# Managing anthropogenic nitrogen inputs to coastal embayments: Technical basis and evaluation of a management strategy adopted for Buzzards Bay.

## Supplementary information on water quality and habitat goals

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Buzzards Bay Project Technical Report

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*Note: This report will be incorporated into the final version of the following document:*

J. E. Costa, B. L. Howes, D. Janik, D. Aubrey, E. Gunn, A. E. Giblin. 1999. Managing anthropogenic nitrogen inputs to coastal embayments: Technical basis of a management strategy adopted for Buzzards Bay. Buzzards Bay Project Technical Report. 56 pages. Draft Final, September 24, 1999.

## INTRODUCTION

In response to the report "Managing anthropogenic nitrogen inputs to coastal embayments: Technical basis of a management strategy adopted for Buzzards Bay[1]," several reviewers requested clarification and additional information on what specific water quality or living resource goals were implied by the "SB," "SA," and "ORW" limits proposed by the Buzzards Bay Project. This supplementary report identifies these water quality targets and explains their basis.

## PROPOSED RECEIVING WATER STANDARDS

The BBP has established total maximum annual nitrogen loading limits (TMALs) as part of its strategy to manage anthropogenic nitrogen to coastal waters. Although specific water quality standards were not adopted as part of that strategy, specific water quality standards were identified in the Citizen monitoring program which were used to define the proposed limits which in turn can be used to identify specific water quality goals for each of the water quality classifications.

For example, the 1992-95 Buzzards Bay Water Quality Monitoring program report, (Costa et al. 1996), identified Eutrophication Index Scores of 65 to 100 as "good to excellent" water quality, 35 to 65 as "fair" water quality, and <35 as typical of "eutrophic" water quality conditions. In the September 1999 report, these scores were used to identify the proposed new ORW, SA, and SB classifications by equating the water quality classifications (ORW, SA, and SB) to specific Eutrophication Index scores, and estimating the equivalent nitrogen loading as shown in Fig. 1. Thus, for shallow embayments (most Buzzards Bay embayments would be classified as this type), the ORW water quality classification goals were equated to roughly a Eutrophication Index score of 65, SA was equated to a Eutrophication Index score roughly of 50, and SB equated a Eutrophication Index score roughly of 40. These water quality goals led to the proposed TMALs of 50, 150, and 350 mg $m^{-3}$ during the hydraulic residence time $V_f$ respectively for the ORW, SA, and SB standards.

In a similar way, the results of the citizen monitoring program can be used to "translate" the proposed TMALs into specific water quality objectives. Thus, as shown in Fig. 2, the ORW, SA, and SB limits for shallow embayments suggest that embayments are being programmed to reach a mean summer time total nitrogen concentration of roughly 0.43 ppm, 0.54 ppm and 0.65 ppm respectively depending upon their water quality classification goal.

The data for Chlorophyl **a** has more scatter (Fig. 3), but the ORW, SA, and SB limits for shallow embayments suggest that embayments are being programmed to reach a mean summer time

[1] J. E. Costa, B. L. Howes, D. Janik, D. Aubrey, E. Gunn, A. E. Giblin. 1999. Managing anthropogenic nitrogen inputs to coastal embayments: Technical basis of a management strategy adopted for Buzzards Bay. Buzzards Bay Project Technical Report. 56 pages. Draft Final, September 24, 1999

chlorophyll concentration of roughly 5, 7, and 9 μg/l for the three respective water quality classification goals. Figure 4 shows projections of secchi depth at each TMAL.

Finally, the response of eelgrass beds, a vital habitat often viewed as the most sensitive indicator to nitrogen loading, is shown in Fig. 5. As shown, the ORW, SA, and SB limits for shallow embayments suggest that embayments are being programmed so that eelgrass will cover on average roughly 30%, 50%, and 80% of the potential core eelgrass habitat area (between 1 ft and 6 feet MLW, see Costa et al., 1999 for an explanation of this parameter).

Presently, the Massachusetts Surface Water Quality Standards (314 CMR 4.04) state only that, with respect to nutrients, impacts "shall not exceed the site-specific limits necessary to control accelerated or cultural eutrophication." The proposed new TMALs would coincide with the specific water quality goals for the five aforementioned parameters, as well as the Alternate Eutrophication Index (when no oxygen saturation score used) as summarized in Table 1. These parameters are surrogate measures for evaluating nitrogen loading and are targets that should not be exceeded. Considerable seasonal variation exists for all these measures, and these standards are for summertime conditions when critical impacts are most likely to occur because of water temperature, weather, or higher plant and animal metabolism and growth. For monitoring and evaluation purposes, means during at least four sample dates during July to August can be considered representative. The respective narrative objectives for each water quality standard are identified in Table 2.

**Table 1.** Proposed water quality standards, for various surrogate measures of nitrogen loading, that correspond to the proposed TMALs for nitrogen identified for waters designated ORW, SA, and SB. Targets are mean summertime concentrations when critical conditions are most likely to occur. See Costa et al (1999) for definition of eelgrass to habitat ratio. Based on best professional judgment.

| Parameter | ORW | SA | SB |
|---|---|---|---|
| Eutrophication Index | 65 | 50 | 40 |
| Alternate Eutrophication Index (no $0_2$) | 65 | 45 | 30 |
| Total N (ppm) | 0.43 | 0.54 | 0.65 |
| Chl a (μg/l) | 5.0 | 7.0 | 9 |
| Secchi depth (m) | 1.9 | 1.5 | 1.3 |
| Eelgrass to core habitat ratio | 0.8 | 0.5 | 0.3 |

Table 2. Narrative objectives for the TMAL limits in Buzzards Bay embayments.

The proposed TMAL limits are presumed to meet the following natural resource and water quality goals for each water quality classification.

ORW: A large portion of eelgrass, shellfish, finfish, and benthic invertebrate habitat remain in a near natural productive state. These goals are presumed to be consistent with Massachusetts Water Quality Standards (314 CMR 4.04) goals for ORWs in that "these waters constitute an outstanding resource as determined by their outstanding socio-economic, recreational, ecological and/or aesthetic values. The quality of these waters shall be protected and maintained."

SA: A majority of eelgrass, shellfish, finfish, and benthic invertebrate habitat remain in a near natural productive state. These goals are presumed to be consistent with Massachusetts Water Quality Standards (314 CMR 4.04) goals for Class SA in that "These waters are designated as an excellent habitat for fish, other aquatic life and wildlife and for primary and secondary contact recreation. In approved areas they shall be suitable for shellfish harvesting without depuration (Open Shellfish Areas). These waters shall have excellent aesthetic value."

SB: Large losses of eelgrass, shellfish, finfish, and benthic invertebrate habitat may occur, but critical or catastrophic losses (complete loss of habitat, large accumulations of nuisance algae, chronic hypoxia [4 ppm] or anoxia) are prevented. These goals are presumed to be consistent with Massachusetts Water Quality Standards (314 CMR 4.04) goals for class SB in that "these waters are designated as a habitat for fish, other aquatic life and wildlife and for primary and secondary contact recreation. In approved areas they shall be suitable for shellfish harvesting with depuration (Restricted Shellfish Areas). These waters shall have consistently good aesthetic value."

## Discussion

An interesting additional interpretation of Figure 2 can be made by considering the fact that the proposed TMALs and resulting total nitrogen concentrations appear to agree with concentrations that may be expected from a conservative contaminant under steady state hydraulic conditions. That is to say, under steady state hydraulic conditions (this condition is assumed to be met because hydraulic turnover time is accounted for when loading is characterized), the nitrogen loadings of 50, 150, 300 mg $m^{-3}$ during the Vollenweider residence time are the equivalent to an expected 0.05, 0.15, and 0.30 ppm increase respectively in nitrogen in the receiving waters. Figure 2 shows that for low loaded systems, the total nitrogen concentrations in upper portions of embayments is roughly 0.38 ppm. If the expected increases (0.05, 0.15, and 0.30 ppm) are added to the approximate amount of 0.38 ppm found in less loaded embayments, these totals are very close to the expected to observed values summarized in Table 1.

The relationship between nitrogen loading and nitrogen concentration is probably more complicated because total nitrogen is not conservative (relationship is not linear on a log-log plot), but Fig. 2 suggests that a lot of the anthropogenic nitrogen converted from inorganic to organic form remains in the water column, so total nitrogen acts somewhat like a conservative contaminant. The approximately 0.38 ppm nitrogen concentration found in the upper half of estuaries is higher than the approximately 0.28 ppm found offshore in Buzzards Bay. The fact this occurs in upper embayments in the less developed watersheds could imply that some sources of nitrogen have not been accounted for, or Buzzards Bay waters near the mouth of embayments have higher nitrogen concentrations than central Buzzards Bay, and this water returns with each tide.

The Buzzards Bay Project adopted watershed nitrogen loading limits rather than water quality standards as the basis of nitrogen management for two fundamental reasons. First, evaluation of existing conditions of receiving waters fails to account for nitrogen in transit from new sources. Because average time of groundwater transit in any particular watershed may exceed 10 years or more, an evaluation of loadings based on watershed loading models was viewed as a more reliable basis for decision making than existing water quality conditions, especially in watersheds with considerable new development away from shore. Second, the use of water quality measurements in receiving waters has difficulties, especially in the context of regulatory decisions. For example, the measurement of low concentrations of nutrients in receiving waters is not always consistent among analytical laboratories, especially those accustomed to measuring higher concentrations in discharge pipes. Equally problematic is the fact that any water quality parameter measured can be highly variable depending on rainfall, weather conditions, time of sampling (with respect to the tidal cycle), salinity, distance from groundwater or point sources, and other factors. For this reason, decisions on where, when, and how often samples are to be taken can have a major bearing on whether a water quality standard has been met.

Despite these difficulties, articulation of water quality standards is fundamental for implementation of watershed or point source TMDLs or TMALs for nitrogen. The water quality standards proposed in Table 1 can also be used to ascertain whether proposed or adopted water quality standards are being met.

The BBP’s nitrogen management strategy represents a linking of estimates of watershed nitrogen loading, using very specific nitrogen loading assumptions, to empirical observations of ecosystem response in a wide variety of Buzzards Bay embayments. The relationship between the assumed loadings and ecosystem response is the basis for the proposed new watershed TMAL’s. The proposed TMALs, loading model, and buildout evaluations can be used to identify watershed and embayment specific “Load Allocations” and “Waste Load Allocations” and other legal requirements needed to establish TMDLS in accordance with regulations established under section 303(d) of the Clean Water Act.

It is worth noting that other nitrogen loading models exist for estimating watershed anthropogenic loadings, but if these models have radically different assumptions about anthropogenic loadings or losses in transit in groundwater, these loading models would need to be related to ecosystem responses as was done by the Buzzards Bay Project to develop TMALs specific to these alternative loading models.

Even where water quality has been evaluated and loadings have been estimated, the most difficult management decision remains, what is an appropriate TMAL for an embayment to protect water quality and living resources? Measures of water quality like chlorophyll and total nitrogen can assist scientists in knowing the degree of eutrophication in an embayment but for citizens and politicians, other factors such as losses of shellfish, finfish, accumulation of nuisance algae, foul odors, poor water transparency, and fish kills, and synergistic impacts such as shellfish and swimming beach closures are the endpoints of greatest public concern. Most waters in Buzzards Bay are designated as SA. Is it acceptable of all these areas to have only 50% of the core eelgrass habitat areas vegetated? A number of scientists are now examining fish populations, shellfish abundance, and other secondary responses to nitrogen loadings, but even when these relationships are defined, environmental management and the establishment of loading limits requires value judgements on how much impairment is acceptable. This is true with the limits proposed here; they are based on a professional judgment.

The BBP's TMAL nitrogen strategy is a generalized empirical approach. This approach does not account for different ecosystem responses in similar embayments with similar loadings, even when fundamental bay features such as bay volume and flushing time have been accounted for. Ultimately more sophisticated computer models will be developed that will account for dozens of features and conditions in any particular embayment, to better predict ecosystem response with changes in nitrogen loading. In the interim, however, the BBP TMAL nitrogen strategy provides a viable framework for local government to plan and minimize the cumulative non-point impacts of growth, and by state and federal agencies to establish TMDLs for sewage treatment facilities and other point sources of pollution to protect sensitive coastal waters.

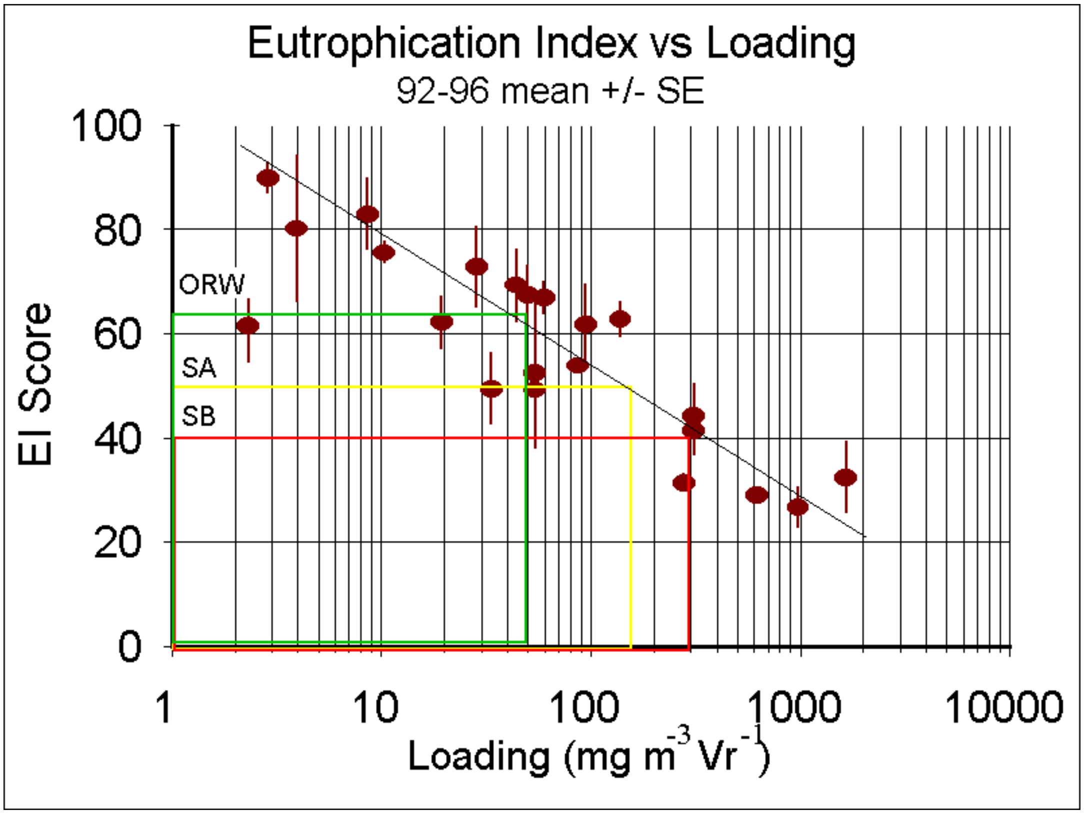


**Figure 1**. Use of Eutrophication Index scores to establish nitrogen loading limits for Buzzards Bay embayments. Regression visually approximated.

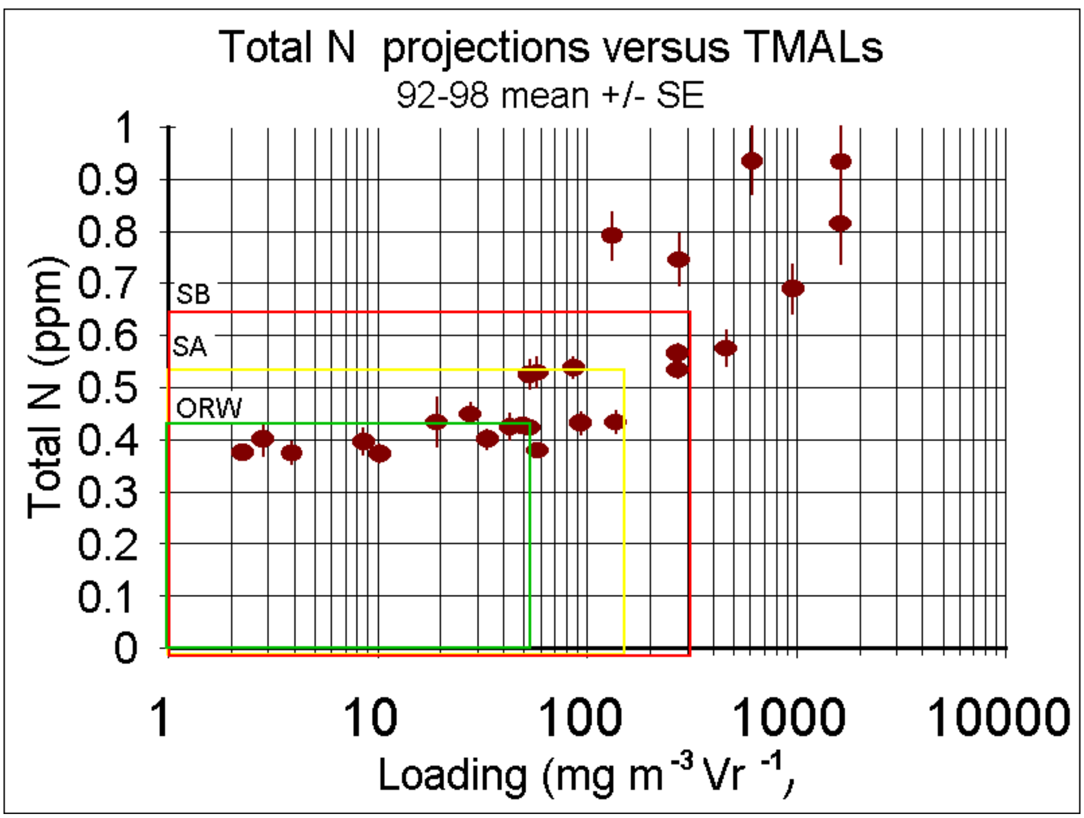


**Figure 2**. Projected total nitrogen concentrations in receiving waters when TMALs are met.

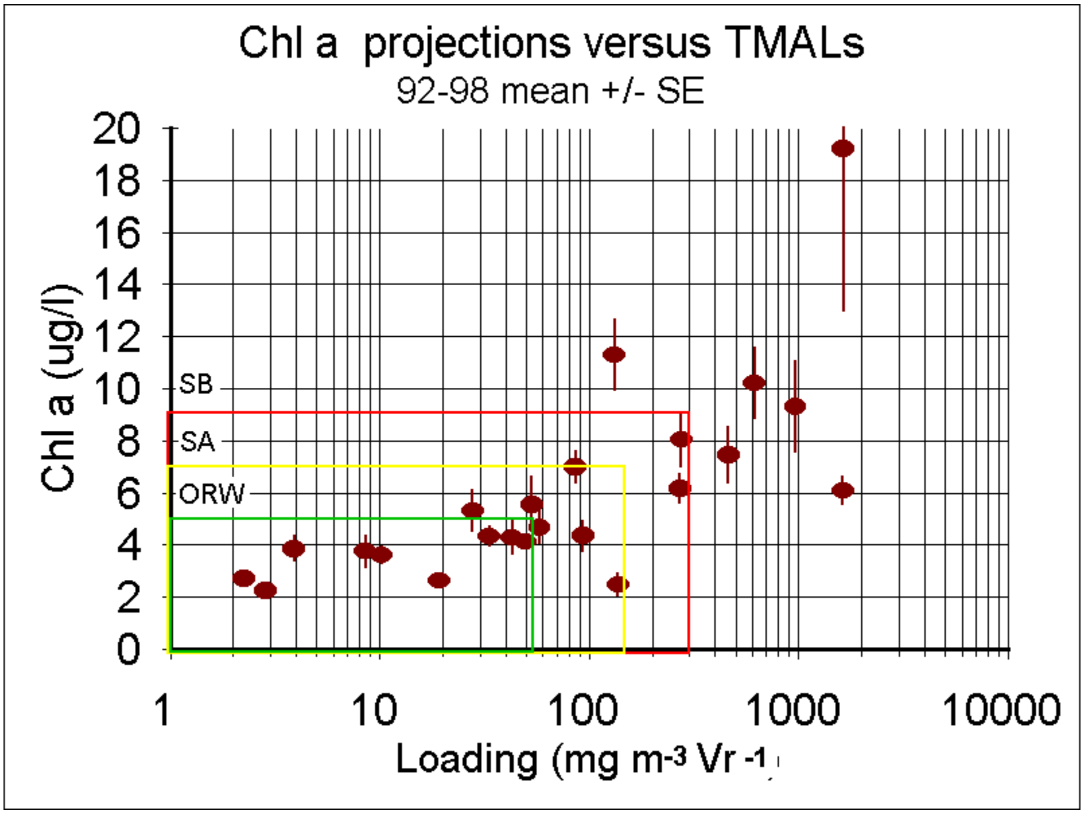


**Figure 3**. Projected chlorophyll ***a*** concentrations in receiving waters when TMALs are met.

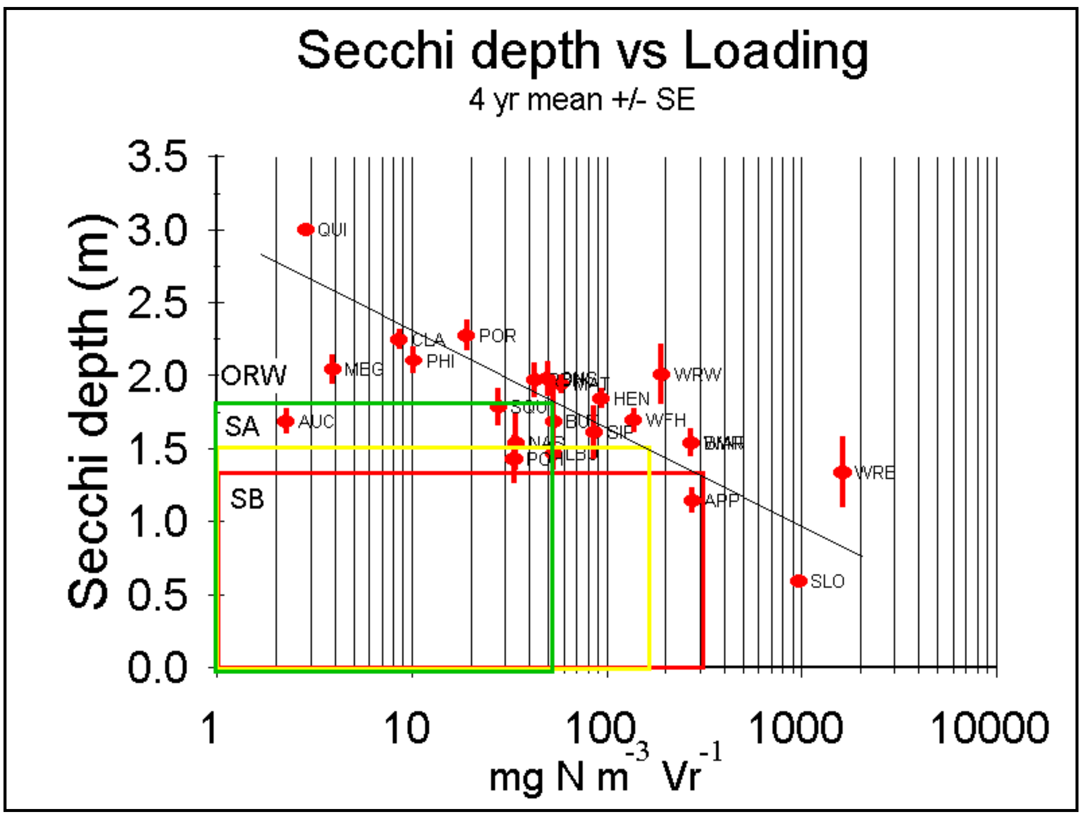


**Figure 4**. Projected secchi depths in response to loading at each TMAL.

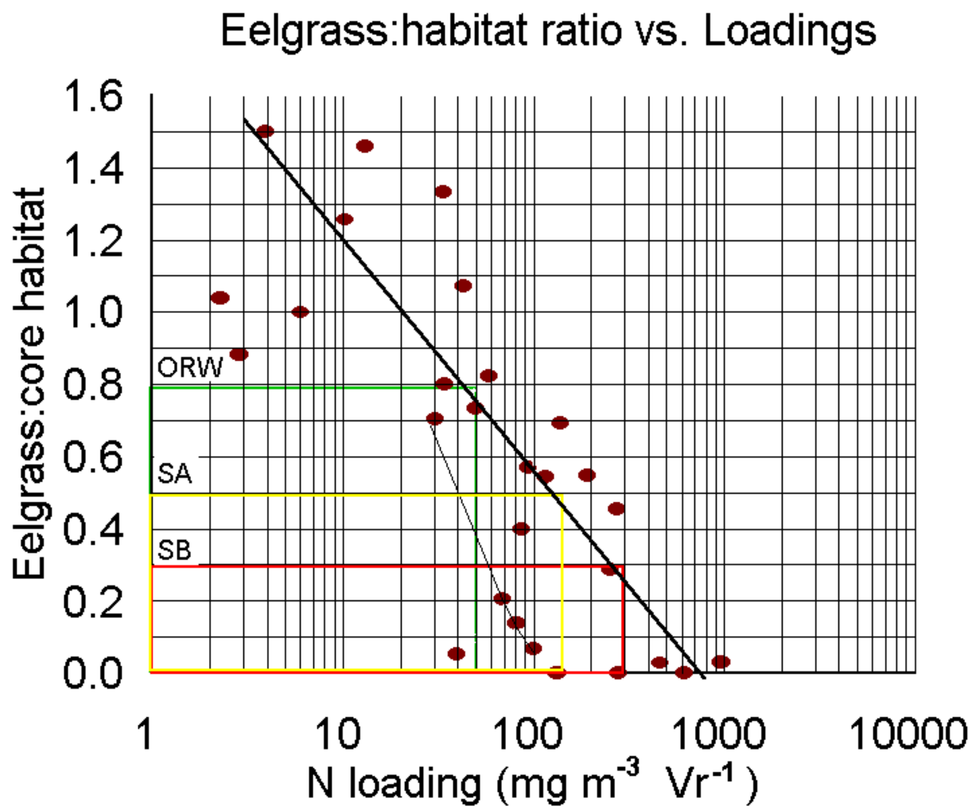


**Figure 5**. Projected eelgrass to habitat ratio in receiving waters when TMALs are met.