SMAST University of Massachusetts Dartmouth
The School for Marine Science and Technology

Massachusetts Department of Environmental Protection

Technical Memorandum
Massachusetts Estuaries Project

To: **Rick Dunn, MA DEP**
Steve Halterman, MA DEP
Brian Dudley, MA DEP

From: **Brian Howes, SMAST, UMass – Dartmouth**
David White, SMAST, UMass – Dartmouth
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Re: **DEP/MCZM/Town of Chatham, Combined Comments on the Technical Memorandum on Cockle Cove Creek Marsh Nitrogen Threshold**

Date: **Draft Report Submitted 5/16/06**
Combined Comments Received 9/11/06
MEP/SMAST Response Submitted 11/30/06

This document responds to comments on the Draft Cockle Cove Marsh Nitrogen Thresholds Technical Memorandum submitted to DEP, May 16, 2006. The comments incorporated initial comments by the DEP (May 19, 2006), reviews by MCZM (June 9, 2006) and the Town of Chatham (August 8, 2006), which were compiled by Rick Dunn, DEP and forwarded to SMAST on September 11, 2006. An effort was made to summarize the most important comments relative to the report that need to be clarified or addressed. In most cases the comments are paraphrased from the documents sent under separate cover.

It is important to note that the document was a Draft Technical Memorandum and not a MEP Nutrient Threshold Report, as mistakenly concluded by some of the reviewers. As a Technical Memorandum, it focused only on key points. An exhaustive analysis and detailed discussion of the literature is well beyond the scope of this project. The primary goal was to determine a nitrogen threshold for the salt marsh system of Cockle Cove Creek and to develop a baseline upon which future assessments can be based.

What follows is a listing of the comments recieved, each with a response that either addresses a question or indicates changes made in the final version of the document.

MASSDEP Comments

1. The report needs to include a better explanation on how you arrived at your conclusions. It was our understanding that the original approach was to review existing studies and to develop a relationship between TN concentration and wetlands impacts be it vegetation, stream bed or some other translator. Instead you appear to have developed thresholds based solely on the fact that bed velocity and flushing control the amount of nitrogen that can be assimilated by the system. The text also appears to indicate that the thresholds were developed empirically but it is unclear how that was done unless it is simply "no more nitrogen than is already there". It is also unclear what the justification was and what data or studies support the use of a concentration based threshold over a loading threshold. All of the above may be because that is the state of knowledge and information in existing studies did not provide sufficient information to calculate a threshold. Even if this is the case, the studies should at least be acknowledged and there should be some discussion why the information provided in those reports was insufficient or inappropriate to draw conclusions or to use.

Response: *The final approach used to develop the nitrogen threshold evolved during the assessment and analysis phase of the project. The initial approach was to conduct a literature survey in an attempt to find salt marsh experimental studies where similar nitrogen thresholds had been developed. No dose/response studies of salt marsh creekbottom communities were found, nor were investigations of macroalgal accumulation versus nitrogen levels in tidal creeks that relevant to the present effort. The general reason for this is stems from the general focus on the stimulatory effects on marsh biota of nitrogen, rather than the potential for further eutrophication these highly productive organic matter rich ecosystems.*

The next approach was to develop the information for a comparative analysis across a variety of salt marshes with various nitrogen levels. This analysis required both mining of existing nutrient data and in some cases conducting field observations and discussions with field scientists to gauge ecosystem response (e.g. macroalgal accumulations). The results of this effort with the field assessment data discussed in the prior sections indicated that Cockle Cove waters were highly nitrogen enriched, but that the system was not impaired. These results then fed into analysis as to the mechanism of this nitrogen tolerance and a functional approach to setting a defensible nitrogen threshold. Although it was not possible to set the absolute upper limit, it was possible to determine an allowable nitrogen threshold that should be workable from a wastewater planning perspective

The threshold as it evolved does rely heavily upon the hydrodynamics a physical structure of the marsh creek system, but that came out of the inter-marsh comparison analysis and the field assessments. However, the problem still remains as to how high a concentration one could push through the system before impairment occurs. No one can determine this from the available data and state of the science at this time. This stems directly from the fact that Cockle Cove supports higher nitrogen levels than other marshes in the region, so it is the "end-member" system. Other systems, that are structured differently show impairment at lower nitrogen levels (for example,

Mashapaquit Creek). However, for CWMP purposes it is clear that the load from the WWTF facility can increase to its planned 0.4 MGD scenario and still maintain an unimpaired resource as long as the concentration is maintained and increasing the nitrogen overloading of Bucks Creek is addressed . The results of the present effort represents a huge advance for the planning process and this study a significant advance in how to set nitrogen thresholds in the up-coming MEP Technical Reports.

2. It appears that the threshold levels given in the report suggest that there can be no change in present concentrations. A concentration of 3.0 mg/L bioactive N entering the system is protective as reported. Assuming that this entering level is measured from Station J/2 (as shown on the first Figure 5.... also there are two Figure 5s in the report), Table 4 shows this existing value as 2.960 mg/L. The report also suggests that a mean of fresh inflow and mid-marsh concentration be set at 2.5 mg/L of total nitrogen. Again referencing Table 4, the average of Stations J/2 and F/3 as currently measured is approximately 2.5 mg/L. Both these existing values indicate that there can be no change in concentration over the existing values. However, this is really left to the reader to infer from the report rather than directly stated. If this was the intent please revise the text to state this directly.

Response: *The concept is relatively straightforward. In Cockle Cove Creek, it appears that the present nitrogen concentration entering the head of the marsh is 3 mg/L bioactive N. Since dissolved organic nitrogen is low and unlikely to interact with marsh systems given the short travel time through the marsh (hours), the inorganic and particulate organic forms are the ones that need to be controlled. In addition, since the marsh drains completely at low tide, there is no need to focus on N loading to the marsh, as is the case with an embayment system that can accumulate N over several tidal cycles. Since Cockle Cove Creek does not accumulate macroalgae and does not show evidence of degradation at present, the management goal should be to keep the concentration of N at its current level. Because the creek bottom response to nitrogen is concentration-dependant, the N load from the watershed can be increased as long as it does not result in an increase in concentration. Specific to Chatham's WWTF, the focus should be on effluent treatment that would maintain a bioactive N concentration of 3 mg N/L at the head of the marsh. This concentration-focused approach means that the N load could be significantly increased without degradation to the salt marsh system. However, as noted in the report, the effect of the increased load to receiving waters down-gradient of the marsh would likely set the upper limit of nitrogen loading from the WWTF because these watercolumn-dominated embayment habitats are responsive to N loading rates. The underlying basis is that tidal marsh creek systems are governed by biogeochemical dynamics that are fundamentally different from watercolumn based systems. It should also be noted that the currently proposed increased effluent inflow to Cockle Cove Creek will result in ~50% increase in total freshwater outflow. While this is proportionally a large increase in freshwater, it is not sufficient to significantly deepen the outflowing waters, increase the area of subtidal creekbottom or cause a significant depression of watercolumn salinity.*

3. It is suggested that a "highly conservative value" of 2.0 mg/L total nitrogen throughout the marsh is desired, then 2.0 mg/L is appropriate. However, it is unclear how this is measured, whether it is an average of fresh tidal and mid-marsh concentration (to be compared to the 2.5

value) or is integrated across the entire marsh in some other way. The report also needs to clarify how this 2.0 mg/L value compares to the existing 1.7 mg/L concentration reported in the original Chatham tech report. One could infer that this 2.0 mg/L value may represent an increase over the 1.7 mg/L and therefore not be conservative but suggests an increased load is possible thereby contradicting the conclusion from the other two values that concentrations must remain the same. Further explanation of this point is required.

Response:

- *The 2.0 mg/L value was the average total nitrogen measured at the mid marsh site. It is conservative since the marsh creek reach between the stream and mid-marsh experiences levels between 3.1 mg TN/L and 2.0 mg TN/L. Selecting the lower value is conservative. Text has been clarified.*

- *The 2.5 mg/L value was the average of the fresh inflow and mid-marsh concentration within the upper salt marsh reach (data provided in tables).*

- *The 1.7 mg/L (1.69) value was the average measured value from the Town of Chatham monitoring program. The value in the present report at that site was 1.92 mg TN/L the standard error was 0.058 of 64 samples. The difference is likely due to the sampling at the lower end of the ebb tide in the present study versus more to mid-ebb in the prior effort. It may also be the result of varying WWTF discharges.*

- *2.0 mg/L is higher than the 1.7 mg/L in the prior work. However, it should be noted that at that time the concept was to hold the level constant, because we did not have sufficient information to allow a higher value. So one part of the answer is that we now have sufficient data to allow the rise. It is not as if 1.7 mg/L was developed analytically as a threshold, it was merely the measured value at that time and was associated with no discernable negative effects on the marsh resource.*

CZM Comments:

4. CZM has expressed concern that the vegetation and macro-invertebrate work conducted by CZM may have been slightly misrepresented in its integration into the report. The details of this are provided in their attached comments. These issues need to be rectified and addressed in the final report.

> **Response:** *SMAST staff did not intend to nor did we misrepresent their work. Instead there appears to be a concern over the specific language used in the Tech Memo. CZM, as is appropriate for an environmental agency, employed regulatory language, while SMAST, writing for both agencies and the community at large, employed more common language. As the Technical Memo will be translated into the regulatory environment by MassDEP, the language remains, but has been clarified to reflect some of CZM's concern.*

In additon, CZM appears to be calling attention to the bulletized "observations" in its comments. These observations were not misrepresented by SMAST, but rather were treated as qualitative notes compared to the quantitative data collected in the rest of the study. The observation of the presence of Phragmites in the eastern tributary reach of the marsh does not indicate degradation. Even if the area is expanding it must be evaluated in light of the dynamics of the system's tidal inlet. Neither CZM nor SMAST staff uncovered any factors likely to be presently "stressing" this salt marsh system.

Both CZM and SMAST staff noted pannes on the salt marsh plain. SMAST staff have attempted to clarify the location of the pannes of concern with CZM, but have not yet been successful. Pannes are common to salt marshes and are not generally indicative of negative conditions. Pannes associated with the lower marsh/barrier beach complex are typical of New England marsh physiography. SMAST has reviewed time-series aerial photographs of this marsh and has not noted any significant changes.

SMAST staff still conclude that the MCZM study supports the following text as found in the Tech Memo:

"The creekbank survey conducted by MCZM (Appendix A) surveyed four taxa of macroinvertebrates. "The most common was the marsh snail, Melampus bidentatus (73.1%), with the ribbed mussel, Geukensia demissa (24.4%), essentially comprising the rest of the invertebrate community. Several individual isopods and fiddler crabs (either Uca pugilator or Uca pugnax) were surveyed. It is important to note that the survey was on the marsh surface and vegetation only and did not include substrate removal. There was significant evidence of Uca burrows, but the presence of crabs in each burrow was not part of the scope of work and was not determined. The taxa list, total and percent total abundance values are listed in Table 2" of Appendix A. Melampus is an important prey species for fish and some avian species as is Uca and smaller life stages of Geukensia. There was no indication of impairment in this survey and the dominant species are typical of healthy Cape Cod salt marshes."

5. CZM also expressed concerns that, while the focus of the report was on potential impacts of increased nitrogen load to the salt marsh system, they are very concerned about the net export out of the Cockle Cove system to nearshore Nantucket Sound as well as the connected Bucks Creek system. The final report needs to clarify how these issues will be addressed either through additional modeling or some other mechanisms.

Response:
(A) The MEP Technical Team agrees with the reviewers that the downgradient systems need to be addressed relative to increasing N loading from the WWTF to Cockle Cove Creek and stated this in the Technical Memorandum. However, it was also indicated at several points that the focus of the present report is on Cockle Cove Creek salt marshes. For example,

"To support the Town of Chatham's planning effort, DEP with the MEP Technical Team (SMAST) and MCZM designed and

implemented a field data collection program for the summer of 2005 focusing on the nitrogen threshold of Cockle Cove Creek as it relates to future potential wastewater discharge from the WWTF. The study was focused on the salt marsh and did not include thresholds for the freshwater stream discharging to the head of the salt marsh. Evaluation of impacts to the nitrogen-enriched Bucks Creek/Sulphur Springs embayments were also excluded, as these loading concerns had been previously described."

"the analysis focused on Cockle Cove Creek and its salt marsh function, not the downgradient sub-embayments of Bucks Creek/Sulphur Springs. Therefore, the nitrogen threshold developed herein relates only to the Cockle Cove Creek salt marsh, the sub-embayment nitrogen threshold remains unchanged."

(B) While additional modeling is being conducted to address this issue, it is not part of the present project which is specific to Cockle Cove Creek.

(C) Given concerns over Phragmites expansion, an analysis of freshwater inflow was added to the Technical Memorandum. One of the conclusions of this analysis was that additional effluent discharges in the watershed of Cockle Cove Creek will result in flow to other of Chatham's estuaries that will also need to be re-evaluated relative to nitrogen impacts at some future time.

6. CZM expressed concern that the data and analysis in the report suggests that the POTW "will not impact the salt marsh system so long as the nitrogen concentration is maintained and the system maintains its present flushing and velocity characteristics." The report further purports that the marsh's characteristics "should allow for a several fold increase in flow" from the Chatham Wastewater Treatment Facility (WWTF).

Their concern is that such broad statements will be used to justify this magnitude of increase in wastewater planning efforts by the Town and that the report needs more documentation to fully support the conclusions made. At a minimum, the report should state or provide a list of all the studies reviewed, the reasons they weren't used in the analysis and citations should be provided in an appendix for all the studies consulted.

Response: *The study derived from concerns over increased discharges from the Town's WWTF. The analysis has expanded beyond it scope to include the likely future discharge to Cockle Cove Creek (0.4 MGD vs 0.1 MGD presently). The future discharge would likely be at a lower TN level than the present effluent. It is clear that increasing the total watershed N load to Cockle Cove Creek would further enrich downgradient Bucks Creek, which is already beyond its N threshold. However, this was known from the previous MEP Nutrient Technical Report. The present study focusing on potential impacts on the Cockle Cove Creek marshes suggests that indeed this sub-system can tolerate higher N loads as long as the TN concentration does not increase over the threshold. The data used in the marsh comparisons is detailed in Table 15. The data comes from a variety of technical report and on-going data sets (now indicted in the "Background Literature"*

section). All of the studies were used, the problem stemmed from the fact that Cockle Cove Creek operates somewhat differently than many of the systems noted. The question seems to imply that there are quantitative studies of Cockle Cove type marshes where a nitrogen dose/response relationship has been determined, so a threshold could be developed. Those studies do not exist, so we developed a comprehensive list of marshes to gather the necessary information from which to make a prediction. Although it was not possible to set the upper limit, it was possible to determine an allowable nitrogen threshold that should be workable from a wastewater planning perspective.

7. CZM expressed concern that there is a real threat that increasing the freshwater content of this system will promote conditions conducive to the spread of this invasive and disruptive species. SMAST should address this issue with CZM and possibly add clarifying language to the document why this isn't a concern.

Response: *Even though this request is outside of the Scope for this project, which focuses on nitrogen thresholds, SMAST staff have always agreed that Phragmites expansion due to increased freshwater seepage (not streamflow, but seepage) was a potential concern. SMAST staff therefore, undertook an evaluation based upon integrating available freshwater inflow data and USGS modeling. This section has been added to the Technical Memo. Note that this effort required significant effort and meetings with the Town of Chatham and the Cape Cod Commission. Additional information from MCZM staff is in process.*

Other DEP comments, compiled by Rick Dunn (9/11/06)

1. We suggest that all threshold concentrations should be consistent as to whether they are Total Nitrogen or Bioactive Nitrogen since going back and forth between the two could be confusing to other readers.

Response: *The discussion sets upper limits of both bioactive and total nitrogen because bioactive nitrogen is the component of the total nitrogen flux into the marsh that is available for uptake by plants or bacteria. Threshold concentrations are normally given as total N but we use bioactive N here as well because of its importance in determining the health of the marsh.The dual use of bioactive nitrogen and total nitrogen has been the approach for other systems in the Town of Chatham.*

2. Please change the date on the memo to May 16th which is the date we received it.

Response: *The final version of the Technical Memorandum report will be dated appropriately.*

3. Table 4 reports some of the nitrogen values in uM and some in mg/L. We are assuming that this is a typo and that all values should be in mg/L since they appear to add up that way.

Response: *All values are in mg/L. Table 4 has been changed accordingly.*

4. Finally, the report notes in several locations that as part of this effort the MEP watershed nitrogen loading was updated to April 2006. It would be helpful to clarify what was actually updated. For example was the water use updated to four quarters rather than three or were there other changes?

> ***Response:*** *The water-use data was updated and new parcel information for Chatham's south facing embayments that became available from the Town of Chatham was incorporated. Note that as of this writing, the Town of Chatham and the Cape Cod Commission (MEP) are still investigating potential "issues" related to the Town's water meter data. However, any new changes are likely to be relatively small.*

Verbatim Comments from Bruce Carlisle & Todd Callaghan, MCZM and Jan Smith, MBP, received by DEP June 9, 2006.

Massachusetts Office of Coastal Zone Management and the Massachusetts Bay National Program have reviewed the MEP Technical Memorandum: Cockle Cove Salt Marsh Nitrogen Threshold ("report"). While it presents informative background on nitrogen and salt marsh interactions and data specific to the Cockle Cove system, we feel that the report's conclusions regarding the nitrogen threshold may be overstated and, at a minimum, limitations and assumptions of these conclusions are not well integrated into these findings. We are also concerned that the vegetation and macro-invertebrate work conducted by CZM may have been slightly misrepresented in its integration into the report. Finally, while the focus of this exercise was on potential impacts of increased nitrogen load to the salt marsh system, there are very real concerns about the net export out of the Cockle Cove system to nearshore Nantucket Sound as well as the connected Bucks Creek system.

> **Response:**
> *1. The MEP Technical Team assessed the available information and derived a best-estimate and conservative nitrogen threshold. The one selected is a regulatory decision. The analysis was conducted and the result emerged.*
> *2. The MCZM report showed plant and macro-invertebrate communities on the marsh plain that are typical of healthy salt marsh systems in the New England region. The report concludes that the Cockle Cove Creek system does not appear to be degraded. Our study supports this conclusion. The MCZM report also states concerns about the potential spread of Phragmites in the eastern finger of the marsh combined with the strong odor of sulfur, and the development of pannes on the marsh plain at the seaward end. While we acknowledge this concern and would support future monitoring of the marsh, we have found no evidence of degradation of this ecosystem and have concluded that it is healthy and capable of absorbing and attenuating future increases in N loading from the WWTF.*
> *3. The issue of Bucks Creek was addressed in MCZM comment #5 in the first section of*

this response document. Throughout all of the MEP efforts and the present study, the MEP Technical Team has been direct in both writing and other communications that "Bucks Creek is currently beyond its nitrogen threshold and that plans to increase nitrogen loading to Cockle Cove Creek will need take Bucks Creek into consideration".

The report states that increasing the nitrogen load to the headwaters of Cockle Cove Creek "will not impact the salt marsh system so long as the nitrogen concentration is maintained and the system maintains its present flushing and velocity characteristics." The report further purports that the marsh's characteristics "should allow for a several fold increase in flow" from the Chatham Wastewater Treatment Facility (WWTF). We are not convinced that the data and analysis in the report support such a broad statement and are concerned that this report will be used to justify this magnitude of increase in wastewater planning efforts by the Town. Because the report only presents the nitrogen flux and attenuation from a single day tidal study (August 3, 2005), conclusions regarding long-term nitrogen should be expressed with caveats about the assumptions. We believe that in order to arrive at this conclusion with more confidence, one would need to know the current nitrogen load from the WWTF and other sources (including the failed on-site systems that were noted in the field and supported by the $d^{15}N$ analysis), the expected N load from the increase in flow from the WWTF, and the marsh's nitrogen attenuation rate. We are also unclear on how one could increase discharge from the WWTF and maintain the current in-stream nitrogen concentration without improving denitrification at the WWTF.

Response: *All of the data that were collected and analyzed for the SMAST report supports the conclusion that this is a healthy marsh system which can effectively absorb and attenuate further increases in N loading from the WWTF. The present conditions of the marsh plain and the tidal creek system show no signs of degradation. The high N concentrations in ebbing creek waters have not resulted in significant accumulations of macroalgae in the creeks. The creek sediments are apparently capable of significant N attenuation through dentrification throughout the length of the creek channel.*

The report's documentation of wastewater nitrogen being incorporated into the salt marsh vegetation is useful as is the baseline of macro-invertebrate and vegetation distribution data. The CZM salt marsh vegetation and macro-invertebrate study (attached as Appendix A) found that the assemblages that we measured were not indicative of a degraded system. The SMAST report implies some level of "health," a term that while useful as an abstract concept with volunteer training, is not particularly applicable here. Also, the report states that we found an absence of bare area or plant die-back which is not necessarily true. While our transects may not have directly crossed these areas, we did observe and note the following (p. 5 CZM report):
At low tide, there is considerable freshwater flow in the creek channel network.
There are some large panne areas in the lower marsh (the seaward end) that do not appear in the 2001 ortho imagery and could indicate recent trajectory toward marsh surface degradation.

Response:

1. The term "healthy" is a commonly used description for salt marsh systems that show no significant signs of impairment. It is qualitative term used to summarize all quantitative information collected from all of the marsh sub systems. We have concluded

from our investigations that this system is functioning normally and has not been negatively impacted to any significant degree by nutrient inputs from the WWTF.
2. The MEP Technical Team has evaluated aerial photographs as suggested and did not conclude that these were indicative of degradation or a trend toward degradation. SMAST then requested to MCZM to clarify the location and if possible its rationale. This information is still being developed.

There are some stands of *Phragmites australis*—the largest being in the marsh "finger" on the east side. Transects 7 and 8 picked up only the edges of this large stand, so that the total abundance reported in the Results section is likely an under-representation (but statistically valid).
There was a distinct, extremely strong odor of sulfur in this same area. Both investigators who regularly spend significant time conducting similar field work in Massachusetts salt marshes noted that this was particularly strong (offensive) and definitely not the characteristic "low tide" odor.

We also stated in our conclusion that there are two dynamics we would recommend watching for:

- The spread of the large *Phragmites* stand in the eastern "finger" and
- The rate and extent of short-form *Spartina alterniflora* and unvegetated marsh pannes.

Response: *We acknowledge the observations by MCZM investigators and would support future monitoring of the marsh but we have found no evidence of any significant degradation of the marsh and have concluded that it has the ability to absorb and attenuate further inputs from the WWTF without negative impacts to the system. In addition the marsh "finger" does not seem to be the focus of much freshwater discharge in relation to the occurrence of the Phragmites australis stands. Instead, these stands appear to be related to elevation (fill) and possibly some areas of tidal restriction (although this was not quantified).*

We are also concerned that the case for increased inputs from the WWTF of nitrogen and freshwater to this salt marsh would be managed solely based upon the presence and abundance of algal mats and not take into account shifts in salt marsh vegetation or habitat types (e.g., one species replacing another, the creation of pannes or unvegetated areas). The report accurately notes that concerns for an increased discharge from the WWTF include the increased amount of freshwater entering the salt marsh system and the fate of any additional nitrogen load, especially how it might affect management of the Bucks Creek/Sulphur Springs system. In our work at this site we noted the encroachment of *Phragmites,* especially on the eastern side of the marsh. There is a real threat that increasing the freshwater content of this system will promote conditions conducive to the spread of this invasive and disruptive species.

The response of Bucks Creek/Sulphur Springs to any increased flow and N load from the WWTF, while important and noted, is not part of the present Technical Memorandum.

The issue of plant community change on the emergent marsh plain due to increased discharge into the headwaters of the tidal creek needs to be assessed relative to the hydrodology and hydrodynamics of the system. First, the freshwater discharge from the WWTF is relatively large compared to the total freshwater flow entering Cockle Cove

Response:
1. A section on freshwater discharge has been added to the Technical Memorandum. The watercolumn salinities under the planned WWTF scenario would still remain high, >24 ppt. Therefore the freshwater flow that would relate to a species shift would be due to an increase in freshwater seepage to the vegetated area rather than a shift in tidal water salinity. It is the MEP Technical Team's conclusion that groundwater modeling to determine the spatial pattern of future groundwater discharge areas will be needed as part of the planning process.
2. It is not clear what evidence suggests the potential for a shift in plant communities as a result of the anticipated level of nitrogen loading. In fact, the level of nitrogen loading to the emergent marsh is most likely to be difficult to distinguish in plant productivity given the mode of delivery (e.g. dissolved in tidal water at high tide).

In addition, we would like to add to this list of concerns the currently unknown fate of any increased nitrogen load to coastal waters. CZM notes that Cockle Cove is adjacent to several south-facing beaches in Harwich and Chatham where there have been significant losses of eelgrass and a commensurate increase in non-native *Codium.* These changes may be related to local water quality and thus may be exacerbated by additional nitrogen loading to Cockle Cove Creek. Before significant increases of WWTF discharge be allowed, it would seem reasonable to explore the fate of the current and projected nitrogen load leaving Cockle Cove Creek to the nearshore Nantucket Sound. The management of these coastal systems should not occur in isolation.

Response: *Although impacts to Nantucket Sound were not a part of this study, an analysis of downgradient embayment/coastal waters would be required to determine potential nitrogen loading effects.*

Below we have attached specific comments on the report. We note that there were considerable instances where the authors cut and pasted text from a previous proposal or other reports and thus the report does not read well. In addition, there were also sections where the authors mislabeled data (e.g., replacing high tide with low tide), thus changing the entire meaning of the data. We recommend that DEP encourage the authors to review this and future reports (memos) with an eye toward improved quality control as these reports have important management consequences and should be of the highest quality.

CZM appreciates the opportunity to work collaboratively with DEP on these important coastal management decisions. We would be happy to discuss our detailed comments and concerns with this report with you.

MCZM Specific Comments on the Report

[Please note in our comments that p = page and P = paragraph]

Pp.1-2; "relative insensitivity of salt marshes to high rates of nitrogen loading…" This phrase is significantly vague in its meaning to the point that it is likely more detrimental to a scientifically based decision making process than it is helpful. CZM recommends striking this phrase unless it can be rewritten to be more specific (e.g., provide the range of nitrogen loads that are considered "high" and that salt marshes may be able to assimilate without changes in the benthic community, macroalgal abundance, phytoplankton community, vegetation distribution and abundance, etc.). This phrase is repeated again on p. 28, third P.

Response: *The ability of salt marshes to absorb and attenuate nitrogen from a variety of sources, including their watersheds, is one of the fundamental principles of the biogeochemistry of these systems. Many general texts contain this and related information, such as Kennish, Ecology of Estuaries or Schlezinger, Biogeochemistry. But, perhaps the best introduction for New England salt marshes can be found in Teal (1986), The Ecology of Regularly Flooded Salt Marshes of New England (and references therein). This was a Community Profile from Fish and Wildlife (Dept of Interior) Biological Report 85(7.4). This document was produced to assist managers involved in ecologically based issues. Also, Nixon 1980. Between coastal marshes and coastal waters: a review of twenty years of speculation and research on the role of salt marshes in estuarine productivity and water chemistry in the volume, Estuarine and Wetland Processes. Other references in the Background Literature section may also prove helpful. It would be most helpful if the salt marsh scientists at MCZM could provide some references as to the over-enrichment of saltmarshes by nitrogen or which demonstrate other marine systems with a higher assimilative capacity for nitrogen.*

p. 2, third P; This paragraph needs some rewrites.

Response: *This paragraph has been re-written*

p. 3 Second P:

- What is the importance of carbon to nitrogen attenuation?
- The last sentence of this paragraph does not seem to follow the sentences prior to it.
- "75.6 g N m^{-2} each growing season." This is only about 0.17 lbs. This is not substantial relative to wastewater loads. It may be inappropriate to include this factoid because the discussion here is about applying wastewater nitrogen to a watershed.
- first bullet, This reads like it was part of the study plan, not a report.

Response:

1. The discussion focuses on Nitrogen attenuation in the marsh because these systems are known to absorb N inputs from groundwater and streams by dentrification and uptake by algae and plants. In doing so, marshes act as nutrient buffers to adjacent offshore waters reducing N loads to these systems from upland sources. Carbon is important to nitrogen attenuation as the energy substrate for dentrification.

2. The last sentence simply shows that the dentrification process in salt marshes discussed in the previous sentence has a greater capacity to absorb and attenuate nitrogen inputs than plant uptake. The fertilization experiments in Great Sippewissett Marsh on Cape Cod quantified this capacity. Therefore, the last sentence supports the previous sentence in this discussion.
3. We do not agree that 75.6 g N m^{-2} is "not substantial relative to the wastewater loads". The present WWTF discharges 1170 kg N/yr to the watershed. If this was added over the marsh surface it would represent 10.4 g N m^{-2} yr^{-1}.
4. It is not clear what the "first bullet" is referring to here.

p. 10, P 1; Again there is this statement about marsh plain being "highly tolerant" to nitrogen input. We recommend not using such generalities in a technical report.

Response: *See response to the first question above.*

p. 13; Having four significant figures in the results is unnecessary.

Response: *The data are to 0.001 mg N/L, as this is the accuracy of the measurements. All MEP reports put data to 0.001 mg N/L. All data were rounded to 3 significant figures.*

p. 13, last P; "…algal production in the tidal creek bottom" This does not make sense. I think the authors mean algal production *on* the creek bottom.

Response: *"In" has been changed to "on".*

Last P; If N and P are not limiting what is limiting macroalgae? Light? Disturbance? This idea is developed later in the report, but it would be helpful if it were briefly stated here are well.
first P; If 40% of the N is being transported downstream to Bucks Creek, does that mean that Cockle Creek marsh is absorbing 60%? Shouldn't this be more clearly stated?
A 60% attenuation rate contrasts with the 44% attenuation rate stated in Table 6. This discrepancy should be explained.
How are the ebb tide measurements "indicative of sediment nitrogen uptake?" This is not made clear in the text. It isn't explained how the fluxes in Table 5 were calculated and why they could not be merely a result of flushing.

Response:
(1) N and P limitation. The document is a Technical Memorandum, not a report. It is overly long, so creating the requested redundancy, was not done.
(2) The text and table correctly state an attenuation rate of 38% (rounded to 40% in discussion). This agrees well with the 44% attenuation from the tidal exchange study (Table 6). However, this means that 60% of the nitrogen entering Cockle Cove Creek is transported down to Bucks Creek, and not (as the reviewer suggests) 40%. Instead, 40% is removed (absorbed is not a proper term in this instance). Therefore, there is no need to change the text.
(3) Ebb tide measurements follow freshwater and nitrogen transport (volume and N load) from the headwaters to the tidal inlet to Bucks Creek. Based upon simple mass balance an

attenuation can be determined. The comment related to "flushing" cannot be answered without clarification as "flushing" does not play a role in the context of these measurements in a fully tidal marsh creek.

p. 16; Station ID's in Table 4 are not the same as those in Figure 5.

Response: *Station IDs in Table 4 have been fully written out.*

Table 6; If sampling occurred from low tide to low tide as stated in title, why was the estimate of Total N Load from the SMAST model converted to an estimate over *two* tidal cycles (as stated in note "c" of the Table 6)? One tidal cycle should encompass low tide to low tide. Should the estimate be relabeled as being over two tidal *phases?*

Response: *The net export of Total N in Table 6 was doubled to approximate a daily net flux of TN. The export based on the modeling of land use data was adjusted*

p. 21; The following result is confusing:
Suspended Particulate Matter - Samples of suspended particulate matter (SPM) were collected near the mouth of Cockle Cove Creek during a tidal cycle, August 3, 2005. The results show that δN^{15} values increase from +5.86 to +6.10 $^{o}/_{oo}$ during the late stages of tidal flooding, and then decrease to +4.04 $^{o}/_{oo}$ during tidal ebb, increasing again to +5.26 $^{o}/_{oo}$ prior to the turn of the tide (Figure 8, Table10).
Why should d15N increase with the flooding tide (see Table 10 also)? This suggests that wastewater is flooding in with the tide. Or are the results from the test so variable that this really isn't a tide-related phenomenon? How sensitive are these d15N tests? There should be some sort of discussion of the accuracy and precision of these tests. It isn't clear why the values are so high at the mouth of the Creek and not quite at, or just barely at, the level typically found in wastewater at the headwaters of the Creek where one might expect the input from the WWTF.

Response: *The sentence was changed. $\delta^{15}N$ actually decreased during tidal flooding and increased during ebb. The results of the $\delta^{15}N$ analyses are accurate to $\pm$ 0.1 $^{o}/_{oo}$.*

pp. 22-24; Figures 5-7 are difficult to read. The d15N values should be larger and some color other than white.

Response: *Figures have been redrawn.*

Table 7; Not all of the data presented in Table 7 are presented in Fig. 5. Note: Inflowing freshwater TN is 3.2 mg/l.

Response: *Table 7 and Figure 5 show $\delta^{15}N$ values of Nitrate in collected water samples. Table 7 does present all the data shown in Figure 5 and vise versa. The TN value 3.2 mg/L cited is from Table 4.*

p. 29; SMAST notes relatively high velocity in Cockle Cove Creek of 1.1 ft/s. It was stated that this assessment was performed via the hydrodynamic model. This may not be a good

characterization. It isn't clear if this one figure represents the creek's average rate of movement or if it is just a point estimate for one place at one time. It is likely that the velocity varies significantly throughout the marsh drainage, so it would be more helpful if actual measurements were taken at various points within the system. We caution that sedimentation could change the rapid export of N from this system. Clearly this site has changed because the 1974 USGS topographical map has a different location for the outlet of Cockle Cove Creek that exists currently.

Response: While *velocities do change over a tide, it is the typical maximum that is important relative to sedimentaiton and so the value is appropriate for this use.. Sedimentation plays a role, but is not the dominant factor in marsh attenuation of nitrogen. However, it is stated that the velocities need to be maintained at present conditons (or greater) for the threshold to apply.*

Page 30 suggests that a level of 2.5 mg/l TN (or 2.0 mg/l to be highly conservative) should be protective of a system that looks like the existing system.

Response: *Correct.*

P. 30 "Increasing the nitrogen load to Cockle Cove Creek will increase the nitrogen transport to these [Bucks Creek and Nantucket Sound] down gradient systems…." Shouldn't we also determine the fate of the exported N? If 40% is being exported from Cockle Cove Creek up into the Bucks Creek system that is already being managed, this may limit the mass of N that can be added to Cockle Creek.

Response: *As stated above to a similar comment, although impacts to Nantucket Sound were not a part of this study, it would be reasonable to set up future monitoring stations in the Sound near the mouth of Buck's Creek.*

p. 30; The second to the last sentence on this page leads one to believe that tertiary treatment produces DIN of 3.0 or 2.5 mg/l. Is this true? Regardless, using DIN at this point is confusing because throughout the report NOx and NH4 (the components of DIN) are reported separately. Question: What is the dissolved O2 in this system? And why was this not presented in the report?

Response:

1. We have replaced DIN with NH4 and NO3 in this sentence to make it consistent with the rest of the report.

2. Dissolved oxygen was not measured in the tidal creeks because the water drains out every ebb tide. Bottom water anoxia is not a problem here.

Verbatim Comments from the Town of Chatham

1. The document needs page numbers.

   Response: *Page numbers have been added to the document*

2. Page 1, Overview, 2nd para.: This paragraph references TN and DIN levels in "mid-marsh" – this should reference the actual station and time period of the data.

   Response: *Station ID's added to text.*

3. Page 2, Overview, 2nd para.: Two sampling locations were located in the freshwater stream discharging to the head of the marsh; this data should be integrated into the analysis.

   Response: The data from the freshwater stream were fully part of the present analysis. However, the stream was not assessed as part of this project.

   The 3rd sentence does not recognize the town of Chatham's involvement in the field work.

   Response: *This has been rectified, however it should be noted that the Town's effort was made clear in Section II and in a number of the Tables.*

   The 4th sentence is poorly worded.

   Response: *This sentence was re-written.*

4. Page 3, top para.: The first sentence is unclear. The last sentence is unclear as to what is meant.

   Response: *Text has been clarified.*

5. Page 3, 2nd para.: No references are provided to support the statements regarding the high assimilative capacity of salt marshes compared to coastal embayments. No references are provided to support the statements regarding the sediment organic carbon levels.

   Response: *These are generally known facts among salt marsh ecologists and biogeochemists. The Technical Memorandum is not meant to be a treatise on salt marshes. However, many general texts contain this and related information, such as Kennish, Ecology of Estuaries or Schlezinger, Biogeochemistry. But, perhaps the best introduction for New England salt marshes can be found in Teal (1986), The Ecology of Regularly Flooded Salt Marshes of New England (and references therein). This was a Community Profile from Fish and Wildlife (Dept of Interior) Biological Report 85(7.4). This document was produced to assist managers involved in ecologically based issues. Also, Nixon 1980. Between coastal marshes and coastal waters: a review of twenty years of speculation and research on the role of salt marshes in estuarine productivity and water chemistry in the volume, Estuarine and Wetland Processes.*

6. Page 3, 3rd para.: No references are provided to support the statements regarding the plant uptake and denitrification by soil bacteria.

   Response: *A "Background Literature" section has been added to the report. Just some of the refereed publications relevant to this region:*

   Valiela and Teal 1979. The nitrogen budget of a salt marsh ecosystem. Nature 280:652-656.

   Kaplan, Valiela and Teal. 1979. Denitrification in a salt marsh ecosystem .Limnology and Oceanography 24:726-734.

   Howes, B.L., P.K. Weiskel, D.D. Goehringer and J.M. Teal. 1996. Interception of freshwater and nitrogen transport from uplands to coastal waters: the role of saltmarshes. pp. 287-310, In: "Estuarine Shores: Hydrological, Geomorphological and Ecological Interactions (K. Nordstrom and C. Roman, Eds.). Wiley Interscience, Sussex, England.

   Hamersley, M.R. and B.L. Howes. 2005. Coupled nitrification-denitrification measured in situ in a Spartina alterniflora with a $^{15}NH_4^+$ tracer. Marine Ecology Progress Series 299:123-135.

   These references contain a large number of others from a variety of systems and regions.

7. Page 4, 2nd para.: Last sentence poorly worded.
   Response: *This sentence was re-written*

8. Page 4, 3rd para.: Last sentence poorly worded.
   Response: *This sentence was re-written*

9. Page 7, 2nd & 3rd para.: Need references to Figure 4.
   Response: *These paragraphs discuss sampling and analysis of macroalgae in the creek bottoms and on the emergent marsh. Figure 3 shows the locations of the sampling stations. Reference to this figure has been added to the text.*

10. Page 9, Figure 3: Difficult to read.
    Response: *The figure was redrafted..*

11. Page 10, 3rd para.: No reference to Table 2 on page 12.
    Response: *The reference to Figure 4 has been replaced with one to Table 2.*

12. Page 10, 3rd para., 3rd sentence: Reference is made to "species diversity was generally ~10"; however, Table 2, column 4 shows only a single value at 10.05, the remaining values are closer to a range of 6-7.
    Response: *The number of species per sample averaged 9.8, in column 2. Benthic ecologists also conduct an analysis presented in column 4, but this is not what was referred to here, nor would it have been appropriate to do so.*

13. Page 10, 3rd para. & Table 2, page 12: No reference range is provided for the Weiner Diversity or Evenness, nor does the text discuss the values obtained in Cockle Cove

Creek. No discussion in the text of the Evenness values and what/how they relate to conditions in Cockle Cove Creek.

Response: *Text added for additional clarification.*

14. Page 10, footnote: spelling errors.

    Response*: The typographical errors have been corrected.*

15. Page 11, figure 4: stations labels are difficult to read. Several locations appear to be located outside the main creek channel; are these actual locations (i.e. feeder channels) or an artifact of the mapping. Why not place this info, and other figures, on the aerial photo as done for Figure 2 and make larger?

    Response: *The figure was redrafted for clarity.*

16. Page 12, Table 2: What does the "D" stand for? This needs explanation.

    Response: *It stands for duplicate. This term has been added to the text.*

17. Page 13, 1st para., 4th sentence: Missing word(s).

    Response: *The sentence has been changed.*

18. Page 13, 2nd para.: Extra words, missing ")"

    Response: *The paragraph has been corrected.*

19. Page 13, 3rd para.: Discrepancy in the units between the text and column headings in Table 4 (page 16). Should indicate the station number for the cited values.

    Response: *All units for Nitrogen should be mgN/L. Table 4 has been corrected accordingly. Station IDs have been added to the text.*

20. Page 13, Flux, Attenuation: This data analysis and interpretation strategy appears to confound the monitoring data and model projections in an unconventional manner. To what extent are projected loads seen in the system? What is the range of the predicted loading?

    Response: *It is not clear how the analysis confounds the monitoring data. The analysis follows standard practice. The question is unclear as to its intent*

21. Page, 16, Table 4: Table heading is very unclear as to which data was collected when, i.e. "summer 2000-2005" vs "summer 2005. The specific periods should be indicated. Data were collected by Chatham from April 05 through December 05 yet only a small subset of this data set is included. The reason for this and the implications on the analysis should be fully explained.

    Response: *The data table has been clarified. We relied most heavily on samplings that had the full suite of measurements needed for the analysis. However,most of the data collected were still used in some form.*

22. Pages 15 & 16: Table 4 is unclear as to which stations are being used as "mid-lower SM". Is this supposed to be CC 4A and B4b, as there is no CC 4B shown on Figure 5.

    Response: *Station IDs have been added to Table 4.*

23. Page 16, Table 4: There is no mention of the data from station CM-K (CC4) or CM-L. Station CC-4 would seem to be important as it monitors what may be entering the main creek channel from the east.

Response: *The loading through this tributary measured at Station CC- 4 is found in Table 5. This station is also discussed in the new freshwater inflow section.*

24. Page 16, Table 4: Different units in the column headings between top and bottom sections.

Response: *The units in Table 4 are now all in mg/L.*

25. Page 16, Table 4: Are the elevated soluble phosphorus levels considered to be a wastewater signal or from some other watershed source?

Response: *The ortho-phosphorus levels do not appear to be particularly elevated for a sediment dominanted marine system. The geochemistry that would support a wastewater signal at mid marsh is unclear.*

26. Page 19, Figure 4: Figure # incorrect, all subsequent figures need to be corrected.

Response: *All of the figure # and table # are now correct.*

27. Page 20, Section B: the discussion on the Stable Isotope results is not convincing. It is unclear how the stable isotope data fits into the development of the N threshold.

Response: *The purpose of the ^{15}N data is simply to determine the likely source of the nitrogen in the system and provide evidence of uptake or transformation. As stated in the text, nitrogen from wastewater effluent has a much different (+10 to +20 $^{0}/_{00}$) $\delta^{15}N$ signal than natural sources in the watershed or from offshore (-1.8 to +8 $^{0}/_{00}$). It is a qualitative indicator, in this study, of whether or not some or any of the nitrogen in NO3, macroalgae and marsh grasses might have come from wastewater effluent. Note that the isotope work was conducted based upon the consensus of DEP, CZM and SMAST staff after discussions of the preliminary project plan.*

The number of observations and standard error values are not presented making it difficult to support the statements without knowing the variability of the results. Figure 8 would benefit from standard error bars around the points.

Response: *All stable isotope data including the data in Figure 8 are from single samples. Consequently, there are no error bars associated with the values. The data presented in this report are accurate to within $\pm$ 0.1 $^{0}/_{00}$.*

28. Most of the values cited in Table 7 overlap the range of values for wastewater and natural sources making any definitive determination of source difficult.

Response: *The data do overlap but overall, as stated in the text, the data provide an indication as to whether wastewater-derived nitrogen is present in the system.*

29. Biological nitrification-dentrification is currently occurring at the Chatham WWTF, as evidenced by the average effluent TN level of 6 mg/L; this would make it difficult to

differentiate the wastewater signal from the natural processes of the salt marsh. Analysis of effluent samples may have provided a better understanding.

Response: *It would seem that that is a matter of perspective. First, it depends upon the selection of the boundary condition. The present study uses the fresh inflow to the marsh as the boundary condition, a decision supported by knowing a priori that there was significant upgradient dentrification. More significant is that there are a variety of processes controlling the ^{15}N signal in Cockle Cove Creek. As we could not do an exhaustive study, we used the data as one means to confirm the source of the nitrogen. It was not planned to collect the information required to also determine the mass transfers between the various N pools.*

30. Page 20, 3rd para.: "sites" vs "sights".

Response: *The text has been corrected.*

31. Page 20, 3rd para.: The number of samples indicated in different ranges differs from the values shown in table 7.

Response: *The text has been corrected.*

32. Page 20, 3rd para.: The value shown for the "inlet" waters is shown as +0.66 however no indication is provided as to what stage of the tide the readings were taken at (ebb vs flood).

Response: *The sample was taken at the inlet to Nantucket Sound and was slected to represent the boundary condition, the flood waters to Cockle Cove Creek. The text has been modifed to clarify this point.*

Page 21, 2nd para.: The 2nd sentence is contradictory to the Figure 8 caption relative to lower ratios at high tide due to dilution from incoming offshore waters.

Response: *The text has been changed to increase clarity.*

33. Page 21, 3rd para.: no references proved for statements relative to emergent plant sources for nitrogen requirements. "from" versus "form".

Response:

1. *Sources of nitrogen for plant requirements are well-documented in the literature. Background references have been added to the Technical Memorandum and these references contain a large number of others from a variety of systems and regions.*
2. *The word "from" has been changed to "form".*

34. Pages 22-24, Figures: very difficult to read; incorrect figure numbers.

Response: *The figures have been redrafted and re- numbered. The data are also included in the associated tables.*

35. Page 25, Figure 8: Needs tide stage shown on figure.

Response: *Figure adjusted.*

36. Page 26, Table 7: two stations labeled "T16" with different locations.

Response: *The sample at the freshwater dike has been re-labeled T16 FW.*

37. Page 28, N Threshold: It is not clear how the seasonal data would be interpreted on an annual basis.

Response: *The seasonal data were not "annualized" for Cockle Cove Creek. Instead, as in the MEP Nutrient Threshold Reports, the theshold analysis focuses on the most sensitive period of the warmer months when the effects of nitrogen enrichment are most pronounced..*

38. Page 29, 4th para.: A significant number of measurements of stream flow were made in the field during the sampling program by SMAST, however, none of this data is presented. This paragraph mentions velocities determined by the hydrodynamic model but does not compare them to the field measurements. Nor is there any analysis of the water column data relative to differences in stream flow at the time of sampling.

Response: *The velocity measurements made in the field by SMAST were used to calculate flows in the creek, which were, in turn used with nutrient concentration data from water samples to calculate nitrogen and phosphorus fluxes through the creek. These data are summarized in Tables 4, 5 and 6. The dominant freshwater inflow pathway is groundwater, making effects on streamflow variations difficult to detect in the watercolumn values. The modeled velocities are the important flows relative to accumulation of macroalgae and fine materials as it is the maximum flows that determine deposition.*

39. Page 30, 2nd para.: Stations Ids should be provided for the referenced nitrogen values.

Response: *Reference to the Stations IDs has been added to the text.*

40. Page 30, 2nd para., 9th sentence: "then" versus "than".

Response: *The text has been changed.*

41. Page 31, next to last sentence: The sentence again references "maintains its present flushing and velocity characteristics" but provides no reference points from the stream flow measurements against which to make future comparisons.

Response: *Velocities were discussed several paragraphs above.*

42. Page 31, last sentence: The wording "a several fold increase in flow" is ambiguous.

Response: *Since the draft report, if appears that the present flow of ~110,000 gpd could be increased to ~430,000 gpd. Again, this is relative to the nitrogen threshold within the salt marsh but does not consider donwgradient systems*.

43. How will this report be used to develop a TMDL for Cockle Cove Creek?

Response: *DEP produces the TMDL reports for the Commonwealth.*