EXHIBIT 14 (M.20)

ATTACHMENT A

Review of "Numeric Nutrient Criteria for the Great Bay Estuary"

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The Great Bay nutrient criteria report was a joy to read and provides an excellent basis for protecting this estuarine ecosystem from nutrient pollution. While many states have narrative nutrient criteria, very few have addressed the difficult challenge of establishing numeric criteria. I applaud the State of New Hampshire for providing some excellent leadership in this area.

The reliance on a weight-of-evidence approach, using several approaches and sources of information, is a strong point of the report. Of the approaches analyzed, some worked better than others. For example, the use of the health of the benthic invertebrate community proved problematic, while relating eelgrass habitat suitability to nitrogen through a relationship to water clarity and penetration worked very well. Similarly, the use of continuous oxygen data proved much more useful for setting nitrogen criteria than did the use of spot sampling for oxygen. The Great Bay report did a beautiful job of explaining the rationale behind each of the approaches tested, as well as in explaining the reasons for using some over others in setting numeric nitrogen criteria. I agree with the report's use of low dissolved oxygen and loss of eelgrass habitat as the two most sensitive and appropriate approaches for setting numeric criteria.

Assumptions in the Great Bay report are well explained and generally well supported by appropriate literature and reasoning. The Great Bay estuary is surprisingly rich in data on nutrient concentrations, dissolved oxygen concentrations, chlorophyll levels, and distribution of seagrasses and macro-algae, and these data were well used in this report.

The Great Bay report takes the approach of setting concentration-based criteria for nutrients rather than using a load-based approach. I found this surprising, as much of the effort in many other estuaries and coastal systems (Chesapeake Bay, Long Island Sound, the Northern Gulf of Mexico hypoxic zone) use a load-based approach (although as noted in the report, the State of Massachusetts has developed a concentration-based approach for protecting estuaries). The NRC (2000) Clean Coastal Waters report stressed the use of loading-based approaches, and specifically warned against using approaches based on inorganic nutrient concentrations; we did this because of inorganic nitrogen concentrations are often low in the most nitrogen-impaired coastal ecosystems, due to the high level of uptake by phytoplankton and other primary producers. The NRC (2000) Clean Coastal Waters report did not consider the use of concentration-based criteria based on total nitrogen, in part because we were aware of no locations where such an approach had been developed and tested.

The Great Bay report has convinced me that the concentration-based approach for setting criteria based on total nitrogen can be powerful and protective. Still, I would have liked to have seen some analysis of how a load-based approach might work in the Great Bay ecosystem. Had the load-based approach also been tested, the authors of the Great Bay report may well have demonstrated that the total-nitrogen concentration approach was more powerful and protective (given the demonstrated strength of that approach, as developed in the report). But we cannot be sure without having seen the load-based approach as well. I would caution other states against using the concentration-based approach without also considering load-based approaches.

The criteria approach developed in the Great Bay report lends itself well to adaptive management. That is, the State of New Hampshire can monitor over time both the concentrations of total nitrogen and the identified sensitive response variables (oxygen concentrations, chlorophyll levels, water clarity and light transmission, and seagrass distribution.), and re-assess the protectiveness of the nutrient criteria periodically into the future. I strongly urge the State to develop a strategy to implement such an adaptive management program for the Great Bay estuary.

While the Great Bay report is well written and extremely well argued, I believe the report would benefit from a stronger executive summary. The lead author of the report, Philip Trowbridge, gave an excellent summary of the report in an oral presentation at the biennial meeting of the Coastal & Estuarine Research Federation in Portland, Oregon, last fall. Perhaps he could use the outline of that talk in revising the executive summary of the report.

Specific Comments on the Report:

1.) When below the limit of detection, data were reported as being at the level of detection, and used in averaging, etc. (page 4). This introduces a slight bias towards higher average concentrations estimated for both total nitrogen and dissolved oxygen, and is therefore not the most conservative approach. I suggest reporting these data as a range, using both zero and the limit of detection. I suspect this assumption is unlikely to affect conclusions in any significant manner, though.

2.) The report assumes that phytoplankton biomass is composed of 50% carbon by weight and 6% nitrogen (page 5). This gives a molar C:N ratio of 9.7, which is fairly high. I think using a lower value for carbon might be more reasonable, perhaps 42 to 45%. I would also suggest a higher value for nitrogen, perhaps 7.5%. This would give a molar C:N ratio that is consistent with the Redfield ratio (approximately 6.8 for C:N). Using total particulate matter concentrations of nitrogen to infer the nitrogen content in living phytoplankton (as the report does) is problematic, as much of the particulate matter is non-living detritus, probably derived from terrestrial sources and seagrasses as well as from phytoplankton. The conclusions of the report are undoubtedly very insensitive to these assumptions, however.

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3.) Similarly, the report assumes a phosphorus content of 1.3% of the weight of phytoplankton, based on measurements of phosphorus in the total particulate matter in the estuary (page 6). This is not justified, and I would suggest using a value more in line with the Redfield ratio (15:1 by moles, so 1.1% phosphorus by weight if one assumes 7.5% nitrogen by weight).

4.) The report uses the molar N:P ratio both for total nitrogen and phosphorus and for inorganic nitrogen and phosphorus to make inferences about nitrogen vs. phosphorus limitation (pages 6 and 28). For justification, the report cites NRC (2000) and Howarth & Marino (2006). These two sources refer specifically to the N:P ratio of biologically available nitrogen and phosphorus, indicating that the ratio of dissolved inorganic nutrients often reflects this availability. NRC (2000) and Howarth & Marino (2006) did not recommend using the N:P ratio of total nitrogen and phosphorus, in part because coastal ecosystems often have relatively high concentrations of recalcitrant organic nitrogen (compared to organic phosphorus, which is recycled more rapidly). I suggest emphasizing the inorganic N:P ratio in the Great Bay report. See Figure 11 on page 29.

5.) The report assumes that total nitrogen in the Gulf of Maine is not changing much over time (page 18). I believe this is assumption is fine, and the report need not worry overly or be defensive about the increased nitrogen load from land having a major influence on the Gulf of Maine in that regard. In general, the inputs and concentration of total nitrogen on the continental shelf off the northeastern US are dominated by inputs of deep North Atlantic water (Boyer, E. W., and R. W. Howarth. 2008. Nitrogen fluxes from rivers to the coastal oceans. Pages 1565-1587 in D. Capone, D. A. Bronk, M. R. Mulholland & E. J. Carpenter (eds.), Nitrogen in the Marine Environment, 2nd Edition, Elsevier, Oxford.). This would probably be particularly true in the Gulf of Maine.

6.) The relationship between total nitrogen and chlorophyll is very strong (page 30), and provides a robust approach for setting a total nitrogen criteria. The report is correct in arguing that the relationship between inorganic nitrogen and chlorophyll should be less strong, due to the large amount of inorganic nitrogen taken up by primary producers. The relationship is nonetheless strong.

7.) The report makes a convincing case that eelgrass has declined significantly in Great Bay since 1996, with some of the area that formerly supported eelgrass now dominated by nuisance macro-algae (page 37). This is a very disturbing trend, and points to the need to better control loss of eelgrass. The development of a total nitrogen criteria level of 0.34 to 0.38 mg N/l, based on proliferation of nuisance algae in Great Bay, seems justified (page 38). The report correctly points out the need to separately assess nitrogen criteria for eelgrass protection based on water clarity.

8.) The report concludes that benthic invertebrate data are dominated by salinity rather than by nitrogen per se (although nitrogen and salinity are correlated). This is a reasonable interpretation.

9.) The regressions between chlorophyll or nitrogen and low dissolved oxygen concentrations are striking, and as the report states, somewhat surprising for grab samples of oxygen taken at one point in time since dissolved oxygen can change dramatically over the course of a day (pages 45-50). Despite the noise in these relationships, it would be tempting to use them to set a nitrogen criteria level, if the more robust continuous oxygen data from the sonde deployments were not available. I agree with the report's use of these datasonde data to set the standard, which seems robust (pages 51-52).

10.) The section on light transmisivity and eelgrasses is very well done, and the correlation between total nitrogen and turbidity (page 65) is very striking. The nitrogen thresholds presented on page 66 appear justified.

Charge Questions:

In writing this review, I was charged with four specific questions on the transparency, defensibility, and reproducibility of the Great Bay report, as well as an assessment as to whether or not the recommended criteria will be adequately protective. I address each of these briefly below.

Transparency: The Great Bay report does an excellent job of stating their assumptions and explaining their analytical approaches, and the limitations of these approaches. The data behind the report are also available on line. This is among the most transparent assessment reports I have seen, and I applaud the authors for this.

Defensibility: The report uses data from a variety of sampling studies, and uses a weight of evidence approach in the assessment of these data. For the most part, the sampling and analytical methods behind these data seem straightforward and are consistent with commonly used and accepted approaches. Importantly, the report does a nice job of stating how the nutrient data were used (ie, in estimating total nitrogen and specific nitrogen pools). As most of the data come from government monitoring programs, it seems likely that QA/QC processes were used. However, the report does not document this. A brief discussion on QA/QC issues, perhaps with reference to appropriate web sites where more information is available, would be very useful.

The report did an excellent job of stating the designated uses of Great Bay and in explaining how those uses could be protected from the nutrient criteria proposed.

Reproducibility: I did not attempt to independently verify the many analyses that are included in the report. However, for the most part these analyses are straightforward, and appear reasonable and well done. Further, the data behind the analyses are available on line, allowing any one to further test the analyses, including making changes in assumptions and approaches. This is very important, and adds greatly to the credibility of the Great Bay nutrient criteria report.

Protective: The proposed nutrient criteria seem quite protective of the designated uses of the Great Bay estuarine system. The criteria could be made even more protective if they are used in the context of adaptive management. The State of New Hampshire should be encouraged to continue to monitor both total nitrogen concentrations and the response of sensitive indicators (dissolved oxygen, chlorophyll, light penetration, water clarity, and eelgrass and macro-algal distributions). These monitoring data should feed into a periodic re-assessment of the nutrient criteria, and the criteria adjusted downward if necessary to protect designated uses of the Great Bay estuary.

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