Technical Review of the Massachusetts Estuary Project Nauset Harbor Embayment System Report for the Town of Orleans

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Executive Summary

The Massachusetts Estuaries Project (MEP), a joint program between the Massachusetts Department of Environmental Protection (DEP) and the University of Massachusetts Dartmouth School of Marine Science and Technology (SMAST), recently released a revised draft study report ("Report") for the Nauset Harbor Embayment System (Howes et al., 2012) located in the Town of Orleans and Eastham, MA. The report presented the results of the application of MEP's Linked Watershed-Embayment Management Model to establish nitrogen loading thresholds that were designed to protect and improve water and habitat quality in the Nauset Harbor embayment. The implementation of these thresholds will involve wastewater management decisions that require significant new infrastructure to reduce present nitrogen discharges to the embayment.

The Town of Orleans retained RPS ASA to provide engineering and technical assistance with reviewing the report. The purpose of the review was to provide the Town assistance in gaining a better understanding of the relative quality of the background data used in the study, the appropriateness of the modeling approach, and the adequacy of the model results.

The major findings developed by RPS ASA in reviewing the Report include the following:

- The MEP Linked Model System consists of a land use model that provides estimates of nitrogen loading to the waterbody under study, a hydrodynamic model that calculates the circulation in the waterbody, and a water quality model that determines the dispersion of nitrogen in the water body. The hydrodynamic model is RMA-2, a two dimensional vertically averaged finite element numerical model originally developed almost 40 years ago (Norton et al, 1973). The water quality model is RMA-4 (King, 1990), a sister model to RMA2 using the same grid and numerical solution. These models, along with the simple loading model form an adequate approach to evaluate the nutrient impacts in the Nauset Harbor System.
- The application of the RMA models in the MEP Linked Model System is flawed in that it does not address potential changes in the physical layout of the beaches, inlet, and bathymetry due to the well documented dynamic nature of Nauset Harbor. At a minimum a sensitivity analysis should be performed to evaluate the range of nitrogen thresholds under different physical configurations.
- The watershed loading assessment may over-estimate loading to the embayment from the use of pilot study effluent values for septic systems as opposed to available longer-term analyses, resulting in a 17% over-estimation of nitrogen loadings. If the lower estimated loading is accurate, in concert with high offshore values observed, offshore

data would indicate water quality conditions which exceed the calculated threshold value and do not support eelgrass habitat are transported into the embayment from offshore, and not controllable by regulatory or engineering measures.

- The assumption of a linear and uniform groundwater source to the embayment is refuted by more recent data indicating that groundwater may circumvent the estuary completely.
- The water quality model calibration to total nitrogen instead of salinity is not a standard approach, and the resultant dispersion coefficients are contrary to expectations based on the embayment characteristics.
- The water quality dataset used in the habitat assessment does not represent a long enough time period to be relevant to the timescales of groundwater nitrogen discharge to the embayment. This time period may also represent an extreme set of water quality conditions, based on observations in other parts of New England.
- There is no quantitative data presented to support a long term trend of increased watershed loading. It doesn't appear that a long term loading study was completed, but rather, that eelgrass coverage decreases indicate that this increased loading occurred.
- These conclusions are consistent with other technical reviews of the MEP Linked Model System including one by the Cape Cod Water Protection Collaborative (CCWPC, 2011) and one by Woods Hole Group (WHG, 2009) assessing the application to the Pleasant Bay System.
- The changes that would be required to meet the suggested threshold nitrogen levels are not supported by the temporal coverage of the observational data. The measures that would be required to achieve the proposed threshold concentrations should be supported by multi-seasonal and multi-year datasets, within and outside of the embayment.

Table of Contents

1 Introduction

The Massachusetts Estuaries Project (MEP), a joint program between the Massachusetts Department of Environmental Protection (DEP) and the University of Massachusetts Dartmouth School of Marine Science and Technology (SMAST), recently released a revised draft study report ("Report") for the Nauset Harbor Embayment System (Howes et al., 2012) located in the Town of Orleans and Eastham, MA. The report presented the results of the application of MEP's Linked Watershed-Embayment Management Model to establish nitrogen loading thresholds that were designed to protect and improve water and habitat quality in the Nauset Harbor embayment. The implementation of these thresholds will involve wastewater management decisions that require significant new infrastructure to reduce present nitrogen discharges to the embayment.

The Town of Orleans retained RPS ASA to provide engineering and technical assistance with reviewing the report. The purpose of the review was to provide the Town assistance in gaining a better understanding of the relative quality of the background data used in the study, the appropriateness of the modeling approach, and the adequacy of the model results.

Applied Science Associates, Inc., now doing business as RPS ASA, has extensive expertise in the development and use of computer models that simulate physical, chemical and biological processes in marine and freshwater environments, including estuaries and embayments. RPS ASA also has experience using the models that comprise the basis for the MEP's Linked Watershed-Embayment Management Model as well as many other models of similar or more sophisticated capabilities. RPS ASA has also provided expert review for a number of modeling studies to ascertain quality of the effort, from data acquisition through model application to analysis of model results. Over its 33-year history RPS ASA has provided solutions for both private and public clients to problems related to these environments.

In the sections below, RPS ASA summarizes its comments and questions relative to the technical approach taken and conclusions reached in the review of the Report. Section 2 provides summary comments plus individual chapter reviews following the format of the Report.

2 Technical Review

The technical review is presented as a series of chapter-by-chapter reviews.

2.1 Overall Report Review

MEP has typically used a standard report format for each of the estuaries and embayments that have been studied under this joint DEP / SMAST activity. The Report will be reviewed for its clarity of communication as well as its completeness in terms of providing supporting information or references for statements made. Neither typographical nor grammar errors will be noted except where they may be confusing or ambiguous. Discrepancies in data presented or used will be noted.

2.2 Review of Chapter I. Introduction

The Report rightly points out that the Nauset Harbor Estuarine System, specifically the beach and inlet, are very dynamic features due to littoral transport processes (pg. 1, para. 3). It is further stated that

> Changes in hydrodynamics wrought by inlet dynamics is a key factor in determining the effects of watershed nitrogen loading on estuarine health (see Sections V & IX). To the extent that the inlet becomes restricted or migrates north or south and tidal flushing is reduced, nitrogen loading impacts will be magnified over present conditions. Any long term habitat management plan for the Nauset Estuarine System must recognize the importance of inlet dynamics and include options to maintain the present (or other suitable) hydrodynamic conditions as evidenced by the creation of a new inlet in the Pleasant Bay system in 2007.
>
> (pg. 1, para. 3 to pg. 2, para. 1)

Further discussion appearing in Section I.2 Site Description (pgs. 8 to 10) emphasizes the dynamic nature of the system and its effect on nutrients. As will be shown in later sections the Report did not include any analyses of the effects of inlet dynamics on circulation or nutrient flushing, a major omission for this system. Without such an analysis it is impossible to determine if the recommended nutrient thresholds are over- or under-estimated. At a minimum, a sensitivity study should have been conducted of the likely effects of changes in the beach and inlet conditions on proposed nutrient reductions recommended.

There appear to be a number of incorrect references to Section IX (e.g., see above quote and Figure I-2 on pg 8) which should be corrected to Section VIII.

The Report rightly points out that

> Unfortunately, most of the smaller sub-basins to the Nauset Estuary (Town Cove, Salt Pond, Nauset Bay sub-systems) are near or beyond their ability to assimilate additional nutrients without impacting ecological health. Nitrogen levels are elevated within these basins and historic eelgrass areas have diminished significantly. The result is that nitrogen management within this estuary is aimed at restoration, not protection or maintenance of existing conditions. In general, nutrient over-fertilization is termed “eutrophication” and when the nutrient loading is primarily from human activities, “cultural eutrophication”. Although the influence of human-induced changes has increased nitrogen loading to the system and contributed to the degradation in ecological health, it is sometimes possible that eutrophication within the Nauset Estuarine System could potentially occur without anthropogenic influence and must be considered in the nutrient threshold analysis. While this finding would not change the need for restoration, it would change the approach and potential targets for management. As part of future restoration efforts, it is important to understand that it may not be possible to turn each embayment into a “pristine” system.
>
> (pg. 11 para. 2)

There does not appear to be any analyses investigating whether eutrophication would occur without anthropogenic influence, thus changing “the approach and potential targets for management.”

2.3 Review of Chapter II. Previous Studies Related to Nitrogen Management

The Report summarizes previous studies of the Nauset Estuary and concludes from Leatherman and Zaremba (1986) that

> …the Nauset Spit Barrier Beach system is extremely dynamic and that the spit is generally retreating landward due to inlet dynamics and overwash processes. Given the dynamic nature of the barrier beach and the inlet as well as the frequency of overwash events during strong winter storms, management of the Nauset Estuary must take into consideration potential alterations to the natural flushing capacity of the system, as was also the case recently for the southern portion of Nauset Beach which forms the main lagoon of Pleasant Bay.
>
> (pg. 14 para. 1)

and from WHOI (1998) that

> …beach erosion rates were higher at the Nauset Inlet. As in Pleasant Bay to the south, the dynamic nature of the Nauset inlet should be considered in the development of a nutrient management plan for the Nauset Estuary.
>
> (pg. 14 para. 2)

As stated above the Report does not address any of these concerns long recognized by other investigators. Any changes to the dynamics of the system, would, by nature, alter the water quality modeled nitrogen concentrations, and necessitate a revision of embayment flushing times, turbulent dispersion coefficients, altering the residence time of external nutrients to the embayment.

Based on the study, there was no relationship between measured denitrification rates and associated groundwater nitrate concentrations. In fact, denitrification supported by groundwater nitrate was found to be small. Most denitrification was fueled by the coupled nitrification/denitrification within the sediment system. Denitrification was related with sediment organic matter content and varied seasonally with organic content and temperature. The authors concluded that:

> …denitrification did not contribute significantly to the direct loss of nitrate from incoming groundwater at Nauset marsh estuary. Therefore most groundwater nitrate reaches the estuary.
>
> (pg.17 para. 5)

The 2000 Coastal Loading Nitrogen Project (Water Resources Office, Cape Cod Commission) stated that 60% of the nitrogen loading to Salt Point was derived from a landfill which was capped in 1997. The delay between the capping and the impacts to water quality are likely not encompassed in data presented in the Report, and if the source determinations are accurate, there should be improvement in water quality in Salt Pond.

In the review of a statistical analysis of the data collected by the Town of Orleans Water Quality Monitoring Program (Fiegel, 2011), the following is stated:

> The dissolved oxygen levels throughout the Estuary exceed the State water quality criterion of 6 milligrams per liter (mg/L) with the exception of samples from the bottom of Mill and Salt Ponds, and at the bottom of the Yacht Club (closed end of Town Cove).
>
> (pg.18 para. 3)

Furthermore, the Report states:

> …MEP water quality monitoring measurements do not seem to support the assertion that a significant reduction in septic nitrogen discharge to the Estuary will improve water quality throughout the system, especially, as dissolved oxygen is already in a healthy state throughout the surface and middle depths."

In later sections of the Report, DO measurements for a single month (July 2003) of bottom waters are presented as evidence that water quality impairments are routinely observed in DO and chlorophyll-a (chl-a) in Salt Pond, Town Cove, and Mill Pond. Although these data indicate that low DO and high chl-a levels are observed for a period of time, a much larger dataset should be used to truly assess the state of DO water quality. As it is presented, it is only evident that July 2003 showed hypoxic conditions in several of the Ponds. Water quality issues were observed in other parts of New England at the same time (Greenwich Bay fish kill in Rhode Island) and thus it is unclear whether larger scale meteorological factors played a role in the observed conditions at these ponds.

The report also notes that the offshore nitrogen levels are high by a factor of two compared with other embayment systems except for the Pleasant Bay System just south of the Nauset System. The report then goes on to say that

> The conclusion of the MEP was that the offshore station was anomolous (sic), partially confounded by the timing of the sampling and the position of the station relative to the tidal inlet. This is supported by the boundary station for the adjacent system, Pleasant Bay, where a similar problem existed until the boundary station was moved and sampled only on the flood tide.
>
> (pg.19 para. 1)

No data was presented nor was an explanation given for why the location of the station and the sampling time had to be changed. Although this data is disregarded, it is stated that an extensive temporal analysis was done, and no consistent trend of increasing or decreasing total nitrogen. The Report then goes on to state that the data employed for model calibration used the first four years of data (2001 – 2005), due to lack of complete sampling in later years (2006 – 2008). It seems contradictory to both exclude valid data points due to 'anomalous' concentrations yet make an assessment about temporal trends in the Estuary.

2.4 Review of Chapter III. Delineation of Watersheds

The delineation of the watersheds for subsequent estimation of the groundwater discharges was done through the use of MODFLOW-2000 in collaboration with the USGS. The MEP 2005 watershed delineation notes a significant expansion of the watershed further into Brewster (Fig III-2, pg, 37) yet reflect a 60-acre decrease in total watershed area. These data are later used in the watershed loading model for nitrogen. The alignment of watershed flow data to stream-gauge data (pg. 34, para. 3) and smoothing of model output data - watershed boundaries, present possible sources of error to the outputs. It appears to be implicitly assumed that all groundwater within the watershed reaches Nauset Estuary at the same rate, though studies by Kroeger and Charette (2008) indicate that in other areas of Cape Cod, the estuary may be bypassed completely and groundwater is discharged directly offshore. Evaporative losses also appear to be excluded from the water balance within the watershed. In light of this information, the apparent linearity between stream-flow and groundwater loading to the Estuary may not be entirely accurate.

2.5 Review of Chapter IV. Watershed Nitrogen Loading to Embayment: Land Use, Stream Inputs, and Sediment Nitrogen Recycling

The overall approach to nitrogen loading to the embayment is predicated upon septic system removal efficiencies estimated from a pilot study at the MassDEP Alternative Septic System Test Center, water usage data for homes which utilize public water, estimates of household water usage for homes with private wells, and fertilizer usage. According to the land use analysis, 50% of the watershed is undeveloped.

The estimated personal water usage is combined with Costa et al's 2002 Pilot Study septic system removal efficiency (adjusted by 10% to incorporate dilution from rainwater) and the removal efficiency is calculated as the difference between the influent and the adjusted effluent concentration, as cited in this Report. However, it is unclear whether there is any inflow and infiltration in the Pilot study influent. The adjustment applied would then be potentially underestimating the removal efficiency, which would be 29% to 33%, instead of 21% to 25%. Observational data over a 6-year period for septic removal efficiencies by Heufelder (2007) indicate that Title 5 septic median effluent concentrations were 19 mg L^{-1}, rather than the 26 mg L^{-1} presented in the Pilot Study. Median effluent removal efficiencies were calculated to be 46% for conventional septic systems. These values are more closely aligned with observations in other estuaries, with the Maryland Office of Planning (Blankenship, 1999) reporting average removal efficiencies of 35%. The usage of the larger removal efficiencies within the loading model would reduce the calculated septic nitrogen loading estimates by roughly 17%. It is not clear why this in-depth study was not used, as it would seem that removal efficiencies and timescales for removal are best captured by these data. These data impact the wastewater coefficient presented in Table IV-1, and the ultimate per capita loading calculation.

Nitrogen attenuation by the freshwater ponds is presented in Table IV-3 (pg. 58) and is another critical factor to determining the overall nitrogen loading to the embayment. In the determination of the attenuation in Depot and Muddy Ponds, the calculated values were reported as

> …based on the available water quality data, these ponds have calculated nitrogen attenuation rates of 82% and 73%, respectively. In order to address some of the data uncertainties (e.g., lack of sediment samples to evaluate the impact of sediment regeneration on surface TN concentrations), MEP staff rounded the rates down to

slightly more conservative percentages: 75% and 70%, respectively.

(pg. 58, para. 1)

Later in the Report it assumed that there is no vertical gradient in nutrient concentrations for modeling purposes. If the gradient is not critical to the validity of model results that include the benthic sources of nitrogen, it is unclear why these attenuation factors were reduced. Work by Westgate (2000) using nitrogen isotopes to assess nitrogen removal within the watershed concluded that the main nitrogen impacts to the watershed are from sources within 480 meters to 730 meters of the shore, with up-gradient sources dramatically diluted by clean groundwater. Kroeger and Charette (2008) indicate that not all groundwater flow in the region will go through the embayment, suggesting non-linearity and non-uniformity in groundwater loading to the embayment. This would further alter estimated loadings.

In the discussion of sediment-water column nitrogen exchange (IV.3.1) within the Report it is not clear what the ultimate source of the sediment nitrogen is. It does not seem that sediment contribution has been distinguished from groundwater sources, and these data may be overestimating the amount of nitrogen introduced to the embayment. The discussion of nitrogen mentions bio-available nitrate nitrogen as the predominate form of nitrogen entering the watershed, however data from Heufelder (2007) indicate that 50% or more of the total nitrogen (TN) from septic systems is in the form or organic nitrogen. According to Seitzinger (2002) using total dissolved nitrogen (TDN) or TN budgets to estimate bioavailable N inputs overestimates bioavailable N inputs. This study showed that approximately 80% of DON from run-off is bioavailable, whereas 20% - 60% of TDN is bioavailable from forests and pastures. The discussion of bio-availability of the TN load would benefit from the additional analysis, as the bioavailable components are those that ultimately influence water quality. It seems that the whole of the nitrogen loading is assumed to be bio-available, when attenuation within the watershed will not only decrease the amount of nitrogen reaching the embayment but also change the nature of the material.

Additional notes:

The Howes and Ramsey Embayment Evaluation and Sensitivity Report (2001) referred to on page 50 cannot be located.

The references to Eichner (2007) and Eichner (2009) on page 57 do not appear to contain information on the attenuation analysis for nitrogen.

It is not clear how the tidally influence stream gauge data at Mary Chase Marsh Creek (pg. 64) can be properly used to assess flow to the embayment.

2.6 Review of Chapter V. Hydrodynamic Modeling

The report indicates that the bathymetry and physical (surface elevation and currents) data were collected in the Fall of 2001 (see pg. 76 paras. 3 and 5). This is more than 10 years earlier than the Report publication date yet no justification for the large time delay was given. Due to the dynamic nature of the Nauset beaches, inlet and associated bathymetry described in Report Chapters I and II, it is important to know why this time delay does not invalidate the study, i.e. are the conditions sufficiently different now than 11 years ago such that the previous data is no longer valid.

Figure V-2 on page 78 of the Report shows the 2001 bathymetric survey lines superimposed on an 1994 aerial photograph which indicates incorrect locations of the beaches, inlet and associated bathymetry relative to the 2001 surveys. This should be corrected since there are numerous overflight images available including 1996, 2005 and 2008 (George Meservey, Town of Orleans, personal communication) which provide a better match to the 2001 survey.

Figure V-3 on page 79 of the Report shows three ADCP transects (A1, A2, and A3) which are not consistent with the two surveys mentioned in the text (see below).

The Report incorrectly refers to two offshore tide gauges (pg. 80 para. 1) but only one was used.

The Report incorrectly states

> The observed astronomical tide is therefore the sum of several individual tidal constituents, with a particular amplitude and frequency.
>
> (pg. 80, para. 5)

The word “frequency” should be replaced with “phase”.

The Report states that a harmonic analysis was performed on the tidal elevation data using 23 tidal constituents (pg. 80 para. 5) yet only eight are presented in Table V-1 (page 83) with no explanation why the other 15 constituents were ignored. There is no constituent phase information presented in Table V-1, only constituent amplitude without explanation even though para. 2 on pg. 83 indicates that phase delay is an indication of tidal damping (as is amplitude attenuation).

The text in para. 3 on pg. 83 refers to Figure V-7 comparing measured and computed tides at the Atlantic Ocean site while the Figure caption indicates that the Town Cove gauge data is presented.

Para. 1 on pg. 84 indicates the ADCP transect survey

> …was designed to observe tidal flow through the Nauset inlet and how the flow was divided into Nauset Bay and Town Cove at hourly intervals. Figures V-8 through V-11 show color contours of the current measurements observed during the flood and ebb tide cycles at each of the three transects surveyed at strategic points in the overall system.

In fact only two transects are shown (Nauset Inlet and Town Cove), each at both flood and ebb tide, in the four figures referred to. The use of the incorrect aerial survey (1994) in Figures V-8 through V-12, which is not representative of the beaches, inlet or bathymetry in 2001, should be updated.

Characterizing the RMA-2 model used as "state-of-the-art" (pg. 90 para. 1) although developed almost 40 years ago (1973) is questionable.

The Report states that

> The extent of the finite element grid was generated using 1994 digital aerial photographs from the MassGIS online orthophoto database.
>
> (pg. 90 para. 6)

but should be corrected to indicate how the grid was actually generated since it does not line up with the beaches and inlet shown in the 1994 photograph.

The phrase in Figure V-12 caption on pg 92 "different grid material types" should be explained.

The distribution of turbulent exchange coefficients discussed on pg. 95 para. 3 should be shown either by table or figure as was done for bottom friction (Manning's roughness coefficients).

Time lag errors discussed on pg. 99 para. 2 and 3 should be corrected to be within "two" time steps, not "one".

It appears that model comparisons with measurements are better at the Town Cove transect than at the Nauset Inlet transect, opposite of what is stated on pg, 102 para.1 of the Report.

The system residence time results presented in Table V-7 of the Report on pg. 105 for Salt Pond (197.1 days) and Mill Pond (27.0 days) need to be explained in relation to the 7.25 day simulation time period. The statement that the modeled residence times are within 10 to 15% of the "true" residence times (pg. 106 para. 3) needs a stronger explanation than "our knowledge of estuarine systems".

2.7 Review of Chapter VI. Water Quality Modeling

The water quality model development includes three major source terms: external watershed loading, rainfall to embayment surfaces, and an internal sediment load. The offshore source of nitrogen, a fourth source term, is assumed to be constant, though the analytical results indicate some variation in the offshore data (see previous discussion). The assumption that there are no vertical gradients in nitrogen concentrations for modeling purposes, and thus rapid mixing within the embayment, does not appear to be supported elsewhere in the Report. This assumption seems to contradict the bottom water DO values presented, as a water-body without stratification would be completely mixed, and low oxygen levels would not likely be observed at depth.

The calibration of the model by tuning the dispersion coefficients to reproduce the analytical nitrogen data (page 111) is not a conventional approach. Nitrogen is non-conservative, as mentioned on page 108. Typically, the model dispersion coefficients would be calibrated to salinity, a conservative tracer. The tabulated dispersion coefficients (Table VI-3 page 112) generated by this approach do not match expectations based on the physical structure of the watershed. The highest dispersion coefficients appear to be derived for the regions that are stated to have the poorest mixing and longest residence times: Salt Pond and Town Cove. As a result it would seem that these regions would quickly disperse incoming nitrogen, and, with the long residence time observed, create hot-spots of high nutrient concentrations.

Also, the time period of the water quality model simulation appears short relative to the timescales of nutrient dynamics within the embayment, unless offshore sources are the predominant source of nitrogen to the region. The impact of nitrogen loading to the embayment is seasonal in nature, and thus there are more dynamic process affecting water quality than can be modeled in a 14.5 day time period. It is not clear whether the dynamics of the system are being captured or if the calibration of the model to total nitrogen data has obscured these processes. It is difficult to use annual averages as a benchmark against which to determine model reproducibility for short model output times.

The percentage reductions reported in Table VI-8 do not appear to be correct. Calculated percent differences are 31% and less.

It is unclear why there is a reduction in the benthic flux for the no-load scenario (Table VI-7), when sediments are treated as a separate source elsewhere in the Report.

2.8 Review of Chapter VII. Assessment of Embayment Nutrient Related Ecological Health

The discussion in Chapter VII is focused on water quality monitoring, historical eelgrass coverage, and benthic community indicators to establish the health of the embayment, focusing on bottom water dissolved oxygen (DO) and chlorophyll-a (chl-a) for water quality indicators. In attempting to determine nitrogen thresholds, the ultimate aim of these observations and the embayment health assessment is to determine the conditions for suitable eelgrass habitat, with restoration efforts focused on recovery of lost habitat based estimates from 1951. In regions that cannot support eelgrass, benthic community structure and species diversity were used as proxies for water quality impacts to benthic habitat.

MEP deployed sensors for DO and chl-a at selected bottom depth locations throughout the embayment for approximately 30 days in late June through July 2003. As mentioned previously, this time period coincided with water quality issues in other areas of New England, specifically Greenwich Bay in Rhode Island. A massive fish kill was documented in Greenwich Bay which is generally thought to be the result of a combination of water column stratification from large freshwater inputs from storm events, followed by hot, windless days, and weak tidal mixing. These meteorological factors may have also impacted the Nauset estuary, and thus this time period may represent extreme water quality conditions. Benthic habitat is also presented as a water quality indicator, however certain benthic species such as the quahog (*mercenaria mercenaria*) are well suited to low levels of oxygen, and this is a competitive advantage for population establishment. Changes to the benthic habitat will alter the shellfish populations.

2.9 Review of Chapter VIII. Critical Nutrient Threshold Determination and Development of Water Quality Target

Nutrient related habitat quality is presented in Table VIII-1, with five of seven segments characterized as significantly impaired. As a result of this assessment, eelgrass habitat was selected as a primary management goal. A threshold value of 0.43-0.50 mg N L^{-1} for tidally averaged TN was concluded to be supportive of high quality eelgrass habitat, based on the available habitat assessment. In order to meet the threshold values, a 54% decrease in septic nitrogen loading was calculated as necessary, with major reductions for Salt Pond, Town Cove, and Nauset Stream.

Although other causes are mentioned as potentially impacting eelgrass habitat, it was concluded that the loss of eelgrass habitat was the result of increased watershed loadings to the system. Land-use change impacts and population increases are the presumed increased loading sources, however changes in pervious surface cover as a result of road construction, associated erosion may be contributing to habitat quality impairments. Additionally, it is not clear that, if the thresholds are met, that eelgrass habitat coverage will be restored.

Considering the magnitude of nutrient loading that would be implied to meet the threshold value of 0.5 mg L^{-1} based on the data contained within the Report, it seems prudent to include extended seasonal and year-round water quality indicator data. Although available data are indicative of water quality issues, the temporal coverage, as well as the time-frame of the analyses do not seem rigorous to justify the efforts required to achieve the threshold loading levels presented in the Report, and it represents a small snapshot of habitat quality. Decadal trends would be useful for the level of watershed change implied should the threshold analysis be considered adequate.

3 Summary of Findings

The major findings developed in reviewing the Report are the following:

- The MEP Linked Model System consists of a land use model that provides estimates of nitrogen loading to the waterbody under study, a hydrodynamic model that calculates the circulation in the waterbody, and a water quality model that determines the dispersion of nitrogen in the water body. The hydrodynamic model is RMA-2, a two dimensional vertically averaged finite element numerical model originally developed almost 40 years ago (Norton et al, 1973). The water quality model is RMA-4 (King, 1990), a sister model to RMA2 using the same grid and numerical solution. These models, along with the simple loading model form an adequate approach to evaluate the nutrient impacts in the Nauset Harbor System.
- The application of the RMA models in the Linked Model System is flawed in that it does not address potential changes in the physical layout of the beaches, inlet, and bathymetry due to the well documented dynamic nature of Nauset Harbor. At a

minimum a sensitivity analysis should be performed to evaluate the range of nitrogen thresholds under different physical configurations.

- The watershed loading assessment may over-estimate loading to the embayment from the use of pilot study effluent values for septic systems as opposed to available longer-term analyses, resulting in a 17% over-estimation of nitrogen loadings. If the lower estimated loading is accurate, in concert with high offshore values observed, offshore data would indicate water quality conditions which exceed the calculated threshold value and do not support eelgrass habitat are transport into the embayment from offshore, and not controllable by regulatory or engineering measures.
- The assumption of a linear and uniform groundwater source to the embayment is refuted by more recent data indicating that groundwater may circumvent the estuary completely.
- The water quality model calibration to total nitrogen instead of salinity is not a standard approach, and the resultant dispersion coefficients are contrary to expectations based on the embayment characteristics.
- The water quality dataset used in the habitat assessment does not represent a long enough time period to be relevant to the timescales of groundwater nitrogen discharge to the embayment. This time period may also represent an extreme set of water quality conditions, based on observations in other parts of New England.
- There is no quantitative data presented to support a long-term trend of increased watershed loading. It doesn't appear that a long term loading study was completed, but rather, that eelgrass coverage decreases indicate that this increased loading occurred.
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4 References to Publications

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