

# Tampa Bay Estuary Program Model Evaluation and Update:

## Nitrogen Load - Chlorophyll a Relationship

Prepared for:



### **Tampa Bay Estuary Program**

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## **FOREWORD**

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## **ACKNOWLEDGMENTS**

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# 1 INTRODUCTION

The Tampa Bay National Estuary Program (TBNEP) developed a Comprehensive Conservation & Management Plan (CCMP), entitled *Charting the Course*, which was the culmination of five years of effort aimed at bringing together the participants of the TBNEP to address the key environmental issues affecting Tampa Bay. The CCMP specifically addressed several major issues, including water quality and habitat loss. The loss of seagrasses in Tampa Bay drew particular interest, given their important role in the ecological functioning of the bay.

Seagrasses provide critical habitat for recreationally and commercially important fish and invertebrate species. Seagrasses in Florida provide juvenile nursery and adult feeding areas for red drum, spotted seatrout, spot, silver perch, sheepshead, snook, shrimp, and the bay scallop (Zieman and Zieman, 1989). Seagrass meadows are also important feeding areas for the Florida manatee. Seagrasses serve to improve water quality by reducing nutrients in the water column and are an important component of the energy and nutrient cycles in coastal environments.

Seagrass extent and condition can be impacted by many factors, including water quality, physical factors such as prop scarring and currents, seagrass disease, and location of seagrass beds in relation to offshore transverse sandbars. The TBNEP Technical Advisory Committee (TAC) recognizes that these and other factors may affect progress towards reaching adopted seagrass restoration goals, and is currently initiating actions which will assist with addressing factors in addition to water clarity and quality (including the initiation of measuring the depth of water at various seagrass beds around the bay, and the monitoring of potential seagrass disease). Actions needed to address additional factors, such as the bay-wide effects of prop scarring or the location of various seagrass beds, will be included in discussions of future monitoring needs.

In Tampa Bay, seagrasses typically grow at depths no deeper than six to eight feet. Light is one of the limiting factors on the depth at which seagrasses can be found. Light requirements for growth vary by seagrass species. Turtle grass, the most common seagrass species in Tampa Bay, has an estimated light requirement of 20.5% of the incident subsurface light (Dixon and Leverone, 1995). For the purposes of seagrass restoration target setting, this was assumed to be the minimum light requirement for seagrasses in Tampa Bay (Janicki and Wade, 1996).

To address the issue of seagrass habitat loss, recommended seagrass protection and restoration targets were developed (Janicki et al., 1995). Seagrass restoration targets were determined by comparing 1990 seagrass extent to that observed in 1950. Seagrass targets were defined as those portions of Tampa Bay that had seagrasses in 1950, did not have seagrasses in 1990, and had not been permanently altered to preclude restoration of seagrasses.

To strive toward the seagrass restoration goal, the TBNEP developed the Nitrogen Management Strategy. The Strategy seeks to prevent future impacts due to excessive nitrogen loadings to Tampa Bay. To address these concerns, a paradigm that relates nitrogen loading to chlorophyll and seagrass was utilized, as shown in Figure 1-1.

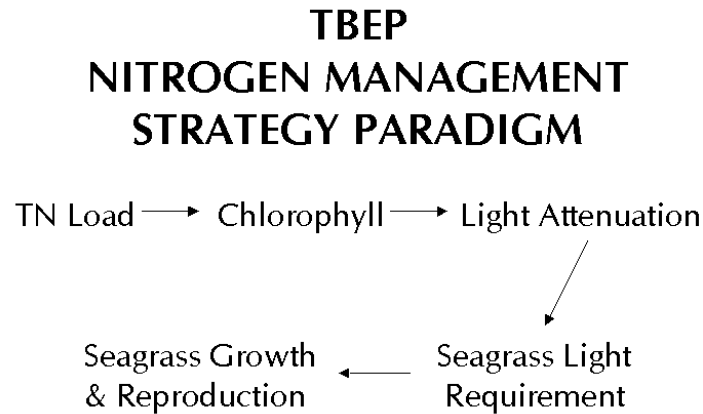


Figure 1-1. The TBNEP Nitrogen Management Strategy Paradigm.

An empirical modeling approach was taken to define the relationships between TN loads and chlorophyll a concentrations and between chlorophyll a concentrations and light attenuation (Janicki and Wade, 1996).

The objective of this report is to re-evaluate the empirical relationship between TN loads and chlorophyll a concentrations using the water quality data collected since 1994 by the Environmental Protection Commission of Hillsborough County (EPCHC) and the 1995-1998 loading estimates developed by the TBEP (Pribble et al., 2001).

## 2 METHODS

A principal working hypothesis was earlier developed that observed chlorophyll a concentrations are directly related to total nitrogen loads, from external sources and from internal exchange of nitrogen between bay segments (Janicki and Wade, 1996). Regression results suggest that the variation in total nitrogen loads could explain the majority of the variation in chlorophyll a concentration.

The estimates of nitrogen loading from internal exchange between segments were derived in the following manner. First, a series of simple dilution equations were written for the segments of Tampa Bay and fit to the observed salinity data and freshwater inflow data. For example, the equation for the Old Tampa Bay segment was written as follows:

$$0 = W_o - Q_o C_o + E_{o,b}(C_b - C_o)$$

where:  $W_o$  = the external load of a dissolved substance to Old Tampa Bay from its watershed (kg/month),

$Q_o$  = the freshwater inflow rate to Old Tampa Bay from its watershed ( $m^3$ /month),

$C_o$  = the concentration of a dissolved substance in Old Tampa Bay ( $kg/m^3$ ),

$C_b$  = the concentration of a dissolved substance in the adjacent subsegment of Middle Tampa Bay ( $kg/m^3$ ), and

$E_{o,b}$  = a transfer coefficient from Old Tampa Bay to the adjacent subsegment of Middle Tampa Bay ( $m^3$ /month).

A dilution equation was written in this manner for each of the five modeled segments (Old Tampa Bay, Hillsborough Bay, and the three subsegments of Middle Tampa Bay). To estimate the average net transfer of water and dissolved substance between the five bay segments, the system of equations was first solved using salt as a conservative dissolved substance. This left only the transfer coefficient terms ( $E$ ) unknown in the series of equations. The transfer coefficient terms were then estimated for the dry season (October-May) and the wet season (June-September).

After estimation of the exchange coefficients between the segments, the series of equations were used to predict monthly nitrogen concentrations. To account for the nonconservative properties of nitrogen in the estuarine system, the predicted

concentrations were related to the observed concentrations using least squares regression methods, as follow:

$$N_{t,s} = \beta_{t,s} \hat{N}_{t,s}$$

where:  $N_{t,s}$  = the observed nitrogen concentration in month t and bay segment s,

$\hat{N}_{t,s}$  = the nitrogen concentration predicted by the simple dilution model in moth t and bay segment s, and

$\beta_{t,s}$  = a regression parameter.

Results of the regression indicated that the variation in the observed nitrogen concentrations could be explained by the variation in the nitrogen concentrations predicted by the dilution model. The degree of the adjustment for nonconservative processes varied monthly and typically fell within plus or minus 5% to 20%.

The relationship between total nitrogen load and chlorophyll a was then derived as follows:

$$C_{t,s} = \alpha_{t,s} + \beta_s L_{t,s}$$

where:  $C_{t,s}$  = average chlorophyll a concentration at month t and in segment s,

$L_{t,s}$  = total nitrogen load at month t to segment s, and

$\alpha_{t,s}$  and  $\beta_{t,s}$  = regression parameters.

Least squares regression methods were used to estimate the regression parameters (Janicki and Wade, 1996). The results of the regressions indicated that the variation in chlorophyll a concentrations could be explained by the variation in total nitrogen load. Monthly specific regression intercept terms were used to avoid any potentially confounding effects of seasonality in the independent and dependent variables.

Water quality data collected by the EPCHC for the period 1995 through 1998 were obtained and incorporated into the TBEP water quality database (Janicki Environmental, 2000). External TN loading data were estimated for the 1995-1998 period as described in Pribble et al. (2001). These data were used to evaluate the TN load - chlorophyll a model developed previously using data from the period 1986 through 1994.



Initially, the TN load - chlorophyll a regression was used to estimate chlorophyll a given the estimated TN loads during 1995 through 1998. Comparisons of the predicted and observed chlorophyll a values, for both monthly and annual mean conditions, were then made. Secondly, the residuals (i.e., the difference of the observed and predicted chlorophyll a values) were examined to assess whether any important differences were observed between those from the 1986-1994 period and those of the 1995-1998 period.

### 3 RESULTS

The results of the two methods used to evaluate the TN load - chlorophyll a regression for Tampa Bay are presented below.

#### **Comparison of Predicted and Observed Chlorophyll a Values Using the 1986-1994 TN Load - Chlorophyll a Regressions**

The following figures present a comparison of the observed mean monthly chlorophyll a values for the 1986-1998 period to the chlorophyll a values predicted by the monthly TN loads and the TN load - chlorophyll a regressions developed from the 1986-1994 data (Janicki and Wade, 1996):

- Figure 3-1 – All bay segments
- Figure 3-2 – Old Tampa Bay
- Figure 3-3 – Hillsborough Bay
- Figure 3-4 – Middle Tampa Bay – 31
- Figure 3-5 – Middle Tampa Bay – 32
- Figure 3-6 – Middle Tampa Bay – 33.

These plots include a line that represents a 1:1 relationship between predicted and observed values. Data points above the line represent months when the predicted chlorophyll a value was greater than that which was observed. Data points below the line represent months when the predicted chlorophyll a value was less than that which was observed. Close agreement in the predicted and observed chlorophyll a values would result in a plot where the points were in close proximity to the line. If any bias in the predicted chlorophyll a values exists then a disproportionate number of points would be found either above (observed > predicted) or below (observed < predicted) the line. In each plot, the 1995-1998 data are presented as circles while the 1986-1994 data are presented as plus signs (+).

The comparisons of mean monthly predicted and observed chlorophyll a values indicate that there is little difference between the regression results from the 1986-1994 and 1995-1998 periods. Table 3-1 presents a comparison of the mean annual predicted and observed chlorophyll a values by bay segment. The differences in the observed and predicted chlorophyll a values were typically greatest in 1996 and 1998 in all bay segments. In 1995 and 1998, the observed mean annual chlorophyll a was typically greater than the predicted mean annual chlorophyll a in each segment. In 1996, the opposite was true, with the mean annual predicted chlorophyll a higher in each segment. In 1997 there was relatively good agreement between the predicted and observed mean annual chlorophyll a values. Overall, the difference in chlorophyll a values was approximately 1.1 : g/L in Old Tampa Bay, 2.0 : g/L in Hillsborough Bay, 2.4 : g/L in Middle Tampa Bay 31, 1.5 : g/L in

Middle Tampa Bay 32, and 1.3 : g/L in Middle Tampa Bay 33. These differences are relatively small compared to the observed mean annual values.

**Table 3-1. Mean annual predicted and observed chlorophyll a values.**

Bay Segment	1995		1996		1997		1998	
	Observed	Predicted	Observed	Predicted	Observed	Predicted	Observed	Predicted
OTB	8.3	7.7	6.9	8.6	8.5	8.9	11.6	9.9
HB	15.1	13.9	9.6	13.1	12.4	13.2	18.4	15.0
MTB-31	12.6	10.4	6.5	9.6	9.5	11.0	13.9	11.1
MTB-32	8.5	7.9	5.8	7.2	7.0	8.4	10.7	8.3
MTB-33	5.5	5.1	3.0	5.3	5.6	5.9	6.4	8.7

**Differences Between Residuals from the TN Load - Chlorophyll a Regressions During 1986-1994 and 1995-1998**

To examine any differences in the relationship between predicted and observed chlorophyll a concentrations during the two periods, 1986-1994 and 1995-1998, the residuals (difference between predicted and observed chlorophyll a) were plotted for each month and for each bay segment for the two periods. Residual chlorophyll a values are shown as a function of month in Figure 3-7, and as a function of bay segment in Figure 3-8, for each of the periods. Inspection of the residual plots suggests that the residuals are very similar for both periods, both for the same month and for the same bay segment.

The results from this analysis reflect very good correspondence between predicted and observed chlorophyll a concentrations, and little change in residuals between the two periods. Thus, the relationship between nitrogen loading and algal biomass has been relatively consistent during the period of 1986 through 1998.

Tampa Bay Estuary Program  
Nitrogen Loading - Chlorophyll a Relationship  
Comparison of Predicted and Observed Chlorophyll a Concentrations

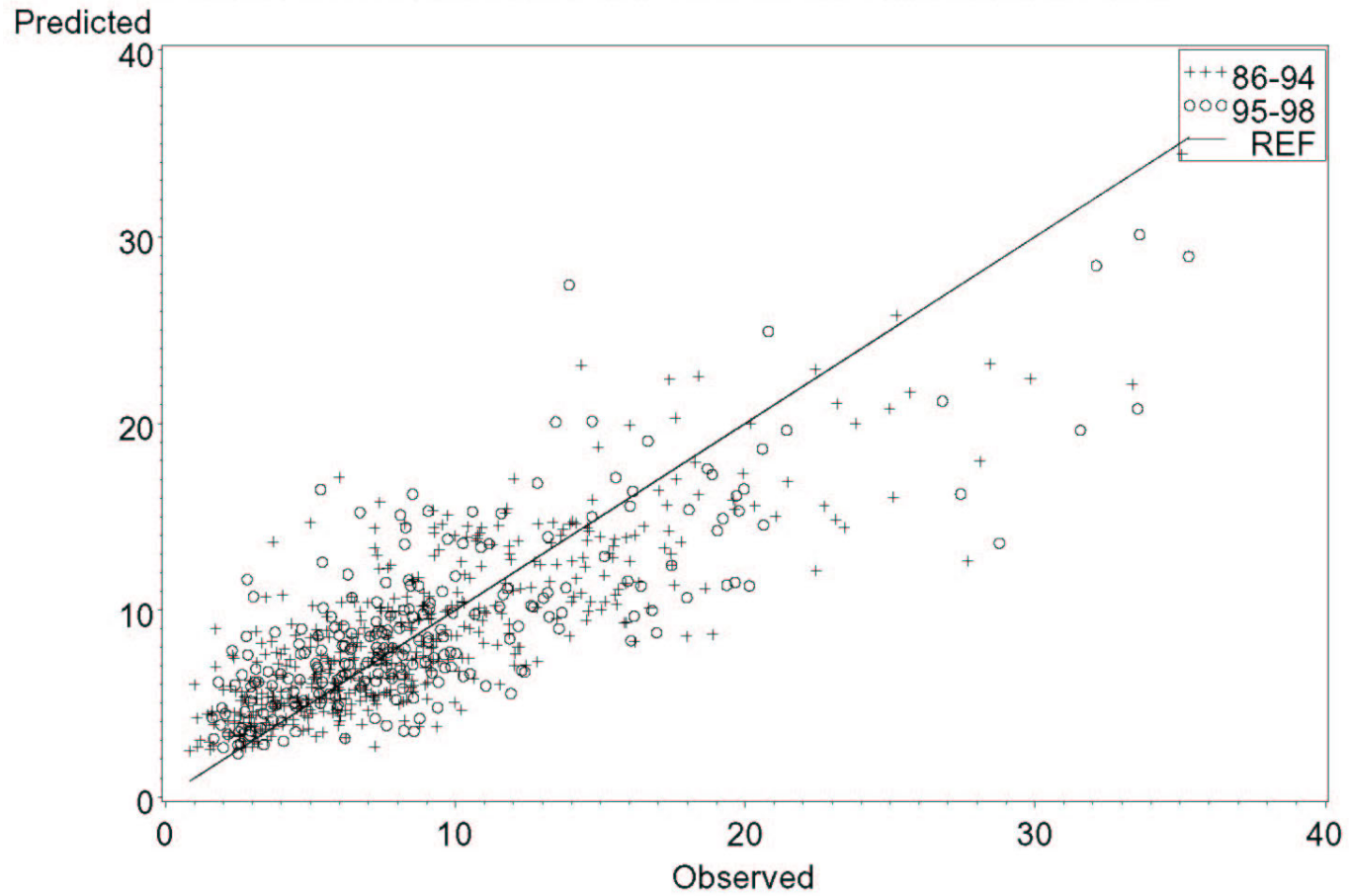


Figure 3-1. Relationship between mean monthly observed and predicted chlorophyll a, all bay segments.

Tampa Bay Estuary Program  
Nitrogen Loading - Chlorophyll a Relationship  
Comparison of Predicted and Observed Chlorophyll a Concentrations  
OTB

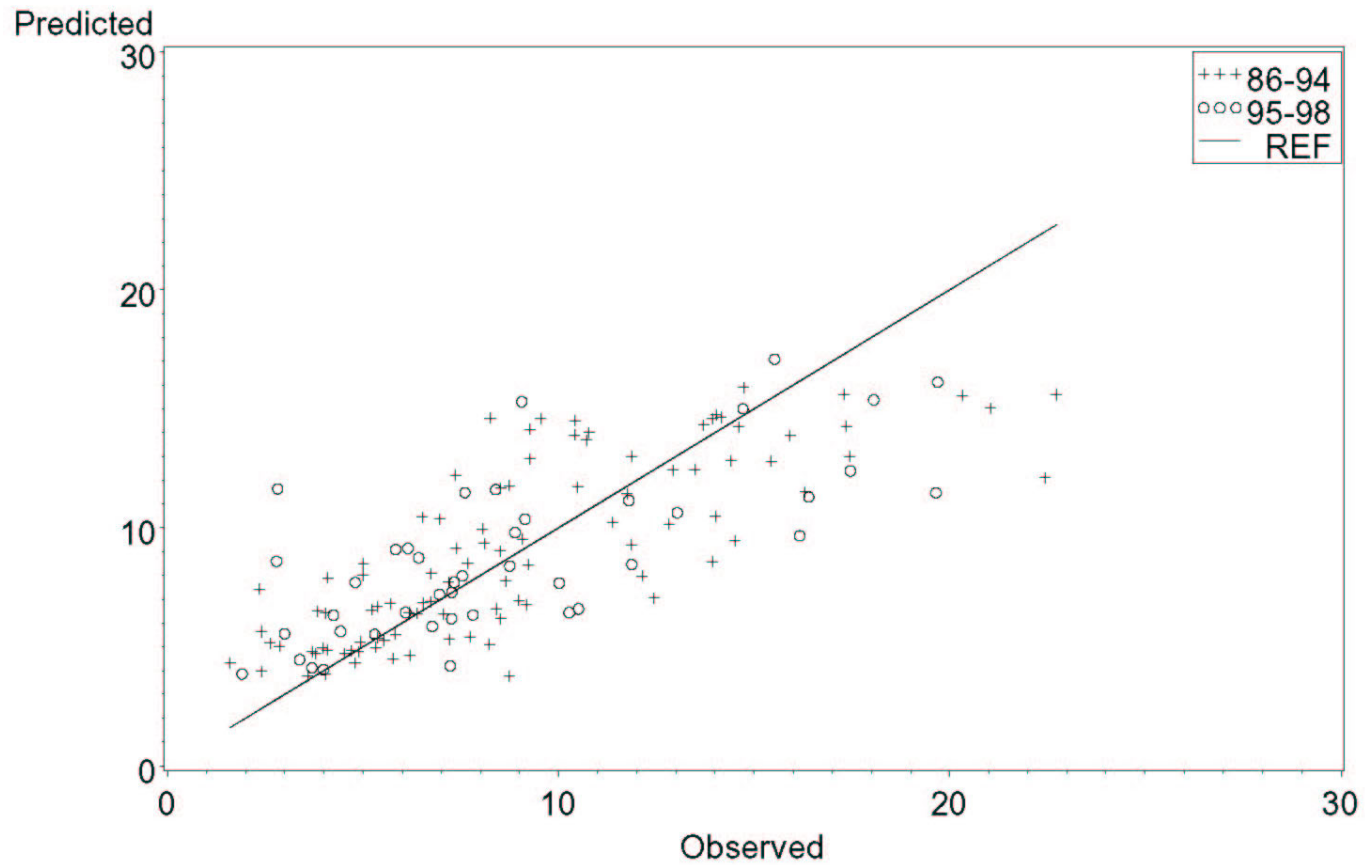


Figure 3-2. Relationship between mean monthly observed and predicted chlorophyll a, Old Tampa Bay.

Tampa Bay Estuary Program  
Nitrogen Loading - Chlorophyll a Relationship  
Comparison of Predicted and Observed Chlorophyll a Concentrations  
HB

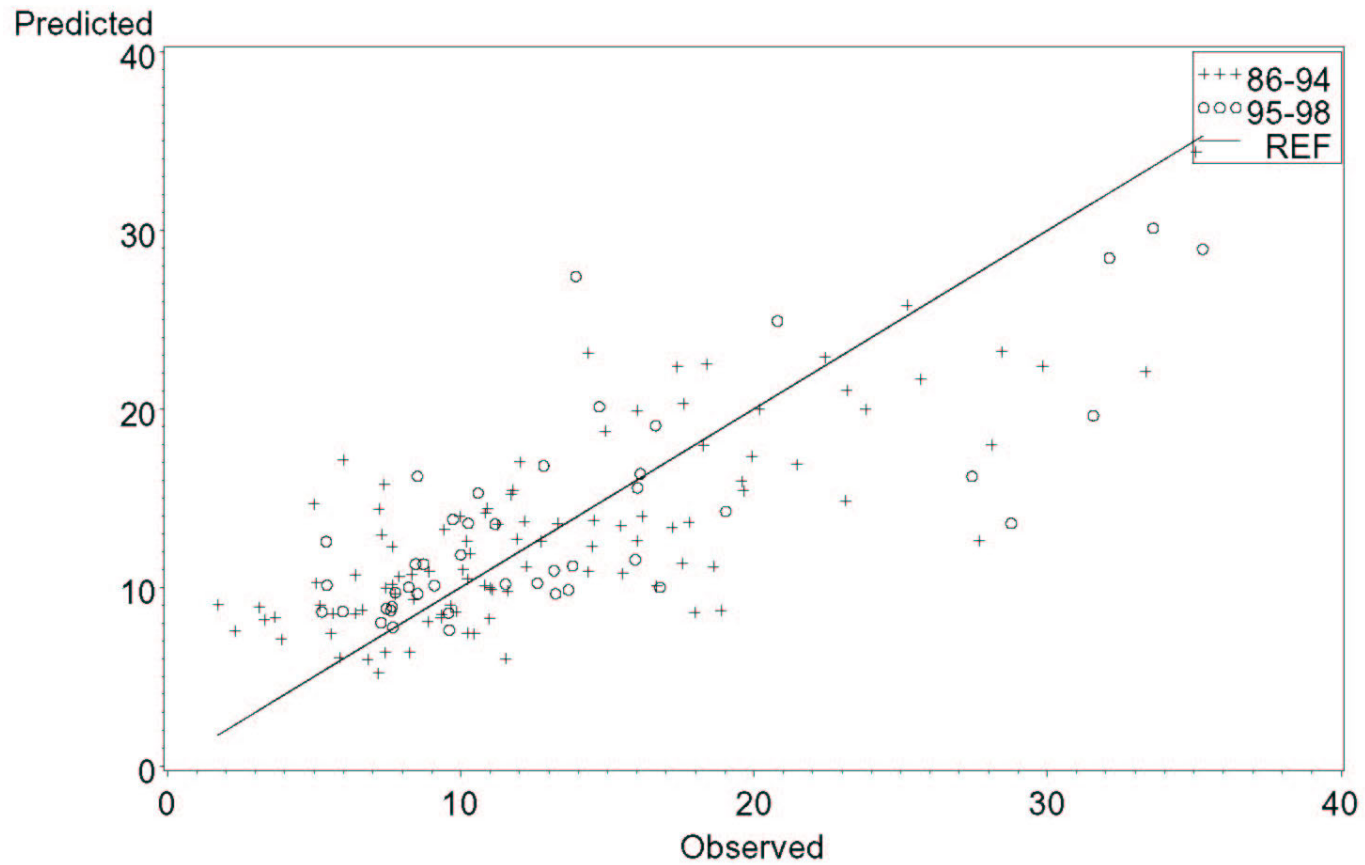


Figure 3-3. Relationship between mean monthly observed and predicted chlorophyll a, Hillsborough Bay.

Tampa Bay Estuary Program  
Nitrogen Loading - Chlorophyll a Relationship  
Comparison of Predicted and Observed Chlorophyll a Concentrations  
MTB31

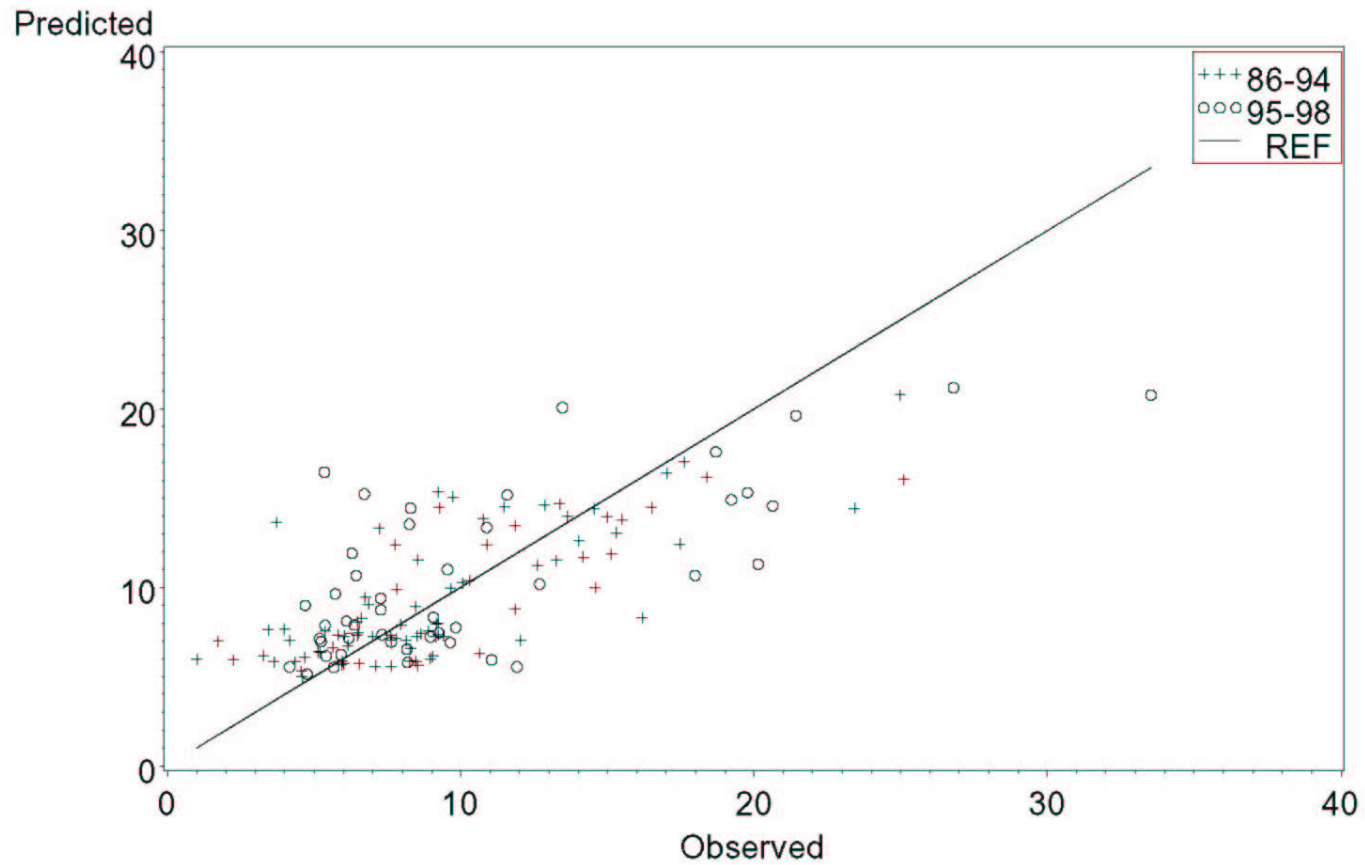


Figure 3-4. Relationship between mean monthly observed and predicted chlorophyll a, Middle Tampa Bay 31.

Tampa Bay Estuary Program  
Nitrogen Loading - Chlorophyll a Relationship  
Comparison of Predicted and Observed Chlorophyll a Concentrations  
MTB32

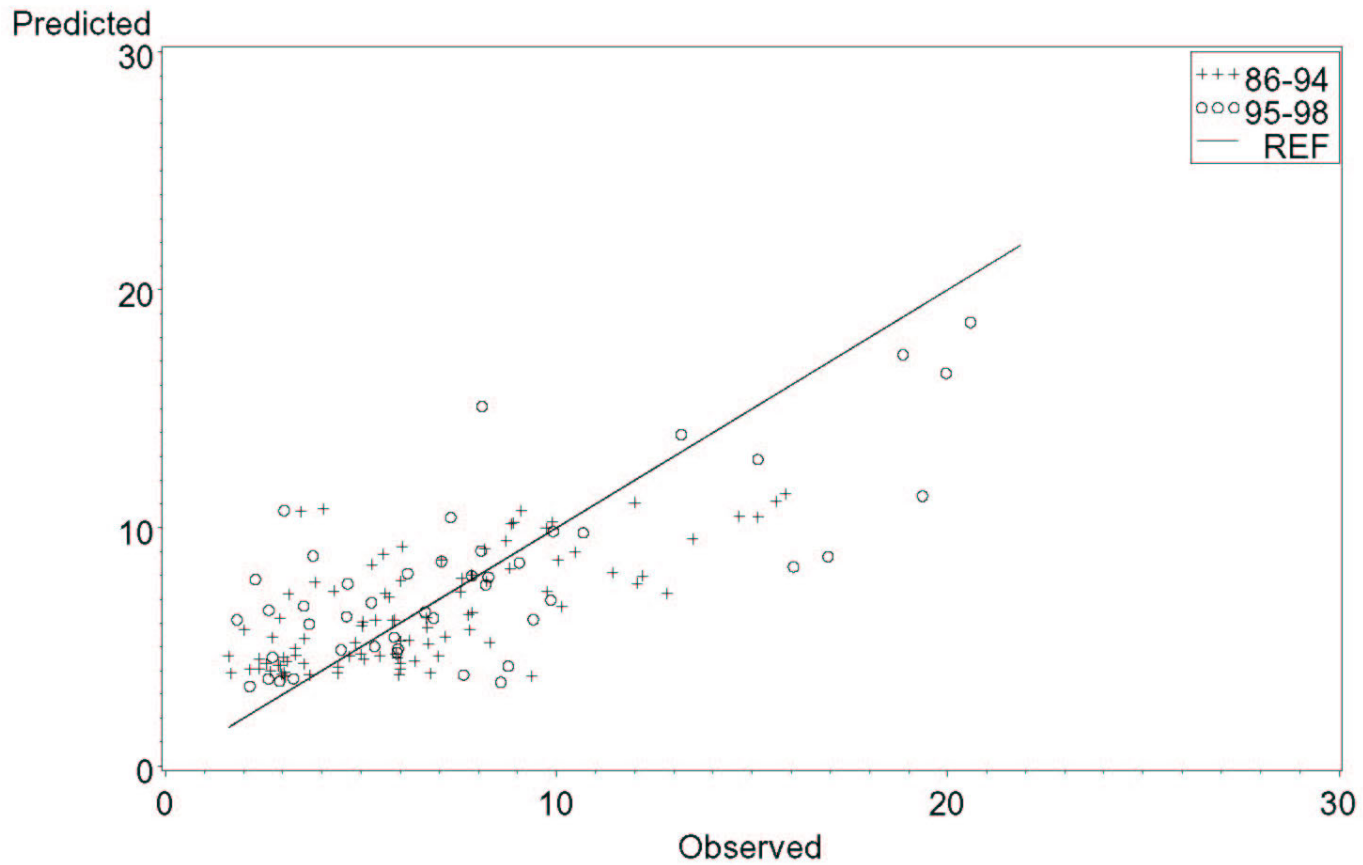


Figure 3-5. Relationship between mean monthly observed and predicted chlorophyll a, Middle Tampa Bay 32.



Tampa Bay Estuary Program  
Nitrogen Loading - Chlorophyll a Relationship  
Comparison of Predicted and Observed Chlorophyll a Concentrations  
MTB33

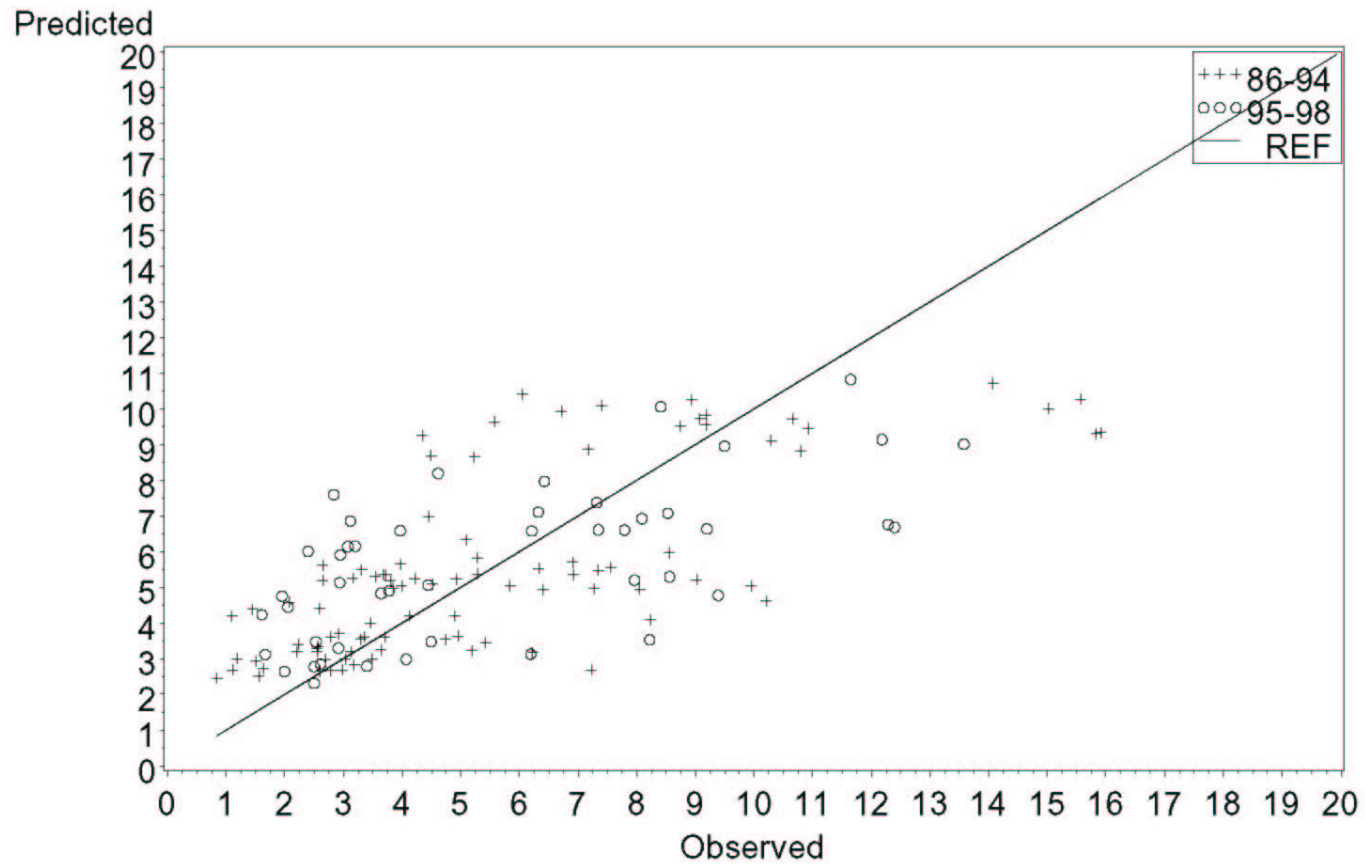


Figure 3-6. Relationship between mean monthly observed and predicted chlorophyll a, Middle Tampa Bay 33.

Tampa Bay Estuary Program  
Comparison of Residual Chlorophyll-a from the Loading Algorithm Regression

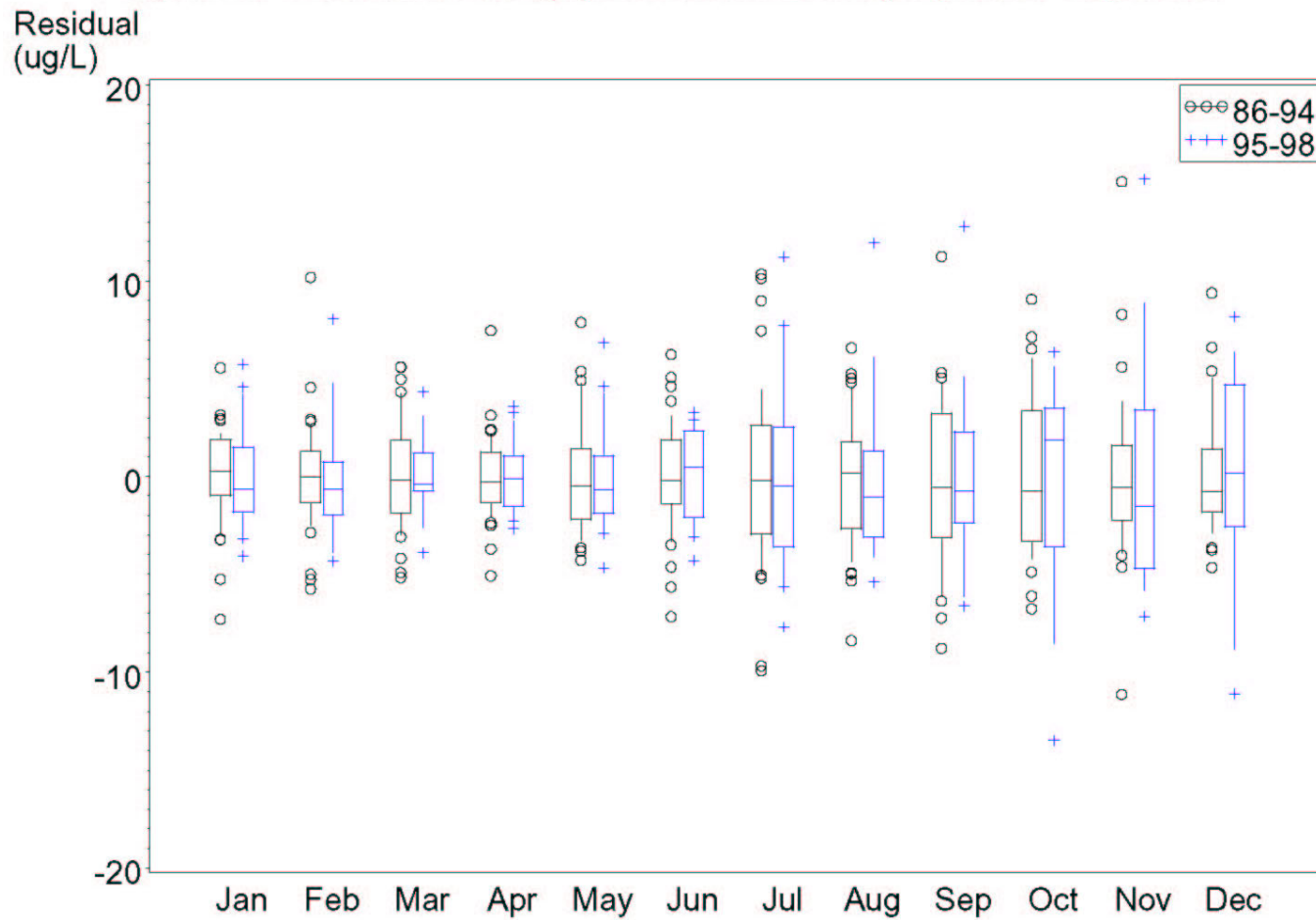


Figure 3-7. Residuals for the 1986-1994 and 1995-1998 periods, by month, for all bay segments.

Tampa Bay Estuary Program  
Comparison of Residual Chlorophyll-a from the Loading Algorithm Regression

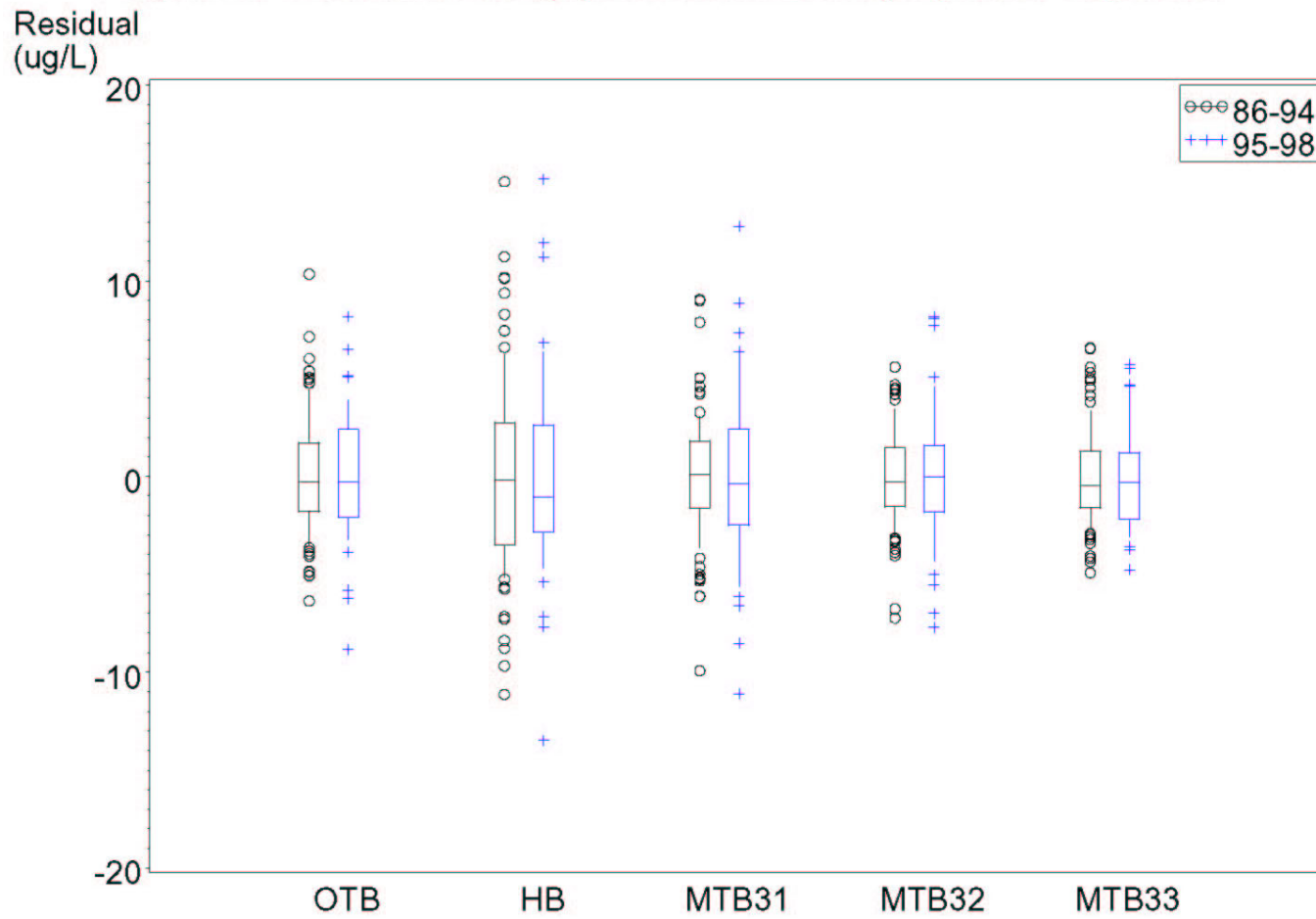


Figure 3-8. Residuals for the 1986-1994 and 1995-1998 periods, by bay segment, for all months.

## 4 DISCUSSION AND CONCLUSIONS

The re-evaluation of the TN load – chlorophyll a model is one component of the overall examination of the nitrogen management strategy adopted by the Tampa Bay Estuary Program. The objective of this report is to re-evaluate the empirical relationship between TN loads and chlorophyll a concentrations using the water quality data collected since 1994 by the Environmental Protection Commission of Hillsborough County (EPCHC) and loading estimates for 1995-1998 developed by the TBEP.

In general, the TN load - chlorophyll a model explains the observed variation in chlorophyll a as a function of TN loads from the watershed. Based on the outcome of these analyses, the relationship between nitrogen loading and algal biomass has been relatively consistent during the period of 1986 through 1998. It is recommended that the empirical relationships between TN loads and chlorophyll a concentrations developed from the 1986-1994 water quality data continue to be employed as part of the model suite relating external nitrogen loads to light attenuation.

## 5 REFERENCES

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