 19003 White Birch Armory	GRASS SWALE (CONVEYANCE)	25811	36	23.13	90	0.94	5.13	499.29	1.47	4.84
57. 29 Littleworth Road Dover	BIORETENTION	9485.8	63	40	100	1.35	7.24	452.87	1.2	2.18
58. Hanson Court Apartments	INFILTRATION TRENCH	1866	100	100	100	0.43	3.1	96.57	0.22	2.34
59. Broadview Urgent Care Animal Hospital	EXTENDED DRY DETENTION POND	1220	8.24	6.38	38.48	0.11	0.72	108.92	0.75	0.45

60. Leathers Lane	WET POND/CREATED WETLAND	15684	62.03	39.42	85.42	2.76	12.62	851.14	2.27	1.9
61. Leathers Lane	WET POND/CREATED WETLAND	56784	63	40	86	4.99	22.79	1525.09	4.04	3.87
62. Leathers Lane	INFILTRATION BASIN	1184	49.18	66.75	78.63	2.2	21.46	786.89	2.28	0.14
63. SILVE1-010-RG	BIORETENTION	131.52	55.08	34.08	99.42	0.03	0.15	11.26	0.03	1.21
64. SILVE1-020-RG	BIORETENTION	180.23	6.32	4.06	19.86	0.12	0.67	82.44	1.1	0.05
65. SILVE1-022-RG	BIORETENTION	255.77	53.07	32.07	99.01	0.07	0.34	26.16	0.07	1.01
66. SILVE1-030-RG	BIORETENTION	129.67	63	40	100	0.01	0.06	3.77	0.01	3.57
67. SILVE1-040-RG	BIORETENTION	95.53	63	40	100	0.01	0.06	3.77	0.01	2.63
68. Storage Barn (Lot 12-2)	WET POND/CREATED WETLAND	2849	50.55	31.51	75.53	0.78	4.13	247.99	0.87	0.9
69. L&T Dental	BIORETENTION	1388	63	40	100	0.19	1.03	64.16	0.17	2.25

70. L&T Dental	POROUS PAVEMENT	162	78	79	97	0.24	2.03	62.23	0.17	0.26

Table 3. Non-Structural Project Summary for DOVER, NEW HAMPSHIRE

Project ID	BMP Type	BMP Storage Capacity	Phosphorus BMP Efficiency (%)	Nitrogen BMP Efficiency (%)	Sediment BMP Efficiency (%)	Removed Phosphorus Load (lb/yr)	Removed Nitrogen Load (lb/yr)	Removed Sediment Load (lb/yr)	Impervious Area Treated (ac)	Runoff Depth (in.)
1. Circle K #7264	CATCH BASIN CLEANING	N/A	2	6	0	0.01	0.33	0	0.37	N/A
2. American Durafilm Co. Inc.	CATCH BASIN CLEANING	N/A	2	6	0	0.02	0.42	0	0.46	N/A
5. Middleton Chiropractic	CATCH BASIN CLEANING	N/A	2	6	0	0.01	0.16	0	0.18	N/A
7. 1795 Gundalow Landing, residential apartments, portland avenue dover nh	CATCH BASIN CLEANING	N/A	2	6	0	0.01	0.31	0	0.37	N/A
9. 19014 Venture Drive	CATCH BASIN CLEANING	N/A	2	6	0	0.01	0.16	0	0.18	N/A

10. Dover III	CATCH BASIN CLEANING	N/A	2	6	0	0.01	0.15	0	0.18	N/A
13. 19003 White Birch Armory	CATCH BASIN CLEANING	N/A	2	6	0	0.01	0.25	0	0.28	N/A
14. Hanson Court Apartments	CATCH BASIN CLEANING	N/A	2	6	0	0	0.08	0	0.09	N/A
15. Broadview Urgent Care Animal Hospital	CATCH BASIN CLEANING	N/A	2	6	0	0.02	0.5	0	0.55	N/A
18. Leathers Lane	CATCH BASIN CLEANING	N/A	2	6	0	0.06	1.24	0	1.47	N/A
19. Storage Barn (Lot 12-2)	CATCH BASIN CLEANING	N/A	2	6	0	0.01	0.16	0	0.18	N/A

Table 4. Land Use Conversion Project Summary for DOVER, NEW HAMPSHIRE

There are no land use conversion projects.

State	NEW HAMPSHIRE
Municipality	DURHAM
Permit Type	MS4
Permit Number	
Major Watershed	N/A
TP Load Reduction Target	N/A
TN Load Reduction Target	N/A
TSS Load Reduction Target	N/A

Table 1. Project Summary Credit for DURHAM, NEW HAMPSHIRE

Project Type	Removed Phosphorus Load (lb/yr)	Removed Nitrogen Load (lb/yr)	Removed Sediment Load (lb/yr)
Structural	25.55	210.1	8933.67
Non-Structural	*13.28	*46.69	0
Land Use Conversion	0	0	0
Total	38.83	256.79	8933.67

*Measured and Modeled Street Sweeping credit was calculated in the *UNHSC Street Sweeping Calculator v1.1* and added to the BATT Non-Structural output.

Table 2. Structural Project Summary for DURHAM, NEW HAMPSHIRE

Project ID	BMP Type	BMP Storage Capacity (ft^3)/ Filter Depth (in.)	Phosphorus BMP Efficiency (%)	Nitrogen BMP Efficiency (%)	Sediment BMP Efficiency (%)	Removed Phosphorus Load (lb/yr)	Removed Nitrogen Load (lb/yr)	Removed Sediment Load (lb/yr)	Impervious Area Treated (ac)	Runoff Depth (in.)
168. UNH SWT0072 SPAULDING HALL	WET POND/CREATED WETLAND	1675	26.84	17.08	46.46	0.96	5.15	350.65	2	0.23
169. UNH SWT0064 ELLIOT ALUMNI CENTER LOT	POROUS PAVEMENT	40709	78	79	97	1.39	11.91	366.07	1	11.21
170. UNH SWT0027 A LOT	INFILTRATION BASIN	733	60.2	77.14	94.02	1.07	11.63	354.82	1	0.2
171. UNH SWT0025 A LOT	INFILTRATION BASIN	315	35.58	51.2	58.14	0.63	7.72	219.42	1	0.09
172. UNH SWT0044 WILDCAT STADIUM	GRAVEL WETLAND	9628	58.68	65.68	95.84	3.13	29.71	1085.08	3	0.88
173. UNH SWT0057 SOCCER FIELD	GRAVEL WETLAND	2098	20.09	23.72	50.03	1.79	17.88	943.98	5	0.12
174. UNH SWT0032 B LOT	INFILTRATION BASIN	3521	94.55	98.85	99.85	1.68	14.91	376.82	1	0.97
175. UNH C LOT	INFILTRATION BASIN	1228	54.14	71.45	85.67	1.93	21.55	646.62	2	0.17

176. UNH SWT0028 A LOT	INFILTRATION BASIN	703	39.7	57.13	64.88	1.41	17.23	489.68	2	0.1
177. UNH SWT0033 E LOT	INFILTRATION TRENCH	1924	77.1	93.25	95.55	1.37	14.06	360.6	1	0.53
178. UNH SWT0026 A LOT	INFILTRATION TRENCH	3570	95.67	98.92	100	1.7	14.92	377.39	1	0.98
179. UNH SWT0012 WEST EDGE	BIORETENTIO N	32670	53	32	99	8.49	43.43	3362.5 4	9	1

Table 3. Non-Structural Project Summary for DURHAM, NEW HAMPSHIRE

Project ID	BMP Type	BMP Storage Capacity	Phosphorus BMP Efficiency (%)	Nitrogen BMP Efficiency (%)	Sediment BMP Efficiency (%)	Removed Phosphorus Load (lb/yr)	Removed Nitrogen Load (lb/yr)	Removed Sediment Load (lb/yr)	Impervious Area Treated (ac)	Runoff Depth (in.)
23. UNH 2022 Street Sweeping and CB Cleaning	CATCH BASIN CLEANING	N/A	2	6	0	0.58	14.79	0	16.35	N/A

Table 4. Land Use Conversion Project Summary for DURHAM, NEW HAMPSHIRE

There are no land use conversion projects.

State	NEW HAMPSHIRE
Municipality	EXETER
Permit Type	MS4
Permit Number	
Major Watershed	N/A
TP Load Reduction Target	N/A
TN Load Reduction Target	N/A
TSS Load Reduction Target	N/A

Table 1. Project Summary Credit for EXETER, NEW HAMPSHIRE

Project Type	Removed Phosphorus Load (lb/yr)	Removed Nitrogen Load (lb/yr)	Removed Sediment Load (lb/yr)
Structural	2.88	24.64	784
Non-Structural	0.01	0.24	0
Land Use Conversion	0	0	0
Total	2.89	24.88	784

Table 2. Structural Project Summary for EXETER, NEW HAMPSHIRE

Project ID	BMP Type	BMP Storage Capacity (ft^3)/ Filter Depth (in.)	Phosphorus BMP Efficiency (%)	Nitrogen BMP Efficiency (%)	Sediment BMP Efficiency (%)	Removed Phosphorus Load (lb/yr)	Removed Nitrogen Load (lb/yr)	Removed Sediment Load (lb/yr)	Impervious Area Treated (ac)	Runoff Depth (in.)
71. BrambleMeadows	BIORETENTION	5096	63	40	100	0.26	1.18	92.18	0.21	6.69
72. BrambleMeadows	INFILTRATION BASIN	5100	96.2	99	100	0.57	4.19	131.68	0.3	4.68
73. McFarland Ford Storage Lot	POROUS PAVEMENT	17413	78	79	97	1.06	9.05	278.21	0.76	6.31
74. McFarland Ford Storage Lot	INFILTRATION TRENCH	492	97.04	99.52	100	0.26	2.25	56.61	0.15	0.9
75. Lary Lane	INFILTRATION BASIN	600	56.96	73.37	82.92	0.73	7.97	225.32	0.72	0.23

Table 3. Non-Structural Project Summary for EXETER, NEW HAMPSHIRE

Project ID	BMP Type	BMP Storage Capacity	Phosphorus BMP Efficiency (%)	Nitrogen BMP Efficiency (%)	Sediment BMP Efficiency (%)	Removed Phosphorus Load (lb/yr)	Removed Nitrogen Load (lb/yr)	Removed Sediment Load (lb/yr)	Impervious Area Treated (ac)	Runoff Depth (in.)
20. BrambleMeadows	CATCH BASIN CLEANING	N/A	2	6	0	0.01	0.24	0	0.28	N/A

State	NEW HAMPSHIRE
Municipality	NEWFIELDS
Permit Type	MS4
Permit Number	
Major Watershed	N/A
TP Load Reduction Target	N/A
TN Load Reduction Target	N/A
TSS Load Reduction Target	N/A

Table 1. Project Summary Credit for NEWFIELDS, NEW HAMPSHIRE

Project Type	Removed Phosphorus Load (lb/yr)	Removed Nitrogen Load (lb/yr)	Removed Sediment Load (lb/yr)
Structural	3.65	33.32	1308.93
Non-Structural	0	0	0
Land Use Conversion	0	0	0
Total	3.65	33.32	1308.93

Table 2. Structural Project Summary for NEWFIELDS, NEW HAMPSHIRE

Project ID	BMP Type	BMP Storage Capacity (ft^3)/ Filter Depth (in.)	Phosphorus BMP Efficiency (%)	Nitrogen BMP Efficiency (%)	Sediment BMP Efficiency (%)	Removed Phosphorus Load (lb/yr)	Removed Nitrogen Load (lb/yr)	Removed Sediment Load (lb/yr)	Impervious Area Treated (ac)	Runoff Depth (in.)
76. Lilly Lane	INFILTRATION BASIN	6815	94.2	98	100	0.5	4.84	153.63	0.35	5.36
77. Retail & Motor Fuel Outlet	EXTENDED DRY DETENTION POND	12530	14	23.13	49	0.17	2.41	127.6	0.69	5
78. Lila Lane	WET POND/CREATED WETLAND	533	52.47	31.89	76.68	0.12	0.67	50.49	0.15	0.98
79. Lila Lane	WET POND/CREATED WETLAND	863	51.77	31.75	76.26	0.2	1.12	83.69	0.25	0.95
80. Lila Lane	INFILTRATION BASIN	3422	91.5	98	99	0.43	4.28	134.71	0.31	3.04
81. 16 Swampscott St	BIORETENTION	1614	54.12	33.12	99.22	0.39	2	149.78	0.4	1.11
82. Stratham Tire	INFILTRATION BASIN	5806	98.9	99.9	100	1.44	12.35	309.46	0.82	1.95
83. Dunkin Donuts	EXTENDED DRY DETENTION POND	26069	14	23.13	49	0.4	5.65	299.57	1.62	4.43

Table 3. Non-Structural Project Summary for NEWFIELDS, NEW HAMPSHIRE

There are no non-structural BMPs.

Table 4. Land Use Conversion Project Summary for NEWFIELDS, NEW HAMPSHIRE

There are no land use conversion projects.

State	NEW HAMPSHIRE
Municipality	NEWINGTON
Permit Type	MS4
Permit Number	
Major Watershed	N/A
TP Load Reduction Target	N/A
TN Load Reduction Target	N/A
TSS Load Reduction Target	N/A

Table 1. Project Summary Credit for NEWINGTON, NEW HAMPSHIRE

Project Type	Removed Phosphorus Load (lb/yr)	Removed Nitrogen Load (lb/yr)	Removed Sediment Load (lb/yr)
Structural	1.79	6.87	535.54
Non-Structural	0	0	0
Land Use Conversion	0	0	0
Total	1.79	6.87	535.54

Table 2. Structural Project Summary for NEWINGTON, NEW HAMPSHIRE

Project ID	BMP Type	BMP Storage Capacity (ft^3)/ Filter Depth (in.)	Phosphorus BMP Efficiency (%)	Nitrogen BMP Efficiency (%)	Sediment BMP Efficiency (%)	Removed Phosphorus Load (lb/yr)	Removed Nitrogen Load (lb/yr)	Removed Sediment Load (lb/yr)	Impervious Area Treated (ac)	Runoff Depth (in.)
1. Shackford Point	BIORETENTION	11245	63	40	100	0.47	1.8	140.46	0.32	9.68
2. Shackford Point	BIORETENTION	2837	63	40	100	0.1	0.39	30.73	0.07	11.16
3. Shackford Point	BIORETENTION	13056	63	40	100	0.72	2.76	215.09	0.49	7.34
4. Shackford Point	BIORETENTION	9668	63	40	100	0.12	0.45	35.12	0.08	33.29
5. Shackford Point	BIORETENTION	4912	63	40	100	0.12	0.45	35.12	0.08	16.91
6. Shackford Point	BIORETENTION	5484	63	40	100	0.13	0.51	39.51	0.09	16.79
7. Shackford Point	BIORETENTION	4261	63	40	100	0.13	0.51	39.51	0.09	13.04

Table 3. Non-Structural Project Summary for NEWINGTON, NEW HAMPSHIRE

There are no non-structural BMPs.

Table 4. Land Use Conversion Project Summary for NEWINGTON, NEW HAMPSHIRE

There are no land use conversion projects.

State	NEW HAMPSHIRE
Municipality	NEWMARKET
Permit Type	MS4
Permit Number	
Major Watershed	N/A
TP Load Reduction Target	N/A
TN Load Reduction Target	N/A
TSS Load Reduction Target	N/A

Table 1. Project Summary Credit for NEWMARKET, NEW HAMPSHIRE

Project Type	Removed Phosphorus Load (lb/yr)	Removed Nitrogen Load (lb/yr)	Removed Sediment Load (lb/yr)
Structural	0.3	1.35	105.35
Non-Structural	0	0	0
Land Use Conversion	0	0	0
Total	0.3	1.35	105.35

Table 2. Structural Project Summary for NEWMARKET, NEW HAMPSHIRE

Project ID	BMP Type	BMP Storage Capacity (ft^3)/ Filter Depth (in.)	Phosphorus BMP Efficiency (%)	Nitrogen BMP Efficiency (%)	Sediment BMP Efficiency (%)	Removed Phosphorus Load (lb/yr)	Removed Nitrogen Load (lb/yr)	Removed Sediment Load (lb/yr)	Impervious Area Treated (ac)	Runoff Depth (in.)
84. Grape Street Project	BIORETENTION	3600	63	40	100	0.3	1.35	105.35	0.24	4.13

Table 3. Non-Structural Project Summary for NEWMARKET, NEW HAMPSHIRE

There are no non-structural BMPs.

Table 4. Land Use Conversion Project Summary for NEWMARKET, NEW HAMPSHIRE

There are no land use conversion projects.

State	NEW HAMPSHIRE
Municipality	PORTSMOUTH
Permit Type	MS4
Permit Number	
Major Watershed	N/A
TP Load Reduction Target	N/A
TN Load Reduction Target	N/A
TSS Load Reduction Target	N/A

Table 1. Project Summary Credit for PORTSMOUTH, NEW HAMPSHIRE

Project Type	Removed Phosphorus Load (lb/yr)	Removed Nitrogen Load (lb/yr)	Removed Sediment Load (lb/yr)
Structural	62.09	562.24	32381.39
Non-Structural	0	0	0
Land Use Conversion	0	0	0
Total	62.09	562.24	32381.39

Table 2. Structural Project Summary for PORTSMOUTH, NEW HAMPSHIRE

Project ID	BMP Type	BMP Storage Capacity (ft^3)/ Filter Depth (in.)	Phosphorus BMP Efficiency (%)	Nitrogen BMP Efficiency (%)	Sediment BMP Efficiency (%)	Removed Phosphorus Load (lb/yr)	Removed Nitrogen Load (lb/yr)	Removed Sediment Load (lb/yr)	Impervious Area Treated (ac)	Runoff Depth (in.)
1. Watson's Landing	BIORETENTION	5793	46	29.5	97.5	2.06	9.48	975.78	2.28	0.7
2. Four Tree Island Parking Lot	POROUS PAVEMENT	2800	78	79	97	0.55	5.12	195.86	0.46	1.68
3. Sagamore Bridge	SAND FILTER	1065	50.23	31.45	98.45	0.32	1.46	142.6	0.33	0.89
4. Plains Park	INFILTRATION TRENCH	315	50.77	79.54	71.81	0.37	5.38	151.3	0.48	0.18
5. Plains Park	POROUS PAVEMENT	2476	78	79	97	0.3	2.78	106.45	0.25	2.73
6. Coakley Road - Hodgdon Brook	BIORETENTION	742	35.71	22.25	88.64	0.38	1.69	210.1	0.54	0.38
7. Coakley Road - Hodgdon Brook	BIORETENTION	574	19.26	12.34	55.95	0.4	1.86	262.76	1.07	0.15

8. Portsmouth Rec Fields and Regional Stormwater BMP's	ENHANCED BIORETENTION	29078	45.44	52.43	82.25	17.27	184.81	9025.48	25	0.32
9. Portsmouth Rec Fields and Regional Stormwater BMP's	GRAVEL WETLAND	34499	24.85	31.2	58.87	19.55	227.68	13375.25	51.76	0.18
10. State Street	BIORETENTION	147	16.1	10.34	48.78	0.1	0.53	62.59	0.34	0.12
11. State Street	SAND FILTER	3506	10.02	6.44	31.48	2.41	13.11	1603.79	13.5	0.07
12. Sagamore Ave	POROUS PAVEMENT	1542	78	79	97	0.61	4.46	170.31	0.4	1.06
13. 85 NH Avenue	GRASS SWALE (CONVEYANCE)	11550	23.79	14.84	82.44	1.26	5.67	980.64	2.71	1.17
14. 67, 73, 121 Corporate Drive	SAND FILTER	79457	63	40	100	4.7	25.27	1581.26	4.19	5.22
15. 67, 73, 121 Corporate Drive	SAND FILTER	42020	63	40	100	2.48	13.33	834.03	2.21	5.24
16. 67, 73, 121 Corporate Drive	SAND FILTER	32641	63	40	100	1.93	10.38	649.11	1.72	5.23
17. 67, 73, 121 Corporate Drive	SAND FILTER	7894	63	40	100	0.46	2.47	154.73	0.41	5.3

18. 67, 73, 121 Corporate Drive	SAND FILTER	12833	63	40	100	0.75	4.04	252.85	0.67	5.28
19. Sanderson Drive	BIORETENTION	1444	53.75	32.75	99.15	0.39	1.71	161.03	0.37	1.08
20. Sanderson Drive	ENHANCED BIORETENTION	2659	89	86	100	0.63	4.37	158.02	0.36	2.03
21. Laurel Court	INFILTRATION BASIN	33586	98.8	100	100	4.78	34.83	1084.21	2.47	3.75
22. Bioretention Systems for Hodgson Brook. Colonial Drive and Schurman Avenue, Portsmouth, NH.	BIORETENTION	587.88	25.15	16.09	69.27	0.39	1.81	243.24	0.8	0.2

Table 3. Non-Structural Project Summary for PORTSMOUTH, NEW HAMPSHIRE

There are no non-structural BMPs.

Table 4. Land Use Conversion Project Summary for PORTSMOUTH, NEW HAMPSHIRE

There are no land use conversion projects.

State	NEW HAMPSHIRE
Municipality	ROCHESTER
Permit Type	MS4
Permit Number	
Major Watershed	N/A
TP Load Reduction Target	N/A
TN Load Reduction Target	N/A
TSS Load Reduction Target	N/A

Table 1. Project Summary Credit for ROCHESTER, NEW HAMPSHIRE

Project Type	Removed Phosphorus Load (lb/yr)	Removed Nitrogen Load (lb/yr)	Removed Sediment Load (lb/yr)
Structural	617.95	3326.33	261302.52
Non-Structural	0	0	0
Land Use Conversion	0	0	0
Total	617.95	3326.33	261302.52

Table 2. Structural Project Summary for ROCHESTER, NEW HAMPSHIRE

Project ID	BMP Type	BMP Storage Capacity (ft^3)/ Filter Depth (in.)	Phosphorus BMP Efficiency (%)	Nitrogen BMP Efficiency (%)	Sediment BMP Efficiency (%)	Removed Phosphorus Load (lb/yr)	Removed Nitrogen Load (lb/yr)	Removed Sediment Load (lb/yr)	Impervious Area Treated (ac)	Runoff Depth (in.)
105. SWT0182	INFILTRATION BASIN	35828.1	90	96	99	26.35	238.14	6145.98	16.45	0.6
106. SWT0183	INFILTRATION BASIN	1372.14	90	96	99	1.01	9.12	235.38	0.63	0.6
107. SWT0184	INFILTRATION BASIN	174.24	90	96	99	0.13	1.16	29.89	0.08	0.6
108. SWT0031	WET POND/CREATED WETLAND	32452.2	44	28	68	12.85	58.83	4447.44	14.9	0.6
109. SWT0095	WET POND/CREATED WETLAND	51183	44	28	68	20.27	92.78	7014.42	23.5	0.6
110. SWT0053	EXTENDED DRY DETENTION POND	4726.26	9	8.56	40	0.38	2.62	381.01	2.17	0.6
111. SWT0091	WET POND/CREATED WETLAND	44932.14	44	28	68	17.79	81.45	6157.77	20.63	0.6

112. SWT0097	WET POND/CREATED WETLAND	20298.96	44	28	68	9.51	36.8	2781.89	9.32	0.6
113. SWT0108	WET POND/CREATED WETLAND	8886.24	44	28	68	3.52	16.11	1217.82	4.08	0.6
114. SWT0185	INFILTRATION BASIN	87.12	90	96	99	0.06	0.58	14.94	0.04	0.6
115. SWT0186	INFILTRATION BASIN	370.26	90	96	99	0.27	2.46	63.51	0.17	0.6
116. SWT0188	INFILTRATION BASIN	2134.44	90	96	99	1.57	14.19	366.14	0.98	0.6
117. SWT0187	INFILTRATION BASIN	566.28	90	96	99	0.42	3.76	97.14	0.26	0.6
118. SWT0065	EXTENDED DRY DETENTION POND	2047.32	9	8.56	40	0.17	1.13	165.05	0.94	0.6
119. SWT0068	EXTENDED DRY DETENTION POND	1219.68	9	8.56	40	0.12	0.68	98.32	0.56	0.6
120. SWT0139	EXTENDED DRY DETENTION POND	5728.14	9	8.56	40	0.46	3.17	461.78	2.63	0.6
121. SWT0144	GRAVEL WETLAND	92303.64	51	57	91	38.47	364.28	14554.35	42.38	0.6

122. SWT0030	INFILTRATION BASIN	2809.62	90	96	99	2.28	17.46	560.58	1.29	0.6
123. SWT0069	INFILTRATION BASIN	22476.96	90	96	99	16.53	149.4	3855.72	10.32	0.6
124. SWT0041	WET POND/CREATED WETLAND	63423.36	44	28	68	22.81	122.96	7472.93	29.12	0.6
125. SWT0175	GRASS SWALE (CONVEYANCE)	225902.16	13	8.56	70	26.43	125.14	31869.53	103.72	0.6
126. SWT0175	GRASS SWALE (CONVEYANCE)	225902.16	13	8.56	70	26.43	125.14	31869.53	103.72	0.6
127. SWT0059	GRASS SWALE (CONVEYANCE)	98075.34	13	8.56	70	11.47	54.33	13836.14	45.03	0.6
128. SWT0003	WET POND/CREATED WETLAND	22498.74	44	28	68	8.91	40.78	3083.36	10.33	0.6
129. SWT0008	WET POND/CREATED WETLAND	36198.36	44	28	68	13.02	70.18	4265.11	16.62	0.6
130. SWT0013	WET POND/CREATED WETLAND	8820.9	44	28	68	3.49	15.99	1208.87	4.05	0.6
131. SWT0020	WET POND/CREATED WETLAND	179358.3	44	28	68	64.5	347.71	21133.09	82.35	0.6

132. SWT0026	WET POND/CREATED WETLAND	120748.32	44	28	68	47.81	218.88	16548.06	55.44	0.6
133. SWT0027	WET POND/CREATED WETLAND	283.14	44	28	68	0.11	0.51	38.8	0.13	0.6
134. SWT0028	WET POND/CREATED WETLAND	103433.22	44	28	68	40.96	187.49	14175.1	47.49	0.6
135. SWT0029	WET POND/CREATED WETLAND	1350.36	44	28	68	0.53	2.45	185.06	0.62	0.6
136. SWT0043	WET POND/CREATED WETLAND	588.06	44	28	68	0.28	1.07	80.59	0.27	0.6
137. SWT0045	WET POND/CREATED WETLAND	2940.3	44	28	68	1.16	5.33	402.96	1.35	0.6
138. SWT0046	WET POND/CREATED WETLAND	27159.66	44	28	68	10.75	49.23	3722.12	12.47	0.6
139. SWT0047	WET POND/CREATED WETLAND	24132.24	44	28	68	9.56	43.74	3307.22	11.08	0.6
140. SWT0048	WET POND/CREATED WETLAND	914.76	44	28	68	0.36	1.66	125.36	0.42	0.6

141. SWT0049	WET POND/CREATED WETLAND	3550.14	44	28	68	1.41	6.44	486.53	1.63	0.6
142. SWT0054	WET POND/CREATED WETLAND	8385.3	44	28	68	3.32	15.2	1149.17	3.85	0.6
143. SWT0056	WET POND/CREATED WETLAND	22629.42	44	28	68	8.96	41.02	3101.27	10.39	0.6
144. SWT0057	WET POND/CREATED WETLAND	4791.6	44	28	68	1.9	8.69	656.67	2.2	0.6
145. SWT0058	WET POND/CREATED WETLAND	5488.56	44	28	68	2.17	9.95	752.18	2.52	0.6
146. SWT0060	WET POND/CREATED WETLAND	12806.64	44	28	68	5.07	23.21	1755.1	5.88	0.6
147. SWT0061	WET POND/CREATED WETLAND	24001.56	44	28	68	9.5	43.51	3289.32	11.02	0.6
148. SWT0062	WET POND/CREATED WETLAND	8668.44	44	28	68	3.43	15.71	1187.97	3.98	0.6
149. SWT0063	WET POND/CREATED WETLAND	28205.1	44	28	68	11.17	51.13	3865.39	12.95	0.6

150. SWT0066	WET POND/CREATED WETLAND	4595.58	44	28	68	1.82	8.33	629.81	2.11	0.6
151. SWT0067	WET POND/CREATED WETLAND	12610.62	44	28	68	4.99	22.86	1728.23	5.79	0.6
152. SWT0071	WET POND/CREATED WETLAND	54297.54	44	28	68	25.45	98.42	7441.26	24.93	0.6
153. SWT0080	WET POND/CREATED WETLAND	34804.44	44	28	68	13.78	63.09	4769.81	15.98	0.6
154. SWT0092	WET POND/CREATED WETLAND	6751.8	44	28	68	2.67	12.24	925.31	3.1	0.6
155. SWT0098	WET POND/CREATED WETLAND	40249.44	44	28	68	15.94	72.96	5516.02	18.48	0.6
156. SWT0129	WET POND/CREATED WETLAND	4573.8	44	28	68	1.81	8.29	626.82	2.1	0.6
157. SWT0131	WET POND/CREATED WETLAND	6098.4	44	28	68	2.41	11.05	835.76	2.8	0.6
158. SWT0133	WET POND/CREATED WETLAND	13960.98	44	28	68	5.53	25.31	1913.3	6.41	0.6

159. SWT0134	WET POND/CREATED WETLAND	17685.36	44	28	68	7	32.06	2423.71	8.12	0.6
160. SWT0135	WET POND/CREATED WETLAND	10606.86	44	28	68	4.2	19.23	1453.63	4.87	0.6
161. SWT0136	WET POND/CREATED WETLAND	21453.3	44	28	68	8.49	38.89	2940.09	9.85	0.6
162. SWT0147	WET POND/CREATED WETLAND	18447.66	44	28	68	7.3	33.44	2528.18	8.47	0.6
163. SWT0150	WET POND/CREATED WETLAND	3528.36	44	28	68	1.27	6.84	415.73	1.62	0.6
164. SWT0151	WET POND/CREATED WETLAND	1698.84	44	28	68	0.61	3.29	200.17	0.78	0.6
165. SWT0004	WET POND/CREATED WETLAND	67626.9	44	28	68	24.32	131.11	7968.21	31.05	0.6
166. SWT0180	INFILTRATION BASIN	2003.76	90	96	99	1.62	12.45	399.8	0.92	0.6
167. SWT0064	WET POND/CREATED WETLAND	2700.72	44	28	68	1.07	4.9	370.12	1.24	0.6

Appendix G

MAAM Invoices

V# 12808-Remit-17
Inv#UNH#14-B951
$99,000.00

University of New Hampshire

CIP MAAM Accounts
55026020-771000-22575 = $65,615.78
55026020-771000-23569 = $33,384.23

UNH Sponsored Programs Administration

51 College Road
Room 109
University of New Hampshire
Durham, NH 03824-3585

INVOICE

BILL TO: City of Rochester
for MAAM
Attention: Katie Ambrose
Address:
Rochester City Hall
31 Wakefield Street
Rochester, NH 03867

DATE: January 3, 2023

TERMS Due on receipt

Re: Piscataqua Region
Monitoring Collaborative
(PRMC) – IMA FY23
Contribution#1

Description	AMOUNT
In support of the field season 2023 PRMC monitoring activities:	
Estuarine Water Quality Monitoring – Expanded temporal and/or spatial scope of ongoing estuarine water quality monitoring program for a more comprehensive understanding of water quality patterns.	$64,000
External Advisors: Monitoring Program Review – Funding for engaging external advisors to review and provide guidance on the overall monitoring program.	$10,000
Tributary Discharge Measurements – Estimating river discharge measurements on the Bellamy, Great Works, and Salmon Falls Rivers. This study is a stated commitment in the MAAM AMP.	$ 5,000
Estuarine Water Quality Monitoring Equipment – Funding will be used to buy new sondes for continuous data collection at the estuarine water quality locations.	$ 20,000
TOTAL BALANCE DUE	**$99,000**

Please make checks payable to:
University of New Hampshire

**Please reference "UNH #14B951" on your remittance.*

Please mail to:
UNH Sponsored Programs Administration
51 College Road, Room 109
University of New Hampshire
Durham, NH 03824-3585

(Tax ID#02-6000937)

Kathryn Ambrose

Digitally signed by Kathryn Ambrose
DN: DC=local, DC=Rochester, OU=ROCH-Staff, OU=CM, CN=Kathryn Ambrose, E=Katie.Ambrose@rochesternh.gov
Reason: I am approving this document with my legally binding signature
Location:
Date: 2023.01.25 09:40:27-05'00'
Foxit PDF Editor Version: 12.0.0

MAAM CIP
55026020-771000-23569

V#12808-17
PRMC2023-#2
$335,700.00

University of New Hampshire

UNH Sponsored Programs Administration

51 College Road
Room 109
University of New Hampshire
Durham, NH 03824-3585

INVOICE

BILL TO: City of Rochester
for MAAM
Attention: Katie Ambrose
Address:
Rochester City Hall
31 Wakefield Street
Rochester, NH 03867

DATE: February 7, 2023

TERMS Due on receipt

Re: Piscataqua Region
Monitoring Collaborative
(PRMC) – IMA FY23
Contribution#2

Description	AMOUNT
In support of the field season 2023 PRMC monitoring activities:	
Light Array Program – Continuation of work that started in 2021 and will continue annually. Provides high resolution data on the light environment in the estuary and fills an important data gap.	$ 42,000
Tier 1 Seagrass Monitoring – Continuation of annual aerial imagery mapping of seagrass in GBE.	$ 75,000
Storm Add-on to Eelgrass Stressor Project – Implementation of a study to investigate the impacts of storm events and inputs on water quality in GBE. This study would collect data to help fill an important data gap.	$ 91,000
Table 1 Contingency – Budget for additional unanticipated costs. Discretionary contingency not included.	$ 14,100
Turbidity Monitoring – Work will focus on collecting data on turbidity and light attenuating components, expanding on data collection conducted in 2022. This study will collect important data on non-nutrient stressors and light dynamics.	$ 67,000
Macroalgal Dynamics – Work will focus on compiling, reviewing, and synthesizing work done to date related to green and red macroalgae in GBE, identifying data gaps related to macroalgae as potential stressors to eelgrass, and development of a monitoring plan to close data gaps (if needed).	$ 25,000
Table 2 Contingency – Budget for additional unanticipated costs. Discretionary contingency not included.	$ 4,850
Shoreline Hardening Survey – A survey to determine the location and extent of hardened shoreline in GBE. Shoreline hardening impacts hydrodynamics, sediment movement, and water quality, all of which can impact eelgrass health. Results of this survey could help inform the analysis and interpretation of the water quality and hydrodynamic studies, and may be useful in identifying and management of non-point source stressors.	$ 15,000
Table 3 Contingency – Budget for additional unanticipated costs. Discretionary contingency not included.	$ 1,750
TOTAL BALANCE DUE	**$335,700**

Kathryn Ambrose

Digitally signed by Kathryn Ambrose
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Reason: I am approving this document with my legally binding signature
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University of New Hampshire

UNH Sponsored Programs Administration

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Room 109
University of New Hampshire
Durham, NH 03824-3585

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UNH Sponsored Programs Administration
51 College Road, Room 109
University of New Hampshire
Durham, NH 03824-3585

(Tax ID#02-6000937)

V# 12808-15
Inv# MAAM-PTAP-1
$8,500.00

University of New Hampshire

MAAM CIP
55026020-771000-21568 = $1,075.39
55026020-771000-22575 = $7,424.61

Department of Civil and Environmental Engineering

Gregg Hall,
35 Colovos Road
Durham, NH 03824
V: 603.862.1445
email: james.houle@unh.edu
Web address: www.unh.edu/unhsc

6-01-2022

To:

Municipal Association for Adaptive Management (MAAM)

Invoice:

Training: Multiple trainings have been offered for MAAM communities on use and applicability of PTAP products. Towns include Milton, Rollinsford, Portsmouth, and Exeter. Trainings also provided updates necessary for more effective database utility which were subsequently programed in the database.

Invoice period Oct 2021 – May 2022

Total Invoice Amount: --- $8,500.00

Remaining Balance: $41,500

James Houle, PhD., CPSWQ, CPESC
Associate Research Professor
The UNH Stormwater Center
Dept of Civil and Environmental Engineering
35 Colovos Road
University of New Hampshire
Durham, NH 03824

Finance Notes: Received 9/16/2022

Kathryn L Ambrose

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Reason: I am approving this document with my legally binding signature
Date: 2022-09-19 09:16:17
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V# 12808-15
Inv# MAAM-PTAP-2
$28,500.00

University of New Hampshire

MAAM CIP
55026020-771000-22575

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Web address: www.unh.edu/unhsc

9-01-2022

To:

Municipal Association for Adaptive Management (MAAM)

Invoice:

Training: Multiple trainings have been offered for MAAM communities on use and applicability of PTAP products. Upgrades to PTAP data controls have been made and users have been trained to use products more effectively. Final reports have been developed for all PTAP towns and are available here:
https://drive.google.com/drive/folders/12eixbpQD97ziFLlF2uGkfSQdhrK0vZSK?usp=sharing

Invoice period June 2022 – September 2022

Total Invoice Amount: -- $28,500.00

Remaining Balance: $13,000

James Houle, PhD., CPSWQ, CPESC
Associate Research Professor
The UNH Stormwater Center
Dept of Civil and Environmental Engineering
35 Colovos Road
University of New Hampshire
Durham, NH 03824

Finance Notes: Received 9/16/2022

Kathryn L Ambrose

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Reason: I am approving this document with my legally binding signature
Date: 2022-09-19 09:17:00
Foxit PhantomPDF Version: 9.7.0

MAAM
55026020-771000-23569

V# 12808 -REMIT 15
Inv UNHSC-PTAP#3
$20,000.00

University of New Hampshire

Department of Civil and Environmental Engineering
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Durham, NH 03824
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5/15/2023

Invoice:

Training: Multiple training courses for the project were developed and delivered to project sponsors.

Reporting: Reports were also developed and available for all participating communities.

Maintenance: Ongoing database maintenance and management has been delivered.

Total Invoice Amount: --- $20,000

James Houle, PhD., CPSWQ, CPESC
Associate Research Professor
The UNH Stormwater Center
Dept of Civil and Environmental Engineering
35 Colovos Road
University of New Hampshire
Durham, NH 03824

Finance Notes: Received 5/15/2023

Kathryn Ambrose

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Reason: I am approving this document with my legally binding signature
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Date: 2023.05.16 08:57:28-04'00'
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Appendix H

Settlement Agreement By and Between Conservation Law Foundation and Cities of Dover, Rochester, and Portsmouth

SETTLEMENT AGREEMENT BY AND BETWEEN CONSERVATION LAW FOUNDATION AND CITIES OF DOVER, ROCHESTER, AND PORTSMOUTH

The Cities of Dover, Rochester, and Portsmouth (collectively "the Municipalities") and the Conservation Law Foundation, Inc. ("CLF"), for good and valuable consideration mutually exchanged and acknowledged, hereby enter into this Settlement Agreement ("Agreement") by and between as follows:

WHEREAS, in January 2020, the United States Environmental Protection Agency (Region 1) ("EPA") issued the "Draft National Pollutant Discharge Elimination System (NPDES) Great Bay Total Nitrogen General Permit for Wastewater Treatment Facilities in New Hampshire" (NPDES Permit No. NHG58A000) (hereinafter "Draft General Permit");

WHEREAS, the Municipalities, CLF, and other interested parties submitted extensive written comments on the Draft General Permit;

WHEREAS, on November 24, 2020, EPA issued the final Great Bay Total Nitrogen General Permit (NPDES Permit No. NHG58A000) (the "General Permit") along with EPA's Fact Sheet and Response to Public Comments, each *available at* https://www.epa.gov/npdes-permits/great-bay-total-nitrogen-general-permit;

WHEREAS, Part 2 of the General Permit contains final effluent limitations and monitoring requirements for each Permittee's wastewater treatment facility ("WWTF") similar to those in the draft permit, although with more recent (updated) flow data and, in keeping with scientific knowledge and past EPA permitting practice, a total nitrogen load limit based on the growing season of eelgrass;

WHEREAS, Part 3 of the General Permit provides for the voluntary submission of a proposal, within 180 days of the effective date of the permit, outlining: (1) an approach to ambient water quality monitoring to determine progress and trends; (2) a method of tracking total nitrogen reductions and additions over the course of the permit; (3) an outline/plan for overall source reductions of total nitrogen over the course of the permit; (4) an inclusive and transparent process for comprehensively evaluating significant scientific and methodological issues relating to the permit, including the assumption of a load-based threshold of 100 kg ha^{-1} yr^{-1} versus any other proposed threshold that might be used for future permitting or planning purposes, including a concentration-based threshold of .32 mg/L;

WHEREAS, the Municipalities may choose to Opt-In to the General Permit and become permittees (the "Permittees");

WHEREAS, EPA's Responses to Comments accompanying the General Permit state that the "assessment of progress on nonpoint source reductions could lead EPA to reissue an adaptive management permit if reasonable grounds exist to do so, or to abandon that approach in favor of a more traditional one insofar as insufficient progress is being made on necessary nonpoint source reductions";

WHEREAS, the Municipalities have opted, or are expected to opt, into the General Permit;

WHEREAS, the Municipalities, along with other permittees, have begun the work of developing an Adaptive Management Plan for submission to the EPA by July 31, 2021;

WHEREAS, CLF has considered appealing EPA's final agency action to issue the General Permit;

WHEREAS, CLF, Dover, Rochester, and Portsmouth have, in good faith, engaged in a facilitated process to reach a negotiated resolution of the General Permit and its administration;

WHEREAS, this Agreement is a resolution of a dispute between the parties relative to the value of the General Permit to achieve a measurable environmental benefit.

NOW THEREFORE, the Parties, for themselves, their successors and assigns, enter into this Agreement for the purposes described above on the terms set forth below:

1. Recitals: The above recitals are incorporated herein by reference.

2. Definitions:

"Consult" or "consultation": Any requirement in this Agreement to "consult" or engage in "consultation" means that the party actor solicits non-binding input, information, or commentary. "Consult" or "consultation" does not in any way mean or imply an approval authority is needed from the party who is being consulted. A party required to "consult" or seek "consultation" with another party retains sole discretion concerning the matter for which consultation is made.

"Eelgrass growing season": The eelgrass growing season refers to that period of each calendar year from April 1 to October 31.

"IMA" or "IMA Group": IMA or IMA group refers to those municipalities who have or are expected to formally execute the Intermunicipal Agreement for Development of an Adaptive Water Quality Management Plan for Great Bay Estuary. Dover, Rochester, Portsmouth, Milton, Newington, and Exeter, so far, have indicated a willingness to execute the IMA, while others have the IMA under consideration.;

"Structural Best Management Practices": A measure or facility intended to treat, prevent, and/or reduce water pollution through installation of a permanent or semi-permanent structure that is either stand-alone or part of a larger construction project.

"Nonstructural Best Management Practices": A measure, facility, practice, or action intended to treat, prevent, and/or reduce water pollution through any means other than a structural best management practice.

3. Purpose: The overriding purpose of this Agreement is to collaboratively implement a plan and set forth commitments between the Municipalities and CLF to improve water quality in the Great Bay Estuary and to take such further collaborative actions in compliance with, and furtherance of, the General Permit and the goals stated in the General Permit and associated Fact Sheet and Response to Comments. For purposes of clarity, this Agreement is solely entered into by Dover, Rochester, and Portsmouth in their capacity as individual communities, and not on behalf of the IMA group of municipalities, and this Agreement does not bind the unincorporated association of Permittees forming the IMA group.

4. Term: This Agreement is effective on the date last signed by all parties and will expire on February 28, 2026. However, any individual Municipality shall no longer be subject to this Agreement if and when that individual Municipality withdraws from or otherwise loses coverage under the General Permit.

5. IMA Executive Board Meetings:

   a. RSA 91-A: The Municipalities agree that, in conducting any and all meetings of the Executive Board of the IMA, the Municipalities will ensure that the requirements of New Hampshire RSA chapter 91-A are observed and followed, so long as not inconsistent with applicable law.

   b. Participation by Stakeholder Committee: The Municipalities agree to specifically invite one designated representative of the Stakeholder Committee (discussed below) to attend and speak at all Executive Board and IMA Member meetings, unless such meeting, or portion thereof, is a non-meeting and/or non-public meeting within the meaning of New Hampshire RSA chapter 91-A. In appropriate circumstances determined by the Executive Board of the IMA, the designated representative of the Stakeholder Committee may be permitted to enter into a non-disclosure agreement to enable the Stakeholder Committee's representative to attend an otherwise non-public meeting. Nothing within this provision is intended to limit the Executive Board's ability to adopt reasonable time, place, and manner requirements concerning the public's right to speak or participate in public meetings of the Executive Board.

   c. Meeting Frequency: Dover, Rochester, and Portsmouth agree to use best efforts to ensure that meetings of the IMA Executive Board and meetings of IMA Members occur at least twice per calendar year, beginning in calendar year 2022.

6. Stakeholder Committee: CLF agrees to establish a Stakeholder Committee separate from the IMA (and not a committee, sub-committee or subsidiary body of the IMA) consisting of organizations and entities with a demonstrated interest in the health, sustainability, and resilience of the Great Bay ecosystem. CLF will engage in best efforts to include one or more members of the business and real estate community. The role of the Stakeholder Committee will be to provide input, perspective, information, review, and monitoring of the IMA activities. The Stakeholder Committee may submit a request for funding or particular cost items as part of the annual IMA budget, though the Municipalities do not hereby guarantee or make any representation herein that such a budget provision will be approved.

7. Tracking Nitrogen Reductions/Additions:

   a. PTAPP: The Municipalities expect that participation in the NHDES Pollutant Tracking and Accounting Pilot Project ("PTAPP") or an equivalent methodology/system will comprise the Municipalities' system and methodology for tracking total nitrogen additions and reductions, an identified part of the adaptive management plan in Part 3 of the General Permit. The Stakeholder Committee may submit any information it deems relevant to the Municipalities' forthcoming submittal of a proposed system and methodology for the aforesaid tracking.

   b. Periodic Consultation: After submitting the adaptive management plan due to EPA by July 31, 2021, the Municipalities or their designee shall thereafter consult with the Stakeholder Committee's designated representative to discuss the Municipalities' planning and execution of ambient water quality monitoring, data gathering, and water quality analysis.

   c. Annual Reporting to IMA: At least two weeks prior to the annual IMA Member meeting each year, and at least two weeks prior to any second meeting of the IMA that takes place in a given year, the Municipalities shall develop a report (to be publicly presented at said IMA Member meeting) on the following:

      i. Structural & Non-structural BMPs planned for the next year including, as applicable, location, estimated cost, and estimated reductions in total nitrogen and/or other pollutants to the extent known or capable of being estimated.

      ii. Structural & Non-structural BMPs implemented during past year including, as applicable, location, cost, and estimated or known reductions in total nitrogen and/or other pollutants to the extent known or capable of being estimated.

The Municipalities shall encourage other IMA Members to provide the information described in subparts i. and ii. of this subparagraph for inclusion in the report. To facilitate this reporting, the Municipalities will work with the Stakeholder Committee to develop a standardized dashboard to compile and present the data in a manner enabling consistent and uniform reporting of implemented and planned progress by the Municipalities individually and collectively. The Stakeholder Committee and CLF may utilize the nitrogen reductions from implementation of the structural and non-structural BMPs reported on the dashboard and Annual Reports as a measure of performance by the Municipalities.

8. Funding Sustainability: Recognizing that sustainable funding is imperative for ongoing water quality efforts, the Municipalities shall consider the adoption (by local ordinance or act) of a stormwater utility by December of 2023. The Stakeholder Committee may provide input or information to the Municipalities by way of either submitting written comments or providing verbal comments, if permitted, during any public speaking forum held by any public body of the Municipalities, and shall be provided notice of such comment opportunities.

9. Total Nitrogen Source Reductions: With respect to voluntary submission of an outline/plan for overall source reductions of total nitrogen over the course of the permit (as called for in Part 3 of the General Permit), the Municipalities and CLF recognize that such submissions are voluntary and are not due to EPA until July 31, 2021. Moreover, CLF and the Municipalities recognize that true adaptive management depends on flexibility and the ability to adapt as more information becomes available. The Municipalities agree to make a submission to EPA as envisioned in Part 3 of the General Permit, to be updated and refined at least annually from the date of first submission and thereafter resubmitted annually to EPA after each annual update. Moreover, the Municipalities also agree to the following features of their overall source reduction plan, as drawn from (i) the "Feasibility Analysis for USEPA's Draft Great Bay Total Nitrogen General Permit" dated May 8, 2020 and drafted by Robert M. Roseen[1], and (ii) letter from NHDES Commissioner Robert Scott to Dennis Deziel dated July 27, 2020[2]:

a) WWTF Effluent Measures: The Municipalities agree, as part of an overall source reduction plan for nitrogen, to consider, plan for, and implement measures, as funded by the governing bodies of each Municipality, that reduce nitrogen in the effluent from their respective WWTFs during the eelgrass

[1] In drawing from this study for purposes of settlement, the Municipalities do not indicate agreement with conclusions and assertions in that study, and reserve the right to disagree in part or in full with said study.

[2] The NHDES letter provides very helpful information and vision for forthcoming water quality project planning and ideas, though by referencing the NHDES letter here, the Municipalities do not adopt said letter, and reserve their rights and the flexibility accorded to them as outlined in Part 3 of the General Permit.

growing season. For example, the Municipalities may develop optimization plans and/or projects aimed at reducing inflow/infiltration, as selected by the Municipalities in their sole discretion.

b) Funding Opportunities: As recognized by NHDES, "[k]ey to many of the actions in the NGP is funding." NHDES Letter of July 27, 2020, at 3. The Municipalities' agree to work with NHDES and others to identify and pursue applicable state, federal, or private grants, subsidies, or other measures aimed at water quality improvements, subject to prior approval of the governing body of Dover, Rochester, and Portsmouth to accept and expend such funding.

c) Structural Best Management Practices: The Municipalities shall plan for and undertake structural best management practices ("BMPs"), as either part of other projects or as stand-alone projects, which improve water quality in the Great Bay Estuary through removal of nitrogen and other pollutants. The structural BMPs shall be the same or similar to those identified or exemplified within Dr. Roseen's report. The structural BMPs undertaken by the Municipalities may include one or more of the following features:

    i. Low Impact Development (LID) Structural BMPs that effectively disconnect impervious surfaces through the use of enhanced infiltration and/or that provide area-wide stormwater treatment.

    ii. Low maintenance designs with an emphasis on pretreatment.

    iii. Regular inspections and maintenance.

d) Non-Structural Best Management Practices: The Municipalities shall plan for and undertake non-structural BMPs as part of the overall total nitrogen source reduction plan submitted to EPA and updated at least annually. Non-structural BMPs may include measures such as the following:

    i. Adoption of stormwater ordinances (or site regulations) that require LID site planning and design strategies to reduce the discharge of stormwater from new development or re-development of private property;
    ii. Leaf and yard waste collection;
    iii. Street sweeping;
    iv. Catch basin cleaning and support programs;
    v. Agricultural strategies;
    vi. Buffer protection;

e) Pilot Testing of Structural or Nonstructural BMPs: The Municipalities agree to collectively fund and undertake pilot testing of innovative structural or non-structural BMPs, such as septic retrofit technology, as selected by the Municipalities in their sole discretion. The pilot testing shall be to determine the cost, feasibility, and efficacy of structural and nonstructural BMPs that the Municipalities have not, to date, attempted or utilized. The pilot testing, if successful, will improve future refinement of the overall source reduction plans and efforts by the Municipalities (and, presumably, other permittees).

f) Other Efforts: The Municipalities also agree to consider and, if authorized by their governing bodies, to undertake other efforts aimed at reducing total nitrogen loads to the Great Bay estuary, such as:

i. Urban fertilizer reduction efforts, including limiting the use and nitrogen content of fertilizers, voluntary incentive programs for residential and commercial properties to reduce fertilizer use, and advocacy for legislation as detailed in the NHDES letter of July 27, 2020 (p. 4);
ii. Oyster restoration, wetlands restoration, salt marsh restoration, and eelgrass restoration;
iii. Septic system retrofit programs;
iv. Septic system legislation, including statewide legislation as detailed in the NHDES letter of July 27, 2020 (p. 4).

10. Identified Water Quality Improvement Opportunities: In addition to the foregoing, the Municipalities have individually identified non-structural best management practices beyond current MS4 obligations; anticipated capital improvement projects and stand-alone projects with structural best management practices; as well as diverse initiatives intended to address water quality improvement in the Great Bay Estuary. These lists of water quality improvement opportunities are attached and incorporated to this Agreement as non-binding statements of present intent by the Municipalities. CLF understands and agrees that completion of these projects is dependent on the continued validity of the General Permit, purchasing approvals from governing bodies of the Municipalities and/or other public officials, funding appropriations of the respective Municipalities (which funding appropriations are at the sole discretion of the governing body of the respective Municipalities), and any other requirements of law, potentially including federal/state/local permitting. The parties recognize that the Municipalities may select projects that are likely to improve water quality, but for which nitrogen removal is only a partial benefit.

11. Petition(s) for Individual Permits: The Municipalities and CLF anticipate that the petition process under EPA's general permit regulations may be used by CLF to request that any owner or operator authorized by the General Permit, including one or more of the Municipalities, be covered instead by an individual permit, *see* 40 C.F.R. § 122.28(b)(3)(i). The Municipalities and CLF expect such petition or possibility thereof will function as a continuing check and incentive to ensure that reasonable further progress is being made by the Municipalities to identify and implement total nitrogen source reductions under the General Permit over its 5-year term. Implementation of these reductions is recognized as a principal assumption of the General Permit. In order to conserve limited resources, and to facilitate speedy resolution of disputes, the Municipalities and CLF agree that any such petition may be concise, briefly setting forth material facts relevant to EPA's consideration of the petition. Any petition shall provide a time-limited opportunity for the Municipality to cure any alleged defect in nonpoint source reduction planning and implementation and, if timely cured to CLF's satisfaction, CLF agrees to withdraw such petition. If the alleged defect is not timely cured to the CLF's satisfaction, CLF will request that EPA promptly act on the petition on the record before it (including any information that may be supplied by the Municipalities and CLF in a reasonably timely manner) and the Municipalities will assent to said request of EPA for prompt action to approve or disapprove the petition. CLF may file a petition for failure of the Municipalities to make reasonable progress towards nitrogen reductions as measured by Paragraph 10. The Municipalities' continued and timely implementation of the lists referred to in the paragraph above, or substantially equivalent efforts in terms of nitrogen reductions (including but not limited to total nitrogen load outputs falling below that permitted by the General Permit for Dover and Portsmouth), during the first three years of the permit term constitute prima facie evidence of reasonable progress towards nitrogen reductions during such time period for the purposes of any petition filed by CLF under 40 CFR § 122.28(b)(3)(i) ("Prima Facie Benefit"). By February 1, 2024, each Municipality shall separately submit to CLF an updated list of water quality improvement opportunities as described in the paragraph above, premised on their respective nitrogen reduction planning efforts that each Municipality is in the process of developing or updating. Based on these updated lists CLF may, in its discretion, extend the Prima Facie Benefit for up to the remaining duration of the permit term on a municipality-specific basis.

12. Additional Great Bay Water Quality Projects: The Municipalities agree to fund, collectively, the total amount of forty five thousand dollars ($45,000) for one or more not-for-profit Great Bay water quality-related projects or initiatives in calendar year 2021, as selected by the Stakeholder Committee and approved by the Municipalities. The Municipalities' approval of the aforesaid water quality projects shall not be unreasonably withheld. The payment and use of the $45,000, or any portion thereof, shall be subject to a mutually satisfactory grant agreement to be drafted by the parties

and executed by the Municipalities, CLF, and the recipient(s) of the $45,000 or any portion thereof.

13. Covenant not to appeal the General Permit: CLF hereby agrees and covenants not to appeal, contest, or otherwise assert any legal challenge to the General Permit. Nothing within this provision affects CLF's ability to timely appeal any final agency action on the petitions described in the preceding paragraph above. Nothing within this provision affects CLF's ability to comment on, appeal, contest, or otherwise challenge any future General Permit re-issuance, modification, or the issuance of an individual permit to Dover, Rochester, and/or Portsmouth. Nor does this provision in any way limit CLF's ability to engage in advocacy or any legal challenge with respect to municipalities that are not a party to this Agreement.

14. Enforceability/Binding/Fees: This Agreement shall be binding on all parties, including their corporate or entity parents, affiliates, successors and assigns. With the exception of petitions for individual permits discussed above (to be filed with EPA) or Clean Water Act citizen suits (to be filed in federal court), the exclusive venue for any disputes arising out of this Agreement shall be the Superior Courts of the State of New Hampshire, in either Rockingham County or Strafford County Superior Court. Each party shall bear their own litigation costs, attorney's fees, and/or expert fees in any such litigation. Prior to filing any action in Superior Court alleging a breach of this Agreement, the filing party shall provide the prospective defendant(s) with prior written notice of the alleged breach and a 30-day opportunity to cure any alleged violation.

15. Force Majeure. No party is considered in breach of this Agreement to the extent performance of their respective obligations is prevent by a force majeure event. "Force majeure event," for purposes of this Agreement, is defined as any event arising from causes beyond the control of the party that delays or prevents timely performance of any obligation under this Agreement despite the party's best efforts to fulfill the obligation. The requirement that the party exercise "best efforts to fulfill the obligation" includes using best efforts to anticipate any potential force majeure event and best efforts to address the effects of any such event (i) as it is occurring, and (ii) after it has occurred to prevent or minimize any resulting delay to the greatest extent possible.

16. Municipal Reservation of Rights: The General Permit includes an adaptive management framework at Part 3, which provides for an ongoing collaborative process. The adaptive management framework includes nitrogen monitoring and reductions elements as well as elements for comprehensively evaluating significant scientific and methodological issues and related load capacity determinations. Through the permitting process, the EPA has published data, analysis, and conclusions through fact sheets and response to comments related to elements subject

to review and revaluation through the adaptive management process. In entering into this Agreement, the Municipalities are not accepting such data, analysis, and conclusions or waiving their objections thereto. Without affecting the Municipalities' obligation to comply with the General Permit during its term, the Municipalities hereby reserve the right to contest any such data, analysis, and conclusions in future proceedings to the extent that ongoing collaboration and the adaptive management process do not satisfactorily resolve such matters.

17. Other Municipalities: This Agreement may be amended by mutual agreement of the parties to include other municipalities who would like to join it for purposes of paragraphs 10 and 11.

18. Other:
   a. This Agreement, which may be executed in a number of counterparts, each of which shall be deemed an original, constitutes the entire agreement and understanding between the parties and supersedes all prior agreements and understandings relating hereto.
   b. This Agreement may be amended only by written Amendment signed by the Parties
   c. If any provision of this Agreement is deemed invalid or unenforceable, the remaining provisions shall remain in full force and effect.
   d. This Agreement shall be governed by and interpreted in accordance with the laws of the State of New Hampshire.
   e. This Agreement may be executed in two or more counterparts, each of which shall be deemed an original, but all of which together shall constitute one and the same instrument.
   f. This Agreement shall be deemed to have been jointly drafted by the parties.
   g. The signatories below expressly represent and warrant that they are authorized and empowered to enter into this Agreement.
   h. This Agreement shall be a public record on file with the City Clerk of each of the Municipalities.

[SIGNATURES FOLLOW]

City of Dover

J. Michael Joyal, Jr.
City Manager
2021.03.25 18:40:48
-04'00'

By: ______________________ *Dated:* ______________________

J. Michael Joyal, Jr., City Manager

City of Rochester

DocuSigned by:
B4F9B7BC7D0C4EB...

By: ______________________ *Dated:* 3/26/2021

Blaine Cox, City Manager

City of Portsmouth

By: ______________________ *Dated:* 3/26/2021

Karen Conard, City Manager

Conservation Law Foundation, Inc.

By: ______________________ *Dated:* 3/26/2021

Thomas F. Irwin, Vice President, Director CLF New Hampshire

3.24.2021

Attachment

Dover Overall Source Reduction Projected Project List[1]

[1] This list is a statement of present intent, is illustrative, and is non-binding. The estimated costs and estimated nitrogen reduction stated below are based on current best estimates and assumptions, and are not intended as binding commitments or as performance guarantees.

Structural Best Management Practices

Fiscal Year	Project	Description	Projected Reduction (lb/yr)	Estimated Cost
Ongoing	I/I	Inflow and Infiltration into the sewer collection system results in elevated peak flows through the WWTP biological system which can affect the nutrient reduction capacity during those events. The City continues to invest heavily in reducing I/I from the collection system	6,008[2]	
2022-2026	Court, Union, and Middle Streets	Capital Improvement Plan work to improve drainage to include BMPs	45[3]	$1,125,000
2022-2024	Fifth and Grove Streets	Capital Improvement Plan work to improve drainage to include BMPs	26[4]	$275,000
2022-2025	Oak Streets	Capital Improvement Plan work to improve drainage to include BMPs	412[5]	$250,000
2026	Atlantic Ave.	Capital Improvement Plan work to improve drainage to include BMPs	17[6]	$375,000
2026	Horne Street	Capital Improvement Plan work to improve drainage to include BMPs	35[7]	$62,500
Planning	Henry Law Park	City is currently looking for funding opportunities to design	568[8]	

[2] Assumption: A storm event causes the effluent to peak to 14 mg/l - assume storm event happens 12 times per year for 2 days each - assume I/I work reduces peak to 8 mg/l - assume during this peak time the flow rate is 5 mg. Equation: LB/YR=6mg/l*5MGD*8.345*24 day/yr

[3] Assumption: Ability to treat approximately 50% of the length of street (5000lf), and associated 60' wide buffer of residential area, with 60% reduction, use Highway rate and residential rate. Equation: LB/YR = Area * NLER*0.6

[4] Assumption: Ability to treat approximately 50% of the length of street (3000lf), and associated 60' wide buffer of residential area, with 60% reduction, use Highway rate and residential rate. Equation: LB/YR = Area * NLER*0.6

[5] Assumption: Ability to treat approximately 50% of the neighborhood area (87 acres) use residential rate. Equation: LB/YR = Area * NLER*0.6

[6] Assumption: Ability to treat approximately 50% of the length of street (2000lf), and associated 60' wide buffer of residential area, with 60% reduction, use Highway rate and residential rate. Equation: LB/YR = Area * NLER*0.6

[7] Assumption: Ability to treat approximately 50% of the length of street (4000lf), and associated 60' wide buffer of residential area, with 60% reduction, use Highway rate and residential rate. Equation: LB/YR = Area * NLER*0.6

[8] Assumption: Ability to treat approximately 50% of the neighborhood area (120 acres) use residential rate. Equation: LB/YR = Area * NLER*0.6

		and construct an innovative, Nitrogen focused Water Quality BMP in the Henry Law Park area. This would be able to capture and provide treatment for approximately 120 acres of highly urbanized commercial and residential areas in the City's Downtown.		

Non-Structural Best Management Practices

Fiscal Year	Project	Description	Projected Reduction (lb/yr)	Estimated Cost
Ongoing	Street Sweeping	The City sweeps the downtown streets approximately 1 time a week. The MS4 permit only requires cleaning twice per year.	43[9]	
Ongoing	Catch Basin Cleaning	Catch Basins are cleaned semi-annually regardless of whether they have reached the MS4 triggering thresholds of 1/2 full sump.	17[10]	
Ongoing	Slow Release nitrogen requirement for all new projects	As part of Site Plan approval, a maintenance plan shall be in place and *"Best practices to minimize environmental impacts, such as the use of low-phosphorus fertilizer and slow-release nitrogen, shall be included in the management plan."*	350[11]	
Ongoing	Water Quality BMP's as standard practice for city reconstruction projects	This is the language from our standard RFQ for design of reconstruction projects: *"As part of the drainage improvements, the City wishes to enhance the drainage system and incorporate easily maintainable, low impact development strategies to provide conveyance, treatment, and infiltration where practical. The Consultant shall make recommendations for an improved drainage system."* The commitment to implementing the water quality work is demonstrated in several recent redevelopment projects.		

[9] Assumption: mechanical, weekly, 9 months, estimate of swept area (50 miles, 30' wide average) use Highway NLER = 10.5. Equation: LB/YR =IA*NLER*0.03*9/12

[10] Assumption: Per Hot Spot Map info, there is 108 ac of city owned impervious area. Assume 1/4 of that area drains to a CB that is cleaned regularly use highway NLER 10.5. Equation: lb/yr = IA*NLER*.06

[11] Assumption: Impact 10 acers of development with reduction assumptions same as above. Equation: lb/yr = Turf Area *1/1000*.9

Ongoing	Ordinances	Threshold for stormwater implementation with 50% nitrogen limits is set at 20,000 square feet or creates more than 4,000 square feet of new impervious area. This is much more stringent than the MS4 requirements which only pertain to disturbance over an acre	75[12]	
2021	Catch Basin Spoils Facility	Capital Improvement plan work to create a facility to clean and treat the liquid/debris from the catch basin maintenance program. Potential to open for other communities to use in the future.		$3,5000,000
2021	SRF Loan for Chapel St. Ravine	Working to incorporate water quality treatment and flood management downstream of substantial stormwater culvert		
Ongoing	Buffers	Ordinance has increased the wetland buffers gaining credit for going green project that shows added nitrogen removal.		
Ongoing	Yard Waste Program	Leaf pick up 6 times annually	95[13]	
Planning	Leaf Pick Up	Bulk leaf pick up program	766[14]	

[12] Assumption: 10 acres of redevelopment a year that fall within the delta between what is required per MS4 and what is included per City of Dover. Assume Commercial Runoff rates apply to all. Equation: LB/YR = Area * NLER*0.5

[13] Assumption: the folks using the leaf removal program are the ones who own residential for 100' along to the 50 miles of city roadway. Assume 10% use the services. Equation: LB/YR = Area * NLER*0.05

[14] Assumption: Increases the area to 80% using service. Equation: LB/YR = Area * NLER*0.05

Innovative Efforts/ Pilot Programs

Fiscal Year	Project	Description	Projected Reduction (lb/yr)	Estimated Cost
Ongoing	Professional Staff	The City has created an Environmental Project Manager Position. This positions focus is dedicated entirely to environmental improvements, including a commitment to the protection and improvement of the Great Bay. This person is taking an active role in organizing regional commitment and implementation of the MS4 permit and the new NGP permit. Just this year, this person participated and was acceded through the NOFA Organic Land Care Program. Additionally, other staff members, particularly Bill Boulanger, is regularly recognized for contributions to innovative stormwater quality improvements and environmental stewardship.		
Ongoing	Training and Commitment to Innovation	Leadership in NEWEA/ Biological Nutrient Removal Classes - Our WWTP staff are at the forefront of discussions for WWTP practices. Ray Vermette acts as president of NEWEA and has traveled around the world looking at innovative technologies and bring them to Dover.		
Ongoing	Organic Fertilizer Program	The city is committed to using only organic, slow-release fertilizers on city owned and maintained properties.	800[15]	
Ongoing	Commitment to exploring new BMP's and participating in innovative initiatives	Berry Brook and the continuation of bringing new BMP's into urban redevelopment settings and working with UNHSWC to test the effect, Volunteering to work with the NHDES/Prep Fellowship team to investigate SAFE strategies for Stormwater Funding, Volunteer to work with SRPC to analyze urban trees and innovative tree box filters, Volunteer to work with SRPC to look at BMP's v/s socioeconomic disparities, participating in the PTAP program, participating in multiple		

[15] Assumption: City maintains 1,000,000 sf of turf. Assume regular application rate for nitrogen of 1 lb/1,000 sf. Assume organic cuts the runoff by 80%. Equation: lb/yr = Turf Area *1/1000*.8

		credit for going green projects lead by PREP		
Summer 2021	Fertilizer Bans and Reductions	Supporting a statewide ban of high nitrogen synthetic fertilizers		
Ongoing	Outreach and Education	The City outreach and education exceeds what is required by the MS4. Staff regularly hold tours or presentations of the innovative BMP's being implemented. Additionally, we are working on a video for the installation of a filtering catch basin BMP. Staff also regularly speak at conferences about technologies and particularly focus on maintenance and long-term performance.		
2021	Climate Adaptation Grant	As part of Climate Adaptation work with the SRPC, city committed to installing a new catch basin filtering device with a tree - similar to a tree-box filter but with improved maintenance capacity	5	
Planning	Sewer System	Advocate for a state-wide requirement to remove nitrogen in septic systems.	381[16]	
Planning	Extending Sewer to Septiced areas	Continually assessing opportunities		

[16] Assumes 20 new septic a year - 60% reduction achieved.

PRIVILEGED & CONFIDENTIAL DRAFT

ROCHESTER, NH - Nitrogen Stormwater and Non-Point Source Reduction Projects

	Project Type	Project / Activity	Project Description	Estimated Load Reduction (lbs/N/yr)[1]	Notes / Additional Benefits
	Structural BMPS				
1		Structural SW BMPs[3]	City installs structural water quality best management practices (BMPs) in highway capital improvement projects, with a goal of treating 100% of the impervious cover. The City also maintains stormwater BMPs installed as part of private development when the City takes ownership of the road/utilities. Upcoming projects that will include stormwater structural practices include: 1. **Colonial Pines Drainage Improvements** - (project related to sewer extensions, below) 2. **Woodman Area Infrastructure Improvements** 3. **Stafford Square Roundabout Installation** 4. **Union Street Parking Lot Reconstruction**[2] - will incorporate water quality treatment practices. 5. **Wakefield Street Reconstruction**[2] - rehabilitation of infrastructure on Wakefield Street from Union Street to Chestnut Hill Road - rehabilitation of sidewalks, pavement and drainage improvements.	TBD	City is currently calculating the estimated nitrogen reductions for each of these projects which will be supplemented.
2		Sewer Extensions	City is in the middle of a sewer extension project (Colonial Pines) that could connect up to 225 homes, currently serviced by septic system, to sewer in an area of the City with high groundwater and a history of failed septic systems. To date 90 homes have been connected through Phase 2. Phase 3 is ongoing and could connect up to another 70 homes. Phase 4 could connect up to 65 homes to the sewer.[2]	1,154	Assumes nitrogen reductions for 225 homes @ 5.13 lbs/prop/yr.
3		Stormwater Outfall Restoration	Construct outfall improvements associated with Woodman Area Infrastructure Improvements. Review capital improvement projects to identify locations where erosion occurs at outfalls and/or where storm water quality improvements can be made.	N/A	Improvements will have secondary reductions in TSS.
	Non-Structural BMPs				
4		Catch Basin Cleaning	City will clean catch basins to ensure that sumps are no more than 50% full at any time. City collects leaf litter and organic waste along curbed streets, once per month as part of the street sweeping program, in the months of April, May, October and November. City/Waste Management also provides curb side collection of bagged leaves/organic waste for two weeks in the fall and two weeks in the spring.	290	CB cleaning also reduces TSS, P, oils/grease and other pollutant discharges
5		Organic Waste and Leaf Litter	City will collect leaf litter and organic waste along curbed streets, once per month as part of the street sweeping program, in the months of April, May, October and November. Provide curb side collection of bagged leaves/organic waste for two weeks in the fall and two weeks in the spring.	690	
6		Street and Pavement Cleaning	City sweeps all curbed streets once per month between April and November. City sweeps all downtown streets at a minimum of once per week between April and November. Sweeps directly connected impervious cover at least <u>two times per yea</u>r (once in Spring and once in Fall). Conduct a sweeping study to determine areas where additional optimized sweeping should be conducted to reduce curbed sediment load and catch basin loads.	250	Street Sweeping / Cleaning also reduces TSS, P, oils/grease, and other pollutant discharges
7		Fertilizer Program	Advocate for and work with the State to develop a Great Bay watershed total nitrogen fertilizer ordinance/regulation that would ban or control the sale of lawn fertilizer containing nitrogen in the watershed. City of Rochester already exclusively uses slow release fertilizer for its properties.		City anticipates nitrogen reductions if enacted, adopted and implemented.
	Other Projects				
8		Sewer System Master Plan	City has selected a contractor and is currently negotiating a scope of work for a Sewer System Master Plan. Once finalized, the City anticipates the Sewer System Master Plan study will be conducted over the next two to three years that will include flow metering and modelling efforts to fully evaluate and reduce sources of inflow and infiltration in the POTW.		The City anticipates the completed Sewer System Master Plan will identify priority projects for the City to implement for the reduction of infiltration and inflow to the POTW with anticipated nitrogen reductions.
9		Private Redevelopment	Enforce the Chapter 218 - Stormwater Ordinance (in place by June 30, 2021) governing new development and redevelopments by reviewing and inspecting private redevelopment in the City and requiring stormwater treatment.	100-300	Structural and non-structural BMPs required by the updated site plan regulations will also reduce other pollutants including TSS, P, oils/grease and other pollutants by disconnecting and treating impervious area.
10		Staffing / Resources	DPW has included in its proposed budget funding for another Assistant Engineer position to focus on stormwater related projects and ordinance enforcement.		
11		Septic System Programs	Advocate for and work with the State and region to develop a Great Bay watershed advanced septic system ordinance/regulation that would encourage advanced nitrogen treatment for private septic systems. Advocate for and work with the State to enforce its requirement for private septic systems to connect to public sewers within 100 feet of waterbodies.		City anticipates nitrogen reductions if enacted, adopted and implemented.
		Total Estimated Cost for SW and NPS Projects	~at least $2 million (excluding sewer extension costs)		

1These are estimates only and may not reflect the actual nitrogen loads resulting from the proposed projects and practices.
2These projects are planned but subject to City Council approval and funding.
3This list is not an exclusive list and is subject to further update and expansion on an annual basis by the City.

Attachment

City of Portsmouth Anticipated Source Reduction List

Note: This list is a statement of present intent, is illustrative, and is non-binding. The estimated nitrogen reduction stated above are based on current best estimates and assumptions, and are not intended as binding commitments or as performance guarantees.

Category	Project/Activity	Description	Reduction (lb TN/yr)
Non-structural	Professional Staff	The City has developed a Stormwater Specialist Position and reorganized personnel to establish a Stormwater Division within the Public Works Department. At the Planning Dept there are staff dedicated to site plan regulation compliance for private property and developments. The majority of the team has completed the Stormwater Management Certificate program offered by UNH Professional Development Training.	Note 1
Non-structural	Professional Consultant	The City has contracted with VHB to conduct past studies specific to stormwater and non-point source projects and planning. This work is ongoing and overlaps with multiple other items in this list.	Note 1
Non-structural	Training/Commitment To Innovation	City wastewater operations staff are trained licensed professionals who participate in professional organizations including New Hampshire Water Pollution Control Association, New England Water Environment Association/WEF, and others. Staff participate in these associations to maintain training and stay in front of the most recent industry trends and to optimize treatment operations.	Note 1
Non-structural	Commitment To New And Innovative BMPs	Commitment to developing new BMPs by working with consultants and the UNH Stormwater Center. Projects and BMP examples include: Community Campus Athletic Fields stormwater treatment, State Street sand filtration and tree box filters, use of compost tea and incorporation of pervious pavement and other LID type projects within the City. The City has and will continue to work with private and public entities in the installation of rain gardens, tree box filters and other stormwater controls.	Note 1
Non-structural	Continuous nutrient load reduction at WWTP	The City recently completed construction of the Peirce Island Wastewater Treatment Facility and are completing the first year of continuous operation. The upgraded facility is performing well and the City will continue to optimize performance moving forward. Recent results can be provided. The City has committed to a baseline monthly average of no more than 8 mg/L Total Nitrogen in addition to any permitted load under the GBTN GP. Operating the facility at 7.5 mg/L (0.5 mg/L reduction) of total nitrogen will result in 6,088 lbs TN/year removed when at a flow of 4.0 million gallons per day or 9,132 lbs TN/year removed when at a flow of 6.0 million gallons per day.	greater than 9,132
Non-structural	Street Sweeping	The City sweeps the downtown streets (weather permitting, 5 nights/week). <u>All</u> streets (100miles) in the City are swept once a month from April through November, well in excess of the MS4 required frequency of 2 times per year.	76
Non-structural	CB Cleaning	The City cleans catch basins bi-annually regardless of whether they have reached the MS4 triggering thresholds of 1/2 full sump.	73
Non-structural	Liquid Biological Soil Amendment Program	The City has restrictions fertilizer use within the limits of wetlands and wetland buffers. The City has switched from conventional fertilizers to using compost tea: this is a fully organic liquid biological soil amendment brewed with compost and amended with organic soluble kelp, humic acid, soluble fish and an organic 15-0-0 amino acid.	961
Non-structural	School Organic Fertilizer Program	Portsmouth Public Schools use only organic fertilizers on athletic fields.	522
Non-structural	Reduced Fertilizer Use Requirement For All New Projects	As part of Site Plan approval, a maintenance plan shall be in place and "*Minimizes the need for fertilizer and pesticide usage and the introduction of pollutants to the environment* " & "*Landscaped areas shall consist of a combination of large and small trees, shrubs, perennial and/or annual flowers, and groundcover. Managed turf areas should be kept to a minimum to reduce mowing and fertilizer needs.* "	Note 1
Non-structural	Fertilizer Bans or Reductions	The City is generally supportive of a statewide ban of high nitrogen synthetic fertilizers.	Note 2
Non-structural	Include Water Quality BMPs As Standard Practice	The City incorporates stormwater controls and other BMPs into City projects. Examples of projects that implemented BMPs include: Brewster Street Reconstruction, Maplewood Ave Reconstruction, Sagamore Ave Reconstruction, Four Tree Island Parking Lot, State Street Reconstruction, Lincoln Avenue Area Drainage Basin Sewer Separation, amongst others.	Note 3
Non-structural	Outreach and Education	Working with stakeholders in the City to address stormwater, sea level rise, and coastal resiliency issues that impact Portsmouth. Addressing the overlap in project needs to address coastal resiliency and impact of tidal changes on stormwater controls in areas like Prescott Park.	Note 1
Non-structural	Pollutant Removal/Outreach and Education	The City outreach and education exceeds what is required by the MS4. Staff regularly hold tours or presentations of the innovative BMP's being implemented. Staff also regularly speak at conferences about technologies and particularly focus on maintenance and long-term performance.	Note 1
Non-structural	Ordinances	Regulations updated with a threshold for stormwater implementation with 50% nitrogen limits set at 15,000 square feet. This is much more stringent than the MS4 requirements which only pertain to disturbance over an acre. Calculation assumes 10 acres of development per year.	75
Non-structural	Ordinances	The City Site Plan Review Regulations promotes the use of Low Impact Development (LID). Low "Applicants shall incorporate Low Impact Development (LID) site planning and design practices to the maximum extent practical (MEP) to reduce stormwater runoff volumes, maintain predevelopment site hydrology, and protect water quality in receiving waters. LID practices may include site design techniques (e.g., maintenance of vegetated buffers, minimizing of disturbance footprint) and structural measures to promote infiltration such as porous pavement, rain gardens or the capture / reuse of stormwater to reduce the stormwater volume discharged from the site.	Note 1

Attachment

City of Portsmouth Anticipated Source Reduction List

Note: This list is a statement of present intent, is illustrative, and is non-binding. The estimated nitrogen reduction stated above are based on current best estimates and assumptions, and are not intended as binding commitments or as performance guarantees.

Category	Project/Activity	Description	Reduction (lb TN/yr)
Non-structural	Development Of Water Quality improvement Recommendations	The City completed extensive water quality testing in the Sagamore Creek in 2018 and 2019. This data was used by the DES to evaluate 303(d) listing and will be a baseline for a Watershed Master Plan.	Note 1
Non-structural	IDDE Follow-up	The City is conducting follow-up testing to the water quality monitoring work completed in Sagamore Creek where pollutants were found to be high.	Note 1
Non-structural	Outreach and Education & Regional Coordination	The City sponsors twice annual Hazardous Household Waste days and collect materials from neighboring towns. Stormwater education and outreach materials are distributed at these events.	Note 1
Non-structural	Regional Coordination of Stormwater O&M	Coordinate with the Pease Development Authority on stormwater related activities, assisting them with their stormwater requirements	Note 3
Non-structural	Operation & Maintenance	Culvert lining at West Road and Edmond Ave which will prevent operational and water quality issues. Systematic video inspection and cleaning of stormwater collection system.	Note 1
Non-structural	Outreach and Education & Regional Coordination	Working with Seacoast Stormwater Coalition to develop BMP implementation and regular operation and maintenance requirements for private properties.	Note 1
Non-structural	Pollutant Tracking	Working with UNH graduate students to assess feasibility and effort to track land use change for the City of Portsmouth. Will assess the efficacy of BMP use for private and public projects.	Note 1
Non-structural	Stormwater Master Plan	Working with VHB to update the City's 2007 Stormwater Master Plan and review of stormwater utility funding option.	Note 1
Non-structural	Buffers	Ordinance has increased wetland buffers with credit for going green projects that show added nitrogen removal	Note 1
Non-structural	Yard Waste & Leaf Pick-up Program	Weekly yard/leaf waste pickups April - December. In 2020 over 1,300 tons of material were collected. Leaf collection requires the use of bags which maximizes the effect of the BMP.	1,608
Structural	Infiltration and Inflow Reduction	While Inflow and Infiltration (I/I) is often considered to be a collection system problem, the extraneous flows end up at the WWTF and can impact the performance of the biological treatment system. The City conducted an sewer system evaluation to identify infiltration and inflow in 2018. This project resulted in four contracts for sewer rehabilitation. The City will be completing the first of those four contracts by October 2023.	Note 3
Structural	Capital Improvements Plan	The City has a 6-year capital improvement plan that includes many projects that will address structural type stormwater and non-point source improvements including, but not limited to the following: Islington Street Phase 2 Complete Street Reconstruction, Peverly Hill Complete Street Reconstruction, Union Street & Willard Avenue Sewer Separation, Fleet Street Sewer Separation, Market Square Upgrade, and Corporate Drive Swales and Roadway.	Note 3

Notes:
1. While these items/projects do not have readily quantifiable nitrogen reduction, the function provided is critical to execution of best management practices, planning and engineering associated with nitrogen reduction.
2. These items will provide the City with additional support when implementing ordinance adjustments and other control and enforcement provisions.
3. The nitrogen reductions for these items will be calculated at a later date.

UNITED STATES ENVIRONMENTAL PROTECTION AGENCY
Region 1
5 Post Office Square, Suite 100
Boston, MA 02109-3912

March 25, 2021

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288 Central Ave
Dover, NH 03820

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Rochester City Manager
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Rochester, NH 03867

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Vice President
Director, CLF New Hampshire
27 North Main Street
Concord, NH 03301-4930

Re: Great Bay Total Nitrogen General Permit

Dear Mr. Joyal, Mr. Cox, Ms. Conrad and Mr. Irwin:

EPA Region 1 is writing this letter in connection with the Great Bay Total Nitrogen General Permit, issued November 24, 2020. This permit represents a great stride forward in regulating nutrient loads into Great Bay by establishing effluent limitations on all 13 New Hampshire wastewater dischargers, in almost all cases for the first time. These limits will act to prevent any future increases in nitrogen load from these dischargers even in the midst of rapid population increases. EPA expects that all eligible dischargers will opt into the General Permit. Due to the mix of nitrogen loading into Great Bay, which is predominated by nonpoint sources of nitrogen, the permit provides a framework and incentive for covered dischargers to pursue nonpoint source reductions that will be necessary if designated uses are to be fully restored. For the reasons explained in the Response to Comments accompanying the General Permit, if these nonpoint source reductions are not diligently pursued, EPA has concluded that timely reissuance of a permit with more stringent effluent limitations will be critical to the expeditious achievement of uses. In furtherance of this goal, EPA also intends to act promptly on any petition for an individual permit under 40 C.F.R. § 122.28(b)(3)(i), for the reasons set forth in Section 11 ("Petition(s) for Individual Permit(s)") of the Settlement Agreement by and between Conservation Law Foundation and the Cities of Dover, Portsmouth and Rochester, dated March 25, 2021.

Ken Moraff

KENNETH MORAFF
Digitally signed by KENNETH MORAFF
Date: 2021.03.25 16:49:00 -04'00'

Water Division Director
EPA, Region 1

cc: Ted Diers, NHDES

Appendix I

Total Maximum Daily Loads (TMDLs) and Alternative Restoration Approaches

Section e of the joint AMP proposes a timeline for completing a TMDL for total nitrogen for the Great Bay or an alternative restoration plan. According to that schedule, the participating communities will make a recommendation to either pursue a TMDL or a specific alternative such as a 5R restoration plan at the end of fourth year of the first general permit term. The development of the TMDL or alternative development will be a major activity of the second permit term. This appendix describes the TMDL process and alternative restoration planning approaches under the Clean Water Act framework. It also provides examples of TMDLs and alternative restoration planning approaches.

Total Maximum Daily Loads

The USEPA provides the following basic information on its webpage entitled "Overview of Total Maximum Daily Loads"[4]:

> "A TMDL is the calculation of the maximum amount of a pollutant allowed to enter a waterbody so that the waterbody will meet and continue to meet water quality standards for that particular pollutant. A TMDL determines a pollutant reduction target and allocates load reductions necessary to the source(s) of the pollutant.
>
> Pollutant sources are characterized as either point sources that receive a wasteload allocation (WLA), or nonpoint sources that receive a load allocation (LA). For purposes of assigning WLAs, point sources include all sources subject to regulation under the National Pollutant Discharge Elimination System (NPDES) program, e.g. wastewater treatment facilities, some stormwater discharges and concentrated animal feeding operations (CAFOs). For purposes of assigning LAs, nonpoint sources include all remaining sources of the pollutant as well as natural background sources. TMDLs must also account for seasonal variations in water quality, and include a margin of safety (MOS) to account for uncertainty in predicting how well pollutant reductions will result in meeting water quality standards.
>
> Expressed mathematically, the TMDL equation is:
>
> **TMDL = ΣWLA + ΣLA + MOS**
>
> Where **WLA** is the sum of wasteload allocations (point sources), **LA** is the sum of load allocations (nonpoint sources and background) and **MOS** is the margin of safety.
>
> Each pollutant causing a waterbody to be impaired or threatened is referred to as a waterbody/pollutant combination, and typically a TMDL is developed for each waterbody/pollutant combination. For example, if one waterbody is impaired or threatened by three pollutants, three TMDLs might be developed for the waterbody. However, in other cases, a single TMDL document may be developed to address several waterbody/pollutants combinations. Neither the CWA nor EPA's regulations define or limit the scale of TMDLs. Some states have been developing TMDLs on a watershed-scale basis. Such state TMDLs may also cover multiple watersheds."

TMDLs are inherently quantitative, and developing TMDLs assumes the ability to identify in-stream water quality targets associated with use attainment and the pollutant loads to achieve those in-stream targets. Determining the appropriate water quality targets can be challenging if the stressors on uses are

[4] https://www.epa.gov/tmdl/overview-total-maximum-daily-loads-tmdls

not well understood or cannot be expressed as quantitative targets. Similarly, determining appropriate pollutant reduction targets and load allocations is not always straightforward because there can be a variety of potential point and non-point sources of pollutants in watersheds. Because of this, the analysis of historic water quality data, collection of field data, scientific interpretation, and the use of various modeling techniques is often needed prior to establishing TMDLs.

Under federal guidance (40 CFR § 122.44(d)(1)(vii)), water quality-based effluent limits in NPDES permits must be consistent with the assumptions and requirements of approved TMDL WLAs. After appropriate TMDL thresholds and allocations have been determined for a waterbody, an implementation plan can be developed to help jurisdictions or other stakeholders reach their numeric load reduction goals. Typically a plan achieves this by providing schedules, management goals, projects, partners, and priorities, as well as outlining monitoring and re-evaluation processes. The USEPA has developed guidance[5] for developing watershed management plans, and this guidance identifies nine key requirements of such plans:

1. Identify causes and sources. Identification of causes of impairment and pollutant sources that need to be controlled to achieve needed the needed load reductions.
2. Pollution reductions needed. An estimate of the load reductions expected from the planned management measures, and the load reductions needed to meet water quality standards.
3. Actions needed. A description of the management measures planned to achieve load reductions.
4. Costs and authority. Estimate of the amounts of technical and financial assistance needed, associated costs, and/or the sources and authorities that will be relied upon.
5. Outreach and education. An information and education component used to enhance public understanding of the project and participation.
6. Schedule. A schedule for implementing the nonpoint source management measures identified in this plan that is reasonably expeditious.
7. Milestones. A description of interim measurable milestones for determining whether management measures or other control actions are being implemented.
8. Success indicators and evaluation: A set of criteria that can be used to determine whether loading reductions are being achieved over time and substantial progress is being made toward attaining water quality standards.
9. Monitoring. A monitoring component to evaluate the effectiveness of the implementation efforts over time, measured against the criteria established under item 8 immediately above.

Examples of TMDLs

New Hampshire has 550 bacteria TMDLs, 31 lake phosphorus TMDLs, and statewide TMDLs that cover pH and mercury. These TMDLs not only include specific pollutant reduction targets, but also allocate necessary load reductions depending on the source. For stationary, point sources, allocations are characterized as a wasteload allocation (WLA) and for widely distributed, nonpoint sources, they are characterized as a load allocation (LA). Below are excerpts and summaries from several TMDL implementation plans developed for complex estuarine environments.

[5] U.S. Environmental Protection Agency. 2008. Handbook for Developing Watershed Plans to Restore and Protect Our Waters. EPA 841-B-08-002. 400 p. https://www.epa.gov/sites/production/files/2015-09/documents/2008_04_18_nps_watershed_handbook_handbook-2.pdf

Wild Harbor Total Nitrogen TMDL (Massachusetts)

https://www.epa.gov/sites/production/files/2018-10/documents/wild-harbor-tn-tmdl-report.pdf

The Wild Harbor estuarine system is located within Town of Falmouth on Cape Cod, Massachusetts. In order to restore and protect this estuarine system, N loadings, and subsequently the concentrations of N in the water, must be reduced to levels below the thresholds that cause the observed environmental impacts. This concentration will be referred to as the target threshold N concentration. It is the goal of the TMDL to reach this target threshold N concentration, as it has been determined for each impaired waterbody segment. The MEP has determined that a N concentration of 0.35 mg/L for this estuarine system at a sentinel station will restore eelgrass habitat in the main Wild Harbor basin. In addition, restoration of benthic habitat for infaunal animals will occur as management alternatives are implemented for eelgrass. To meet the TMDL, a 32% reduction of the total watershed nitrogen load for the entire system will be required.

Chesapeake Bay Nutrient and Sediment TMDL (Maryland and Virginia)

https://www.epa.gov/chesapeake-bay-tmdl

The Chesapeake Bay receives drainage from 64,000 mi2 in six states. The Bay experiences "dead zones" of low dissolved oxygen and has also lost much of its historical coverage of submerged aquatic vegetation. In the early 2000s, the USEPA ad states developed Bay-specific water quality criteria and use definitions. In 2010, the USEPA and states developed a TMDL for nitrogen, phosphorus, and sediment loads to the Bay, intended to achieve the Bay-specific dissolved oxygen and water clarity goals. A sophisticated modeling framework was used to identify nutrient loads that are expected to achieve dissolved criteria. The states have since developed watershed implementation plans to guide restoration.

Neuse River Basin Total Nitrogen TMDL (North Carolina)

https://files.nc.gov/ncdeq/Water%20Quality/Planning/TMDL/FINAL%20TMDLS/Neuse/Neuse%20TN%20TMDL%20II.pdf

The Neuse River basin encompasses nearly 6,000 square miles over 19 counties in eastern North Carolina. At New Bern, the Neuse takes on estuarine characteristics as it widens but remains shallow, frequently resulting in minimal discharge and long hydraulic residence times. The Neuse River Basin TMDL seeks to address chlorophyll-a exceedances in the estuary by managing total nitrogen levels. A sophisticated modeling framework was employed to predicted nutrient reductions needed to attain the in-stream chlorophyll-*a* target. North Carolina has also adopted nutrient offset and credit trading program to support implementation.

Alternative Restoration Approaches

The TMDL is one approach for developing water quality restoration goals. However, EPA and New Hampshire recognize that other approaches are sometimes viable or even preferred under the Clean Water Act framework. USEPA has encouraged the use of "…alternative approaches, in addition to

TMDLs, that incorporate adaptive management and are tailored to specific circumstances where such approaches are better suited to implement priority watershed or water actions that achieve the water quality goals of each state…"[6] The EPA describes an alternative restoration approach as a "near-term plan, or description of actions, with a schedule and milestones, that is more immediately beneficial or practicable to achieving water quality standards [than a TMDL]"[7]. Because alternative plans are created and executed locally, they offer more flexibility for communities during the restoration process. They are especially well-suited for adaptive management efforts in which the understanding of stressors and responses is evolving based on iterative implementation and monitoring.

Most TMDL alternatives fall into two categories within the Clean Water Act framework:

- 4b Plan. The designation "4b" refers to the category of the 303(d) list for impaired waters with enforceable pollution control programs already in place that are expected to solve water quality problems. A Category 4b plan allows states and EPA to recognize actions that provide a more appropriate and effective response to impairment than TMDL development.
- 5r Plan: The designation is derived from to the category 5 of the 303(d) list for impaired waters (impaired waters needing a TMDL or alternative restoration plan), and from the word "restoration". A 5r plan will usually include USEPA's nine minimum elements for watershed management plans, including the identification of needed pollutant reductions and management actions. From this perspective, 5r plans share many of the characteristics of TMDL-based implementation plans, but can be more flexible and adaptive.

Like TMDLs, alternative watershed-based plans are subject to review and approval by EPA. If the water quality restoration activities do not result in significant water quality improvements or attain their applicable water quality standards, the waterbody might be removed from the 5R subcategory and reprioritized for TMDL development.

Examples of Alternative Watershed Restoration Plans

In New Hampshire, organizations and communities have worked with the NH Department of Environmental Services to produce 25 watershed-based plans, many of which represent alternatives to the traditional TMDL-based planning approach. As of March 2021, EPA has accepted 53 alternative restoration plans from 17 states[4]. Below are several examples of TMDL alternatives developed in New Hampshire and other states.

5R Plan for the Savannah River Basin, Georgia and South Carolina:

https://epd.georgia.gov/document/publication/savannahharbor5rplan09152015pdf/download

The Savannah River, including the Harbor, serves as the boundary between Georgia and South Carolina. The Savannah Harbor is located at the mouth of the Savannah River where it discharges to the Atlantic

[6] U.S. Environmental Protection Agency. 2013. A Long-Term Vision for Assessment, Restoration, and Protection under the
Clean Water Act Section 303(d) Program. https://www.epa.gov/sites/production/files/2015-07/documents/vision_303d_program_dec_2013.pdf

[7] U.S Environmental Protection Agency. 2021. "Alternative Restoration Plans". https://www.epa.gov/tmdl/alternative-restoration-plans

Ocean. This 5R plan documents the total pollutant loading of oxygen-demanding substances (5-day Carbonaceous Biochemical Oxygen Demand [CBOD5] and ammonia) that can assimilate and still prevent excessive exceedances of dissolved oxygen criteria. The 5R process allowed the major municipal and industrial point sources to cooperatively determine how the assimilative capacity would be divided among them, subject to state and USEPA approval.

Winnicut River Watershed Restoration and Management Plan, New Hampshire

https://nhrivers.org/wp-content/uploads/2019/10/WinnicutRiverWRMP.pdf

The Winnicut River is one of seven major tributaries to Great Bay. The water quality and habitat of the Winnicut River and several of its tributaries have been degraded by increased nonpoint source (NPS) pollution resulting from rapid land development in the watershed over the past 20 years. Impacts associated with NPS pollutants have led to impairments included on the NHDES 2014 303(d) list for Aquatic Life Use, Primary Contact Recreation, and Secondary Contact Recreation, due to low levels of dissolved oxygen and elevated levels of *E. coli* bacteria. The primary goal of this watershed management plan is to assess the Winnicut River watershed and identify actions that will improve in water quality and aquatic habitat.

Reedy River 5R Plan (South Carolina):

http://cleanreedy.org/

The Reedy River has headwaters near Greenville, SC, and is listed as impaired for excessive nutrients. Efforts at developing a TMDL in the 2010s were hampered by insufficient data and model calibration challenges. Local stakeholders chose the 5R process to take leadership in the monitoring, modeling, and restoration efforts. The Reedy River Water Quality Group includes a wide range of stakeholders from local governments and utilities to environmental groups and regional planning agencies. The South Carolina Department of Environmental Health Control and USEPA are active participants with approval authority of the 5R plan. The group is currently in the modeling stage and expects to develop the draft 5R plan in 2022.