EXHIBIT 28 (AR K.13)

DRAFT

NEW HAMPSHIRE
DEPARTMENT OF ENVIRONMENTAL SERVICES

Analysis of Nitrogen Loading Reductions for Wastewater Treatment Facilities and Non-Point Sources in the Great Bay Estuary Watershed

December 2010

NEW HAMPSHIRE DEPARTMENT OF Environmental Services

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Definitions of Acronyms, Important Terms, and Units

Acronyms
CWA: Clean Water Act
DES: New Hampshire Department of Environmental Services
EPA: United States Environmental Protection Agency
NPS: Non-point source
TMDL: Total Maximum Daily Load
WWTF: Municipal Wastewater Treatment Facility

Important Terms
303(d) list: The "303(d) list" is so named because it is a requirement of Section 303(d) of the Clean Water Act (CWA). The 303(d) list includes surface waters that are: (1) Impaired or threatened by a pollutant or pollutant(s); (2) Not expected to meet water quality standards within a reasonable time even after application of best available technology standards for point sources or best management practices for non-point sources; and (3) Require development and implementation of a comprehensive water quality study (i.e., called a Total Maximum Daily Load or TMDL study) that is designed to meet water quality standards.
Design Flow: The average daily design flow is the wastewater flow rate that the municipal wastewater treatment facility was built to handle on each day.
Env-Wq 1703.14: The narrative water quality standard for nutrients. For estuaries, which are Class B waters, the standard states that: "Class B waters shall contain no phosphorus or nitrogen in such concentrations that would impair any existing or designated uses, unless naturally occurring."
Impaired: Not meeting water quality standards and therefore not supporting designated uses such as aquatic life and recreation.
Numeric Nutrient Criteria: Nitrogen concentrations, chlorophyll-a concentrations, and levels of light attenuation above which designated uses, such as aquatic life and recreation, would be impaired. Numeric nutrient criteria are needed to replace the narrative nutrient criteria in Env-Wq 1703.14, which states, in part: "Class B waters shall contain no phosphorus or nitrogen in such concentration that would impair any existing or designated uses, unless naturally occurring." DES has proposed numeric nutrient criteria for the Great Bay Estuary which would protect against eelgrass loss and low dissolved oxygen. Once adopted, these criteria would take the place of Env-Wq 1703.14 for the Great Bay Estuary. The proposed criteria are defined in a 2009 report by DES titled "Numeric Nutrient Criteria for the Great Bay Estuary" (available at: http://des.nh.gov/organization/divisions/water/wmb/wqs/documents/20090610_estuary_criteria.pdf).
Subestuary: A subsection of a larger estuary. The subestuaries of the Great Bay Estuary are distinct waterbodies defined by geography and hydrology. DES analyzes data from each of the subestuaries separately to make assessments for water quality impairments.

Definitions of Acronyms, Important Terms, and Units (cont.)

Total Maximum Daily Load (TMDL): The TMDL represents the maximum amount of a pollutant that a body of water may receive and still meet its water quality standards, with a margin of safety.

Watershed: A watershed is the area of land where all of the water that drains off of it goes into the same place (i.e., the same subestuary). Watersheds come in all shapes and sizes. They cross county, state, and national boundaries.

Watershed Nitrogen Load (aka Nitrogen Load): The existing nitrogen load from the watershed to a subestuary. This load does not include nitrogen contributed to the subestuary from ocean waters.

Watershed Nitrogen Loading Threshold (aka Nitrogen Loading Threshold): The maximum nitrogen load from the watershed that can be assimilated by a subestuary while still having nitrogen concentrations in the subestuary less than or equal to the numeric nutrient criteria. The loading threshold only applies to nitrogen loads from watersheds. Nitrogen loads from the ocean are taken into account in the development of the nitrogen loading threshold.

Units

cfs: Cubic feet per second
CFSM: Cubic feet per second per square mile
L/s: Liters per second
mg N/L: Milligrams of total nitrogen per liter
mg/L: Milligrams per liter
MGD: Million gallons per day
sq.mi.: Square miles
ppt: Parts per thousand
tons N/year: Tons of nitrogen per year

1 Executive Summary

In 2009, the New Hampshire Department of Environmental Services (DES) published a proposal for numeric nutrient criteria for the Great Bay Estuary. The report found that total nitrogen concentrations in most of the estuary needed to be less than 0.3 mg N/L to prevent loss of eelgrass habitat and less than 0.45 mg N/L to prevent occurrences of low dissolved oxygen. Based on these criteria and an analysis of a compilation of data from at least seven different sources, DES concluded that 11 of the 18 subestuaries in the Great Bay Estuary were impaired for nitrogen. Under the Clean Water Act, if a water body is determined to be impaired, a study must be completed to determine the existing loads of the pollutant and the load reductions that would be needed to meet the water quality standard. Therefore, DES developed models to determine existing nitrogen loads and nitrogen loading thresholds for the subestuaries to comply with the numeric nutrient criteria. DES also evaluated the effects of different permitting scenarios for wastewater treatment facilities on nitrogen loads and the costs for wastewater treatment facility upgrades. This modeling exercise showed that:

- Nitrogen loads to the Great Bay, Little Bay, and the Upper Piscataqua River need to be reduced by 30 to 45 percent to attain the numeric nutrient criteria.
- Both wastewater treatment facilities and non-point sources will need to reduce nitrogen loads to attain the numeric nutrient criteria.
- The percent reduction targets for nitrogen loads only change minimally between wet and dry years.
- Wastewater treatment facility upgrades to remove nitrogen will be costly; however, the average cost per pound of nitrogen removed from the estuary due to wastewater facility upgrades is lower than for non-point source controls.
- The permitting options for some wastewater treatment facilities will be limited by requirements to not increase pollutant loads to impaired waterbodies.
- The numeric nutrient criteria and models used by DES are sufficiently accurate for calculating nitrogen loading thresholds for the Great Bay watershed.
- Additional monitoring and modeling is needed to better characterize conditions and nitrogen loading thresholds for the Lower Piscataqua River.
- This nitrogen loading analysis for Great Bay may provide a framework for setting nitrogen permit limits for wastewater treatment facilities and developing watershed implementation plans to reduce nitrogen loads.

2 Introduction

In 2009, the New Hampshire Department of Environmental Services (DES) published a proposal for numeric nutrient criteria for the Great Bay Estuary[1]. These criteria were developed over a four-year period through an open process that involved local experts from universities, state agencies, federal agencies, municipalities, and non-governmental organizations. The report found that total nitrogen concentrations in most of the estuary needed to be less than 0.3 mg N/L to prevent loss of eelgrass habitat and less than 0.45 mg N/L to prevent occurrences of low dissolved oxygen. Eelgrass habitat and dissolved oxygen are both critical for supporting aquatic life in the Great Bay Estuary.

Based on these criteria and an analysis of a compilation of data from at least seven different sources, DES concluded that 11 of the 18 subestuaries in the Great Bay Estuary did not meet surface water quality standards and specifically did not comply with Env-Wq 1703.14, the narrative standard for nutrients[2]. These impairments were added to New Hampshire's 2008 303(d) list on August 14, 2009, approved by the U.S. Environmental Protection Agency (EPA) on September 30, 2009, and have subsequently been retained on the 2010 303(d) list. Nine of the 11 impaired subestuaries were the Great Bay, Little Bay, Upper Piscataqua River, and the tidal rivers that flow into these areas. The other two impaired subestuaries were Portsmouth Harbor and Little Harbor/Back Channel at the mouth of the estuary (Table 1, Figure 1).

Under the Clean Water Act, if a waterbody is placed on the 303(d) list, a study must be completed to determine the existing loads of the pollutant and the load reductions that would be needed to meet the water quality standard. However, additional research by DES was needed to complete this study because critical information was not available. Nitrogen loads to the Great Bay Estuary were estimated previously, but only for the whole estuary, not all of the smaller subestuaries that were added to the 303(d) list. The contribution from individual point sources of nitrogen and the variability in nitrogen loads over time had not been adequately quantified. There were no pre-existing models of the Great Bay Estuary that could be used to estimate the nitrogen loading thresholds to comply with the numeric nutrient criteria. Finally, the costs associated with nitrogen load reductions at individual wastewater treatment facilities were unknown.

Therefore, for this report, DES developed models to estimate the existing nitrogen loads to each of the impaired subestuaries and to predict the watershed nitrogen load thresholds needed to meet the new criteria. Permitting options on individual wastewater treatment facilities were evaluated in terms of the nitrogen load reductions. The accuracy of the models were quantified. Capital and operations/maintenance costs for wastewater treatment facility upgrades were also estimated. DES has also responded to comments received from EPA, municipalities, researchers, and advocacy groups on a previous draft of this report. The governing questions for this report were:

- What are the watershed nitrogen loading thresholds to meet the numeric nutrient criteria and how much of reduction would these require from existing loads?
- What would be the effects of different permitting scenarios for wastewater treatment facilities on nitrogen loads and requirements for non-point source reductions?
- How much will wastewater treatment facility upgrades cost?

Figure 1: Watersheds and Subestuaries of the Great Bay Estuary

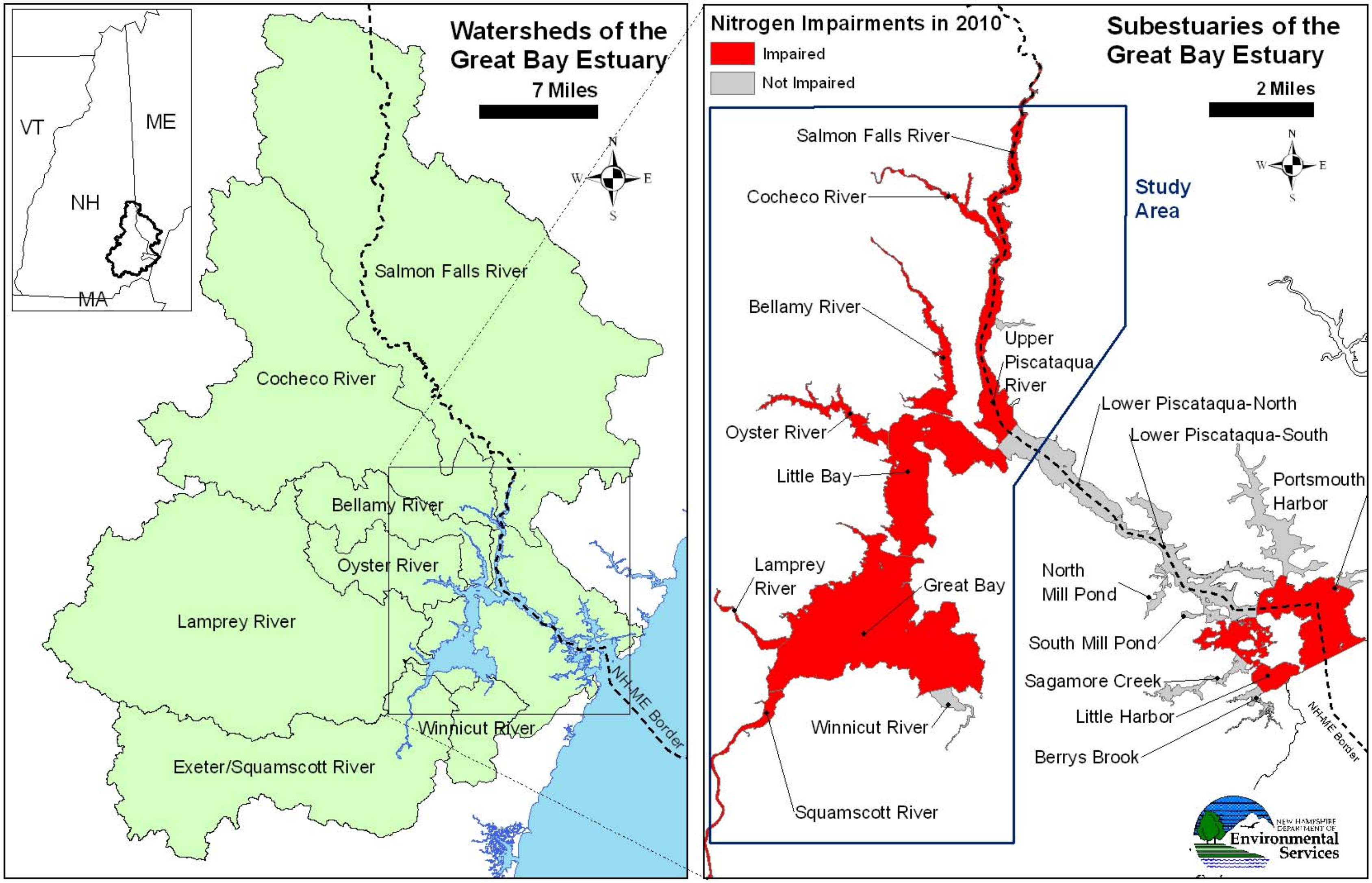

Table 1: Subestuaries of the Great Bay Estuary and Nitrogen Impairments

Subestuary	Dissolved Oxygen Impairment due to Nitrogen[1]	Eelgrass Loss Impairment due to Nitrogen[1]	Subestuary Included in this Study?
Tidal River Subestuaries			
Winnicut River			Y
Squamscott/Exeter River	Y	Y	Y
Lamprey River	Y	Y	Y
Oyster River	Y	Y	Y
Bellamy River		Y	Y
Cocheco River	Y*	NA**	Y
Salmon Falls River	Y	NA**	Y
Downstream Subestuaries			
Great Bay	Y	Y	Y
Little Bay		Y	Y
Upper Piscataqua River		Y	Y
Lower Piscataqua River North			
Lower Piscataqua River South			
Portsmouth Harbor		Y	
Little Harbor		Y	
Other Subestuaries			
North Mill Pond			
South Mill Pond	Y		
Sagamore Creek			
Berrys Brook			

1. Source: 2010 305b/303d List for New Hampshire
* Impairment based on elevated chlorophyll-a and nitrogen concentrations.
** The historical presence of eelgrass in the Cocheco and Salmon Falls Rivers has not been confirmed.

3 Methods

3.1 Study Area

The ten subestuaries included in this study were the Great Bay, Little Bay, Upper Piscataqua River, and the seven tidal rivers that flow into these areas (Figure 1). Nine of these ten subestuaries are impaired because excess nitrogen causes violations of the dissolved oxygen standard or loss of eelgrass or both. As shown on Table 1, violations of the dissolved oxygen standard were evident for the Great Bay and all of the tidal river subestuaries except for the Bellamy River, which has not been monitored for dissolved oxygen as much as the others. Eelgrass loss is evident in all of the impaired subestuaries except for the Cocheco and Salmon Falls Rivers. The historical presence of eelgrass in these subestuaries has not been confirmed so the absence of eelgrass is not necessarily an impairment. The Winnicut River subestuary is the only subestuary included in this study that is not impaired for nitrogen. This subestuary was included because its watershed contributes nitrogen to the Great Bay, which is impaired.

The impaired subestuaries of Portsmouth Harbor and Little Harbor/Back Channel and other subestuaries were not evaluated in this report because of the high salinity and complex hydrology in these areas which necessitates a different modeling approach.

The study area includes watershed areas and estuarine waters on both sides of the New Hampshire-Maine border. The watershed for each subestuary is the land area that drains to the subestuary.

3.2 Existing Watershed Nitrogen Loads

Existing watershed nitrogen loads were calculated to understand how much nitrogen was currently being loaded to each of the ten subestuaries.

For the purposes of this evaluation, the following sources were identified as contributors to the nitrogen load to the subestuaries. .

- Municipal Wastewater Treatment Facilities (WWTFs)
- Non-Point Sources (NPS) in Watersheds
- Groundwater Discharge to the Subestuary
- Atmospheric Deposition to the Subestuary

The nitrogen loads to the subestuaries were estimated for three two-year periods: 2003-2004, 2005-2006, and 2007-2008. The methods for estimating the nitrogen loads are similar to those used by the Piscataqua Region Estuaries Partnership for State of the Estuaries Reports[3] with minor differences. Detailed methods and results for the model of the existing watershed nitrogen loads are provided in Appendix A.

3.3 Watershed Nitrogen Loading Thresholds

Watershed nitrogen loading thresholds are the maximum nitrogen loading that each subestuary can receive without having negative effects. The numeric nutrient criteria[1] are nitrogen concentrations below which negative effects are not likely to occur. Therefore, the purpose of the watershed nitrogen loading threshold model was to predict the nitrogen loading that will keep nitrogen concentrations below the numeric nutrient criteria in each subestuary.

The numeric nutrient criteria were developed for two different endpoints: (1) To prevent occurrences of low dissolved oxygen; and (2) To protect eelgrass habitat. These endpoints were chosen because they are the two most common, and important, effects of elevated nitrogen in estuaries.

Low dissolved oxygen may occur from elevated nitrogen in estuaries[4-8]. Fish and other species require sufficient concentrations of dissolved oxygen in the water to survive. In nitrogen-limited systems, such as estuaries[9], increasing nitrogen inputs will increase primary productivity. Respiration of the organic matter created by the primary productivity consumes oxygen from the water column and sediments. The resulting low oxygen conditions affect fish and benthic communities[5,6,8]. The numeric nutrient criterion derived by DES to prevent occurrences of low dissolved oxygen is a total nitrogen concentration of 0.45 mg N/L[1].

Eelgrass (*Zostera marina*) is the base of the estuarine food web in the Great Bay Estuary. Healthy eelgrass beds filter water and stabilize sediments[10] and provide habitat for fish and shellfish[11,12]. While eelgrass is only one species in the estuarine community, the presence of eelgrass is critical for the survival of many species. Excess nitrogen effects eelgrass several ways, both directly and indirectly. The most common indirect effect of nitrogen is decreased light availability. Increasing nitrogen inputs to nitrogen-limited environments, such as estuaries[9] stimulates primary productivity in the form of phytoplankton, epiphytes (algae that grows on plants), and rooted or free-floating macroalgae. The increased phytoplankton in the water column, epiphytes on eelgrass leaves, and mats of macroalgae in eelgrass beds result in too little light getting to the eelgrass plants, resulting in die off[13-17]. The numeric nutrient criterion derived by DES to protect eelgrass habitat is a total nitrogen concentration of 0.3 mg N/L[1].

The basic premise employed to calculate nitrogen loading thresholds for the subestuaries was that steady state concentrations of nitrogen in an estuary will be equal to the watershed nitrogen load divided by the total water flushing rate from freshwater and ocean water. Estuaries are complicated systems with variability due to tides, weather, and stream flows. However, by making the steady state assumption, it is not necessary to model all of these factors. The steady state assumption is appropriate for calculations based on annual or multi-year average conditions which approximate steady state conditions. Therefore, calculations for this analysis were made using average values for three two-year periods: 2003-2004, 2005-2006, and 2007-2008.

The nitrogen loading threshold calculation was completed in three steps. First, fresh water inputs to each subestuary were computed. Second, ocean water inputs to each subestuary were estimated using salinity measurements in the subestuary and the fresh water inputs. Finally, the total water flushing rate was combined with the numeric criteria for total nitrogen to calculate the watershed nitrogen loading thresholds that would result in nitrogen concentrations in the subestuary that were equal to the numeric criteria.

For each subestuary, three different watershed nitrogen loading thresholds were calculated. The first two thresholds were calculated such that the total nitrogen concentration in the subestuary would be equal to the numeric criteria for the prevention of low dissolved oxygen (0.45 mg N/L) and for protecting eelgrass habitat (0.30 mg N/L). The third threshold was only calculated for the tidal river subestuaries. The purpose of this third threshold was to establish watershed nitrogen loading limits that would protect eelgrass habitat in the downstream subestuaries of Great Bay, Little Bay, and the Upper Piscataqua River. This third threshold can be alternatively described as a "downstream protective value". In general, the thresholds for preventing occurrences of low dissolved oxygen and protecting eelgrass in downstream areas were higher than the thresholds for protecting eelgrass habitat in the tidal river subestuaries.

Detailed methods and results for the model of watershed nitrogen loading thresholds are provided in Appendix B.

3.4 Watershed Nitrogen Loads for Different Permitting Scenarios for Wastewater Treatment Facilities

Watershed nitrogen loads for different permitting scenarios were calculated to understand how much nitrogen could be removed from the subestuaries, in terms of delivered load to the subestuaries, if WWTFs were required to remove nitrogen. The calculation also determined the quantity of nitrogen from non-point sources that would have to be reduced in addition to WWTF upgrades in order to meet the watershed nitrogen loading thresholds.

The nitrogen loads for 33 different scenarios were calculated. The matrix of scenarios consisted of three permitting options for WWTFs and eleven different percent reduction values for non-point sources. The three different permitting scenarios for WWTFs were effluent concentration limits for total nitrogen of 8 mg N/L, 5 mg N/L, and 3 mg N/L with effluent flow equal to design flow. Non-point source reductions were estimated for deciles of the existing non-point source load between 0 and 100 percent. The predicted nitrogen loads for each scenario were compared to the watershed nitrogen loading thresholds to determine whether the scenario would result in compliance with the numeric nutrient criteria. A different matrix was calculated for each subestuary for each of the three two-year periods (2003-2004, 2005-2006, and 2007-2008).

Detailed methods and results for the watershed nitrogen loads for different permitting scenarios are provided in Appendix C.

3.5 Quality Assurance

Quality assurance tests were used to understand uncertainty in the DES models of existing watershed nitrogen loads and watershed nitrogen loading thresholds. These tests quantified the precision, accuracy, and sensitivity of the models using Monte Carlo simulations and comparison between measured and predicted nitrogen concentrations in the subestuaries. The results of these tests are summarized in the paragraph below.

The quality assurance tests confirmed that the DES models have sufficient precision and accuracy for their intended purpose. In the tidal river subestuaries, the modeled watershed nitrogen loads and loading thresholds have average error bars of +/-10 percent and +/-12 percent, respectively. The error bars for the watershed nitrogen loads and loading thresholds for downstream subestuaries are +/-6 percent and +/-29 percent, respectively. The average difference between the predicted nitrogen concentrations in the subestuaries and measured concentrations was -11%. This level of error is comparable to the error in elaborate water quality models that have been used to establish nitrogen loading thresholds for other estuaries such as Long Island Sound. The most important input variables for the models were ocean nitrogen concentration, stream flow in tributaries, salinity in the subestuaries, and the numeric nutrient criteria. The model was most sensitive to the value of the numeric nutrient criteria when applied to the downstream subestuaries with high salinity and when using the criteria for protecting eelgrass habitat.

In addition to validating the models, DES requested a review of the numeric nutrient criteria that have been proposed for the Great Bay Estuary through the EPA's Nutrient Scientific Technical Exchange Partnership and Support (N-Steps) program. These reviews were conducted by scientists at Cornell University and the University of Maryland who are recognized experts in estuarine water quality. The reviewers found that the numeric nutrient criteria were well supported by the scientific literature and reasoning. The criteria were supported by a large amount of water quality data for the Great Bay Estuary. The use of multiple lines of evidence to develop the criteria enhanced confidence in the results.

In combination, the independent review and quality assurance tests show that the proposed numeric nutrient criteria and the models used by DES are sufficiently accurate for calculating watershed nitrogen loading thresholds for the Great Bay Estuary.

Detailed methods and results for the quality assurance tests are provided in Appendix D.

3.6 Capital and Operation/Maintenance Costs for Wastewater Treatment Facility Upgrades

The costs of upgrading WWTFs to remove nitrogen were estimated to understand the effects of different permitting scenarios on communities and the cost effectiveness of upgrading individual WWTFs. There are 18 WWTFs that contribute nitrogen to the Great Bay Estuary. Four of the WWTFs are in Maine and the rest are in New Hampshire.

There are two components of the cost for nitrogen removal at each of the 18 WWTFs – total capital cost (the sum of actual construction, design, and construction administration/resident inspection) and increases in annual operation & maintenance costs. DES used several approaches to estimate both the capital and the operation & maintenance costs for each WWTF: (1) The most recent consulting engineering work performed for a community; (2) Specific information extracted from the 2007 New Hampshire Seacoast Region Wastewater Management Feasibility Study[18]; and (3) Generalized information from reports generated for similar studies in Massachusetts, Connecticut and states bordering the Chesapeake Bay Estuary[19,20]. Current operation & maintenance costs were primarily based on 2009 operating budgets obtained from the wastewater facility operators. Added to the existing operating budgets were estimated costs associated with more advanced treatment levels for nitrogen removal based on a publication from EPA[21]. Amortized capital costs plus annual operation & maintenance costs were combined to estimate the total annual cost for each treatment level for nitrogen removal.

Detailed methods and results for the cost estimates are provided in Appendix E.

3.7 Responsiveness Summary

In October 2009, DES released a draft of this report for stakeholder review. The comments received and the DES responses to these comments are summarized in Appendix F. DES strove to incorporate the comments received as much as possible within the capabilities of the existing modeling approach.

4 Results

In each of the following sections, average values from 2003-2008 of the existing nitrogen load, watershed nitrogen loading thresholds, effects of WWTF permitting, and costs have been summarized for each subestuary.

The seven tidal river subestuaries have been summarized individually, followed by an overall combined summary for the Great Bay, Little Bay, and Upper Piscataqua. It was not necessary to summarize the separate modeling results for the Great Bay, Little Bay, and the Upper Piscataqua because these results were incorporated into the overall summary. Moreover, protections for the Great Bay, Little Bay, and the Upper Piscataqua River were included in the summaries for the tidal subestuaries through the watershed nitrogen loading thresholds to protect downstream uses.

The results are summarized on Tables 2a and 2b. Detailed results for each subestuary are provided in Appendices A, B, and C.

4.1 Winnicut River Subestuary

Existing Nitrogen Loads
The annual average watershed nitrogen load to this subestuary between 2003 and 2008 was 30.9 tons per year. There are no wastewater treatment facility discharges in this watershed. Therefore, 100 percent of the existing nitrogen load is from non-point sources.

Nitrogen Loading Thresholds to Meet Criteria
The watershed nitrogen loading thresholds to prevent low dissolved oxygen and to protect eelgrass in the subestuary are 24.3 tons per year and 14.6 tons per year, respectively. In order to protect eelgrass in the downstream subestuaries of Great Bay and Little Bay the watershed nitrogen loading threshold is 23.6 tons per year.

The Winnicut River subestuary is not currently impaired for nitrogen. Eelgrass loss has been documented in this subestuary but there are insufficient data on nitrogen concentrations to formally add this subestuary to the 303d list. The nitrogen loading thresholds for local conditions would apply if this subestuary were to be added to the 303d list based on additional data. The threshold for protecting downstream uses is applicable now.

Percent Reduction Needed in Nitrogen Loads
Existing nitrogen loads need to be reduced by 6.6 tons per year (21 percent) to prevent low dissolved oxygen and by 16.4 tons/year (53 percent) to protect eelgrass in the subestuary. In order to protect eelgrass in the downstream subestuaries of Great Bay and Little Bay the existing nitrogen loads need to be reduced by 7.4 tons/year (24 percent).

Effects of Wastewater Treatment Facility Permitting Options on Nitrogen Loads
There are no WWTFs that discharge in the Winnicut River watershed.

Table 2(a): Measured nitrogen loads, nitrogen loading thresholds, and percent reductions needed for the tidal river subestuaries

	Winnicut		Exeter		Lamprey		Oyster		Bellamy		Cocheco		Salmon Falls	
Description	(tons/yr)	(%)	(tons/yr)	(%)	(tons/yr)	(%)	(tons/yr)	(%)	(tons/yr)	(%)	(tons/yr)	(%)	(tons/yr)	(%)
Measured nitrogen load	31		212		239		60		48		281		336	
Threshold to prevent low DO locally	24	21%	140	34%	226	5%	54	11%	57	-19%	195	31%	360	-7%
Threshold to protect eelgrass locally	15	53%	88	58%	140	41%	29	52%	31	36%	122	57%	222	34%
Threshold to protect eelgrass downstream	24	24%	162	24%	182	24%	48	21%	38	21%	177	37%	214	36%

Note 1: The percent column for each subestuary is the percent that the measured nitrogen load needs to be reduced to match the nitrogen loading threshold.
Note 2: Shaded cells indicate cases where the historical presence of eelgrass in this subestuary has not been confirmed so the objective of protecting eelgrass locally may not be relevant.

Table 2(b): Measured nitrogen loads, cumulative nitrogen loading thresholds for different conditions, and percent reductions needed for the Great Bay, Little Bay, and the Upper Piscataqua River

	Total	
Description	(tons/yr)	(%)
Measured nitrogen load	1408	
Threshold to protect eelgrass in downstream areas only	989	30%
Threshold to protect eelgrass in downstream areas and prevent low DO in rivers	966	31%
Threshold to protect eelgrass in all areas	774	45%

Note 1: The percent column for each subestuary is the percent that the measured nitrogen load needs to be reduced to match the nitrogen loading threshold.

4.2 Exeter River Subestuary

Existing Nitrogen Loads

The annual average watershed nitrogen load to this subestuary between 2003 and 2008 was 211.5 tons per year. WWTF discharges in this watershed accounted for 44.3 tons of nitrogen per year (21 percent of the total). The remaining 167.3 tons per year (79 percent) of the watershed nitrogen load was from non-point sources.

Nitrogen Loading Thresholds to Meet Criteria

The watershed nitrogen loading thresholds to prevent low dissolved oxygen and to protect eelgrass in the subestuary are 140.3 tons per year and 87.8 tons per year, respectively. In order to protect eelgrass in the downstream subestuaries the watershed nitrogen loading threshold is 161.7 tons per year.

Percent Reduction Needed in Nitrogen Loads

Existing nitrogen loads need to be reduced by 71.2 tons per year (34 percent) to prevent low dissolved oxygen and by 123.7 tons/year (58 percent) to protect eelgrass in the subestuary. In order to protect eelgrass in the downstream subestuaries the existing nitrogen load needs to be reduced by 49.8 tons/year (24 percent).

Effects of Wastewater Treatment Facility Permitting Options on Nitrogen Loads

There are two WWTFs that discharge in this watershed: Exeter and Newfields. The nitrogen load from the Exeter WWTF accounts for 96 percent of the delivered point source nitrogen load to this subestuary.

- If the WWTFs receive permits that limit the effluent nitrogen concentration to 8 mg N/L at design flow, 6.4 tons per year would be removed from the estuary. In addition, non-point sources would have to be reduced by 39 percent to prevent low dissolved oxygen and 70 percent to protect eelgrass locally. In order to protect eelgrass in downstream areas, non-point sources would have to be reduced by 26 percent.
- If the WWTFs receive permits that limit the effluent nitrogen concentration to 5 mg N/L at design flow, 20.6 tons per year would be removed from the estuary. In addition, non-point sources would have to be reduced by 30 percent to prevent low dissolved oxygen and 62 percent to protect eelgrass locally. In order to protect eelgrass in downstream areas, non-point sources would have to be reduced by 17 percent.
- If the WWTFs receive permits that limit the effluent nitrogen concentration to 3 mg N/L at design flow, 30.1 tons per year would be removed from the estuary. In addition, non-point sources would have to be reduced by 25 percent to prevent low dissolved oxygen and 56 percent to protect eelgrass locally. In order to protect eelgrass in downstream areas, non-point sources would have to be reduced by 12 percent.

4.3 Lamprey River Subestuary

Existing Nitrogen Loads
The annual average watershed nitrogen load to this subestuary between 2003 and 2008 was 238.9 tons per year. WWTF discharges in this watershed accounted for 34.7 tons of nitrogen per year (15 percent of the total). The remaining 204.1 tons per year (85 percent) of the watershed nitrogen load was from non-point sources.

Nitrogen Loading Thresholds to Meet Criteria
The watershed nitrogen loading thresholds to prevent low dissolved oxygen and to protect eelgrass in the subestuary are 226.1 tons per year and 140.1 tons per year, respectively. In order to protect eelgrass in the downstream subestuaries the watershed nitrogen loading threshold is 182.4 tons per year.

Percent Reduction Needed in Nitrogen Loads
Existing nitrogen loads need to be reduced by 12.8 tons per year (5 percent) to prevent low dissolved oxygen and by 98.7 tons/year (41 percent) to protect eelgrass in the subestuary. In order to protect eelgrass in the downstream subestuaries the existing nitrogen load needs to be reduced by 56.5 tons/year (24 percent).

Effects of Wastewater Treatment Facility Permitting Options on Nitrogen Loads
There are two WWTFs that discharge in this watershed: Newmarket and Epping. The nitrogen load from the Newmarket WWTF accounts for 88 percent of the delivered point source nitrogen load to this subestuary.

- If the WWTFs receive permits that limit the effluent nitrogen concentration to 8 mg N/L at design flow, 20.9 tons per year would be removed from the estuary. In addition, non-point sources would not have to be reduced to prevent low dissolved oxygen, but would have to be reduced by 38 percent to protect eelgrass locally. In order to protect eelgrass in downstream areas, non-point sources would have to be reduced by 17 percent.
- If the WWTFs receive permits that limit the effluent nitrogen concentration to 5 mg N/L at design flow, 26.1 tons per year would be removed from the estuary. In addition, non-point sources would not have to be reduced to prevent low dissolved oxygen, but would have to be reduced 36 percent to protect eelgrass locally. In order to protect eelgrass in downstream areas, non-point sources would have to be reduced by 15 percent.
- If the WWTFs receive permits that limit the effluent nitrogen concentration to 3 mg N/L at design flow, 29.5 tons per year would be removed from the estuary. In addition, non-point sources would not have to be reduced to prevent low dissolved oxygen, but would have to be reduced 34 percent to protect eelgrass locally. In order to protect eelgrass in downstream areas, non-point sources would have to be reduced by 13 percent.

4.4 Oyster River Subestuary

Existing Nitrogen Loads

The annual average watershed nitrogen load to this subestuary between 2003 and 2008 was 60.4 tons per year. WWTF discharges in this watershed accounted for 11.8 tons of nitrogen per year (19 percent of the total). The remaining 48.6 tons per year (81 percent) of the watershed nitrogen load was from non-point sources.

Nitrogen Loading Thresholds to Meet Criteria

The watershed nitrogen loading thresholds to prevent low dissolved oxygen and to protect eelgrass in the subestuary are 53.5 tons per year and 29.2 tons per year, respectively. In order to protect eelgrass in the downstream subestuaries the watershed nitrogen loading threshold is 47.7 tons per year.

Percent Reduction Needed in Nitrogen Loads

Existing nitrogen loads need to be reduced by 6.8 tons per year (11 percent) to prevent low dissolved oxygen and by 31.2 tons/year (52 percent) to protect eelgrass in the subestuary. In order to protect eelgrass in the downstream subestuaries the existing nitrogen load needs to be reduced by 12.7 tons/year (21 percent).

Effects of Wastewater Treatment Facility Permitting Options on Nitrogen Loads

There is one WWTF that discharges in this watershed: Durham.

- If the WWTF receives a permit that limits the effluent nitrogen concentration to 8 mg N/L at design flow, the nitrogen load from the WWTF would *increase* by 18.6 tons per year because the design flow (2.5 MGD) is so much higher than current flows (1.0 MGD) and because nitrogen concentrations in effluent are already less than 8 mg N/L at this facility. Under this scenario, non-point sources would have to be reduced by 52 percent to prevent low dissolved oxygen and 100 percent to protect eelgrass locally. In order to protect eelgrass in downstream areas, non-point sources would have to be reduced by 64 percent.
- If the WWTF receives a permit that limits the effluent nitrogen concentration to 5 mg N/L at design flow, the nitrogen load from the WWTF would *increase* by 7.2 tons per year because of the reasons stated above. Under this scenario, non-point sources would have to be reduced by 29 percent to prevent low dissolved oxygen and 79 percent to protect eelgrass locally. In order to protect eelgrass in downstream areas, non-point sources would have to be reduced by 41 percent.
- If the WWTFs receive permits that limit the effluent nitrogen concentration to 3 mg N/L at design flow, 0.4 tons per year would be removed from the estuary. In addition, non-point sources would have to be reduced by 13 percent to prevent low dissolved oxygen and 63 percent to protect eelgrass locally. In order to protect eelgrass in downstream areas, non-point sources would have to be reduced by 25 percent.

Nitrogen loads from WWTFs are projected to increase for some permitting scenarios; however, it is unlikely that nitrogen loads from a WWTF will be allowed to increase. First, DES interprets RSA 485-A:12,II and Env-Wq 1703.03(a) to mean that pollutant loads to an impaired waterbody must be held at or below existing levels until a TMDL or wasteload allocation has been established. Second, it is typically more expensive and harder to provide reasonable assurance for non-point source load reductions relative to point source reductions.

4.5 Bellamy River Subestuary

Existing Nitrogen Loads
The annual average watershed nitrogen load to this subestuary between 2003 and 2008 was 47.9 tons per year. There are no wastewater treatment facility discharges in this watershed. Therefore, 100 percent of the existing nitrogen load is from non-point sources.

Nitrogen Loading Thresholds to Meet Criteria
The watershed nitrogen loading thresholds to prevent low dissolved oxygen and to protect eelgrass in the subestuary are 56.8 tons per year and 30.7 tons per year, respectively. In order to protect eelgrass in the downstream subestuaries of Great Bay and Little Bay the watershed nitrogen loading threshold is 37.8 tons per year.

Percent Reduction Needed in Nitrogen Loads
Existing nitrogen loads do not need to be reduced to prevent low dissolved oxygen, but need to be reduced by 17.2 tons/year (36 percent) to protect eelgrass in the subestuary. In order to protect eelgrass in the downstream subestuaries the existing nitrogen loads need to be reduced by 10.1 tons/year (21 percent).

Effects of Wastewater Treatment Facility Permitting Options on Nitrogen Loads
There are no WWTFs that discharge in the Bellamy River watershed.

4.6 Cocheco River Subestuary

Existing Nitrogen Loads
The annual average watershed nitrogen load to this subestuary between 2003 and 2008 was 281.3 tons per year. WWTF discharges in this watershed accounted for 130.1 tons of nitrogen per year (46 percent of the total). The remaining 151.2 tons per year (54 percent) of the watershed nitrogen load was from non-point sources.

Nitrogen Loading Thresholds to Meet Criteria
The watershed nitrogen loading thresholds to prevent low dissolved oxygen and to protect eelgrass in the subestuary are 194.6 tons per year and 122.1 tons per year, respectively. In order to protect eelgrass in the downstream subestuaries the watershed nitrogen loading threshold is 177.2 tons per year.

Percent Reduction Needed in Nitrogen Loads
Existing nitrogen loads need to be reduced by 86.7 tons per year (31 percent) to prevent low dissolved oxygen and by 159.2 tons/year (57 percent) to protect eelgrass in the subestuary. In order to protect eelgrass in the downstream subestuaries the existing nitrogen load needs to be reduced by 104.1 tons/year (37 percent).

Effects of Wastewater Treatment Facility Permitting Options on Nitrogen Loads
There are two WWTFs that discharge in this watershed: Rochester and Farmington. The nitrogen load from the Rochester WWTF accounts for 98 percent of the delivered point source nitrogen load to this subestuary.

- If the WWTFs receive permits that limit the effluent nitrogen concentration to 8 mg N/L at design flow, 81.4 tons per year would be removed from the estuary. In addition, non-point sources would have to be reduced by 4 percent to prevent low dissolved oxygen and 52 percent to protect eelgrass locally. In order to protect eelgrass in downstream areas, non-point sources would have to be reduced by 15 percent.
- If the WWTFs receive permits that limit the effluent nitrogen concentration to 5 mg N/L at design flow, 99.7 tons per year would be removed from the estuary. In addition, non-point sources would not have to be reduced to prevent low dissolved oxygen, but would have to be reduced by 39 percent to protect eelgrass locally. In order to protect eelgrass in downstream areas, non-point sources would have to be reduced by 3 percent.
- If the WWTFs receive permits that limit the effluent nitrogen concentration to 3 mg N/L at design flow, 111.8 tons per year would be removed from the estuary. In addition, non-point sources would not have to be reduced to prevent low dissolved oxygen, but would have to be reduced by 31 percent to protect eelgrass locally. In order to protect eelgrass in downstream areas, non-point sources would not have to be reduced.

The historical presence of eelgrass in this subestuary has not been confirmed so the objective of protecting eelgrass locally may not be relevant.

4.7 Salmon Falls River Subestuary

Existing Nitrogen Loads

The annual average watershed nitrogen load to this subestuary between 2003 and 2008 was 335.9 tons per year. WWTF discharges in this watershed accounted for 32.0 tons of nitrogen per year (10 percent of the total). The remaining 303.9 tons per year (90 percent) of the watershed nitrogen load was from non-point sources.

Nitrogen Loading Thresholds to Meet Criteria

The watershed nitrogen loading thresholds to prevent low dissolved oxygen and to protect eelgrass in the subestuary are 360.1 tons per year and 221.8 tons per year, respectively. In order to protect eelgrass in the downstream subestuaries the watershed nitrogen loading threshold is 214.3 tons per year.

Percent Reduction Needed in Nitrogen Loads

Existing nitrogen loads do not need to be reduced to prevent low dissolved oxygen, but need to be reduced by 114.1 tons/year (34 percent) to protect eelgrass in the subestuary. In order to protect eelgrass in the downstream subestuaries the existing nitrogen load needs to be reduced by 121.5 tons/year (36 percent).

Effects of Wastewater Treatment Facility Permitting Options on Nitrogen Loads

There are six WWTFs that discharge in this watershed: South Berwick, Berwick, North Berwick, Milton, Rollinsford, and Somersworth.

- If the WWTFs receive permits that limit the effluent nitrogen concentration to 8 mg N/L at design flow, the nitrogen load from the WWTFs would *increase* by 24.1 tons per year because the design flows are so much higher than current flows in several WWTFs and because nitrogen concentrations in effluent at the Somersworth WWTF are already less than 5 mg N/L. Under this scenario, non-point sources would not have to be reduced to prevent low dissolved oxygen but would have to be reduced by 45 percent to protect eelgrass locally. In order to protect eelgrass in downstream areas, non-point sources would have to be reduced by 48 percent.
- If the WWTFs receive permits that limit the effluent nitrogen concentration to 5 mg N/L at design flow, the nitrogen load from the WWTFs would *increase* by 3.1 tons per year because of the reasons stated above. Under this scenario, non-point sources would not have to be reduced to prevent low dissolved oxygen but would have to be reduced by 39 percent to protect eelgrass locally. In order to protect eelgrass in downstream areas, non-point sources would have to be reduced by 41 percent.
- If the WWTFs receive permits that limit the effluent nitrogen concentration to 3 mg N/L at design flow, 10.9 tons per year would be removed from the estuary. In addition, non-point sources would not have to be reduced to prevent low dissolved oxygen, but would have to be reduced by 34 percent to protect eelgrass locally. In order to protect eelgrass in downstream areas, non-point sources would have to be reduced by 36 percent.

Nitrogen loads from WWTFs are projected to increase for some permitting scenarios; however, it is unlikely that nitrogen loads from a WWTF will be allowed to increase from existing levels. First, DES interprets RSA 485-A:12,II and Env-Wq 1703.03(a) to mean that pollutant loads to an impaired waterbody must be held at or below existing levels until a TMDL or wasteload allocation has been established. Second, it is typically more expensive and harder to provide reasonable assurance for non-point source load reductions relative to point source reductions.

The historical presence of eelgrass in this subestuary has not been confirmed so the objective of protecting eelgrass locally may not be relevant.

4.8 Great Bay, Little Bay, and Upper Piscataqua River Subestuaries

In the previous sections, each of the tidal river subestuaries was evaluated separately. However, the individual nitrogen loading thresholds can be combined to determine the total load threshold for Great Bay, Little Bay, and Upper Piscataqua River needed to achieve different conditions of compliance with the numeric nutrient criteria. This calculation was needed to provide overall loading reduction numbers for the watershed. The results for individual subestuaries may differ from this average assessment.

Three general conditions of compliance were evaluated. The first condition was protecting eelgrass in the Great Bay, Little Bay, and Upper Piscataqua River only. The second condition was protecting eelgrass in the Great Bay, Little Bay, and Upper Piscataqua River while also preventing low dissolved oxygen in the tidal river subestuaries. The third condition was protecting eelgrass in all subestuaries.

Existing Nitrogen Loads
The annual average watershed nitrogen load to this subestuary between 2003 and 2008 was 1,407.8 tons per year. WWTF discharges in this watershed accounted for 379.1 tons of nitrogen per year (27 percent of the total). The remaining 1,028.6 tons per year (73 percent) of the watershed nitrogen load was from non-point sources.

Nitrogen Loading Thresholds to Meet Criteria
The watershed nitrogen loading threshold to only protect eelgrass habitat in the Great Bay, Little Bay, and Upper Piscataqua is 988.9 tons per year. The threshold to prevent low dissolved oxygen in the tidal river subestuaries and to protect eelgrass in the downstream subestuaries is 965.7 tons per year. In order to protect eelgrass in all subestuaries the watershed nitrogen loading threshold is 774.4 tons per year.

Percent Reduction Needed in Nitrogen Loads
Existing nitrogen loads need to be reduced by 418.8 tons per year (30 percent) to only protect eelgrass habitat in Great Bay, Little Bay, and the Upper Piscataqua. Existing loads need to be reduced by 442.0 tons per year (31 percent) to prevent low dissolved oxygen in the tidal river subestuaries and to protect eelgrass in the downstream subestuaries. In order to protect eelgrass in all subestuaries the existing nitrogen load needs to be reduced by 633.4 tons per year (45 percent).

Effects of Wastewater Treatment Facility Permitting Options on Nitrogen Loads

There are 18 WWTFs that discharge in the watershed or otherwise contribute nitrogen to the Great Bay, Little Bay, and the Upper Piscataqua River. The four largest WWTFs in terms of delivered load are Rochester, Dover, Exeter, and Newmarket. These four WWTFs account for 34 percent, 27 percent, 11 percent and 8 percent of the delivered point source nitrogen load to these downstream subestuaries, respectively.

The nitrogen loading thresholds to meet the first and second conditions were approximately equal. Therefore, protecting eelgrass in the downstream areas and preventing low dissolved oxygen in the tidal rivers would require approximately the same nitrogen load reductions. Protecting eelgrass in the tidal river subestuaries would require greater reductions in nitrogen loads. Therefore:

- If the WWTFs receive permits that limit the effluent nitrogen concentration to 8 mg N/L at design flow, 116.8 tons of nitrogen per year would be removed from the estuary. In addition, non-point sources would have to be reduced by 32 percent to prevent low dissolved oxygen in the tidal river subestuaries and to protect eelgrass in the Great Bay, Little Bay, and Upper Piscataqua. In order to protect eelgrass in the tidal rivers also, non-point sources would have to be reduced by 50 percent.
- If the WWTFs receive permits that limit the effluent nitrogen concentration to 5 mg N/L at design flow, 215.2 tons of nitrogen per year would be removed from the estuary. In addition, non-point sources would have to be reduced by 22 percent to prevent low dissolved oxygen in the tidal river subestuaries and to protect eelgrass in the Great Bay, Little Bay, and Upper Piscataqua. In order to protect eelgrass in the tidal rivers also, non-point sources would have to be reduced by 41 percent.
- If the WWTFs receive permits that limit the effluent nitrogen concentration to 3 mg N/L at design flow, 280.8 tons of nitrogen per year would be removed from the estuary. In addition, non-point sources would have to be reduced by 16 percent to prevent low dissolved oxygen in the tidal river subestuaries and to protect eelgrass in the Great Bay, Little Bay, and Upper Piscataqua. In order to protect eelgrass in the tidal rivers also, non-point sources would have to be reduced by 34 percent.

For each of the three scenarios listed above, the delivered nitrogen load from WWTFs cumulatively would decrease. However, as noted for the Oyster River and Salmon Falls River subestuaries, the nitrogen loads from some WWTFs would increase if these facilities are permitted at design flow. Two of the WWTFs that discharge to the Lower Piscataqua River (Kittery and Pease WWTFs) would also increase their nitrogen loads if permitted with nitrogen limits at design flow. As stated in previous sections, it is unlikely that increasing nitrogen loads will be permitted for any WWTF. Therefore, the non-point source reductions predicted for the different scenarios are likely to be higher than will actually be necessary.

4.9 Capital and Operation/Maintenance Costs for Wastewater Treatment Facility Upgrades

The capital costs for upgrading all 18 of the WWTFs in the watershed in both New Hampshire and Maine to meet nitrogen effluent limits of 8 mg N/L, 5 mg N/L, or 3 mg N/L are estimated to total $197 million, $267 million, and $354 million, respectively.

Operation and maintenance costs are also expected to increase when the WWTFs are upgraded, but not as steeply. The operation and maintenance budgets for all the WWTFs will increase cumulatively by $2.72 million, $7.63 million, and $10.84 million in order to achieve the nitrogen effluent limits of 8 mg N/L, 5 mg N/L, or 3 mg N/L. The operation and maintenance budget for the 18 WWTFs currently is $18.89 million.

Amortized capital costs plus annual operation & maintenance costs were combined to estimate the total annual cost for each treatment level for nitrogen removal. A range of interest rates from 2% to 5% were selected to bracket the potential rates for a 20 year bond. The results are summarized in Table 3. Overall, if all of the WWTFs were given nitrogen effluent limits of 8 mg N/L at design flow, a total of 116.8 tons of nitrogen per year would be removed from Great Bay, Little Bay, and the Upper Piscataqua for an annualized cost of $14.80-$18.56 million. The cost per pound of nitrogen removed would be $63-$79 per year. For the 5 mg N/L nitrogen permit limit, 215.2 tons or nitrogen would be removed for an annualized cost of $23.98-29.08 million at an annualized cost per pound of $56-$68 per year. Finally, for the 3 mg N/L nitrogen permit limit, 280.8 tons of nitrogen would be removed for an annualized cost of $32.48-$39.24 million at an annualized cost per pound of $58-$70 per year. The costs per pound of nitrogen removed are likely overestimated because the nitrogen load reductions at most WWTFs are partially cancelled out by several WWTFs for which the nitrogen load would increase under the permitting scenarios. Increasing nitrogen loads at WWTFs are unlikely under any permitting scenario.

In terms of cost per pound of nitrogen removed, the Rochester, Dover and Newmarket WWTFs are the most cost-effective upgrades. The cost per pound of nitrogen removed from the estuary each year for these WWTFs would be $6-7 per lb, $30-35 per lb, and $32-39 per lb, respectively, for the 3 mg N/L permit scenario. Nitrogen removal at these facilities would be more cost effective than at other facilities because these facilities contribute the majority of the existing nitrogen load from wastewater treatment facilities.

WWTF upgrades are more cost effective and more likely to achieve reductions than most options for reducing non-point sources. An evaluation of non-point source offsets for nutrient trading in Virginia[22] found the annualized cost of nitrogen reduction from agriculture ranged from $8/lb to $470/lb. Stormwater treatment to remove nitrogen would cost between $54/lb and $2,215/lb annually[22]. The minimum cost for nitrogen removal by connecting homes using septic systems to a WWTF would be $30/lb to $560/lb annually[22]. For the Long Island Sound TMDL, the average cost effectiveness for agricultural controls and stormwater management were assumed to be $5 and $133 per pound of nitrogen removed, respectively, using annualized costs[23]. In addition to cost, the feasibility of non-point source controls will depend on how much of the existing nitrogen load is from the different types of non-point sources. For example, if nitrogen from agriculture is a small percent of the total nitrogen load, nitrogen reductions on agricultural lands will not be effective, regardless of the cost. The contribution of agriculture, stormwater, and septic systems to the existing nitrogen load is not currently known. Future modeling will be done by DES to answer this question.

Details of the methods and results, including the cost estimates for individual wastewater treatment facilities, are provided in Appendix E.

Table 3: Estimated capital costs and increases in operation and maintenance costs associated with different levels of nitrogen removal at the 18 wastewater treatment facilities discharging to the Great Bay Estuary

Permit Scenario	Capital Costs ($ millions)	Amortized Capital Costs[1] ($ millions/yr)	Increased O&M Costs[2] ($millions/yr)	Total Increase in Annual Costs[3] ($ millions/yr)
8 mg/L Nitrogen Effluent Limit	$197.41	$12.07-$15.84	$2.72	$14.80-$18.56
5 mg/L Nitrogen Effluent Limit	$267.31	$16.35-$21.45	$7.63	$23.98-$29.08
3 mg/L Nitrogen Effluent Limit	$353.91	$21.64-$28.40	$10.84	$32.48-$39.24

1. Amortized capital costs were estimated for 20 year bond. A range of interest rates from 2% to 5% were used to bracket the potential amortized rate.
2. Increased operation and maintenance (O&M) costs represent increases of O&M from existing operating budgets associated with nitrogen removal.
3. Sum of amortized capital and increased O&M costs.

5 Discussion

Several of the key observations from the DES modeling are summarized below.

Nitrogen loads to the Great Bay, Little Bay, and the Upper Piscataqua River need to be reduced by 30 percent to 45 percent to attain the numeric nutrient criteria.
Nitrogen loads to the Great Bay, Little Bay, and Upper Piscataqua from all sources will need to be reduced by 30 percent to 45 percent to meet the numeric nutrient criteria. The range of values corresponds to the nitrogen load needed to only protect eelgrass in the downstream areas of Great Bay, Little Bay, and the Upper Piscataqua (30 percent) and the nitrogen load needed to protect eelgrass in all areas (45 percent). For most of the tidal subestuaries, the nitrogen load threshold to protect eelgrass in the downstream areas is similar to but lower than the nitrogen load threshold to prevent low dissolved oxygen in the tidal river subestuary. Therefore, if watershed nitrogen loads are reduced enough to protect eelgrass in the downstream areas, the dissolved oxygen impairments in the tidal river subestuaries will be eliminated also.

Both wastewater treatment facilities and non-point sources will need to reduce nitrogen loads to attain the numeric nutrient criteria.
WWTFs account for 27 percent of the delivered nitrogen load to the Great Bay, Little Bay, and Upper Piscataqua. Given that nitrogen loads need to be reduced by 30 to 45 percent, non-point source nitrogen loads will have to be reduced considerably to meet the numeric nutrient criteria. If all of the WWTFs were given nitrogen effluent concentration limits of 8, 5, or 3 mg N/L the delivered load of nitrogen from WWTFs would fall by 31, 57, or 74 percent, respectively. At the same time, non-point sources of nitrogen would need to be reduced by 29-50 percent, 20-41 percent, or 13-34 percent, respectively. The percent reductions for non-point sources are presented as a range with the low end associated with protecting eelgrass in the downstream subestuaries and the high end associated with protecting eelgrass everywhere.

The percent reduction targets for nitrogen loads only change minimally between wet and dry years.
While average values have been used in this summary report, DES modeled the nitrogen load reductions needed to achieve the numeric nutrient criteria for three different periods: 2003-2004, 2005-2006, and 2007-2008. The purpose of this modeling was to understand the effect of different rainfall amounts on the ability of the subestuaries to assimilate nitrogen. Total precipitation in 2003-2004, 2005-2006, and 2007-2008 was 43.7, 67.9, and 51.4 inches, respectively. This represents a variability of 22 percent over the three years. The modeling showed that both the nitrogen loads and the nitrogen loading thresholds for the subestuaries increased during the 2005-2006 period with higher precipitation. However, the percent reduction in the nitrogen loads needed to meet the thresholds remained relatively constant, having an average variability of less than 5 percent in the downstream subestuaries. Therefore, the percent reduction goals set in this report should be applicable to all years regardless of the precipitation amount. The effects of precipitation on the models are shown in Appendices A, B, and C.

Wastewater treatment facility upgrades to remove nitrogen will be costly; however, the average cost per pound of nitrogen removed from the estuary due to wastewater facility upgrades is lower than for non-point source controls.
The capital costs for upgrading all 18 of the WWTFs in the watershed to meet nitrogen effluent limits of 8 mg N/L, 5 mg N/L, or 3 mg N/L are estimated to total $197 million, $267 million, and $354 million, respectively. The average annualized cost per pound of nitrogen removed from the estuary through WWTF upgrades is $58-70 per lb for the 3 mg N/L permit scenario. The Rochester ($6-7/lb), Dover ($30-35/lb), and Newmarket ($32-39/lb) WWTFs are the most cost-effective upgrades. Nitrogen removal from non-point sources is generally more expensive and less likely to be successful than WWTF upgrades.

The permitting options for some wastewater treatment facilities will be limited by requirements to not increase pollutant loads to impaired waterbodies.
For seven of the 18 WWTFs discharging to the Great Bay Estuary, if nitrogen effluent concentration limits are set at design flow, the permitted nitrogen load from the facility would increase. The increase is because these WWTFs either have design flows that are much higher than the actual flows or because these facilities already have low nitrogen concentrations in effluent or both. However, it is unlikely that nitrogen loads from a WWTF will be allowed to increase from existing levels. First, DES interprets RSA 485-A:12,II and Env-Wq 1703.03(a) to mean that pollutant loads to an impaired waterbody must be held at or below existing levels until a TMDL or wasteload allocation has been established. Second, it is typically more expensive and harder to provide reasonable assurance for non-point source load reductions relative to point source reductions.

The numeric nutrient criteria and models used by DES are based on sound science and are sufficiently accurate for calculating nitrogen loading thresholds for the Great Bay watershed.
The models used in this report were developed by DES using simple, mass-balance calculations in spreadsheets. This approach was adopted in order to answer management questions in a timely manner and at a reasonable cost. However, for these simple models, low cost does not mean low quality. DES used extensive quality assurance tests to show that these models had low error. DES also initiated a review of the numeric nutrient criteria that have been proposed for the Great Bay Estuary by nationally experts from Cornell University and the University of Maryland. The reviewers found that the numeric nutrient criteria were clearly explained and well supported by the scientific literature and reasoning. Therefore, the independent review and quality assurance tests show that the proposed numeric nutrient criteria are based on sound science and that the DES models are more than sufficient for their intended purpose of developing watershed nitrogen loading thresholds for the Great Bay Estuary.

Additional monitoring and modeling is needed to better characterize conditions and nitrogen loading thresholds for the Lower Piscataqua River.
The DES models do not cover the Lower Piscataqua River, Portsmouth Harbor, and Little Harbor because of the high salinity and complex hydrology in these areas. The models are sensitive to variability in input variables in subestuaries where the salinity is close to the salinity of the ocean. Monitoring data in the Lower Piscataqua River and Portsmouth Harbor are limited. More detailed models and additional monitoring are needed in the Lower Piscataqua River and

Portsmouth Harbor to better characterize the effects of nitrogen and to determine nitrogen loading thresholds for these areas. This work would be directly relevant to permitting decisions for the four WWTFs that currently discharge to the Lower Piscataqua River: Portsmouth, Newington, Pease Tradeport, and Kittery. Resources are needed before this work can begin.

This nitrogen loading analysis for Great Bay may provide a framework for setting nitrogen permit limits for wastewater treatment facilities and developing watershed implementation plans to reduce nitrogen loads.

This report presents the results of a modeling exercise to better understand: (1) The existing nitrogen load to the subestuaries; (2) The nitrogen loading thresholds for subestuaries to attain the numeric nutrient criteria; (3) The effects of different permitting scenarios for WWTFs on the nitrogen load to the subestuaries; (4) The reductions in non-point source nitrogen loads needed for the different permitting scenarios; and (5) The estimated costs of WWTF upgrades.

All of this information is needed to establish permit limits for nitrogen for WWTFs; however, this report does not actually set these permit conditions. The information in this report should be used to develop detailed Watershed Implementation Plans with steps that can be taken in a phased manner to reduce nitrogen loads from both point and non-point sources by 31 to 45 percent on average. Watershed Implementation Plans should be developed for each of the Winnicut, Exeter, Lamprey, Oyster, Bellamy, Cocheco, and Salmon Falls River watersheds. Permit limits for nitrogen at each WWTF should be determined within the context of these plans.

The Watershed Implementation plans should be developed concurrently with additional research to refine our scientific understanding of the system. The next steps in terms of scientific research are to:

- Identify non-point sources of nitrogen in the watershed and reductions in the non-point source loads if best management practices are implemented.
- Develop models and nitrogen loading thresholds for the Lower Piscataqua River, Portsmouth Harbor, and Little Harbor.
- Continue research on nutrient criteria and existing models. The watershed nitrogen loading thresholds in this report are based on the best available science and are not expected to change substantially. However, new scientific information may result in some adjustments.
- Develop a comprehensive monitoring program to track the effectiveness of phased implementation activities.

6 References

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